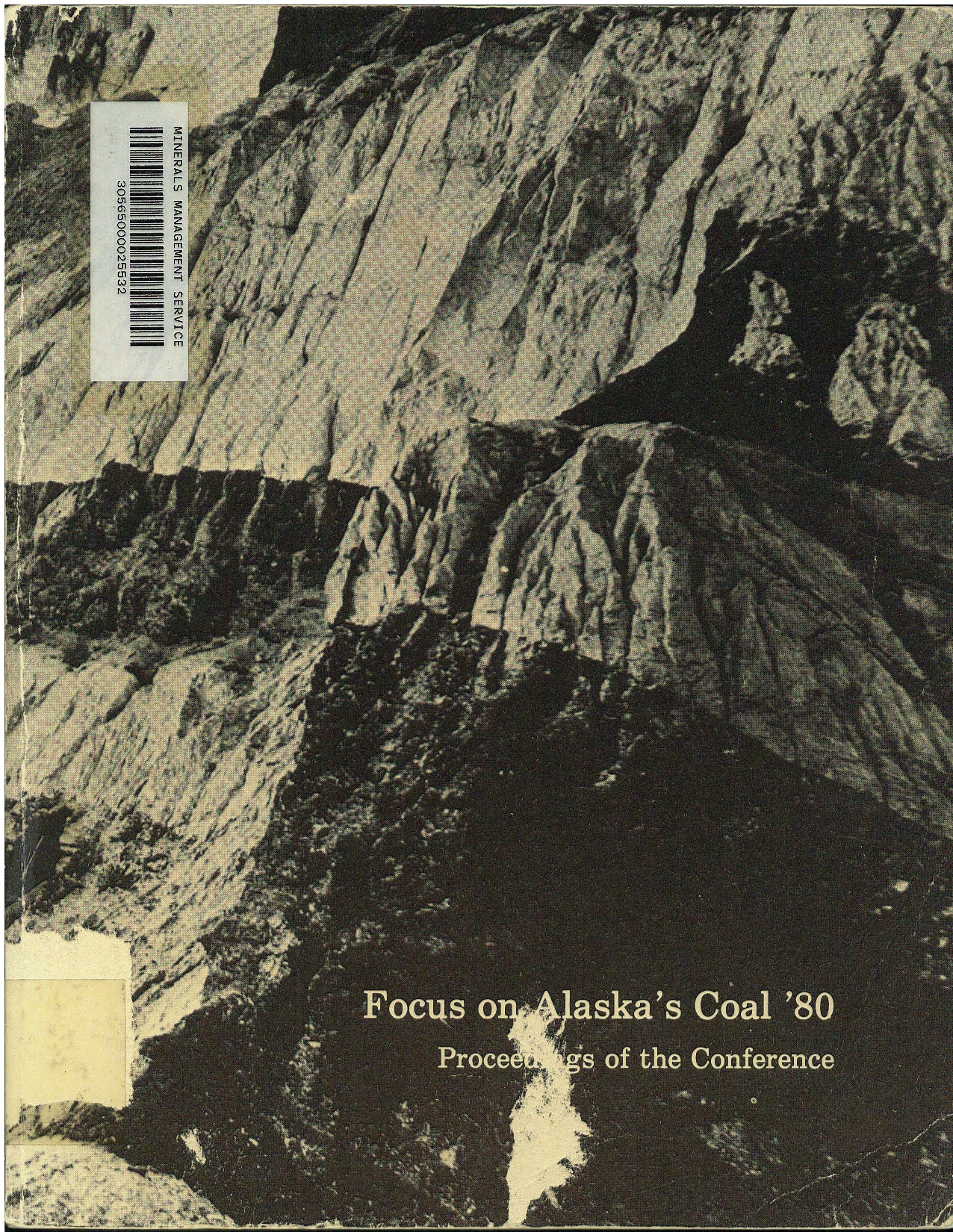

Focus on Alaska's Coal '80

Proceedings of the Conference

MIRL Report Number 50

Focus on Alaska's Coal '80

Proceedings of the Conference held at the University of Alaska, Fairbanks October 21-23, 1980

Editors

P. Dharma Rao and Ernest N. Wolff

School of Mineral Industry
University of Alaska, Fairbanks

Division of Minerals & Energy Management
State of Alaska

Division of Energy & Power Development
State of Alaska

Mining and Mineral Resources Research Institute
Office of Surface Mining

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Chairman - Wyatt Gilbert, Acting State Geologist, State Division of Geological & Geophysical Surveys, Fairbanks

Preface

Earl H. Beistline
Dean, School of Mineral Industry, University of Alaska, Fairbanks

The importance of Alaska's large coal resources to the Nation's and World's energy need is becoming more obvious as time passes. In addition, Alaska's coal is of major significance to the State's and community's economy, as well as being an important facet in developing a balanced diversification of energy sources.

Because of the continued and increasing interest in Alaska's coal resources, the second of a series of conferences was held on the University of Alaska, Fairbanks campus during October 21-23, 1980. This conference, "Focus on Alaska's Coal 1980" followed an earlier conference "Focus on Alaska's Coal 1975". For the 1980 Conference, 227 people registered for the meetings, including 63 from out of state.

Sponsors of the 1980 conference were: Division of Mineral and Energy Management State of Alaska, Division of Energy and Power Development State of Alaska, Mining and Mineral Resources Research Institute, Office of Surface Mining, and the School of Mineral Industry, University of Alaska, Fairbanks.

The principal objectives of the conference were to bring together current knowledge on Alaska's coal resources, mining methods, utilization and marketing, and every interested party to share this knowledge. The excellent papers presented and the large number of participants indicates that the objectives were accomplished.

Interest in Alaska coal is evident from these activities, such as:

1. Shipment of 30,000 tons of coal from Usibelli Coal Mine to Korea in December 1980;

2. Announcement of an agreement by Usibelli Coal Mine to sell 7.1 million metric tons over a 10 year period to Sun Eel Shipping Co., Ltd. for shipment to Korea;

3. Acquiring of Bass-Hunt-Wilson lease holdings by Diamond Shamrock;

4. Exploration core drilling activities by Canadian Superior Exploration for Doyan at Little Tonzona coal field, Korean interests in cooperation with Chugach Native Association in Bearing River coal fields, and Chignik coal field by Resources Associates of Alaska for Bristol Bay Native Corporation;

5. There has been an enormous number of inquiries by coal companies from the lower 48 states looking into the possibility of investing in Alaska's coal.

All in all, the future of Alaskan coal appears very bright. Anticipated is that Alaska will have an increasing opportunity to serve the energy needs of the Pacific Rim nations, and to supply coal and/or its conversion products to the West Coast markets of the United States.

The success of this conference is due to the excellent efforts of many individuals. Special thanks are due to: Mary Langan, Consulting Editor, Louella Finch for typing the final manuscript, Jane Smith for her assistance in compiling the final manuscript, the State of Alaska for coal research funding, the University's Office of Conferences and Institutes for making numerous arrangements for the meeting, and to Dr. P.D. Rao and his associates who coordinated the numerous major and minor details of the overall conference.

I express sincere thanks and appreciation to the conference committee members, the speakers and the participants for valuable contributions made to "Focus on Alaska's Coal 1980".

The intent of the sponsoring units is to have another coal conference in the future and to update current coal resource knowledge and production activities.

September 1, 1981 Earl H. Beistline

Opening Ceremonies

Chairman: Earl H. Beistline
Dean, School of Mineral Industry, Univ. of Alaska, Fairbanks

The conference this year is sponsored by a number of units and this is well spelled out in the program you have. The sponsors are, first of all, the State Division of Minerals and Energy Management, the State Division of Energy and Power Development, the Mining and Mineral Resources Research Institute, which is out of the Federal Office of Surface Mining, and the School of Mineral Industy of the University of Alaska, Fairbanks.

The organizing committee is also stated in the program, and the members of that committee that put this together were Dr. Ernest N. Wolff, who is the associate director of the University's Mineral Industry Research Laboratory, Bob Sanders, formerly of the State Division of Minerals and Energy Management, but now with Diamond Shamrock Corp., and Greg Edblom with the State Division of Energy and Power Development. These three people were members of the committee that helped to put this together, and there were others. There is one other person on the committee who really was the guiding light for preparing the program and for arranging the many details of the conference, and that is Dr. P.D. Rao, who is the Professor of Coal Technology in our Mineral Industry Research Laboratory. P.D. knows what it is to put on a Coal Conference, because this is his second one. Let's give them all a big hand.

Now the objectives of the Conference, again, are stated in the program and can be further summarized as a look at what is known about Alaska coal at the present time. What activities are underway, and what are future directions to pursue in utilizing Alaska's large resources for the benefit of the State, the nation, and really, the world. Last night, in the Fairbanks Daily News-Miner, there was an editorial pertaining to the conference. One paragraph stated, "With its vast coal resources, Alaska can be in the forefront of our nation's drive to become less dependent on foreign sources of energy. Here we have only begun to tap this resource, but it promises to supply an abundant energy source for decades to come. And it also appears likely, that Alaska coal will come to be a valuable export, as well as creating jobs here and helping to trim our national balance of payments". I think that fairly well sums up the objective.

As you can see, there is a considerable amount of information that will be presented in the program. We have a very tight schedule and we're going to have to move along. But as we get into the program and you start to hear a lot of facts and a lot of information, it reminds me of a story. I have one story that I use, a year at a time, so this will be about the last time that I'll use this story. I think I've spoken to every audience, so maybe a number here have heard it. This sort of emphasizes the difference between fact and opinion; this is something that you folks will probably be doing throughout the entire conference. It goes like this:

You have to have a setting, first. The setting is a railroad car, with four seats in a particular section. Now, a Colonel and a Sergeant are sitting on one side and facing them is a young woman, blond, and an elderly matron. Now the train enters a tunnel; the car is completely dark. There is the sound of a kiss and the resounding sound of a slap. When the car emerges, one fact is certainly well-known. The Colonel has been slapped pretty hard on the cheek. Now, the elderly woman thinks she knows what has happened. The Colonel has leaned over and kissed the blonde and has been slapped for his insolence. The blonde is of the opinion that the Colonel intended to kiss her, but in the darkness kissed the matron and got slapped for his trouble. The Colonel assumes that the Sergeant kissed the blonde, that the blonde thought it was the Colonel and slapped him by mistake. The Sergeant has all of the facts. He knows that he kissed his own wrist and slapped the Colonel just as hard as he could.

So much for fact and opinion; I'm sure as we go through the papers you will discern in your own opinion what is fact and what, perhaps, is the opinion of the speaker. Also, I want to congratulate you folks who have gotten here at this time of the day. Especially if you drove out on Airport Road when the lights were on earlier this morning, or maybe last night as you went in. Because by the Goldstream Theater there is an advertisement, and the name of the show, coincidentally, happens to be "The Coal Miner's Daughter". Don't know any more about it, but you didn't stop there, you came out here, and I think this is fine. Sometime we'll all have to find out just what that show is about.

Now, to welcome you to the campus today, is Dr. Howard Cutler. Dr. Cutler is an outstanding educator. He's had a long career in academic institutions, both as an administrator and as a teacher. He's held positions at Pennsylvania State University, University of Illinois, Chicago, Iowa and Minnesota. He's been Academic Vice-president at the University of Alaska and then Chancellor of the University of Alaska, Fairbanks. In addition, for ten years he was Executive Vice-president of the Institute of International Education, in Washington, D.C. He has also served on the National Advisory Coal Research Board of the U.S. Dept. of Interior, during the years 1960 to 1964. Dr. Cutler has certainly been an excellent friend of our School of Mineral Industries, as we pursue our objectives of teaching, research and public service activities.

At this time, it is certainly my pleasure to present to you the Chancellor of the University of Alaska, Fairbanks, Dr. Howard Cutler.

Welcome

Howard A. Cutler
Chancellor, University of Alaska, Fairbanks

The human brain is a marvelous instrument. It begins operating from the very moment one is born and continues without stopping until one gets up to make a public address.

It is my great pleasure to welcome you, once again, to a Coal Institute on the Fairbanks Campus. The function of the University is to maintain sustained interest in those values and concerns of man in which we put great stock. For, if in any single generation we fail to pass those values on to you, they are lost forever.

The University has had a long and sustained interest in coal. We are blessed with untold resources. But we have also had the wisdom to continue to support this interest when it has not been as strong as it is now. Just as now the University must be strong in supporting the interest in such things as foreign languages, which don't always have the current popularity. For we know that our coal markets will depend on the international markets and our international markets will depend on our ability to communicate with our fellow world citizens.

It is this sustained interest in the area of coal that has brought us here today. For without it we would not be in the important position that the University finds itself at this time. There is a national interest in coal, and when they went to select the centers of intellectual interest in coal, they selected the University of Alaska, Fairbanks, as one. Now, we don't have all the solutions and we hope that you are here to help us in that. We hope to bring you some of the information and some of the problems. It has been said, "If you think the problem is bad now, just wait until we solve it".

I hope that your conference will be a successful one in helping all of us come to a solution of not only a local and national, but an international problem--that of energy, in particular its relationship to the extraction of coal.

Welcome...and best wishes for a good conference.

Comments from State Division of Energy and Power Development

Clarissa Quinlan
Director, Division of Energy and Power Development, Anchorage

Thank you very much. By the way, the "Coalminer's Daughter" is a great movie with Loretta Lynn. If any of you are country-western fans, I highly recommend it.

Thank you very much Dean Beistline, and particularly Dr. Rao. It's a pleasure to be here. The last major conference addressing Alaskan coal took place some three years ago, and there certainly have been important developments since that time. One of those changes has been an increased level of interest as evidenced by the number of participants attending the conference today.

The topic of energy has become increasingly commonplace in all of the media. Energy is recognized as an essential component in both government and private planning. In fact, often it seems the key to the growth of industrial civilization. I think this is highlighted by the recent interest in the Iran-Iraq conflict and the potential disruption to petroleum supplies it has on the entire free world. This sharpening focus has been accompanied by an accelerated effort to discover, assess, control and utilize the earth's energy resources. It's not surprising that Alaska finds itself at the forefront of these international and national activities.

Alaska is in the unusual position of being rich in a number of renewable and nonrenewable resources. With an estimated two to five trillion short tons of coal, Alaska is unquestionably one of the world's storehouses of the resource. This supply amounts to approximately 40% of estimated U.S. resources and 15% of world resources. It could be expected that pressure to develop the state's coal resources would be even greater if it were not for the inaccessibility of the majority of the fields under current economic conditions, and certainly a more critical factor is the uncertain land status situation.

Despite Alaska's distance from out-of-state markets, its low-sulfur coal has attracted the attention of potential importers for several years. However, 1980 appears to be the year in which markets will be secure and development, particularly of the Beluga coal field, becomes economically feasible, now that the markets are almost there.

There are three especially strong indicators that the time has finally arrived. The study completed last year for leaseholders, Dick Bass, William Hunt and Starkey Wilson, have found it economically feasible to mine Beluga coal for export to Pacific rim countries. The proposed project would include a work force of approximately 630 people; a port facility in a new town site accomodating 13,000 people. Similarly, in addition to the Starkey Wilson group, Placer Amex and Cook Inlet Corp. have been pursuing the export of steam coal. More recently, attention has been placed on the federal grant that the two companies have received to study the feasibility of a 54,000 barrel-per-day methanol plant in the Beluga area.

Negotiations, I understand, are also underway to deliver Healy coal to Japan, Korea and possibly Taiwan. Coal will be hauled by rail from the Usibelli Coal Mine to Seward and then shipped to the Orient. The amount of the eventual export, I'm sure, is in the area of four to six million tons per year, with possible expansion at a later date.

On a much smaller scale is the potential utilization of coal in remote villages. For example, the state legislature has recently funded a $250,000 study by the Alaska Power Authority. It will determine the economics of using coal for space heating and electrical generation in Northwest Alaska.

With all these activities taking place, what are the major interests of the State of Alaska in coal development? Very briefly, there are five basic issues that the state will be looking at. Long-term economic diversification and stability, a fair price for our coal resources, acceptable levels of environmental and social impacts, provision of employment for Alaskans, and insurance of a long-term energy supply for the people of the state. It's this last element which our office is most concerned with. The others are addressed by other agencies, which I'm sure you'll be hearing from today.

The function of the Division of Energy and Power Development, in coal development, has been primarily in the area of planning and public information. Over the past four years, we have on the preliminary basis addressed the potential problems and opportunities related to coal development in the State of Alaska, and these efforts have been centered on the Beluga coal field. Again, they are preliminary in nature. What we are attempting to do is to determine whether there are any major problems that came up which could not be overcome; which, perhaps, could hinder or delay the development of the Beluga field. We've recently published the Alaska Regional Energy Resources Planning Project volume. It is a federally funded project and it deals with Beluga coal. In it we examine potential socio-economic impacts, permitting, land tenure, technology, transportation and environmental impacts associated with large-scale coal development in the area. As I think we all know today, it looks as though there are no insurmountable problems. It all seems to be coming together.

This investigation was preliminary in nature and I know that much more in depth studies are underway to identify those areas that are going to have to be pursued a little bit further. Two other major studies are currently looking at coal as one of several energy alternatives for in state use. The first is the railbelt electric power alternative study. Coal fired generation is already an important source of electrical power in the Fairbanks area. However, the potential use of coal for the entire railbelt, including the Kenai Peninsula and Anchorage area as well as Fairbanks, will be assessed in the alternative study. The alternatives to the Upper Susitna Dam Project study, which I'm sure many of us are familiar with, will also be assessed. The study will assess the role which coal and other energy resources may play in meeting the future power needs of the railbelt area. The contract was recently awarded by Battelle Pacific Northwest Laboratories and the project manager, Mr. Ward Swift, is here today. I'm sure he would be more than happy to discuss your perceptions as to the role that coal will play in the railbelt.

The other study is the long-term energy plan for the State of Alaska. In the 1980 legislative session, our division was funded and given the mandate on a very specific basis to look at developing a comprehensive long-term energy development plan for the State of Alaska. In it we will examine the potential for in state utilization of coal and other energies. The project will address energy development, not only from the power perspective, but also in terms of fuel needs for transportation, heating and other uses. Proposals are presently being evaluated, with the final selection of the contractor expected by the end of the week.

The last and most important area I'd like to address today is a more active state involvement with the private sector, now that development is starting to take place on an accelerated basis, particularly at the Beluga field. In the past the state's involvement has been primarily in three forms, resource and feasibility studies, some liason activities between developers and markets, and supportive mining interests and ventures at the national level, paticularly in the ongoing D-2 battle, the result of which we still don't know.

As coal development begins to accelerate, however, it becomes even more important that a closer working relationship between developers, the state and local government should take place. This is particularly critical when we're assessing social, economic and environmental impacts arising from the development, and when we're formulating mitigating strategies to deal with potential negative impacts. I think it's critical that the state and the private sector take a look at this so that we can develop realistic alternatives. Without this coordination, delays and unexpected problems will occur. I am particularly hopeful that the state's Beluga coal task force will serve as the focus for this cooperative effort, with the result being a timely development acceptable to all parties concerned.

This conference has attracted numerous knowledgeable participants capable of helping us identify and discussing these areas of mutual interest and concern. It's of concern, not only to the government but to the private sector as well. I am eager to see how these issues are addressed during the next three days, and look forward to the possibility that this conference may serve as a jumping off point, so that we can start developing a more formal relationship in this area.

Thank you very much.

Comments from State Division of Minerals and Energy Management

Ross Schaff
Acting Director, Division of Minerals & Energy Management, Anchorage

When Dr. Rao and Dean Beistline asked me to appear here today and make a few comments, I tried to beg off. I didn't think being born in Scraton, Pennsylvania and breathing coal dust for the first two years of my life, and hauling ashes for the next ten, really qualified me as a speaker before this august body. Nevertheless here I am in a dual role as the acting Director of the Division of Minerals and Energy Management, as well as the Director of the State Geological Survey. I'm going to come somewhere in between those two, and title my talk, "Coal, Energy and Ignorance, an Alaska Enigma".

To me Alaska coal is an enigmatic situation for several reasons. First of all, it's well-known, in Alaska at least, that Alaska coal is one of the largest energy resources of the nation. McGee and Emmel of the State Geological Survey have compiled various resource estimates and arrived at an average value of about one to several trillion tons as a hypothetical resource. Bob Sanders, over here, is going to get up shortly after me and disagree highly with that figure as being far too low. Nevertheless, the point is that this is an enormous energy resource, at least equivalent to the world's reserves of oil. So if this nation is really serious about finding energy, Alaska is an obvious source. The state energy office concluded in one of their compilations that in Alaska we have perhaps 50% of the nation's coal.

The enigma is that despite the overtures made to coal in Washington, D.C., there are very few evaluation programs sponsored by the federal government to look at this resource. There are some good exceptions--Jim Callahan of USGS, and work by the Bureau of Mines--but according to Don McGee of the State Survey, most of Alaska's coal is in NPRA--the National Petroleum Reserve, Alaska. That's an area about the size of Indiana. It should have been named NCRA--National Coal Reserve--in view of the negative results of the federal government's exploration program for oil and gas, and its national coal reserve. One has to ask where is the systemic evaluation of this tremendous resource by the federal government?

I know enough about coal and the accompanying exploration, economic and environmental problems to know that development of North Slope coal will tax the ingenuity of industry and government, but to me we have an enigma of the first order when we have a billion dollar budget for synthetic fuels, and billion dollar budgets for hydroelectric projects within view of 2.5 billion tons of coal resources.

We have a national program for wood consumption, which to me is another name for forced depletion. We import nearly 50% of our petroleum from foreign nations who attempt to dilute or dictate our foreign policy, yet there is enough coal in Alaska to keep the nation's energy budget in the black, if you'll excuse the pun.

So as Willie Aiken said to the first base umpire the other day, when he forgot to put his foot on first base in the World Series game, "What's the problem?". Is it capital outlay in markets, perhaps? But Cle Conwell's paper, which will be presented later in this conference, shows that the cost of heating oil in Alaska villages will be three times the cost of an equivalent Btu in coal. Technological know how? Maybe. But I think Joe Usibelli has shown us how to mine and reclaim land in permafrost. The Germans, during World War II, showed us how to make innumerable products from various hydrocarbon derivitives. Is it bureaucracy? Well, that's a touchy one. I don't think we should use this as a cop out. Sure there are too many of us, probably. Yeah, we are inefficient and maybe we cost too much--I see Joe shaking his head, there. But can we say that the fundamental reason that Alaska coal resources are not used by this nation is bureaucracy? I don't think so. I think a fundamental reason for the enigma of Alaska's coal resources is national ignorance. I'll give you a few examples from personal experience.

A member of the Senate Energy Committee recently remarked to me that over 40% of the citizens of the United States do not realize that we must import oil. That's an appalling conclusion. Now that statement was made for the current Iranian crisis. But there's little reason to suspect that it's lower. For those of you in the mineral industry, you can find little solace in the fact that most citizens know that gasoline at least comes out of the ground somewhere. But it's no insurance that they realize that the car came out of the ground, also.

A second experience. Recently I was in the office of a senator from a leading eastern coal producing state, discussing the Alaska national interests land issue, or as we call it the D-2 issue. The Chief of Staff of this senator was completely unaware that Alaska had coal. Despite the general ignorance of Alaska, I would have expected from a coal producing state a better knowledge of Alaska's coal. In short, the minerals potential and the coal potential of Alaska is not known, in my experience, elsewhere.

I'll give you one final example. As most of you know, Congress is agonizing its way towards the possible conclusion to the D-2 issue. There have been several amendments recently, proposed on the house side, to alter the senate version of HR 39, mainly by Congressmen Udall and Seiberling. The one that really concerns me is the proposal to place certain designated areas into wildlife refuges. Namely the Copper River Delta, which includes portions of Bering River Coal field, the Tesh Cook Lake area and the Utukok area of NPRA. Don McGee, of the State Geological Survey, did a very quick estimate for me as to what impact this would have on coal. He determined that approximately 55% of the coal of NPRA is probably in the Utukok area. I talked to Jim Callahan this morning, and we won't argue over the exactness of that figure, but it's a high percentage of NPRA coals in the Utukok area. We also estimate that probably about 80% of Alaska's coal is in NPRA. So we're dealing with a very large energy resource--coal--that is being placed into a wildlife refuge.

Now placing a resource in a wildlife refuge normally is not a problem because, theoretically, resource development can take place within a wildlife refuge. But there's a little section in a previous law passed by Congress, which Dean Beistline and I have agonized over from time to time, and that's public law 9587, which explicitly states that there can be no surface mining of coal in a wildlife refuge. Which means then, Congressmen Udall and Seiberling are either acting out of ignorance, or...I'll leave that call to you. I would say that in all probability they do not realize that there is such an immense energy resource that is being placed into this kind of a status.

I'll conclude with that statement. I noticed in my mail yesterday a note from the American Geological Institute, and I thought that because there would be some coal entrepreneurs here, that I'd bring this announcement to you. It seems to me it's the best deal in the United States right now for coal, if you're selling it. I'll read it to you; it's very brief. "A recent DOE Newsletter reports that New York State will dump 500 tons of compressed coal brick in the Atlantic to build a reef that will host aquatic plants, and provide a refuge for fish, about 2 1/2 miles off the Long Island coast. State and federal agencies are providing 2.9 million dollars for the project." If my quick division is correct, that's about $6,000 a ton.

Thank you.

Coal resources of Alaska

Robert B. Sanders
Diamond Shamrock Corp., Anchorage

History

Although the Alaskan Natives and some of the early explorers may have utilized coal and oil shales as fuels, the first written record of interest in coal is that of Captain Nathaniel Portlock who discovered and used coal at Port Graham in 1786. The first serious attempts for the commercial utilization of Alaskan coal began in 1855 when Siberian fur traders opened a coal mine at Port Graham for export to California in the United States. Although the export market never developed, the mine produced coal for local and maritime markets until 1865.

Later in the 19th Century, it became standard practice for the whaling ships and U.S. Revenue cutters to take on coal from beds near Cape Sabine on the Arctic Coast. The riverboats plying the Yukon, Kuskokwim and other rivers also won small quantities of coal for local use, and at least 16 mines operated on the Yukon in the last decade of the 19th Century. These were all abandoned before about 1910 as river traffic decreased, and what little traffic there was converted to oil fuel.

The need for large amounts of heat to thaw frozen ground for placer gold mining as well as for domestic uses was met with coal wherever available, and at least a hundred small mines operated around the turn of the century. The operators' rights to the coal was apparently pedis possessio, but nevertheless coal "interests" were bartered well before the general mining laws of the U.S. were extended to the Territory of Alaska in 1903 (e.g. the 1892 sale of Robert Lee's coal interests at Chugiak to Alaska Packers Association for $1,765.00).

In addition to those mines along the Yukon and other navigable rivers, around the turn of the century there were mines at Admiralty Island, Herendeen Bay, Chignik, Cape Lisburne, Kachemak Bay, Unga Island, Niak and Chicago Creek.

The last, near Candle on the Seward Peninsula, entered an 80 ft. lignite seam in 1903 and produced almost continuously into the 1940's, despite early attempts by the federal government to halt its unlicensed exploitation of the coal.

The mineral laws of the U.S. were first extended to the Territory of Alaska by the Act of June 6, 1900 (31 Stat. 327), making it possible for prospectors to claim coal as a locatable mineral. Many coal entries were made under this Act in the Bering River and Matanuska Valley coal fields by prospectors apparently unaware that this law permitted location only on surveyed land, of which there was none in these Alaskan coal fields.

The Alaska Coal Act of April 28, 1904, (3 Stat. 525), allowed location without the precedent government survey, and most of the earlier claims were relocated under this authority. However, because of the accusations of fraudulent claims by "dummy entrymen" on behalf of "East Coast monopolies", all of the claims became suspect. Spurred by a biased Washington press and Collier's Weekly (a magazine) the matter of the Alaskan Coal Claims became a national sensation, and ammunition in the growing ideological feud between Gifford Pinchot, Chief of the Bureau of Forestry and champion of preservationism, and R.A. Ballinger, Commissioner of the General Land Office and later Secretary of the Interior.

In response to the controversy, on November 17, 1906, President Theodore Roosevelt withdrew all Alaska public lands from entry under the Coal Claim Laws. Although initially done under questionable authority, Congress validated the withdrawal in the Act of May 28, 1908 (35 Stat. 424). Enmeshed in the Pinchot-Ballinger controversy, the legal processing of the coal claims stagnated, leaving the calimants in the unenviable position of having to do annual assessment work, but unable to remove or sell coal. Under these conditions, most of the claims were abandoned, with only 2 of the 900 claims going to patent.

At this time, domestic production supplied only 2% of the territorial coal consumption, the remainder being imported from British Columbia, Austraila, Japan or the State of Washington at an average consumers price of $15 per ton. In addition to the many claimants and investors who were financially ruined, consumers having to buy this expensive imported (and import taxed) coal while local coal might have been had for $3 per ton, were understandably unhappy. Pinchot was burned in effigy in Katalla, then a town of several thousand which hoped to serve as a railhead for Bering River coal. In Cordova the people shoveled several tons of the expensive imported coal into Prince William Sound as a "Coal Party Protest".

During the Congressional investigation which followed, it was found that some of the General Land Office staff had been on a clandestine Bureau of Forestry payroll, allegedly hired to disrupt and delay the Land Office patenting operations while leaking information to Pinchot with which to embarrass Ballinger. Several hundred people lost large sums of money when caught in the middle of these dirty politics, work ceased on the several coal railroads that had begun in the Bering River area, and the coal industry in Alaska was stillborn.

Between 1880 and 1915, the total reported coal production of the Territory of Alaska was 70,000 short tons valued at approximately $450,000 (see Table 1). This was mainly the production of the Wharf Mine at Port Graham, which produced one to 3,000 tons of subbituminous coal per year at a price calculated to have been $3 to $6 per ton, but also included several thousand tons of coal produced from the McDonald Property on Bering Lake in 1907. Not included in these data are the "pirated" output of the "illegal" Chicago Creek Mine on the Seward Peninsula and the mines at Herendeen Bay, Chignik Bay and Unga Island, and other mines operated within the local and native economy. The pre-1914 price data based on Table 1 appears too erratic to be trusted.

In 1914, President Wilson authorized construction of the Alaska Railroad, choosing a route which closely passed the Matanuska, Little Susitna, Broad Pass and Healy coal fields. That same year the federal government, now having a vested interest in coal development, enacted the Alaska Coal Leasing Act under which mines were developed in McKinley National Park and the Nenana, Matanuska Valley and Bering River coal fields. Also in 1914, the U.S. Navy undertook extensive testing of Matanuska and Bering River coal, concluding that the former was suitable, but the latter unsuitable, for naval use. This proved the death knell of the lingering dreams of Katalla and Bering River entrepreneurs.

The building of the Alaska Railroad to the Matanuska coal field in 1916, and the Nenana coal field in 1918, created a market and the transportation necessary for large scale mine development. Between 1916 and 1940, coal production increased fairly steadily to 174,000 tons per year. Primary production was of bituminous coal from the Wishbone Hill district of the Matanuska coal field and of subbituminous coal from Healy Creek and Suntrana areas of the Nenana coal field.

The tremendous military build up in the Anchorage and Fairbanks areas during and after World War II created market and profit incentive for further exploration and development, and additional mines were opened at Healy, Nenana, Jarvis Creek, Broad Pass, Costello Creek and the Little Susitna and Wishbone Hill areas of the Matanuska Valley. The price of coal jumped about 50%. Similarly, lack of fuel forced Wainwright and Barrow to open coal mines. Most of these wartime ventures were short-lived, but overall production rose rapidly through the postwar years to 861,000 tons in 1953. The military market grew so rapidly that the ominous switch from coal to diesel fuel by the Alaska Railroad in the early 1950s did not adversely affect the Alaska coal industry. In fact, production continued to increase in the face of this transition, peaking at about 925,000 tons per year in 1966 and 1967. The 1968 Congressional decision to convert the Anchorage military bases to gas power generation signalled the doom of the last Matanuska Valley mine, the Evan Jones, and displaced about 100 workers.

The only mine surveying the pandemic transition to gas and oil was the Usibelli Coal Mine at Healy in the Nenana field. This stripping operation produces approximately 700,000 tons per year subbituminous C coal from three 17-20 ft. thick beds, primarily for public utility and military markets in the Fairbanks area. The price varies greatly between, contracts depending on the contract specifications for values added by washing, classifying and drying, and through transportation, tippling, etc., but probably averages approximately $20 per ton. This is approximately $1.25/MM Btu (compared with No. 2 fuel oil at $7.64/MM Btu at $1.00/gallon.

LAND STATUS: Under its mandate to designate "mineral lands" the federal government has officially classified approximately 33 million acres in Alaska as "prospectively valuable for coal". This represents about 9% of the state. The majority of these coal lands have been selected by the State of Alaska under the Statehood Act (72 Stat. 339), or by the Alaska Native corporations created under the Alaska Native Claims Settlement Act (85 Stat. 688). However, much coal land remains under federal title in the National Petroleum Reserve, Alaska, Alaska National Wildlife Refuge, Chugach National Forest and the newly created Denali National Park and Preserve, Alaska Peninsula National Wildlife Refuge, Kenai National Wildlife Refuge, Kobuk National Park, Yukon Delta National Wildlife Refuge, Yukon-Charley Rivers National Preserve and units of the Alaska Maritime National Wildlife Reserve. Additional coal may exist in the Innoko, Koyukuk, Nowitna and Kanuti National Wildlife Reserve, and in areas transected by waterways protected as wild and scenic rivers.

The extent to which most of these federally controlled coal fields can be prospected and developed is not clear, as the regulations pertaining to the new units created under the Alaska National Interest Lands and Conservation Act of 1980 have not yet been finalized, nor has the RARE II study in Chugach National Forest been completed. All or parts of the Broad Pass, North Slope, Circle-Eagle, Kobuk, Lisburne, Lower Yukon, Etolin Straits, Bering River, Kenai and Nenana coal areas or fields are involved in this temporarily unsettled status.

The State of Alaska has title to most of the Cook Inlet (Susitna Basin) coal region (Beluga, Yentna, Little Susitna and Kenai coal fields), the Matanuska field, central portion of the Nenana coal belt (Healy coal field), and portions of the North Slope, Herendeen Bay and Robinson Mountain fields. State selections pending include additional lands in the foregoing coaliferous areas, as well as in the poorly studied Seward Peninsula coal area, and the abandoned coal sites that occur along the Yukon and Koyukuk Rivers. Some of the "state selections" are in conflict with units created under the Alaska National Interest Lands and Conservation Act and will presumably be denied.

Acquisition of coal rights from the State of Alaska follows procedures based on those of the old federal system of the Mineral

Leasing Act of 1920 (42 Stat. 437), with lands classified for "competitive" or "noncompetitive" leasing and with a system of "coal prospecting permits" which may be converted to lease upon the proof of discovery of a commercial coal deposit (AS 38.05.150). However, since October, 1975, no new coal leases or coal prospecting permits have been issued by the Department of Natural Resources, except through the automatic Preferential Rights to Lease provisions of a coal prospecting permit. This "freeze" was originally an outgrowth of the Kachemak lease sale court decision regarding the need for public notice prior to lease issuance. Although new statutes have corrected the original problem, the "freeze" has been continued due to the administration's disenchantment with the lease royalty provisions. It is unlikely that any new coal prospecting permits or coal leases will be issued until new regulations under AS 38.05.150, or a new statute, have been adopted.

In the meantime 415 applications for coal prospecting permits are pending. These are for approximately 1,989,500 acres, mostly in the Beluga-Yentna coal field(s). As of October 1, 1980, there were 52 coal leases (102,989 A.) and 8 coal prospecting permits under application for conversion to coal leases (15,849 A.) considered extant by the state's Division of Mineral and Energy Management. At this time, the only state lands available for noncompetitive leasing (and therefore available for issuance of coal prospecting permits) are those lands patented or tentatively approved by Bureau of Land Management for patent to the state, tentatively approved as of June 30, 1968. Lands patented or tentatively approved to the State subsequent to June 30, 1968, have not been opened to coal leasing or prospecting. The only lands presently classified for competitive leasing are 6,710 acres near Healy, 1,870 acres in the Matanuska Valley and approximately 200,000 acres near Pt. Lay on the northwest coast. The state is currently revising the regulations under the existing statute and hopefully will be in a position to offer and issue coal rights within the year.

Several of the 13 Native corporations established under the Alaska Native Claims Settlement Act (ANCSA, 85 Stat. 688) acquired coal lands. The most significant holdings are:

Cook Inlet Region, Inc.'s interests in the Cook Inlet-Susitna coal region, especially in the Beluga coal field;

Doyon's interests in the Nenana coal belt, especially in the Farewell area and in the Eagle-Circle area;

Arctic Slope Regional Corporation's interest in the North Slope coal field;

Chugach Natives, Inc.'s interest in the Bering River coal field; and

The Aleut Corporation's and Bristol Bay Native Corporation's interests in the Herendeen Bay-Chignik coal field.

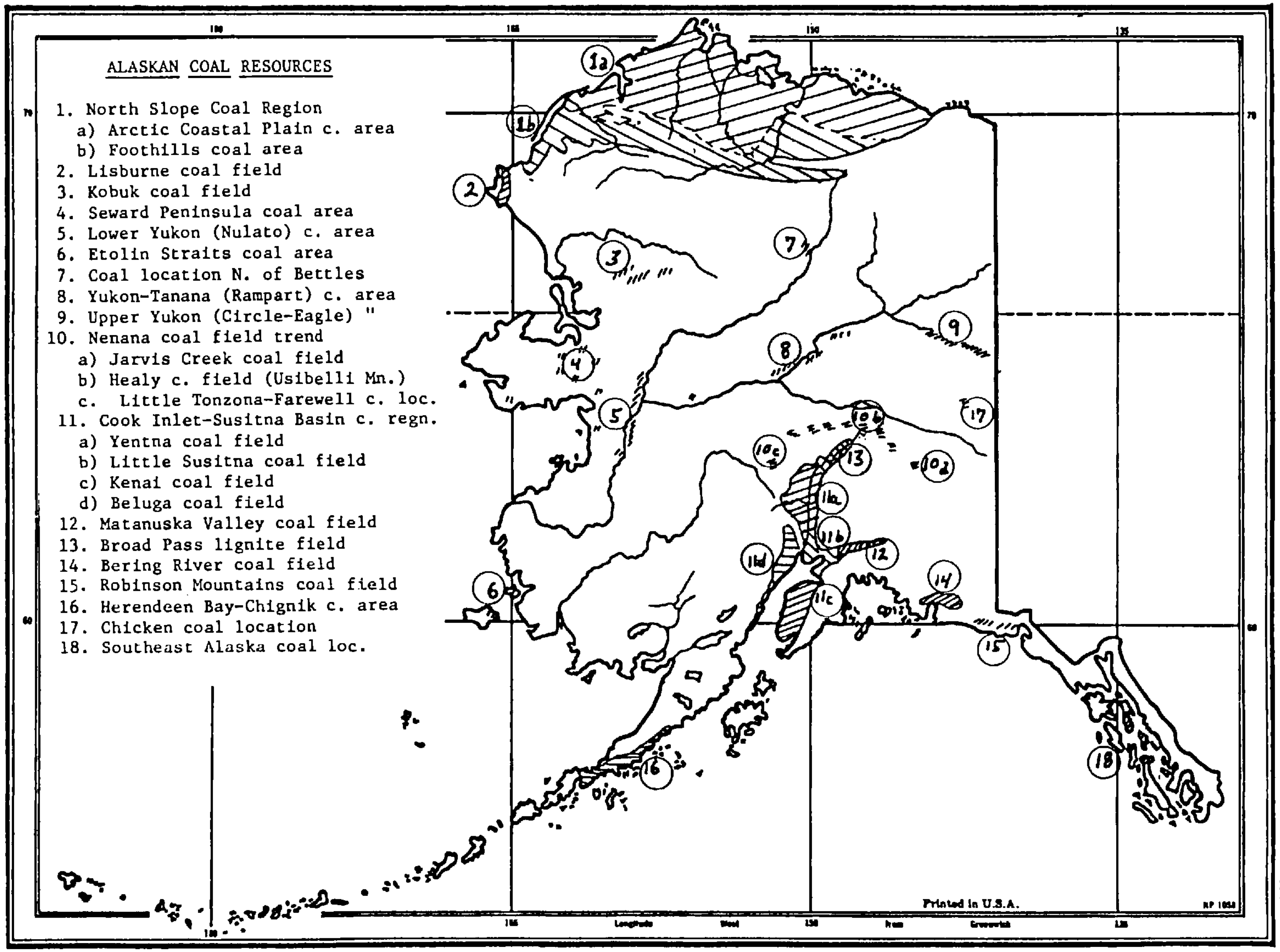
The acquisition of coal or exploration rights on these privately administered lands would be through private negotiation, the state and federal bureaucracy not being involved except through the surface mining controls, safety and taxation.

The Surface Mining Control and Reclamation Act of 1977 (91 Stat. 445) affects all significant coal mining, both surface and underground, regardless of land title. The Act mandates consideration of special regulatory changes for Alaska, and the National Academy of Sciences and National Academy of Engineering recently completed a study recommending to the Secretary of Interior certain regulatory alterations. In addition, the State of Alaska is in the final steps of drafting a plan by which the State would assume enforcement jurisdiction ("primary") over surface mining. Until the Department of Interior adopts regulations for Alaska and the State's primacy bid is resolved, the working conditions and constraints under the Act will remain unknown. However, it may be safely stated that all phases of mining, including exploration and the very availability of mining lands will be severely impacted.

RESOURCES: Early attempts to estimate Alaska's coal resources as by Brooks (1901, 1909) and Gates (1946) were based on such incomplete and unreliable data as to give only a general idea of the order of magnitude of the resource. The great interest in coal during and after World War II resulted in several excellent coal resources studies by the U.S. Bureau of Mines and Geological Survey, which were compiled into statewide estimates by Farrel Barnes in 1960 and 1976. Although many new data have been developed, the updated statewide estimates of Rao and Wolff (1975), McGee and O'Connor (1975) and McConkey et al (1977) have been ignored in the various Department of Interior resource estimates of the (d)(2) lands. Even the Department of Energy's 1980 report: "Transportation and Market Analysis of Alaska Coal" quotes the archaic data in preference to its own McConkey Report and the several unpublished resource revisions prepared by its own Alaska field office.

The federal government's apparent refusal to consider the assessments incorporating the post-1967 calculations of even its own U.S. Geological Survey geologists is not understood; but because these federal studies received such widespread distribution as compared to the more recent compilations, Barnes' now grossly out-of-date figures continue to be quoted. Worse, many qualitative and quantitative statements now known to be false have been blindly repeated, perpetuating myth through repetition by what Stefansson so aptly called the "standardization of error".

The accompanying table of resource estimates shows Barnes' 1967 data as well as data cited more recently. The fact that all authors cited quote the same datum for resources identified, (e.g. Broad Pass), does not necessarily indicate this to be an estimate


ALASKAN COAL RESOURCES
1. North Slope Coal Region
a) Arctic Coastal Plain c. area
b) Foothills coal area
2. Lisburne coal field
3. Kobuk coal field
4. Seward Peninsula coal area
5. Lower Yukon (Nulato) c. area
6. Etolin Straits coal area
7. Coal location N. of Bettles
8. Yukon-Tanana (Rampart) c. area
9. Upper Yukon (Circle-Eagle) "
10. Nenana coal field trend
a) Jarvis Creek coal field
b) Healy c. field (Usibelli Mn.)
c. Little Tonzona-Farewell c. loc.
11. Cook Inlet-Susitna Basin c. regn.
a) Yentna coal field
b) Little Susitna coal field
c) Kenai coal field
d) Beluga coal field
12. Matanuska Valley coal field
13. Broad Pass lignite field
14. Bering River coal field
15. Robinson Mountains coal field
16. Herendeen Bay-Chignik c. area
17. Chicken coal location
18. Southeast Alaska coal loc.
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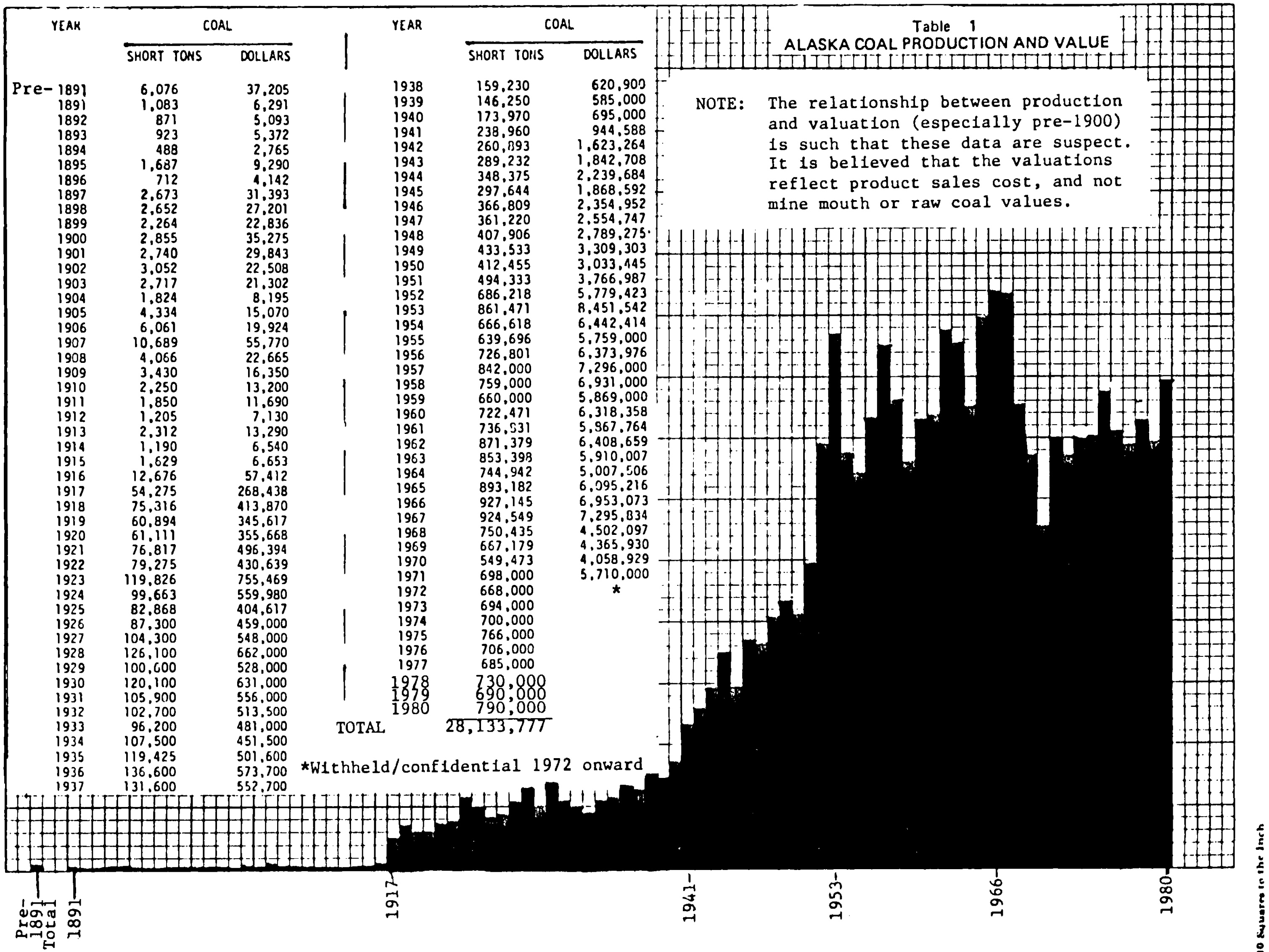
MAP NO. CO949 ALASKA

Table 1
ALASKA COAL PRODUCTION AND VALUE

YEAR	COAL SHORT TONS	COAL DOLLARS
Pre-1891	6,076	37,205
1891	1,083	6,291
1892	871	5,093
1893	923	5,372
1894	488	2,765
1895	1,687	9,290
1896	712	4,142
1897	2,673	31,393
1898	2,652	27,201
1899	2,264	22,836
1900	2,855	35,275
1901	2,740	29,843
1902	3,052	22,508
1903	2,717	21,302
1904	1,824	8,195
1905	4,334	15,070
1906	6,061	19,924
1907	10,689	55,770
1908	4,066	22,665
1909	3,430	16,350
1910	2,250	13,200
1911	1,850	11,690
1912	1,205	7,130
1913	2,312	13,290
1914	1,190	6,540
1915	1,629	6,653
1916	12,676	57,412
1917	54,275	268,438
1918	75,316	413,870
1919	60,894	345,617
1920	61,111	355,668
1921	76,817	496,394
1922	79,275	430,639
1923	119,826	755,469
1924	99,663	559,980
1925	82,868	404,617
1926	87,300	459,000
1927	104,300	548,000
1928	126,100	662,000
1929	100,000	528,000
1930	120,100	631,000
1931	105,900	556,000
1932	102,700	513,500
1933	96,200	481,000
1934	107,500	451,500
1935	119,425	501,600
1936	136,600	573,700
1937	131,600	552,700
1938	159,230	620,900
1939	146,250	585,000
1940	173,970	695,000
1941	238,960	944,588
1942	260,893	1,623,264
1943	289,232	1,842,708
1944	348,375	2,239,684
1945	297,644	1,868,592
1946	366,809	2,354,952
1947	361,220	2,554,747
1948	407,906	2,789,275
1949	433,533	3,309,303
1950	412,455	3,033,445
1951	494,333	3,766,987
1952	686,218	5,779,423
1953	861,471	8,451,542
1954	666,618	6,442,414
1955	639,696	5,759,000
1956	726,801	6,373,976
1957	842,000	7,296,000
1958	759,000	6,931,000
1959	660,000	5,869,000
1960	722,471	6,318,358
1961	736,931	5,967,764
1962	871,379	6,408,659
1963	853,398	5,910,007
1964	744,942	5,007,506
1965	893,182	6,095,216
1966	927,145	6,953,073
1967	924,549	7,295,834
1968	750,435	4,502,097
1969	667,179	4,365,930
1970	549,473	4,058,929
1971	698,000	5,710,000
1972	668,000	*
1973	694,000	
1974	700,000	
1975	766,000	
1976	706,000	
1977	685,000	
1978	730,000	
1979	690,000	
1980	790,000	
TOTAL	28,133,777	

*Withheld/confidential 1972 onward

NOTE: The relationship between production and valuation (especially pre-1900) is such that these data are suspect. It is believed that the valuations reflect product sales cost, and not mine mouth or raw coal values.



independently derived by many, but rather indicates the acceptance of Barnes' work by subsequent authors while lacking newer data. The estimates of McConkey (1977) were derived by literature search, and generally utilized updated estimates as creating a new limit rather than as replacing the prior estimates. The total resources given herein are statistically ludicrous in that they are the sum of data expressed in the nearest billion of tons and nearest thousand tons. Considering "significant figures" the total Alaskan onshore coal resource is estimated to be 216 billion to 4,216 billion tons, of which 141 billion tons are identified resources. An additional 1,430 billion tons are believed to lie beneath Cook Inlet (to 10,000 ft.), raising the upper total limit to 5.65 trillion tons.

North Slope

The area north of the Brooks Range may constitute the world's largest coal province; it is also one of the least known and one of the least probable for large-scale utilization. In the West Central Arctic--including National Petroleum Reserve, Alaska (NPRA) (12)*--the coal occurs in the 1,000 to 15,000 ft. thick Corwin formation, a deltaic sequence in the upper Cretaceous Nanushuk Group. These coal beds occur in series, with eight or nine individual coal beds commonly totaling 25-30 ft. of coal. Although individual beds in excess of 7 ft. and a few of 20 ft. class are described, most individual beds are 1-3 ft. thick. Of the approximate 150 described coal beds, Callahan (personal communication) describes only 28 individual beds as "thick", but additional groups of beds could be considered synergistically as "thick". On the Arctic coastal plain (1a), the thick wet tundra vegetation generally restricts coal outcrops to stream cuts. These coals are generally of subbituminous "A" rank with low (2-10%) ash and sulfur (0.2-0.3%) and occur in simple, broad, open folds at 6-10° dip.

To the east of the National Petroleum Reserve, Alaska (NPRA) there are few coal outcrops, and most data are from seismic shot holes and oil well logs. Very few data have been published. East of the Reserve, the coal bearing unit is placed in the Colville Group, of late Cretaceous or early Tertiary age. The coal is generally less mature and of lesser rank (subbituminous C and lignite) than are the coals to the West on Arctic coastal plain.

As one approaches the Brooks Range foothills (1b) to the south, the coals are incorporated in progressively tighter and asymmetric folds with axial thrusting and the coal rank increases to high volatile B bituminous. Significant locations include the Corwin Bluffs where eighty coal beds including beds of 5 1/2 and 9 ft.

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*Numbers in parenthesis refer to location on accompanying map.

have been described; the Cape Beaufort area where 12 and 17 ft. beds occur in proximity; and on the Kukpowruk River where a 20 ft. bed of high volatile bituminous coking coal occurs. The last locality has been opened and extensively studied since 1954 by Morgan Coal Co., Union Carbide Corp. and Kaiser Engineers.

Although the presence of coal appears pandemic in the Nanushuk and Coleville groups, points of actual observation are few and far between except in the far west. This makes correlation and resources estimation difficult. On the basis of restricted projections, Barnes (1967) estimated 120,197 million tons of coal, of which 101 million tons was subbituminous, as "identified resources". On the basis of additional well log information, and using liberal, but realistic, projections, Tailleur and Brosge (1976) calculated the additional speculative resource to be between 220 billion* and 3.35 trillion tons; of which 1-50 billion tons are on the Chukchi Shelf. This raises the total resource of the North Slope to between 321 and 3,471 billion tons. Schaff, in COACMAR (1980), using these data plus a 22% factor for additional area, estimated between 402 and 4,000 billion tons of hypothetical sources, plus 60 to 146 billion tons identified resources for a total coal resource of between 460 and 4,146 billion tons.

Difficulty of access, transportation and lack of local large consumptive market essentially negate the probability of large-scale development of the North Slope coals in the near future. Utilization for village needs, however, is considered overdue in light of high local energy costs and the proximity of coal. The most probable large-scale exploitation of these coals may be as liquid or gaseous pipeline feedstock through *in situ* conversion, but this would be many years in the future.

Along the coast of the Lisburne Peninsula (2), where the Brooks Range meets the sea, low volatile bituminous coal is found in the Mississippian Kapaloak formation of the Lisburne Group. The area has been severely deformed and the coal beds are described as crushed, broken, lenticular and without persistence. The thickest bed reported is 4 ft.

Interior Alaska

The interior of Alaska, (i.e., the area between the Alaska and Brooks Ranges), contains several areas where coal bearing rocks occur. Although the state's best known field lies in this province, the majority of these coal locations are known from very incomplete river bank exposures, the surface of most of the area being covered by Quaternary and recent deposits. Over much of the area the extent and distribution of the coal, even the very delineation of the coal bearing basins, has not been determined. Ex-

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*Billion used in U.S. sense, i.e. 1×10^9.

ploration costs in these areas would be high, but the potential for large volumes of subbituminous (and locally bituminous) coal is also large. Transportation may be the critical factor for development.

Nenana Coal Fields

A series of individual Tertiary coal bearing basins extends in a discontinuous belt from up to 30 miles wide, for at least 150 miles along the north slope of the Alaska Range in the Alaska interior. Although several of the basins bear individual coal field names, e.g. Jarvis Creek, Tatlanika, Hood River, Healy, Lignite, Suntrana and Teklanika, et al., they are sufficiently similar that they can be considered under a single title. The coal in these Oligocene-Miocene basins is generally subbituminous C or B, varying generally between 8,500-9,500 Btu. Sulfur content is low, about 0.2%. Throughout most of the area, the overlying sandstones are poorly indurated, making stripping operations favorable.

The easternmost coal field identified in this trend is the Jarvis Creek Coal field (10a) near Big Delta on the Richardson Highway. There are reported to be thirty coal beds greater than 1 1/2 ft. thick and one 8-10 ft. thick seam. The area is gently folded. The coal ranges from 7,800 to 8,300 Btu, typical for Nenana coal, but contains 1.0 to 1.3% sulfur, which is abberantly high. Barnes (1967) indicates over 76 million tons identified resource, but this author agrees with McGee and O'Connor (1975) in feeling that 90% of this would now be better classified as hypothetical resources under the more recent resource classification scheme. This field has been explored under a federal Coal Prospecting Permit, and an application for conversion to lease is pending. This prospect is described by Metz herein.

The Healy, Lignite and Suntrana coal fields lie in the central portion of the Nenana Belt along the Alaska Railroad and the Anchorage-Fairbanks Highway (10b). Several properties in these areas were developed with the construction of the Alaska Railroad in 1918, and many operated during and shortly after World War II. Subbituminous C coal in beds 10-60 ft. thick occurs in cyclical series of poorly cemented graded clastics.

The Usibelli Mine (10b), the only currently active mine in the state, produces about 700,000 tons of coal annually from a series of three 20 ft. thick beds totaling about 60 ft. of coal in a 235 ft. section in moderately dipping fault blocks. Reserves of at least 250 million tons are estimated on Usibelli's state and federal leases. The coal is subbituminous C, averaging about 8,000 Btu, with 27% moisture and 0.2% sulfur, which is considered typical of the Nenana coals.

Immediately to the north, Meadowlark Farms, a subsidiary of Amax, demonstrated commercial quantities of coal in obtaining state coal leases in similar ground, but containing Tertiary diorite intrusions. The carbonization and pyrolitic effects of these are not known.

Until recently, the western end of the string of Nenana coal basins was thought to be seen in the thin and dirty subbituminous coal beds observed in the Kantishna Hills. This hypothesis is now supported by discovery of several coal outcrops about 100 miles further west in the Farewell-Little Tonzona area (10c). The U.S. Geological Survey reports seven beds thicker than 30 inches and a single 285 ft. section containing about 115 ft. of subbituminous coal in a steeply dipping tertiary sequence. The thicker, 110 ft. bed, is similar to that at Jarvis Creek in quality, being richer in sulfur (0.7-1.7%) than the Nenana coals at Healy. Other coals in the area are of elevated rank, marginally bituminous, presumably through diastrophic carbonization. Canadian Superior is currently studying these prospects under contract from Doyon. Speculative resources of 1.5 billion tons could be present.

The coal resources of the entire Nenana coal fields trend are believed to be about 7 billion tons identified and 10 billion tons undiscovered (i.e., speculative and hypothetical) for a total reserve of 17 billion tons.

Other Occurrences in the Interior Region

Borderline subbituminous to bituminous coal is found in 2 ft. beds in several locations along a 120 mile stretch of the Kobuk River, essentially between Kiana and Chugnak (3). The extent and distribution are essentially unknown.

About 36 miles northeast of Bettles, on the middle fork of the Koyukuk River, a 9-10 ft. bed of bituminous coal and extensive additional float have been reported (7). The extent and distribution are unknown.

Along the lower parts of the Yukon River (5), in the Kaltag to Galena segment, bituminous coal in 1-3 ft. beds are reported from several locations in the Kaltag formation (Late Cretaceous). Several small mines were operated for the riverboat market at the turn of the century, including the Pickert Mine, near Nulato, where a 30" seam of fair to good quality coking coal was worked. Conwell (1977) designates this area as the Nulato Coal Field on his map of energy resources. A 10 ft. bed of coal is reported from the vicinity of Anvik.

Coal and lignite have been reported from several sites along the lower Kuskokwim River, including a report of a 6 ft. bituminous coal bed (Barnes, 1967).

Along the Etolin Straits, on Nunivak and Nelson Islands (6), bituminous coals with high coking values are reported, but in beds less than 2 ft. thick. North along the coast, around Unalakleet, lignite and coal were once mined from beds reported to be up to 8 ft. thick.

Several areas of lignite bearing Cretaceous rocks occur in a complex of isolated basins in Paleozoic and Mesozoic metamorphic and igneous terrane on the Seward Peninsula (4). The strata are apparently deformed, at least locally. A steeply dipping 80 ft. bed of lignite at Chicago Creek on the Candle River was opened in 1908 and mined almost continuously until after World War II. Farther upstream on the Candle, steeply dipping lignite beds reported to be 19-66 ft. thick and 58 ft. thick were also mined (Kugruk and Superior Mines). The state is currently studying these occurrences and may develop the coal for use in Kotzebue. Near the confluence of the Yukon and Tanana Rivers (Rampart Area, 8), thin, late Cretaceous bituminous coals were mined for the riverboat traffic at the turn of the century. Although the known coal beds are thin (less than 36 in.), impure and of limited "run", the area has not been explored sufficiently and should remain of interest for the potential local market. Several miles to the north, at the confluence of the Dall and Yukon Rivers, a 4-5 ft. bed of subbituminous coal was described by the USGS in 1973.

Thin, subbituminous coal seams are observed in open folds along an 80 mile segment of the Upper Yukon River near the Canadian (9), between the towns of Eagle and Circle, both of which are served by road. At Washington Creek, five coal beds greater than 4 ft. thick and at less than 45^{o} dip are reported. Schaff, Committee on Alaskan Coal Mining and Reclamation (COACMAR), 1980, estimates hypothetical resources of 100 million tons in this area. A "pocket" of bituminous "coking coal" was mined near the mouth of the Nation River and described as Devonian in age on the basis of the age of adjacent strata. However, this is more likely a tertiary coal, locally carbonized along a fault. Most of the Circle-Eagle coal is now within Yukon-Charley rivers National Preserve and is "off limits" even to investigation.

About 50 miles south of the upper Yukon River coal area at Chicken (17), an outcrop of vertically dipping Tertiary strata includes a subbituminous coal bed greater than 22 ft. thick, which was opened in the 1930s. The extent of the coal is unknown, but the area of tertiary exposure itself is limited to only a few square miles.

So little is known about these several areas of outcrops that resource estimation, even on a speculative basis, is of dubious value. With the exception of Chicago Creek, no resources have been estimated as "identified". McGee and O'Connor (1975) estimate the hypothetical resources of the Middle and Upper Yukon (8,9) areas to total 200 million tons, but this datum ignores the Kobuk, Koyukuk, Seward, Unalakleet, Lower Yukon, Etolin, Bettles and other occurrences. The total resource from these areas must be in billions of tons, but because of National Park Service stewardship we will probably never know.

Southcentral Alaska

Cook Inlet-Susitna Basin Coal Region

The Tertiary sedimentary basin now partially occupied by Cook Inlet contains enormous coal resources. In dealing with coal, this area has been traditionally divided into several coal fields: The Yentna coal field (11a) lying to the north of the Castle Mountain fault, the Little Susitna coal field (11b) extending into the Matanuska Valley, the Kenai coal field (11c) occupying the western part of the Kenai Peninsula, and the Beluga coal field (11d) lying to the west of Cook Inlet. Because of differences in rock and occurrence, the adjacent Matanuska and Broad Pass coal fields (12, 13) are not discussed as portions of the Cook Inlet-Susitna Basin Coal Region.

The thickest and highest ranked coal in the Cook Inlet-Susitna Basin coal region are in the Beluga area (11d) where at least 8 seams of 8,000 Btu, subbituminous coal occur in beds over 20 ft. thick. These include the Canyon Bed, 23 ft. thick, with "indicated resources" of 66 million tons; the Drill Creek Bed, 65 ft., 64 million tons; the Capps Bed, 50 ft., 366 million tons; the Chuitna Bed, 52 ft., 1,219 million tons, and the Beluga Bed, 30 ft., 12 million tons, (Barnes 1966) totalling 1,727 million tons. Additional beds are known, and the logs of Pan American Petroleum No. 2 State show 42 significantly thick coal beds in the 7,450 ft. of Tyonek strata penetrated. Although some of these thick coal beds have been traced for several miles along rivers, there is a lack of data away from the rivers, so Barnes' (1967) identified resources estimate of 2 1/4 billion tons is based on a mere selvage of the possible coaliferous area.

Based on more recent data, Swift et al., (1980) identified at least 750 million tons as being economically extractable under present conditions from approximately 50,000 acres in the Capps and Chuitna areas. Resources for the entire Beluga area are unknown, but this area alone probably exceeds the 29 billion ton resources estimate that McGee and O'Connor (1975) ascribed to both the Beluga and Yentna (11a) coal fields. Most of the Beluga coals range from 6,600 to 8,200 Btu (8,500-9,800 MMF) with 16 to 22% ash, 20-30% moisture and 0.1 and 0.2% sulfur. Recently discovered beds beneath the Chuitna bed are cleaner (7-8% ash) but washing and drying are considered necessary for most of Beluga coal, especially for the anticipated export market. Papers in this volume by Rao, Bechtel, Wolff and Nakabayashi address the beneficiation of Beluga coal through washing, drying or addition of oil. Plans for both the sale of bulk beneficiated coal and for the conversion of the coal to methanol are being seriously considerd at this time, as will be discussed in the papers of Kirshenbaum and Ramsay, to be presented here.

The coal sequence of the Beluga coal formation dips synclinally eastward under Cook Inlet, extending in the subsurface of the

Kenai Peninsula (11c). McGee and O'Connor (1975) estimated 1.3 trillion tons of lignite to subbituminous coal as hypothetical and speculative resources to a depth of 10,000 ft. under Cook Inlet, of which 53.2 billion tons were in beds over 20 ft. thick. The prospects of _in situ_ recovery from beneath Cook Inlet and the Kenai Peninsula are intriguing.

In addition to these Tyonek Formation coals, the younger Beluga and Sterling exposed on the Kenai Peninsula contain coals. The coals found near the surface on the Kenai Peninsula are less mature than are the Tyonek Formation coals of the Beluga field, with greater ash and volatiles and less fixed carbon. They are generally dull, platy and cleated in appearance with considerable evidence of woody and bark tissues, and of marginal lignitic to subbituminous rank. Most beds are 2-3 ft. thick and lenticular, but 7 ft. beds are known, including one mined several times at Homer. McGee and O'Connor (1975) estimated 24 billion tons hypothetical resources of coal on the Kenai Peninsula, of which 300 million tons are the demonstrated resources estimated by Barnes (1967). The majority of the Kenai coal field is under state and native title, with intensive recreational, private and municipal surface use which will probably preclude surface mining. There may be potential for underground recovery, however.

The Tyonek Formation coals of the Beluga field reappear north of the Castle Mountain fault and Mt. Susitna intrusives in the Yentna coal field (11a). Around the western margin of the basin moderately to steeply dipping coal seams have been reported, including 15 ft. beds on Johnson Creek and the Nakochena River, a 25 ft. "bed" near Mt. Fairview and a 55+ ft. "bed" on Sunflower Creek. These western margin coals are similar to those of the Beluga coal field. Blumer (this volume) describes these coals as 5,400-9,450 Btu (a.r.) with 6-40% ash, 20-30% moisture and 0.1-0.2% sulfur, and reports 500 million tons identified resources in five 10-45 ft. thick beds to depths of 250 feet.

In the more central and eastern portion of the Yentna Basin these coals are to 8,000 ft. deep, but surface exposures of younger, thinner (to 6 ft.) beds of dirty, low rank subbituminous coals have been utilized for years by the placer miners of the Dutch and Peters Hills. Reed et al., (1978) estimated 64 million ton "resource" presumably as "inferred" in this area. The hypothetical resource must be several billion tons. The Alaska Railroad and the Parks Highway follow the eastern margin of the Yentna basin.

The coals of the Little Susitna coal field (11b) are similar to those of the adjacent eastern margin of the Yentna field; platy, dirty lignitic to subbituminous coals in thin, generally lenticular beds. The only known commercial deposit, at Houston, was exhausted through surface and shallow underground mining, producing about 90,000 tons of subbituminous coal during World War II.

The total coal resource for the Cook Inlet-Susitna coal province (i.e. the Beluga, Kenai, Yentna and Little Susitna coal fields and that beneath Cook Inlet) are believed to be approximately 1.5 trillion tons; of which 11 billion tons are identified resources (see McConkey et al., 1977). At least 750 million tons have been blocked out for immediate mining.

Broad Pass Lignite Field and Nearby Locations

The Broad Pass Lignite field (13) is an apparent northern extension of the Cook Inlet-Susitna Basin coal region, following the Chulitna River in what appears to be a graben. These are lignitic coals in 5-10 ft. horizontal beds, believed to be younger than are the coals in the Yentna Basin to the south. Although of low calorific value, its location adjacent to the railroad makes this an interesting prospect. Barnes (1967) estimated 64 million tons inıormal resource in a 7 sq. mile area of this inferred 300 sq. mile field. Projection of these data is of doubtful validity, but McGee and O'Connor's (1975) hypothetical resource estimate of 110 million tons is believed overly conservative.

West of Broad Pass, a small outlying area of subbituminous coal at Costello Creek was mined between 1940 and 1954. At Yanert, on the Alaska Railroad in McKinley (now Denali) National Park, a small amount of coal was mined shortly after World War I. At least two other mines operated in the National Park area, including one at Highway Pass where a 1-3 ft. bed was mined for use in the park buildings.

Matanuska Coal Field

To the east of the Little Susitna coal field are older, early Tertiary (Eocene?) coals (12). These older and more mature coals of the Chickaloon Formation have been diastrophically carbonized to progressively increased rank eastward up the Matanuska Valley, from high volatile bituminous at Wishbone Hill to anthracite on Anthracite Ridge.

In the Wishbone Hill district three series of coal beds with individual beds to 23 ft. occur in a large, steeply dipping faulted syncline. The coal beds are thin, 2-3 1/2 ft., and contain shale partings. They run 12,000-12,500 Btu with 11% ash and 0.3-0.5% sulfur. The most productive mines were on the gentler dipping (11-30%) south limb.

The largest mine in the district, Evan Jones, produced 6 million tons of coal per year before closing in 1968. Eight beds were mined, including one (the #3 seam) 8-12 ft. thick. Underground mining operations ceased in 1952, leaving an estimated 100 million tons identified resources. Also on the south limb are the Eska Mines, operated by the Alaska Railroad intermittently from 1919 through World War II as a contingency supply. Identified resources of 600,000 tons remain in the Eska property.

The coal beds on the steeper dipping (25-35^{o}) north limb of the Wishbone Hill syncline were exploited by the Wishbone Hill, Buffalo, Baxter and Premier Mines. The coal beds are quite variable in both thickness and quality, but are generally in 2-3 ft. beds. A Bureau of Mines core drilling program, 1949-1958, indicated that the area is structurally complex, with numerous small faults offsetting the coal beds. Although a large resource of coal existed, 112 million tons according to Barnes (1967), the most readily exploitable 6 million tons have already been removed, the remainder being generally too deeply buried or in blocks too small to attract development at this time.

The Chickaloon District is based on a small area (12 sq. miles) of Chickaloon Formation outcrops exposed in a complexly folded, faulted and dike intruded synclinal structure. Low volatile bituminous coal occurs in disturbed lenticular beds to 14 ft. thick. Although some samples have shown strong coking tendencies, the intense deformation and lack of coal bed uniformity, purity and continuity have discouraged mining. In 1921 the U.S. Navy built a coal mining town at Chickaloon, but had to abandon it when it was later discovered that the coal could not be mined at a reasonable cost and was not generally satisfactory for Naval use. Barnes (1967) estimated 23 million tons (best considered as hypothetical resource) in a small portion of the area.

The Anthracite Ridge District at the eastern end of the Matanuska Valley coal field contains thin and discontinuous lenses of semianthracite and, locally, anthracite, in a complex of tight folds, faults and intrusions. Although most of the coal exposures are of beds best measured in inches, beds to 10 and 16 ft. thick are reported. However, continuity beyond 100 ft. is generally lacking, and the thicker coal occurrences tend to be associated with diabase dikes. Based on a study of the 90 known outcrops and eight cores, Waring (1936) estimated "several million" tons of coal present, mostly semianthracite.

Total resources for the Matanuska Valley coal field have been estimated at 248 million tons (McGee and O'Connor, 1975) to 274 million tons (Barnes, 1967), including identified resources of 99 million to 125 million tons respectively. The total resource, most hypothetical, is probably closer to 500 million tons, with a little over 100 million tons as "identified" resource.

Gulf of Alaska Tertiary Basin

The Bering River coal field (14) on the Gulf of Alaska is the state's most historically renowned coal field, being the focus of the Alaska coal "scandal" (Pinchot-Ballinger controversy) that shook the Roosevelt and Taft Administrations. After 60 years of study by numerous geologists from the federal, private and military sectors, the area remains problematic. The coal ranges from low volatile bituminous in the west to semianthracite in the east in this 6 x 20 mile area. The coal occurs in the Kushtaka Formation of early or mid-Tertiary age. The area is so extremely deformed that the term "coal bed" is not applicable, the coal generally occurring as pods, lenses, along faults or as discordant masses along the axes of compressed isoclinal and disharmonic folds. Although spectacular outcrops of seemingly 20-30 ft. thick coals may be observed, thorough study has shown that these are not true bed thicknesses. The "common knowledge" presence of coking coals in the area is not supported by published data, although Douglas Colp (personal communication) has noted successful coke testing in the field. Hypothetical resources to 3,000 ft. are 3.6 billion tons, of which only 1,500 tons are classified as "measured resources" (Queen Vein on Carbon Creek).

Coal in beds up to 6 ft. thick have been reported from the Robinson Mts. (15). These are apparently in the Kultieth Formation, an age and facies equivalent of the Kushtaka Formation of the Bering River coal field and, according to Irv Palmer, U.S. Geological Survey (personal communication), the coal is similarly distorted.

Alaska Peninsula

Chignik-Herendeen Bay

High volatile bituminous coal occurs in the upper Cretaceous Chignik Formation at Herendeen Bay, in the Chignik area, and presumably in the hundred mile area in between. The area has been moderately to extensively folded and faulted. Dips are generally in excess of 30° and continuity of the homoclinal limbs is not great. The coal beds are generally 1-2 ft. thick, but 4 and 6 ft. beds have been reported in the Chignik area.

McGee and O'Connor (1975) estimate hypothetical resources of 240 million and 2.9 billion tons respectively in the Chignik and Herendeen Bay areas, exclusive of the unexplored intervening area. Schaff, Committee on Alaskan Coal Mining and Reclamation (COACMAR) 1980, estimates 300 million tons for each of these sites. Considering the area between these locations, the author estimates 1.5 billion tons hypothetical resource.

Unga Island

Beds of tertiary lignite up to 4 ft. thick occur in a single low dip ($8-10^{\circ}$) homocline on Unga Island and in the adjacent portions of the Alaskan Peninsula. The only analytic data on this coal showed 26% ash, 25% moisture and 0.5% sulfur (a.r.) giving 8,100 Btu (MMF).

Southeastern Alaska

Coal occurs at several locations in the Alexander Archipelago (18). On Kuiu, Kupreanof, Zarembo and Prince of Wales Islands thin beds of Tertiary lignite occur. At Kotznahoo Inlet on Admiralty Island are 2-3 ft. beds of impure, sulfurous bituminous coal. A small mine supplied Juneau with some of this coal prior to 1929.

Concluding Remarks

The total coal resource of Alaska is estimated to be 476 billion to 4,216 billion tons, of which only 14 billion tons are classified as identified resources. An additional 1,430 billion tons are believed to lie beneath Cook Inlet. To quote such data without an understanding of the caveats discussed in their derivation would be folly. Therefore, please read the two boring pages preceding the resource estimation table and map herein.

In considering the coal resources of Alaska, one must bear in mind the fact of the myriad working conditions encompassed by the state. To say merely that Alaska is cold and snowy is a dangerous oversimplification. Alaska is not environmentally homogenous. Conditions vary from the arctic desert, an area of meager precipitation which is ankle deep with water due to poor runoff and percolation, to the southeastern rainforests and southwestern cloud shrouded barrens of the Aleutians. Mining plans must be atuned not only to the characteristics of the deposit but to the local working conditions as well. Some of the unique Alaskan working conditions such as temperature and permafrost have severe impact on mining operations and equipment, but must not be considered as state-wide problems.

The major hurdle to be overcome in developing Alaskan coal resources is transportation. The surface transportation facilities of Alaska are very poorly developed. The potential for developing surface transportation is decreased by severe physiological barriers such as the Alaska and Brooks Ranges, which form east-west bulwarks cut by passes in the seemingly least advantageous locations. Between these ranges are hundreds of miles of wetlands posing a road building nightmare. The ice bound coast of the northern half of the state essentially precludes effective direct ocean access to the state's largest coal province. Finally, and most persuasively, the federal government has created a series of "institutional barriers" through new parks, refuges and monuments that effectively isolate much of the richest coal areas. Although a great percentage of the Alaskan coal resource is currently deemed unexploitable due to lack of transportation and institutional barriers, one need not despair--Alaska has such an enormous coal resource that there remains an overwhelming number of development prospects. Better, the state's geology is so poorly known that the potential for discovery of new coal fields is high. Many of the identified coal areas are based on "lost" outcrops; who knows what a proper drilling program would uncover?!!

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Coal occurrences of the Nanushuk Group, western Arctic Alaska--An update

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Introduction

Coal in northern Alaska occurs in two sedimentary rock sequences, the Nanushuk Group of Early to Late Cretaceous age and the Colville Group of Late Cretaceous age. The coals in the Nanushuk Group have been more thoroughly investigated for several reasons, including early interest in their commercial possibilities and accessibility for local utilization at Barrow and Wainwright, and apparent general superiority in overall quality.

The Nanushuk Group was originally mapped and subdivided on a regional scale in the Western Arctic by Chapman and Sable (1960). More recently, Ahlbrandt and others (1979) completed a wide ranging study using modern sedimentological concepts and techniques and newly acquired subsurface data, primarily for the purpose of evaluating the oil and gas potential of the Nanushuk Group rocks in the National Petroleum Reserve--Alaska (NPRA). Of particular interest with respect to coal occurrence is their application of a deltaic sedimentation model to reconstruct depositional environments of the facies represented by the Kukpowruk Formation (transitional near shore marine to nonmarine) and the Corwin Formation (nonmarine). These two formations make up the Nanushuk Group in the foothills and Arctic Coastal Plain of the western North Slope.

Geologic Setting

Tectonic disturbance has greatly affected the distribution and rank of coal beds between the foothills and the Coastal Plain, resulting in a considerable difference in the methods of investigation and the facility of interpreting the results. In the foothills the outcrop area of the Corwin Formation is discontinuous, (Fig. 1) and most, if not all, observed stratigraphic sections represent only the lower part of the original thickness of the formation. The Corwin occupies the central parts of numerous broad and relatively simple synclinal basins separated by tightly folded, east trending anticlines; most of the anticlines are complicated by high angle reverse faults or north directed thrust faulting in the Kukpowruk Formation, and many are breached through to the underlying Torok Formation. The thermal maturity of the rocks, as illustrated by apparent coal rank and near surface

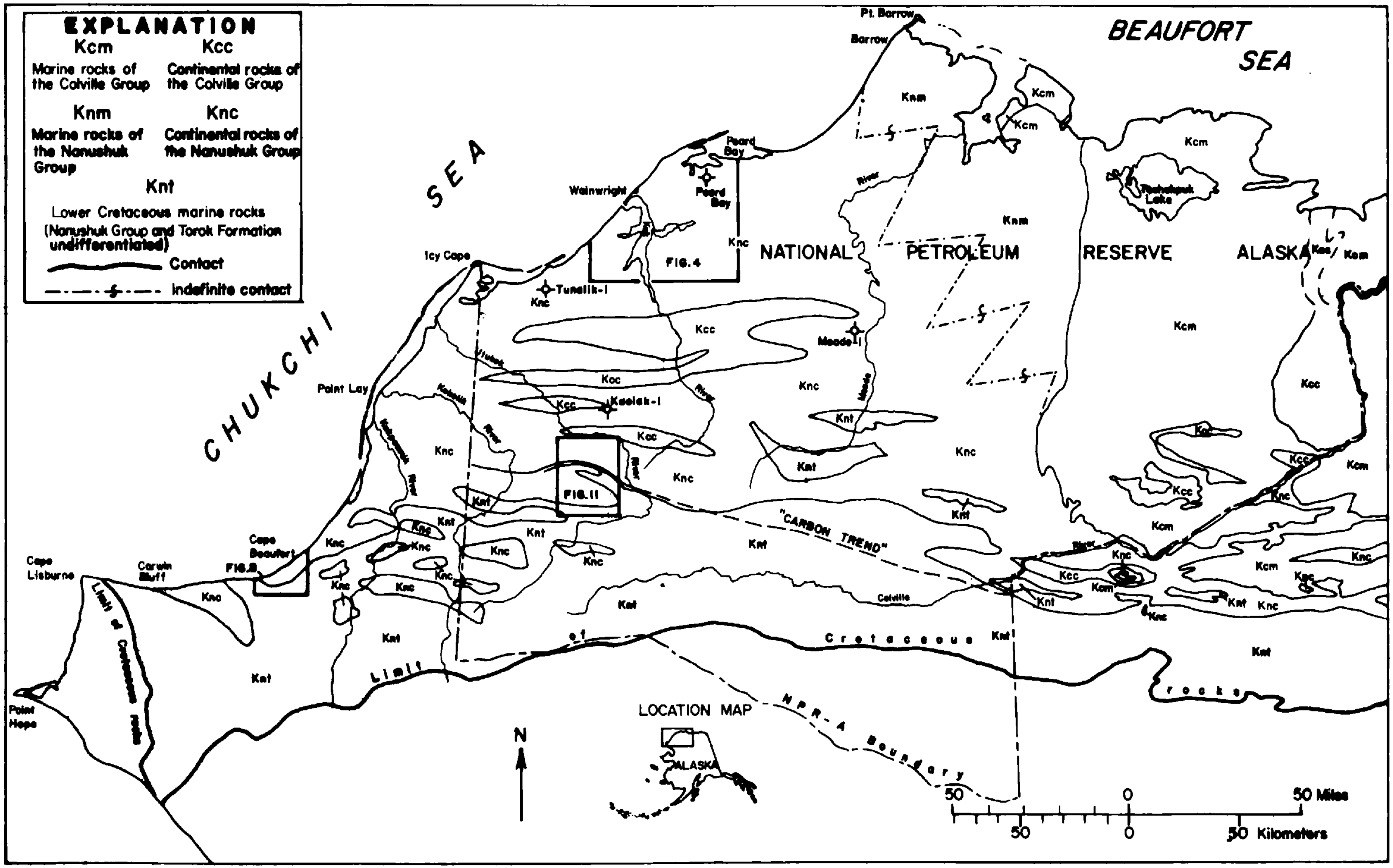


Figure 1- Geologic map of northwestern Alaska (adapted from Preliminary Geologic Map of Alaska, Beikman, 1978)

seismic velocities, both suggest a much greater depth of burial, uplift and erosion in the foothills than in the Coastal Plain.

In the foothills, resistant sandstone beds form low rubble ridges and benches which clearly define the major structural features, but exposures of the intervening shale and siltstone intervals, including coal beds, occur only in cutbanks of the larger streams and along the sea cliffs at Corwin Bluff. In the absence of subsurface data, the outcrop positions of coal beds can only be inferred in the interstream areas by reference to the bedding traces of associated sandstone beds.

In the Coastal Plain, the Nanushuk Group forms a continuous subcrop beneath Pleistocene and Holocene surficial deposits. It has a general homoclinal dip to the south, averaging about 50 feet to the mile in the western part of NPRA. Prior to the Navy's oil and gas exploration program on Naval Petroleum Reserve No. 4 (PET-4) during the late 1940's and early 1950's, little was known about the thickness and distribution of the coal bearing rocks in the Coastal Plain, except for isolated exposures along the Kuk River near Wainwright and on the Meade River. Two of the early Navy wells, the Meade and the Kaolak, penetrated about 1,200 feet and 4,000 feet respectively of coal bearing rocks, which were recognized as equivalent to the Corwin Formation exposed in the foothills belt. On the Reserve (redesignated National Petroleum Reserve--Alaska (NPRA) in 1976), more recent deep wells have furnished improved stratigraphic control and coal thickness data, and, together with a widespread reconnaissance scale seismic grid, provide the basis for a reasonably accurate estimate of hypothetical coal resources in the Coastal Plain.

Recent Investigations

Prior to 1978, subsurface investigations, other than those directly related to oil and gas exploration, consisted of drilling by the U.S. Bureau of Mines at Cape Beaufort and on the Kukpowruk River, by Lounsbury and associates near Wainwright, and trenching and shallow hole augering by the Geological Survey at numerous localities in the foothills between Cape Beaufort and the Utukok River. In the winter of 1978, the U.S. Geological Survey (USGS), with the cooperation of Husky Oil Company and Geophysical Services, Inc., began an experimental program to determine the feasibility of obtaining shallow subsurface data on coal bed thickness and distribution, by logging seismic shotholes in the foothills and Coastal Plain of the western National Petroleum Reserve--Alaska, initially using the natural gamma radiation tool. This method, despite its obvious limitations as compared to a drilling program devoted solely to coal explortion, has been successful in obtaining accurate and precisely located data on coal beds over a wide area, at a cost several orders of magnitude lower than any other method for obtaining comparable information. During the 1979 and 1980 seasons, a gamma-gamma density tool was also used, which resulted in better definition of coal bed thickness and aided in resolving the ambiguity between log responses of coal and clean sandstones that arises from using the natural gamma tool alone.

During the three years in which the shothole logging program was conducted, the spacing of holes was one quarter mile in the Coastal Plain and one sixth mile in the foothills. The drilled depths were 75 feet and 105 feet, respectively. The number of holes available for logging varied. The time required for logging averaged 10 to 15 minutes per hole, using both tools. Under ideal conditions, which were rare, this permitted logging every second hole in the foothills. In the Coastal Plain, the terrain, shallower holes and easier drilling resulted in a more rapid pace for the seismic operation as a whole, and it was seldom possible to obtain both types of log on a systematic basis. This limitation was offset by the fact that the low dip results in more continuous stratigraphic coverage for a given horizontal spacing of holes than in the foothills.

Typical log responses (Fig. 2) of coal beds reflect the low natural radiation of most coals and the density contrast between coals and the enclosing rock. Where the natural gamma log is used alone, ambiguity sometimes results from the similarity of log responses for clean sandstone and for coal. Also, particularly in the Coastal Plain, a similar ambiguity is possible in the responses of coal and ice lenses on both logs. These ambiguities normally could be resolved by an observation of the proportions of coal and ice in the drill cuttings.

Depositional Environment

Because a companion article in this volume is devoted to a detailed interpretation of the environments of deposition of the Nanushuk Group rocks in the foothills, the following discussion is limited to a summary of the regional depositional framework as it relates to the stratigraphic distribution and geometry of coal beds or zones observed in our studies.

Together with the upper part of the Torok Formation, the Nanushuk Group in the Western Arctic is thought to represent a prograding deltaic depositional system (Fig. 3) initiated in Early Cretaceous time. The system included uplift and erosion of older rocks in the western Brooks Range and Lisburne Peninsula area and deposition of the resulting detritus in the Colville Trough, a foredeep which developed north of, and generally concurrently with, the Brooks Range uplift. In the west, the progradation apparently was nearly continuous, with only minor local marine transgressions. The overall thickness of the Nanushuk Group decreases from southwest to northeast, from more than 11,000 feet at Corwin Bluff to zero in eastern National Petroleum Reserve--Alaska. The coal bearing facies, the Corwin Formation, comprises the full thickness

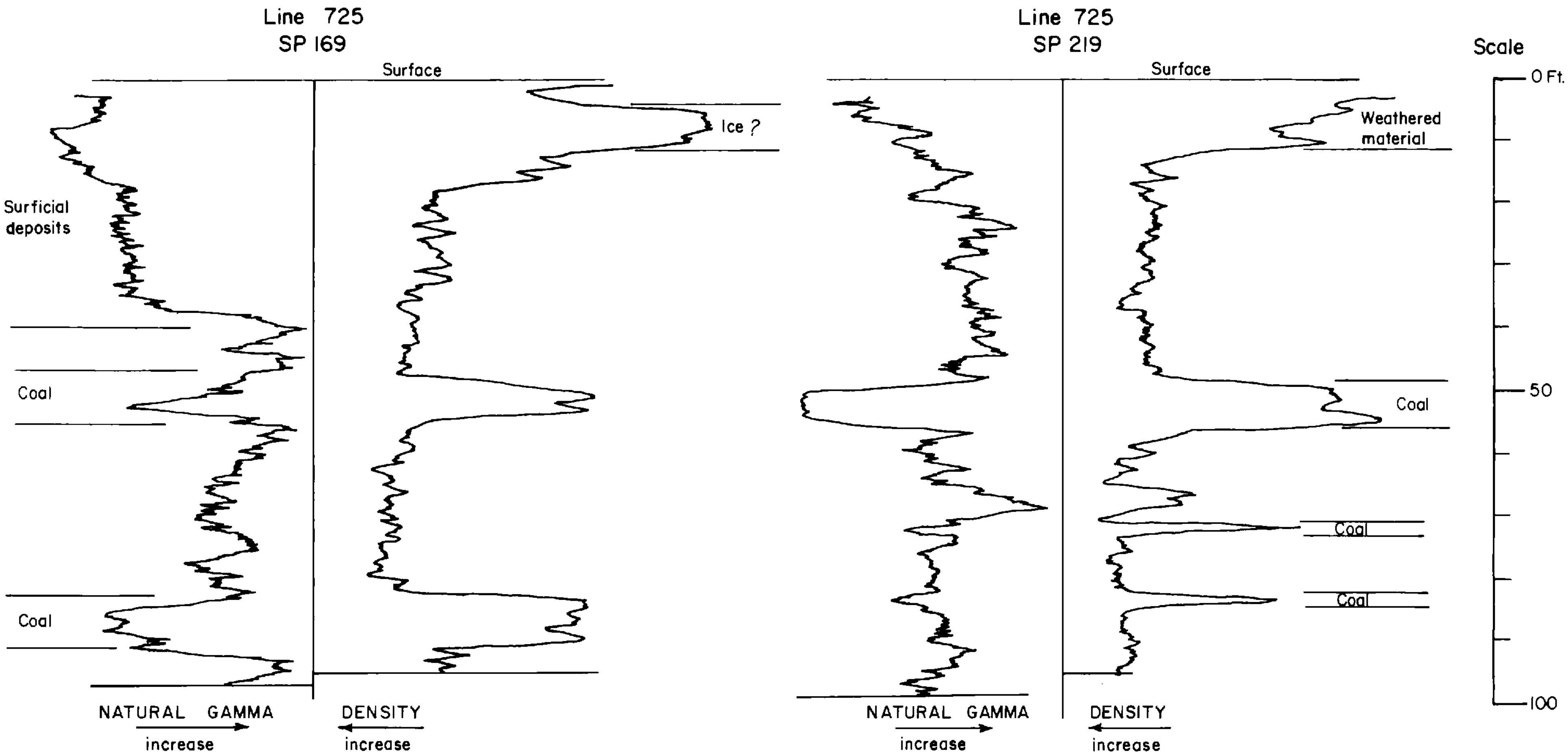


Figure 2 - Typical log responses (Elusive Creek syncline; lines and shotpoints shown on fig. 10)

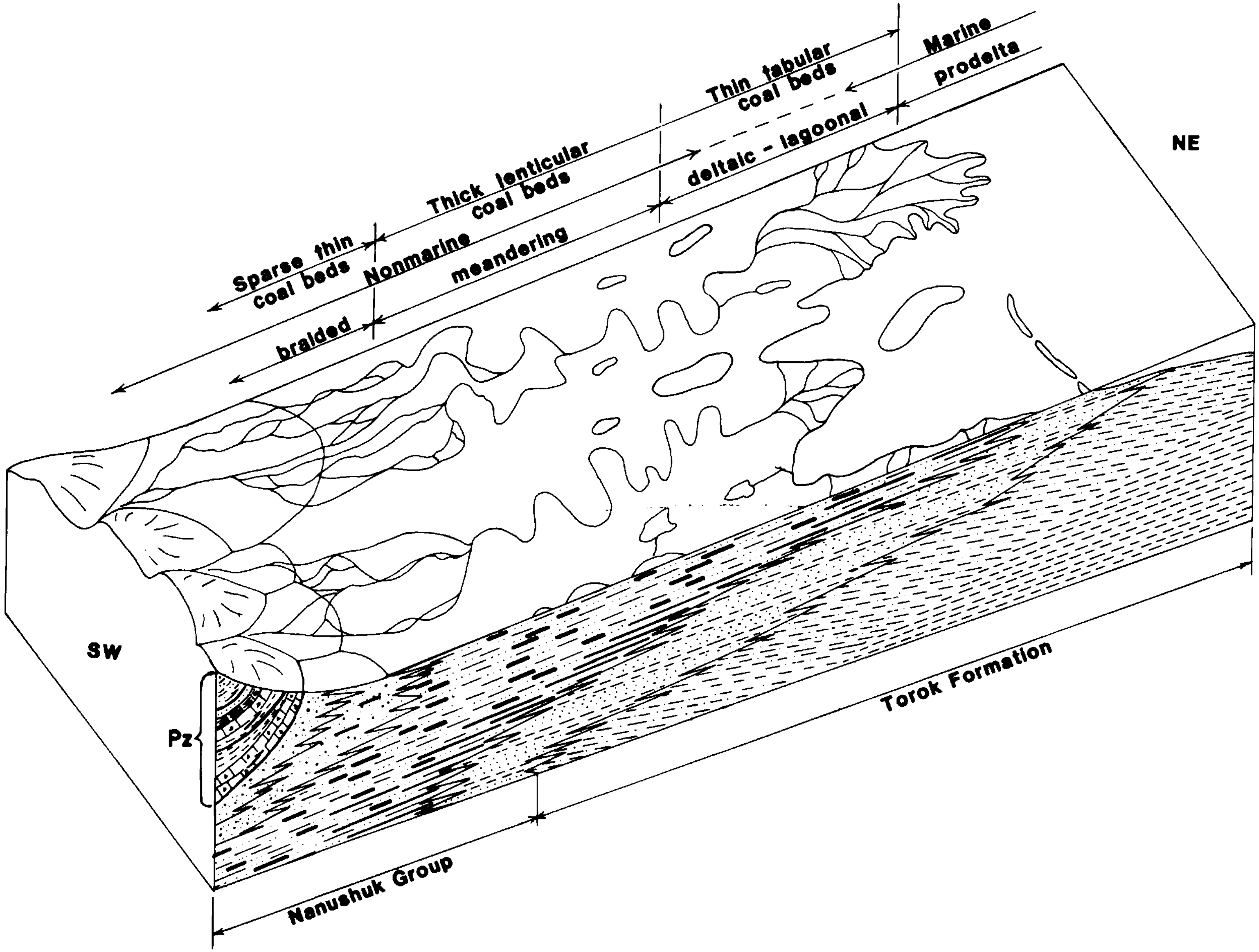


Figure 3 - BLOCK DIAGRAM OF PRINCIPAL DEPOSITIONAL ENVIRONMENTS INFLUENCING THE DISTRIBUTION OF COAL FACIES DURING DEPOSITION OF THE NANUSHUK GROUP .

exposed at Corwin Bluff and is about 4,000 feet thick in west-central NPRA. As noted previously, the original thickness in the foothills in southern NPRA was probably much greater than this, possibly 3,000-6,000 feet greater, based on coal rank. On the basis of gross lithology, coal bed distribution and sulfur content, the depositional environment of the thicker coals in the Corwin Formation seemingly differs somewhat from the modern analogues most commonly used as models for deltaic sedimentation. The low sulfur content of most coals in the section suggests isolation from salt or brackish water influences, as might be expected in an upper delta plain or flood plain environment. However, the low ratio of coarse to fine clastics in the associated rocks suggests deposition by streams with low gradients, as might be expected in more seaward parts of the delta system. Such conditions might be found in a wide band of swampy coastal lowland traversed by numerous moderate sized streams.

Coal Occurrence—Arctic Coastal Plain

In the Coastal Plain near Wainwright (Fig. 4) shallow subsurface data from shotholes, along with logs from two deep exploratory wells, have permitted a rough zonation for the Corwin Formation. The coals in the lower part of the Corwin are relatively thin, but laterally continuous, some being correlatable for as much as 12 miles between seismic lines (Fig. 5, beds 2 and 3). Coals in the Corwin are overall low in sulfur, but the sulfur content of these lower coals is relatively higher and more erratic than that of coals higher in the Corwin, suggesting peat deposition in inter-distributary bays in the lower (more seaward) part of the delta system, and therefore subject to periodic exposure to salt or brackish water. Coals higher in the Corwin were probably deposited in backswamp areas between stream channels in an upper delta plain or flood plain environment, where thicker accumulations were possible due to greater stability of channels and more prolific plant growth. These stratigraphically higher coals are as much as 30 feet thick, but tend to thin and split over short distances (Fig. 6, bed 18). Coals in the zone of transition between these two environments, where beds 6-10 feet thick are laterally persistent for as much as 6 miles, probably have the best commercial potential (Fig. 5, beds 4, 6, 7; Figure 7, beds 4 and 5).

Coal Occurrence—Foothills

In the foothills, due to greater structural complexity and steeper dips, the data on coal bed distribution and geometry are more fragmentary than in the Coastal Plain. Except for the type section of the Corwin Formation at Corwin Bluff, every stratigraphic section which has been measured and described to date has contained substantial gaps, and as mentioned previously, the original thickness does not appear to have been preserved in any of the

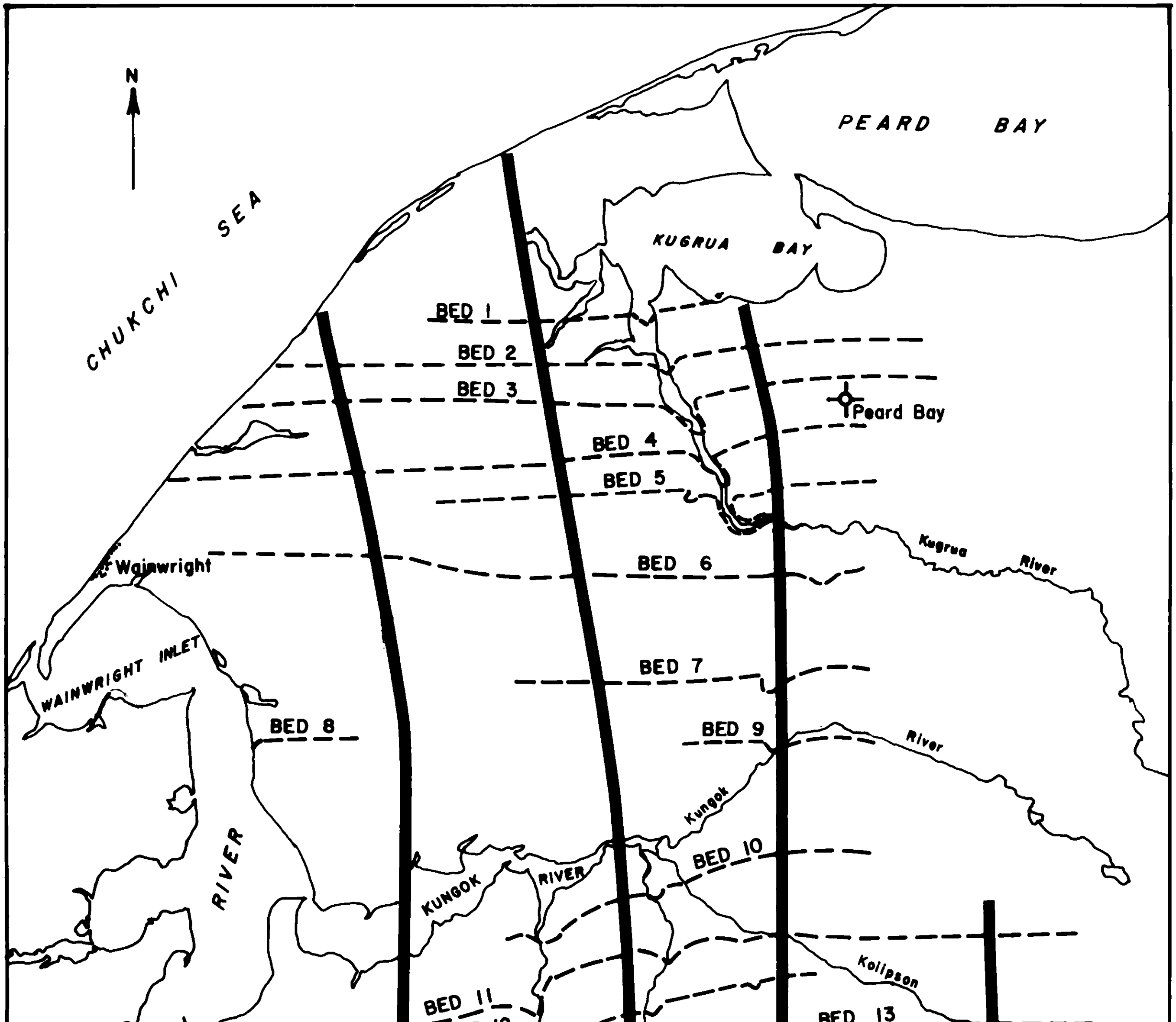


Figure 4 - Coal bed subcrop distribution and seismic lines, Wainwright area, Alaska

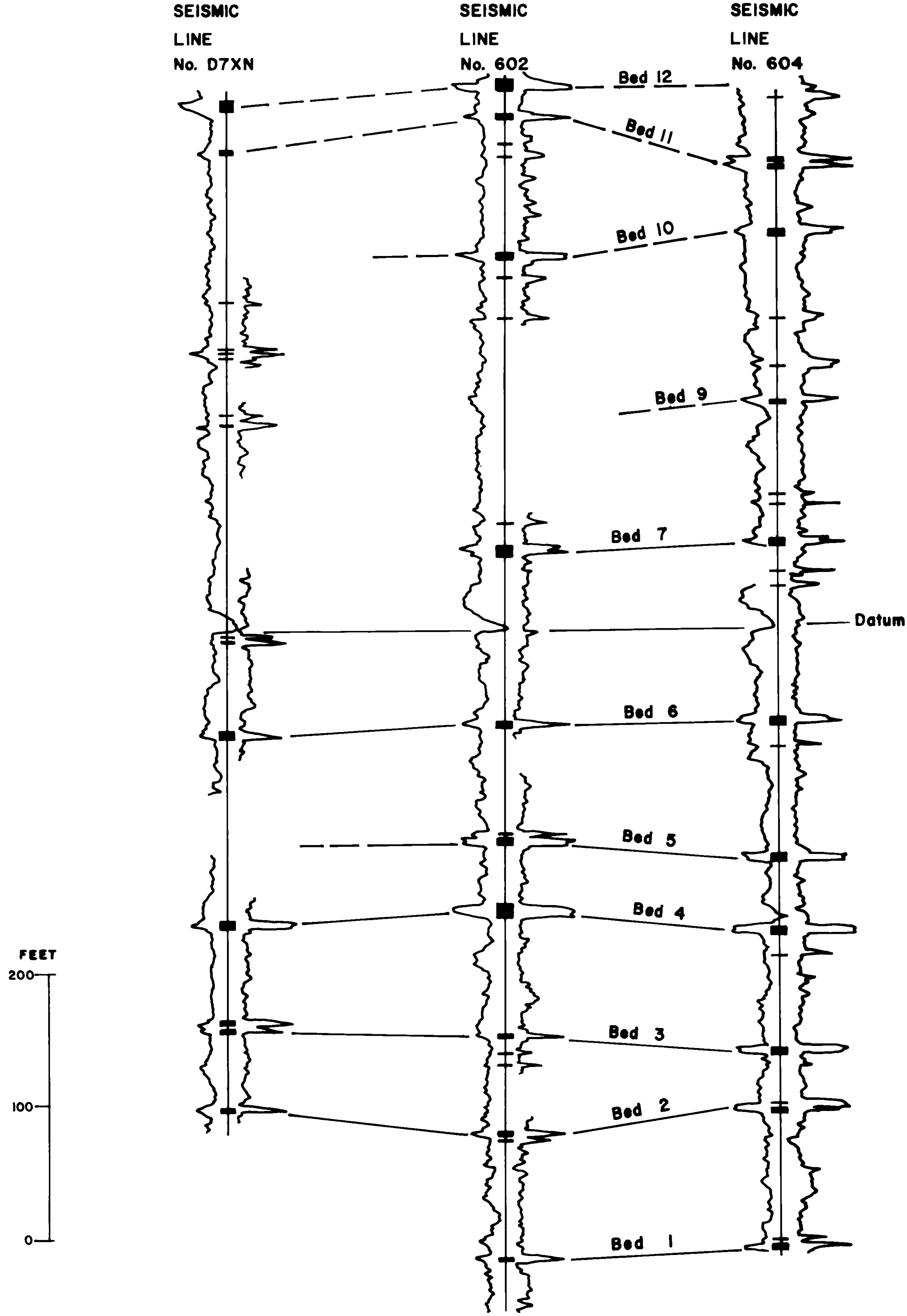


Figure 5

Coal correlations from composite log sections along seismic lines, Wainwright area, Alaska.

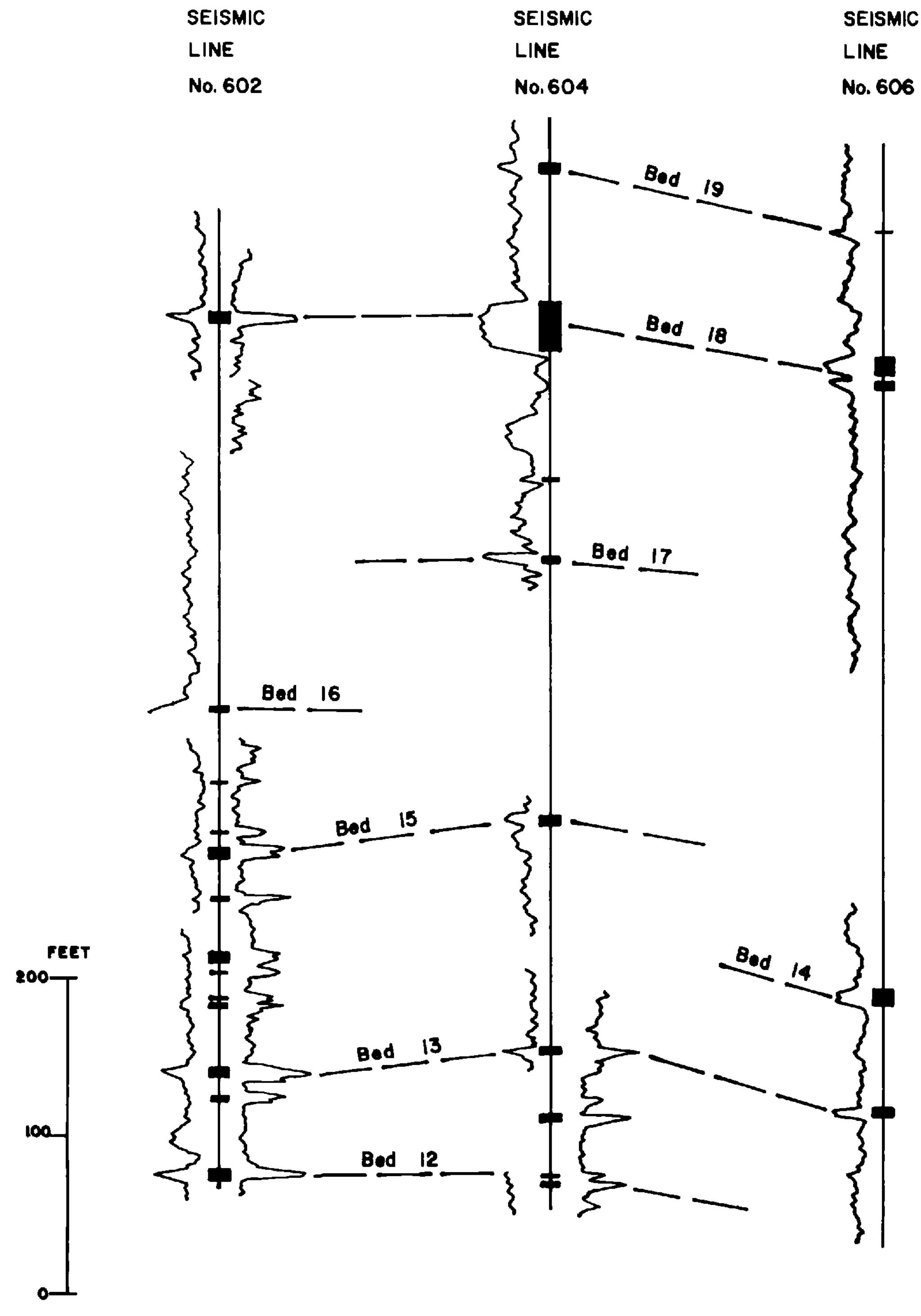
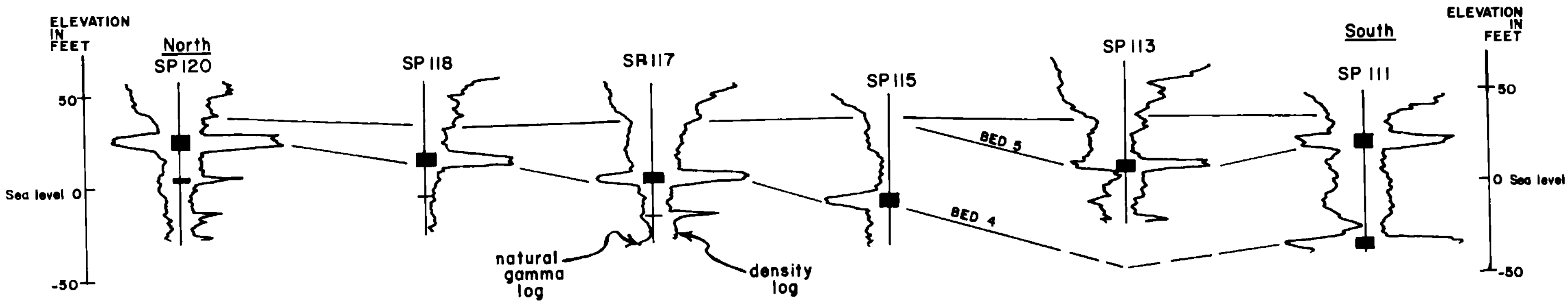
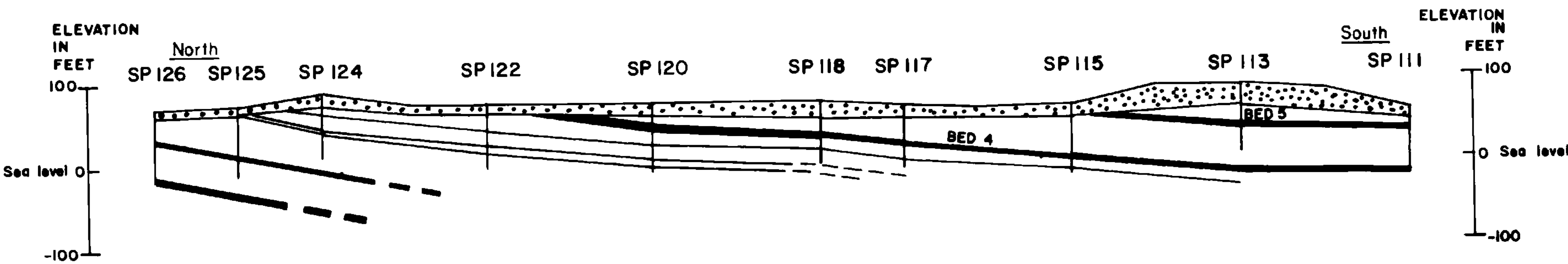


Figure 6

Coal correlations from composite log sections along seismic lines, Wainwright area, Alaska.



Log correlations of coal beds along seismic line 604



Shallow cross section along seismic line 604

Figure 7 - Log correlations and cross section along seismic line 604, Wainwright area, Alaska.

structural basins. Even along the lower Utukok and Kokolik Rivers, where the Corwin is overlain by rocks thought to belong to the Colville Group, structural relationships and the difference in the degree of induration between the two units suggests a significant depositional hiatus, during which a substantial thickness of the Corwin was removed by erosion.

Cape Beaufort Area. At Cape Beaufort, the Corwin Formation occurs in the Liz-A syncline, a doubly plunging syncline about 15 miles long (Fig. 8), and attains a thickness of about 8,000 feet. The lower 2,000 feet of the Corwin consists predominantly of interbedded shale, siltstone and thin sandstone beds with thin coals and carbonaceous shale zones, which probably represents a lower delta plain environment of deposition. An overlying zone about 2,700 feet thick contains somewhat thicker sandstone beds and several moderately thick (6 to 10.5 feet) and laterally persistent coal beds (Fig. 9, beds 10-20), at least one of which can be correlated for about 11 miles northeast to southwest along the outcrop, which in this area is generally parallel to the dominant paleocurrent direction as determined by Ahlbrandt and others (1979). In terms of the deltaic depositional model, the coal forming swamps during deposition of this zone were probably elongate subparallel to the stream channels. An overlying zone, about 1,600 feet thick, contains no known significant coal beds. The uppermost 1,700 feet of the section at Cape Beaufort includes thick lenticular sandstones and the two thickest coal beds (Fig. 9, bed 7, 16.5 feet and bed 8, 11.5 feet). Neither of these thick coals can be traced for more than about 5 miles, and the thicker of the two splits and thins rapidly to the southwest along the outcrop.

Utukok River Area. Coal beds were mapped in the Elusive Creek, Oxbow and Lookout Ridge synclines, on the basis of a few surface exposures along Elusive and Avingak Creeks, several auger holes and geophysical logs, mainly along four seismic lines (Fig. 10). Tentative correlations were made using color infrared aerial photography between these control points. Where available, seismic record sections provided approximate dips used in construction of composite stratigraphic sections.

The thickness of the Corwin Formation in the Lookout Ridge syncline is about 1500 feet above the transition zone mapped along the south limb of the syncline. The upper 800-900 feet contains six coals. Of these, only the beds 3 and 5 (Fig. 10) can be correlated for a significant distance. Along line 605, bed 3 thins from 12 feet to 8 feet in a distance of 2 miles to the east, and to 6.5 feet in a distance of 3 miles to the west (Fig. 11). Bed 5 thins and splits from about 10 feet westward to 6.5 feet in 1.3 miles. Along line 137 (Fig. 12), bed 3 apparently maintains a relatively constant thickness from south to north over a distance of 2.3 miles.

In the Oxbow syncline the thickness of the Corwin section is estimated to be about 2,500 feet, judged from an ill-defined base and a poor seismic record section. Beds 3 and 5 from the Lookout

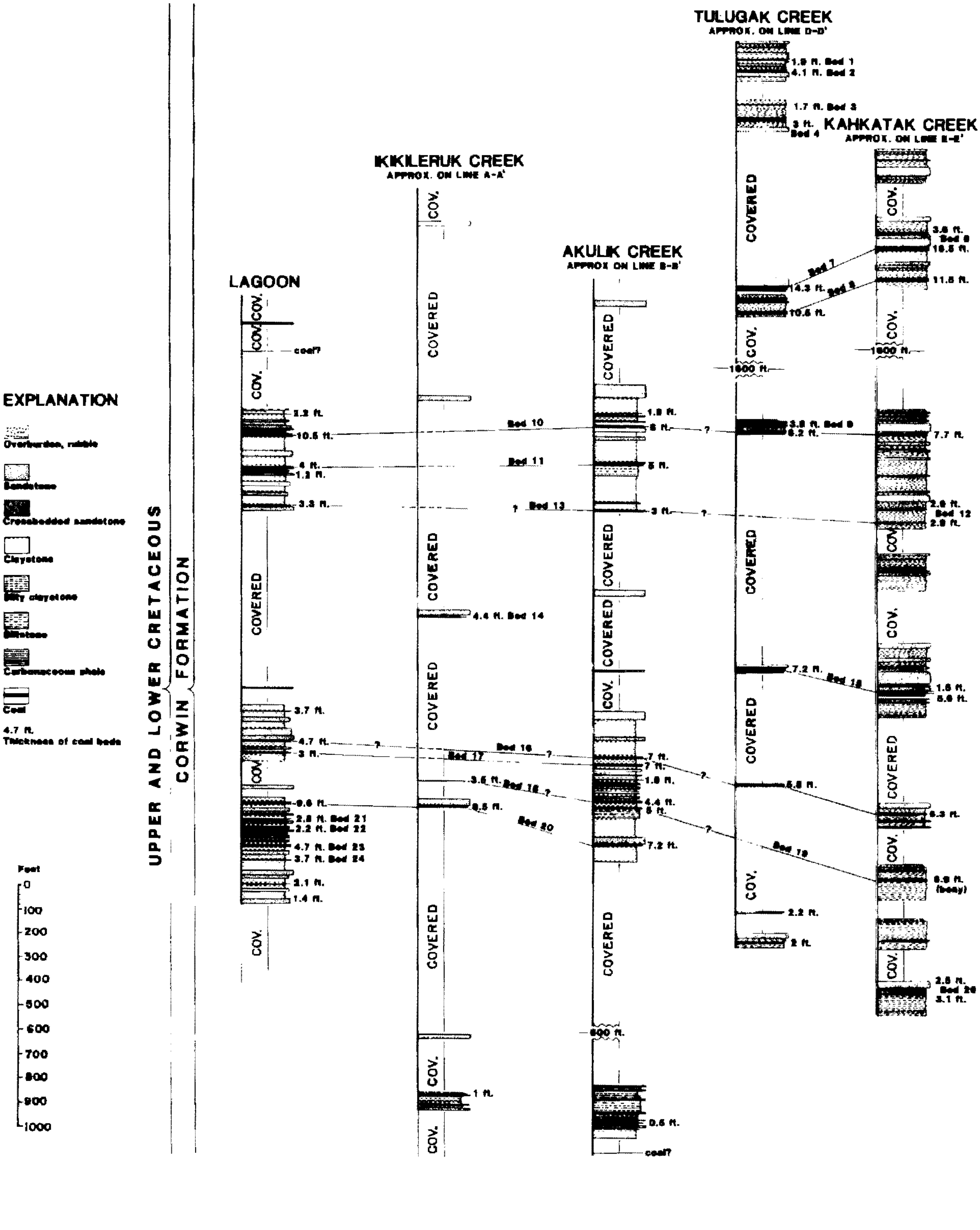


Figure 9 - Stratigraphic sections of the upper part of the Corwin Formation, Cape Beaufort area, Alaska.

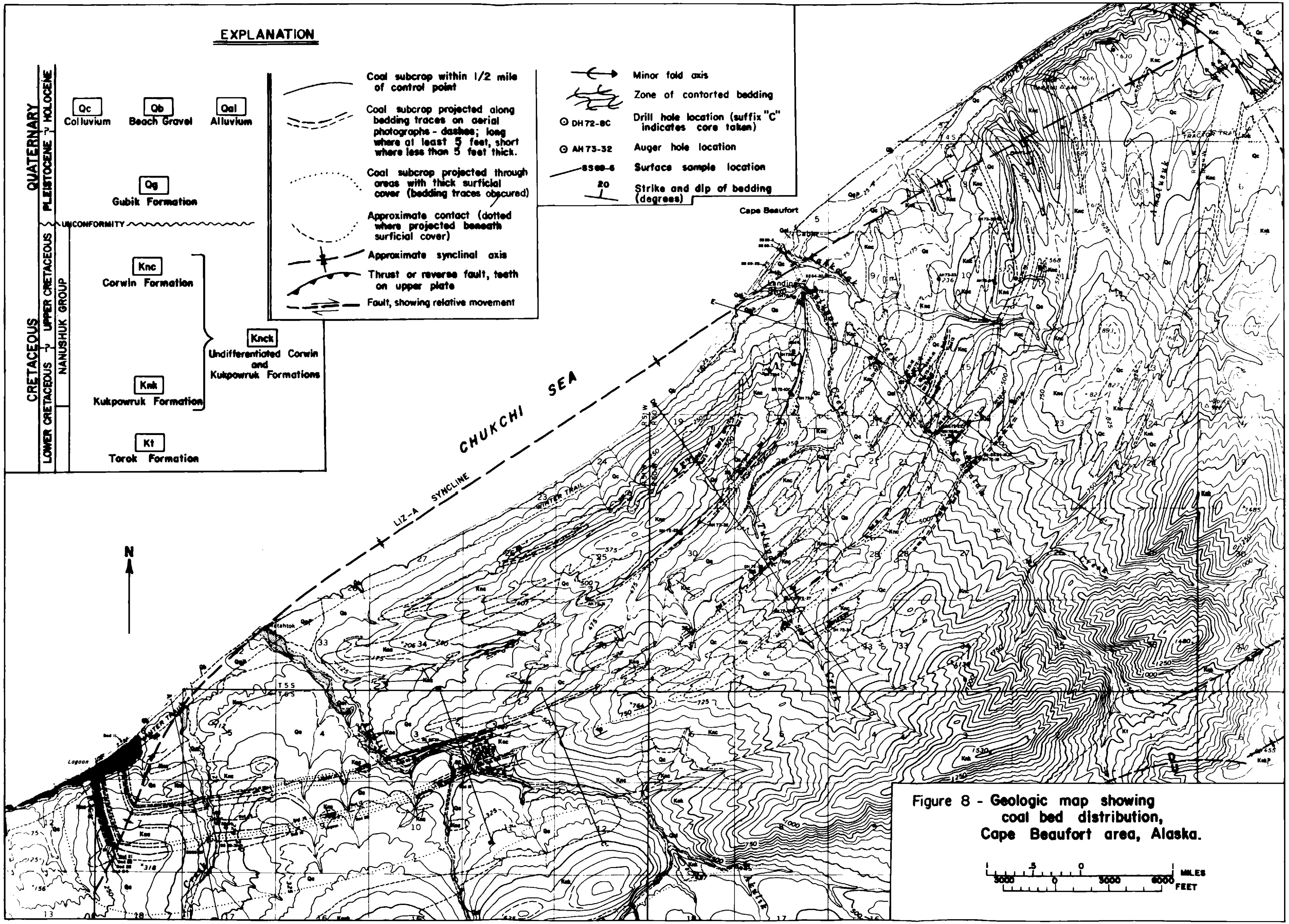
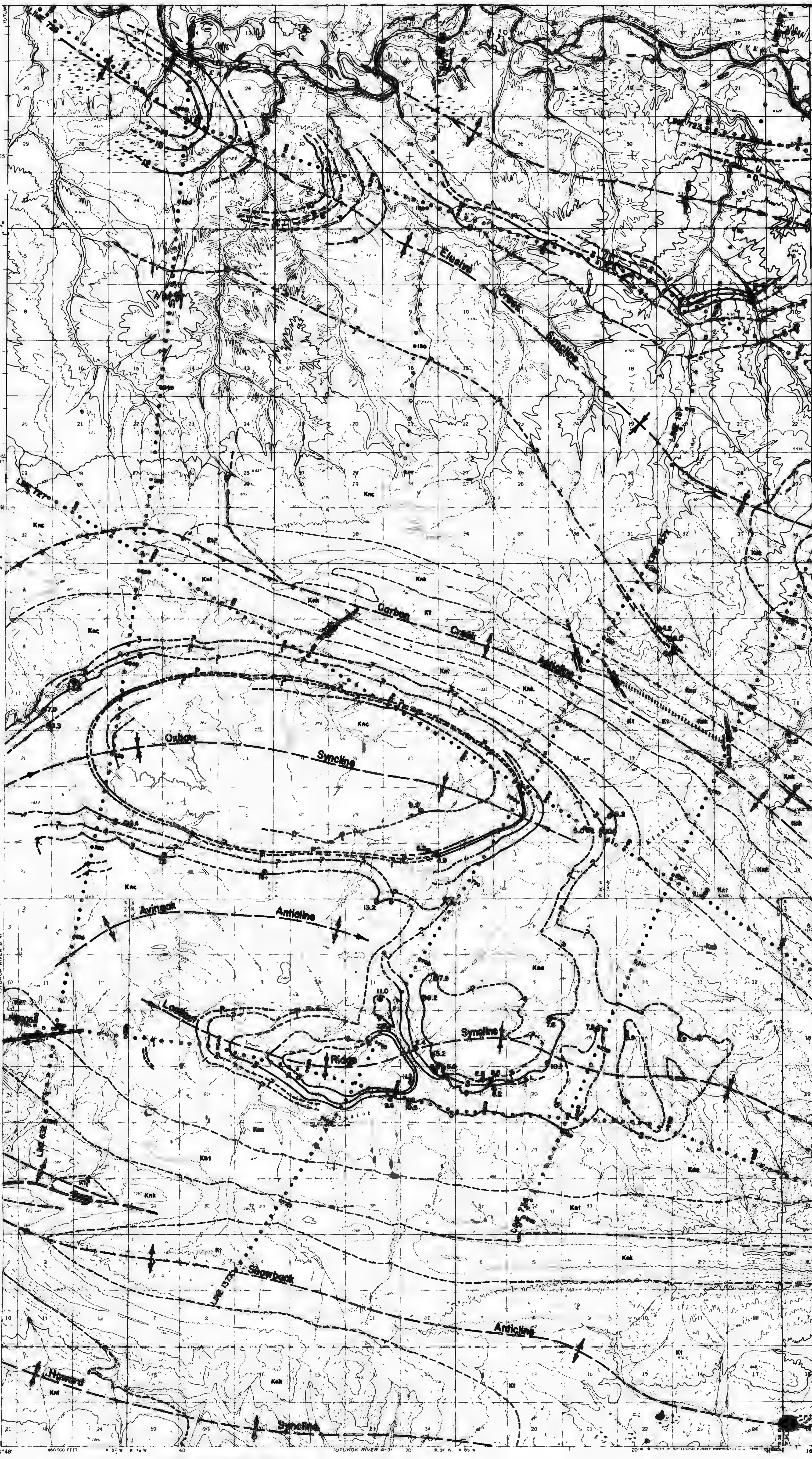


Figure 8 - Geologic map showing coal bed distribution, Cape Beaufort area, Alaska.



- E X P L A N A T I O N -

0 1 2 3 4 Miles

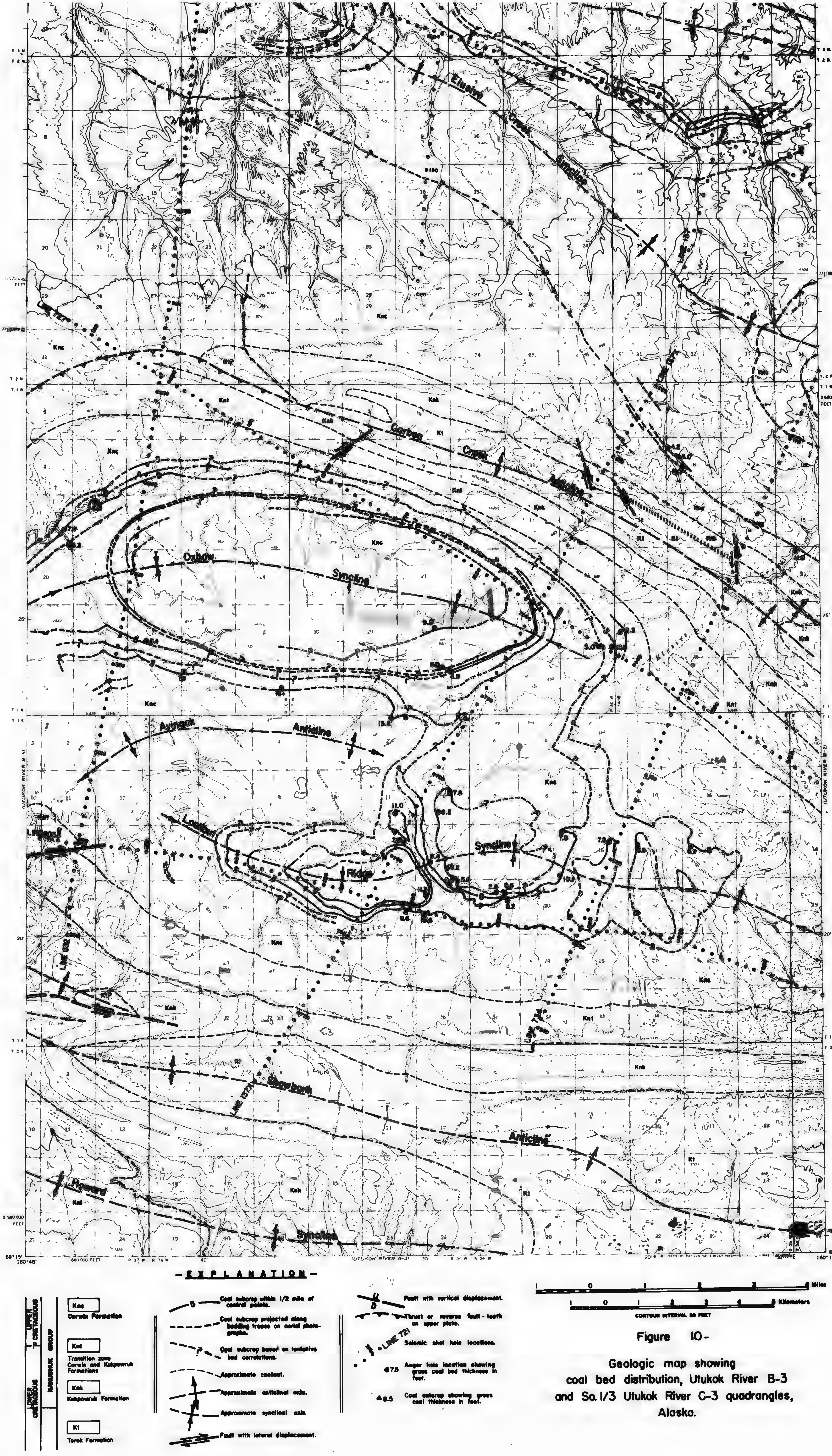


Figure 10-

Geologic map showing coal bed distribution, Utukok River B-3 and So. 1/3 Utukok River C-3 quadrangles, Alaska.

FIGURE 11

GEOPHYSICAL LOG CORRELATIONS ALONG SEISMIC LINE 606
ALONG SOUTH LIMB AND AXIS OF LOOKOUT RIDGE SYNCLINE

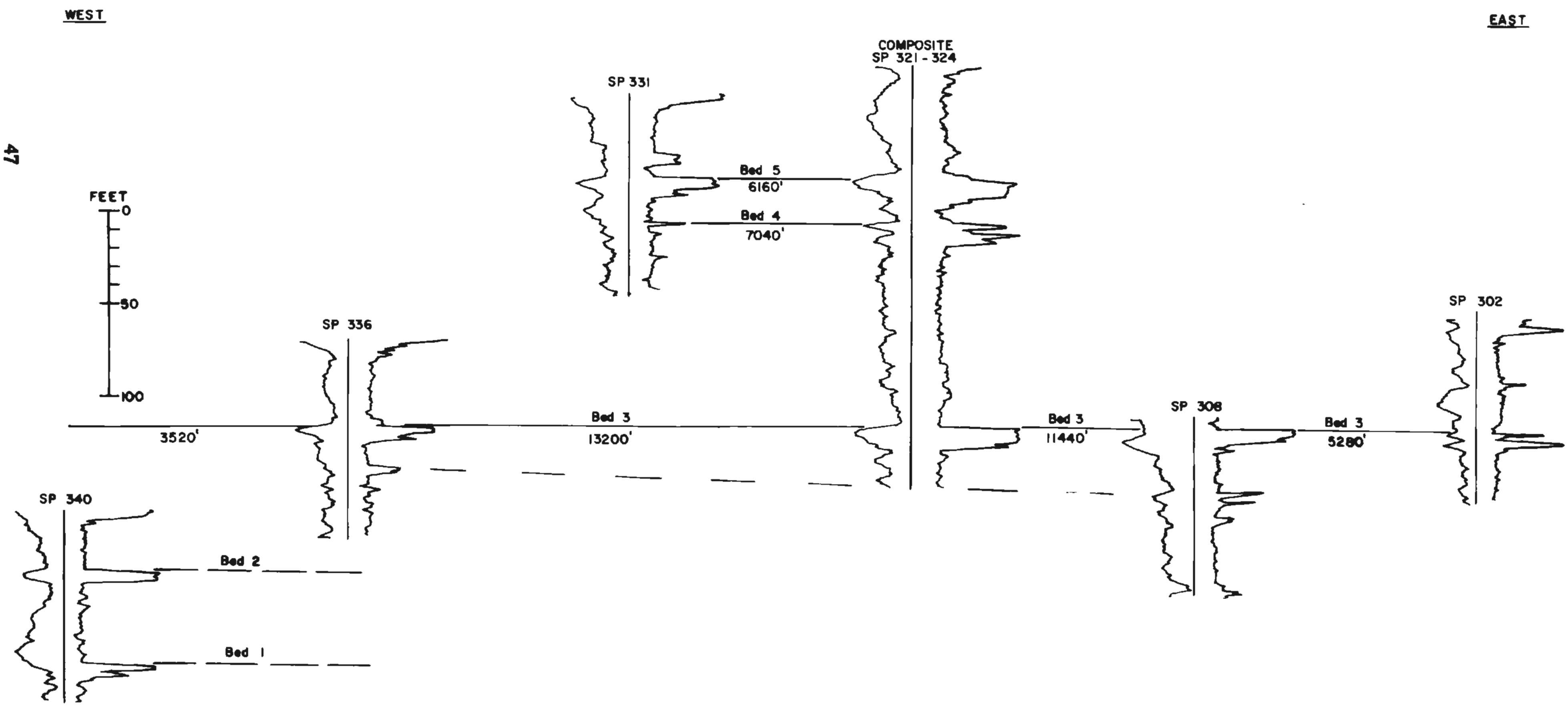
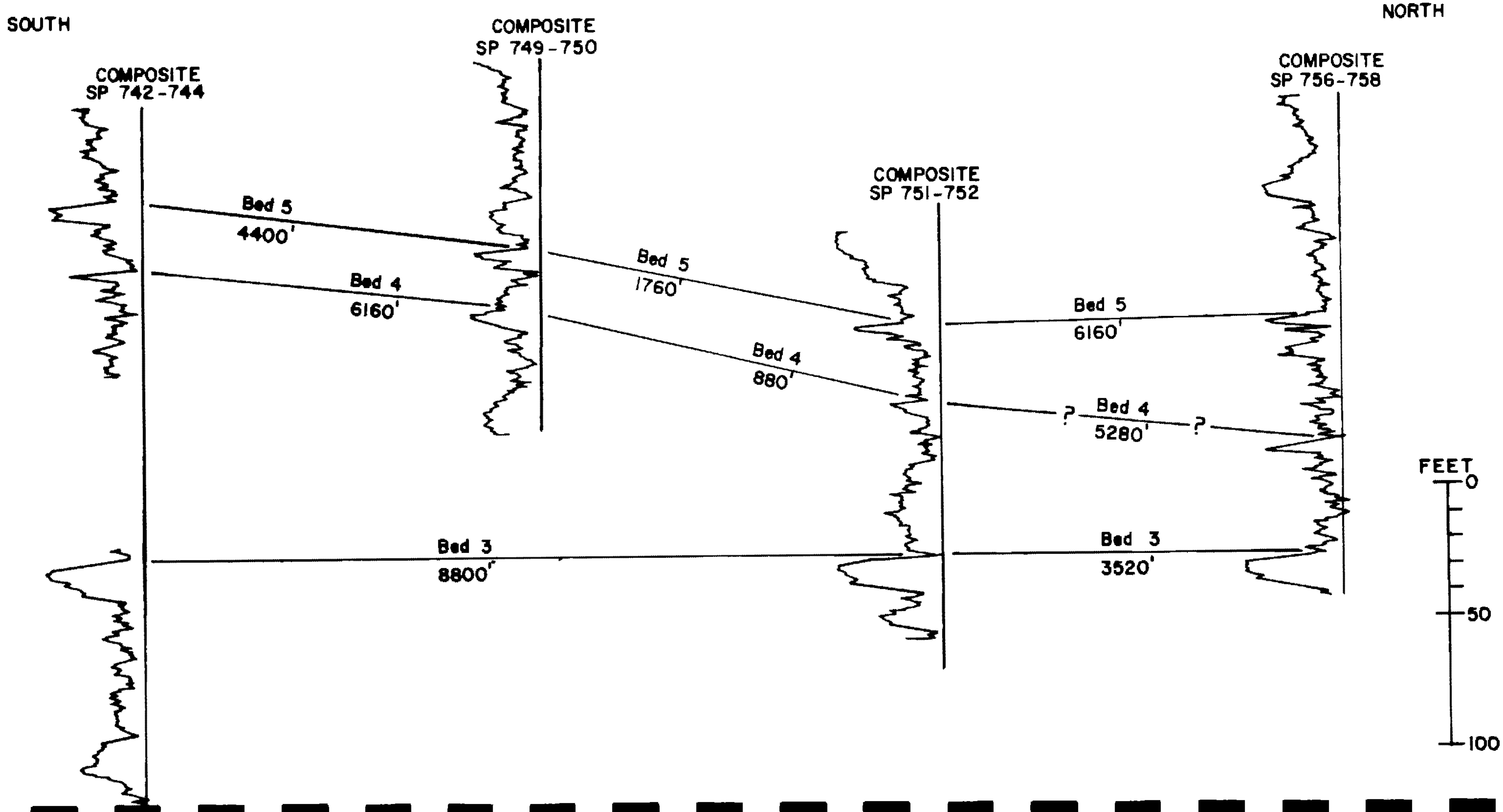


FIGURE 12

GEOPHYSICAL LOG CORRELATIONS ALONG SEISMIC LINE 137
ACROSS LOOKOUT RIDGE SYNCLINE



Ridge syncline have been correlated with 7 and 8.5 foot coals respectively on line 632 across the Oxbow syncline, on the basis of stratigraphic position. Above these, an interval of about 800 feet contains numerous thinner coals, 2.5 to 5 feet thick, which appear to be lenticular and discontinuous. Near the top of the section in the Oxbow syncline, a coal about 9 feet thick was augered on the south limb. A bed with a gross thickness of about 9 feet was observed in shotholes 167 and 169 on line 727, approximately in the same stratigraphic position on the north limb. This bed appears to be shaly or to contain numerous partings in the lower 2 feet.

Along seismic line 725 (Fig. 10) on the axis and north limb of the Elusive Creek syncline, 14 coal beds were observed within a stratigraphic interval of about 2,600 feet. Bed 3 (8 feet thick) in this section seems, on the basis of seismic information, to correlate with an 11 foot bed which outcrops on lower Elusive Creek on the south limb of the syncline. A very tentative correlation is also suggested with bed 3 in the Lookout Ridge and Oxbow synclines. If correct, this correlation suggests greater continuity for this bed in the northeast-southwest direction, subparallel to the most probable paleocurrent direction, than in the east-west direction (Fig. 11).

Coal Sampling

Several hundred samples of coal were collected from various parts of the region. Drill cuttings from the seismic shotholes have provided the most widespread coverage. Other methods of collection included channel sampling of outcrops and beds exposed by trenching, auger cuttings and drill cuttings from holes at Cape Beaufort and from several of the deep exploratory wells in the Coastal Plain. Three beds at Cape Beaufort and one on the Kukpowruk River were cored by the U.S. Bureau of Mines, and one bed on the Kuk River by Lounsbury and Associates. Part of a 5 foot bed was cored in the Tunalik test well near Icy Cape. Even though only the core samples conform to the ASTM standards for coal rank determination, cuttings samples from holes drilled with compressed air appear to be a reliable indicator of rank if the coal is penetrated at a sufficient depth to preclude weathering effects (about 25-30 feet in the foothills). Ash content could only be determined with certainty from cores or channel samples from good surface exposures. However, the drill cuttings from thick beds at Cape Beaufort, which were recovered using a reverse circulation drilling system and cyclone separator, were clean and the ash contents are comparable to the core analyses where beds were sampled by both methods. Most of the shothole samples were floated in perchlorethylene to separate coal from rock particles prior to being analyzed, and so the analyses actually represent a 1.62 specific gravity float fraction of the coal thickness observed in the geophysical logs. For purposes of comparison, the 1.5 specific gravity float fraction from parting free core samples at Cape Beaufort constitutes about 70 to 75 weight percent of each sample.

Analyses and Rank

Prior to 1977, the only unweathered samples available for analysis were the cores and drill cuttings from Cape Beaufort, the Kukpowruk River and the Kuk River.

Analyses of cores and cuttings samples from the Bureau of Mines drilling on the Kukpowruk River and at Cape Beaufort were discussed in previous reports (Warfield and others, 1969; Callahan and Sloan, 1978). Some additional comments on the Cape Beaufort coals were included here to illustrate some relationships between various types of samples and between apparent rank and stratigraphic position.

Figure 13 illustrates graphically the variation in heating values on a moist, ash free basis of 23 coal beds distributed over a stratigraphic interval of about 5,500 feet at Cape Beaufort. Obviously, analyses of outcrop samples and drill or auger cuttings from a depth of less than 30 feet are not a reliable indication of rank, as there is no consistency between samples from different points on the same bed, nor any discernible heating value vs. stratigraphic position relationship among these samples. The very low values (8,000-9,600 Btu) for surface samples from beds 11 through 24 indicate severe weathering effects. These samples were taken from near vertical exposures along the lagoon at the northwest end of the basin. In contrast, the unweathered cores and drill cuttings exhibit a relatively narrow range of values among samples from the same bed, and a progressive increase in heating value with stratigraphic position (i.e., original depth of burial). The best fit line on Figure 13 represents moist, ash free Btu values of core samples and drill cuttings from a depth greater than 30 feet.

C.C. Boley, of the Grand Forks Energy Research Facility, performed limited washability studies on core samples from beds 7 and 8 at Cape Beaufort. Figures 14 through 17 show logs of two complete and one partial core of bed 7 and one core of bed 8, along with analyses of the whole core, 1.5 specific gravity float and 1.5 specific gravity sink fractions of the segments of the cores as indicated. Based on studies, it appears that the upper 6 to 8 feet of bed 7 could be upgraded to a product with an average Btu value of about 12,720 (as received), ash content of 7.5 percent. and which would represent about 73% of the gross tonnage. For bed 8, the figures would be about 12,970 Btu, 7.3% ash and the product would represent about 76% of gross tonnage. P.D. Rao (1980) has done extensive additional chemical and petrographic characterization studies on these samples.

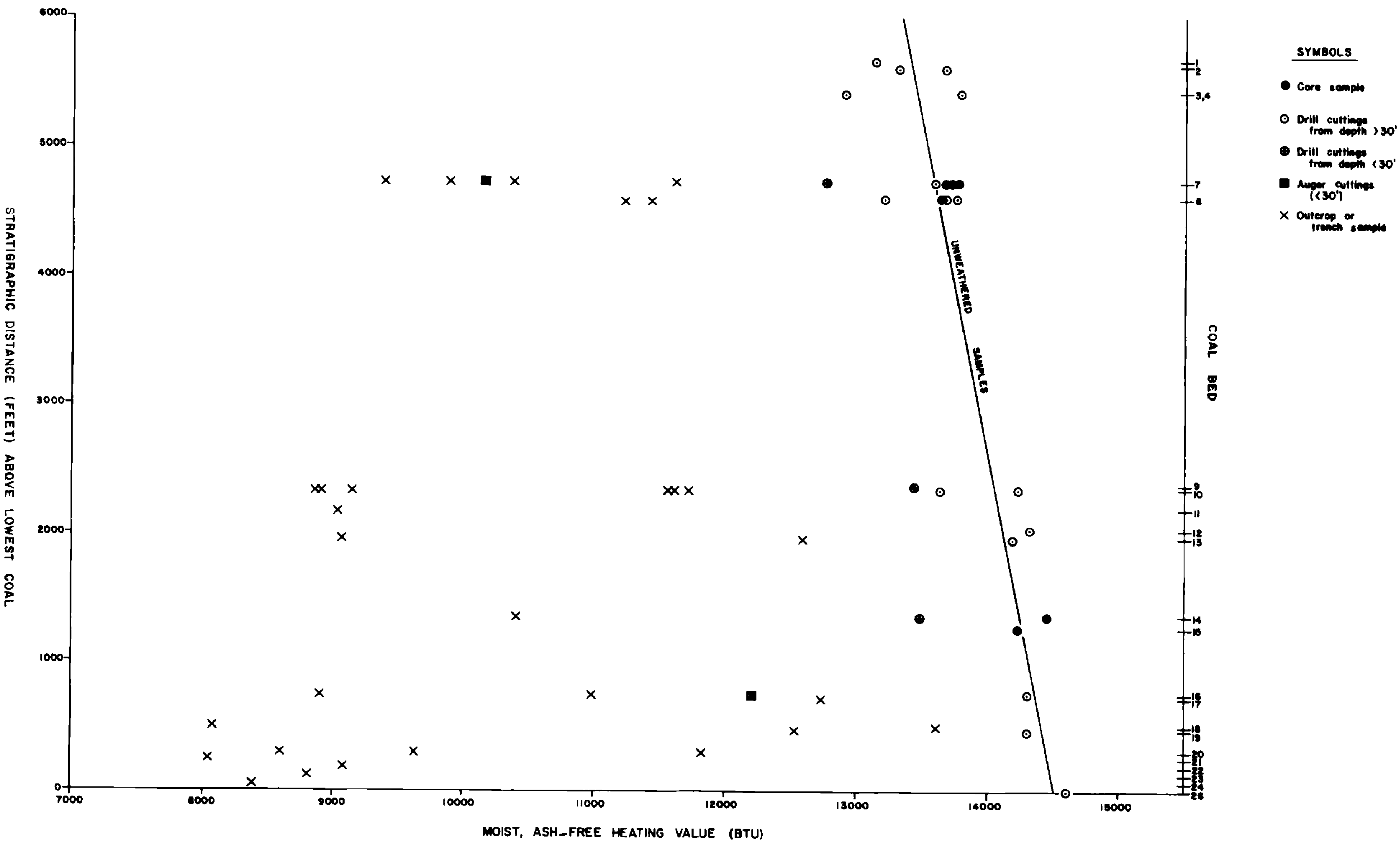
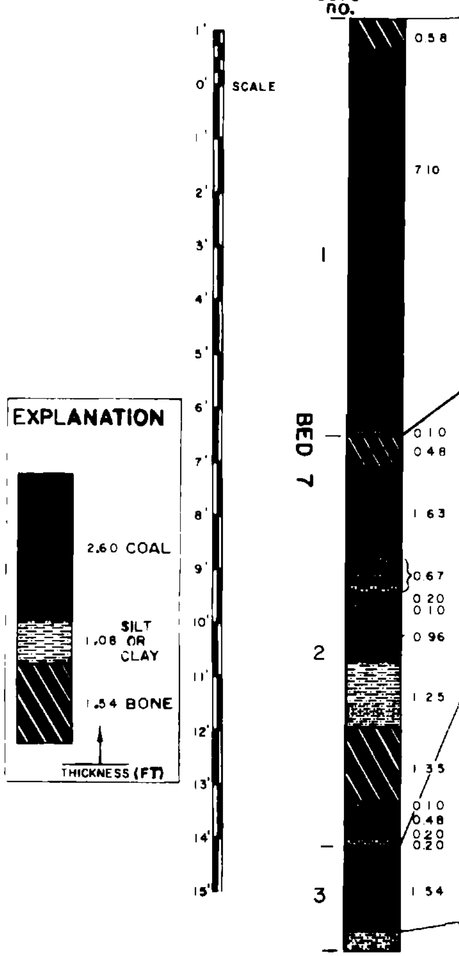


Figure 13 - Relationship of rank (heating value) to depth and sample type, Cape Beaufort area, Alaska.

FIGURE 14 - Analysis of core samples, bed 7, DH72-3C, Cape Beaufort, depth 135.3-152.9 ft.

(Hole location shown on fig. 8)



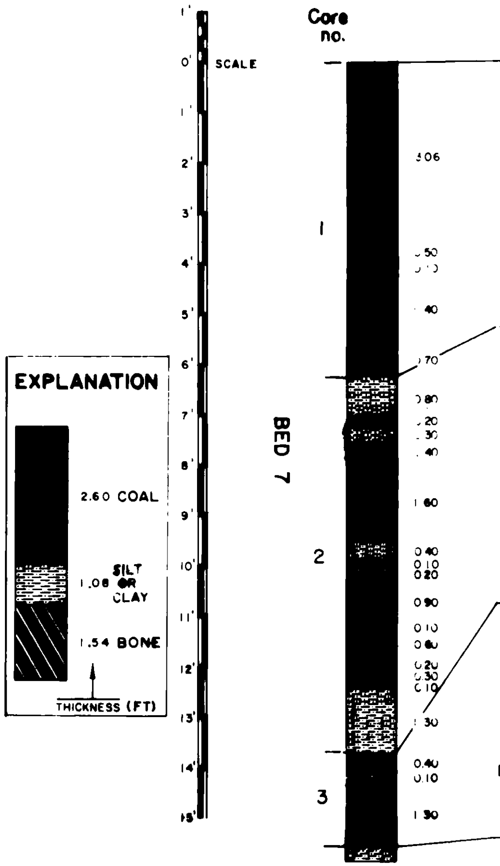
Sample no.	Fraction	Weight percent	Basis*	Btu/lb	Proximate Analysis: Moisture	Volatile Matter	Fixed Carbon	Ash	Ultimate Analysis: Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur
DH 72-3C	whole core	100.	1	11,057	2.8	28.3	51.7	17.2	4.1	65.1	1.0	12.4	0.2
			2	11,377		29.2	53.2	17.7	3.9	67.0	1.0	10.2	.2
			3	13,818		35.4	64.6		4.8	81.4	1.2	12.3	.3
			4	13,586									
DH 72-3C	1.5 sp. gr. float	68.6	1	12,680	2.8	31.7	57.8	7.7	4.7	73.8	1.1	12.4	.2
			2	13,040		32.6	59.5	7.9	4.5	75.9	1.2	10.3	.2
			3	14,170		35.4	64.6		4.9	82.4	1.3	11.2	.3
			4	13,835									
DH 72-3C	1.5 sp. gr. sink	31.4	1	7,980	2.7	21.1	41.9	34.3	3.0	49.4	.7	12.5	.2
			2	8,200		21.8	43.1	35.2	2.8	50.7	.7	10.5	.2
			3	12,650		33.6	66.4		4.3	78.3	1.1	16.1	.3
			4	12,682									
DH 72-3C	whole core	100.	1	7,180	3.3	23.4	29.4	43.9	3.3	41.5	.7	10.5	.1
			2	7,423		24.2	30.4	45.4	3.1	42.9	.7	7.8	.1
			3	13,601		44.4	55.7		5.6	78.7	1.3	14.2	.2
			4	13,658									
DH 72-3C	1.5 sp. gr. float	46.7	1	12,530	3.2	35.3	51.7	9.9	5.2	72.4	1.1	11.2	.2
			2	12,940		36.4	53.3	10.3	5.0	74.7	1.2	8.6	.2
			3	14,420		40.6	59.4		5.6	83.3	1.3	9.6	.3
			4	14,036									
DH 72-3C	whole core	100.	1	12,500	2.5	38.7	49.7	9.1	5.2	71.1	1.2	13.2	.3
			2	12,820		39.7	51.0	9.3	5.1	73.0	1.2	11.2	.3
			3	14,140		43.8	56.2		5.6	80.5	1.3	12.4	.3
			4	13,871									
DH 72-3C	1.5 sp. gr. float	86.7	1	13,310	2.6	39.8	53.5	4.6	5.5	75.5	1.2	12.9	.3
			2	13,660		40.4	54.9	4.7	5.6	77.2	1.3	10.9	.3
			3	14,330		42.4	57.6		5.9	81.0	1.3	11.4	.3
			4	14,014									
DH 72-3C	1.5 sp. gr. sink	13.3	1	5,590	2.5	24.2	23.9	49.4	2.8	34.5	.5	12.7	.1
			2	5,740		24.8	24.5	50.7	2.6	35.4	.5	10.7	.1
			3	11,640		50.3	49.7		5.2	71.8	1.0	21.8	.3
			4	11,988									

* 1 As received
2 Moisture Free
3 Moisture and Ash Free
4 Moist, Ash Free

FIGURE 15 - Analysis of core samples, bed 7, DH-72-7C

Cape Beaufort, depth 43.0-59.9 ft.

(Hole location shown on fig. 8)



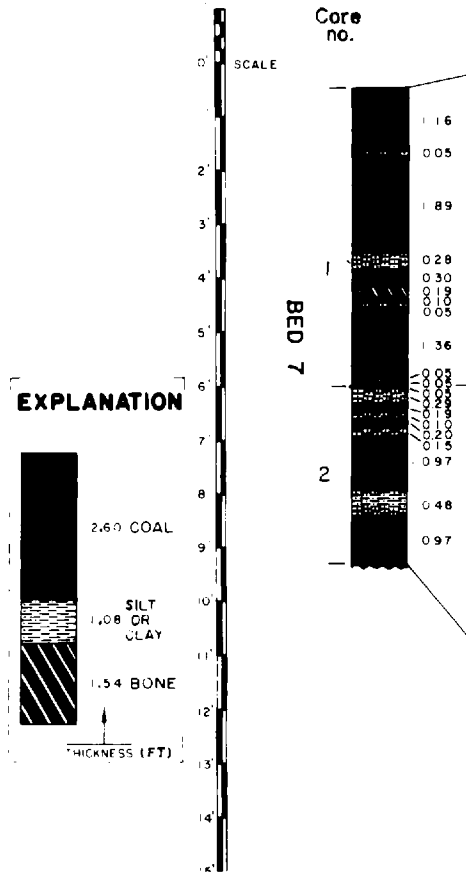
Core no.	Sample no.	Fraction	Weight percent	Basis*	Btu/lb	Proximate Analysis: Moisture	Volatile Matter	Fixed Carbon	Ash	Ultimate Analysis: Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur
1	DH 72-7C	whole core	100.	1	11,240	3.3	31.5	49.1	16.1	4.5	65.4	.9	12.8	.3
				2	13,615									
	DH 72-7C	1.5 sp. gr. float	77.4	1	12,770	3.0	33.9	55.7	7.4	4.5	73.3	1.1	13.4	.3
				2	13,170		34.9	57.4	7.7	4.3	75.6	1.1	11.1	.3
				3	14,260		37.8	62.2		4.7	81.8	1.2	12.0	.3
				4	13,888									
	DH 72-7C	1.5 Sp. Gr. sink	22.6	1	7,360	2.5	28.3	33.4	35.9	2.8	45.7	0.6	14.8	.2
				2	7,540		29.0	34.2	36.8	2.6	46.9	.6	12.9	.2
				3	11,930		45.9	54.1		4.2	74.2	.9	20.5	.3
				4	12,026									
2	DH 72-7C	whole core	100.	1	7,070	3.1	22.7	30.2	44.0	3.0	41.9	.6	10.3	.2
				2	7,300		23.5	31.1	45.4	2.8	43.3	.6	7.8	.2
				3	7,300		43.0	57.1		5.1	79.3	1.1	14.3	.3
				4	13,481									
	DH 72-7C	float	35.4	1	12,350	3.3	35.4	50.6	10.7	5.0	70.1	1.0	13.0	.2
				2	12,770		36.6	52.3	11.1	4.8	72.4	1.1	10.4	.2
				3	14,370		41.2	58.8		5.4	81.5	1.2	11.7	.3
				4	13,970									
	DH 72-7C	sink	64.6	1	5,950	3.1	20.1	24.3	52.5	2.8	34.9	.6	9.3	.1
				2	13,747									
3	DH 72-7C	whole core	100.	1	12,140	2.8	37.0	48.8	11.4	5.1	68.8	1.1	13.3	.3
				2	13,854									
	DH 72-7C	1.5 sp. gr. float	83.2	1	13,280	3.0	39.7	52.9	4.4	5.5	75.2	1.8	13.3	.4
				2	13,680		40.9	54.5	4.6	5.3	77.5	1.2	11.0	.4
				3	13,680		42.9	57.1		5.6	81.3	1.3	11.5	.4
				4	13,954									
	DH 72-7C	1.5 Sp. Gr. sink	16.8	1	3,720	2.5	20.0	15.0	62.4	2.5	22.8	.4	11.8	.2
				2	8,820		20.6	15.4	64.0	2.3	23.4	.4	9.8	.2
				4	11,416									

* 1 As received
2 Moisture Free
3 Moisture and Ash Free
4 Moist, Ash Free

FIGURE 16 - Analysis of core samples, bed 7, DH72-10C,

Cape Beaufort, depth 52.2-61.05 ft.

(Hole location shown on fig. 8)

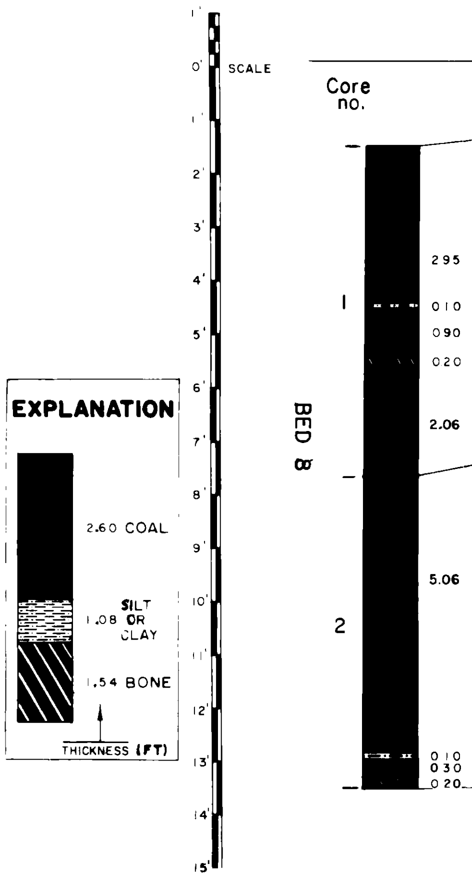


Core no.	Sample no.	Fraction	Weight percent	Basis*	Btu/lb	Proximate Analysis: Moisture	Proximate Analysis: Volatile Matter	Proximate Analysis: Fixed Carbon	Proximate Analysis: Ash	Ultimate Analysis: Hydrogen	Ultimate Analysis: Carbon	Ultimate Analysis: Nitrogen	Ultimate Analysis: Oxygen	Ultimate Analysis: Sulfur
1	DH 72-10C	whole core	100.	1	11,130	3.3	31.3	48.4	16.9	4.5	64.3	1.0	13.1	.2
				2	11,510		32.4	50.1	17.5	4.2	66.5	1.0	10.5	.2
				3	13,960		39.3	60.7		5.1	80.6	1.2	12.8	.3
				4	13,621									
	DH 72-10C	1.5 sp. gr. float	75.9	1	12,720	3.0	34.3	55.4	7.4	4.9	73.0	1.1	13.4	.3
				2	13,100		35.3	57.1	7.6	4.7	75.3	1.1	11.1	.3
				3	14,190		38.2	61.8		5.1	81.4	1.2	12.0	.3
				4	13,833									
	DH 72-10C	1.5 sp. gr. sink	24.1	1	7,540	3.3	23.1	36.6	37.1	3.1	46.1	.6	13.0	.2
				2	7,790		23.9	37.8	38.3	2.8	47.7	.6	10.4	.2
				3	12,640		38.7	61.3		4.6	77.3	.9	16.9	.3
				4	12,587									
2	DH 72-10C	whole core	100.	1	8,430	3.4	25.9	35.2	35.6	3.7	49.1	.7	10.7	.2
				2	8,720		26.8	36.4	36.8	3.5	50.8	.8	7.9	.2
				3	13,810		42.4	57.6		5.5	80.5	1.2	12.5	.3
				4	13,704									
	DH 72-10C	1.5 sp. gr. float	48.9	1	12,600	3.0	35.6	53.0	8.5	5.1	71.9	1.1	13.2	.3
				2	12,980		36.7	54.6	8.7	4.9	74.1	1.1	10.9	.3
				3	14,220		40.2	59.8		5.4	81.2	1.2	11.9	.3
				4	13,882									
	DH 72-10C	1.5 sp. gr. sink	51.1	1	6,680	3.3	21.3	30.0	45.5	3.0	40.0	.5	10.9	.1
				2	6,900		22.0	31.0	47.0	2.7	41.3	.5	8.3	.2
				3	13,020		41.4	58.6		5.2	78.0	1.0	15.6	.3
				4	13,138									

* 1 As received
2 Moisture Free
3 Moistrue and Ash Free
4 Moist, Ash Free

FIGURE 17 - Analysis of core samples, bed 8, DH 72-8C, Cape Beaufort, depth 96.9-109.8 ft.

(Hole location shown on fig. 8)



Core no.	Sample no.	Fraction	Weight percent	Basis*	Btu/lb	Proximate Analysis: Moisture	Proximate Analysis: Volatile Matter	Proximate Analysis: Fixed Carbon	Proximate Analysis: Ash	Ultimate Analysis: Hydrogen	Ultimate Analysis: Carbon	Ultimate Analysis: Nitrogen	Ultimate Analysis: Oxygen	Ultimate Analysis: Sulfur
1	DH 72-8C	whole core	100.	1	10,880	2.9	31.4	48.0	17.6	4.3	63.9	0.9	12.7	0.5
				2	11,200		32.4	49.5	18.2	4.1	65.8	1.0	10.4	.6
				3	13,690		39.6	60.5		5.0	80.4	1.2	12.7	.7
				4	13,448									
	DH 72-8C	1.5 sp. gr. float	68.7	1	12,740	2.9	34.1	55.1	8.0	4.9	73.2	1.1	12.5	.3
				2	13,120		35.1	56.7	8.2	4.7	75.4	1.1	10.3	.3
				3	14,290		38.2	61.8		5.1	82.1	1.2	11.2	.4
				4	13,954									
	DH 72-8C	1.5 sp. gr. sink	31.3	1	7,800	2.2	27.4	36.9	33.6	3.0	48.3	.6	14.3	.2
				2	7,970		28.0	37.7	34.3	2.8	49.4	.6	12.7	.2
				3	12,140		42.6	57.4		4.3	75.2	.9	19.2	.3
				4	12,248									
2	DH 72-8C	whole core	100.	1	12,070	3.0	35.6	49.6	11.8	5.0	69.2	1.1	12.7	.2
				2	12,440		36.8	51.1	12.2	4.8	71.4	1.1	10.3	.2
				3	14,160		41.8	58.2		5.5	81.3	1.3	11.8	.2
				4	13,839									
	DH 72-8C	1.5 sp. gr. float	82.7	1	13,030	3.0	37.2	53.5	6.4	5.2	74.0	1.2	13.0	.2
				2	13,420		38.3	55.1	6.6	5.0	76.2	1.2	10.7	.2
				3	14,380		41.0	59.0		5.4	81.6	1.3	11.5	.2
				4	14,003									
	DH 72-8C	1.5 sp. gr. sink	17.3	1	7,230	2.1	27.5	31.8	38.5	3.1	45.7	.6	12.0	.2
				2	7,390		28.1	32.5	39.4	2.9	46.7	.6	10.3	.2
				3	12,180		46.4	53.6		4.9	76.9	1.0	17.0	.3
				4	12,382									

* 1 As received
2 Moisture Free
3 Moisture and Ash Free
4 Moist, Ash Free

In the Oxbow-Lookout Ridge syncline area shown on Figure 10, samples have been taken from beds 3 and 5 from auger cuttings, outcrop channel samples and shothole drill cuttings. In Table 1, 17 analyses from bed 3 and 22 from bed 5 have been segregated on the basis of sampling methods and handling to illustrate the effects on the results. The moist, ash free Btu values for shothole cuttings appear reasonably consistent, whether the samples have been floated in perchloroethylene or analyzed in the condition in which they were collected, if the bed was penetrated at a depth greater than 30 feet and a sufficient distance from the outcrop. All but one of the analyses for these beds indicate an apparent high volatile A bituminous rank. As for the Cape Beaufort samples, shallow drill cuttings, auger cuttings and outcrop channel samples exhibit a wide range in heating value, on both dry, ash free and moist, ash free basis, indicating a wide variation in weathering effects. The drill cuttings samples cannot be relied on for ash content determinations, but the outcrop samples represent channel cuts excluding visible partings, and the ash content for these samples probably indicates the percentage of closely associated mineral matter, which would probably not be eliminated by washing. It is noteworthy that the ash content (average and range) of the floated shothole samples from bed 3 is within 1 or 2 percentage points of that of the channel samples from the same bed.

Except at Cape Beaufort, the heating value vs. stratigraphic position relationship for foothills areas cannot be readily demonstrated, owing to insufficient analyses of unweathered samples over a significant stratigraphic interval at any one locality. The coal beds mapped along line 725 (Fig. 10) occur in a stratigraphic interval of about 2,600 feet. Shothole samples have been taken from several of these coals, but analyses are not yet available. Analyses of unweathered samples of bed 3 from a shothole on line 137 and of bed 13 on line 632, indicate a range of Btu values from 14,044 to 14,452 (moist, ash free) in the 2,300 foot interval between these coals (177 Btu/1,000 ft.), which is fairly consistent with the trend at Cape Beaufort. However, neither the thickness of the section nor the number of analyses is sufficient to make such a comparison with much assurance.

The apparent rank of coal samples from shotholes and shallow coreholes in the Coastal Plain ranged from subbituminous A to lignite, but has been predominantly in the subbituminous B range. Eleven samples from the Peard Bay well (Fig. 1) exhibit a progressive increase in heating values from 10,308 Btu (subbituminous B) to 11,432 (subbituminous A) (moist, ash free) in a stratigraphic interval of about 800 feet. Moisture content varies widely in the shothole samples, but is predominantly in the 15 to 20 percent range. In the Peard Bay well samples, moisture content decreases with depth from 18.4 to 13.0 percent over the 800 foot interval. As noted previously, samples from lower in the stratigraphic sequence have somewhat higher sulfur values, from 0.4 to 1.4 percent in the lower 1,000 feet as opposed to 0.2 to 0.9 percent in the upper 1,300 feet in the Wainwright area.

TABLE I - SUMMARY OF COAL ANALYSES, LOOKOUT RIDGE - OXBOW SYNCLINE AREA

	Basis*	Btu	Proximate				Ultimate						Range of Values		
			M	VM	FC	ASH	H	C	N	O	S	ASH	Btu	ASH	O
Analyses of 17 coal samples from bed 3															
Average of 4 samples from 30' or greater depth, floated in perchlorethylene	1	13585	2.6	37.8	55.2	4.5	5.5	76.5	1.6	11.9	0.2	4.2	12998 to 13135	2.2 to 7.0	10.7 to 13.1
	2	13937		38.8	56.6	4.6	5.4	78.6	1.6+	9.8	0.2	4.4	13455 to 14410	2.3 to 7.1	9.1 to 10.4
	3	14605		40.7	59.3		5.6	82.2	1.7	10.2	0.2		14381 to 14777		9.3 to 11.2
	4	14272											13930 to 14481		
Average of 4 samples from 30' or greater depth, analyzed as collected	1	11856	3.0	34.4	47.1	15.5	4.9	66.9	1.4	11.0	0.3	15.5	10496 to 12546	11.0 to 24.0	10.8 to 11.8
	2	12224		35.5	48.6	15.9	4.7	69.0	1.5	8.6	0.3	15.9	10762 to 12984	11.4 to 24.6	8.3 to 9.1
	3	14529		42.2	57.8		5.6	82.1	1.7	10.3	0.3		14289 to 14738		9.6 to 11.4
	4	14238											14127 to 14398		
Average of 6 samples from less than 30' depth floated in perchlorethylene (No ultimate analyses)	1	11975	5.5	33.1	54.4	7.0					0.3		9967 to 13797	3.2 to 11.4	
	2	12636		35.0	57.6	7.4					0.3		10923 to 14109	3.5 to 12.2	
	3	13622		37.8	62.2						0.3		12420 to 14745		
	4	12927											11318 to 14481		
Average of 3 outcrop channel samples, excl. visible partings analyzed as collected	1	11223	10.6	33.7	50.6	5.1	5.3	65.6	1.6	22.2	0.2	5.1	10850 to 12650	3.3 to 7.3	14.8 to 24.3
	2	12520		37.6	56.6	5.8	4.6	73.2	1.8	14.3	0.3	5.8	11670 to 13560	3.5 to 8.4	11.8 to 15.7
	3	13283		39.9	60.1		4.9	77.7	1.9	15.2	0.3		12740 to 14060		12.2 to 17.2
	4	11870											11043 to 13122		
Analyses of 22 coal samples from bed 5															
Average of 7 analyses-samples from >30', floated in perchlorethylene (3 ultimate analyses)	1	13322	2.7	35.3	55.8	6.2	5.4	75.6	1.5	11.5	0.2	5.8	12640 to 13670	3.9 to 11.4	11.4 to 11.5
	2	13685		36.3	57.3	6.4	5.2	77.8	1.5	9.2	0.2	6.1	12949 to 14022	4.0 to 11.7	9.1 to 9.3
	3	14615		38.8	61.2		5.5	82.8	1.6	9.8	0.2		14513 to 14731		9.5 to 9.9
	4	14288											14169 to 14428		
Average of 7 analyses-samples analyzed as collected from >30' depth (1 ultimate analysis)	1	11718	3.5	33.6	47.4	19.9	4.9	68.0	1.3	12.2	0.2	13.3	10317 to 12688	8.6 to 24.5	
	2	12142		34.8	49.1	16.1	4.7	70.6	1.4	9.3	0.2	13.9	10696 to 13184	9.0 to 25.4	
	3	14471		41.6	58.4		5.5	82.0	1.6	10.8	0.2		14254 to 14595		
	4	14090											13958 to 14315		
Average of 3 analyses-samples from <30' depth floated in perchlorethylene (No ultimate analyses)	1	12550	4.3	34.2	56.2	5.4					0.3		11565 to 13498	4.6 to 6.0	
	2	13101		35.7	58.7	5.6					0.3		12295 to 13831	4.9 to 6.1	
	3	13886		37.8	62.2						0.3		12928 to 14736		
	4	13339											12175 to 13505		
Average of 5 analyses-samples from less than 30' depth analyzed as collected (No ultimate analyses)	1	10463	11.8	28.9	51.8	7.5					0.2		10243 to 10731	5.6 to 9.5	
	2	11907		32.8	58.8	8.4					0.2		11793 to 12068	6.6 to 10.6	
	3	13008		35.8	64.2						0.3		12774 to 13304		
	4	11427													

* 1 - As received
2 - Moisture Free
3 - Moisture and Ash Free
4 - Moist, Ash-Free

In the Tunalik-1 test well (Fig. 1), the base of the Corwin Formation was picked at about 3,700 feet. The moist, ash free Btu values of coal cutting samples from this well range from 9,995 at a depth of 725 feet to 13,398 at a depth of 3,280 feet.

The increase in Btu value with depth in the Peard Bay well is about 1,400 Btu/1,000 feet, and in the Tunalik well about 1,600 Btu/1,000 feet (based on a projection of very limited data). This much greater rate of change, as compared to the foothills, most likely reflects the difference in the coalification process. Overburden pressure and dewatering are thought to be a dominant factor in the diagenesis of lower rank coals (i.e., physical changes), such as those in the Coastal Plain, whereas temperature and time are thought to have played a more important role in producing chemical changes in higher rank coals (Teichmuller and Teichmuller, 1966).

Coking Tests

Carbonization studies have been performed on several of the high volatile A bituminous coal beds in the foothills of the western Arctic, by C.C. Boley of the Grand Forks Coal Research facility (Warfield and Boley, 1969; Warfield and others, 1966). The coals included in these studies were beds 15 and 16 at Cape Beaufort, a 20 foot coal on the Kukpowruk River, and a bed on the Kokolik River on the north limb of the Oxbow syncline, which appears to fall within the same stratigraphic interval as bed 3 in the Lookout Ridge-Oxbow syncline area (Fig. 10). On the basis of bench scale coking tests, the unweathered samples were judged to be directly comparable to the Sunnyside, Utah, coal used by Kaiser Steel as a base coal for the production of coke. The Kokolik River sample, collected by trenching, was probably oxidized; it required a higher proportion of medium volatile blending coal to produce coke comparable to the others.

Coal Resources

The minimum bed thickness used for resource calculations is 2.5 feet for subbituminous coal and 1.2 feet for bituminous coal. The geographic line of demarcation between these two rank categories is not well-defined due to lack of analyses between the Coastal Plain and the foothills, and in any case it varies in the subsurface depending on stratigraphic position. At present, it is assumed to trend across the southern part of the Coastal Plain at the surface. In the Coastal Plain and the northernmost part of the foothills, where the structure is relatively simple and well ties to the base of the coal bearing rocks are available, the calculation of the volume of coal bearing rocks using seismic structure mapping is reasonably accurate.

Table 2 is a summary of hypothetical coal resources of the Nanushuk Group in the Coastal Plain and northernmost part of the foothills of the National Petroleum Reserve, Alaska (NPRA). It does not include resources west of NPRA or coal bearing rocks occurring in isolated structural basins south of the "Carbon trend" (Fig. 1), a completely faulted, anticlinal feature crossing the southwestern part of NPRA. These structural basins are separated by complex anticlinal trends or fault zones, and well ties to the base of the coal bearing rocks are not available. The base of the formation must be picked arbitrarily in a zone of poor surface exposures and projected into seismic record sections, which characteristically lose most of their definition on the flanks of the basins. Seismic structural mapping of these basins, incorporating the most recent data, is incomplete, and it would be misleading to incorporate the existing fragmentary resource data from this southern area into a regional resource estimate.

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Table 2 Hypothetical Coal Resources in the Nanushuk Group
in the National Petroleum Reserve--Alaska
(In Millions of Tons)

Rank	Depth (ft) / Thickness (ft)	0-1,000	1,000-2,000	2,000-3,000	3,000-4,000	4,000-5,000	5,000-6,000	Subtotals*	Total*
Subbituminous	2.5-5.0	87,700	72,600	33,500	2,130	--	--	196,000	478,000
	5.0-10.0	96,300	79,600	36,800	2,340	--	--	215,000	
	10.0+	29,900	24,800	11,500	727	--	--	66,900	
Bituminous	1.2-5.0	64,900	52,900	36,600	13,600	1,780	149	170,000	370,000
	5.0-10.0	46,500	37,900	26,300	9,770	1,280	107	122,000	
	10.0+	29,600	24,200	16,700	6,220	813	68	77,600	
Subtotals*	1.2-5	153,000	125,000	70,100	15,700	1,780	149	366,000	848,000
	5.0-10.0	143,000	117,000	63,100	12,100	1,280	107	337,000	
	10.0+	59,500	49,000	28,200	6,950	813	68	145,000	

*Totals and subtotals rounded to 3 significant figures

Deltaic coals and sediments of the Cretaceous Torok, Kukpowruk, and Corwin Formations in the Kokolik-Utukok Region, National Petroleum Reserve in Alaska

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U.S. Geological Survey, Anchorage

Abstract

Study of the Cretaceous Torok, Kukpowruk and Corwin Formations of Albian to Cenomanian Age in the western part of the National Petroleum Reserve in Alaska has led to development of a model for deltaic coal accumulation. The lithologies, fossils and primary sedimentary structures in the rocks of these formations indicate that they were deposited as parts of a large, high-constructional delta, called the Corwin Delta, which apparently prograded northeastward across the western part of the North Slope of Alaska. The Torok, Kukpowruk and Corwin Formations are interpreted as recording deposition in prodelta, delta-front and delta-plain environments, respectively. The Torok Formation consists of shale with thin interbeds of siltstone and fine-grained sandstone. The Kukpowruk Formation is composed of fine- to coarse-grained, cross-bedded sandstone with interbeds of shale and siltstone. It intertongues with both the underlying Torok and overlying Corwin Formations. The Corwin consists of fine- to coarse-grained sandstone, sandstone with interbeds of siltstone and shale, carbonaceous shale and coal. Coal occurs in lower delta-plain strata of the Corwin Formation as sparse, thin, discontinuous beds. Thicker and more numerous coal beds developed on platforms underlain by abandoned channels and splay deposits in the middle delta-plain environment. Upper delta-plain and alluvial deposits are not found in the study area, probably because of postdepositional tectonism and erosion.

The full text of this presentation will be published as a supplement to these proceedings.

Geologic and economic evaluation of Bituminous coal Kukpowruk River region, northern coal field, Alaska

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Chief Geologist, Kaiser Engineers, Inc.

Introduction

The Kukpowruk Region, in the Northern Alaska Coal Field, has been assessed to contain the largest deposits of quality bituminous and coking coal in Alaska (Fig. 1). Pursuant to this assessment, geologic and economic evaluation studies of the Northern Coal Field and the Kukpowruk Coal Basin area were made by Kaiser Engineers during the period from 1970-1977. The scope of work for these studies were to:

1. Geologically evaluate certain lease acreage for confidential clients,

2. Confirm coal quality of selected target areas and

3. Determine strip and underground coal resource potentials.

Location

The Kukpowruk study area lies north of the Delong Mountains in the extreme western part of Northern Alaska. The area is bordered on the west by the Chukchi Sea and on the east by the Naval Petroleum Reserve No. 4 (now the National Petroleum Reserve, Alaska) (Fig. 2).

The principal coal outcrops of the Kukpowruk Basin occur along the Kukpowruk River approximately 150 miles due north of the Eskimo village of Kotzebue, and 28 miles south-southeast of Point Lay, a Distant Early Warning (D.E.W.) line radar station.

Geography

Geographically, the Kukpowruk study area lies in the extreme northern part of the Arctic foothills physiographic province, with a relief of about 30-350 feet above sea level. Low broad ridges surfaced with sandstone rubble reflect the distribution of underlying resistant rocks. Although these rubble ridges are conspicuous features on aerial photos, and constitute the main structur-

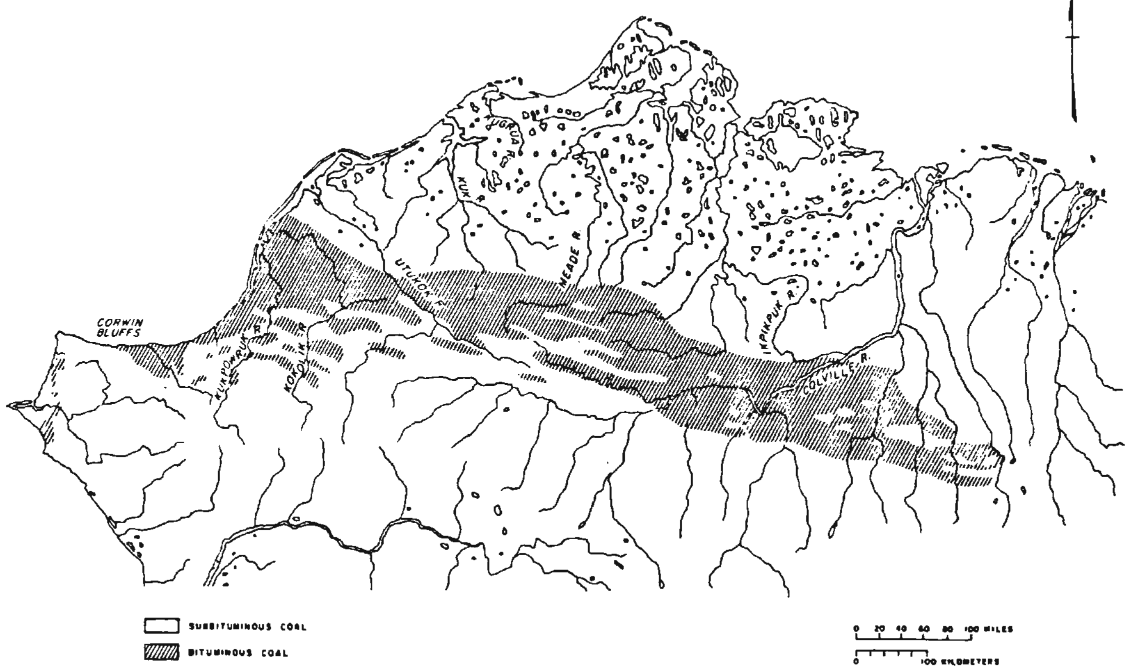

Figure 1 COAL BEARING ROCKS OF NORTHERN ALASKA

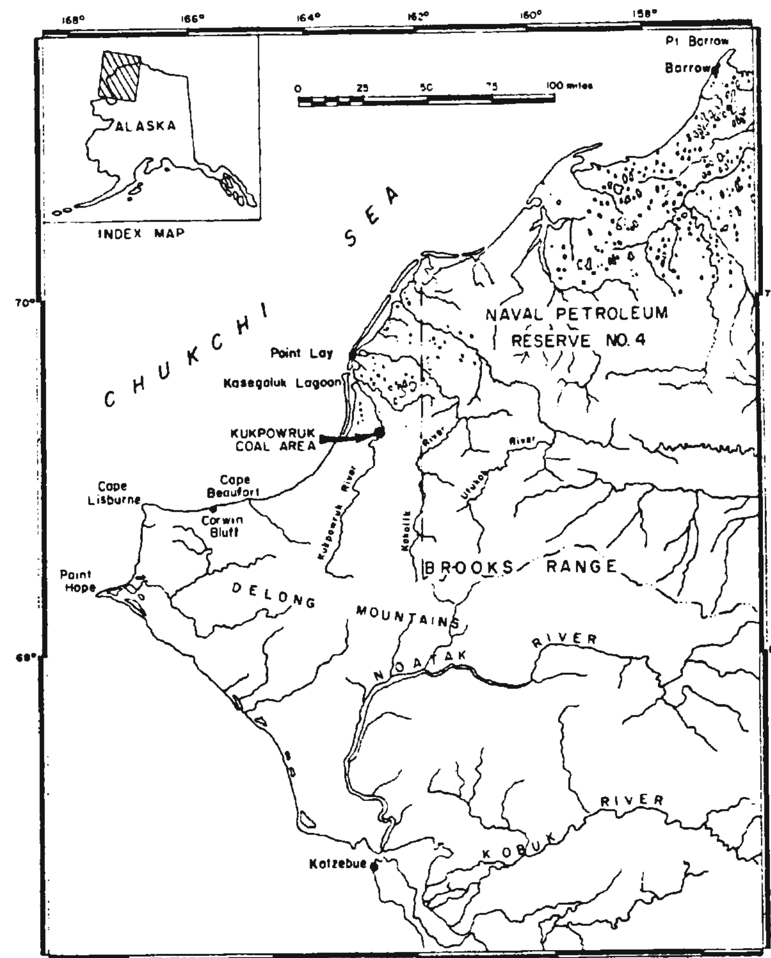

Figure 2 INDEX AND LOCATION MAP
KUKPOWRUK, ALASKA
COAL AREA

al markers in the area, they are not always reliable for stratigraphic correlation.

The Kukpowruk River (meaning "Big River" in Eskimo), is a major arctic river with its headwaters in the Delong Mountains. It is 160 miles long and enters the Chuckchi Sea about 10 miles south of Point Lay. The major bedrock and coal outcrops are found along this river and its tributary drainages.

Geology

The Kukpowruk coal has been known and studied since 1925 by the U.S. Geological Survey, the U.S. Bureau of Mines and private companies. Coal beds of potential economic significance are confined almost entirely to the Corwin Formation, which is Lower to Upper Cretaceous in age. The Formation consists predominantly of intertonguing nonmarine coastal facies of shale, siltstone, claystone, sandstone, coal, conglomerate and bentonitic clay (in decreasing order of abundance).

In the Kukpowruk area, the coal bearing Corwin Formation is exposed in the axial areas of major synclines that are cut by the Kukpowruk River.

Bituminous coal and carbonaceous shale occur in beds ranging in thickness of 1 inch to 22 feet. The coal, shiny to dull, hard, with well developed cleat structure, outcrops below ledges, low cliffs and in rubble of resistant sandstone. It is also manifest in tundra frost heaves or exposed in tunnel dumpings of burrowing ground squirrels.

About 80% of the mapped bedrock exposures consisted of shale, claystone and thin bedded sandstone, with shale and claystone occurring in sets of beds as much as several hundred feet thick. The silty shale, claystone and sandstone contain carbonaceous plant remains, and ironstone nodules which occur in definite layers. Thick sandstone beds, medium to fine grained, commonly contain massive crossbeds with fore set beds 2-3 feet thick and inclined as much as 30% from the top set beds. Many sandstone and siltstone beds are higly lenticular, pinching out abruptly or grading laterally to shale.

The ironstone consists of layered or zoned beds of calcareous and siliceous nodules with plant remains, and are most abundant in the coally parts of the formation.

Remnants of burned coal beds are common in the hills away from the river and are evidenced by fussed shale and sandstone "clinkers" weathering to reddish orange. At some locations, a natural coke has been formed.

Structure

The structure of the Kukpowruk Basin area is a series of east-west trending isoclinal folds occuring parallel to the front of the Delong Mountains.

Strata continuity is displaced by large-scale thrust faults and high angle reverse faults that occur principally on anticlinal axies. The degree of deformation and faulting decreases northward with gently undulating folds on the coastal plane province of the basin.

The coal geology of northern Alaska is analogous to that of the east slope of the Rocky Mountains and the Western Great Plains. As in western United States, the mountain building process is an important factor in developing high rank coals. Since the rank of coal is a function of age of deposition and thermal and structural deformation, bituminous coals are found in the folded and faulted seams of the foothill strata. Lower rank coals are found in the coastal plain, which is less disturbed.

In the principal area of coal occurrence, where a 22 foot coal seam outcrops along the Kukpowruk River, a simple open symmetrical fold plunges to the west with the dip of the bedding steepening abruptly to almost 90^{o} near the north and south boundaries of the structures. The 22 foot coal seam, however, has an average dip varying 12 to 15 degrees to the north-northeast within this synclinal structure (Fig. 3).

Two large vertical transverse faults were mapped on the southern limb of the syncline (called the Howard) which effects the principle 22 foot coal seam. One fault has a vertical displacement of 30 feet, and a horizontal throw of 1,750 feet (Fig. 4).

Coal Seam Geology

In northern Alaska coal beds greater than 42 inches in thickness occur only in the Corwin Formation. Of these, only one 22 foot seam appears to have any economic significance at the present time.

12 coal beds, 1 to 9 feet in thickness, occur above the 22 foot seam, and outcrop where the Kukpowruk River cuts through the south and north limbs of the aforementioned Howard syncline. These exposures, however, were not extensive enough to determine if mineable thicknesses occur, nor was exact correlation of beds of similar thickness between the synclinal limbs possible, because of the discontinuity of outcrops and lack of recognizable marker beds (Fig. 5).

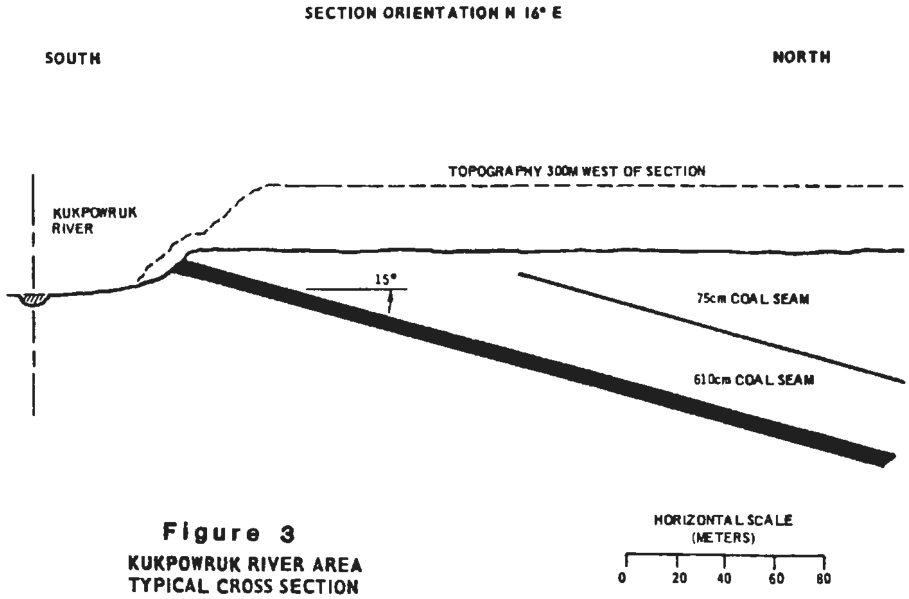

Figure 3
KUKPOWRUK RIVER AREA
TYPICAL CROSS SECTION

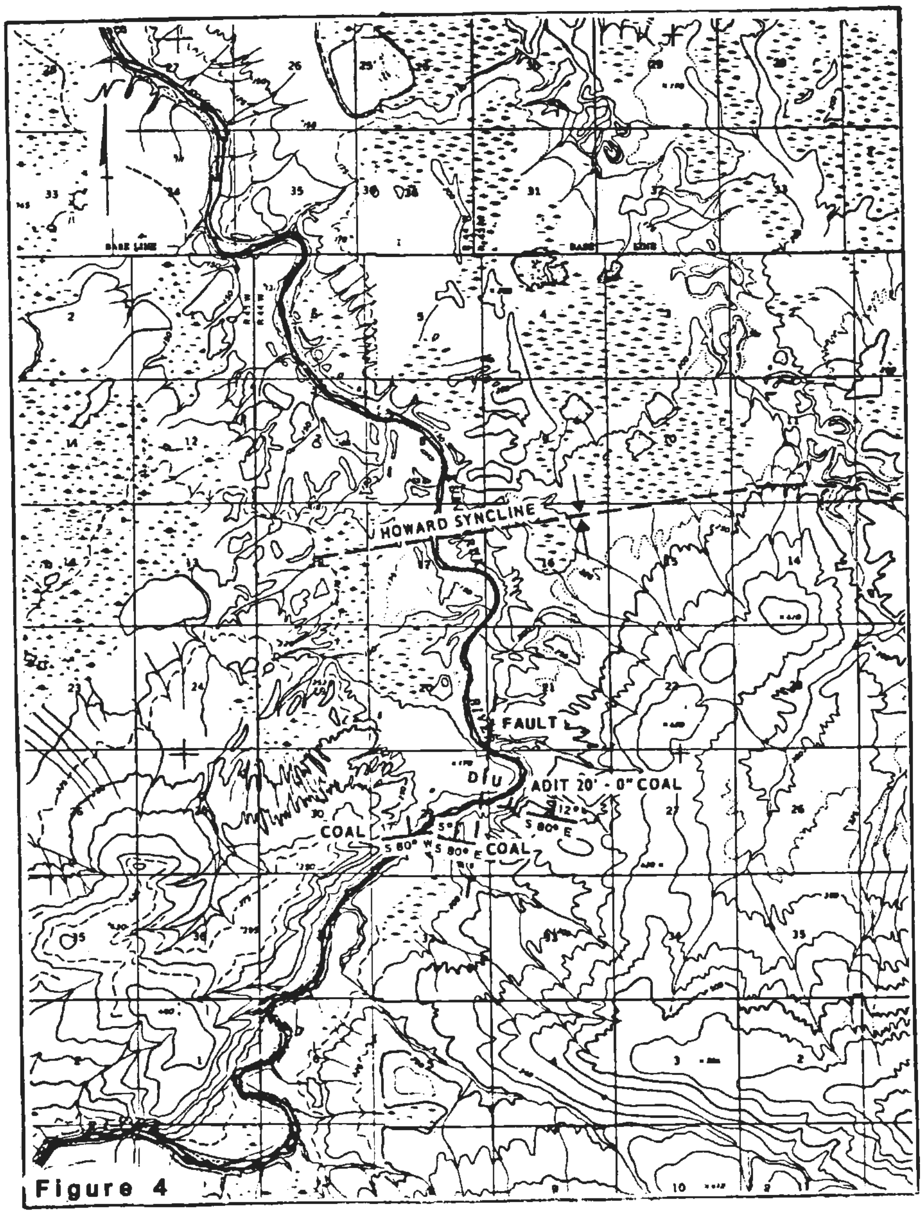

Figure 4

Coal beds crop out only along the Kukpowruk River and some small tributaries, and lateral correlation of coal bed projections away from the river drainages were estimated by drill hole data, coal rubble, and on the projection of resistant sandstone beds stratigraphically associated with the coal.

The coal characteristics of the 22 foot seam are described as a hard, bright vitrain clarain rich coal with well developed cleat structure. Kaolinite occurs as a secondary mineralization film on the cleat faces. Interlaminated carbonaceous shale occurs locally as very thin, lenticular lenses (Fig. 6).

The roof and floor rocks consist of a thick sequence of very friable, completely incompetent claystone.

Coal Quality

The Kukpowruk River coal has been analyzed as high volatile C bituminous, soft coking, with low ash and sulfur contents. Test results on a Proximate analysis basis demonstrate the following coal characteristics for selected Kukpowruk coal:

Moisture	2.8%
Ash	3.5%
Fixed Carbon	58.5%
Volatile Matter	35.2%
Total Sulfur	0.25%
FSI	4.5%
Btu	13,860

The Kukpowruk coal is almost the same as high quality Western United States high volatile coal, in terms of merit calculation. Merit calculation is a factor based on moisture, ash, volatile matter and total sulfur, without taking coking properties into consideration.

The Kukpowruk coal is comparable to Australian soft coking coal in quality and appears suitable for control of ash and sulfur in coke operations.

Coal Weathering Properties

Coal mining will be on a year round basis, but coal shipping is expected to be concentrated in a short summer period because of ocean ice conditions. Therefore, mined coal will have to be stockpiled. Limited oxidation studies suggest that Kukpowruk coal is storable for reasonable periods, without excess loss of coking properties. The oxygen contact of Kukpowruk coal after 5 months of oxidation was slightly increased (0.2 to 1.0% moisture and ash

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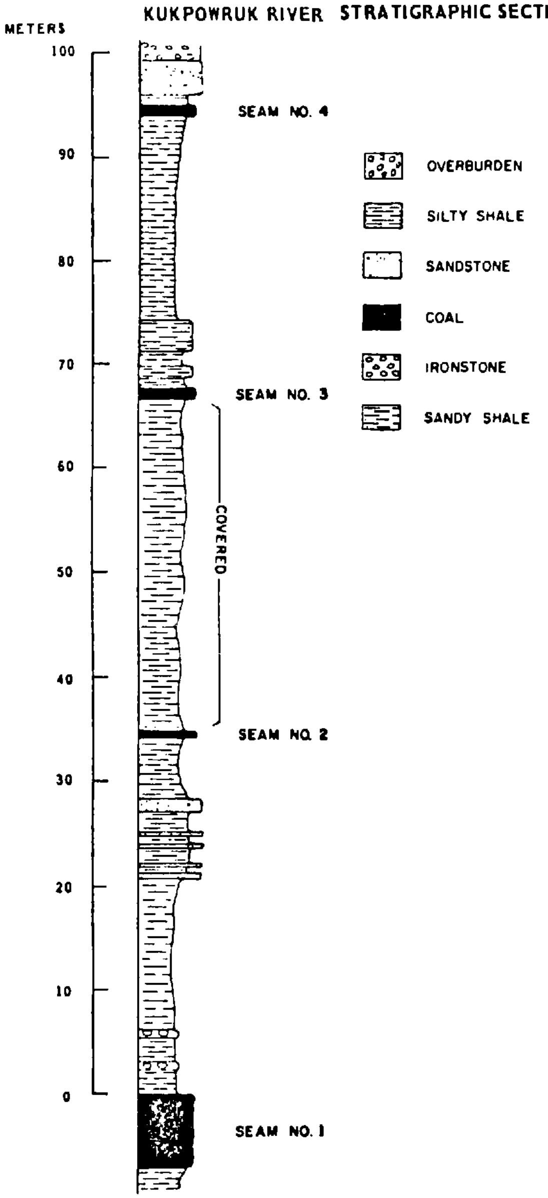
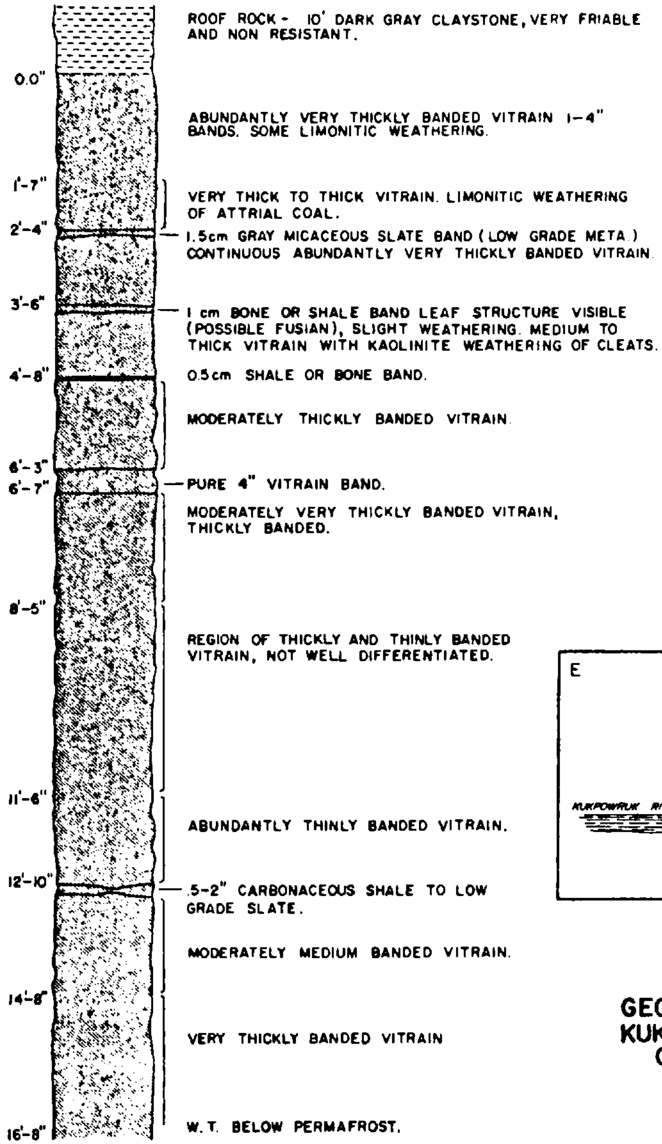
KUKPOWRUK RIVER STRATIGRAPHIC SECTION



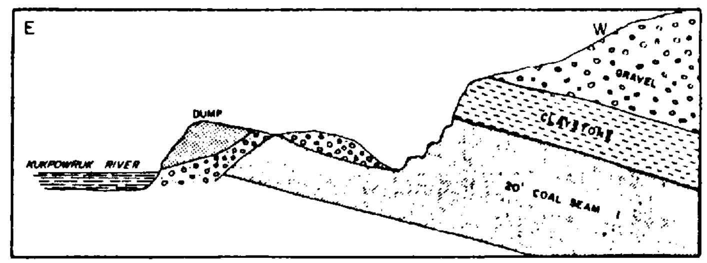
RIVER TRAVERSE

Figure 5



SCALE: 1"=2'

Figure 6



GEOLOGY OF CHANNEL ALONG KUKPOWRUK RIVER JUST EAST OF USBM DRILL HOLE # 1 free basis) and heating values were slightly decreased (80 to 150 Btu/lb moisture and ash free basis).

Coal Resources

The coal deposits of northern Alaska are characterized by a notable lack of exploration. The only area in northern Alaska which has been explored as having a potential for an export market is the Kukpowruk River region.

The economic potential of Kukpowruk depends upon the quantity of coal economically extractable with current technology, and on viable land/ocean transportation.

Since economic viability of the northern Alaska coal fields has not been established, the quantity of bituminous coal delineated by detailed exploration in the Kukpowruk Basin has been classified as "resources" as opposed to "reserves".

The Kukpowruk resource base represents an estimate of all coal in the ground meeting specific geometrical requirements (seam thickness and depth of cover), whether economically recoverable or not. Coal "reserves" are estimates of coal which can be recovered economically using current technology. Reserves are calculated by government agencies by applying recovery factors to a resource base. This is a very simplistic approach and does not give adequate consideration to the economic aspect of reserve determination.

Implicit in government reserve determination techniques is the assumption that the cost of mining and transporting coal to market is essentially the same in northern Alaska coal field as in coal fields in other states. However, it is obvious that mining and transportation costs and capital amortization charges will be significantly higher in northern Alaska than elsewhere.

To account for the high anticipated costs in northern Alaska, it is recommended that the minimum seam thicknesses should be 42 inches for bituminous coal and 10 feet for subbituminous coal.

The Kukpowruk bituminous coal reserve base estimate was based on the following parameters:

Strippable Resources

a. minimum seam thickness: 42 inches*
b. maximum overburden: 120 feet
c. stripping ratio: 5:1
d. maximum degree of dip: 20^{o}

Underground Resources

a. minimum seam thickness: 42 inches
b. maximum strata overburden: 2,000 feet

* Note: Obviously, seams thinner than 42 inches can be effectively removed in multiseam operations which also contain thicker seams.

The bituminous coal reserve base using the above parameters is summarized in Table 1.

Table 1. Bituminous Coal Resource Base of Kukpowruk Coal Basin, Northern Alaska Coal Field, in Million Short Tons (M.T.)

Mine Method	Resource Classification		
	Measured & Indicated	Inferred	Total
Strippable [1]	16.9	98.4	115.3
Underground	about 100 M.T. Total [2]		

[1]It must be emphasized that the strippable coal estimate does not represent estimates of "mineable" coal tonnages. There is a high degree of geologic uncertainty with respect to the existence of the coal, and recover factors have not been applied. The estimates do form, however, a very rough approximation of order-of-magnitude for in situ coal tonnages which may be amenable to surface mining.

[2]The underground resource data is proprietary and only a general statement can be made.

Transportation of Coal

An economic evaluation of transportation modes of Kukpowruk coal from surface and underground mining locations consisted of two scopes of work:

First, estimating the total delivered cost of surface and underground mined coal to an ice free ocean port in southern Alaska. Two routing locations were considered as shown in Figure 7: Dutch Harbor, using seasonal tug and barge, and Seward, using railroad.

Second, comparing this cost with F.O.B. port prices for competing North American and Canadian coal. In the same manner as infrastructure development costs in remote areas, the need to construct and operate a transportation system significantly affects the economics of a remote mining project, particularly with a bulk commodity of relatively low unit value, such as coal. It has been assumed that most supplies would be backhauled on the coal transportation system or barged to a point near the mine site.

The two modes of transportation are evaluated as follows:

All Year Shipping by Railway

This system would involve the construction of a railway through delicate permafrost region from the minesite to the Alaska Railway at Nenana, southwest of Fairbanks. For the Kukpowruk River mine site, approximately 720 miles of new railway would be constructed. This route would also permit development of other resources in the Alaskan interior. Potential rail routes are shown on the Alaska map (Fig. 7).

The unit trains would be unloaded at an ice free port in the Seward-Whittier area. Because this transportation system would operate all year, stockpile requirements would be nominal. A stockpile of 250,000 tons capacity should be adequate to ensure a smooth flow of coal. The port facility would be designed so that train unloading and ship loading could take place.

Seasonal Shipping by Barge

Coal would be transported from the mine site to the Chukchi Sea coast by means of haulage trucks, belt conveyor or slurry pipeline (Fig. 7).

Truck haulage would be by 180 ton bottom dump trucks over a heavy-duty all weather road, which would connect the mine site to the coal storage and barge loading facility on the Chukchi Sea. This distance would be 25 miles for the Kukpowruk River mine.

An alternative method of transporting the coal from the mine to the barge loading facility would be by means of a 36 inch belt conveyor over substantially the same route as would be used for truck haulage.

At the barge loading facility on the Chukchi Sea coast, sufficient stockpile capacity would be required to permit the storage of a minimum of 9 months production of coal. Loading facilities would handle load two 60,000 ton load capacity barges simultaneously. To reach water deep enough for safe barge operation, a long rock filled pier would be required.

Coal haulage to an ice free port at Dutch Harbor would be by seven 4,400 horsepower tugs and nine 60,000 ton load capacity barges with a loaded draught of 33 feet. Tugs would drop off barges at both ends of the trip and pick up other barges which would have

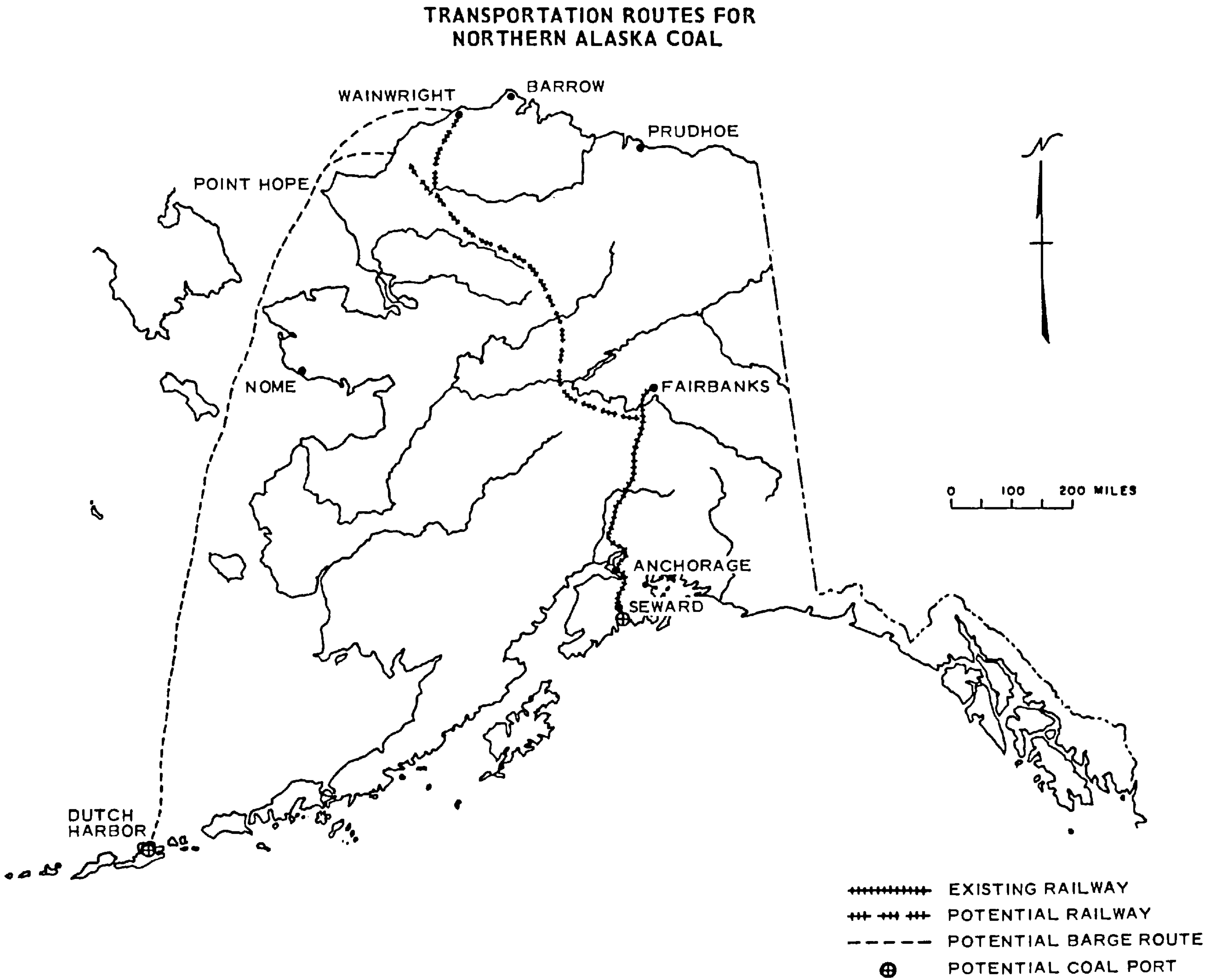

TRANSPORTATION ROUTES FOR
NORTHERN ALASKA COAL
WAINWRIGHT
BARROW
PRUDHOE
POINT HOPE
NOME
FAIRBANKS
ANCHORAGE
SEWARD
DUTCH
HARBOR
0 100 200 MILES
EXISTING RAILWAY
POTENTIAL RAILWAY
POTENTIAL BARGE ROUTE
POTENTIAL COAL PORT

Figure 7

been either loaded or unloaded at the respective port facility. This operating procedure would maximize the productivity of the tugs.

The barges would be unloaded at the ice free port of Dutch Harbor. This port facility would have stockpile capacity of 3.75 million tons of coal and sufficient berthing capacity to permit the unloading of two barges and the loading of one bulk carrier simultaneously. Transportation routes are shown in Figure 7.

A third method of transporting the coal from the mine site to the Chukchi Sea coast would be by means of a slurry pipe constructed over the same route as would be used for the haulage road and the belt conveyor. The slurry system would consist of a 16 inch slurry line and a 12 inch return water line. The coal would be dewatered and stockpiled at the barge loading facility for shipment during the ice free season.

Transportation cost estimates will not be discussed because the studies are either outdated cost wise or are proprietary in nature. Suffice it to say that rail transportation is expensive because there would be insufficient volume to ammortize capital costs efficiently. Truck-conveyor-slurry pipeline and barge transportation is, in order of magnitude, about 1/8 as expensive as rail haul.

Constraints to Kukpowruk Coal Development

The principal constraints to the development of northern Alaska coal resources are related to environmental problems, social and economic problems, technical problems and marketing and transportation problems.

Environmental Constraints

Environmental constraints to coal mining in northern Alaska are classified in three general categories:

First, impact on the existing environment more from the influx of population than from the mining operation itself.

Second, problems caused by climatic conditions: social and operational dificulties typical of a cold, remote location.

Third, difficulties in reclaiming mined land: permafrost safeguards and revegetation.

From a macroscopic viewpoint, much of northern Alaska is considered to be environmentally sensitive. The harsh climate has resulted in many unique animal and plant species. Because of the limited ability of the land to support wildlife, many animal species either migrate or have a very large range area. However, the extent of the caribou calving areas and bear denning areas is restricted. The location of mines or transportation systems in these areas could have major impact on wildlife populations. Also, the location of transportation systems on migration routes could affect wildlife species considerably.

Permafrost areas, especially wet tundra, are very susceptible to environmental degradation. Careless travel activities over the tundra surface during summer months could have long-term effects on the thermal equilibrium of the active zone. The reestablishment of equilibrium could result in either progressive erosion or replacement of vegetation with different plant communities than previously existed. Transportation corridors constructed across tundra would require surface insulation to prevent progressive melting of the underlying permafrost, and resulting problems of foundation instability.

The cold, harsh climate and strong, prevailing winter winds are constraints to mining operations. There are no year round seaports in northern Alaska. Surface water freezes during the winter, causing difficulty in designing water and sewage systems. The effects of the cold weather and darkness upon various aspects of human activity represent major considerations. Labor productivity will decline significantly during winter months. Cold weather will also adversely affect the metallurgy and lubrication of machinery, as well as operator comfort.

During the summer months, poor surface drainage will cause mining problems. Handling of saturated, silty soils will be difficult. Dewatering of blastholes and mining pits will require careful attention.

The reclamation program will be constrained by surface conditions and biological factors. During the winter, frozen soil is difficult to handle. However, when the soil melts it becomes a wet, soupy substance which could be even more difficult to handle. The extreme variations between seasons, and the short growing season mean that scheduling of reclamation activities is more critical in northern Alaska than in the Lower 48 states. Research work on Arctic reclamation techniques is still in the early stages. There has been insufficient time for feedback on test results and resulting modifications to reclamation methods. The relative merits of using native or non-native species have not been determined. Much more work must be done before an acceptable reclamation procedure can be determined.

Social and Economic Constraints

The following social and economic problems will impede the development of coal mining in northern Alaska: labor, housing, transportation distances, high construction costs to accommodate permafrost conditions, high energy consumption for heating buildings and equipment, basic lack of existing utilities and infrastructure, and low labor and equipment productivity.

It will be difficult to attract and maintain a suitable labor force in the Arctic. The majority of the public does not wish to work and live in a remote location. In existing northern communities the incidence of mental illness, drug abuse and alcoholism is far greater than in less isolated localities. Remote locations are typified by a shortage of qualified workers, high turnover, low productivity and labor disharmony.

Technical Constraints

Problems involving technical constraints appear to be the most easily overcome of all problems relating to surface mining in northern Alaska. Noncoal surface mines are currently being operated under climatic conditions comparable to conditions in northern Alaska.

The principal cold weather problems encountered in mining equipment are related to inadequacies in metallurgy, lubrication, hydraulic systems and operator facilities. During very cold weather, most metals become brittle and develop cracks even if normal loads are applied.

Presently, no large-scale electrical power supply is available in northern Alaska. New electrical systems would have to be built and operated for coal mining projects. The extreme load fluctuations caused by cyclical mining equipment could cause severe electrical system difficulties.

Marketing Constraints

Potential markets for Alaskan coals are limited by coal quality and by problems in transporting coal from an isolated area with no infrastructure, under Arctic conditions. Although some of the coal reserves are of coking quality, no high quality, low volatile coking coal has been discovered; thus, Alaskan coals cannot command a premium price. Potential markets would be available in Japan and Korea for both coking and thermal coal, and in the western United States and Alaska for thermal coal. Thermal coal could also be converted to other energy forms by gasification or liquefaction, to compete in other markets in Alaska. Transportation beyond the Pacific Ocean area would probably be too costly for coal of this quality to be competive with coal from other market areas.

In the near future, marketing of coking and thermal coal in Japan would be in direct competition with coal of equal or superior quality from Australia, Siberia, China and southeast Asia. High volatile coking coal from the western United States would also be competitive. A market for thermal coal or coal conversion products may be developed in the western United States, although competition could be expected from coal produced in the western and northern plains states. However, environmental constraints to mining may be more restrictive in these states because of the greater population density and existing industry.

Transportation Constraints

Marine, land and air transportation systems would be involved in northern Alaska coal development. Transportation constraints are principally related to climate, physical features and lack of existing facilities.

Marine transportation from the North Slope of Alaska is generally limited to shallow draft ships and barges operating during the short summer season. The shallow water and extensive continental shelf, together with the Arctic ice pack and lack of dock facilities, considerably complicate marine transportation and loading/unloading operations. Shallow water, extending to 12 miles or more offshore, limits the use of large, deep draft ships and requires lightering with shallow draft ships and barges over most of the coastline.

The Arctic ice pack extends south in the Bering Sea to approximately 61 degrees north latitude in the winter months, with floating ice extending as far south as the Pribilof Islands near the 56th parallel. During the summer months, the Bering Sea is ice free for approximately 5 months, the Chukchi Sea for 3 months, and a narrow channel around Point Barrow is open for only 1 to 3 months. Pack ice may remain on or near Point Barrow until late summer, and occasionally remains throughout the summer. Eastward of Point Barrow, the pack ice seldom goes far offshore; ice movement and therefore coastal navigation along the Arctic coast is controlled primarily by winds.

Ground transportation in the North Slope area is presently limited to winter travel with tractors and sleds because the tundra, when thawed, will not support heavy vehicles and even low ground pressure vehicles damage its surface. A newly constructed gravel highway paralleling the Alaska pipeline route from Fairbanks to Prudhoe Bay is presently the only land access route to the North Slope. Construction of transportation facilities for movement of coal overland to a seaport would be costly and require special construction methods adapted to Arctic conditions.

Ground transportation would probably be by rail, truck, belt conveyor or slurry pipeline. Construction of transportation facilities in permafrost regions would require specialized techniques to reduce the effects of the permafrost. Insulation of road and track beds would be required. Mechanical stabilization of cut slopes and prevention of ice formation in culverts will require further attention. With pipelines, steps must be taken to prevent freezing within the pipe and thawing of permafrost if the pipe is buried. Above ground pipelines and conveyor belts can interfere with animal migration routes. Mechanical components of transportation are subject to cold weather problems such as starting system failures, lubrication failures and low temperature material failures.

Conclusions

As a result of the economic and geologic evaluation of the Kukpowruk coal deposits, certain conclusions have been made with respect to the geology and coal resources:

Geology and Reserves

The Kukpowruk River area coal has been assessed to contain the largest deposits of quality bituminous and coking coal in Alaska.

The Kukpowruk coal has been analyzed as high volatile C bituminous, soft coking, with low ash (3.5%) and low sulfur (0.25%) content.

The bituminous coal resource base for the Kukpowruk Basin total 16.9 million short tons of strippable coal on a measured and indicated basis, and approximately 100 million short tons of underground coal on an inferred basis.

With the exception of the Kukpowruk River area, the degree of exploration has not been sufficient to provide good estimates of coal resources in other coal bearing areas of northern Alaska.

Coal in seams greater than 20 feet thick has not been identified to any great extent in northern Alaska. The exceptions are the 20 foot thick Kukpowruk Seam and coal intersections of up to 30 feet in thickness, which were encountered in test wells on Naval Petroleum Reserve No. 4. It is suspected that much of the coal intersected by the test wells is carbonaceous shale. Generally, the coal seams encountered in northern Alaska are thinner than those encountered in other western states.

Past estimates of strippable coal in northern Alaska are overstated. Very little flat lying coal exists. Therefore coal reserves with less than 120 feet of overburden are limited.

Given the geology and the costs of northern Alaska, most coal cannot be mined economically with current technology.

Environment and Reclamation

The environment of northern Alaska is harsh. Special construction and equipment operating techniques will be required.

The potential for success of reclamation projects in the Arctic is unknown.

Insufficient data exists to make detailed environmental impact assessments of potential northern Alaskan mining activity.

Technical Feasibility

The coal deposits of northern Alaska could be mined with currently available equipment and mining techniques.

Economic Feasibility

The only bituminous coal source from northern Alaska which would be competitive with other northern American coals is the Kukpowruk River coal--but only when mined at a rate of 5 million tons per year, to support the costly shipping and mine complex infrastructure.

In regard to strippable coal: assuming a minimum production life of 20 years and 80% recovery of in place coal, geologic "reserves" would have to contain a minimum of 125 million tons of bituminous coal, with a stripping ratio of less than 5 cubic yards of overburden per ton of coal, to support a strip mining operation. This is far in excess of the current measured and indicated reserves of about 17 million tons to a depth of 120 feet and with a minimum seam thickness of 42 inches.

Kukpowruk coal reserves would have to be expanded by a factor of 10 before this coal would be competitive with existing North American coal sources.

Currently, identified underground coal resources for the Kukpowruk Basin are not economically mineable.

Paleogeography and paleoclimate of the Arctic Alaskan Cretaceous coals

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Abstract

High biologic productivity, as indicated by the enormous volume of the arctic Alaskan coal deposits of Late Cretaceous age, combined with the plant megafossils of those deposits, suggest the deposit was not formed in polar latitudes. These two observations are in conflict with the common paleogeographic reconstructions based on paleomagnetic data from the North American craton, and the assumption that arctic Alaska was fixed with respect to North America by Late Cretaceous time. These reconstructions put arctic Alaska within a few degrees of the pole at the time the coals were formed. Even with significant climatic warming, the low sun angle and long winters of such high latitudes are probably incompatible with the observations. A possible solution to the problem is to bring arctic Alaska in from the south along with the proposed allochthonous terranes of southern Alaska.

Introduction

Extensive sequences of coal are found in the Cretaceous Nanushuk and Colville Groups of northern Alaska. Coal resource estimates for northern Alaska range from 100 billion tons to 4 trillion tons (Tailleur and Brosge, 1975; Barnes, F.F., 1967) (Figure 1). These occurrences seem anomalous when one considers that accepted North American paleogeographic reconstructions for the Cretaceous and Cretaceous paleomagnetic data (Irving, 1979) put northern Alaska within ten degrees of the north geographic pole (Figure 2). This raises the question as to whether it is possible for these northern Alaskan coals to have been derived from forests growing so close to the magnetic, and by implication, geographic pole.

Paleoclimatology and Paleobotany of the North Slope Region

Smiley (1967, 1969) interpreted the paleoclimate of Late Cretaceous northernmost Alaska as that of a "humid coastal plain, near sea level". From an analysis of the latest Early Cretaceous (Albian) to latest Cretaceous (Maestrichian) Nanashuk and Colville floras, and Vakhrameev's (1964) Late Jurassic to Albian sequences in the Kolyma and Lena River areas of Eastern Siberia, Smiley

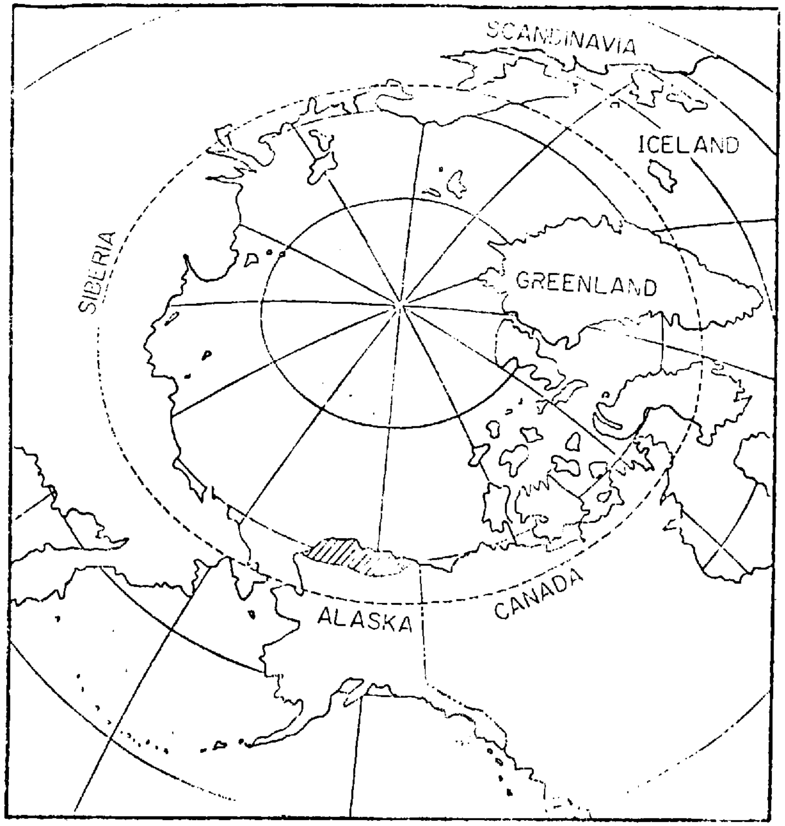


Fig.1 Present location of the Arctic Alaskan Coal Province (hatched area). Tailleur and Brosge (1975) estimated coal reserves of between 100 billion and 4 trillion tons for the province.

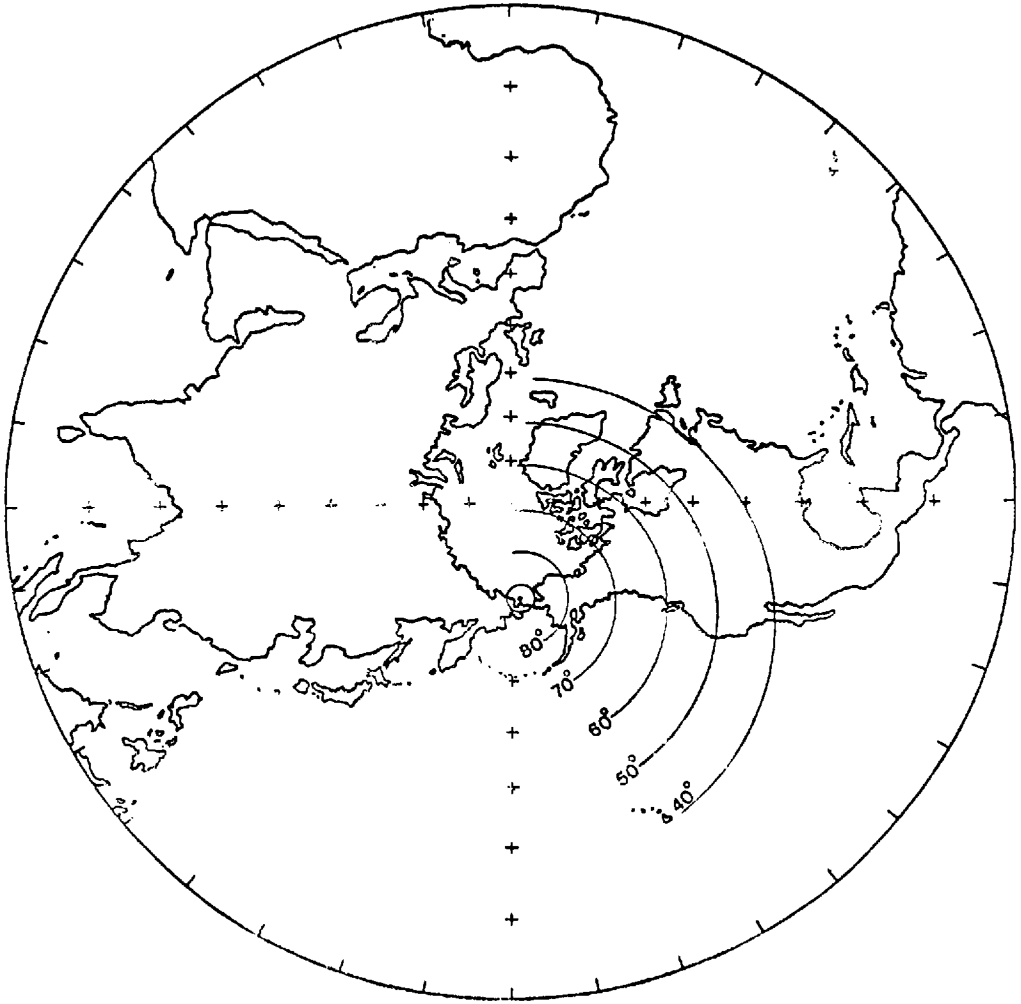


Fig.2 Mid-Cretaceous (100 million years before present) pole position and paleolatitudes for North America and Alaska assuming Arctic Alaskan plate was in its present position relative to North America in the Early Cretaceous. (Paleopole from Irving, 1979)

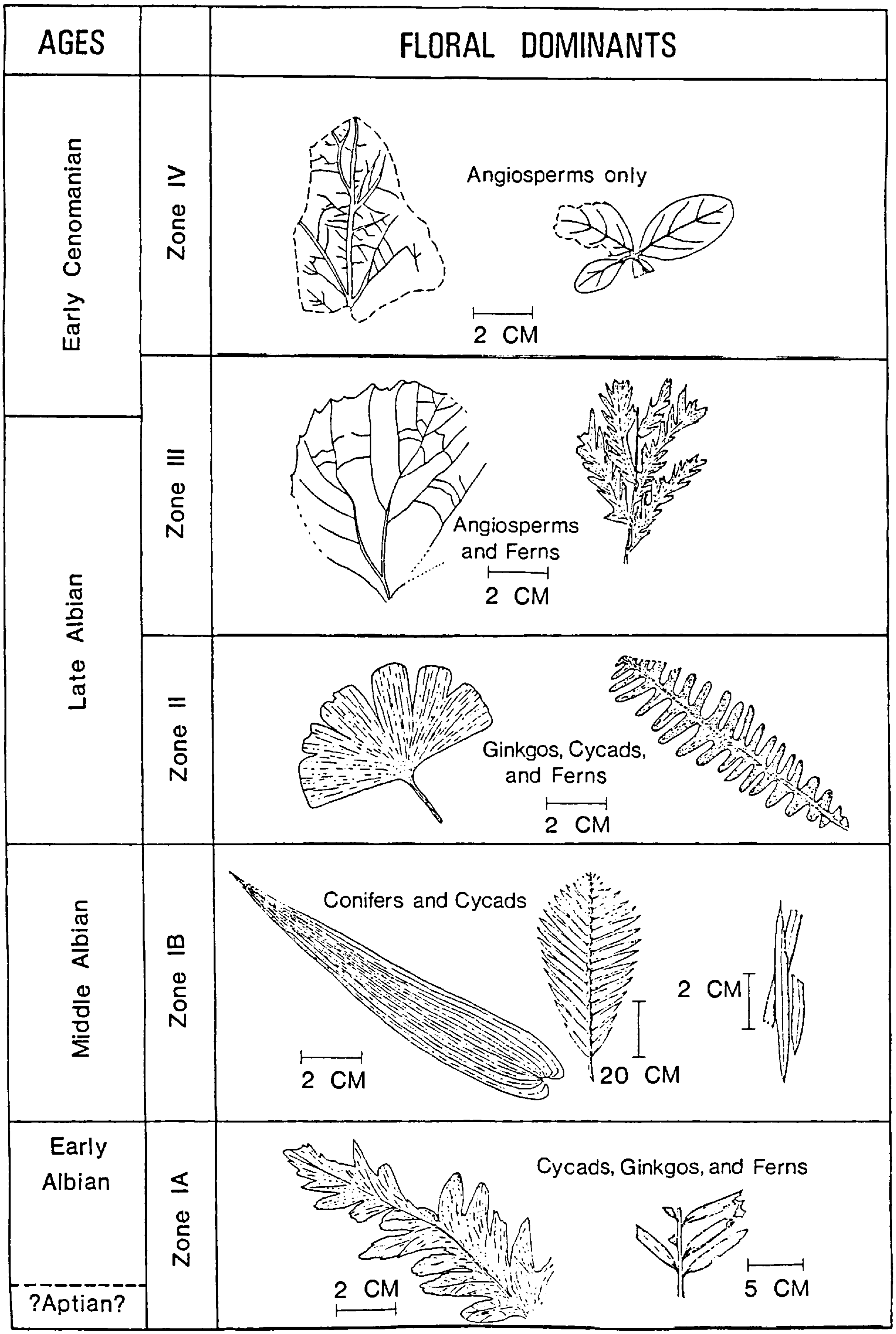
decided that the observed paleobotanical distributions were the result of a widely recognized "world-wide" warming (Frakes, 1979). This warming trend peaked during the Albian and was followed by world-wide cooling through the Maestrichian.

Vakhrameev (1964) determined that Mesozoic Eurasian vegetation zones were nearly symmetric about the present north geographic pole and parallel to present isotherms (see also Chaney, 1940). From these data Smiley (1967) concluded that Eurasia had not rotated nor changed its latitude since the Jurassic, and that the Atlantic Ocean had existed since the Late Mesozoic. At that time (1967) Smiley observed that all paleoclimatic variations could be attributed to world-wide cooling and warming without continental drift, or shifts in the inclination of the Earth's axis of rotation. Within the last ten years, general acceptance of plate tectonics has grown so that it now represents a major paradigm of geology. Smiley's earlier interpretations of Alaskan paleoclimatology have to be reconsidered in the light of modern plate tectonic hypotheses.

Even if the Cretaceous was warm enough to permit extensive forests in the polar regions, where accepted plate reconstructions would put this part of Alaska at that time, which is 20^{o} further north than Smiley believed (Figure 2), plant life in those regions would be subject to extreme seasonal variations in light conditions. Incident light would also be limited to oblique angles, placing additional constraints on the amount of photosynthesis possible, thus adding to the problems of producing a huge coal deposit. Wolfe (1978) notes that broad leaved evergreens with medium sized leaves rarely occur north of 50 latitude today. He hypothesizes that the light conditions at latitudes greater than 50^{o}, regardless of the climate, would impose seasonal variations that are too severe for the general survival of broad leaved evergreens, and that deciduous forms would predominate with perhaps a slight broad leaved evergreen component.

In northern Alaska Smiley observed the Albian floral dominants to be "ferns, cycadophytes, dissected ginkgoids and conifers" (Figure 3). Almost all contemporary cycads and conifers have evergreen habits, while the only contemporary ginkgoid, *Ginkgo biloba* is deciduous. However, the weight of the paleobotanical evidence would seem to be against an extreme polar location for the development of these coals.

The sometimes ambiguous relationships between living and extinct plant species leads to a problem inherent in paleontological generalizations. Interpretation of paleoclimates and botanical habit, for instance deciduous vs. evergreen, is prone to error if based soley upon taxonomic and strict evolutionary relationships. Paleoclimatic interpretation should also be based upon the physical aspects of the paleobotanical material. Useful physiognomic characteristics of broad leaved foliage include: type of margin, size, texture, type of apex and the type of base and petiole



after Scott and Smiley, 1979

Fig. 3

(Wolfe, 1970, 19791); however, the physiognomic characters have yet to be studied in the Cretaceous floras of arctic Alaskan.

One solution to the severe polar light regime is to assume the earth's spin axis was inclined less than the present 23.5° during the Late Cretaceous. This hypothesis was suggested by Wolfe in his interpretations of Tertiary floras of Western Washington and the Gulf of Alaska (Wolfe, 1978). A large gradual decrease in the angle of inclination (to approx. 5° in the middle Eocene) followed by a rapid increase (to approx. 25°-30° at the end of the Eocene) could possibly account for the Tertiary climatic trends described by Wolfe. Wolfe suggests that the spin axis of the earth changed in response to precession and astronomical perturbations similar to those hypothesized by Milankovitch (1938). The actual mechanisms that could be responsible for such variations in the inclination of the earth's axis are necessarily complex and have yet to be adequately explained. While they could account for some of the observed variations in climate and paleobotanical distributions, these variations can also be explained through changes in the local paleogeography.

Paleogeography and Evolution of the Actic

The paleogeographic configuration of the elements making up the North Pacific, Arctic and North American tectonic systems must have had an effect on the paleoclimate of arctic Alaska. It has become apparent on the basis of paleomagnetic, structural and sedimentary observations that northern Alaska has not remained rigidly fixed with respect to North America throughout the Paleozoic and Mesozoic (Tailleur, 1969, 1973; Newman et al., 1977; Sweeney et al., 1978; Churkin et al., 1979; Mull, 1979; Newman et al., 1979, Kerr, in press). The arctic Alaskan plate (Figure 4) as defined by Newman et al. (1977, 1979) and Churkin (1973) is believed to be bordered on the south by the Kobuk Suture and on the north by a typical Atlantic type margin. Arctic Alaska's eastern and western margins are less well-understood. The eastern margin is probably marked by the Porcupine orocline near the MacKenzie Delta. In the west several boundaries have been suggested (Sweeney, 1978; Patton and Tailleur, 1977) and include different parts of Siberia, although most include a significant portion of Chukotka (see Sweeney, 1978, for a discussion of this problem). The motion commonly ascribed to the arctic Alaskan plate is a counterclockwise rotation out of the Canada Basin, initiated in the latest Jurassic and completed by the latest Cretaceous. This hypothesis puts arctic Alaska in northern Canada in the Early Jurassic, with Early Cretaceous rotation followed by a continental collision with parts of southern Alaska in mid-Cretaceous time. This reconstruction results in some possible conflicts with the bathymetry (Newman et al., 1979) and with the available magnetic anomaly data from the Arctic Ocean (Vogt et al., 1979). If the arctic Alaskan plate is taken to include the Chukotka and/or Kolyma blocks of Siberia, as some authors propose (Churkin, et

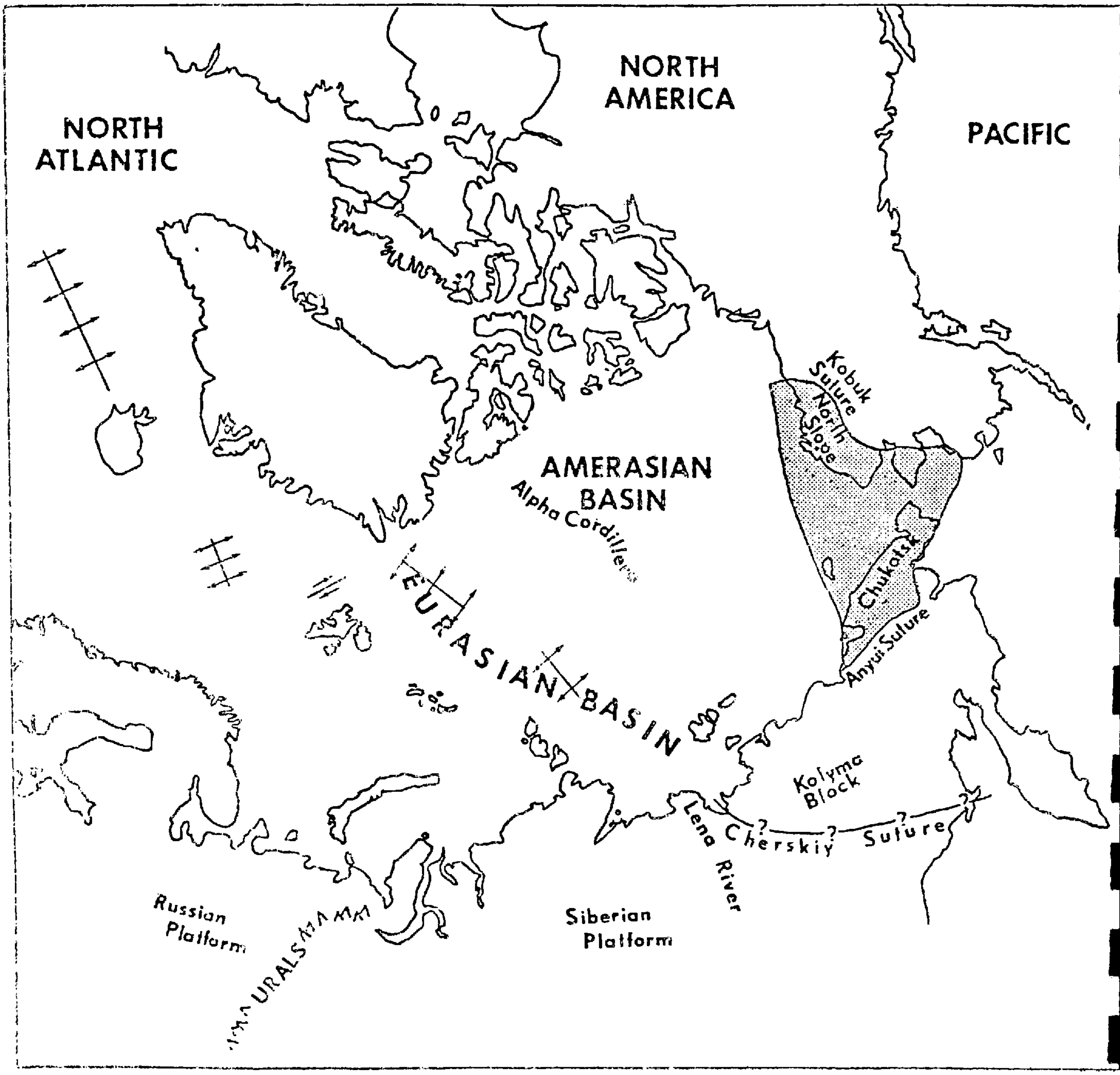


Fig.4
Arctic Alaskan plate (shaded) and its relation to other Arctic tectonic elements. Plate boundaries shown are those of Churkin (1979).

al., 1980; Sweeney, 1978; Churkin, 1973; McElhinney, 1973), these problems are accentuated and a space problem develops in both the prerotation configuration and the space available for rotation.

In terms of the timing of the "arrival" of arctic Alaska in its present position relative to North America, the geologic evidence suggests that it should be in place sometime in the Cretaceous, the exact time depending on how far south one places the collisional boundary. A pervasive thermal event that reset many of the radiogenic geochronologic clocks of arctic Alaskan rocks at 100 million years (Turner et al., 1979) can perhaps be considered circumstantial evidence for a Late Cretaceous arrival. Plate tectonic evidence for the emplacement of the arctic Alaskan plate in or near its present position by the latest Cretaceous is in part based upon interpreting the Alpha Cordillera as a fossil spreading center. If this was the case, then the timing of cessation of active spreading on the Alpha Cordillera is determined by the presence of Maestrichian silicoflagellates in sediments from the central valley (Ling et al., 1973). If the Alpha Cordillera were the spreading ridge involved in the initial opening of the Arctic Ocean and the rotation of the arctic Alaskan plate, then presumably all major arctic Alaskan plate movements must have been completed by the latest Cretaceous. The nature of the Alpha Cordillera is critical to this timing argument.

There is evidence that indicates the Alpha ridge is neither an active nor a fossil spreading center. The Alpha Ridge lacks almost all the geophysical indications associated with an active spreading ridge, such as seismicity (Wetmiller and Forsyth, 1978) and elevated heat flow (Judge and Jessop, 1978). Similarly, if the Alpha Ridge had been an inactive spreading center since the Late Cretaceous, it should have long ago cooled and adjusted isostatically (Delaurier, 1978). Within 40-70 million years following the end of active spreading, the topographic relief on the Alpha Ridge should be less than 500 meters instead of the observed 2,900 meters. Alternative origins for the Alpha Cordillera have been proposed by several authors: a sunken crustal block (King et al., 1966), a transform fault swarm (Hall, 1970; 1973), a subduction or deformation zone (Herron, et al., 1974). Herron, Dewey and Pitman's (1974) subduction hypothesis would indicate a more southerly origin for the arctic Alaska plate as opposed to a rotation, an origin more consistent with the Cretaceous coals.

Large scale and disparate northward motions have been proposed for most of southern Alaska and parts of western Canada (Monger and Irving, 1980; Stone, 1979; Hillhouse, 1978; Jones et al., 1978; Packer and Stone, 1974). Perhaps a similar origin is indicated for arctic Alaska. One of the consequences of the overall "collage" hypothesis for the formation of southern Alaska as proposed by a number of authors (Stone and Packer, 1979; Jones and Silberling, 1979; Stone, 1977; and others) is that there is no obvious piece of original or "ancestral" Alaska. One of the few pieces of Alaska that can possibly be tied to the rest of North America is the Tindir area near the Yukon River/Canada border.

The remainder of the terranes forming interior Alaska have yielded little evidence as to their place of origin or time of arrival.

It is conceivable that there was motion of an oceanic plate from the "Pacific" into the "Arctic" as indeed has been proposed by Churkin (Churkin and Trexler, 1980) for somewhat earlier times. In this case, a model involving the northward motion of the arctic Alaskan plate from the Pacific region, along with all the other components of the Alaskan and West Coast collage, is quite plausible.

A Pacific origin for the arctic Alaskan plate does not require arctic Alaska to be in its very northern position by the Late Cretaceous, the lower latitude giving both less extreme sunlight variations and a warmer climate (Figure 5). In this hypothesis the Alpha Cordillera could then be the isostatically adjusted remnant of a trench system active during the northward motion of the arctic Alaskan plate. The tectonic features of arctic Alaska usually considered as having been caused by the collision could then have been formed to the south and also moved northwards. In this way they would not necessarily represent events at the time of collision.

Conclusions

Present geotectonic models for arctic Alaska may be in disagreement with some Cretaceous paleoecologic and climatic interpretations based upon paleobotanical evidence. Geophysical information from the arctic Alaska and the Arctic Ocean tectonic systems is generally incomplete, permitting only speculation on the evolution of the arctic system. Proposed times for the arrival of the arctic Alaskan plate in its present position, previously considered to be pre-Maestrichian, depended in part upon an interpretation of the Alpha rise as a rift system. Delaurier (1978) has shown the Alpha Cordillera was probably not a spreading center. Herron et al., (1974) have suggested that the Alpha Ridge was at one time an island arc system. This hypothesis allows speculation as to a southerly origin for arctic Alaska in a manner not unlike the other fragments of the Alaskan collage.

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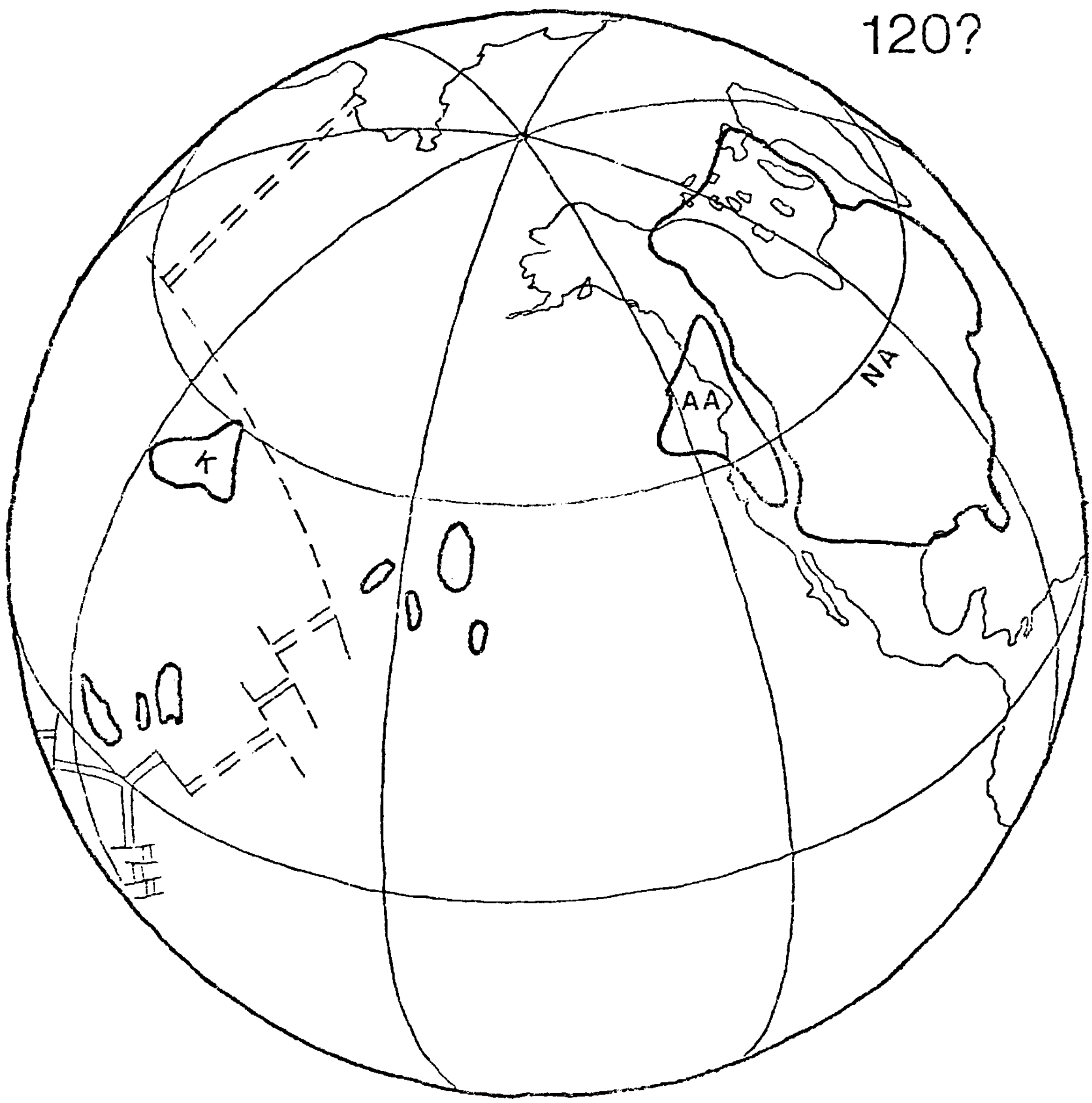

Fig.5
Possible location of the Arctic Alaskan Plate in the Early Cretaceous (circa. 120 MYBP). AA=Arctic Alaskan Plate, NA=North American Plate, K=Kolyma Plate.

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Reconnaissance engineering geology of the Beluga coal resource area, southcentral Alaska

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Abstract

Reconnaissance work in the Beluga coal resource area has revealed several environmental and engineering geologic factors that may affect future development and that deserve further consideration and study. Factors of concern include slope stability, earthquake hazards, volcanic hazards. erosion and flood potential. One complex landslide is east of the proposed Capps coal field mining area, covering about 16 km^2. Many smaller slides, mostly slumps, are in the vicinity and along bluffs of major streams. Another zone of landsliding is along the west coast of Cook Inlet; linear geomorphic features along the Nikolai escarpment, northeast of the Chakachatna River, suggest possible large-scale gravitational spreading.

Evidence of faulting, including escarpments prominent lineaments sag ponds and sheared rock, was observed where a possible fault has been postulated by others as an extension of the Lake Clark and Castle Mountain faults. Additional work is needed to determine the extent and recency of faulting in order to evaluate that aspect of earthquake hazards. The potential hazard presented by Mount Spurr and other volcanoes has not been studied in detail; however, work is in progress to establish a chronology of ash fall events. Coarse grained volcaniclastic deposits occur in at least three different parts of the area; these may yield other important information concerning the volcanic history and hazards to the area.

In July 1979, flooding occurred along the Beluga River as a result of the breakout of glacier dammed Strandline Lake. Flooding of this type is recurrent and threatens engineering structures such as bridges and other low lying facilities. In a proposed mine area of the Capps coal field, two core holes were drilled to a total depth of about 180 m to determine the geotechnical properties of coal bearing Tertiary rocks. Principal lithologic types sampled were: sandstone, siltstone, claystone, coal and diamicton (glacial till). Based on strength index tests these geologic materials can be categorized as ranging from soft soil to soft rock. Much of the material can be easily excavated because of its softness, but, for the same reason, such material also may be susceptible to slope failures and to rapid erosion by running water during the mining process.

Introduction

The Energy Lands Program of the U.S. Geological Survey is focused on investigations in regions of energy resource development and has the following objectives: (1) determining the extent and understanding the nature of environmental constraints to resource development, especially those constraints related to geologic hazards and the response of geologic materials to mining and related construction activities, (2) assessing environmental geologic effects of energy related developments, and (3) providing information for decision making regarding efficiency of methods for extraction and enforcement of regulations. Achieving these objectives involves collecting and synthesizing data on landforms, bedrock and surficial geologic materials, active geologic processes and geologic hazards.

The ongoing project discussed here is investigation of the Beluga area, known to contain large coal resources relatively accessible for exploitation (Patsch, 1975). The Beluga area project has two principal phases: (1) surficial geologic mapping and (2) geotechnical studies of bedrock and surficial geologic material that are involved in ongoing geologic processes, and that would be encountered during coal mining activity. The Beluga area is on the west side of Cook Inlet, about 90 km west of Anchorage (Fig. 1). It extends westward from the Susitna River in the vicinity of Mount Susitna, to the Chigmit Mountains and the base of Mount Spurr in the Tordrillo Mountains, and south to Cook Inlet.

It lies within two political subdivisions: the Kenai Peninsula Borough and the Matanuska-Susitna Borough. Major cultural features include: the electric generating power plant at Beluga; Tyonek Village; the Tyonek Timber, Inc., camp, chipmill and dock; and a limited road network not joined to the main Alaska road net.

Two major proposed coal mining areas shown in Figure 1 are the Capps field and the Chuitna field. Proposed transportation corridors extend from the coal fields to the coast in the vicinity of Granite Point and Congahbuna Lake, and possibly from there to the highway and railroad east of the Susitna River. The Congahbuna area has also been considered as the site of a proposed plant for converting coal to methanol.

The physiographic and geologic features of the Beluga area (Fig. 1; Schmoll and Yehle, 1978) can be classified into three principal units: (1) high mountains and foothills consisting mainly of Mesozoic and lower Tertiary metamorphic and igneous rocks, (2) an adjacent plateau underlain primarily by Tertiary coal bearing sedimentary rocks with a variable, relatively thin cover of Quaternary glacial deposits, and locally a thicker cover of possibly Tertiary glacial deposits, and (3) lowlands underlain by relatively thick Quaternary deposits, chiefly of estuarine and alluvial origin, that are separated from the plateau by major escarpments.

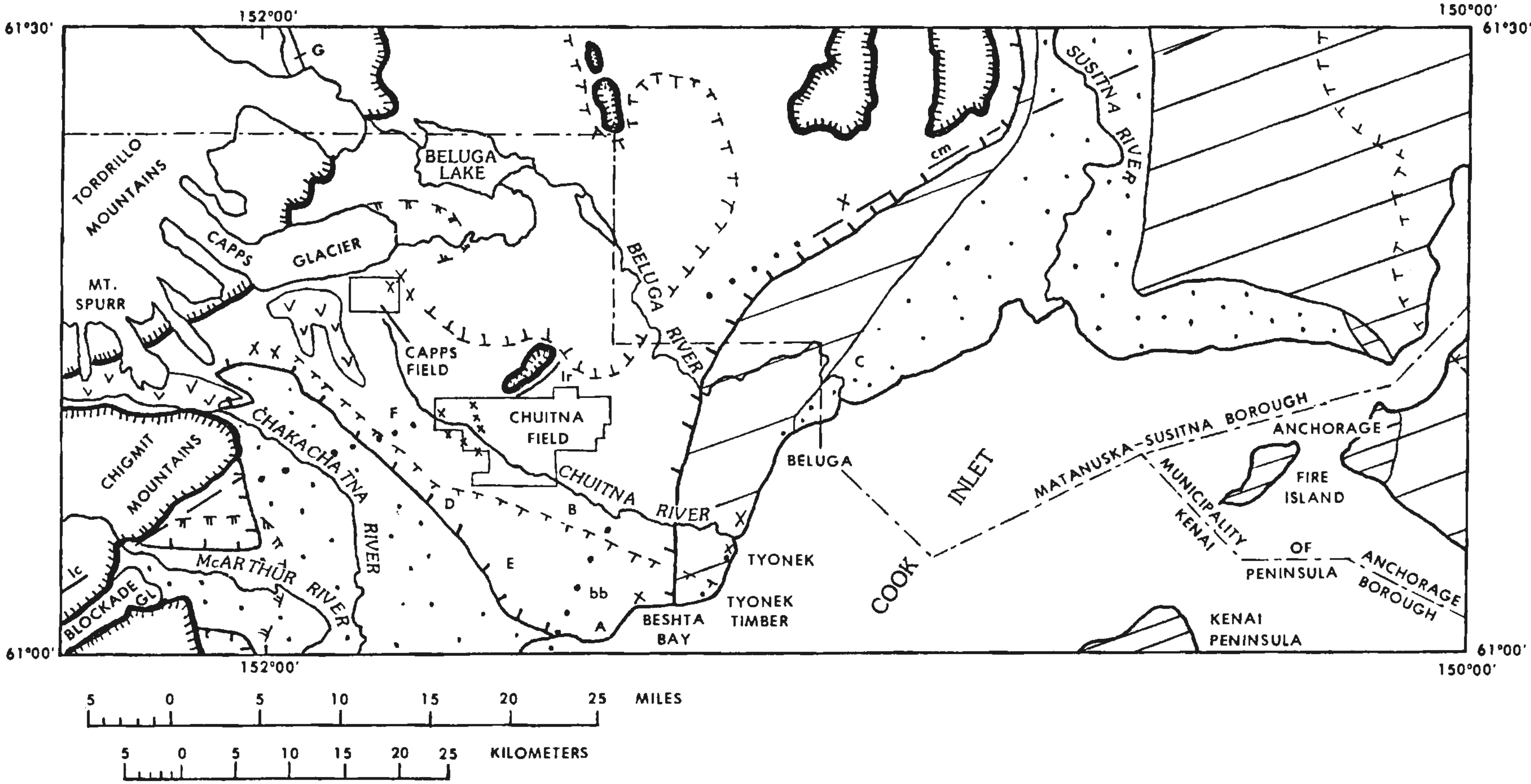

Figure 1: Beluga coal resource area, generalized physiography and geology.

The escarpments bounding the plateau are both structural and erosional in nature, and are referred to informally as the Nikolai escarpment on the southwest side and the Susitna escarpment on the southeast side. The bedrock geology has not been studied in detail, but the Tertiary sedimentary rocks are discussed briefly because of their importance both as the resource rocks and as major determinants of environmental geologic effects.

Tertiary Sedimentary Rocks

The Tertiary sedimentary rocks of upper Cook Inlet basin are entirely continental in origin and comprise forearc basin deposits of both early and late Cenozoic tectonic cycles (Fisher and Magoon, 1978). Surface exposures in the Beluga area were described in some detail by Barnes (1966), whose work emphasized coal deposits. The Tertiary rocks throughout the basin had been called the Kenai Formation; primarily on the basis of subsurface data compiled during exploration for oil and gas, the Kenai was raised to group rank, its divisions assigned to five formations, and their type sections were defined by Calderwood and Fackler (1972). From oldest to youngest these formations are the West Foreland, Hemlock, Tyonek, Beluga and Sterling, all in the Kenai Group.

The West Foreland Formation was subsequently removed from the Kenai Group (Boss and others, 1976; Magoon, Adkison and others, 1976) in recognition of the widespread unconformity between it and the overlying formations; it was generally regarded as early Eocene in age (Franklinian biostratigraphic (floral) Stage of Wolfe, 1968). It is thought to be latest Paleocene (Wolfe and Tanai, 1980) and is the sole representative in these rocks of the earlier Cenozoic tectonic cycle. In this area it consists chiefly of sandstone and conglomerate that have markedly volcaniclastic components, and it is barren of coal deposits. As much as 630 m has been measured in sections exposed northwest of the Capps field area along Capps Glacier (Adkison and others, 1975; modified by Magoon, Adkison and others, 1976), although only about 270 m is identified in the type section in a drill hole about 60 km to the south. Within the Beluga area, it crops out mainly northwest of the Lake Clark and Castle Mountain faults (Fig. 1).

The Hemlock Conglomerate, apparently principally sandstone, is the lowest formation in the Kenai Group, although Boss and others (1976) proposed that it be considered a member of the Tyonek Formation, and Magoon, Adkison and Egbert (1976) in their regional map compilation, did not map it separately from the Tyonek. The Hemlock is the basal unit of the late Cenozoic tectonic cycle and is generally regarded as early Oligocene in age, assigned to the Angoonian Stage (Wolfe, 1977; Wolfe and Tanai, 1980); it is the chief reservoir bed for oil in most of the Cook Inlet fields. It is present in the subsurface in the Beluga area (Calderwood and Fackler, 1972), and has been mapped northwest of the Castle Mountain fault by Detterman and others (1976). However, Magoon, Adkison and Egbert (1976) have suggested that the Hemlock Formation might be restricted to the southeast side of the Bruin Bay fault.

The Tyonek Formation underlies the area of Capps coal field, as well as most of the Beluga area southeast of the Lake Clark-Castle Mountain fault system. It is late Oligocene to middle Miocene in age; outcrops both near Capps Glacier and also along the Chuitna River serve as the type section for the Seldovian Stage (Wolfe and others, 1966; Wolfe, 1977). The Tyonek Formation is generally finer grained than the West Foreland Formation, and includes sandstone, siltstone and claystone; it also contains numerous coal beds, some more than 10 m thick. At the type section of the formation in a well south of Tyonek, 2331 m are assigned to the Tyonek Formation and include at least 15 substantially thick coal bed sequences. Stratigraphic thickness of the exposed beds is not well-known, and only a small part of the type section is presently exposed, including two principal coal beds in each outcrop area.

In the Capps field area the upper bed is the Capps coal bed (named by Barnes, 1966, who thought from surface exposures that there was but one principal bed) and the lower one is the Waterfall coal bed, the separate identity of which was established by Patsch (1975) through intensive subsurface exploration. In places, what was originally mapped (Barnes, 1966) as the Capps bed is now regarded as the Waterfall bed, whereas at other places the original mapping designation is retained.

The Tyonek Formation, as exposed throughout this area. seems to represent only the upper part of the formation; this is supported by a recently published radiometric age of about 15.8 million years, derived from a volcanic ash from one of the coal beds along the Chuitna River (Turner and others, 1980, p. 95; see also Triplehorn and others, 1977).

Rocks asigned to the Beluga Formation (late Miocene age; Homerian Stage and lower part of Clamgulchian Stage) crop out along the lower Beluga and Chuitna Rivers and along Beshta Bay east of Granite Point, and include sandstone, siltstone, claystone and coal (Magoon, Adkison and Egbert, 1976; Barnes, 1966; Wolfe and Tanai, 1980). Total stratigraphic thickness of the formation is poorly known from outcrops; about 1.234 m of it is present at the type section in a well near Beluga.

The Sterling Formation (late Miocene and Pliocene age; Clamgulchian Stage) is not known to crop out in the area, but it is reported in the subsurface overlying the Beluga Formation, for example in the Beluga well, where the uppermost 1,100 m include both Sterling Formation and overlying Quaternary deposits.

In the vicinity of Granite Point[1] (Fig. 1. loc. A) there are good exposures of bedded diamicton along the bluffs; these deposits may be of glaciomarine origin, at least in part. They were thought to be Pleistocene in age and presently are so mapped (Barnes, 1966; Magoon. Adkison and Egbert, 1976; Schmoll and Yehle, 1978). However, apparently interbedded in the diamicton is at least one anomalous coal layer, and lower in the section are interbeds of sandstone that are similar in appearance to those of known Tertiary age.

The association of glacial and nonglacial deposits is difficult to explain regardless of the age; the coal may have been deposited in place or transported as a whole from another area, perhaps by glaciotectonic means. Search for microfossils within the deposits is now underway, and these, if found, should aid in determination of a more definitive age, and possibly establish correlation with diamictite assigned to the Beluga and Sterling Formations in drill holes on the Kenai Peninsula (Boss and others, 1976).

Deposits that have been recorded as overlying the coal bearing rocks in the Chuitna coal field (B.J.G. Patsch, written communication, 1979) are also inferred to be similar in lithology, and possibly in age, to those exposed at Granite Point. We are studying the deposits at Granite Point in some detail because they have not been described before, and because they are the only surface exposures of deposits that may be considerably more extensive in the subsurface than was believed initially. They are in an area that has potential as a port site, and as the site of industrial development. It is important to understand how these deposits are likely to respond to construction activity.

Capps Field Area

Some of our work, thus far. has been concentrated in the area of proposed mining in the Capps coal field, because it was thought that this area might be the first to be developed (Placer Amex, Inc., written communication, status report, Dec. 1977); apparently this is no longer true. The surficial geology of that area was mapped at a scale of 1:31,680, and a generalized version of a part of this map is shown in Figure 2.

To date we have had two holes drilled within the Capps field area (Fig. 2). The objective of the drilling was to obtain core samples, to determine basic geotechnical properties of the material needed to evaluate geologic hazards, and to help predict the response of geologic materials to large-scale coal mining and related development in the Capps coal field. Specifically, such things as natural and cut slope stability, spoil pile stability,

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[1]Apparently named because of the large granitic boulders along the beach; there is no granitic bedrock in this vicinity.

ground response to seismic activity, blasting effects, excavatability, building characteristics and erosion potential need to be determined.

Figure 2, Explanation:

Mapping based on interpretation of 1:40,000 scale 1952 air photos. Deposits presumed to be 2 m or more in thickness and covered by as much as 1 m of organic silt and fine sand, locally containing a high percentage of volcanic ash.

<u>Quaternary Deposits</u>

a	Alluvial stream deposits--Chiefly pebble gravel and sand with some organic silt
af	Alluvial fan deposits--Mostly pebble and cobble gravel with some sand and organic silt
c	Colluvial deposits--Mixed earth materials of bedrock and surficial origin, including organic deposits and volcanic ash moved by gravity down moderate to gentle slopes
l	Landslide and possible landslide deposits--Areas of ground having moderately to very irregular surfaces
m	Ground moraine and kame deposits--Chiefly pebbly sandy silt with cobbles and boulders; bedrock common locally
me	Lateral moraine deposits of the Carlson Lake moraine complex--Pebbly to cobbly sandy silt
oc	Possible outwash channel deposits--Pebble gravel in glacier related meltwater channels
p	Pond and thick organic deposits--Chiefly organic silt, organic fine sand and peat; includes some solifluction deposits

<u>Tertiary Bedrock</u>

b	Tyonek Formation of Miocene to Oligocene age; mainly sandstone, siltstone, claystone and coal; thin cover of Quaternary colluvial deposits included in places
bc	Includes Capps coal bed
cw	Includes Waterfall coal bed
	Contour

Figure 2, Explanation. (Continued)

Geologic contact

Principal stream

Trench

Section corner with designations

Pond, small lake

Test hole: 1, U.S. Geological Survey core hole, 1979:
2, U.S. Geological Survey core hole, 1980

The 1979 hole was located so that the two major coal beds, the Capps and the Waterfall, and the over and interburden would be recovered, as well as material equivalent to that involved in landsliding. Penetration of 121 m was achieved, reaching to the upper part of the Waterfall bed, but relatively little of the interburden was recovered. In 1980, a second hole was drilled to a depth of 61 m at a site about 1 km southwest of the 1979 hole; all of the Waterfall bed, some of the Waterfall overburden, and about 27 m of underlying material was cored, with generally better recovery.

Both geotechnical and geophysical logs from the 1979 hole have been described in detail (Chleborad and others, 1980).

Laboratory testing of core material is currently in progress, but the preliminary field tests indicate that the test hole material can be categorized as ranging from soft soil to soft rock, as compared with typical strength values (Fig. 3). The sandstone of the interburden and also below the Waterfall bed was so friable that recovery was extremely poor. This friability suggests that the interburden could be excavated easily, but also that it may be susceptible to rapid erosion.

Environmental Geology

Landslides

A study of the geomorphology of the area revealed a substantial number of landslides, including some of large size. They are found in two principal geomorphic environments: (1) along river and coastal bluffs and (2) along the glacially eroded major escarpments. Landslides are more common in rocks of the coal bearing Tyonek Beluga Formations, and less so in the dominantly

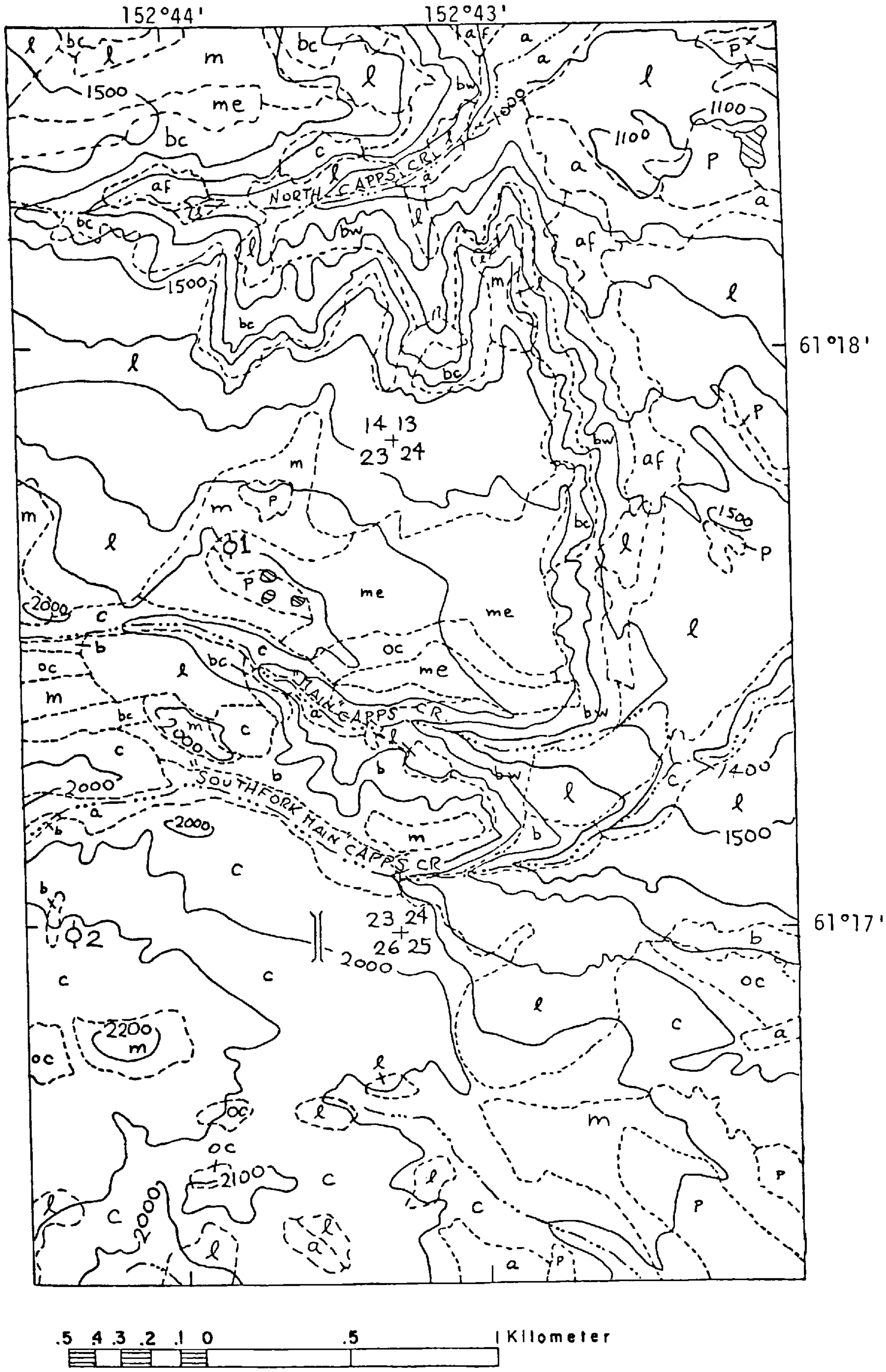

Figure 2: Mapping based on interpretation of 1:40,000 scale 1952 airphotos. Deposits presumed to be 2 m or more in thickness and covered by as much as 1 m of organic silt and fine sand, locally containing a high percentage of volcanic ash.

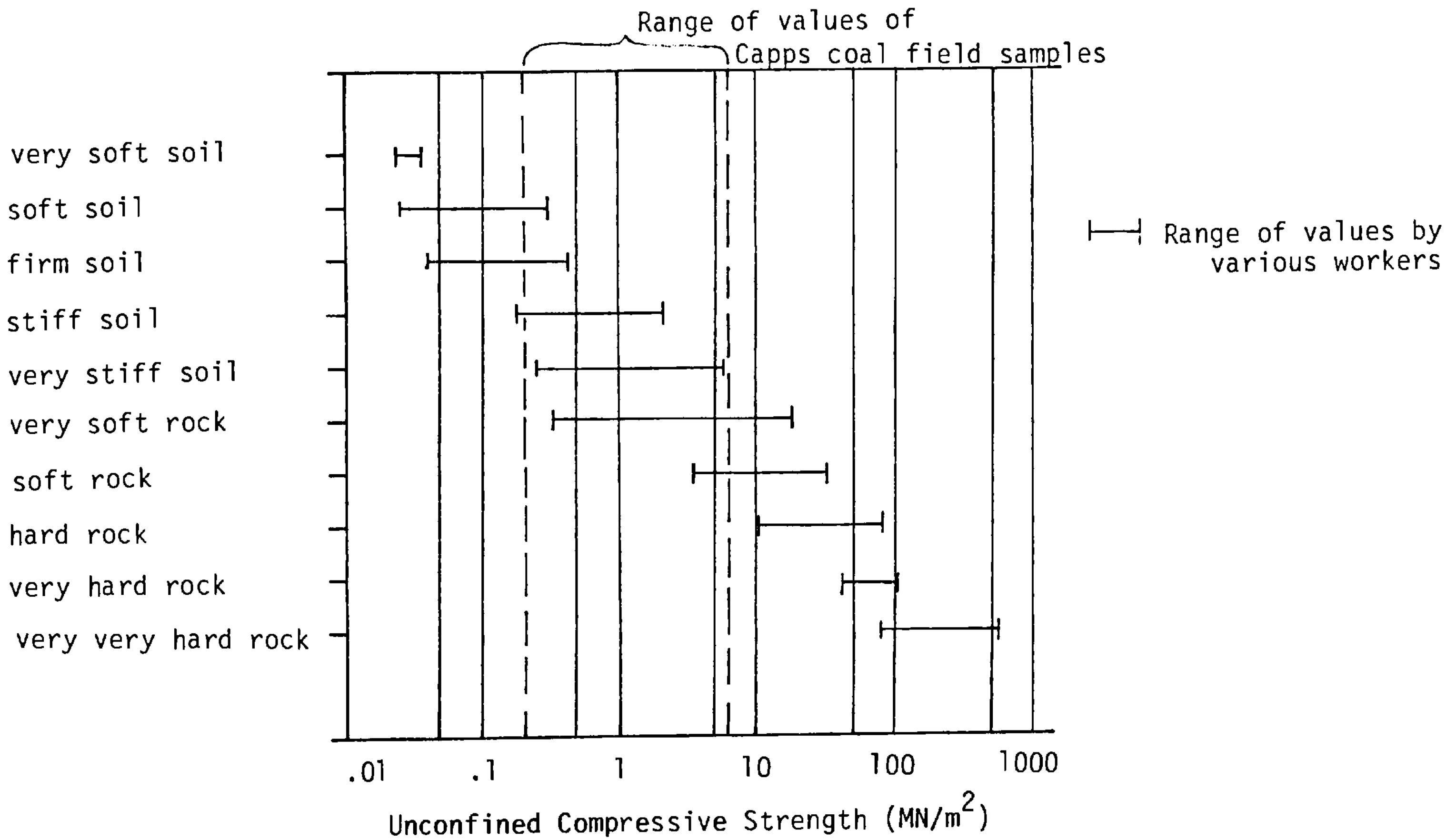

Figure 3: Relationship between hardness and unconfined compressive strength in meganewtons per square meter. (Chleborad and others, 1980, modified from Jennings and Robertson, 1969).

coarser grained West Foreland Formation; some are related to the Bootlegger Cove Clay.

The largest of the landslides, about 16 km^2 in extent, is just east of the proposed mining area in the Capps coal field. It is a complex landslide and has surface indications of various types of movement. Parts of this slide may have moved as many as 7,000-10,000 years ago, whereas other parts near the head are presently active. There are several smaller landslides, also within and adjacent to the Capps field, some of which show signs of active retrogressive enlargement. These slides appear to involve the fine grained facies of the Tyonek Formation in association with coal beds or carbonaceous zones. The susceptibility of such materials to landsliding indicates the need for detailed study. and for awareness of possible slope stability problems in the coal mining areas.

River bluffs are affected by many small landslides, most of which seem quite old; however, one (Fig. 1, loc. B) occurred in late 1978 or early 1979 along the Chuitna River and partially blocked the river. Slides of this type are numerous within the area of the Chuitna coal field. Such slides have occasionally caused siltation of the Chuitna River, which is the principal clear fishing and salmon spawning stream in the area. This natural siltation is minor, however, compared to that which could result from coal mining. To minimize such effects, development plans for the Capps field suggest that all drainage from the coal mining area be diverted to the glacier fed Beluga River, which is naturally silt laden during part of the year. Preserving the quality of the Chuitna River may prove more difficult if the Chuitna field is developed, unless a similar diversion system or other protective measures are planned.

Mass wasting also is noted along coastal bluffs, especially north and south of the mouth of the Chuitna River, where silt and clay is exposed near sea level. Where similar material is exposed along the Beluga River (Fig. 1, loc. C), it contains marine mollusk shells that have been dated by ^{14}C analysis as about 14,000 years old, about the same age as shells from the Bootlegger Cove Clay in the Anchorage area (Schmoll and others, 1972), providing a rather confident stratigraphic correlation. The Bootlegger Cove Clay then apparently extends across upper Cook Inlet to the Beluga area and underlies a portion of the lowland. The Bootlegger Cove Clay is well known to have been a "bad actor" during the 1964 Alaska earthquake, and is responsible for other but less dramatic stability problems as well. Some of the coastal slides in the Beluga area are known to have been reactivatd during the 1964 earthquake (Foster and Karlstrom, 1967), but are less extensively developed than at Anchorage.

Another zone of sliding along the coast in the Beshta Bay area (Fig. 1) is underlain mainly by claystone and coal bearing rocks of the Beluga Formation. Some of these slides appear to have moved recently and may still be moving, as indicatd by tilted trees.

Along the Nikolai escarpment (Fig. 1) are several straight, smooth ridges a few kilometers long, a few hundred meters wide and parallel to the slope, that are separated from each other by narrower, grabenlike depressions. Although first thought to be lateral moraines, the anomalous appearance and position of these ridges have led to the consideration that they might be the result of large-scale gravitational spreading, perhaps in a manner analogous to that inferred for sacking features (Zischinsky, 1966; Radbruch-Hall and others, 1976). These features should be investigated in more detail should development on them be anticipated.

Faults

The Beluga area is crossed by regionally extensive faults that have been projected beneath surficial deposits or water, to intersect near the Beluga River (Detterman and others, 1976; Magoon, Adkison and Egbert, 1976). These faults are the Castle Mountain fault, which is mapped in the northeast part of the area; the Lake Clark fault in the southwest; and the Bruin Bay fault south-southwest of the area[1]. The topographically most prominent fault within the area is along the southeast side of Lone Ridge, and is here called the Lone Ridge fault. Granitic rocks are on the northwestern side and, presumably, Tertiary sedimentary rocks are on the southeastern side of the Lone Ridge fault. Sheared rocks, sag ponds and springs are present along the escarpment that marks the line of this fault. To the northeast and southwest, no similar evidence of surface faulting is seen; however, numerous lineaments visible on aerial photographs roughly parallel the projected fault traces. On the basis of such lineaments, the Lone Ridge fault may be a segment of the Lake Clark fault, whereas the Castle Mountain fault may be more readily traceable to the Bruin Bay fault, perhaps along the line of the southern part of the Susitna escarpment. The scant evidence presented by the mapping of lineaments suggests that the faults may lie en echelon through the area, as suggested by Hackett (1977) on the basis of geophysical interpretations.

No direct evidence for faulting has been found along the Nikolai escarpment, which trends across the generally northeast-southwest structural grain of the region. Although glacial erosion may be responsible for the present position of the escarpment, the linearity of the feature suggests that the escarpment may be fault controlled in part.

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[1]On some compilations, most recently Beikman (1980), the term Castle Mountain fault is used to include the Lake Clark fault as well.

The Castle Mountain fault east of the Susitna River has been active in Holocene time (Detterman and others, 1974; Bruhn, 1979), but we have not been able to establish evidence of equally young activity on faults west of the river. Should construction development take place, however, some of the lineaments should be examined for recent fault activity.

The entire area lies within seismic zone 3 (International Conference of Building Officials, 1976) and ground shaking from major earthquakes can be expected to produce Modified Mercalli Intensities of VIII or more, and to cause major damage to structures. Probable seismic acceleration for various periods have been described by Thenhaus and others (1979).

Volcanic Activity

There is evidence of volcanic activity in the Beluga area, at least intermittently, from before the time of deposition of the coal beds to the present. Fine grained tephra (volcanic ash) beds have been recognized within the coal deposits (Triplehorn and others, 1977; Turner and others, 1980); the most recent deposition was in 1953.

Coarse grained volcaniclastic deposits are found in several different parts of the area, and are of different ages in each. These deposits originated as air falls, volcaniclastic debris flows, and (or) volcanic mud flows from present day Mount Spurr or from an ancestral volcano. None of the flows can be demonstrated to have reached the sites of proposed coal mining. However, a few kilometers west of Capps coal field, a relatively thick sequence of upper Tertiary or lower Quaternary volcaniclastic deposits overlie the coal bearing rocks. Exploitation of any coal beds that may lie beneath the volcaniclastic deposits probably would require underground mining, because of the thickness and nature of the overburden.

A thin bed of volcaniclastic material in the diamicton of Granite Point (Fig. 1, loc. A) suggests that at least some volcaniclastic debris of probable late Tertiary age might have extended considerably farther south and east than presently mapped.

Near the southern edge of the plateau (Fig. 1, loc. E) there are accumulations of volcaniclastic debris at the surface within the bounds of the Nikolai moraine. It is unclear whether these deposits were moved by the glacier as part of the moraine, or whether they were emplaced directly as volcaniclastic debris flows. Such flows may have spread over the glacier.

Volcaniclastic debris from Mount Spurr partly fills the upper Chakachatna valley and is probably of Holocene age, at least in part.

Thus, volcaniclastic debris flows have spread into the area at various times in the past, and there is a potential for repeated activity of this sort. Such flows, however, would probably be restricted to the major valleys and would not cover the plateau areas.

Evidence of recent volcanic activity is restricted to tephra that has been noted in most of the windblown deposits of the area. and within peat deposits. Most tephra probably originated from Mount Spurr, although some of the ash beds may be from other more distant volcanoes to the southwest. At least one tephra sequence probably came from Hayes Volcano, a small vent about 35 km northwest of Mount Spurr (U.S. Geological Survey. 1976)[1].

We have studied the tephra beds in the area in a reconnaissance fashion, and have dated several beds in an effort to establish a tephrochronology to give a preliminary estimate of the frequency of air fall volcanic activity. Thus far, ^{14}C dates of about 3,000 and 6,000 years before present have been obtained from tephra beds at several sites, suggesting that at about these dates there was fairly widespread air fall activity. The accumulation of at least 12 tephra beds within the last 12.000 years indicates considerable additional activity, which we have not yet dated as closely.

The most recent tephra was deposited in 1953 during the eruption of Crater Peak on the south side of Mount Spurr. One to 3 cm of this material can be seen at the level of the grass roots in many places. Crater Peak is releasing steam and sulfurous smelling vapors at present, and certainly has the potential for future eruptions.

Ground Surface Conditions

Ground conditions in the Beluga area range from firm (bedrock and well drained gravel hills) to very soft (peat and muskeg).

The area is covered in part by several morainal systems that provide hummocky but relatively firm and well drained ground that has only local ponds and poorly drained areas. The two most prominent moraines (Fig. 1) are here informally named the Carlson Lake moraine. a large loop primarily in the Beluga River drainage, formed by glaciers; and the Nikolai moraine,[2] a lateral moraine that generally parallels the Nikolai escarpment and that formed along the northeast side of coalescing glaciers in the Chakachatna River and McArther River drainages. Both moraines may be about

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[1]The distance from Mount Spurr given in this reference is incorrect.

[2]The term "Nikolai Creek glaciation" applied to a moraine of similar age on the Kenai Peninsula by Krinsley (1953), but not used subsequently (Karlstrom. 1964, p. 13), is here abandoned.

the same age as the Elmendorf Moraine at Anchorage, which is dated at late Pleistocene (Schmoll and others, 1972).

Morainal deposits which lie outside the Carlson Lake and the Nikolai moraines may be middle to early Wisconsin or older. Inside the two prominent moraines, and closer to existing glaciers, there is a complex of moraines which thus far have yielded early Holocene ages. Younger moraines may be restricted to the immediate vicinity of existing glaciers.

Beyond the Carlson Lake and Nikolai moraines are larger areas of poorly drained ground. A potential transportation corridor from the Capps field to the coast is likely to cross one such area. Tracked vehicles already have had difficulty crossing soft, bog-surfaced ground in this corridor (Fig. 1, loc. F). Development of surface routes across such areas will require extensive use of suitable fill material. The best sources of sand and gravel are in the southeastern part of the Nikolai moraine, 25 km or so distant from the corridor. However, lower grade sources of fill material could probably be developed from closer sources such as the volcaniclastic deposits, glacial deposits in the Nikolai moraine, or older diamicton within the Chuitna field or near Granite Point.

The proposed principal transportation corridor extending northeastward to the existing highway and railroad would have to cross the extensive silt clay deposits that have been correlated with the Bootlegger Cove Clay, and that will undoubtedly rate as poor foundation material with some risk of ground instability; proper route selection, however, could minimize this problem.

Flooding

The Beluga River is occasionally subject to flooding because of the breakout of glacier dammed lakes, the largest of which is Strandline Lake, which has an area of about 8.6 km^2 (Fig. 1, loc. 6). Such breakouts are known to have occurred in 1958, 1974 and in July 1979. The 1979 flood washed out approaches to the only bridge over the Beluga River connecting two segments of the local road network (Fig. 1, loc. C). The effects of flooding along the major portion of the Beluga River are somewhat mitigated by the presence of Beluga Lake and lower Beluga Lake, which serve as holding basins for the main surge of a flood; but the shores of the lakes then are subject also to sudden rises of water levels. Recurrent floods of this type should be considered in long-range planning.

Summary

Slope failures have occurred and are continuing in several parts of the Beluga area. The potential for slope failure appears to be high in places that may undergo coal mining and related development; many of the existing natural slope failures involve coal bearing strata and associated clay rich beds. The likelihood of significant earthquake or volcanic activity probably is not high during the relatively short time span of mining operations. but should a major earthquake or eruption occur during that time, it could affect much of the area and should be assessed. The soft ground conditions in large areas make careful route and site planning necessary; sources of good quality fill material are abundant locally, but are not readily available close to where they probably will be most needed. Although other major streams may have some potential for flooding, especially following landslide or ice jam blockage, the Beluga River is the most susceptible because of the presence of glacier dammed lakes within its watershed.

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Geology-coal resources and mining plan for the Chuitna River field, Alaska

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C.C. Hawley and Associates, Inc., Anchorage

The Chuitna River Coal Field lies approximately 50 miles west of Anchorage in the upper Chuitna River area. This Tertiary subbituminous deposit is situated in the southern part of an area generally referred to by the U.S. Geological Survey as the Beluga-Yentna Region". The majority of the lease is situated between Lone ridge to the northwest, Lone Creek to the east and the Chuitna River to the south (Figures 1, 2, and 3).

Significant geological ground work for the area was laid by Barnes in his 1966 report covering the regional coal outcrops. The present lease holders, The Bass-Hunt-Wilson Venture, began their involvement with the property in 1967 by obtaining prospecting permits from the state. Exploration drilling programs started in 1968 and were carried on annually in an effort to outline the vast local coal reserves. The property was elevated to State Coal lease status in 1972 and became known as the B-H-W leases and the Chuitna River Coal Field.

In August of 1980, close spaced grid drilling was undertaken to study a possible open pit production area outlined by Bechtel, Inc., a consulting engineering firm. A comprehensive program of 70 rotary drill holes and 29 core holes was designed to generate geologic, engineering and hydrologic data for reserve computation, interburden and overburden determination and preliminary pit design. The proposed pit area, one of a number of possible mining options being considered by BHW, would generate an annual production of 9.3 million short tons with a cumulative stripping ratio of 4.4 over the life of the mine. Total mineable reserves are relatively large, considering the proposed area occupies only 20 percent of the BHW leases.

Topography

Regional topography is that of a broad piedmont lowland of generally low relief (Barnes, p. 5). The lease area itself is part of a glaciated plateau cut by post glacial stream erosion and covered by till and outwash material. Elevations vary from 350' on the Chuitna River to 1400 feet at the base of Lone Ridge. Lowland areas are covered with muskeg and numerous small lakes, and spruce and birch trees occupy the higher elevations. Local drainage is generally south to the Chuitna River Canyon, which is the most dramatic topographic feature.

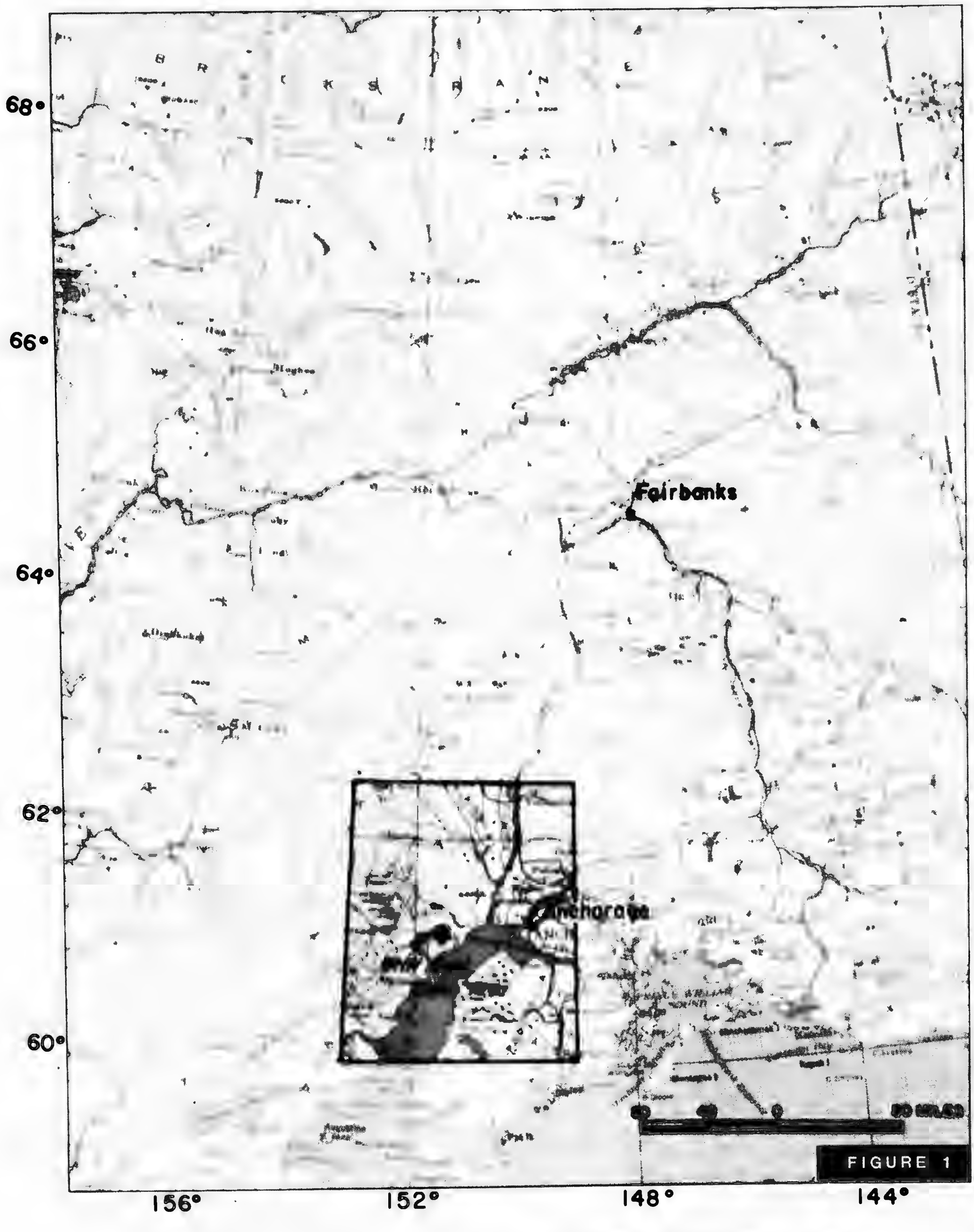


PLATE I: General Location of the Chuitna River Coal Field

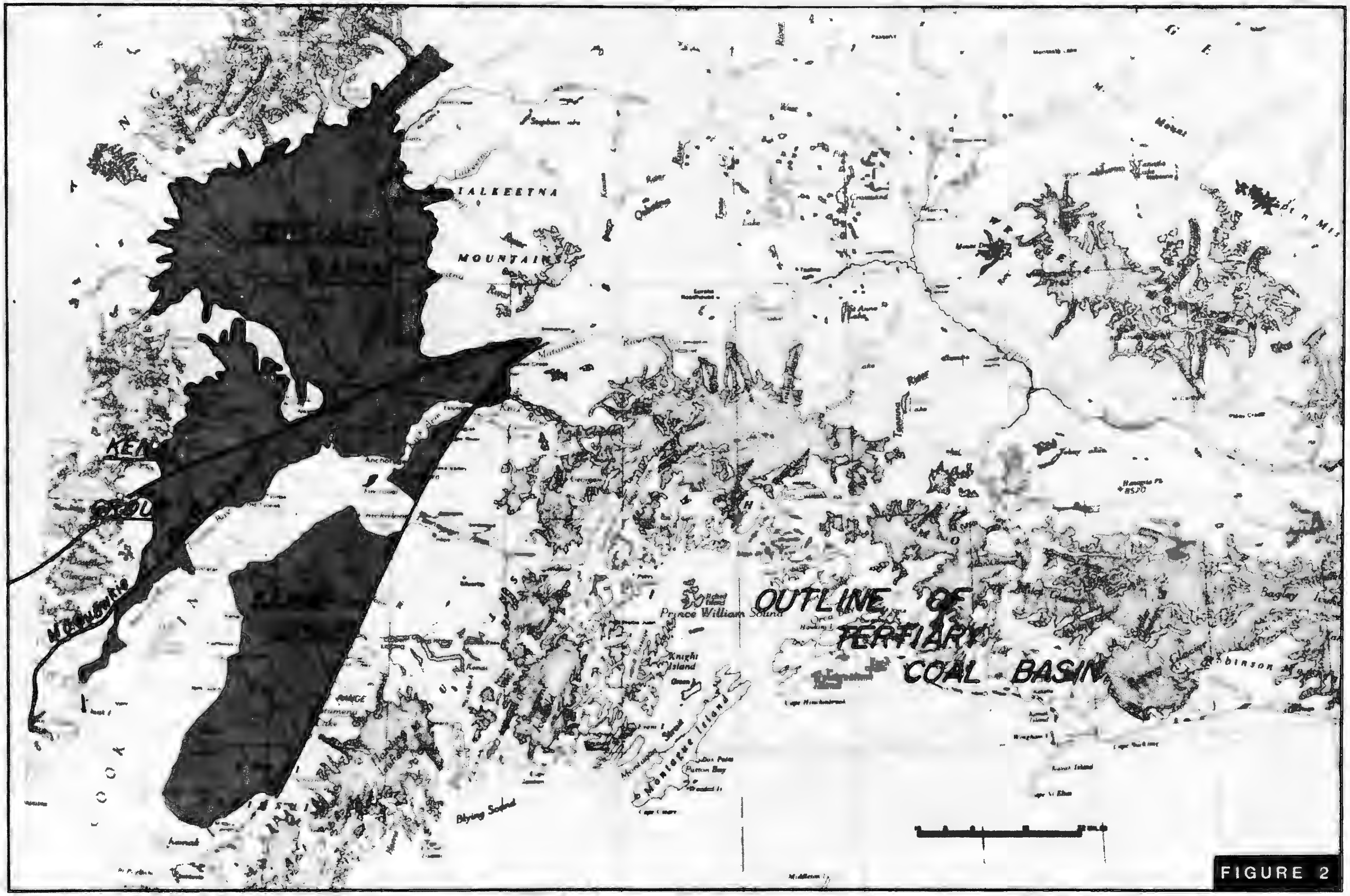
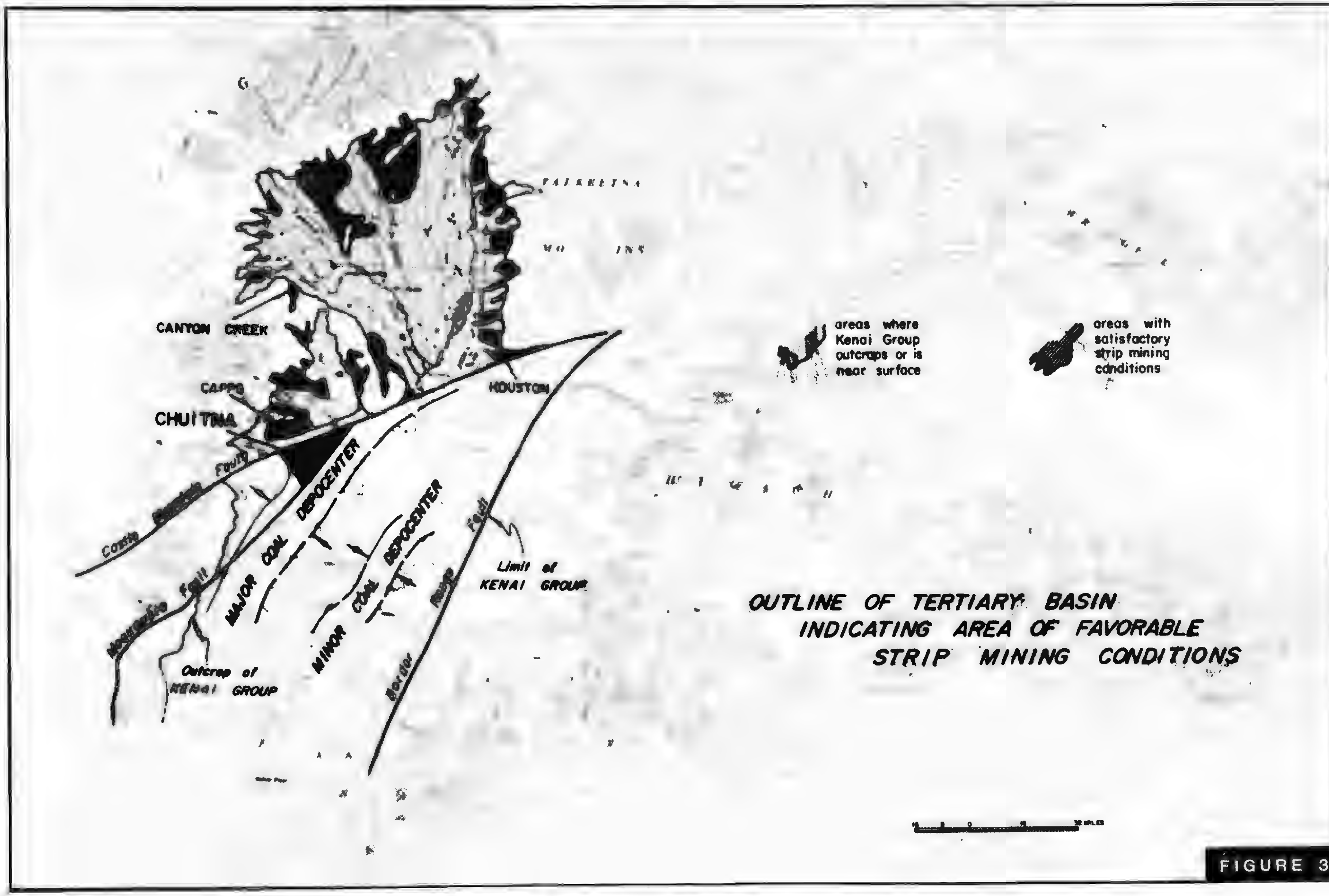

TALKEETNA
MOUNTAINS
Matanuska
Prince William Sound
OUTLINE OF TERTIARY COAL BASIN
Knight Island
Montague Island
Blying Sound

FIGURE 2



OUTLINE OF TERTIARY BASIN INDICATING AREA OF FAVORABLE STRIP MINING CONDITIONS

FIGURE 3

Geology and Stratigraphy

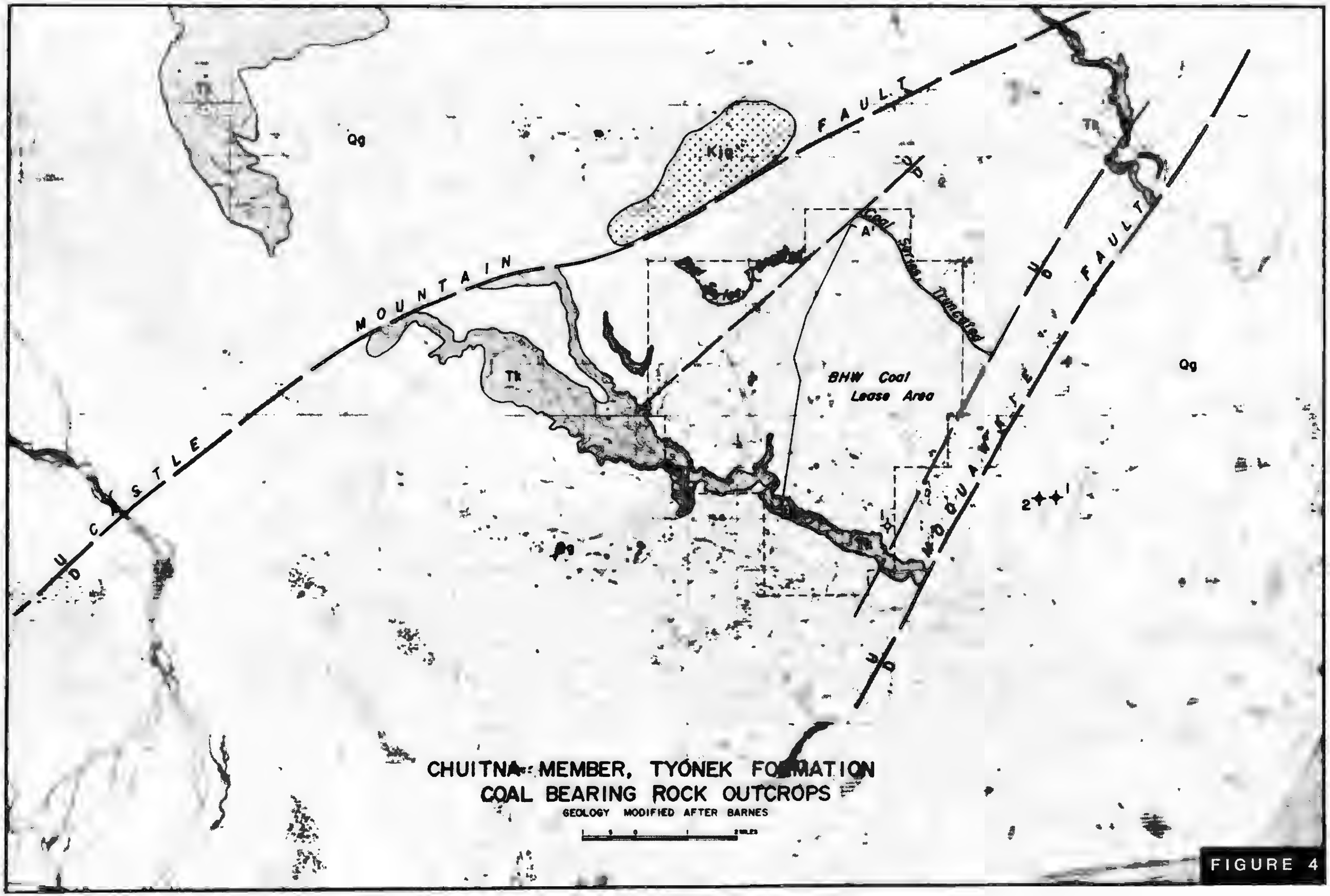
Economic geology in the Cook Inlet Basin is dominated by terrestrial sediments of Tertiary age. As early as 1898 geologists such as Eldridge and Spurr recognized coal deposits in Tertiary outcrops. Subsequently, various authors such as Barnes have made more detailed studies of the exposed coal.

Oil and gas discoveries on the Kenai Peninsula in the 50s prompted continued seismic work and exploration drilling programs, which led to the oil and gas discoveries in the Tertiary basin beneath Cook Inlet. This extensive data base has provided petroleum and coal geologists a means to understand the stratigraphic relationships of the Tertiary Formations in the basin and along its margins. In 1972 Calderwood and Fackler proposed elevating the "Kenai Formation" to the Kenai group, subdividing it into five formations: (in upward order) the West Foreland Formation, Hemlock Conglomerate, Tyonek Formation, Beluga Formation and Sterling Formation.

The coal measures of the Chuitna River Field represent a major section of the Chuitna member of the Tyonek Formation (Adkison, et al., p. 12). Outcrops of these sediments along the upper Chuitna River Canyon (Figure 4) were used by Wolf, Hopkins and Leopold in their paleobotanical studies as the type section for their Seldovian time stratigraphic unit. They place the depositional age of the outcrops at early Miocene (Wolf, et al., p. A14).

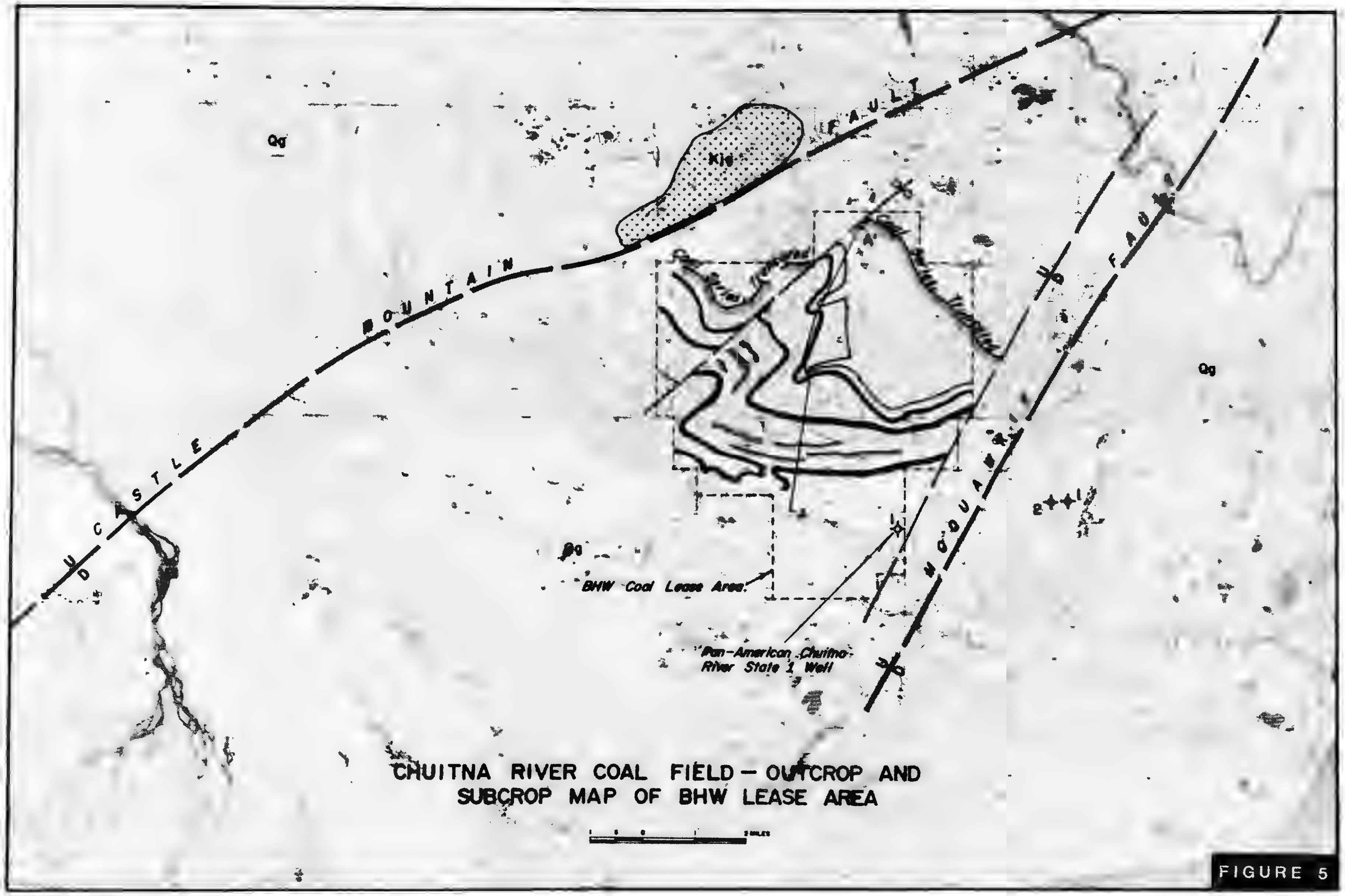
In general the Tyonek Formation consists of a basal conglomeratic unit, the Middle Ground Shoals Member and the upper, finer grained, coal bearing Chuitna Member. The Middle Ground Shoals unit consists of interbedded sandstone, pebble to cobble conglomerate and minor siltstone (Adkison, et al., p. 8) and corresponds to the upper part of the lower "Kenai Formation" described by Barnes. The Chuitna River State 1 well drilled by Pan American Petroleum (Figure 5) penetrated the majority of the Tyonek Formation, and the well logs indicate that the Middle Ground Shoals member is represented by the interval from 1844 to 6210 feet. It appears to be resting unconformably on the Chickaloon Formation, due to the fact that the Hemlock Conglomerate and West Foreland Formation are not represented in this sequence (Adkison, et al., p. 12).

The Chuitna Member of the Tyonek consists of poorly indurated, interbedded, sandstone, siltstone, claystone, minor conglomerate and numerous thick coal beds (Adkison, et al., p. 8). It is probably the upper strata of this sequence which outcrops in the Chuitna river canyon and was called the Middle Member of the "Kenai Formation" by Barnes in 1966. Adkison, Kelley and Newman worked on the same outcrops and their 1975 report contains precise lithologic descriptins of the strata. Their statement concerning the probability of their measured sections 16 and 17 lying in the upper part of the Tyonek and corresponding to the upper 600 feet



CHUITNA MEMBER, TYONEK FORMATION
COAL BEARING ROCK OUTCROPS
GEOLOGY MODIFIED AFTER BARNES

FIGURE 4



CHUITNA RIVER COAL FIELD — OUTCROP AND SUBCROP MAP OF BHW LEASE AREA

FIGURE 5

of strata in the Pan American well, agrees with stratigraphic correlations between BHW drill holes, the Pan American well and the Adkison, Kelley and Newman measured sections. The lithologic sequence and character of the coal beds indicated by footages 50 to 1500 feet on the Pan American well log correspond closely to the stratigraphy of the Chuitna River Field. It is probable that the upper 1844 feet of the Pan American well logs represents the Chuitna member of the Tyonek Formation.

The stratigraphically highest coal bed in the Pan American well corresponds to the Chuitna Bed referred to by Barnes. This bed outcrops for seven miles in the Chuitna river canyon and is called the Brown Coal in the Chuitna River Field. This bed and five lower coal units comprise the bulk of the reserves of the BHW leases. The entire sequence from highest to lowest is referred to as the Brown, the Yellow, the Green, the Blue, the Orange and the Red Coal Beds.

Assay data indicates that this is extremely clean, low sulfur, low ash coal of subbituminous C rank (Table 1). The three lower beds, the Blue, Orange and Red are within 300 feet of the surface in the northern lease area and are particularly clean, averaging .176 percent sulfur and 7.63 percent ash with Btu ranges from 7800 to 8200.

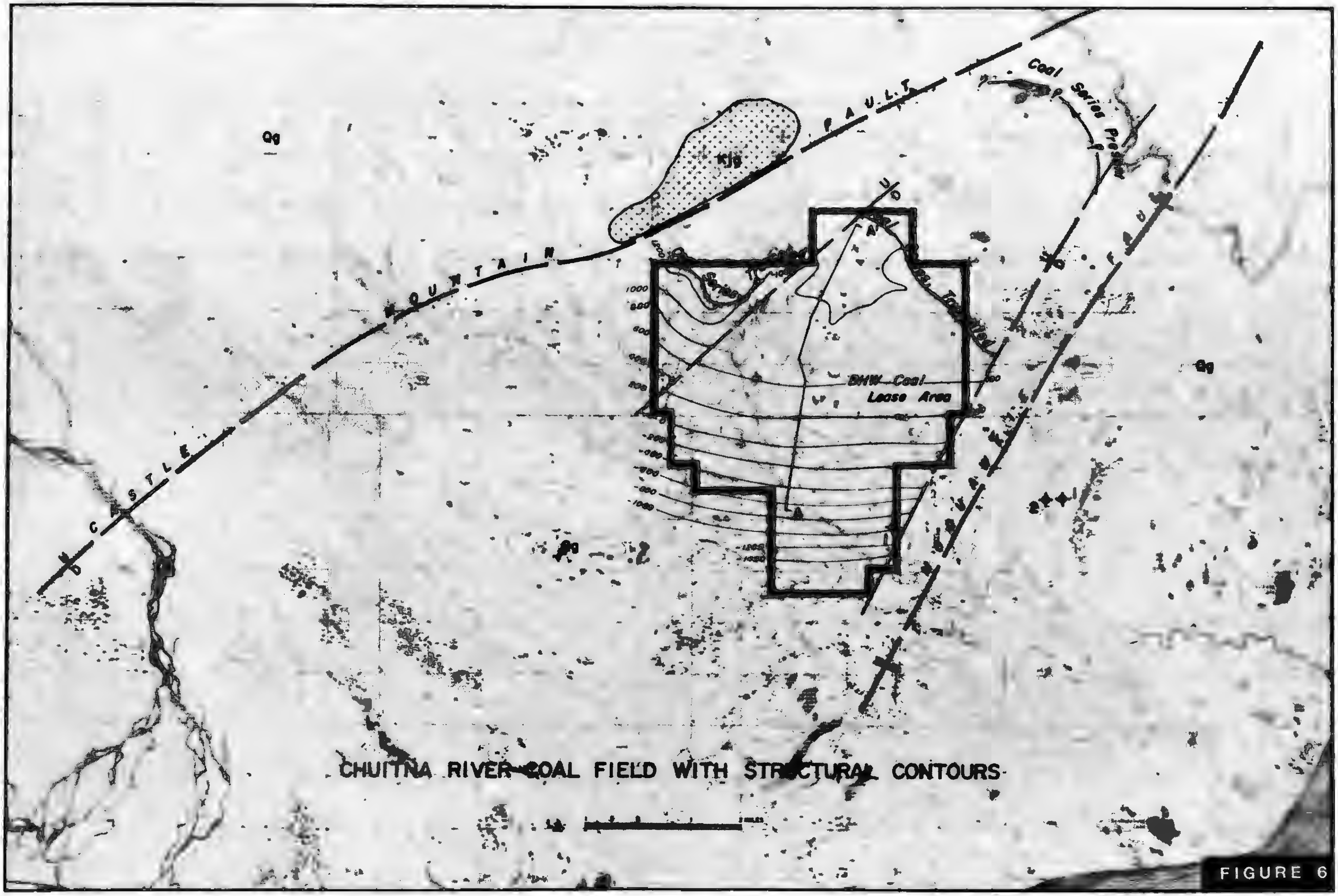
Structure

Regionally the lease area is bounded on the northwest by the Castle Mountain Fault zone and on the southeast by the Moquawkie Fault zone (Figure 6). A minor fault running en echelon with the Castle Mountain system forms the northwest boundary of the proposed pit area.

Local structure in the lease area is generally very simple. The beds are relatively flat lying in the northern proposed pit area, with a gentle dip to the south which increases as one approaches the Chuitna River. Dip of the outcropped beds measured by Barnes varied from 0° to 15° south. A notable exception to the overall simplicity is a mild structural anomaly in the central part of the lease. This condition could possibly have been created by a slightly plunging anticline and syncline configuration, noted in the Bechtel study, but present drilling density is too sparse to make a satisfactory determination. Minor faulting occurs in a northeast-southwest trend sporadically through the lease, but no excessive displacement is detectable in the proposed pit area.

Mine Plan

The preliminary feasibility study drafted by Bechtel revolves around a tentative 30 year pit boundary. Preliminary engineering



CHUITNA RIVER COAL FIELD WITH STRUCTURAL CONTOURS

FIGURE 6

indicates extraction by a walking dragline and a truck and shovel. A port facility and ocean going vessels are being considered for transportation to Pacific Rim markets.

Two walking draglines, each with 50 yard bucket capacity, are planned for overburden removal. Two 15 yard rock shovels will load and a series of 120 ton haulage trucks will move the overburden to an intermediate area, making it available for reclamation use. The design of the pit allows reclamation to be carried on as coal extraction progresses.

Coal removal will be facilitated by the use of two 16 yard coal shovels and a series of 85 ton haulage trucks. The blasted coal will be moved from two separate working faces to provide operating flexibility. Plans are for haulage from mine to port facility to be handled by a cable conveyor system.

Conclusion

The Chuitna River Coal Field is a deposit of unquestionable economic viability. It is a relatively shallow, low sulfur coal within 12 miles of tidewater. Climatic conditions would allow year round mining and access by ocean going vessels. More importantly, it lies on uninhabited state land uncontested by any federal land acquisitions. Development would provide a source of long-term state revenue, in conjunction with employment for local residents and a stable means to combat the present boom/bust economy in Alaska.

Table 1

Net Coal Thicknesses and Assay Data
for Major Seams
Chuitna River Field, Alaska

Seam	Average Net Coal Thickness, ft.	% Ash	% Sulfur	Heating value BTU/lb.
Brown	28	10.13	0.33	7845
Yellow	5-15	18.19	0.28	6782
Green	20	11.25	0.23	7862
Blue	28	7.34	0.16	8216
Orange	16	7.99	0.20	8054
Red	33	7.57	0.17	7828

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Review of Mobil coal leases - Yentna Region, Alaska

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Ladies and gentlemen, it gives me great pleasure to be here today to discuss Mobil's coal holdings in the Yentna River Basin of southern Alaska. I will discuss the geology, coal resources and development plans for Mobil's leases. Two of these items are fairly objective; however, discussing development plans becomes quite subjective in nature.

As orientation, the first illustration (Fig. 1) indicates Mobil's coal leases in the Beluga-Yentna Region of Alaska. We currently hold some 23,000 acres in 8 leases on the western flank of the basin. These are arranged in 2 tracts; the north, which we refer to as Johnson Creek, and the south, which we refer to as Canyon Creek.

The general area is located 90 miles northwest of Anchorage and 45 miles north of Cook Inlet. Access into the area is by air, with the Skwentna landing strip 20 miles east of the leases.

Let me briefly review the geology of the area. The second illustration (Fig. 2) is a slight modification from the map in U.S. Geological Survey Bulletin 1202-C, Geology and Coal Resources of the Beluga-Yentna Region, Alaska, by Ferrel Barnes. In 1973, when Mobil became interested in the possibility of acquiring Alaskan coal, this report was a mainstay of our knowledge of the area. From that point in time, up to today, our working knowledge of a small part of the larger area has not changed the scientific geologic aspect as put forth by Barnes.

The basement complex is a series of metamorphic and igneous rocks identified as Early Jurassic to Late Cretaceous in age. To a coal geologist, anything below the coal bearing horizon is considered basement. Our only work on these rocks has been to map where possible (or infer where covered) the contact with the overlying Kenai Formation.

The Kenai, which is our formation of interest, lies uncomformably upon the basement metamorphic and igneous materials. The Kenai consists of nonmarine clastics of a highly lenticular nature. It is interspersed with coal beds of subbituminous and lignitic nature. The only things that we have found in the Kenai resembling marker horizons are the coal seams themselves. Previous geologists have noted the Kenai as being of Miocene Age with possibly some Oligocene or Pliocene present. Our work has done nothing to either strengthen or refute this dating.

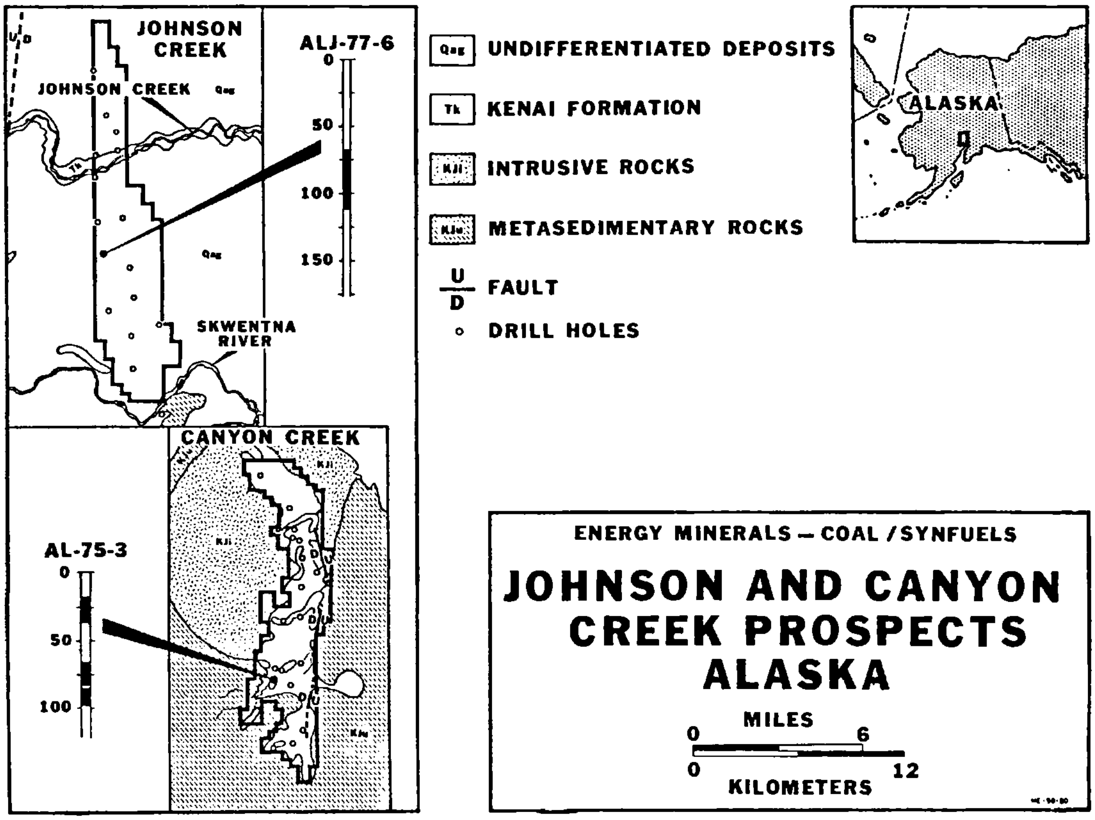

Figure 1: Johnson and Canyon Creek prospects, Alaska.

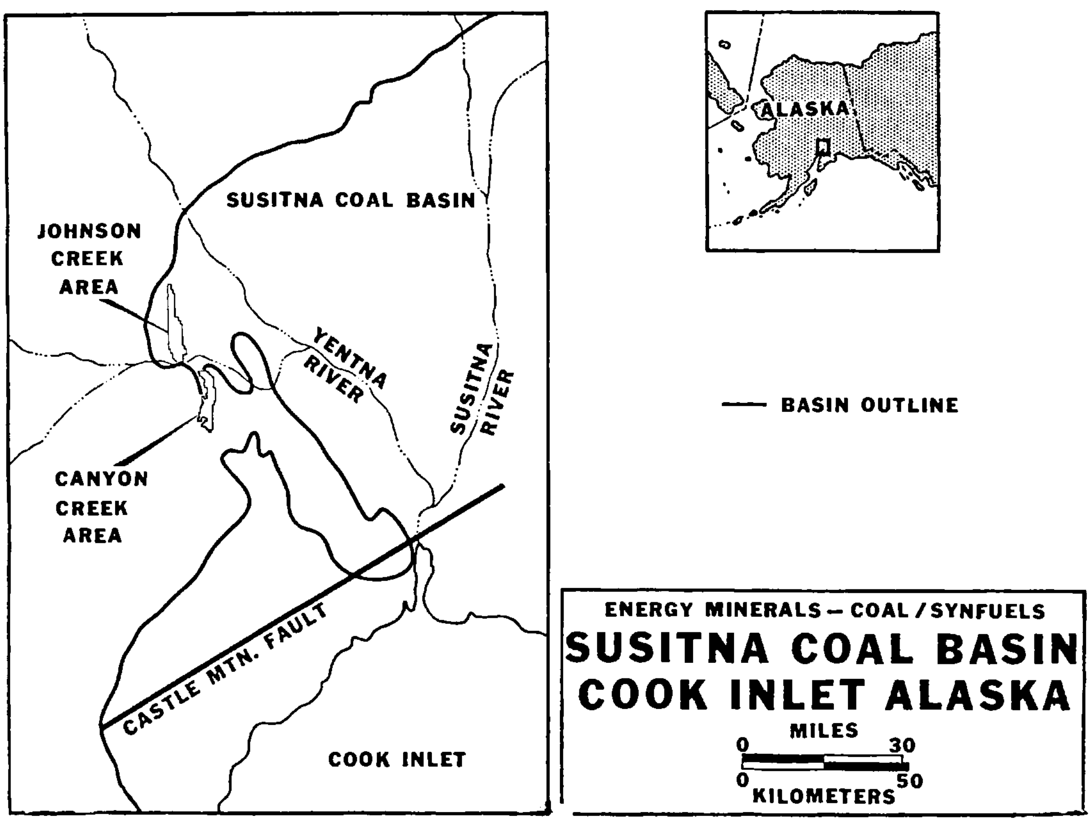

Figure 2: Susitna Coal Basin, Cook Inlet, Alaska.

Overlying the Kenai are the extensive unconsolidated Quaternary deposits. These are the glacial till and outwash materials and the alluvial sands and gravels that tend to mask all of the underlying formations. The Quaternary deposits range in thickness from a few feet to more than 400 feet, as identified by our drilling.

The structure in the general Johnson Creek area was estimated from outcrops along Johnson Creek itself and from five miles to the south along the Skwentna River. Everything in between is covered with Quaternary sands and gravels. This outcrop information indicates the Kenai is striking North 18° West and is dipping basinward from 16° to 20°. I might add that it was virtually impossible to correlate the coals from one outcrop to another prior to drilling.

In the Canyon Creek area we had the benefit of several outcrops to help with our projections. In the Canyon Creek tract, a north-trending fault dropped the Kenai on the east side of the block, exposing Jurassic metamorphics.

We believe the faulting in this case saved the Kenai from erosion, preserving the coal section. On the west side of the Canyon Creek tract, the Kenai dips at 10° to 15°. On the east side adjacent to the fault the coal beds are vertical to overturned 20°, indicating drag on the sediments along the fault plane.

In 1975, armed with the scant outcrop data, and with prospecting permits in hand, we went to work to check some basic assumptions concerning coal continuity, thickness, depth and of course, quality. We drilled 2,000 feet in 17 holes. We found that the drills utilized were undersized and were not capable of penetrating the gravels, especially the sequence in the Johnson Creek area. Six of the 1975 project holes were abandoned within 30 feet of the surface.

In 1977 we went back, using much larger drills and trying a couple of new techniques to penetrate the gravels. This time we drilled 14 holes penetrating about 5,000 feet, or an average of 350 feet per hole, which just happens to be 13 feet more than the deepest hole drilled in 1975.

Based on the 1975 and 1977 drilling results, we applied for leases on the prospecting permit areas. Upon granting of the leases in 1979, we went back to the field for some in fill drilling. This time we drilled seven holes for 2,250 feet, or an average of 320 feet per hole.

As a result of this information, we have identified both our lease blocks as potentially multiple seam mining sequences. In the Johnson Creek area, we have from five to seven seams ranging from 10 up to 40 feet in thickness. In the Canyon Creek area, we have up to five seams potentially mineable. Individual seams range in thickness from 10 to 45 feet. In one area in Canyon Creek we have a coal zone where four distinct seams come close together, giving us 63 feet of net coal in a 77 foot interval.

In developing resource calculations we applied the following criteria:

No seam sequence of less than 10 feet net coal was considered.

No ratios of greater than 10:1 (virgin) were considered for any given point.

No depth greater than 250 feet was calculated regardless of the ratio (in a few cases at 250 feet, we were still working with a 5:1 ratio).

The bottom line in this analysis is that we have identified an in place resource, well in excess of 500 million tons of coal, to depths of 250 feet. Additional coal resources occur below these depths as the seams continue on downward. However, for our present calculations, we feel that 250 feet is an adequate depth for us to consider.

Now that we have talked about the quantity, I feel it is time to mention quality. Similar to the Beluga Lake area, the Johnson and Canyon Creek quality is often dependent upon the amount of partings in the seam. The ash for various seams and sample locations has a wide range, that being from 6 to 40 percent. This, of course, directly affects the calorific values received. Our present work has established ranges in Btu from 5,400 up to a high of 9,450, depending upon the amount of ash present. Sulfur content is constant at one tenth to two tenths percent in all samples. These numbers I have just given are an as received--the moisture content ranging from 20 to 30 percent.

In analyzing the situation, we see some seams that we believe will maintain over 8,500 Btu/lb for quite a lateral distance. We have looked at some of the other seams--especially those high in ash--and have found that the limited samples we have washed clean, up to an 8,500 ± Btu/lb product. These were the results for simple laboratory testing at a 1.5 specific gravity float. Recovery on these samples ranged from 70 to 80 percent at this float media.

We fully realize we still have a great amount of sampling work to do on our lease tracts. However, our preliminary indications are that by a simple washing of those seams that are high in ash and a blending operation with the higher quality seams, an 8,500 Btu/lb product should be achievable.

So far in my talk today, I have given you an overview of the geology and coal resource. Now let me discuss development or, in this case, development problems.

Mobil's past work had identified a large resource of subbituminous coal, and we have evaluated the simple schematics for mining and transportation. In comparison to other lease holders south of us in Beluga Lake, we still have a lot of sampling and drilling yet to be completed to bring our properties up to an equal footing for knowledge of resource and potential mine economics.

You have all read various journals about energy crises, the resurgence of coal, energy independence etc. You have also heard about new processes being developed such as Solvent-Refined Coal, or SRC; coal gasification; coal to methanol, and carrying further from this, Mobil's newly developed methanol to gasoline. All of this indicates that coal production should be increasing. This increase is factual--it is happening--but not by great leaps and bounds.

I could talk all day about the problems in the coal industry in the Lower 48 states and then compare those problems with an Alaskan operation. You have all heard this several times, so I do not feel that I need to reiterate the difficulties of developing this coal field. Basically, the situation can be boiled down to the old phrase "supply and demand". It is fairly obvious to all that the primary market for much of the Alaskan coal is the Pacific Rim countries. The economics of supplying coal that can compete against energy, whether it be coal or oil, from other countries or other parts of the United States will determine Alaska's share of the coal market place.

I feel one of the major problems facing Mobil's Alaska coal is identifying enough developable resource. The costs of developing a mine or mining complex, the infrastructure for that complex--transportation facilities to the coast and coastal loading facilities--are all interwoven into the economics of delivering energy to the market place.

Without enough resource to guarantee the potential customer an adequate volume, longevity and dependability of supply, market contracts cannot be acquired. In reviewing the capital requirements needed to develop mines and delivery systems in this area, I doubt that Mobil will start detailed development without a firm market commitment.

However, we have identified a resource. We will continue to gather data on our leases, further evaluating the quantity and quality of that resource, and refining our estimated delivery cost. We will watch the various processes that are being developed to upgrade coal into higher quality products of a more easily transportable form, to see if this new emerging technology can be applied to this area. We are confident that some time in the future the cost of extracting, processing and delivering Alaskan coal energy will mesh with delivery costs of fuel from other areas in the Pacific Rim market place. The main thing that we cannot tell you at this time is when that will happen.

Ground-water reconnaissance near Graphite Point, Alaska

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U.S. Geological Survey, Anchorage

Abstract

The Granite Point area, on the west shore of Cook Inlet near Tyonek, has been proposed as a site for port facilities and an industrial complex to process coal from the Beluga coal fields. Present plans are to use ground water to supply the needs of this development.

The geologic unit that is most likely to be tapped to produce this water is a seaward thickening wedge of unconsolidated sediments overlying Tertiary sedimentary bedrock. These sediments have good potential for yielding many hundreds of gallons per minute to wells north of the Chuitna River or south of Nikolai Creek.

However, in the area between these streams, which includes the Granite Point area, the unconsolidated sediments are generally too thin for large capacity wells. Near Granite Point, wells are likely to be completed in weakly consolidated sediments of the Kenai Group. The uppermost formation of the Kenai Group at Granite Point is the Beluga Formation, which is generally fine grained and has poor potential for supplying water to industrial wells. The underlying Tyonek Formation contains conglomerate units that have slight potential for supplying water to large capacity wells. The depth to the Tyonek Formation is unknown.

If industrial wells cannot be developed from the Tyonek and Beluga Formations, they may be developed in the sediments underlying the northeastern part of the McArthur Flats, about 6 miles west of Granite Point. An oil well in McArthur Flats 12 miles west of Granite Point penetrated about 800 feet of unconsolidated sediments composed largely of sand and gravel.

Water samples from five wells in the area between Granite Point and Beluga River were of generally good quality. However, all samples might require some treatment for iron and color. Dissolved iron concentrations of the samples ranged from 0.41 to 6.2 milligrams per liter (mg/L), and color ranged from 5 to 200 units.

Introduction

Granite Point is on the west side of Cook Inlet near the village of Tyonek (Fig. 1). The Granite Point area has been proposed by Cook Inlet Region, Inc. and Placer Amex, Inc. as a site for a 54,000 barrel per day methanol plant. Granite Point is also the likely site for bulk loading facilities for coal mined from the Beluga coal fields.

The proposed methanol plant will require 7.2 million gallons of water per day, if no recycling is used. However, current plans are to recycle water and use 0.6 million gal./day as make up (Noel Kirschenbaum, Placer Amex, Inc., written communication, 1980). Additional, unspecified quantities of water will be required for the bulk loading facilities and other commercial and residential development in the area. Present plans call for utilizing ground water to supply the needs of the plant and much of the other development in the area.

Most of the data on wells and water quality contained in this report are from the files of the U.S. Geological Survey and were collected by many hydrologists during the past 20 years. I have collected only those data pertaining to the Capps Creek area. The pronoun "we" in this report refers to all these hydrologists.

Ground Water

The potential for developing large quantities of ground water depends largely on the occurrence of extensive deposits of unconsolidated materials that are more than 200 ft. thick. All of the high capacity industrial and municipal wells in the Cook Inlet basin are completed in unconsolidated Quaternary sediments. Wells in Tertiary materials rarely produce more than 50 gal./minute.

The coastal area west of Cook Inlet is underlain by a seaward thickening wedge of unconsolidated glacial and alluvial materials, overlying weakly to moderately consolidated sediments of the Kenai Group. North of the Chuitna River and south of Nikolai Creek (Fig. 2) the wedge of unconsolidated alluvial and glacial materials may be hundreds of feet thick near the coast. Between Nikolai Creek and Chuitna River in the Granite Point area, the unconsolidated materials are much thinner.

At Beluga the power plant well penetrated the top of the Tertiary sediments at 420 ft. below land surface. In this well we assumed that a density increase on the gamma-gamma log at 420 ft. indicates a transition to consolidated materials. We used the geophysical log because it is commonly difficult to distinguish, on the basis of drill cuttings, unconsolidated Quaternary sediments from weakly consolidated Tertiary sediments. The geological log of the well at Beluga shows a sequence of interlayered sand,

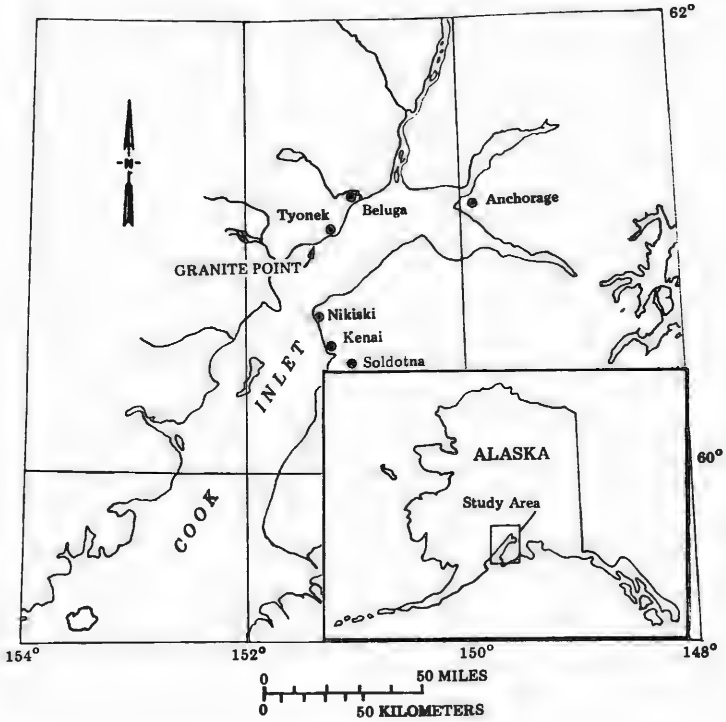

Figure 1.–Location of the Cook Inlet basin, Granite Point, and communities mentioned in text.

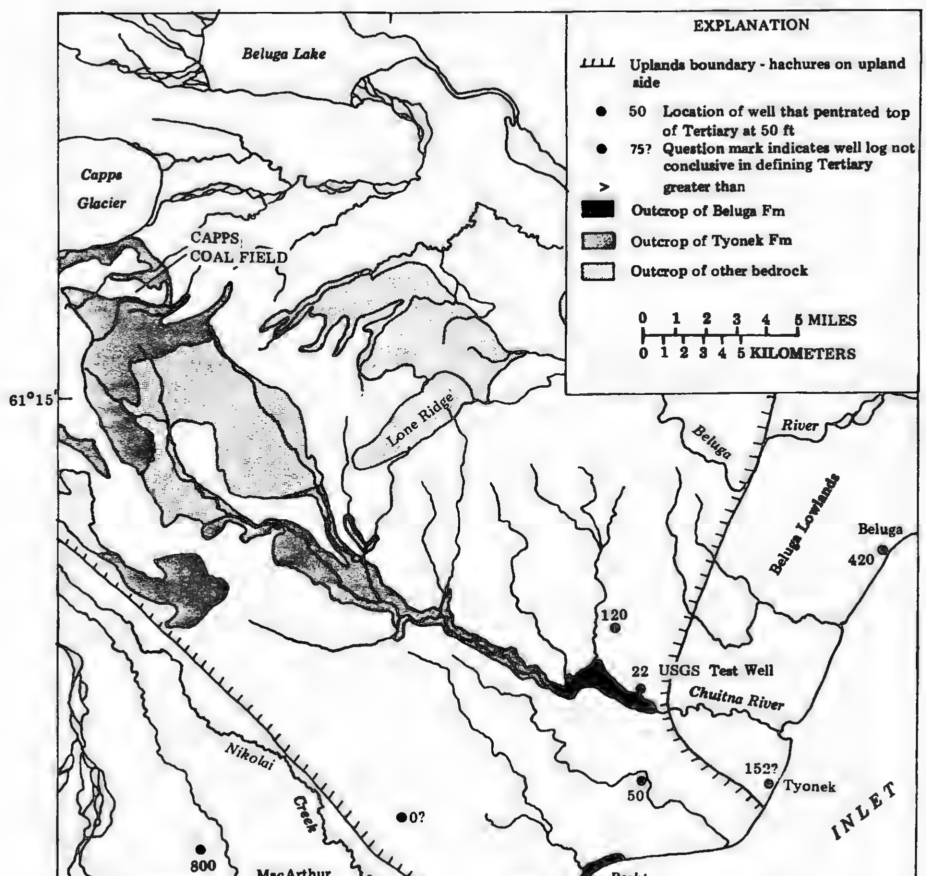

Figure 2.–Granite Point area, showing bedrock outcrops, depth to bedrock in wells, and locations of sites mentioned in text.

gravel and silty clay that is similar to those penetrated by many wells in the Anchorage, Nikiski, Kenai and Soldotna areas. Such deposits typically contain multiple aquifer systems in which permeable sand and gravel units are interlayered with much less permeable, and areally extensive, glacial and lacustrine deposits.

No logs are available to us for water wells in the unconsolidated materials in McArthur Flats, and there are probably not more than five water wells in the area. However, the log of an oil well about 12 miles west of Granite Point records the top of Tertiary at 800 ft. By analogy with other areas in the Cook Inlet basin, we expect that 800 ft. of Quaternary sediments contain aquifers capable of supplying water to high capacity industrial wells.

In the uplands (Fig. 2) the Quaternary materials are generally too thin to supply the large quantities of water required for industrial wells. An oil well near Granite Point recorded Tertiary materials at land surface, and Tertiary sediments crop out along the bluffs at Beshta Bay. Within a 4 mile radius from Granite Point, Tertiary sediments of the Beluga Formation or the underlying Tyonek Formation are the only potential aquifers. The Beluga Formation consists primarily of coal and weakly-to-moderately consolidated sandstone, siltstone and claystone. Wells completed in the Beluga Formation at Tyonek, and elsewhere in the Granite Point area, typically produce less than 50 gal./minute. Wells commonly penetrate interlayered fine sandstone, claystone and coal, and are completed in coarse sandstone units or gravelly sandstone units that are less than 10 ft. thick. Figure 2 summarizes the available information on thickness of unconsolidated materials and distribution of outcrops of Tertiary bedrock.

In 1978 the U.S. Geological Survey drilled a test well near the Chuitna River, about 6 miles northwest of Tyonek. The well penetrated about 22 ft. of unconsolidated gravel over clay that is probably Tertiary in age. The Tertiary sediments consisted of interlayered clay and coal to 320 ft. At that depth the drill penetrated water bearing conglomerate that may be either a minor conglomerate of the Beluga Formation, or a part of the underlying Tyonek Formation.

The Tyonek Formation generally contains coarser materials than the Beluga Formation (Adkison, Kelly and Newman, 1975), and therefore has a somewhat greater potential for ground water development. No wells near Granite Point are known to be completed in the Tyonek Formation. However, the U.S. Geological Survey has drilled into the Tyonek Formation in the Capps Creek field (Fig. 2). That drilling, which was completed in October 1980, showed no units that were capable of supplying the large quantities of water required by industrial wells. In three of the five wells, coal units were the principle aquifers and produced 20-50 gal./minute of ground water. In the fourth and fifth wells, water bearing sandstone and conglomerate produced less than 25 gal./minute to each of the wells.

Base Flow

After several days of no precipitation or snowmelt runoff, the water flowing in streams is entirely derived from drainage of ground water and is termed base flow. In order to aid in our evaluation of the ground water resources, we have initiated biannual measurements of the base flow at five sites near Granite Point. Not enough data have been collected to estimate low flow characteristics of streams in the Granite Point area. However, Scully, Krumhardt and Kernodle (written communication, 1980) have analyzed low flow of Chuitna River. The low flow characteristic they use is the 7 day minimum flow that occurs with a 10 year recurrence interval (termed $M_{7,10}$). They found the $M_{7,10}$ for the Chuitna River to be about 0.4-0.6 cubic feet per second per square mile. If base flow of the Granite Point area approaches 0.4 cubic feet per second per mile, then the requirements of the proposed methanol plant and much of the port facility could be met by diversion of some of the small creeks draining the uplands near Granite Point.

Ground Water Quality

Ground water in the area may require treatment for iron and color. Ground water commonly contains iron in concentrations that exceed the national water quality standards for drinking water (U.S. Environmental Protection Agency, 1975). For some uses, colored water may also be objectionable. At Nikiski, the most highly colored water clogs ion exchange beds in an industrial water treatment system (Charles Ross, Union Chemical Co., oral communication, 1978).

A water sample from a well 9 miles north northeast of Granite Point (first well in the following table) contained about 0.150 milligrams per liter (mg/L) of arsenic. The same sample also contained 6.2 mg/L of dissolved iron. The results of analyses for selected constituents of five ground water samples from the Granite Point-Beluga area are presented below. More complete analyses are available from the U.S. Geological Survey, Water Resources Division.

No chemical analyses have been made of ground water in the McArthur Flats area. However, the eastern extent of McArthur Flats near Cook Inlet is an area in which ground water is generally moving toward the land surface. Ground water emerges in many springs and small spring fed creeks and sloughs. Streambed materials in many of these springs, and in the streams below springs, are heavily stained by iron and contain reddish slime deposits probably formed by iron fixing bacteria.

Conclusions

Industrial water supplies are probably available from ground water sources in McArthur Flats, about 6 miles from Granite Point, and possibly from surface water sources in the uplands near Granite Point. However, the successful completion of industrial supply wells in the uplands near Granite Point is unlikely. Ground water is likely to require treatment for iron and may require treatment for color producing compounds. No water quality data are available from springs or wells in McArthur Flats.

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Location	Date	Depth (ft.)	Iron (mg/L)	Hardness as $CaCO_3$ (mg/L)[3]	Color (units)	Dissolv. solids (mg/L)
Sec. 8, T.12 N., R. 11 W.	9-30-77	68	6.2[1]	290	12	354[2]
Sec. 20, T.12 N., R. 11 W.	6-23-78	320	0.44[1]	32	200	88[3]
Sec. 3, T.12 N., R. 11 W.	9-30-77	97	1.8[1]	75	40	98[2]
Sec. 1, T.11 N., R. 11 W.	11-13-70	177	2.4[4]	40	10	218[3]
Sec. 1, T.11 N., R. 11 W.	10-04-66	100	1.6[1]	46	5	157[3]
Sec. 25, T.13 N., R. 10 W.	11-18-76	515	1.5[1]	41	12	171[3]

Footnotes: 1 = dissolved
2 = residue on evaporation at 180°C.
3 = calculated
4 = total

Where do we go from here?

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It is a pleasure to have the opportunity to speak to you on this occasion of the "Focus on Alaska Coal--1980", and it is also a pleasure to have the opportunity to revisit my long time friends here at the University of Alaska.

The subject of coal has been of interest to me from the time that I first mined coal at age seventeen as a means to work my way through college and obtain a degree in Mining Engineering. My association with coal stretches back over a period of thirty years beginning as a coal miner in the Pennsylvania Anthracite Mines, where I progressed to an Assistant to the Divisional Superintendent. My work in the mines was followed by a varied career in production, engineering and academia. I suspect my fascination with coal has a genetic basis. My family has been associated with coal for over five generations both as coal miners and mine bosses. Maintaining the tradition is my oldest son who is a mining engineer and my youngest son who is studying to be a mining engineer.

After this short introduction, I would like to share with you a few lessons that I have learned which may be relevant to the development of Alaskan coals. One of the early lessons that I learned is that few people want to use coal. In 1948 when I went to work as a coal mine laborer, the company that I worked for was operating twenty-six deep mines and a large number of surface mines. It had been, at one period in its long history, the wealthiest corporation in the world. By 1955, the same company could claim only two deep mines and a greatly reduced number of surface mines with thousands of men permanently unemployed. Many of the unemployed miners had long previously converted their homes to oil and gas heating but continued to vigorously support the use of coal as long as it was being used by someone else. The company went into bankruptcy.

This situation resulted from the fact that abundant foreign oil and domestic natural gas became available as a result of victories in war and our nation's expanding international role. The public then immediately took steps to change from the less preferred and less costly coal to the more preferred but higher costing oil and gas. History teaches us that the industrial revolution in England and Europe, where large tonnages of coal were first used in the manufacture of steel, was brought about mainly because the then-preferred forest and wood supplies had been depleted.

Another lesson that I learned was that the reason for resistance to the use of coal derives basically from the fact that it is a solid and that it contains ash. The liquid and gaseous hydrocarbon fuels do not have these problems. In addition to the traditional problem of coal being the least preferred fuel, other problems have developed to hinder the usage of coal through the numerous environmental regulations of recent years. Add to these problems the increased difficulty of mining coal as a result of the many new safety laws and regulations, and it is not difficult to understand the origin of the somewhat cynical cliche' that is frequently passed through the coal industry that "you cannot mine it and you cannot burn it".

There are historic difficulties in getting society to use abundant and low-cost coal when other preferable but higher-cost fuels are available. It is probably safe to predict, therefore, that since coal was the first of the fossil fuels mined it will probably also be the last.

Moreover, I have long suspected that our national planners have rightfully taken the position that it is always best to use someone else's irreplaceable natural resources, if they are available, rather than our own. To those areas, regions and people who depend upon coal for an immediate livlihood, or as a hope for the future, this rational plan often seems extremely irrational. The net result of this attitude is that the huge reserve of coal that we have within our borders has historically provided us with energy independence. However, we need to remember that this independence is based on a nonpreferred fossil fuel. This nonpreferred fuel independence has caused great dependence on the rapidly depleting and uncertain supply of preferred fuels which in turn causes repeated boom and bust cycles in the coal industry.

This nation's luxurious habit of using coal when necessary, and not using it if at all possible, is a major factor in our current depression. We are probably looking at a translation of the boom and bust cycle of the coal industry into the national economy. It might be said that the boom and bust cycle disease is spreading. We can hope that the wide scale swings in coal usage during the past years will be somewhat dampened in the future as a result of all forms of conversion, as well as a result of export demands, but it is quite unlikely that these cycles will ever completely go away. I predict that the economic health of the nation in the future will correlate directly with the economic health of the coal industry. This will be a direct reversal of trends of the recent past, where a healthy national economy correlated with a weak coal industry.

Currently, in the Appalachian coal fields, we continue to operate at high tonnage levels which are comparable with those of the 1973 boom period. Current production, however, is substantially below industry capacity, and overall coal realization value is down as a result of weak demand for metallurgical coal. Failure to reach capacity is due in large measure to overloaded export facilities, caused by a demand for lower valued steam coals. Although there is currently a growing and impressive overseas market for steam coal, it appears that our port facilities are currently inadequate to handle this developing demand. This current demand is so great, as a result of the Middle Eastern War, that as of a few days ago there were 12,500 railroad cars waiting to serve 92 ships in the Port of Norfolk. Some ships waited for as long as 35 days, with loading delay cost well over one hundred million dollars.

So much for the bad news. Now, let's talk about the good news. Or, where do we go from here? There is no doubt about the extensive future use of coal, including Alaskan coal. The extensive use of your coal, like the use of your oil, will undoubtedly reach a maximum tonnage when many of the nation's other coal fields are at and beyond maturity. In the meantime, a great deal of work needs to be done. Motivation for the type of work that needs to be done can easily be derived from studying the experiences of Minnesota, Illinois and West Virginia, to name a few.

Many years ago at the University of Minnesota, during a period when the reserves of direct shipping iron ores appeared to be unlimited, research was undertaken on the beneficiation of the iron bearing Taconites. This research must have looked irrelevant at the time that it was undertaken. Almost forty years of work went into Taconite research before the actual use of this extremely finely disseminated iron ore was realized. When the seemingly inexhaustable direct shipping iron ores of Minnesota were finally depleted, private industry turned extensively to the years of documented research conducted by the University of Minnesota, and used these findings as a basis for giving birth to a whole new Taconite based industry in that state. This industry continues to flourish and grow.

The experience of the State of Illinois closely follows that of Minnesota in that it was once believed that none of the Illinois coals could be coked. Nevertheless, the State of Illinois undertook thirty to forty years of research work to overcome early doubts. This work eventually had a major impact on getting significant quantities of Illinois coal used in coke production. Hence, the usage of Illinois coal in coking is alive and well today thanks to far sighted research policies.

A final and very recent example can be shown by some universities like West Virginia University that, along with a number of federal agencies, conducted much research over many years on the mining, preparation and utilization of coal, involving both gasification and liquefaction. The payoff to many years of coal research is evident in the many already-in-place mine site power stations, and the scheduled new liquefaction plants that are planned for development in different parts of the United States. Hence, one of the nation's first full scale coal-to-liquid commercial plants will be jointly constructed at Morgantown, West Virginia by the federal government and private American industry, as well as with German and Japanese government participation.

The lesson that is clear for Alaska is that with oil flowing, and with the availability of financial resources, the development of more knowledge and understanding of Alaskan coal is needed. Although an excellent beginning has been made in your School of Mineral Industry, this is only a basic beginning. There is need for much more applied research involving a substantial commitment of resources. There is an obvious need for more mining exploration research derived through extensive drilling programs, and making liberal use of mathematical based sampling theory. There is also a need for coal cleaning studies, mineability studies, transportation studies and world market studies.

Consideration should be given to the development of a complete coke testing facility with pilot scale coke test oven and petrographic laboratory. Tests of Alaskan coals with blends of other world coals could shed much light on some possible interesting combinations. Extensive coal characterization studies are needed to see how Alaskan coals differ from other comparable coals. Differences in coal properties determine whether coal will or will not be used. Cold weather extraction and transportation studies as well as studies based on the geographic position of Alaska relative to present and future markets are obvious and logical needs.

An extensive compilation of the foregoing types of research can do much to hasten the time when Alaskan coals will be used. With an expected gradual increase leading to large increases in the use of Alaskan coals, the state will greatly benefit by the many new developments taking place in the coal industry today. With such present and future developments, large-scale production of Alaskan coal may not suffer from the many problems encountered in other coal industries of the world.

Finally, coal has always been a civilizing influence. Where there are large reserves of coal such as the billions or trillions of tons that are estimated to occur within Alaska's borders, we can fully expect the eventual development of large permanent population centers. Many of the great population centers of the world were literally built and maintained on top of coal reserves. Gold rushes, oil rushes, and religious movements have had a powerful effect on the spreading and redistribution of population; but perhaps the greatest rush of all is the coal rush. It appears that Alaska's pending coal rush will be the next great and exciting event to happen to your state.

Geology and coal resources of the lower Lignite Creek area

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Introduction

The Lower Lignite Creek Basin is located four miles north of Healy, Alaska. It is the site of present mining and will be the site of much future mining in the Nenana Coal Field. The coal bearing group in the Nenana Coal Field is of Tertiary age, overlain in some areas by several thousand feet of Tertiary gravels - the Nenana gravels.

In areas mined by surface methods the Nenana gravels are eroded off, and up to one hundred feet of Quaternary outwash gravels overlay the coal bearing formations. The coal bearing group is divided into five formations: Healy Creek, Sanctuary, Suntrana, Lignite and Grubstake. The Healy Creek formation is the oldest, at early Miocene age; the Grubstake formation is the youngest, at late Miocene or early Pliocene age.

Only two members of the coal bearing group--the Healy Creek and Suntrana--have been mined, and it is unlikely that the other members contain economic deposits of coal.

Geology

Lignite Creek, near its mouth, lies on the north limb of a west-plunging anticline which has brought the coal bearing formation near enough to the surface to allow surface mining of the Suntrana formation. Mining is presently in progress on the south side of Lignite Creek in the Poker Flats area. The coal bearing formation is cut off to the south by a fault having perhaps several thousand feet of vertical displacement, with the upthrust side to the north. South of this fault, Nenana gravels are exposed at the surface.

The Lower Lignite Basin is bordered on the west by the Nenana River and on the southeast by an outcropping of the Birch Creek schist. A syncline north of the Lower Lignite Basin causes the Nenana gravels to be exposed to the north, making the coal bearing group too deep for surface mining. The coal bearing group continues its surface exposure to the east on either side of Lignite Creek, and to the northeast towards Jumbo Dome, on hornblende dacite intrusive. The Lower Lignite Basin therefore extends about three miles in an eastwest direction, and about two miles north south. (Figures 1, 2 and 3.)

The Suntrana formation is well exposed throughout the Lower Lignite area, with all six of the coal seams in the formation outcropping within the Lignite Creek valley. For about one half mile north and south of Lignite Creek, the Suntrana formation is exposed on the surface. Over much of the plateaus on either side of Lignite Creek, and particularly to the south in the Poker Flats area. the coal bearing formation is overlain by twenty to sixty feet of outwash gravels.

In addition to the large fault south of the Lower Lignite Basin, which can easily be traced for ten miles to the east, there is evidence of much local secondary faulting. Small thrust faults have been observed in the active pit area. A series of about three thrust faults striking roughly eastwest, with the overthrust side to the south, caused the lowest coal seam in the active pit to be stacked nearly triple thickness when the fault followed the weakness at the footwall of the coal seam. About two thousand feet to the west a single thrust plane was observed with the overthrust side to the north. Drilling data indicates that we can expect to find more faulting as mining progresses. The final structure may prove to be very complex.

The Suntrana Formation

The Suntrana formation contains the strippable coal seams in the Lower Lignite Basin. There are six coal seams in the Suntrana formation designated by numbers one through six (the lower seam being number one). Partings between seams average eighty feet between one and two; thirty feet between two and three; eighty-five feet between three and four; and one hundred fifty feet between four and six. Partings are typically coarse, pebbly sandstone near the hanging wall of the coal seams, grading to fine sandstone and ending with a clay and silt bed from two to fifteen feet thick at the footwall of the next coal seam. Parting sandstones are chiefly of poorly consolidated quartz and black chert, which deteriorates rapidly when exposed. (Figures 4 and 5.)

Coal seams six, four and three (averaging twenty-one, twenty-one and seventeen feet thick respectively) are presently being mined, and hold the bulk of surface mineable reserves for the Lower Lignite area. Three, four and six seams are subbituminous C coals averaging eight thousand Btus per pound, six percent ash, twenty-seven percent moisture and 0.2 percent sulfur. Five seam is very thin or absent in the Lower Lignite Basin. Two seam is about seven feet thick, of poor quality and thus will not likely be mined. One seam contains mineable reserves near its outcrop but mining will be complicated by two clay and bone partings within the seam.

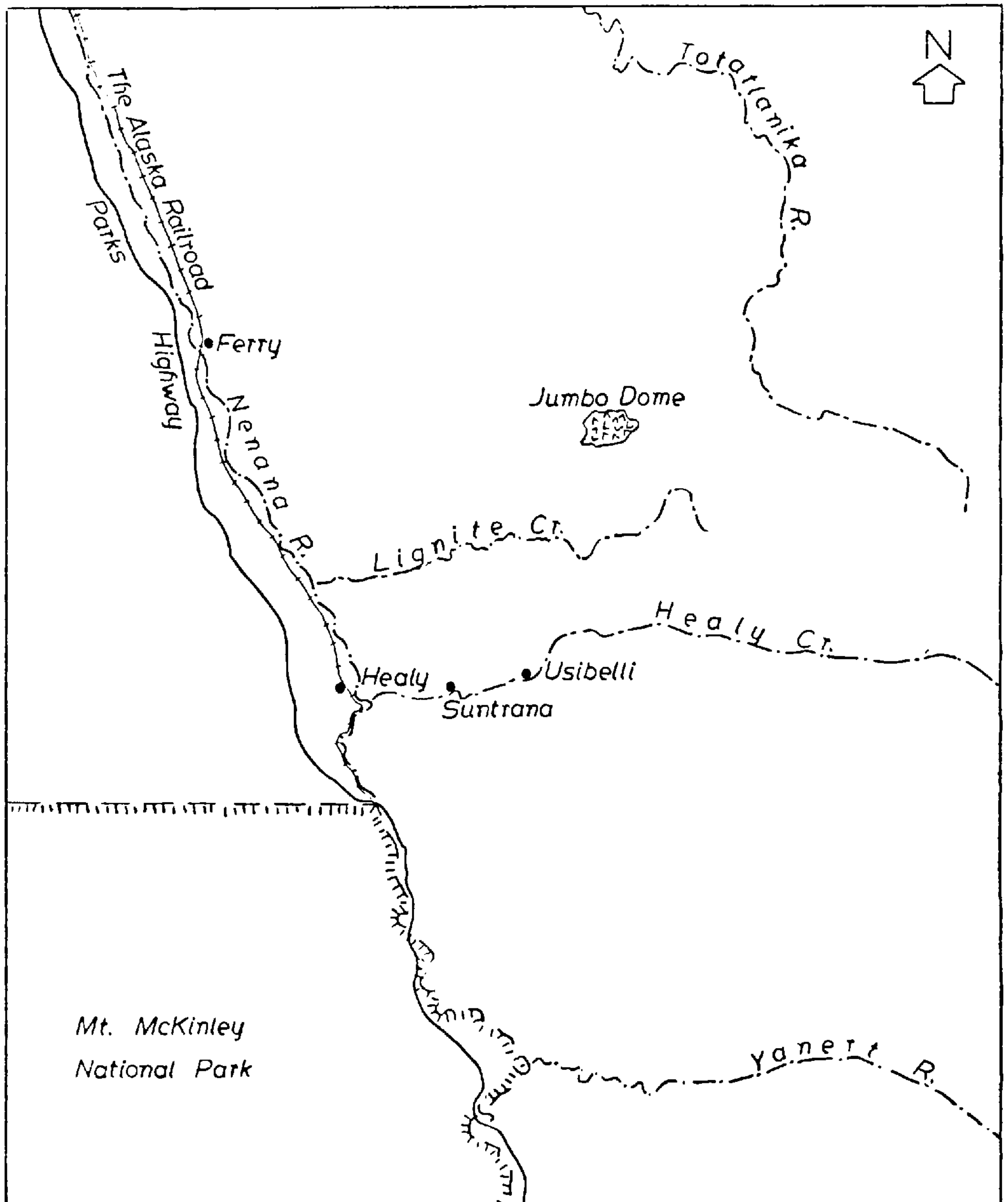

Fig. 1 Map of Healy

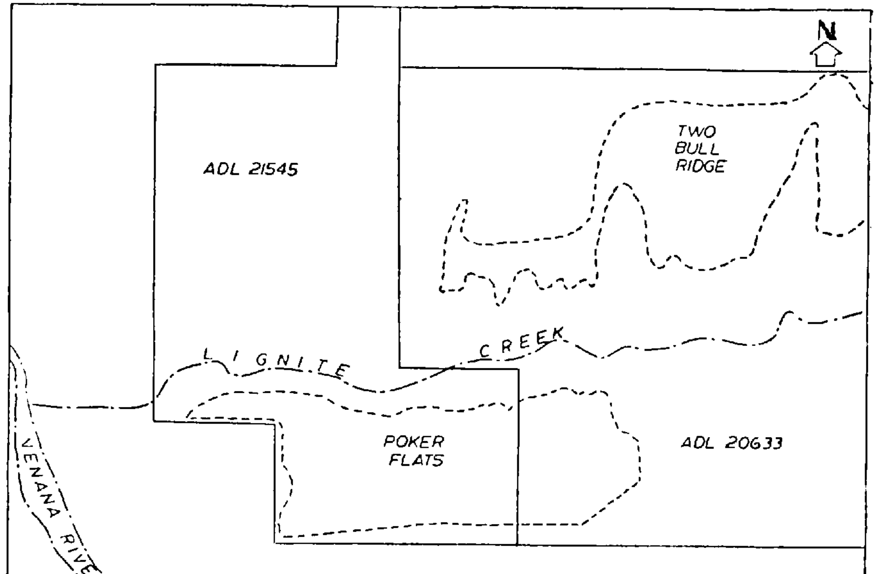

Fig. 2 Lower Lignite Basin

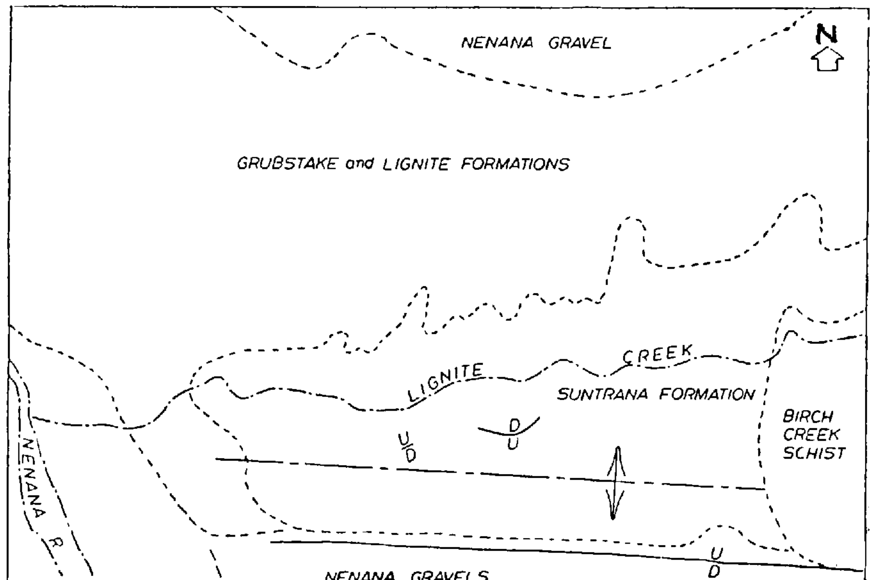

Fig. 3 Geology of the Lower Lignite Basin

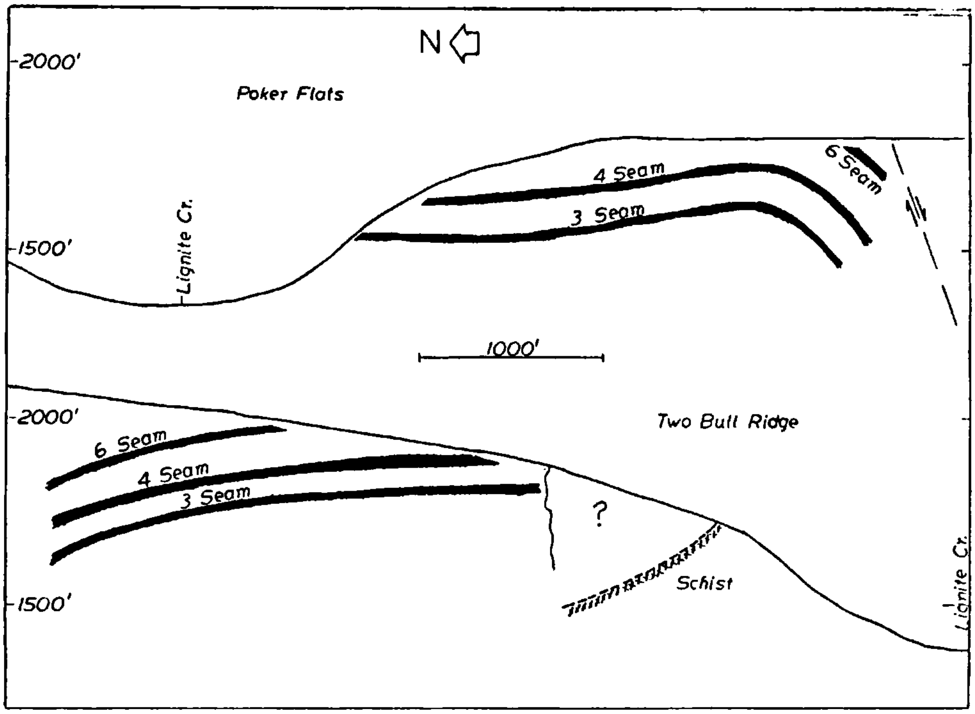

Fig.4 Structural Sections of Upper Suntrana Formation at Lower Lignite

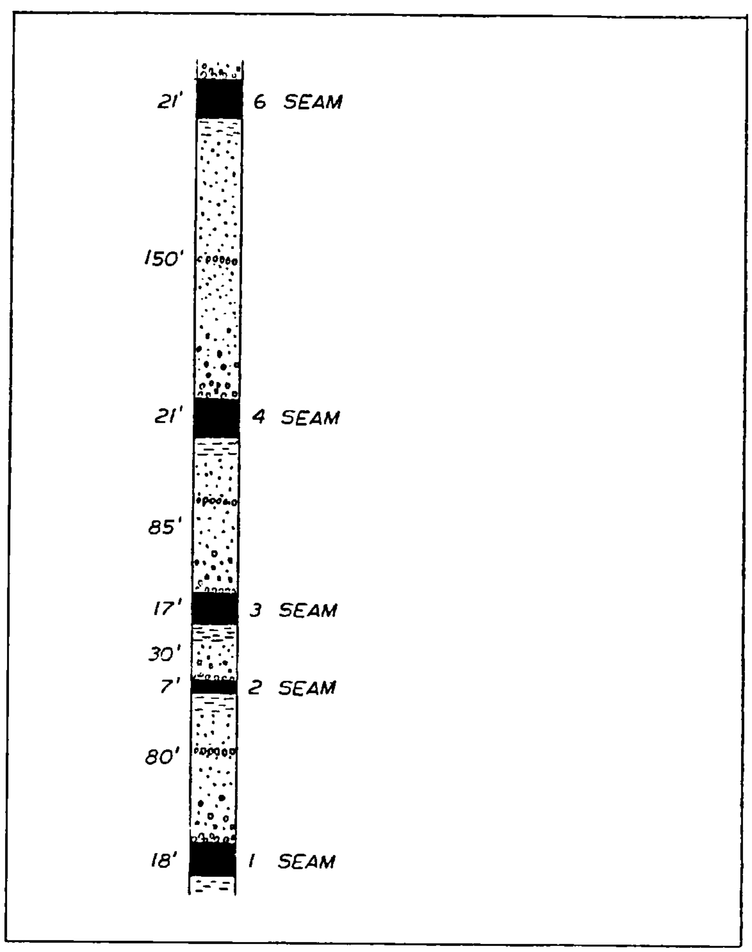

Fig. 5 Typical Section of Suntrana Formation at Poker Flats

Coal Resources

Exploration is fairly extensive in the Lower Lignite area, and proven reserves of approximately eighty million tons exist at a stripping ratio of less than five to one. The active mining area at Poker Flats has design reserves of twenty-eight million tons at a stripping ratio of 4.5 to one. The Two Bull Ridge area, about one and one half miles northeast of Poker Flats, has proven reserves of thirty-eight million tons at a stripping ratio of 3.6 to one. The remaining reserves are located in smaller pockets throughout Lower Lignite.

In addition to proven reserves of eighty million tons, the resource potential of Lower Lignite may be even greater. There are limited exposures of the Healy Creek formation in the area, and the potential for both surface and subsurface reserves exists, as the Healy Creek formation was mined extensively in the Healy River valley to the south. Where the coal bearing group contacts the Birch Creek schist there is often a thick coal bed lying directly on the schist, the resource potential of which has not yet been analyzed. The area within the Lower Lignite Basin with surface exposure of either coal bearing formation or Nenana gravels, which overlays the coal bearing group, covers about five square miles. Assuming a conservative total coal thickness of fifty feet below this area, the resource potential might be as high as 250 million tons at depths up to several thousand feet. It is unlikely that this resource will be developed in the near future, but developments in underground mining and insitu gasification might make this resource recoverable at a later date.

Future Development

Usibelli Coal Mine, Inc.'s operations will likely center around Lower Lignite for at least the next twenty-five years. Present proven reserves of eighty million tons could last for twenty years at theoretical maximum output for Usibelli.

Exploration drilling is presently concentrated around Lower Lignite and will continue for several years into the future. During the 1980 season, detailed outcrop mapping was initiated at Lower Lignite and will extend for the next couple of years to the east up to the Lignite Creek drainage.

Mining activity by Usibelli in Lower Lignite began in 1976 at the presently active Poker Flats pit. Reserves in that pit will last thirty-five years at present production rates. The next area which will likely be mined is the Two Bull Ridge area northeast of Poker Flats, where another fifty years of production is possible at present production rates. Hopefully, the demand for coal from Lower Lignite will increase and the life of the area will be shortened. After Lower Lignite is mined out, Usibelli holds additional reserves east of Lower Lignite that most certainly will be developed.

Conclusion

Much work has been done on geologic mapping and exploration of the Lower Lignite Basin by both industry and government concerns. This work has been valuable in the development of coal mining in Lower Lignite. As mining progresses we discover many hidden geologic features which will yield a detailed picture that could only be seen by physically uncovering the coal.

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Remaining coal resources of the Matanuska field

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Exploration drilling for oil and gas has shown Cook Inlet Basin to be a major coal basin (Fig. 1). The Matanuska coal field is the very northeastern part of the basin extending easterly from the Little Susitna field at Houston, past the Wishbone Hill district near Sutton, and continuing past Chickaloon to Anthracite Ridge. These coals occur in the Tertiary Chickaloon formation. Because of structural deformation, and to a small extent because of igneous intrusions, the rank of these coals increases from subbituminous in the Little Susitna Field, to bituminous at Wishbone Hill, to some anthracite at and beyond Chickaloon.

The Matanuska coals had an important influence on the history of development of Southcentral Alaska. The extent of these coals had been known before 1900. Together with gold at Fairbanks, they were an important reason for the start of construction of the Alaska Railroad as a private venture in 1903. Development of the Matanuska coal field became important to fuel the trains. A branch line reached Eska by 1917, however, railroad construction did not get far until the Federal Government took over and finished it in 1923.

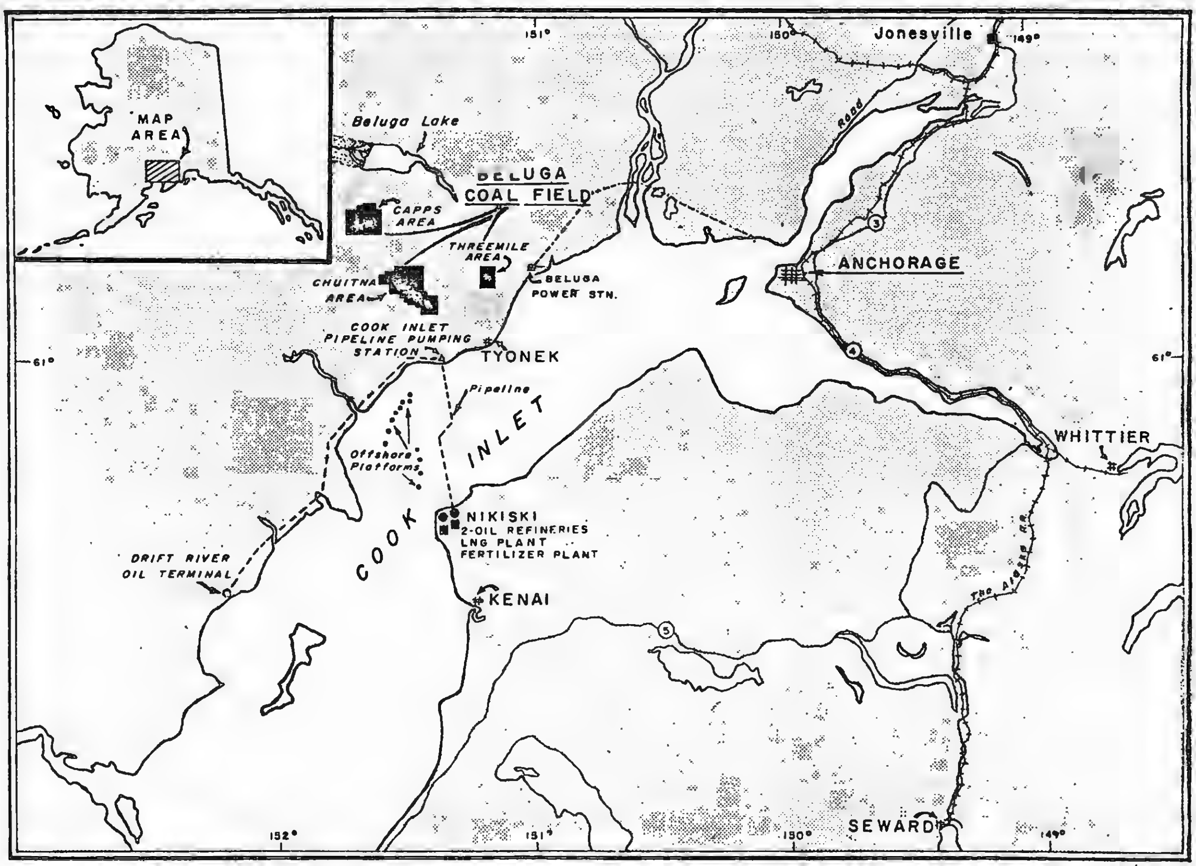
The U.S. Navy became interested in Matanuska coals as fuel for its ships. First mining was done by the government in 1913 for a Navy test. First commercial production was in 1916 from along Moose Creek.

In 1920, the Evan Jones Coal Mine at Jonesville (Fig. 2) was opened to become the largest producer in the field; it stayed in almost continuous operation until its closing in 1968. During its 48 year active life the mine produced about 6 million tons of washed coal. Since 1934, the earliest date for which records are available, 2,330 different men worked at the mine.

The following is a very brief review of the various coal districts within the Matanuska field.

The Little Susitna District is a two to three mile wide strip along the southern slope of the Talkeetna Mountains at the west end of the field. Several coal beds are known to exist but they are thin, less than three feet, and the one known nine foot bed is reported to be quite dirty. Mining has been done on a small-scale at four locations, one of these is at Houston and is now mined out. Some coal prospecting permit activity has taken place during recent years, but these permits have by now been relinquished.

Figure 1



LOCATION MAP Figure 2

The Chickaloon and Anthracite Ridge districts are at the east end of the field. During the early days of coal development these areas were extensively mapped and explored. The district is heavily faulted and is intruded by dikes and sills. Coal beds are therefore very chopped up, and would be difficult to mine except on a very small scale. One 100 acre coal lease exists in the district, and land status books show several sections of land to be under coal prospecting permit. The possible resource base is 25 million tons (Barnes, 1967).

The Wishbone Hill district accounts for the bulk of the estimated coal resources of the Matanuska field. Barnes (1967) tabulates 52 million tons of indicated resources, plus 54 million tons of inferred resources. Of this total, nearly half is held under lease by the Evan Jones Coal Company. Four other coal leases in the Wishbone Hill district are recorded in the state land status records.

Placer Amex, Inc. purchased an interest in the Evan Jones Coal Company in 1956, and from 1959 to the closing of the mine in 1968 was the managing joint venture partner of the property. The property still maintains one coal lease which covers a natural mining block of the remaining underground coal reserves.

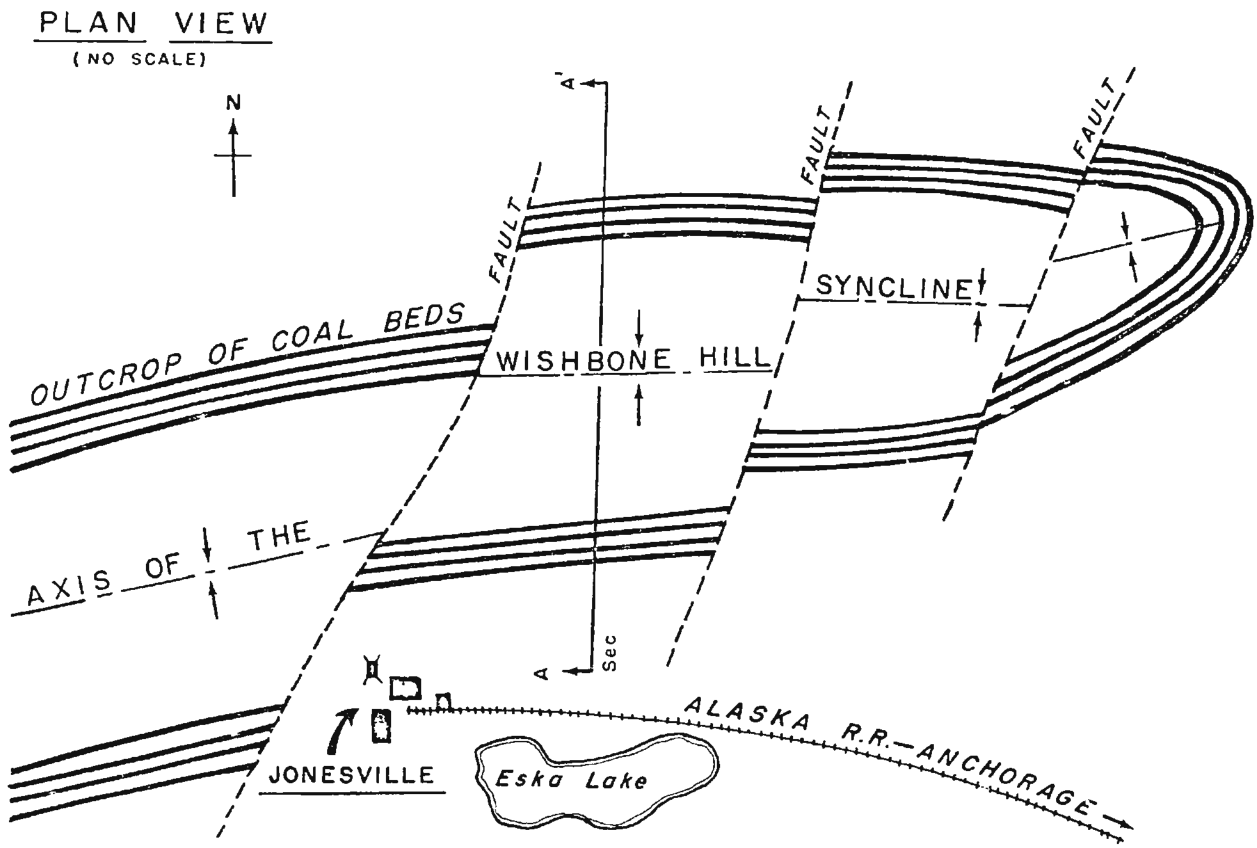
The generalized plan of the geologic structure of Wishbone Hill coals is shown in Figure 3. Several coal beds occur in a "canoe shaped" syncline which is cut by several transverse faults. In the early days, coal was mined from underground as shown in the schematic cross section in Figure 4, or as shown in a more refined version in Figure 5. In 1952, strip mining was first attempted along the north limb of the syncline and by 1959 all underground operations had been phased out, with coal coming from deep open pits.

The Evan Jones Coal Mine was closed down in 1968, following discovery of oil and gas in Cook Inlet and the eventual conversion to natural gas of the power plants at the two large military bases near Anchorage, which at that time represented about 95% of the company's coal market. All equipment and plants were sold at that time, and the Alaska Railroad pulled the rails from Palmer to the mine.

At the present time there is not market for the remaining coal. However, since this is one of the highest quality steam coal reserves in Alaska, Placer Amex is constantly monitoring possible developing markets in the local and Anchorage areas as well as for export. Because of current national and world energy problems, the day of reactivating the mine could be approaching.

To reopen the mine, a complete, new, underground mine and wash plant would have to be engineered, built and equipped. Some factors favorable to reopening the mine are the existence of substantial remaining reserves of good quality steam coal with established highway and railbed access, existing power and a local

Figure 3



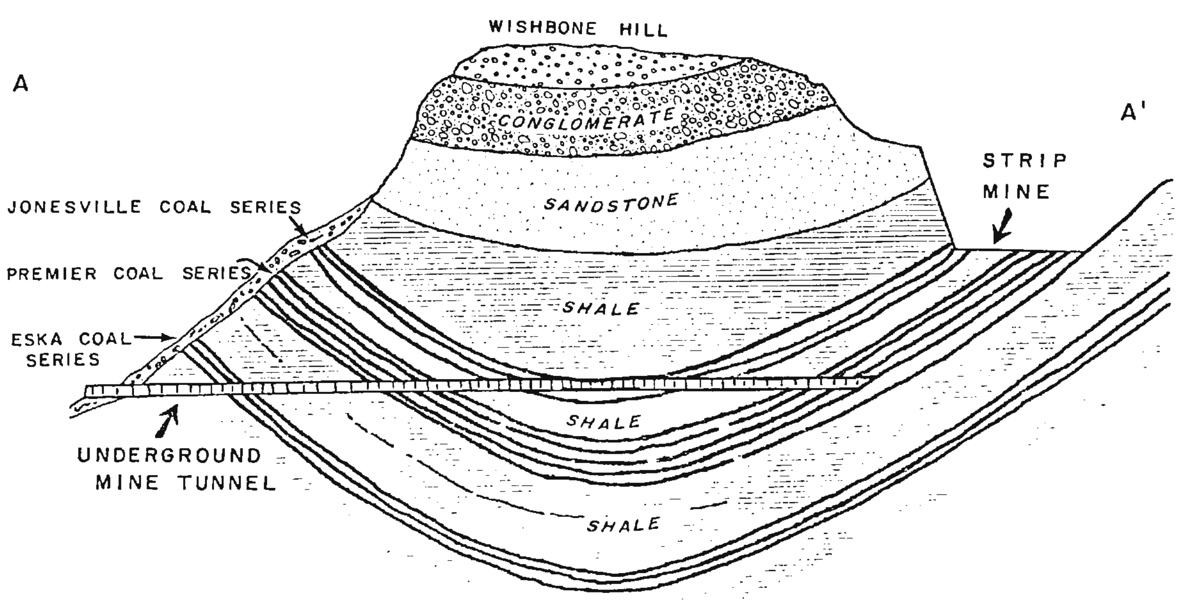


Figure 4 SCHEMATIC CROSS-SECTION
(NO SCALE)

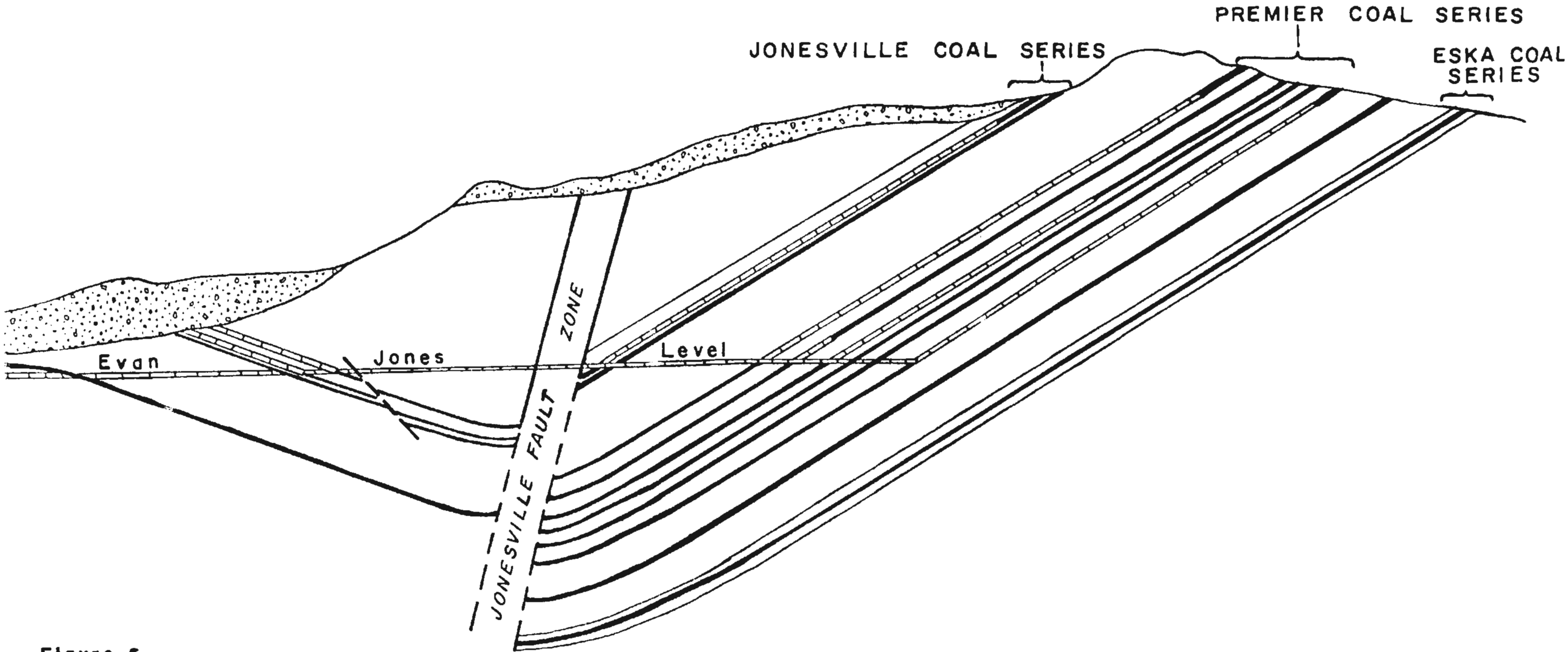


Figure 5

GEOLOGIC STRUCTURE SECTION THROUGH WISHBONE HILL, MATANUSKA COAL FIELD, ALASKA *(AFTER BARNES, U.S.G.S BULL. 1016).*

(NO SCALE)

labor pool and infrastructure. For export, the harbors at Anchorage, Whittier or Seward are possibilities, all with established railroad access.

The remaining Evan Jones coal reserve is estimated to consist of some 30 to 50 million recoverable tons of good quality, compliance bituminous steam coal, which for years had been sold under washed coal specifications of:

Moisture (as received)--8.5% Max.
Ash (dry)--15% Max.
Btu (dry)--12,090
S--0.4 - 0.5%
Ash Fusion—2,800° F.

The coal beds are steeply dipping, averaging 30° to 45°, and the beds can be gassy. An innovative mining method is needed for production. A few years ago the company completed a preliminary economic analysis for putting the mine into production at a rate of 500,000 tons/year of clean coal, and using hydraulic mining and hydraulic coal transport to the surface.

Escalated to present costs, sucn an operation would require an investment approaching $50 million and produce coal at somewhat more than $2.00 per million Btu. This is not cheap except in comparison to imported crude, which now costs between $5.00 and $6.00 per million Btu.

A hydraulic mining method (Figs. 7,6) was studied because other methods are difficult in steeply pitching seams. It is also a safer method when mining is done on the retreat and with ventilation forced into the gob to reduce dust and gases. Hydraulic mining, as envisioned, is in use at the Balmer Coal Mine in British Columbia and also in Russia and Japan. Under certain conditions, hydraulic mining can have higher productivity and better resource recovery. However, extensive testing of the method would be necessary at the property to make certain that hydraulic mining will work. Following testing, design and permitting, a new mine could be put into production in two years.

In conclusion, first future production from the Matanuska field would likely come from the reopening of the Evan Jones Mine. At a proposed rate of half a million tons per year, there is in excess of 50 years of life left in the property to supply utility coal for the Anchorage area, or steam coal for export. The Chickaloon district could possibly supply some specialty coal and even anthracite on a small-scale. The aerial extent of the Matanuska field is large so that there is room for yet undiscovered coal at depth.

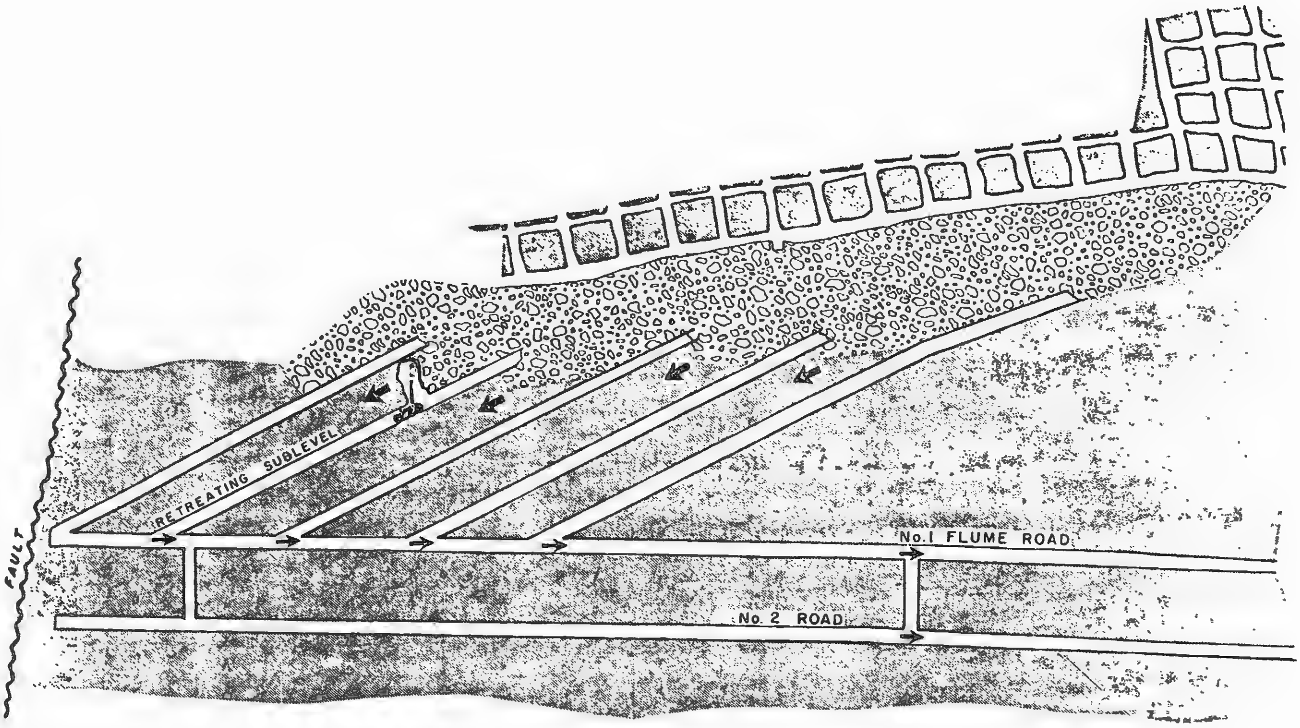


Figure 6 HYDRAULIC MINE PLAN

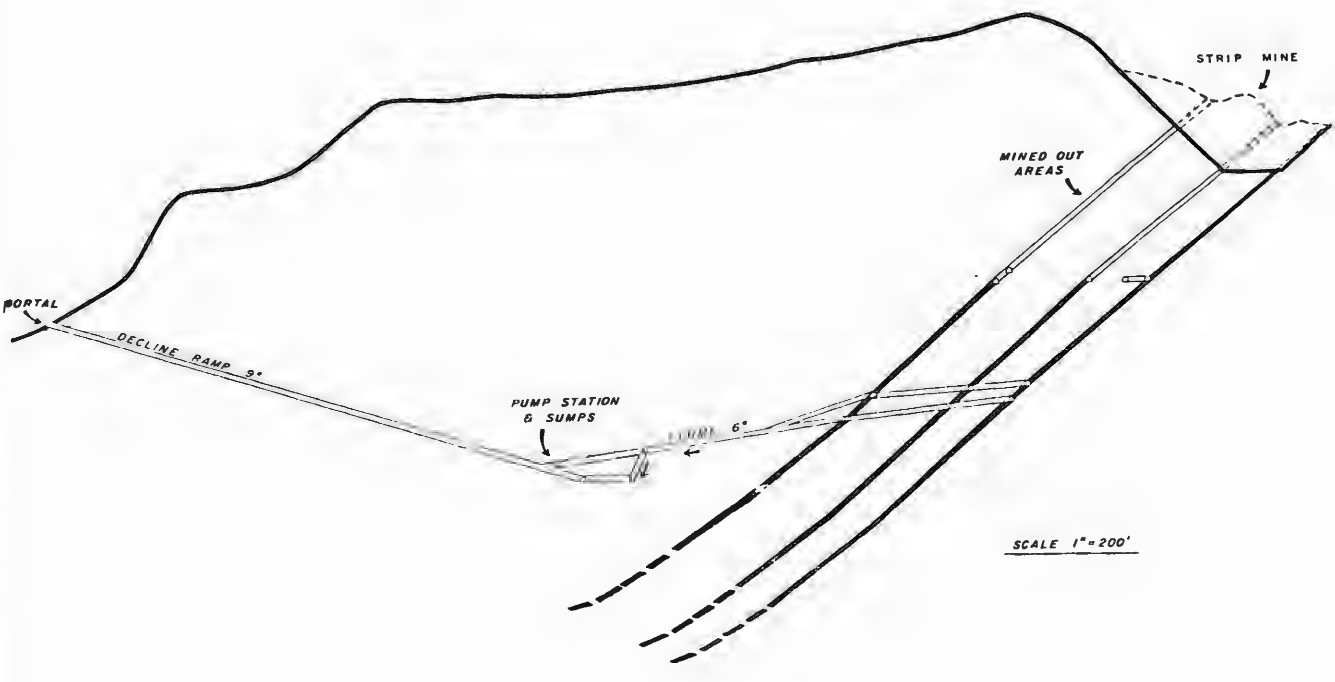


Figure 7 PROPOSED HYDRAULIC MINE LAYOUT

References

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Acknowledgement

The content of this paper is based on a perusal of reports by others, largely the U.S. Geological Survey, the U.S. Bureau of Mines and others, as well as internal company reports.

Reconnaissance survey for coal near Farewell, Alaska

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Abstract

The U.S. Geological Survey conducted reconnaissance surveys for coal in the Farewell area in 1977. Most of the area studied is covered by coarse granular Quaternary sediments, unconformably overlying the Tertiary sedimentary rocks. Outcrops of bedrock are sparse and occur only in river bluffs, a few residual hills in the Deepbank Creek area, and small stream valleys where surficial deposits have been sufficiently eroded to expose the underlying bedrock.

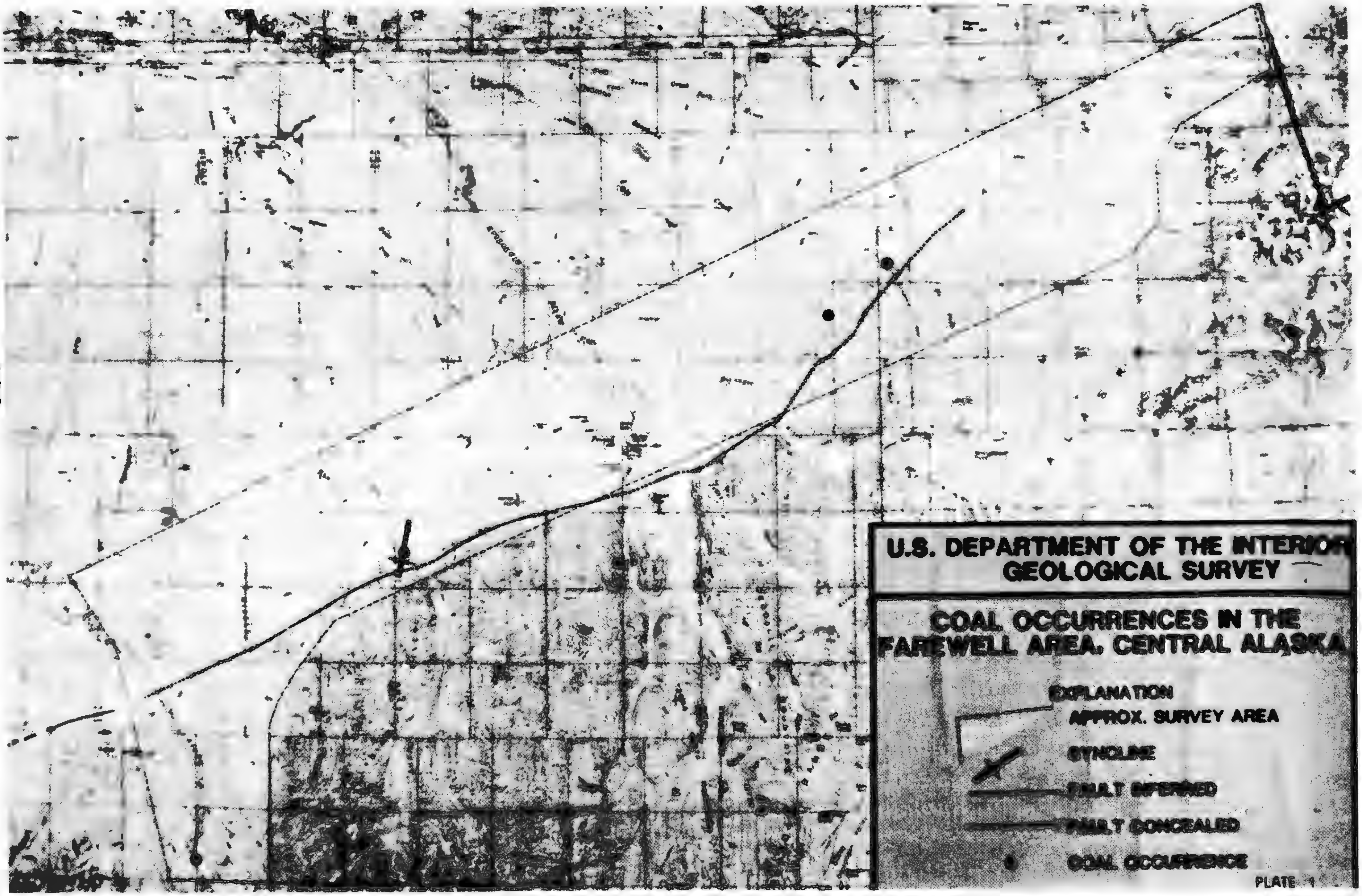
Outcrops of subbituminous coal were found along the Little Tonzona River and along the unnamed tributaries of Deepbank Creek. An outcrop of bony coal was found along the Windy Fork of the Kuskokwim River.

The surveys indicate the presence of a potentially large resource of subbituminous coal in the Farewell area. Neither the areal extent of the coal bearing rocks nor the maximum depth of their burial is known. If the steep dips recorded at the outcrops are regionally representative, most of the resource would lie far below the surface; however, the observed attitudes may simply reflect localized tilting and faulting adjacent to the Farewell fault.

Introduction

A reconnaissance survey for coal was conducted in August 1977 by the U.S. Geological Survey in the Minchumina basin around Farewell, Alaska. The survey area is along the northern front of the Alaska Range from Big River to the western boundary of Mt. McKinley National Park (pl. 1). Survey work was hampered by dense smoke from a large forest tundra fire in the area.

Most of the area studied is covered with coarse granular Quaternary sediments that unconformably overlie Tertiary sedimentary rocks. Outcrops of bedrock are sparse and occur only in river bluffs, a few residual hills in the Deepbank Creek area, and small stream valleys where the surficial deposits have been sufficiently eroded to expose the underlying bedrock.


U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
COAL OCCURRENCES IN THE
FAREWELL AREA, CENTRAL ALASKA
EXPLANATION
APPROX. SURVEY AREA
SYNCLINE
FAULT INFERRED
FAULT CONCEALED
COAL OCCURRENCE
PLATE 1

ERA Helicopters, Inc., of Anchorage, Alaska, supplied contract helicopter support. Field operations were based at Farewell Lake Lodge. Sample analyses were performed by the Department of Energy (formerly the Bureau of Mines) Coal Laboratory in Pittsburgh, Pennsylvania.

Previous Investigations

Coal bearing rocks were found in the Farewell area by Brooks (1911) in 1902 when he traversed the northern foothills of the Alaska Range from the South Fork of the Kuskokwim River to Mt. McKinley. Brooks mapped small enfolded exposures of Tertiary rocks in the valleys of the Little Tonzona River and Pingston Creek and also reported coal outcrops immediately southwest of the junction of the two forks of the Kuskokwim River. Priestly reported considerable quantities of lignitic coal exposed in the Big River valley (Brooks 1910, 1911 and 1925).

Fernald (1960) briefly described the surficial geology of the Farewell area and located the Farewell fault but did not identify any Tertiary rocks or coal. Sainsbury and MacKevett (1965) reported thick, nonmarine sedimentary rocks near the White Mountain mercury mines. W.H. Condon reported coal bearing rocks exposed for several kilometers along the Cheeneetnuk River, including a 2 meter wide exposure of bright, brittle coal of probable bituminous rank (Barnes, 1967).

Gary Player (written communication, 1970) conducted a reconnaissance survey of the Farewell area in 1970 and reported exposures of Tertiay coal bearing rocks from the Big River to the Little Tonzona River. A 59 meter sequence of coal bearing rocks was reported along the Little Tonzona River. Thirty meters of this sequence was described as clean, subbituminous coal. Player reported a second exposure of coal bearing rocks along the banks of an unnamed tributary of Deepbank Creek. Float and outcrops suggest at least one bed of coal, 6 meters or more thick, there.

Geologic Setting

The area described is on the southeastern edge of a gently sloping piedmont surface north of the Alaska Range. The piedmont merges into the lowlands of the upper Kuskokwim River valley. The piedmont and the lowlands form the Minchumina basin, which is part of an area of low relief stretching from the upper Tanana basin in the north to the Holitna lowlands in the southwest. Most of the piedmont and lowlands is covered with coarse granular sediments deposited in glacial moraines, outwash slopes, flood plains and alluvial fans (Fernald, 1960). Outcrops of bedrock are limited to residual hills, river bluffs and stream valleys where erosion of surficial gravels has exposed the bedrock.

The Farewell fault separates the Minchumina basin from the Alaska Range. This right lateral strike slip fault is part of the Denali fault system. The Farewell fault is the major structural feature in the area and is thought to be responsible for the tilting and folding of the Tertiary coal bearing sequences that lie north of the fault.

South of the fault, Paleozoic siltstones, argillites and limestones, intruded locally by porphyritic granitic stocks and dikes, form the Alaska Range. North of the fault, Devonian limestones and shales are exposed near White Mountain and the Farewell airstrip, and Tertiary nonmarine coal bearing sequences of conglomerate, sandstone, siltstone, volcanic rock and coal outcrop in scattered places from the Big River to Kantishna.

Rocks immediately south of the Farewell fault are severely deformed, as expressed in the chevron and overturned folds found in the area. Rocks north of the fault appear to be less deformed and are generally tilted and contain minor bedding plane faults as in the Little Tonzona outcrop, or are folded into gentle synclines as in the Windy Fork outcrop.

Coal Occurrence

Outcrops are sparse throughout the region. Few continuously exposed stratigraphic sequences extend more than a few hundred meters. Outcrops of coal were found in stream bank cuts along the Little Tonzona River and along the drainages of the unnamed tributary creeks of Deepbank Creek (plate 1). An outcrop of bony coal (ash content, 30-62 percent) was found along the Windy Fork of the Kuskokwim River.

All samples were collected from hand dug trenches that extended 15 to 60 centimeters into the outcrop. Bed moisture was preserved by sealing samples in polyethylene lined canvas bags.

Little Tonzona River Area

An isolated exposure of Tertiary nonmarine sedimentary rocks crop out along the southwest bank of the Little Tonzona River in Sec. 27, T. 31 N., R. 20 W., Seward Meridian. The Tertiary strata strike N. 73° E. and dip 47°-63° NW. Three minor bedding plane faults with associated drag folds occur in the section (plate 2).

Seven seams of coal, each at least one meter thick, are exposed in this outcrop. Areas of disturbed bedding are not included in the calculations, although they probably represent additional coal beds. Coal samples were taken from shallow trenches and analyzed by the Department of Energy Coal Laboratory in Pittsburgh, Pennsylvania (Table 1). Heating values for the coal ranged from 8,466 to 9,517 Btu per pound on a moist ash free basis and from 7,848 to

DETAIL "B"

DETAIL "A"
DISTURBED AREA

EXPLANATION

SCHEMATIC SECTION OF OUTCROP AT LITTLE TONZONA RIVER

- COAL
- CLAY
- SILTY CLAY
- BONE
- GRAVEL COVER

PLATE 2

Table 1 Coal Analysis (all samples weathered)

A.--Little Tonzona Outcrop T. 31 N., R. 20 W., Section 27, Seward Meridian

Sample #	Thickness (meters)	Dip	USDOE #	FSI**	Sample Conditions*	BTU/lb	Proximate Analysis: Moisture (Mod)	Proximate Analysis: Volatile Matter	Proximate Analysis: Fixed Carbon	Proximate Analysis: Ash	Ultimate Analysis: Hydrogen	Ultimate Analysis: Carbon	Ultimate Analysis: Nitrogen	Ultimate Analysis: Oxygen (Ind)	Ultimate Analysis: Sulfur	Ultimate Analysis: Ash
TS-A-77-1	1.8	35°	K80540	0.5	A	7,848	25.3	35.6	32.3	6.8	6.0	46.9	0.5	38.8	1.0	6.8
					B	10,505	--	47.7	43.1	9.2	4.3	62.8	0.7	21.8	1.3	9.2
					C	11,564	--	52.5	47.5	--	4.7	69.1	0.8	24.0	1.5	--
					D	8,466										
TS-A-77-6	2.7	47°	K80541	0.5	A	8,137	19.1	40.1	30.9	9.9	5.7	48.1	0.7	33.8	1.7	9.9
					B	10,058	--	49.6	38.1	12.3	4.5	59.4	0.9	20.8	2.1	12.3
					C	11,466	--	56.6	43.4	--	5.1	67.7	1.0	23.7	2.4	--
					D	9,111										
TS-A-77-7	1.3	47°	K80542	0.5	A	7,947	22.5	37.9	30.7	8.9	6.1	46.7	0.7	36.5	1.1	8.9
					B	10,259	--	49.0	39.6	11.4	4.6	60.3	0.9	21.3	1.4	11.4
					C	11,586	--	55.3	44.7	--	5.2	68.1	1.0	24.0	1.6	--
					D	8,790										
TS-A-77-8	6.8	47°	K80543	0.5	A	8,295	21.5	41.0	29.8	7.7	6.1	48.4	0.7	35.9	1.2	7.7
					B	10,564	--	52.2	38.0	9.8	4.7	61.6	0.9	21.4	1.6	9.8
					C	11,707	--	57.9	42.1	--	5.2	68.3	1.0	23.7	1.8	--
					D	9,047										
TS-A-77-13	3.1	67°	K80544	0.5	A	8,018	21.5	40.3	30.1	8.1	5.9	47.5	0.6	36.5	1.4	8.1
					B	10,217	--	51.4	38.3	10.3	4.5	60.5	0.8	22.1	1.8	10.3
					C	11,392	--	57.3	42.7	--	5.0	67.5	0.8	24.7	2.0	--
					D	8,784										
TS-A-77-15	2.3	67°	K80545	0.5	A	8,164	16.0	40.7	31.6	11.7	5.4	48.8	0.7	32.1	1.2	11.7
					B	9,724	--	48.5	37.6	13.9	4.3	58.2	0.9	21.3	1.4	13.9
					C	11,295	--	56.3	43.7	--	5.0	67.5	1.0	24.7	1.7	--
					D	9,347										
TS-A-77-16	7.9	67°	K80546	0.5	A	8,022	19.6	40.7	31.8	7.9	5.7	47.9	0.7	36.7	1.1	7.9
					B	9,974	--	50.6	39.5	9.9	4.4	59.5	0.9	24.0	1.4	9.9
					C	11,067	--	56.2	43.8	--	4.9	66.0	1.0	26.6	1.5	--
					D	8,768										
TS-A-77-18	3.7	67°	K80547	0.5	A	8,210	14.5	41.8	32.1	11.6	5.3	48.3	0.5	33.1	1.1	11.6
					B	9,598	--	48.8	37.6	13.6	4.3	56.5	0.6	23.7	1.3	13.6
					C	11,108	--	56.5	43.5	--	5.0	65.4	0.7	27.4	1.5	--
					D	9,388										
TS-A-77-20	4.8	67°	K80548	0.5	A	8,237	15.3	43.6	30.2	10.9	5.4	47.9	0.6	34.4	0.7	10.9
					B	9,728	--	51.5	35.6	12.9	4.4	56.5	0.7	24.5	0.8	12.9
					C	11,169	--	59.1	40.9	--	5.0	64.9	0.9	28.2	1.0	--
					D	9,337										
TS-A-77-22	1.0	67°	K80549	0.5	A	8,075	20.0	42.5	31.1	6.4	5.7	47.8	0.6	38.8	0.7	6.4
					B	10,095	--	53.1	38.9	8.0	4.4	59.8	0.8	26.3	0.9	8.0
					C	10,972	--	57.7	42.3	--	4.7	65.0	0.8	28.6	1.0	--
					D	8,673										

**Free Swelling Index (FSI)

B.--Outcrops in the Deepbank Creek Area - T. 30 N., R. 20 W., Section 13, Seward Meridian

TS-A-77-24	1.4+	38°	K80550	0.5	A	8,186	21.5	36.0	35.9	6.6	5.7	49.1	0.7	37.2	0.7	6.6
					B	10,429	--	45.9	45.7	8.4	4.2	62.5	0.8	23.0	0.9	8.4
					C	11,386	--	50.1	49.9	--	4.6	68.2	0.9	25.1	1.0	--
					D	8,813										
TS-A-77-27	6.3	55°	K80551	0.5	A	8,828	14.7	42.9	35.7	6.7	5.5	52.6	1.0	34.0	0.2	6.7
					B	10,354	--	50.3	41.8	7.9	4.6	61.7	1.2	24.5	0.3	7.9
					C	11,240	--	54.6	45.4	--	5.0	66.9	1.3	26.6	0.3	--
					D	9,517										

C.--Windy Fork Outcrop - Samples are Bony Coal - T. 27 N., R. 26 W., Section 19, Seward Meridian

TS-A-77-29	.5	37°	K80552	0.5	A	6,627	3.3	25.5	28.8	42.4	3.5	38.4	1.2	14.3	0.2	42.4
					B	6,856	--	26.4	29.7	43.9	3.2	39.7	1.3	11.7	0.2	43.9
					C	12,212	--	47.1	52.9	--	5.7	70.8	2.2	20.9	0.3	--
					D	12,232										
TS-A-77-32	2.7	40°	K80553	0.5	A	4,123	3.4	29.6	8.9	58.1	2.5	26.2	0.6	12.5	0.1	58.1
					B	4,270	--	30.6	9.2	60.2	2.2	27.1	0.6	9.8	0.1	60.2
					C	10,724	--	76.9	23.1	--	5.6	68.1	1.5	24.6	0.3	--
					D	11,071										
TS-A-77-35	2.9	40°	K80554	0.5	A	6,357	3.7	24.5	28.4	43.4	3.4	38.4	0.9	13.8	0.2	43.4
					B	6,602	--	25.4	29.6	45.0	3.1	39.9	0.9	10.9	0.2	45.0
					C	12,013	--	46.3	53.7	--	5.6	72.5	1.7	19.8	0.3	--
					D	11,971										
TS-A-77-37	6.3	40°	K80555	0.5	A	5,551	2.5	23.8	22.8	50.9	3.2	32.9	0.9	12.0	0.2	50.9
					B	5,694	--	24.4	23.4	52.2	2.9	33.7	0.9	10.0	0.2	52.2
					C	11,910	--	51.0	49.0	--	6.2	70.5	1.9	21.0	0.5	--
					D	12,336										
TS-A-77-39	4.6	40°	K80556	0.5	A	7,228	3.5	26.8	30.2	39.5	3.7	41.4	1.0	14.1	0.3	39.5
					B	7,487	--	27.7	31.4	40.9	3.4	42.9	1.1	11.4	0.3	40.9
					C	12,671	--	46.9	53.1	--	5.8	72.5	1.8	19.3	0.6	--
					D	12,616										
TS-A-77-41	10.5	40°	K80557	0.5	A	5,981	2.8	23.4	26.5	47.3	3.3	35.8	0.9	12.4	0.2	47.3
					B	6,153	--	24.0	27.3	48.7	3.1	36.8	0.9	10.2	0.2	48.7
					C	11,994	--	46.9	53.1	--	6.0	71.8	1.8	19.9	0.4	--
					D	12,234										
TS-A-77-43	3.9	40°	K80558	0.5	A	3,968	1.9	18.7	16.6	62.8	2.5	23.9	0.7	10.1	0.1	62.8
					B	4,043	--	19.1	16.9	64.0	2.3	24.3	0.7	8.6	0.1	64.0
					C	11,224	--	53.0	47.0	--	6.4	67.6	2.0	23.9	0.2	--
					D	12,338										
TS-A-77-45	5.2	40°	K80559	0.5	A	8,438	3.7	31.2	35.2	29.9	4.2	48.7	1.2	15.6	0.4	29.9
					B	8,766	--	32.5	36.5	31.0	3.9	50.6	1.2	12.8	0.4	31.0
					C	12,711	--	47.1	52.9	--	5.7	73.4	1.8	18.5	0.6	--
					D	12,473										
TS-A-77-50	2.2	39°	K80560	0.5	A	5,504	4.0	24.8	23.5	47.7	3.3	33.6	1.3	13.7	0.4	47.7
					B	5,735	--	25.8	24.5	49.7	2.9	35.0	1.4	10.5	0.4	49.7
					C	11,409	--	51.3	48.7	--	5.9	69.6	2.8	21.0	0.8	--
					D	11,363										

* Sample Conditions:
A - As received
B - Moisture Free
C - Moisture-Ash Free
D - Moist-Ash Free, calculated using Moist, Mm-free Btu = (Btu - 50S)/[100 - (1.08A + 0.55S)] x 100 using values from the as received analysis

8,295 Btu per pound on an as received basis. Sulfur content varied considerably from bed to bed, ranging from 0.7 percent to 1.7 percent (as received). The outcrop is described in detail below.

Outcrop Description in the Little Tonzona River Area
(from youngest to oldest)

Lithology	Description	Measured Thickness (meters)
Coal	Dull, grayish brown; amber inclusions 1-2 mm in diameter; very woody with whole log casts visible; sample #TS-A-77-22; top of bed not exposed.	1.0
Clay	Dark gray; silty; highly plastic.	1.1
Coal	Dull, grayish brown to black; numerous amber inclusions 1-2 mm in diameter; very woody, especially in the upper portion of the bed with log casts visible; 0.3 meter bony coal parting occurs 3.7 meters above base of unit; sample #TS-A-77-20 was taken above the the parting and sample #TS-A-77-18 was taken below the parting; overall equivalent thickness of coal for classification standards is 8.2 meters.	8.8
Clay	Light gray to brown, highly plastic, little or no silt content. Bottom of clay not exposed.	0.2
Covered	Coal float in moderate quantity.	4.3
Fault zone	Mostly composed of folded and/or pulverized coal with some clay partings; amount and direction of displacement unknown. (See p1, 2A)	3.9
Covered	Gravel cover.	0.6
Coal	Reddish brown; moderately woody with some areas of vitrain present; coal is uniform throughout bed with no partings present; sample #TS-A-77-16; top and bottom of bed not exposed.	7.9

Lithology	Description	Measured Thickness (meters)
Covered	Gravel cover.	1.2
Fault zone	Folded and faulted clay and coal; coal is pulverized; no indication of large-scale offset.	2.54
Clay	Dark gray to black; silty; plastic.	0.9
Coal	Dark gray to brown; moderately woody, especially in the upper part of the unit; bands of vitrain present, especially in lower part of unit; 10 centimeter, light gray, highly plastic clay parting occurs 3.4 meters from bottom of the unit; sample #TS-A-77-15 was taken above the parting and sample #TS-A-77-13 was taken below the parting. Strike is N. 73° E., dip 67° NW. Overall equivalent thickness of coal for classification standards is 5.3 meters.	5.9
Fault zone	Highly contorted coal and clay; coal is pulverized and folded; thin layer of gravel, similar to overlying gravels, underlies distorted beds; no evidence of repeated section. Overlying coal seems to be a continuation of the same bed as the coal involved in the folding (see pl. 2B).	0.9
Clay	Light gray; highly plastic; little or no silt content.	0.08
Coal	Dull brown, with bright bands of vitrain; two dark gray, highly plastic clay partings, one 2.4 cm thick, 4.3 m above the base, and the other 1.2 cm thick, 3.9 m from the base of the unit; ironstone concretions less than 5% by volume; sample #TS-A-77-8; bottom of bed not exposed; overall equivalent thickness of coal for classification standards is 6.7 meters.	6.8
Covered	Gravel cover; 20% of float is coal.	13

Lithology	Description	Measured Thickness (meters)
Coal	Dull-dark-brown, with numerous bands of vitrain. Two dark gray, highly plastic, silty clay partings: one is 0.15 meters thick and occurs 1.3 meters stratigraphically above the base of the bed; the other is 0.2 meters thick and occurs 2.7 meters above the base of the bed. Sample #TS-A-77-7 was taken in the upper 1.3 meters of coal. Sample #TS-A-77-6 was taken in the lower 2.7 meters of coal. Overall equivalent thickness of coal for classification standards is 3.5 meters.	4.2
Clay	Light gray; highly plastic, little or no silt; bottom of clay bed not exposed.	0.3
Covered	Gravel cover; 40% of float is coal.	19
Coal	Dull-gray-black; very woody; bedding somewhat distorted, with minor undulations present; strike is N. 38° E., dip 35° NW.; sample #TS-A-77-1; top and bottom of bed not fully exposed.	1.8

Summary and Comparison of Little Tonzona Coals

Seven coal beds, each at least 1.0 meter thick, were measured in the Little Tonzona outcrop. Calculated on the basis of U.S. Geological Survey Circular 633 (Bass, Smith and Horn, 1970), these coals yield an aggregate thickness of 34.5 meters, or approximately 41 percent of the measured interval. Of the remaining 49.5 meters of interval, 38.1 meters were covered--the underlying bedrock could not be determined, and 7.3 meters were in faulted areas.

Analyses (Table 1) indicates that, except for the sulfur content, the coal is similar in rank and quality to Tertiary Alaskan coals in the Nenana field; the Little Tonzona coal contains about three times the percentage of sulfur in coal from the Nenana field.

Upper Tributaries of Deepbank Creek Area

Outcrops are sparse through Sec. 13, T. 30 N., R. 20 W., Seward Meridian. Coal beds are the dominant outcrop forming rock, usually occurring in 1 to 1.5 meter outcrops of highly weathered coal. Complete thickness was almost impossible to ascertain, owing to heavy vegetative cover. Samples were taken on a 1.4 meter bed and a 6.3 meter bed. The two measured outcrops are described below.

First Outcrop in the Deepbank Creek Area

Lithology	Description	Measured Thickness (meters)
Coal	Highly weathered; reddish brown; vitreous; weathers into large flat plates; strike N. 35° E., dip 38° NW.; sample #TS-A-77-24; top and bottom of bed not exposed.	1.4

The second outcrop sampled is along the east bank of another tributary of Deepbank Creek, Sec. 13, T. 30 N., R. 20 W., Seward Meridian, where a 7.9 meter section is exposed around a small knoll and in a stream channel (pl. 3).

Second Outcrop in Deepbank Creek Area
(from youngest to oldest)

Lithology	Description	Measured Thickness (meters)
Coal	Dark-gray-black; vitreous, lower part of coal increasingly woody, coal surfaces are slickensided; strike N. 60° E., dip 48-55° NW.; sample #TS-A-77-27; top of bed not exposed.	6.3
Shale	Very dark gray; carbonaceous; bottom of bed not exposed.	1.6

EXPLANATION

SCHEMATIC SECTION OF OUTCROP AT UNNAMED TRIBUTARY OF DEEPBANK CREEK

- COAL
- SHALE
- CONGLOMERATE

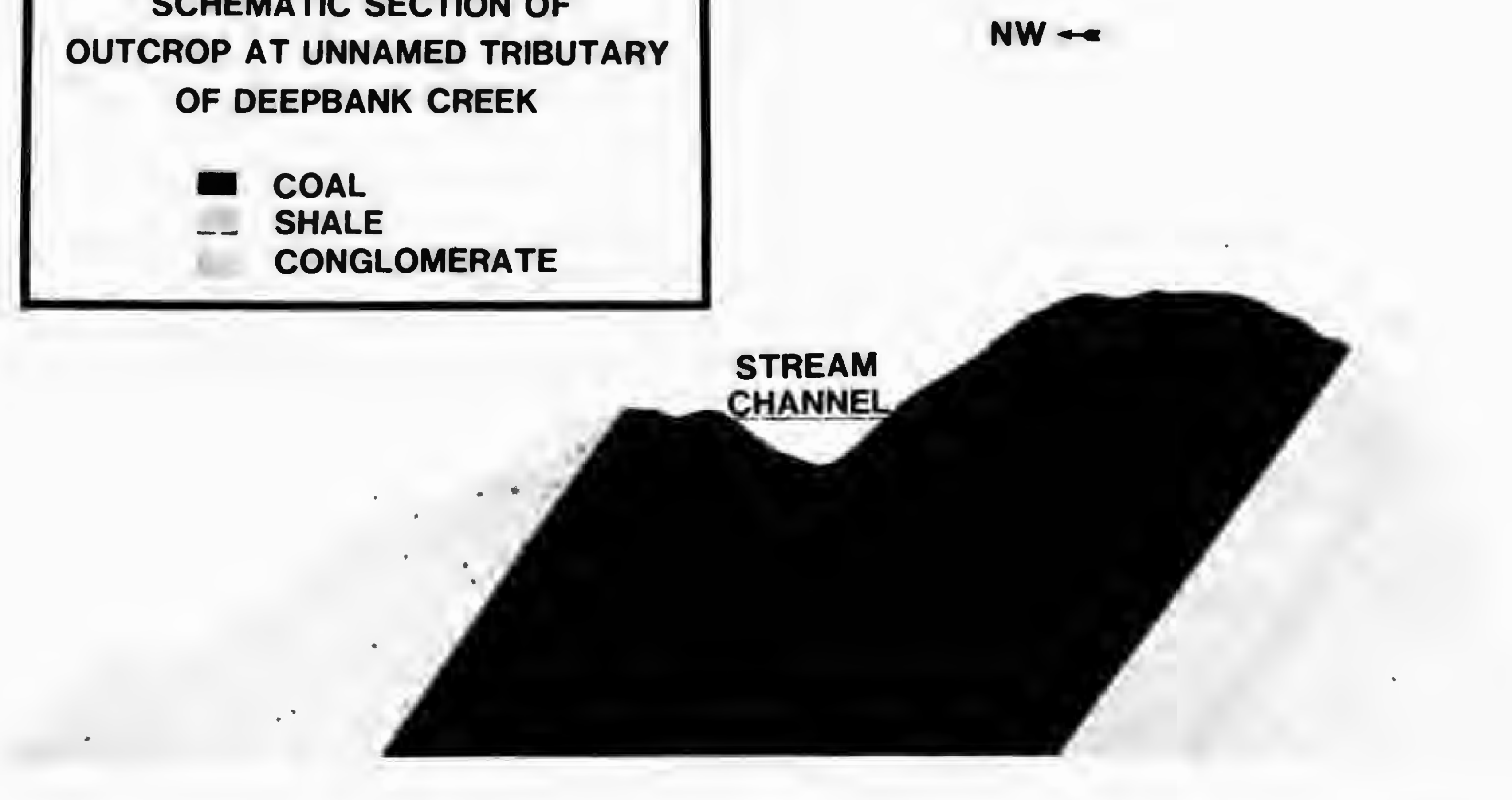


PLATE 3

Summary and Comparison of Deepbank Creek Coals

Weathered samples (Table 1) taken from outcrops along the upper tributaries of Deepbank Creek are comparable in rank and quality to Tertiary Alaskan coals of the Nenana field. The sulfur content is lower than for the coals from Little Tonzona and is roughly the same or slightly higher than for the Nenana coal. The dip of bedding is steep (48-55°); however, owing to the proximity of the outcrop areas to the Farewell fault, the steep dips recorded may not be representative of regional structural attitudes. Additional information from drilling would be necessary to determine both the structural configuration and thickness variation of the coal as it extends into the Minchumina Basin.

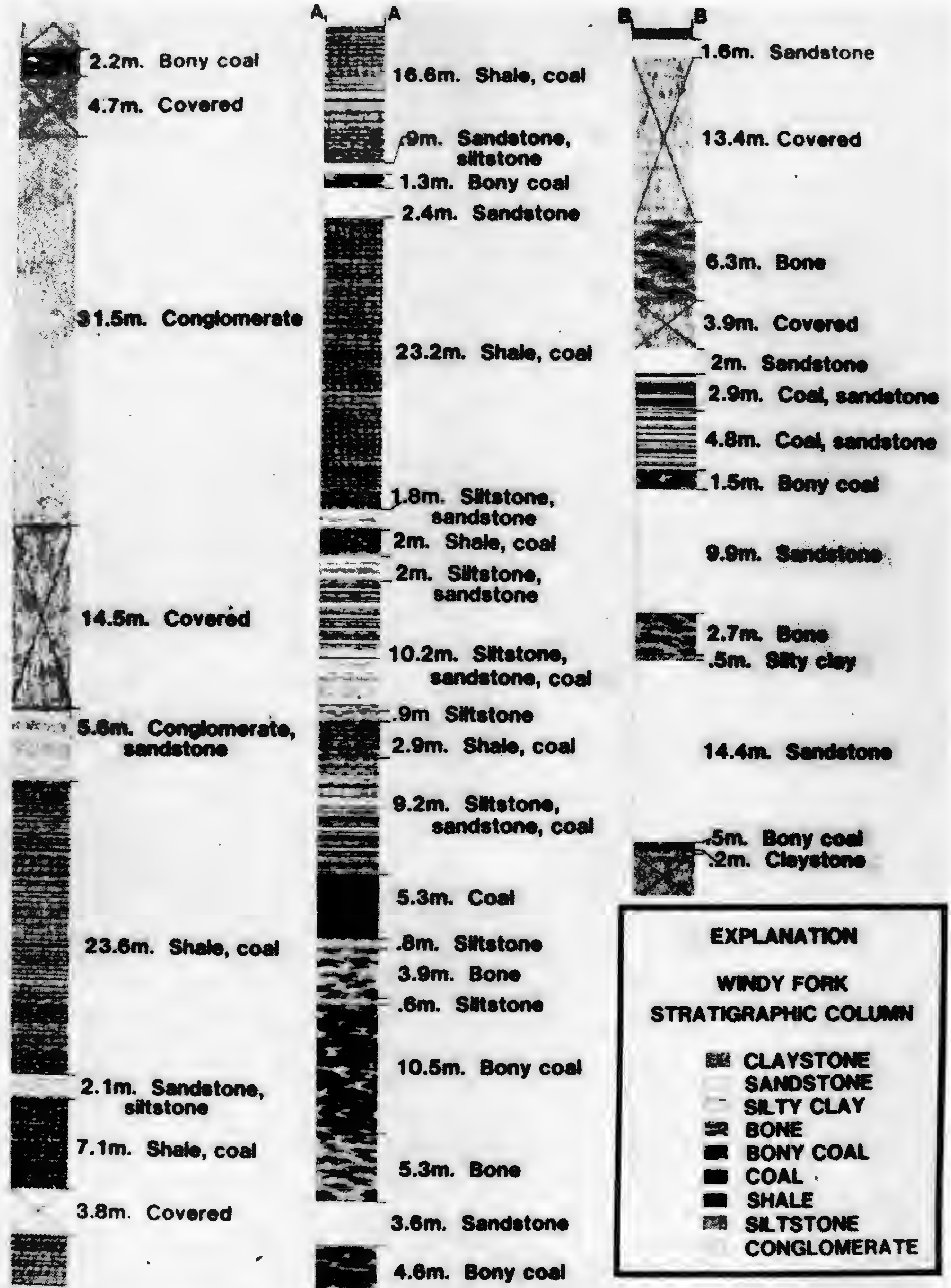
Windy Fork Area

Thick beds of bony slickensided coal crop out along the west bank of the Windy Fork of the Kuskokwim River.

A stratigraphic section was measured in the west limb of a north trending syncline. Conglomerate, sandstone, siltstone and bony coal are the dominant components of the 267.5 meters of section measured. The section is described below and illustrated on Plate 4. The sample analyses are in Table 1.

Measured Stratigraphic Section in the Windy Fork Area
(from youngest to oldest)

Lithology	Description	Measured Thickness (meters)
Bony coal	Dull black with bands of vitreous material; slickensided; interval of high vitrinous material in the center 0.6 meters of bed; strike is N. 30° W., dip is 39° NE.; sample #TS-A-77-50; top and bottom of bed not exposed.	2.2
Covered	Gravel and vegetation cover.	4.7
Conglomerate	Light brown to tan; contains sandstone stringers; sandstone stringers become part of a fining upward sequence from pebble conglomerate to fine grained sandstone in upper third of the bed; contains wood fragments and fragments of coal as lag deposits;	31.5


2.2m. Bony coal
4.7m. Covered
31.5m. Conglomerate
14.5m. Covered
5.6m. Conglomerate, sandstone
23.6m. Shale, coal
2.1m. Sandstone, siltstone
7.1m. Shale, coal
3.8m. Covered
A A
A, A
16.6m. Shale, coal
.9m. Sandstone, siltstone
1.3m. Bony coal
2.4m. Sandstone
23.2m. Shale, coal
1.8m. Siltstone, sandstone
2m. Shale, coal
2m. Siltstone, sandstone
10.2m. Siltstone, sandstone, coal
.9m Siltstone
2.9m. Shale, coal
9.2m. Siltstone, sandstone, coal
5.3m. Coal
.8m. Siltstone
3.9m. Bone
.6m. Siltstone
10.5m. Bony coal
5.3m. Bone
3.6m. Sandstone
4.6m. Bony coal
B B
B B
1.6m. Sandstone
13.4m. Covered
6.3m. Bone
3.9m. Covered
2m. Sandstone
2.9m. Coal, sandstone
4.8m. Coal, sandstone
1.5m. Bony coal
9.9m. Sandstone
2.7m. Bone
.5m. Silty clay
14.4m. Sandstone
.5m. Bony coal
.2m. Claystone
EXPLANATION
WINDY FORK
STRATIGRAPHIC COLUMN
CLAYSTONE
SANDSTONE
SILTY CLAY
BONE
BONY COAL
COAL
SHALE
SILTSTONE
CONGLOMERATE

Lithology	Description	Measured Thickness (meters)
Conglomerate (continued)	channel deposits identifiable; upper and lower contacts not exposed.	
Covered	Gravel and vegetation cover.	14.5
Conglomerate, sandstone	Cobble to pebble conglomerate, grading upward into a medium to fine grained sandstone. Gradational sequence repeated several times. Conglomerate is light brown to tan, subangular to subrounded; sandstone is light brown to tan, top of bed not exposed.	5.6
Coal, shale	Interbedded, individual beds 2 to 4 centimeters thick; coal frequently has bright bands of vitrain; shale is dull-gray-black carbonaceous; coal comprises 85% of upper half of unit and 40% of lower half; strike N. 30° W.; dip 41° NE.; top of interval not exposed.	23.6
Sandstone, siltstone	Gray weathering to brown; sandstone is fine siltstone to medium grained and grades upward into siltstone.	2.1
Shale, coal	Interbedded, beds 2-4 cm thick; coal frequently has bright bands of vitrain; shale is dull-gray-black, carbonaceous; 40-50% coal; bottom of bed not exposed.	7.1
Covered	Heavy vegetation cover.	3.8
Coal, shale	Interbedded, beds 3-5 cm thick; coal has numerous bright bands of vitrain; shale is dull-gray-black, carbonaceous; coal comprises 85% of upper half and 40% of lower half; strike N. 30° W., dip 41° NE.; top of interval not exposed.	16.6
Sandstone, siltstone	Sandstone is light gray to tan, very fine grained, grades upward into a light gray siltstone.	0.9

Bony coal	Contains fine grained sandstone lenses; slickensided; bony coal intervals from 5-35 cm thick.	1.3
Sandstone	Light gray to tan; plant fossils; sandstone is coarse grained in lower portion and becomes finer upward, gradational contact with bony coal.	2.4
Shale, coal	Interbedded; individual beds 2-60 cm thick; coal is dull-gray-black with some bands of vitrain, comprises 30% of the interval.	23.2
Siltstone, sandstone	Siltstone is gray, weathering to brown; sandstone is medium grained; contains plant fossils and thin coal stringers.	1.8
Shale, coal	Interbedded shale and coal; 30-40% coal.	2.0
Siltstone, sandstone	Interbedded; siltstone is gray, weathering to brown; sandstone is gray, weathering to brown, medium grained, contains plant fossils and thin coal stringers.	2.0
Siltstone, sandstone, coal	Interbedded; coal 10% in lower part and up to 60% in upper; sequence grades upward into overlying sandstone.	10.2
Siltstone	Dark gray, weathering to brown; contains sandstone stringers and plant fossils.	0.9
Coal, shale	Interbedded; individual beds 2-10 cm thick; coal is dull brown, with some bands of vitrain; shale is dark gray. Coal comprises approximately 75% of the total bed.	2.9
Siltstone, sandstone, coal	Interbedded; individual beds less than 10 cm thick; vitreous coal makes up 50% of the interval; gray fossiliferous brown weathering siltstone makes up 20% of the lower half of the unit, increasing to 40% in the upper half of the unit; fine grained, gray sandstone is 30% of the lower half of the unit, decreasing to 10% in the upper half of the unit.	9.2
Coal	Vitreous; highly fractured; slickensided; a 0.1 m fossiliferous siltstone parting 0.8 m above base is gray weath-	5.3

Lithology	Description	Measured Thickness (meters)
Coal (continued)	ering to brown. Sample #TS-A-77-45; overall thickness of coal for classification standards is 5.1 m.	
Siltstone	Gray, weathering to brown; fossiliferous.	0.8
Bone	Carbonaceous shale with coal; coal fragments vitreous, slickensided, carbonaceous shale dull black, slickensided; sample #TS-A-77-43.	3.9
Siltstone	Dark gray; carbonaceous; contains wood and plant fragments.	0.6
Bony coal	Dull-gray-black with bright bands of vitrain; fragmented, slickensided; contains 10% sandstone lenses and partings; sample #TS-A-77-41.	10.5
Bony shale	Dark gray, with bands of vitrain; 60% shale, 40% coal.	5.3
Sandstone	Dark gray, weathering to light gray; fine grained.	3.6
Bony coal	Dull-gray-black with numerous bands of vitrain; slickensided; contains 10% partings of sandstone and shale, with sandstone partings more numerous near top; sample #TS-A-77-39.	4.6
Sandstone	Dark gray, weathering to buff gray; fine to medium grained.	1.6
Covered	Coal float present.	13.4
Bone	Dull gray with bands of vitrain; slickensided; sample #TS-A-77-37; top and bottom of bed not exposed.	6.3
Covered	Coal float present.	3.9
Sandstone	Gray brown, weathering dark brown to tan; medium grained; contains plant fossils.	2.0

Lithology	Description	Measured Thickness (meters)
Coal, sandstone	Dull gray with vitrain bands; contains thin stringers of sandstones; thickness of individual coals range from 2-10 cm thick; sample #TS-A-77-35.	2.9
Coal, sandstone	Interbedded; coal is highly fractured, slickensided, vitreous; sandstone is grayish brown, fine grained.	4.8
Bony coal	Dull-gray-brown; woody; contains concretions of ironstone up to 30 centimeters in diameter.	1.5
Sandstone	Grayish brown, weathering to light brown, fine grained.	9.9
Bone	Dull-gray-black with bands of vitrain; numerous clay partings; sample #TS-A-77-32.	2.7
Siltstone	Dark gray, weathering to light gray; contains wood fragments; coarsens downward into very fine grained sandstone.	0.5
Sandstone	Dark gray, weathering to light gray or tan; very fine grained; strike N. 20° E., dip 37° SE.	14.4
Bony coal	Numerous clay partings (10%); sample #TS-A-77-39.	0.5
Claystone	Light gray; contains wood fragments; bottom of bed not exposed.	0.2

Summary and Conclusions

The data indicate the presence of a large resource of subbituminous coal in the Farewell area. Neither the areal extent of the coal bearing rocks nor the maximum depth of their burial is known. If the steep dips recorded at the outcrop are regionally representative, most of the resource would lie far below the surface, and mining by conventional methods would probably not be economic; however, the observed attitudes may simply reflect localized tilting and faulting adjacent to the Farewell fault.

The presence of bituminous coal on Windy Fork, as well as reports of bituminous coal farther southwest along the Cheeneetnuk River, suggests that the coal tends to increase in rank southwestward from the Little Tonzona River outcrop.

The extent, depth of burial and actual (unweathered) quality of the coals in the area cannot be determined without drilling.

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Mining, processing and marketing of coal from Jarvis Creek Field

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The Jarvis Creek Coal Field is located on the north peak of the Alaska Range about 30 miles south of Big Delta, Alaska. The field includes about 16 square miles. Access is available by gravel road.

Wahrhaftig and Hickox (1955) estimated 5.9 million tons of indicated coal and 7.5 million tons of inferred coal were available. They correlated the Jarvis Creek coal bearing rocks with those in the Nenana field.

In 1970 the U S. Bureau of Mines conducted limited drilling. Further drilling was done by Owen, Loveless and Associates in 1977, which blocked out more than 1 million tons of strippable coal.

The coal is subbituminous C, with a heating value between 8,000 and 9,000 Btu per pound and an ash content of 5% to 13%. From bottom to top of the mining section, the sequence includes 10 feet of coal, 5 feet of interburden, 2 feet of coal, 1 foot of interburden, 2 feet of coal, 1 foot of interburden, and 2 feet of coal. The section has a strike length of 4500 feet and a width of about 400 feet. The 10 foot seam requires no washing. Since the material above this seam must be stripped anyway, coal from the thinner seams should be washed. Some washability tests have already been run. Present plans call for crushing to minus two inches and washing the minus 2".

From the recent drilling program a mine plan for Jarvis Creek is proposed that would include stripping and production of 500 tons of coal per day on a seasonal basis from May through September. Current reserve estimates indicate a 20 year mine life with a stripping ratio of 5 to 1. Coal preparation would initially be limited to crushing and screening, with washing initiated later.

Mining, coal preparation and support facility capital costs are estimated for 0, 5, 10 and 15 years and are 1.4, 1.1, 1.7 and 1.6 million dollars respectively. Estimated annual operating costs for the operation are approximately 1.7 million dollars.

Local coal production will provide less expensive energy for Alaskans, and will also produce local jobs and allow cash assets to remain in local communities.

The full text of this presentation will be published as a supplement to these proceedings.

Coal for Alaska Villages

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Introduction

On the world scene, wood was used for heating through the 17th century. With the advent of the industrial revolution in the 18th century, coal began to replace wood. By the late 1880s it was the dominant fuel. In the middle half of the 20th century, oil replaced coal and dominated the fuels market, almost completely replacing coal in the transportation segment of industry. Today price controls and the high price of oil have again focused attention on coal.

The use of coal in Alaska lagged behind that of the rest of the U.S. during the early part of the 20th century. By 1947 the importance of coal in the U.S. and the world was declining. In Alaska, however, coal use and production increased from 100,000 to 900,000 tons per year from 1938-67. Although the steam powered river boats and mining ventures operating around the turn of the century used wood, coal did play an important part in Alaska's development.

Coal was an important fuel in the Chignik fishery, and a coal mine operated at Chignik from 1880 until about 1914. In rural Alaska as many as 20 coal mines were in operation in 1910, and probably more than 60 coal mines have operated and closed in Alaska (Fig. 1). The village of Wainwright mined coal on the Kuk River as illustrated in Figure 2. Coal from the Meade River mine provided fuel for Barrow until 1947. Other villages mined or scavenged coal from Alaska's beaches and riverbanks until wood and coal were replaced by oil. Many individuals, particularly on the Kenai Peninsula and near Wainwright, still scavenge coal.

In Alaska's villages the need for fuel for home heating increased as the design of native homes changed from sod huts to the more conventional types with more space and less insulation. The increased demand for energy in these villages and the escalating price of oil may force a return to coal usage.

Fuel Pricing

The pricing of oil and coal is complex because both vary greatly in physical and chemical properties. The price of oil is influ-

Figure 1. A coal mine operating near Cape Lisburne in northwestern Alaska in 1904 (Collier, 1906).

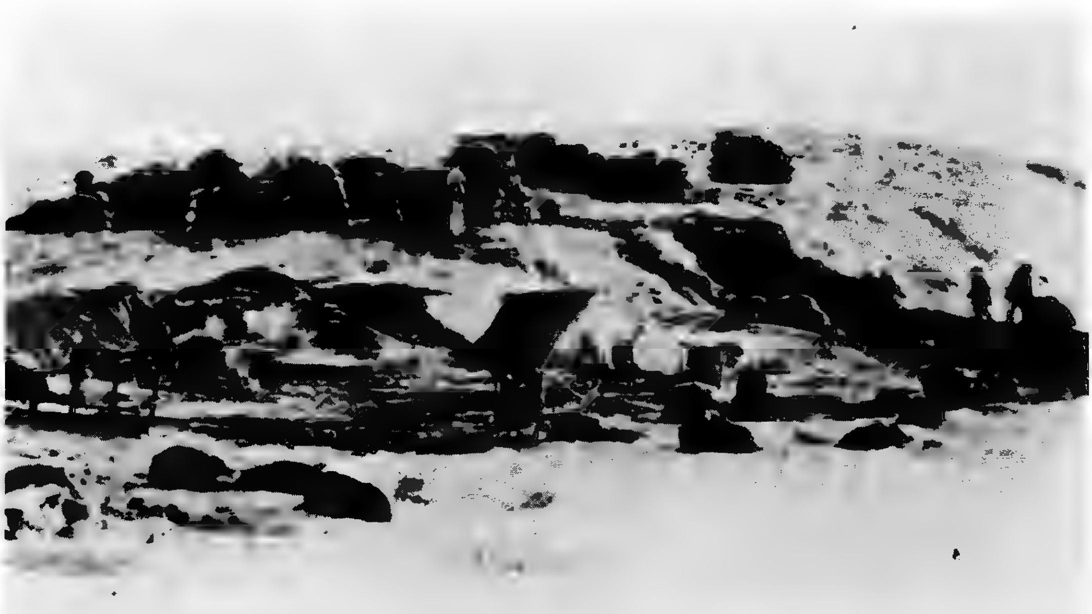

Figure 2. Mining and sacking coal on the Kuk River south of Wainwright, Alaska prior to 1930 (Smith and Mertie, 1930).

enced by specific gravity, which is expressed in degrees according to an American Petroleum Institute formula. Low sulfur "sweet" oil demands a premium price over high sulfur "sour" oil. Oil is subject to both international and domestic price controls, based on an artificially controlled OPEC price. Table 1 indicates selected world oil prices as of September 1, 1980.

Crude oil was in adequate supply and at a fairly constant average price of about $3.00 per barrel during the 1960s (about $0.54/million British thermal units (MBtus)). In 1973 OPEC abruptly increased the price of crude oil from $3.01 to $5.11 and then to $11.65 per barrel. This was the beginning of a rapidly escalating price for oil and a dual pricing system in the U.S. Today's OPEC base price is $30.00 per barrel with an average price of about $32.00 per barrel ($5.52 per MBtus), an increase of over 1,000 percent in current dollars. Figure 3 shows the dramatic price increase of world oil from 1978 to date.

In general coal prices are a producer to supplier negotiated contract price per ton, but cost per ton may be misleading in evaluating coal as a fuel. On a comparative basis (dollars per Btus) the price is influenced by the rank of coal, which may vary from less than 6,000 Btus for lignite to over 14,000 Btus for a low volatile bituminous or semianthracite coal. Coal costs also vary according to producing area, from a low of about $5.00 per ton in Montana and South Dakota to a high of $56.00 per ton in Arkansas. Because lower rank coals are usually mined at lower cost, this also affects the cost per ton. For valid comparison, fuels must be evaluated on a MBtu basis.

Coal has not increased in price as dramatically as oil. In 1970 the average U.S. price of coal was about $7.00 per ton for 12,200 Btu coal ($0.28 per MBtus). The price of coal has increased in current dollars to about $30.00 per ton for an 11,000 Btu coal ($1.37 per MBtus). Figure 3 indicates the increase in price per MBtus and the widening cost gap that favors coal as a fuel.

There is only one direct comparison of oil vs. coal in Alaska. Coal is available on the retail market in Fairbanks at $46.00 per ton for an 8,000 Btu coal ($2.87 per MBtus). Heating oil is available at $1.05 per gallon ($7.01 per MBtus). Thus coal is about 60 percent less expensive than oil in Fairbanks. The fuel savings for some Alaskan villages could be much greater with a change from oil to coal, especially for those near coal fields or convenient shipping routes.

Alaska Coal Fields

Figure 4 shows the location of Alaskan coal fields. Alaska has two major coal fields, the Northern field and the Cook Inlet-Susitna field. There are lesser but still large coal fields in many other areas of the state. Coals in small fields such as

Table 1. Selected world crude prices ($/bbl)
(from Oil and Gas Journal)

Saudi light 34°	30.00
United Arab Emirates-Murban 39°	31.56
Iranian light 34°	35.00
Iraq--Basrah light 35°	31.96
Kuwait blend 31°	31.50
Algeria Saharan 44°	37.00
Nigeria--Bonny light 37°	37.00
Libyan Es Sider 37°	36.78
Indonesia--Minas 34°	31.50
Venezuela--Tia Juana 26°	29.88
Ecuador--Oriente 30°	34.08
*United Kingdom--Forties 36.5°	36.25
*Norway--Ekofish 42°	37.15
*Mexico--Isthmus 34°	34.50
Malaysia--Miri 38°	36.30
*Canadian heavy 22°	30.90
*U.S.S.R.--Romash-Kinskaya 32.4°	36.00

*Not members of the Organization of Petroleum Export Countries (OPEC) nations. Prices are F.O.B. point of loading. The weighted price of foreign oil delivered to the U.S. is about $32.00 per barrel.

The U.S. also controls the price of oil and although the present average price is about $17.00 per barrel, some U.S. oil companies demand and receive above-OPEC prices, as illustrated in table 2.

Table 2. Selected U.S. crude prices ($/bbl)

Alaska--North Slope upper tier 27°	14.27
North Slope free market 27°	20.76
Cook Inlet (Drift River) 35°	33.28
California heavy (Kern River) 13°	24.30
Wyoming Sweet	38.00
West Texas sour	36.00
West Texas intermediate	38.00
Oklahoma sweet	38.00
Gulf Coast sweet	38.00
Michigan sour	35.00

North Slope upper tier oil is price controlled. North slope free market is F.O.B. Alyeska Pump Station No. 1 (Prudhoe Bay).

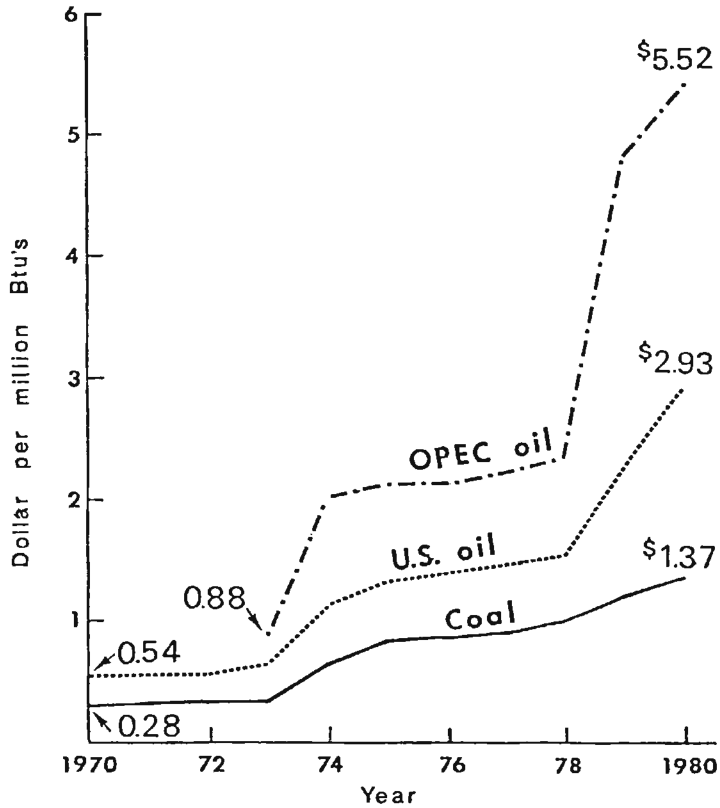

Figure 3. Cost of coal, average U.S. crude oil and OPEC crude oil in dollars per MBtu's.

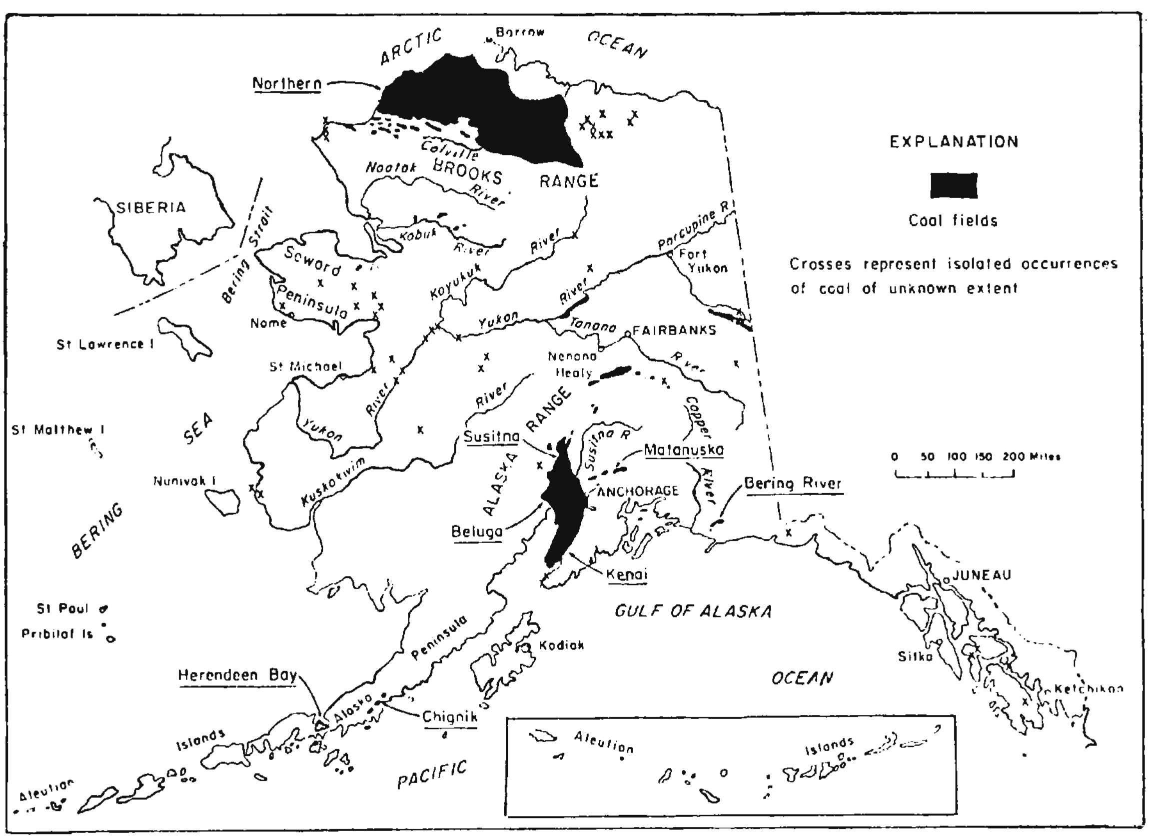

Figure 4. Location of Alaskan coal fields.

Healy are well-known. In spite of the paucity of data, there is sufficient information to select villages as candidates for conversion from oil to coal.

Cost of Coal vs. Cost of Oil

For comparison of coal with oil, an assumption will be made that reserves are adequate in each area selected for mining, and that coal can be mined on a smallscale in an arctic region for $30.00 per ton. This cost reflects an escalation for 1981 based on extensive cost analysis by Bottge (1977) for a coal mine near Wainwright (9,350 Btu coal or $1.60 per MBtus). Dee Lane of the Rural Community Action Program provided the wholesale cost of fuel in selected rural villages. These figures have been updated to show approximate retail cost on October 7, 1980.

Estimated mining and transportation costs of coal to selected villages, and 1980 fuel oil costs are shown in Table 3. The fuel costs are compared by the common denominator of dollars per MBtu. The following areas have been selected as mine sites.

1. Wainwright for the Arctic Ocean coast
2. Cape Dyer for the Chukchi Sea
3. Unalakleet for Norton Sound
4. Herendeen Bay for the Bering Sea
5. Nulato for the Yukon River
6. Anaktuvuk Pass for the one village.

Savings made on a MBtu basis by changing from oil to coal are show in Table 3. Of course, every mine developed must be appraised on a site specific basis.

Coal is available for use in Alaskan villages, and the savings in cost by switching from oil to coal is easily demonstrated. A factor favoring local coal over imported fuel oil is physical and political availability. Many economists believe the present U.S. policy subsidizes foreign oil producers. A policy change bringing U.S. prices to the level of foreign oil would place an additional financial burden on Alaskan villages. Another consideration is the political instability of the Middle East, which could lead to rationing of petroleum products.

Oil is the primary fuel base in the transportation industry. Current technology and our dependence on air transportation may preferentially mandate oil supplies to the transportation industry. This may dictate a change to coal for heating and power generation where it is readily available. Unfortunately changes canot occur overnight.

Another argument for using coal is that mining wages are paid to local workers. The dollars for fuel would circulate within the state rather than drain "Outside" (of Alaska).

Table 3. Comparative cost of coal vs heating oil

Village	Mine	Cost of heating oil per gallon	Cost of coal delivered to village (dollars/ton)	Cost per MBtu's oil	Cost per MBtu's coal
Wainwright	Wainwright	$1.50	$30.00	$10.00	$1.67
Point Lay	Local	1.50	30.00	10.00	1.25
Point Lay	Wainwright	1.50	60.00	10.00	3.33
Point Hope	Cape Dyer	1.50	39.00	10.00	1.07
Kavalina	Cape Dyer	1.75	59.00	11.67	2.11
Kotzebue	Cape Dyer	1.35	78.00	9.00	2.78
Teller	Unalakleet	1.60	70.00	10.67	3.50
Nome	Unalakleet	1.35	60.00	9.00	3.00
Unalakleet	Unalakleet	1.50	30.00	10.00	1.50
Goodnews Bay	Herendeen Bay	1.30	90.00	8.67	3.75
Togiak	Herendeen Bay	1.50	80.00	10.00	3.33
Dillingham	Herendeen Bay	1.35	80.00	9.00	3.33
Anaktuvak Pass	30 miles north	2.50	39.00	16.67	1.95
Nulato	Nulato	1.57	30.00	10.47	1.67

Applications of Coal

Coal must compete with oil in convenience of use as well as price. The coal stove for heating and cooking is readily available, but inconvenient. An available solution may be a coal stove for heating and cooking, with a back up oil system for use when occupants are away for an extended period.

The second area of consideration is the generation of electrical power. The coal fired steam electric generator loses its competitive edge over its oil fired equivalent because of higher capital cost and environmental concerns. Good coal fired steam turbine units as small as 25 hp are available, but there is greater price escalation with decreasing size compared to diesel generators or gas turbines. Obviously each size must be evaluated separately. For example, manufacturers quote in a range of $175.00 per kw for a large gas turbine. A similar coal fired unit might run $2,000 per kw. However, if there is a use for waste heat, the economics of steam power generation rapidly change to favor coal.

Low Btu coal gas can be used in a gas turbine for power generation, and the waste heat used to produce steam for electrical power. It can also be directly used for home heating. A small city the size of Nome or Kotzebue should be considered for such an installation.

Suggested Coal Program

Alaska has a vast coal resource, but each project must be site specific and information must be developed for each mine site. Because politics and cost may dictate a return to coal, an expanded coal program is required. The state or federal Geologic Survey could expand the exploration of coal fields, particularly in areas such as Nulato, Unalakleet and Cape Dyer. Research is required for competitive utilization of coal in electrical power generation; here again the research should be site specific.

Summary

In summary, most Alaska villages could use the readily available Alaskan coal resource. Research might start with a stronger coal geology program to better understand the coal resource base, followed by site specific coal development programs to implement the conversion from oil to coal for heat and electrical power.

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Mining and conversion of homes to coal for home heating at AtKasuk, Alaska

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Moening-Grey & Associates, Anchorage

The community of Atkasuk is located approximately 75 miles south of Barrow on Alaska's North Slope--the Arctic Coastal Plain (Figs. 1 & 2).

Access to the community is by plane, however, cat trains or other all terrain vehicles may be used during the winter months.

Atkasuk has a current population of about 100 people, residing in some 21 homes. Other facilities include a power generating station, warm storage shop, a small store, a combination school and community meeting building and a safety building or jail.

At the present time, residents burn fuel oil for heating purposes. The fuel oil is also used in heating the various community buildings. A conservative fuel estimate for a single family dwelling averages 2 1/2 barrels per month or some 30 barrels per year. In addition, the school and other municipal structures consume another 900 barrels or so per year. Total consumption for the village, exclusive of power generation and vehicle use, is approximately 1500 barrels or 63,000 gallons annually.

Planned expansion of the community will further increase this use. At the present time, plans call for construction of a much larger school facility, 4-plex apartment building and a number of additional single family residences.

Fuel last year was selling for about $2.10 a gallon, resulting in an average cost for each family of some $3,000.00 per year. Heating expenses for the entire community are somewhat in excess of $130,000 per year.

A locally operated coal mine would supply most of these heating requirements at a lower cost, while at the same time providing employment of local residents in the mining, transport and distribution of the fuel.

Atkasuk was selected as a pilot project for the North Slope at the request of the local residents and under Borough sponsorship, due to the availability of a nearby coal source with existing drilling and related exploration and test information.

Historically, coal from the Meade River deposits was used by the local people for their hunting and fishing camps. Before the 1940's, residents of Barrow depended on driftwood and petroleum residue from Cape Simpson as a fuel source. However, because of an increase in population, an acute fuel shortage occurred.

Because of this shortage, an examination of the Meade River deposits was made in June, 1943 by the Bureau of Mines. At that time they concluded that the coal was of sufficient quality and quantity to be mined economically and supplied to Barrow. Hydraulic stripping was suggested as the appropriate mining method and the necessary equipment was purchased and delivered by tractor drawn sleds during the winter of 1943-44. That winter, some 100 tons of coal were dug by hand from exposures along the river and sledded to Barrow for distribution to the residents.

The following spring, hydraulic equipment was used to remove about 2500 cubic yards of overburden from an area along the banks of the river immediately south of the town site. This pit produced about 45 tons before flood waters covered the coal deposits. Late rains in the fall again flooded the pit and caused another halt in mining, and subsequent abandoment of this mining method (Aerial Photo, Fig. 3).

During the winter of 1944-45, the Alaska Native Service enlarged a prospect shaft and mined some 500 tons of coal from one 60 by 65 foot room. A room and pillar type of underground mining proved satisfactory, with the frozen soils providing needed support and warmer underground temperatures allowing winter operations. Underground mining proceeded in subsequent years, producing between 400 to 2,000 tons of coal annually. The mine was shut down in 1964 when natural gas wells were brought into production near Barrow.

Surficial geologic conditions in the vicinity of the Meade River Mine are relatively uncomplicated. In general, Pleistocene deposits of sands and silty sands overlie the Cretaceous series that contain the coal beds. Prior to the deposition of the Pleistocene sands, the Cretaceous beds--a part of the Umiat Formation composed primarily of clay and coal with interbedded shales and sandstones--were warped into a broad anticline dipping about 1^{o} in an easterly direction.

Locally, erosion due to meandering of the Meade River has stripped some of the clay and higher coal so that in some cases the present seams appear as truncated beds, dipping below the old erosional surface. (Proposed Site Plan, Fig. 4; cross sections, Figs. 5 & 6.)

Four seams have been identified in the mine area through outcrop and drilling information. The upper bed is about 34 inches in thickness, the second some 5 to 6 feet thick and two lower seams about 1 foot each. The coal seams are separated by beds of clay. All of these contain a fairly good quality subbituminous coal.

During our initial investigation, three areas in the vicinity of the original mine were incorporated into the mining plan (Fig. 4).

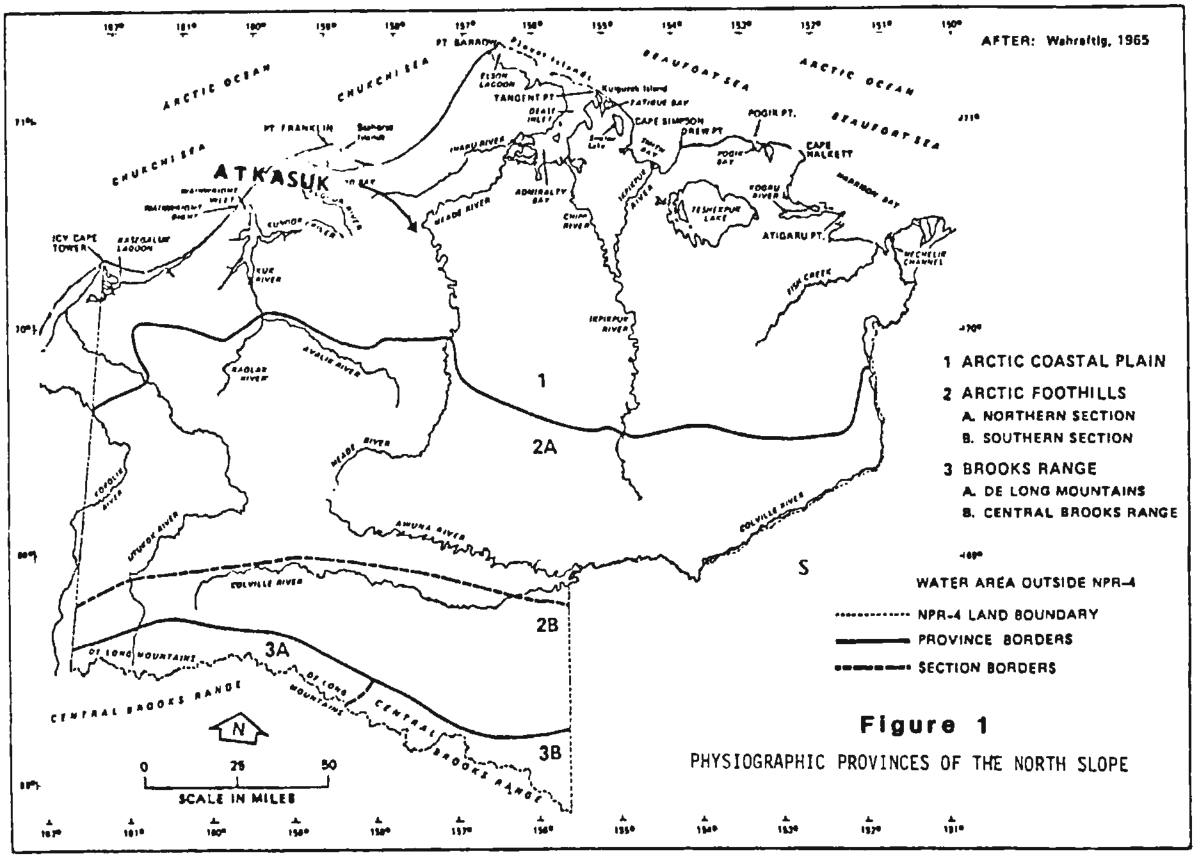

Figure 1

PHYSIOGRAPHIC PROVINCES OF THE NORTH SLOPE

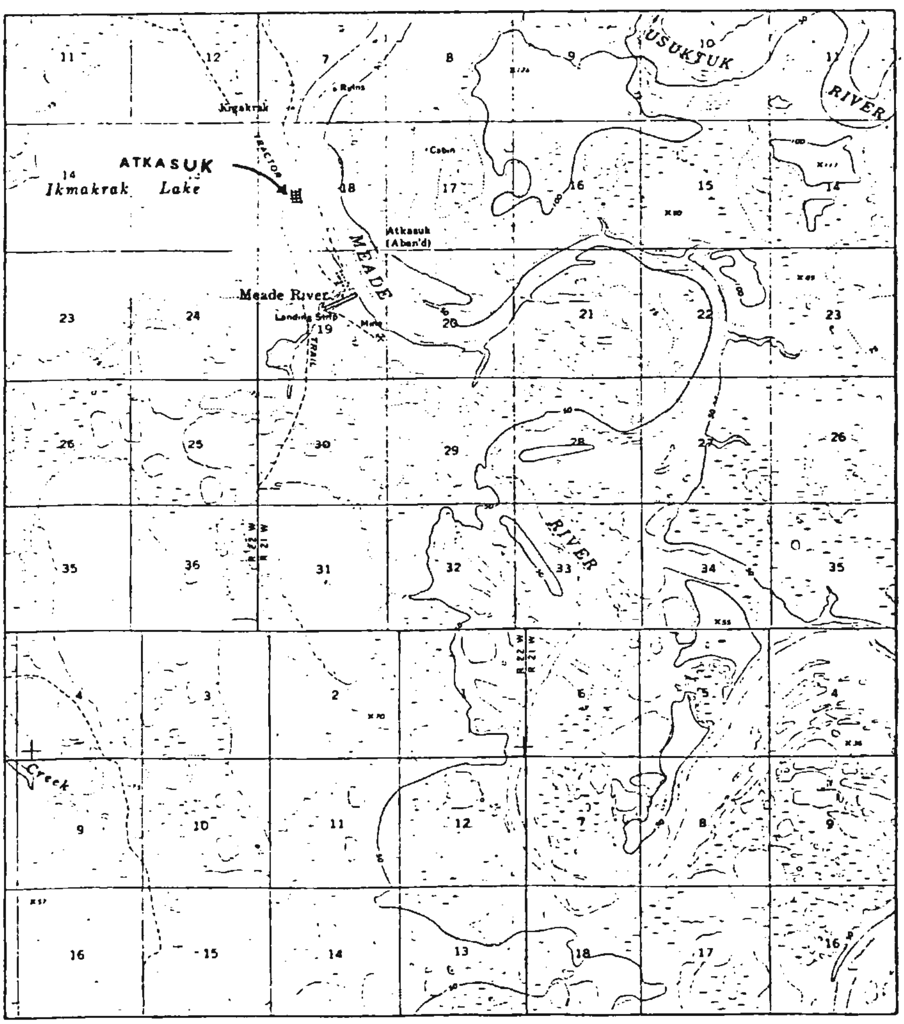

Figure 2

VICINITY MAP

From:U.S.G.S. Topographic Map

Meade River (B-3), Alaska

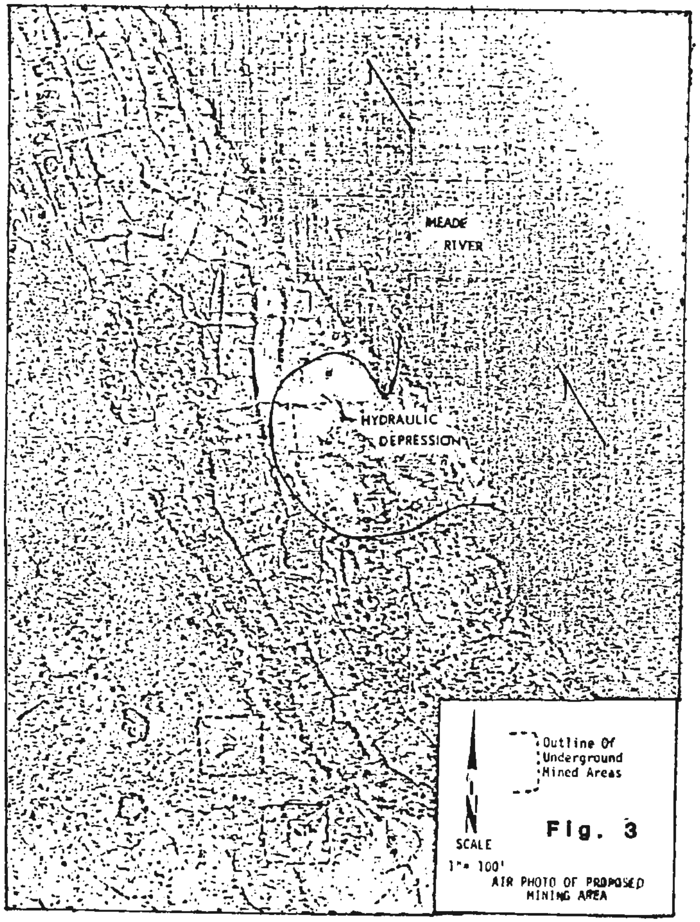

Fig. 3 AIR PHOTO OF PROPOSED MINING AREA

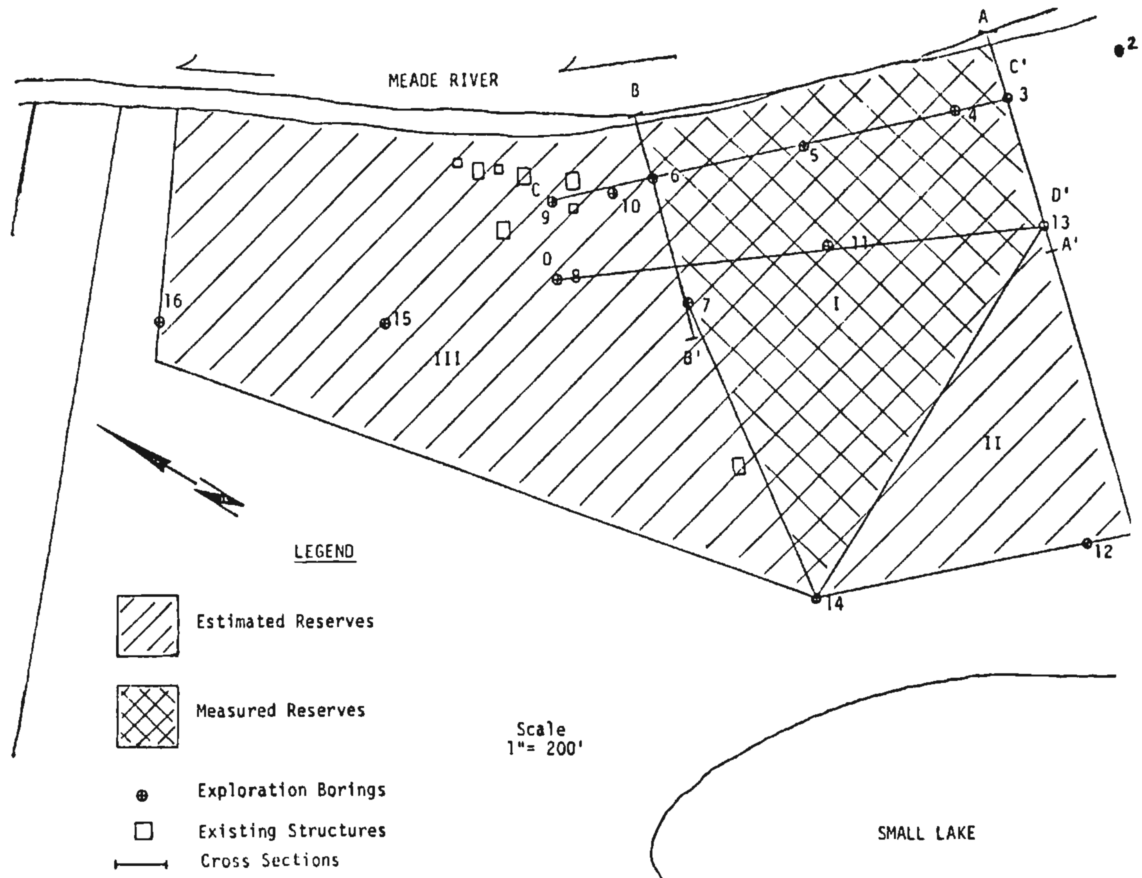

Fig. 4 PROPOSED MINE SITE PLAN
ATKASOOK, ALASKA

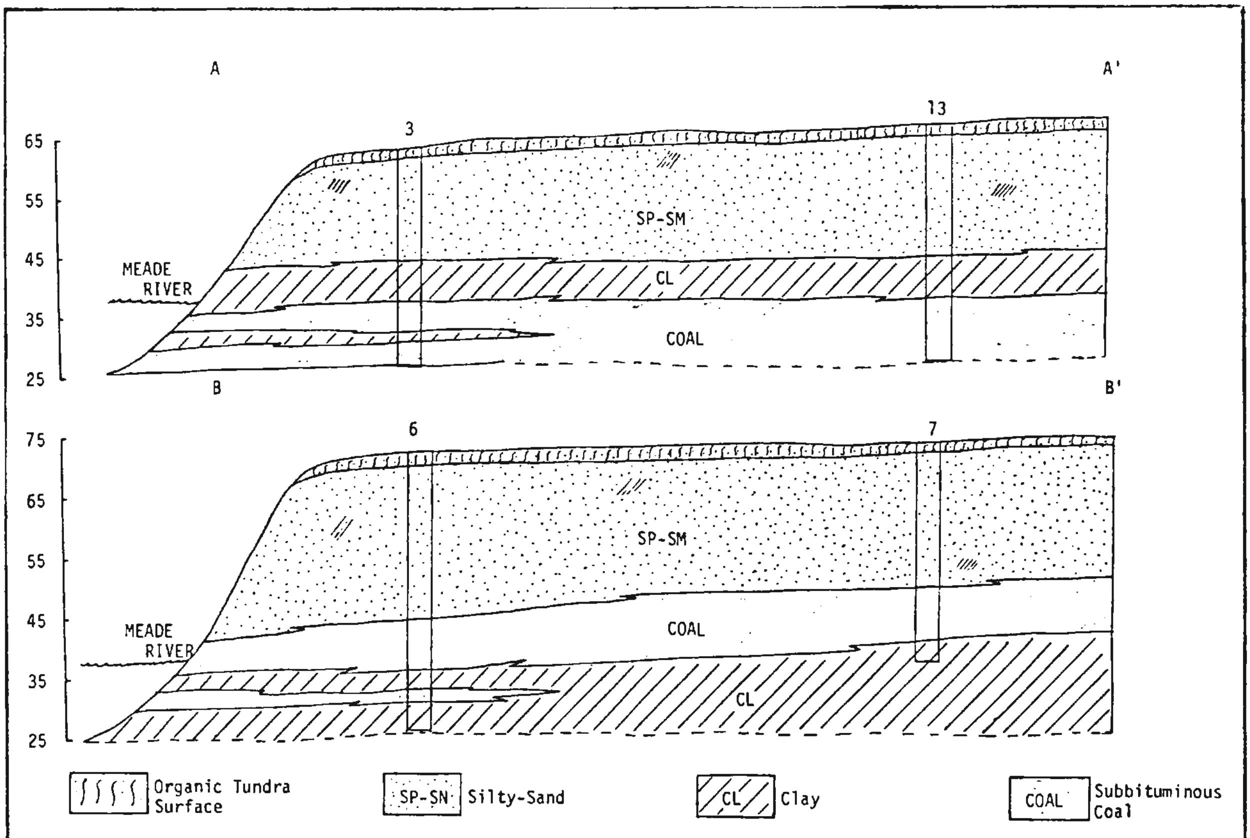

Figure 5
CROSS SECTIONS
MEADE RIVER AREA
ATKASUK, ALASKA

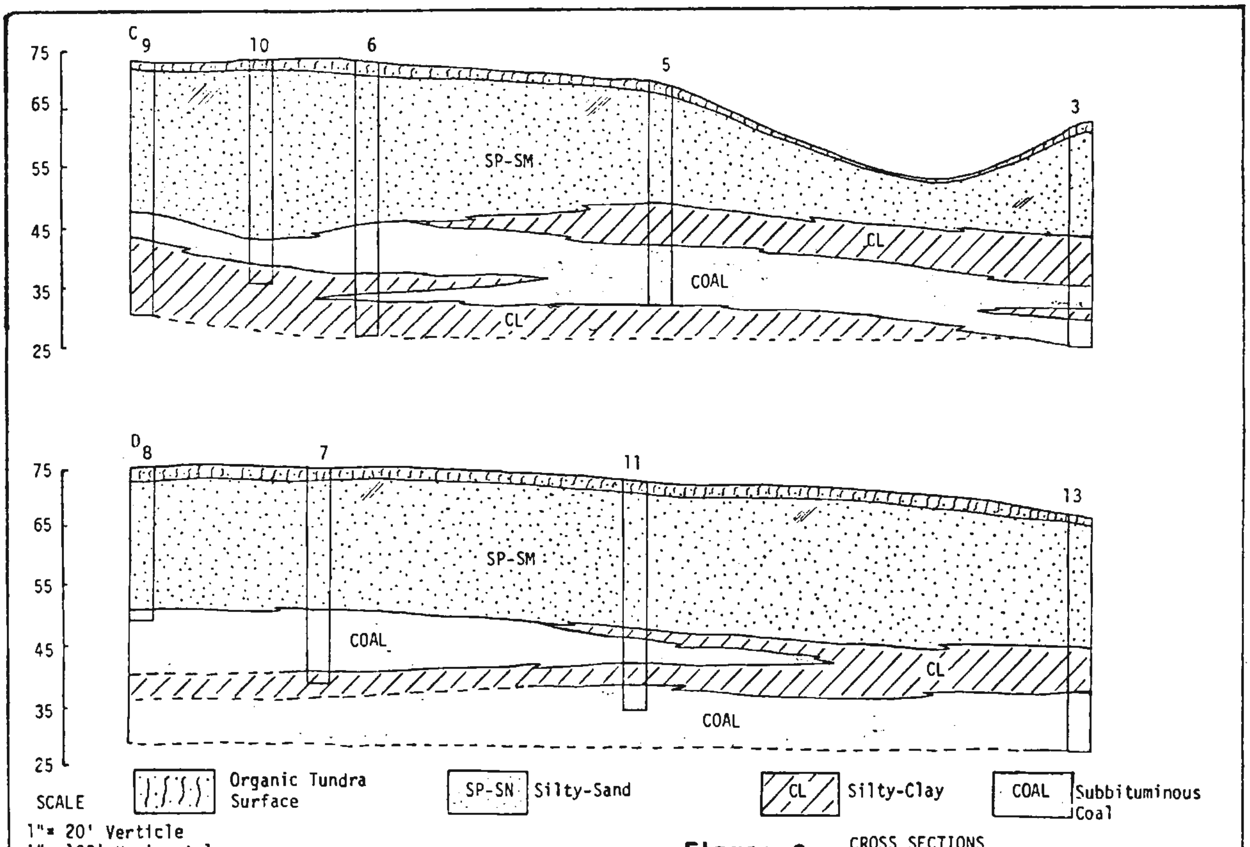

Figure 6 CROSS SECTIONS
MEADE RIVER AREA
ATKASUK, ALASKA

These total approximately 19 acres in size. Initial coal recovery would begin within Area One, containing a measured reserve of some 36,000 short tons. At a maximum coal use, Area One would supply community needs for about 70 years. An additional 65,000 tons could probably be blocked out in the remaining areas, Two and Three. However, more exploration would be necessary before mining could progress into these sections (Fig. 7).

Due to numerous factors, including costs, safety, equipment on hand and the size of the operation, a surface mine was planned for this area. In general, stripping ratios are satisfactory, on the order of 3 to 1 on the measured reserves in Area One.

Mining operations would commence in the depression cut by the hydraulic stripping previously mentioned. Removal of top soil, overburden and coal would proceed outward from an initial semicircular cut, which would be about 300 feet in length (Fig. 8,9,10).

Because of the frozen or permafrost condition of the subsurface, overburden removal will be accomplished by a strip and thaw method. In other words, successive stripping would proceed after a newly exposed area has thawed to an appropriate depth. Overburden would be pushed toward the initial reclamation area in the southern part of the depression.

Suitable topsoil would be removed and stockpiled directly adjacent to the initial reclamation area. Once the predetermined reclamation elevation is reached, the topsoil would then be regraded and compacted for seeding. In this manner, the mine would expand in a northerly and westerly direction, with simultaneous reclamation.

Overall, the impact of this coal mine on the residents of Atkasuk is considered very favorable. The mine will bring with it increased employment, lowering of fuel costs, strengthening of the local economy and a general decrease in dependence on imported goods. Depending upon the success of this program, we would expect to see similar conversions in other communities on Alaska's North Slope and, hopefully, elsewhere in Alaska.

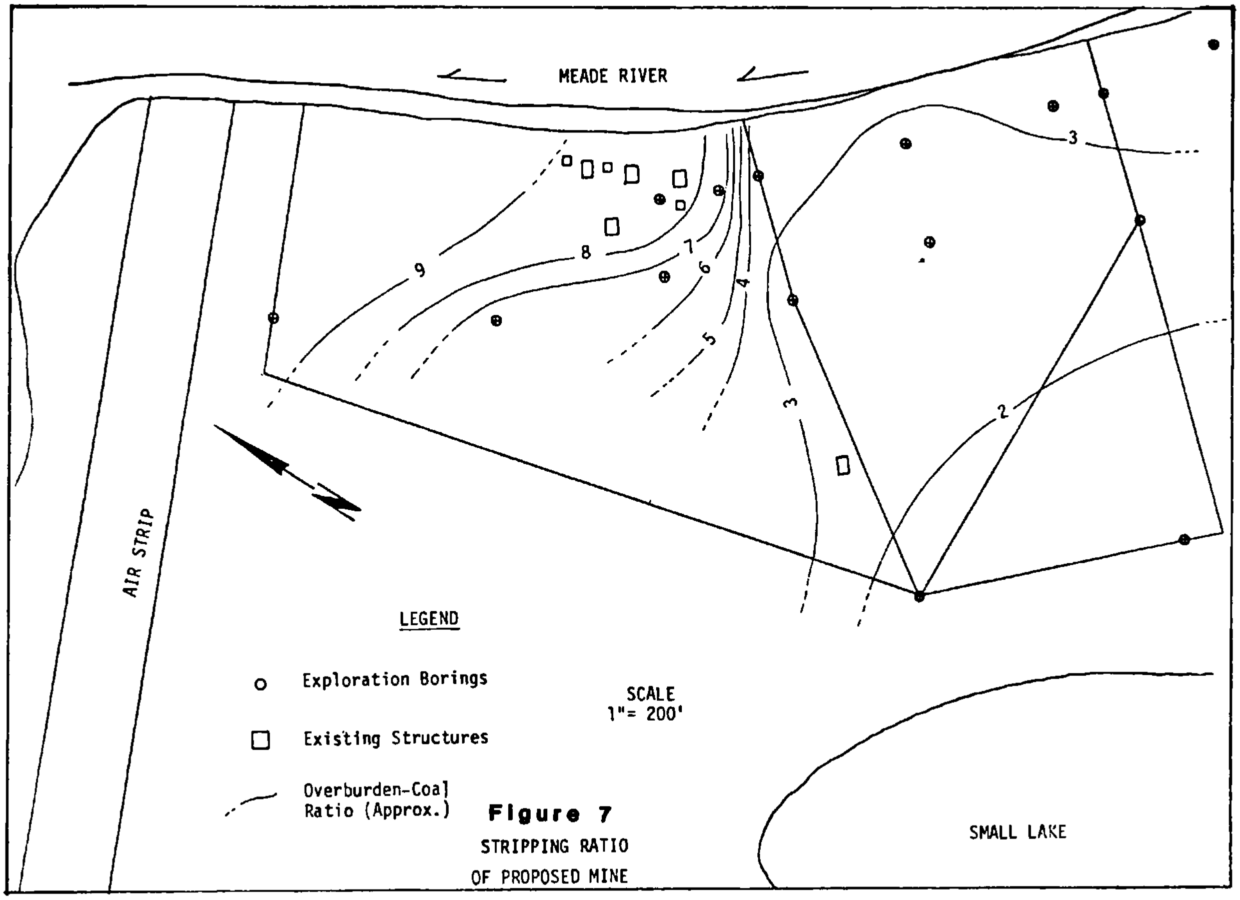

Figure 7
STRIPPING RATIO
OF PROPOSED MINE

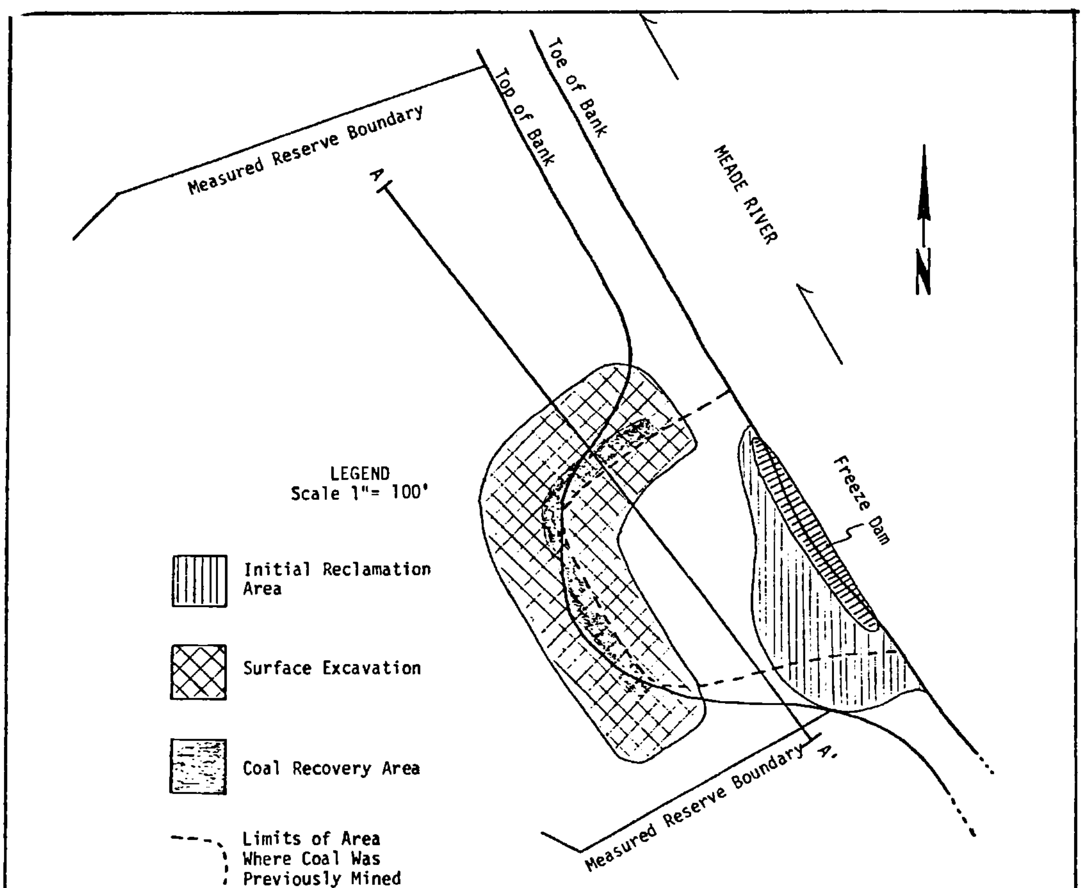

Figure 8
MINING AND RECLAMATION SCHEME
FIRST YEAR OF OPERATION
ATKASUK, ALASKA

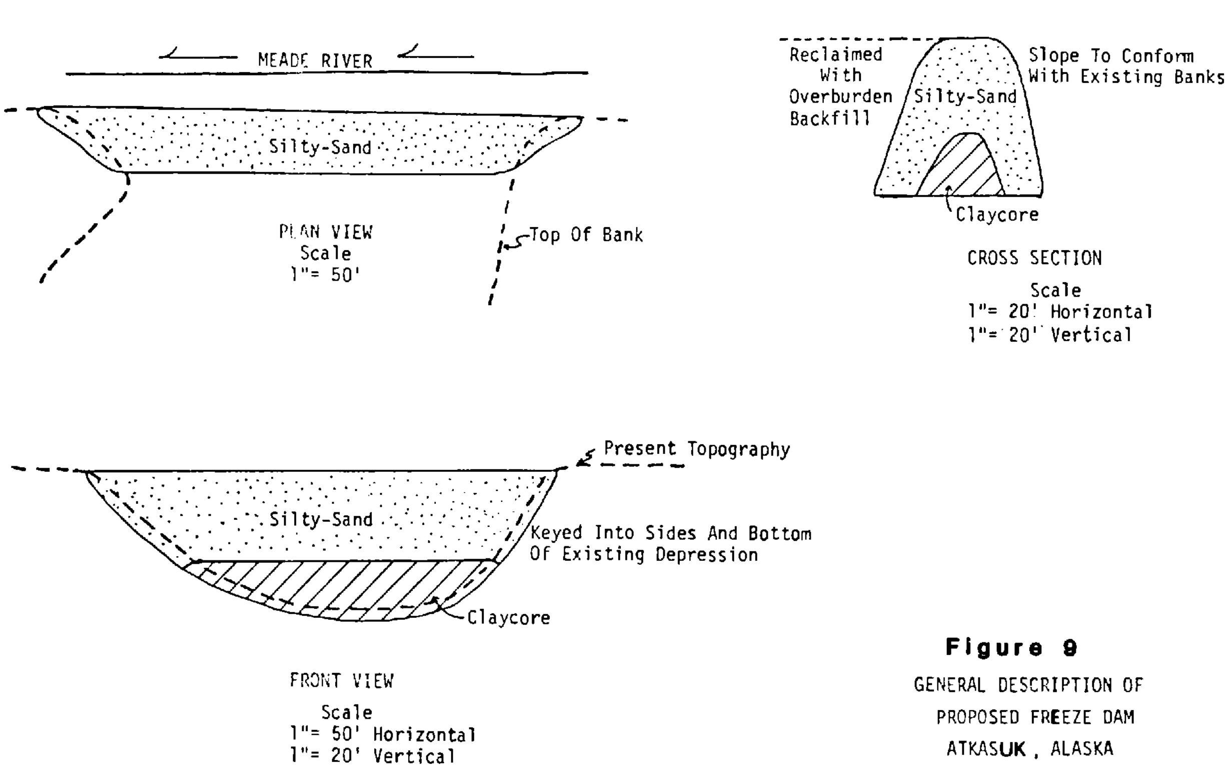

Figure 9
GENERAL DESCRIPTION OF
PROPOSED FREEZE DAM
ATKASUK, ALASKA

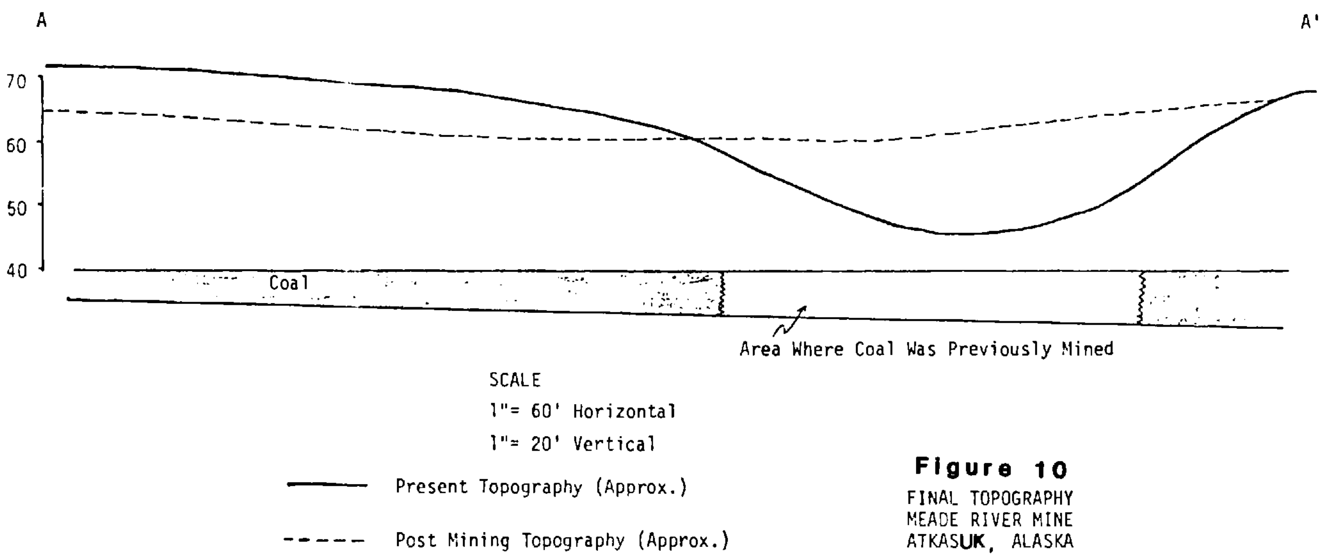

Figure 10
FINAL TOPOGRAPHY
MEADE RIVER MINE
ATKASUK, ALASKA

Palynology and coal

Rena McFarlane
Graduate Student, University of Alaska, Fairbanks

Coal researchers should be aware of the value of pollen. Pollen and spores trapped in coal during its formation may store information on its mode of deposition, past climate, age and physiographic environment. Most important to coal developers is how pollen stratigraphy provides a basis for coal seam correlation.

Pollen is transported by water, wind, insects and birds. It will settle out and be preserved in anaerobic and acidic environments. Best preservation occurs where post depositional oxidation is minimal and compaction of sediments is not severe enough to cause distortion. Most coals are favorable environments for preservation, with the exception of high rank coals. Metamorphism will cause a gradual carbonization of pollen and spores. In these high rank coals it is hard to isolate the pollen from the matrix without damaging them.

Pollen grains are extracted from coal by a series of chemical and mechanical treatments. Acids and bases are used which dissolve or disaggregrate mineral and certain organic fractions of the matrix. Pollen grains have a tough resistant outer wall that enables them to withstand chemical treatment. Organic materials are destroyed by oxidation using, for example, nitric acid and potassium chlorate. Heavy liquid flotation is used to separate different density fractions. At the end of these treatments, microscope slides are made of the residue.

The pollen extracted from coal will represent a particular floral assemblage. The differentiation of floral assemblages through time depends on replacement of one assemblage by another because of the introduction of new groups, in addition to the extinction and movement or migration of old groups. Correlating a coal seam may depend on recognizing the pollen assemblage changes from coal to coal. These changes include variation in the species (or genera) content, variation in the stratigraphic ranges of the different pollen and changes in the relative abundance of pollen and spore types. Correlation is made when assemblages are matchable and abundances reasonably similar.

The two main groups of Alaskan coals that have been examined palynologically are the North Slope Cretaceous coals and the Tertiary coals ranging from Homer to Healy. Work in this field is very limited. Most all quantitative palynological work in the state has been restricted to Quaternary problems.

An abstract published in 1969 (Ames and Riegel, 1969) is the only published mention of coal seam correlation using palynology done in the state. This study correlated four seams in the Matanuska Coal Field, on opposite sides of the Premier Fault, over a distance of about 2,000 feet. Several U.S. Geological Survey open-file reports have been published on the lithology and palynology of Tertiary rocks near Capps Glacier (Adkison, Kelley and Neuman, 1975) Homer, (Adkison, Kelley and Newman, 1975) and the Kenai peninsula (Adkison and Neuman, 1973). These are qualitative studies of both coal and rock units. Checklists of the genera identified are provided.

Jack Wolfe has made significant contributions in the field of Tertiary paleobotany in Alaska (Wolfe, 1972, 1977, 1980). Most of his work deals with megaplant fossils but palynological findings are often used. The palynological work, however, entails an overview om many lithologic units, coal and rock. Wolfe has demonstrated many climatic trends during the Tertiary, including the loss of dominance of warm temperate broad leaved forest trees after mid-Miocene, and the proliferation and abundance of cool temperate families such as Bethulaceae (birch). Wolfe has proven that megafossil plants are more clearly dianognostic of the Seldovian Homerian and Clamgulchian stages, but microfossils are more useful in determining stage assignments for subsurface samples (Wolfe, 1966).

Some coal seams from the Nenana Coal Field were examined palynologically by Leopold (Wahrhaftig and others, 1969). Checklists of pollinating flora from the Miocene age Suntrana Formation showed that the percentage of flora now exotic or foreign (or extinct) to Alaska was 49%. Palynological information suggests that by Quaternary time the flora of southern Alaska was modernized on a generic basis (Leopold, 1969).

A Penn State group studied the palynology and petrography of certain coals of the Arctic Slope of Alaska including Meade River, Kuk Inlet and the Umiat area (Dutcher, Trotter and Spackman, 1957). A more detailed description of the Cretaceous pollen and spore assemblages in Kuk and Meade River was done by Stanley (Stanley, 1967). The microfossils in this study were useful in making age assignments for the deposits.

A master's thesis on the petrography and palynology of seam numbers 6, 5 and 4 of Usibelli Coal Mine, Nenana Coal Field, is currently underway by the author. The work is supported by the Mineral Industry Research Laboratory, University of Alaska. Coal samples have also been collected by another graduate student, Steve Hardy, from the area to be flooded by the proposed Susitna Dam project. These samples have been processed for pollen and spores, but not examined. It is hopeful that they will be examined soon. Results from these slides may indicate interesting areas to be more intensively collected and studied before the area may be flooded if the Dam is built.

The following plate shows photographs of Tertiary age pollen and spores extracted from seam number 6, Nenana Coal Field. All of these genera are extant in Alaska. However, today some of them are restricted to warmer climates.

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Pollen and Spores from the Suntrana Formation,
Nenana Coal Field

PLATE 1

(all figures, 1 cm = .02 mm)

Figure 1. Picea (spruce)

2. Tsuga (hemlock)

3. Drosera

4. Sphagnum (moss)

5. Polypodiaceae (fern)

8 ~~6.~~ Onagraceae

6 ~~7.~~ Tilia (linden or basswood)

7 ~~8.~~ Ilex (holly)

9. Itea

10. tricolpate grain

11. Salix (willow)


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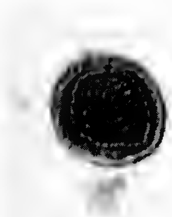
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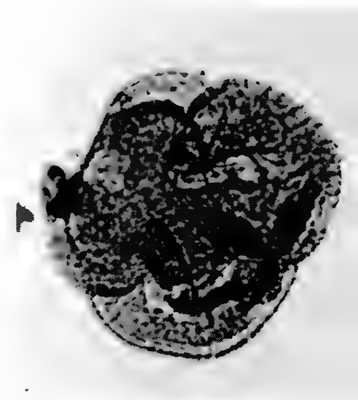
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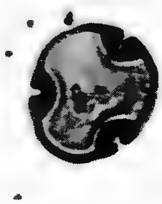
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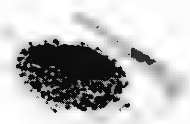
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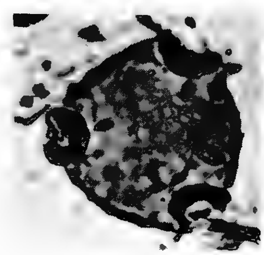
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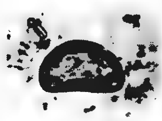
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11

Petrological, mineralogical, and chemical characterizations of certain Alaskan coals and washibility products

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Mineral Industry Research Laboratory, Univ. of Alaska, Fairbanks

Abstract

Petrological, mineralogical and chemical characterization provides basic information needed for proper utilization of coals. Since many of these coals are likely to be beneficiated to reduce ash, the influence of coal washing on the characteristics of the washed product is important.

Twenty samples of Alaskan coal seams were used for this study. The coals studied ranged in rank from lignite to high volatile A bituminous with vitrinite/ulminite reflectance ranging from 0.25 to 1.04. Fifteen raw coals were characterized for proximate and ultimate analysis, reflectance rank, petrology, composition of mineral matter, major oxides and trace elements in coal ash. Washability products of three coals from Nenana, Beluga and Matanuska coal fields were used for characterization of petrology, mineral matter and ash composition.

Petrological analysis of raw coals and float sink products showed that humodetrinite was highest in top seam in a stratigraphic sequence and higher towards the top of a seam. Suberinite was identified in all tertiary and Cretaceous coals studied. Significant differences were found in the petrology, mineralogy and ash composition of float sink products, indicating that in evaluating coal resources it is not adequate to characterize the raw coals alone. Characterization of float sink products will help understand the nature of the product obtainable from the raw coal rather than coal as mined.

Acknowledgements

This study was conducted under the sponsorship of the U.S. Department of Energy (USDOE) under contract No. ET-78-S-01-3197. Sample collection and washability studies were conducted under a separate USDOE sponsored study with the cooperation of Joseph A. Cavallaro and Albert W. Deurbrouck, Pittsburgh Mining and Technology Center, USDOE. Laboratory investigations were assisted by Kyle Morrow and Jane Smith, students in geology, Sam Yang and Sam Chang, graduate students in mineral preparation, and Namok Veach, State Division of Geological and Geophysical Surveys.

Thanks are due to Dr. Earl H. Beistline, Dean, School of Mineral Industry, University of Alaska, Fairbanks, for his interest and encouragement in coal investigations, and to Dr. Syed Akhtar for his interest and review of the manuscript.

Introduction

Coal utilization is dictated by the characteristics of the coal. Among the characteristics most generally sought are the proximate analysis, ultimate analysis, mean maximum reflectance of vitrinite, coal petrological composition, composition of ash, both major oxides, minor as well as trace elements, nature and concentration of mineral matter in coal, and finally the washability characteristics that permit evaluation of the coal to its amalnability to reduction of ash and sulfur and improvement in heating value. It is also important to know the characteristics of the washed coal in terms of coal petrology, ash and mineral matter composition, since they would be different from the raw coal.

Twenty samples--collected under the washability characterization program sponsored by the Department of Energy (Rao and Wolff, 1, 2)--were used for this study. Two samples were selected for total characterization as described above. Twelve samples were selected for raw coal characterization. Ash analysis and vitrinite reflectance were determined for the five remaining samples.

Coal Fields Sampled

The twenty samples used for this study were collected for the Department of Energy Washability study program. Six hundred pound channel samples were collected and transported to the laboratory in heavy-duty plastic bags in gunny sacks. Details of sample location, geology of the area, the stratigraphic section and complete washability data are presented elsewhere by Rao and Wolff (1, 2). Certain essential information is reviewed here for completeness. Figure 1 is a map of Alaska showing major coal resource areas and sampling locations.

Nenana Coal Field

The Nenana coal field is located about 110 miles south of Fairbanks on the Parks Highway at Healy. The field extends 80 miles in the eastwest direction and is one to thirty miles wide (3, 4, 5). The coal bearing formation consists of sandstones, siltstones, claystone, shale and numerous thick coal beds and is divided into five formations by Wahrhaftig et al., (6). Samples numbered UA-100, 101, 102, 103, 104, 105 and 119 were collected in this field at Usibelli Coal Mine.

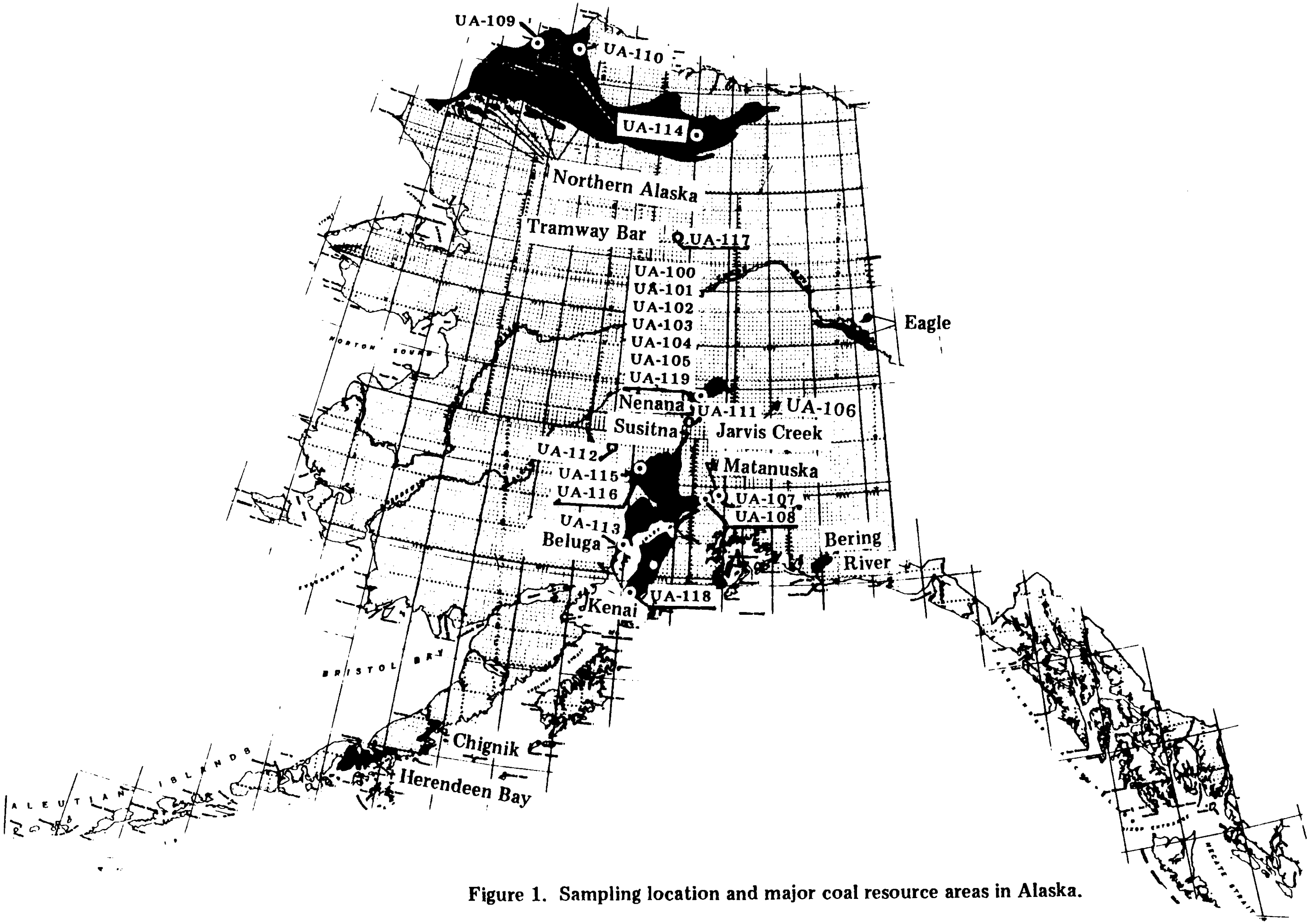


Figure 1. Sampling location and major coal resource areas in Alaska.

Jarvis Creek Coal Field

The Jarvis Creek coal field is located about 125 miles southeast of Fairbanks on the north side of the Alaska Range. The coal field is 16 square miles in area and the site of sporadic mining activity. It is about 6 miles via a pioneer gravel road from the Richardson Highway, Mile 242. The coal field has been mapped by Wahrhaftig and Hickcox (7). It is Tertiary in age and has been correlated to the Healy Creek formation of the Nenana coal field, 100 miles to the west.

The coal bearing formation consists of a sequence of interbedded lenses of poorly consolidated sandstone, siltstone, claystone and conglomerate. Although there are numerous coal beds, those with thicknesses exceeding 2-1/2 feet are rare.

Matanuska Coal Field

Matanuska coal field is about 45 miles northeast of Anchorage on the Glenn Highway. In the Upper Matanuska Valley the coal increases in rank from high volatile A bituminous at the Castle Mountain Mine, to anthracite at the Anthracite Ridge. The coal in the Wishbone Hill District of the Lower Matanuska Valley is high volatile B bituminous. The coal seams are limited to the Chickaloon formation of Tertiary age. This formation consists of nonmarine rocks that include all gradations from coarse sandstone and conglomerate to claystone. It is concealed by a mantle of Quaternary deposits or by a capping of younger Tertiary conglomerate (8, 9).

Coal was mined extensively in this area until 1968 when the Evans Jones coal mine ceased operations.

There are two coal beds exposed at the Castle Mountain Mine (not operated since the early 1960's). The lower bed, 7.0 feet thick, was sampled (UA-107). Another coal seam was sampled at the Premier Mine (UA-108) and is from a region highly faulted and at the creek of an anticline.

Northern Alaska Coal Field

The great bulk of Alaska's coal resources lie in the northern Alaska field, north of the Brooks Range. Coal bearing Cretaceous rocks are known or inferred to underlie about 58,000 square miles (Barnes, 10). Coal beds of potential economic significance are confined almost entirely to the Corwin formation. The Cretaceous rocks include sandstone, conglomerate, siltstone, shale and coal. Although these rocks are mostly of marine origin, nonmarine coal bearing rocks predominate in some areas and intertongue with the marine rocks.

Wainwright

Sample No. UA-109 was from an outcrop on the east bank of the Kuk River, about 14 air miles from Wainwright. The seam is 5 feet thick and the bottom of the seam is approximately 4 feet above the river level. The stratigraphic position of this bed has not been definitely established, but according to Barnes (10) it is believed to be in rocks correlative with the Chandler formation. Coal outcrops have been described and in fact some have been mined for a distance of 10 miles along the Kuk River. There are two principal beds exposed at the outcrops with approximately 10 feet of coal. The individual beds ranging in thickness from 2 to 6 feet with 10 to 50 feet overburden outcrop along the Kuk River (Tonges and Jolley, 11).

Meade River

Coal outcrops along the west bank of the Meade River near the village of Atkasuk. Coal for shipment to Barrow has been mined during the forties and early fifties in an open trench and underground. The U.S. Bureau of Mines has done extensive drilling in this region and delineated the coal bearing areas for mining purposes (Sanford and Pierce, 12). Four coal seams have been identified in this locality. The top No. 1 bed is 34 inches thick, the No. 2 bed is 5 to 6 feet, the lower No. 3 and No. 4 beds are approximately 12 inches and the beds are separated by 1 to 2 feet of clay (12). The seam that is sampled for this study is No. 2 bed (UA-110).

Sagwon Bluff

Rocks in the Sagavanirktok quadrangle are part of a thick sequence of submarine volcanic and nonmarine carbonate rocks of Mississippian through Tertiary age. Coal has been reported in Ignek formation of Cretaceous age and Sagavanirktok formation of Tertiary age. The sampled coal outcrop (UA-114) was from the bluffs on the Sagavanirktok River adjacent to the Trans Alaska Pipeline. The sampling location has not been mapped in detail and the age of the formation in which the coal occurs has not been determined (Cretaceous to Tertiary).

Broad Pass Coal Field

Broad Pass coal field is located near Broad Pass station, 166 miles south of the Alaska Railroad and Parks Highway. The field may be divided into two basins. The Costello Creek Basin (Wahrhaftig, 13) is on the west side of the railroad and covers about seven square miles.

Coal Creek Basin is located on the east side of the Alaska Railroad and lies in an area three miles long and one mile wide

(Hopkins, 14). About 1 1/2 square miles are known to be underlain by coal bearing rocks.

Coal was mined from the basin until the mid-1940's. The sample collected (UA-111) was from an outcrop near the former Coal Creek mine. The seam is 8 feet thick and is covered by unconsolidated sediments. Access to the locality is via an old wagon trail from the Parks Highway. The trail crosses several streams and its use is limited to four-wheel-drive vehicles.

Little Tonzona Coal Bed

Occurrences of coal near Farewell were first observed by Brooks (15) in 1902. Capps (16) described 20 foot thick coal beds in Tertiary nonmarine sedimentary rocks south of Kantishna. The Little Tonzona coal bed, however, was first described in 1977 by Player (17) and recently by Sloan et al., (18).

Coal beds occur in Tertiary nonmarine sandstone, siltstone and volcanic rocks in widespread isolated exposures north and south of Farewell fault, from big River northeast to Kantishna and beyond (Player, 17). The sampled seam occurs in an isolated exposure of Tertiary nonmarine sedimentary rocks on the southwest bank of the Little Tonzona River. Beds strike N60^{o}E to N70^{o}E and dip 55^{o} to 70^{o} northwest. The total stratigraphic thickness measured by Player is about 195 feet, and the sample (UA-112) was collected from the exposed portions of the coal seam.

Tramway Bar Coal Occurrence

Occurrence of coal near Tramway Bar was first reported by Schrader (19) in 1899 and has been mined for local use (Smith and Mertie, 20, p. 316). The occurrences are at the northeastern part of the Yukon-Koyukuk Province. The province is a broad tract of Cretaceous and Tertiary rocks that stretch across westcentral and southcentral Alaska from the Brooks range to the Yukon River delta (Patton, 21).

Coal is exposed along the north bank of the Koyukuk River in three seams, a 3 foot seam, an 8 inch seam and a 17 1/2 foot seam. The top portion of the 17 foot seam was covered and was difficult to sample. The bottom 13 feet of the seam was sampled, including bands of interbedded shale. The coal bed dips at 56^{o} and the sample was cut horizontally across the seam at a level six feet above the river.

Cook Inlet Sedimentary Basin

Nonmarine sedimentary rocks of Cook Inlet basin exceed 18,000 feet in thickness, and in some parts of the basin they may extend to 27,000 feet. The rocks outcrop as far north as Peters Hills and continue south to Homer, forming a belt 200 miles long and 70 miles wide. Although these formations are known to be coal bearing since the early 1900's, recent discoveries of petroleum and gas fields sparked intensive drilling that resulted in a greater understanding of the geology of these Tertiary rocks.

From purely geographical considerations the sedimentary basin is divided into three coal fields: a) Kenai field, b) Beluga field and c) Yentna field. The coal is of Tertiary age and is limited to the Kenai group (formerly Kenai Formation). Coal is interbedded with coarse to fine grained sandstone, siltstones and occasional conglomerates. The Kenai Group is subdivided into four formations which include (from older to younger) Hemlock Conglomerate, Tyonek, Beluga and Sterling Formations.

a. Kenai coal field. Much of the Kenai lowland is underlain by coal bearing rocks. Coal exposures are found extensively on steep bluffs along the east shore of the Cook Inlet, rising at places to 200 feet above the beach. Barnes and Cobb (22) made a detailed study of those outcrops and presented extensive sections of these exposures. The beds are not massive in thickness; Barnes, however, identified at least 30 beds ranging in thickness from 3 to 7 feet.

Coal has been mined in the Homer district since 1888. There has been no mining since 1951 when the Homer Coal Corporation ceased operations. Some residents of the Homer areas still collect coal from the beach for domestic use, particularly after a severe storm. The sample collected (UA-118) is from the Cabin Bed and the location is equivalent to locality 117 of Barnes (22). The seam is 6 feet thick and has about 5 feet overburden at the sampling location. The seam outcrops on a vertical face, and sampling was accomplished with the aid of technical rock climbing equipment.

b. Beluga coal field. Barnes (25) defined the Beluga-Yentna region as the broad lowland west of lower Susitna River that is bounded on the north and west by the Alaska Range, and on the south by Upper Cook Inlet and the Chakachatna River. The Beluga Coal field is part of Cook Inlet sedimentary basin and is located approximately 60 miles west of Anchorage on the northwest shore of Cook Inlet. The field can be subdivided into three coal bearing regions. Region 1, the Three Mile Creek Basin, located about 6 miles from Cook Inlet, contains approximately 22 steeply dipping seams averaging 10 feet in thickness. Region 2, the Chuitna Basin, is located about 17 miles from Cook Inlet. There are at least two mineable coal beds, one of which exceeds 40 feet in thickness, outcropping along the Chuitna River. Region 3, the Capps Basin, lies 26 miles from Cook Inlet. This area has two seams in the Tyonek formation: the Upper Capps Bed with an average thickness of 17 feet, and the Waterfall Bed (Capps Bed of Barnes) with an aggregate thickness from 20-49 feet. The latter has an average mineable thickness of 30 feet, with interburden varying from 80 to 280 feet. Sample No. (UA-113) was from this seam and represents the bottom 30 feet of the seam. The top 6 feet is dirty and will be sampled separately in future investigations.

The lower part of the Tyonek Formation is well exposed south of the Capps Glacier and the section is described by Adkison, Kelley and Newman (23). The location is about two miles north of the sample location of UA-113. These beds were designated part of the type section of the Seldovian stage by Wolff, Hopkins and Leopold (24).

c. Yentna coal field. There are numerous outcrops of the Kenai Group in the northern part of the Beluga-Yentna region. Much of the area is covered by a mantle of Quaternary deposits, Barnes (25) concludes, "outcrops of the Kenai Formation (now Kenai Group), though mostly of small extent, are so widely distributed as to leave little doubt that the formation underlies much of the lowland areas". Occurrences of coal in the Fairview Mountain area were first described by Capps (16). An outcrop on Chicago Gulch was determined by Wolff, Hopkins and Leopold (24) to be Seldovian. Of all the coal outcrops in the region, the thickest was Locality 2, described by Barnes (25). The bed is 55 feet thick and has no visible partings. The middle part of the bed was covered with gravel and could not be reached for sampling. The part of the bed below (UA-115) and above (UA-116) were sampled separately. The sampled outcrop is approximately 23 air miles from Peters Creek and access was via helicopter. Peters Creek is about 25 miles on Peters Creek Road from the Cache Creek Station on the Parks Highway.

Laboratory Procedures

Sample Preparation

Figure 2 is a flowsheet of procedures used in the laboratory for processing samples for washability studies (Rao and Wolff, 1, 2). Washability products of 1 1/2 inches to 100 mesh materials were used in this study. Raw coal and float sink products crushed to 20 mesh were used for petrographic analysis. Samples pulverized to 60 mesh were used for the preparation of low and high temperature ashes. High temperature ash was prepared by oxidizing pulverized coal in quartz boats at 750°C. This ash was used for the determination of all major oxides, trace and minor elements. Mineral in coal was isolated by oxidizing pulverized coal at a temperature less than 150°C, using LFE model LTA-302 low temperature asher in excited oxygen plasma to obtain essentially unaltered mineral components of coal. The ash was further pulverized in an agate mortar covered with alcohol, to prepare for x-ray diffraction and infrared spectrometric analyses.

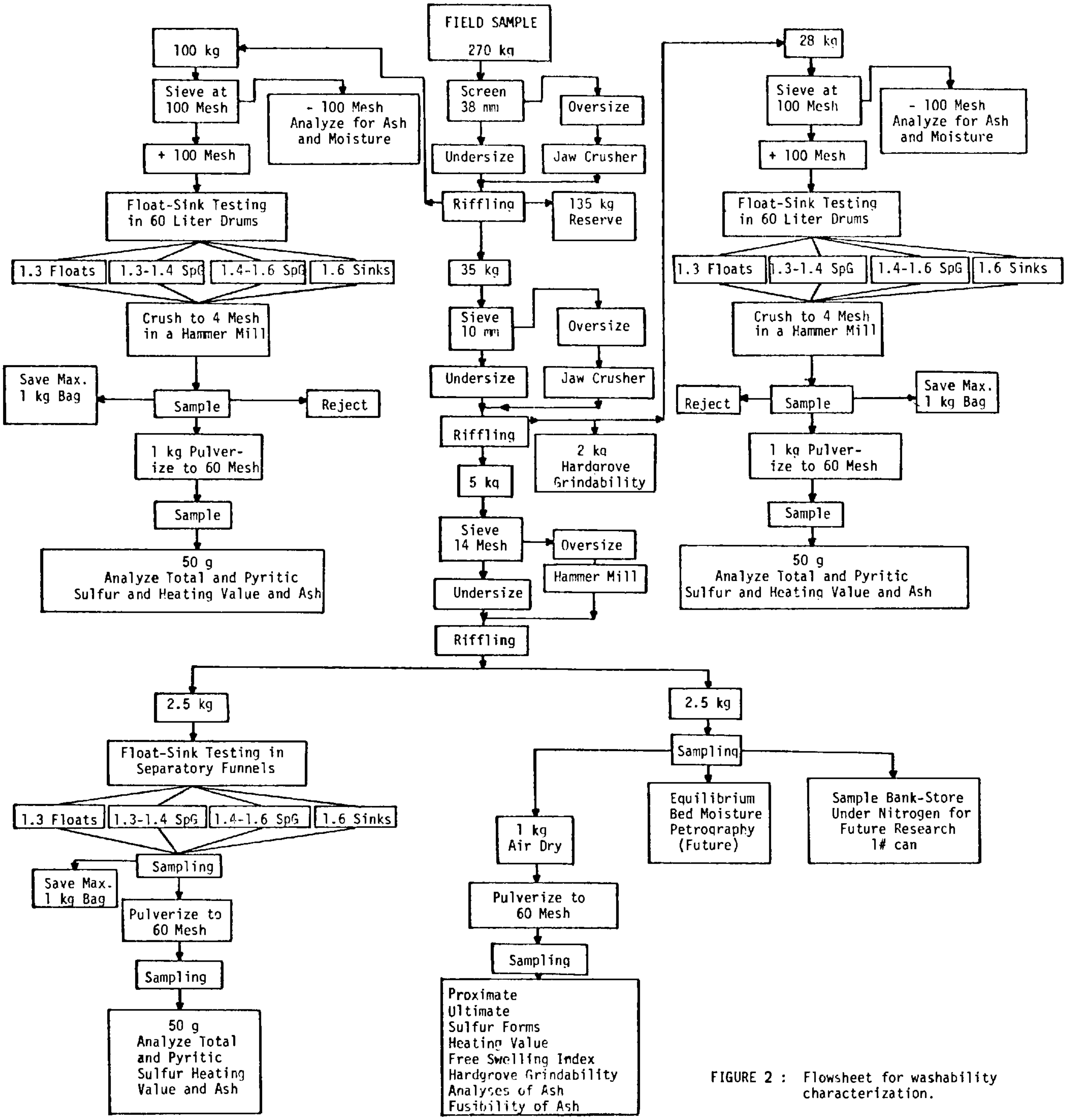


FIGURE 2 : Flowsheet for washability characterization.

Coal Petrology

Procedures recommended by the American Society for Testing and Materials (ASTM), specifications D2797-72, D2798-72 and D2799-72, were generally followed for petrological studies. Coal samples crushed to 20 mesh were made into 1" diameter pellets using epoxy binder under pressure. Grinding of the pellets was done on 120 micron diamond lap followed by 30 micron metal bonded diamond lap with Buehler automet for 2 minutes. Polishing was done using automet with 1 micron and 0.05 micron alumina suspensions for 2 minutes each stage, followed by one minute of polish with distilled water flooding.

A special technique was needed for preparation of thin sections of subbituminous "C" coals, since these coals dry out and crack with normal procedures. Blocks of coal with 1" x 2" face x 1" thick were ground with 30 micron diamond lap followed by 1 micron alumina and finished with .05 micron alumina. The piece was kept wet all the time (stored under water) to prevent drying and resultant cracking. A glass slide is cleaned with acetone and dried, the polished face is rinsed with a jet of acetone quickly wiped clean and glued to the face of the glass slide with a few drops of methyl methacrylate adhesive, commonly sold as super glue and other trade names, while applying heavy pressure with the thumb. After five to ten seconds, pressure can be released and the slide covered with a wet paper towel for 10 minutes. The coal piece is cut off with a diamond saw leaving coal on the slide, one to two mm thick. The slide was held in a plastic slide holder and ground on 30 micron diamond lap while carefully applying pressure to whichever side appeared opaque. The slide could be ground down within a few minutes. Further thinning was done on 1 micron alumina. The face was finished with .05 micron alumina. The slide was cleaned (wiped with a tissue) and immediately covered with a glass slide, again using super glue.

The procedure should be completed rapidly. Long soaking in water will allow the adhesive to peel off and the coal to dry out and fracture severely while in air. From the time the block is glued to the glass slide the section should be processed to completion.

Reflectance Measurements

All polished sections were dried in a dessicator prior to measurement of reflectance. Low rank coal particles fracture badly due to dessication. Reflectance apparatus consisted of Leitz orthoplan microscope with MPV-3 system (Figure 3), with a motorized drive for the stage. A square leaf diaphram with a 5 micron square measuring area of the specimen was used. All reflectance measurements were made using a filter to give peak transmittance at 546 nm wave length. Bausch and Lomb Company optical glasses were used as reflectance standards. Maximum reflectances were measured in oil for 100 vitrinite/ulminite particles using two pellets.

Petrological Analysis

Terminology and procedures approved by the International Committee for Coal Petrology (26) and Stach's textbook of coal petrology (27) were followed. Brown coal terminology was used for all subbituminous and lower rank coal, and hard coal terminology was used for bituminous coals. Tables 1 and 2 summarize the macerals of brown coals and hard coals (26). A thousand points were counted between 2 pellets for petrological analysis. Point counts were made under both normal incident light and fluorescent incident light excitation (blue light) for liptinite macerals and fluorescent vitrinite. The fluorescence system consisted of Leitz SmLux microscope, ploempak fluorescence incident light illuminator and 100w mecury lamp, fitted with I2 cube (Figure 4). Figures 5, 6 and 7 show the occurrence of various macerals. Figure 8 shows fluorescence colors of liptinite macerals in fluorescence (blue light). In reflected light, examination of fluorescence of liptinite macerals makes their identification unambiguous.

Determination of Minerals by X-Ray Diffraction

An internal standard method recommended by Rao and Gluskoter (28) was used for the quantitative analysis of minerals in low temperature ash. A Phillips Norelco X-Ray diffraction system with CuK Ni-filtered radiation at 40 Kv, 15 ma was used.

Mineral matter residue obtained from low temperature ashing was first ground in an agate mortar to minus 200 mesh. As an internal standard, 0.02 grams of finely powdered pure fluorite was mixed with 0.1 grams of sample on a weighing paper, followed by hand mixing grinding in an agate mortar for 25 minutes under ethanol.

The back packed cavity mount technique described by Rao and Gluskoter (28) was used and was found effective in avoiding orientation of powdered grains along the preferred cleavage faces of minerals.

A preliminary scan of the samples from 2^{o} to 60^{o} revealed that the minerals in the samples were quartz, calcite, dolomite, siderite, kaolinite, illite and expandable clay.

The calibration curves of two series of standard mixes (Rao, 29) were used. The first set (Standard QCD) of standards consisted of quartz, calcite and dolomite and the second set (Standard PSA) of plagioclase, siderite and analcime. Details of preparation of standards and standard curves were presented by Rao (29).

Figure 3. Leitz orthoplan microscope with MPV 3 reflectance measurement system and vario-orthomat photomicrographic camera system.

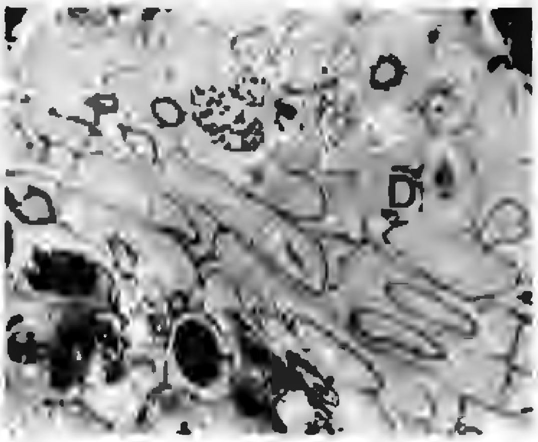
Figure 4. Leitz Sm-Lux microscope for reflected light fluorescence examination of Liptinite macerals.

TABLE 1. Summary of the Macerals of Brown Coals (26)

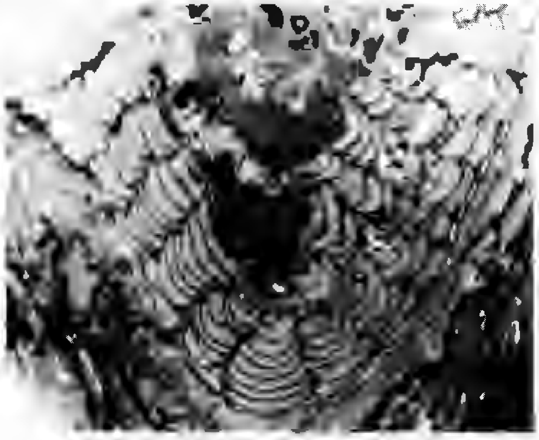
Group Maceral	Maceral Subgroup	Maceral	Submaceral
Huminite	Humotelinite	Textinite	
		Ulminite	Texto-Ulminite Eu-Ulminite
	Humodetrinite	Attrinite	
		Densinite	
	Humocollinite	Gelinite	Porigelinite Levigelinite
		Corpohuminite	Phlobaphinite Pseudophlobaphinite
Liptinite		Sporinite	
		Cutinite	
		Resinite	
		Suberinite	
		Alginite	
		Liptodetrinite	
		Chlorophyllinite	
Inertinite		Fusinite	
		Semifusinite	
		Macrinite	
		Sclerotinite	
		Inertodetrinite	

TABLE 2. Summary of the Macerals of Hard Coals (26)

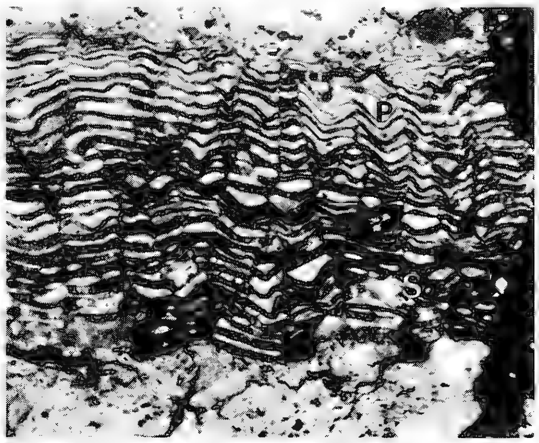
Group Maceral	Maceral	Submaceral
Vitrinite	Telinite	Telinite 1 Telinite 2
	Collinite	Telocollinite Gelocollinite Desmocollinite Corpocollinite
	Vitrodetrinite	
Exinite	Sporinite	
	Cutinite	
	Resinite	
	Alginite	
	Liptodetrinite	
Inertinite	Micrinite	
	Macrinite	
	Semifusinite	
	Fusinite	Pyrofusinite Degradofusinite
	Sclerotinite	
	Inertodetrinite	



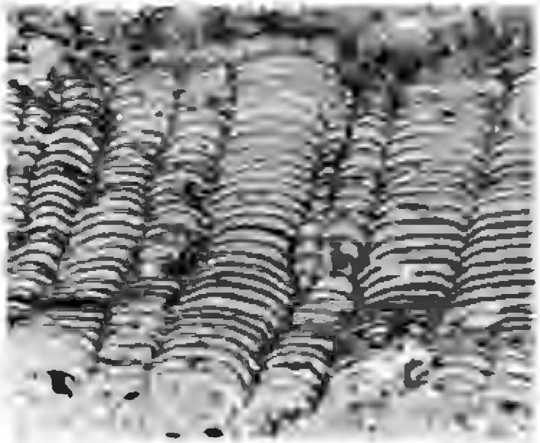
A. Corpohuminite bodies, partly dense(D) and partly porous(P) in a root section (UA-103)



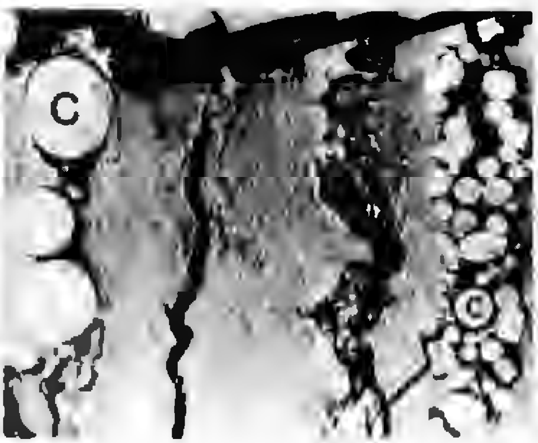
B. Phlobaphinite(P) and suberinite (S) in a traverse section of root bark (UA-113)



C. Pholbaphinite (P) cell fillings and thick suberinites (S) cell walls of a cortex (UA-101)



D. Phlobaphinite (P) with thin suberinite (S) cell walls (UA-103)

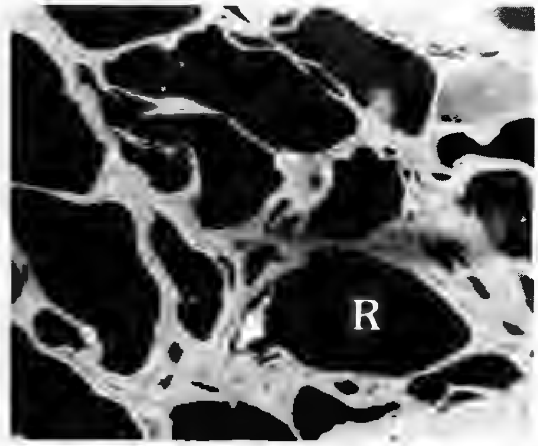


E. Large and small corpohuminites (C)(UA-113)

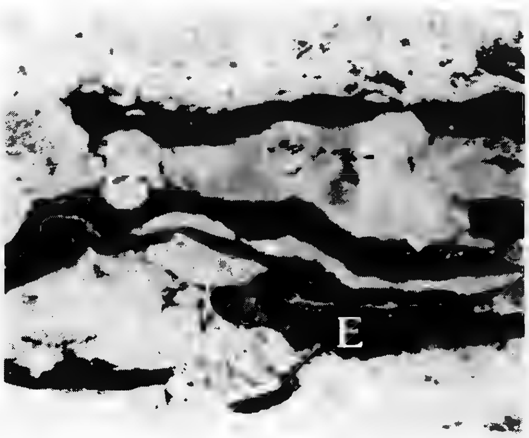
F. Corpohuminites (C) in ulminite (U)(UA-113)

Figure 5. Photomicrographs of Beluga and Nenana coals showing corpohuminites and associated macerals. Oil Immersion 500 X

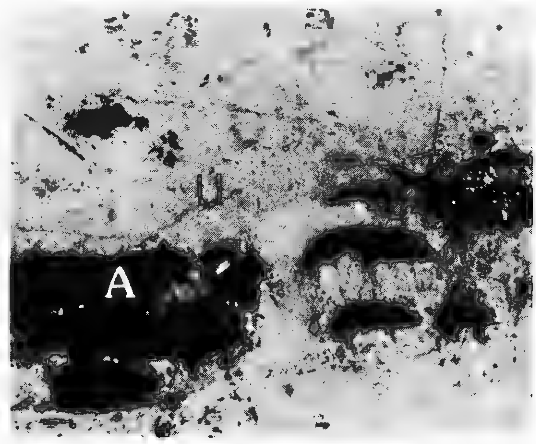
A. Autocthonous resinite (R) in cell tissue (UA-100)



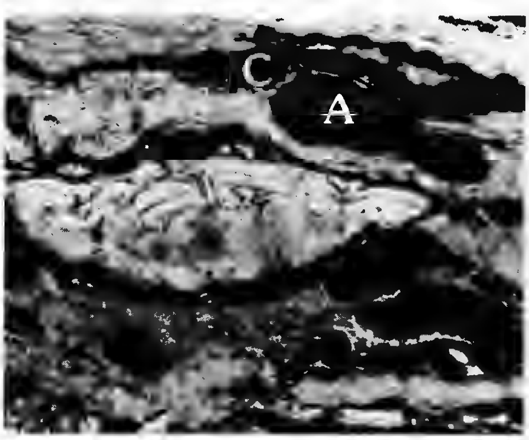
B. Resinite (R) cell fillings surrounded by thin cell walls (UA-108)



C. Exsudatinite (E) filling cracks (UA-110)



D. Alginite (A) embedded in ulminite (UA-110)



E. Alginite (A) and cutinite (C) (UA-113)

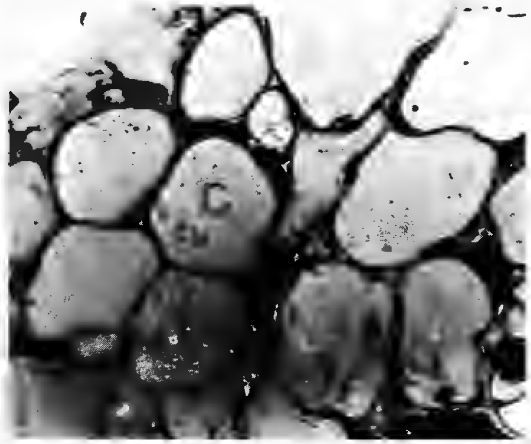
F. Sporinite (S), cutinite (C), inertodetrinite (I), in humodetrinite (H) (UA-100)

Figure 6. Photomicrographs of Beluga, Nenana, Matanuska and Northern Alaska coals showing liptinite and associated macerals. Oil Immersion 500 X

A. Sclerotinite (S) and Exinite (E)(UA-113)

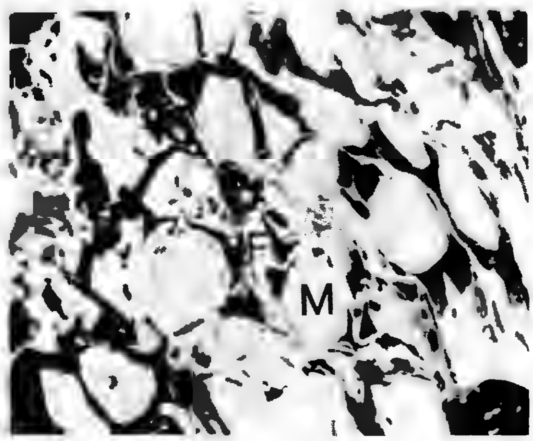
B. Increase in reflectance (↑) of ulminite tissue possibly due to fungal activity (UA-100)

C. Porigelinite (P) filling fusinite (F) cell lumens (UA-109)



D. Corpocollinite (C) filling cell lumens (UA-113)

E. Typical Eu-ulminite (UA-119)

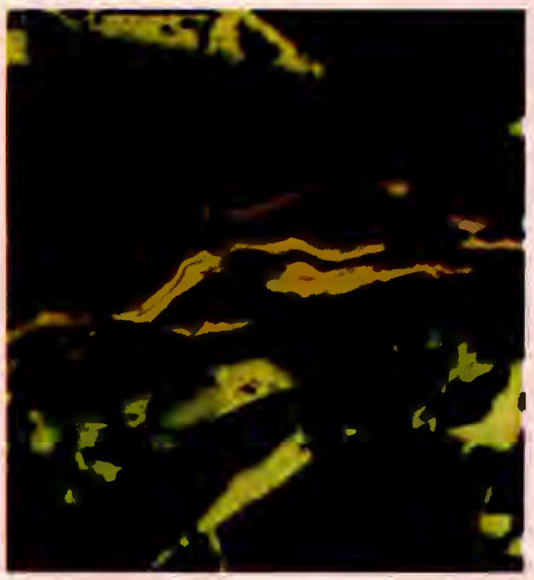


F. Macrinite (M) filling fusinite (F) cell cavities (UA-109)

Figure 7. Photomicrographs of Beluga, Nenana and Northern Alaska coals showing various macerals. Oil Immersion 500 X

A. Suberinite

B. Resinite filling cell cavities. Same as Figure 6B.



C. Exsudatinite filling fractures. Same as Figure 6C.

D. Alginite. Same as Figure 6D.

Figure 8. Photomicrographs of liptinite macerals in fluorescence (blue light excitation) reflected light, air.

An internal standard of 0.2 grams of fluorite powder and a clay mixture diluent containing equal amounts of kaolinite, montmorillonite and illite were added to the series of standard mixes. The standard mixes were pulverized by an automatic mortar grinder for 120 minutes in order to obtain an optimum grain size. The mounted standards were x-rayed from 14° to 34° with a scanning speed of 1/4 degrees per minute and a chart speed of 1 inch per minute. Integrated peak height intensities of each mineral were measured in recorded chart units with 500 counts full scale. The reflections of minerals used for peak height measurements were quartz (101) 3.34°A, calcite (104) 3.04°A, dolomite (104) 2.89°A, siderite (104) 3.15°A and fluorite (111) 3.15°A. Three mounts were prepared for each standard mix and each mount was x-rayed twice. The average value from the six patterns was used for the calibration curves.

The calibration curves were constructed by plotting the respective peak height intensity ratios of these minerals with fluorite as the ordinate, and grams of the respective minerals per 0.2 grams of fluorite as the abscissa.

Identical settings of x-ray diffractometer and recorder were used for samples and standards. Percentages of the minerals were obtained by referring directly to their respective calibration curves, using internal standard sample peak height ratios (Rao, 29).

Infrared Spectrophotometric Determination of Kaolinite

Procedures described by O'Gorman and Walker (30) and Gong and Suhr (31) were used. Kaolinite used for the preparation of standards was pulverized wet in an agate mortar and the minus 2μ fraction separated by sedimentation. LTA samples were pulverized in an agate mortar wetted with ethanol. A 1 mg sample or standard was mixed with 200 mg of KBr and pelletized in an evacuated die with pressure maintained at 10 tons/sq. inch for 10 seconds. The pellets were scanned, using a Perkin-Elmer model 283B double beam grating infrared spectrophotometer. Kaolinite is determined using the 910 cm -1 peak. The baseline method (O'Gorman and Walker, 30) was used. The baseline is obtained by connecting the background lows on either side of the peak with a straight line. Standard curves were drawn of absorbance vs concentration of kaolinite, and these gave an excellent straight line relationship.

Determination of Chemical Composition of Ash

Atomic absorption and emission spectrochemical procedures were used for the analysis. Procedures outlined by Rao (29) were generally followed and are briefly described below. For atomic absorption analysis, sample digestions were made by both lithium metaborate fusions and hydroflouric acid digestions.

Atomic Absorption Analysis

A Perkin-Elmer model 603 atomic absorption spectrophotometer was used. In the lithium metaborate fusion procedure: (Meldin, Suhr and Bodkin, 31) 0.2 g of coal is mixed with 0.8 g of lithium metaborate and fused for 10 minutes in a graphite crucible at 950°C. The fusion is dissolved in 80 ml of 4% HNO_3 solution while stirring over a magnetic stirrer. The solutions are transferred to polyethylene bottles, capped tightly and are used for the determination of SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, TiO_2 and MnO, using standard analytical procedures.

Digestion with Hydrofluoric Acid

0.5 gms of coal ash is weighed and transferred to a 3" diameter Teflon evaporating dish. The sample is moistened with 2 ml distilled water. After an addition of 4 ml perchloric acid, the dish is heated on a hot plate until nearly dry. The dish is cooled and 1 ml perchloric acid and 10 ml HF are added and evaporated to near dryness. The dish is cooled and 1 ml $HClO_3$ and 5 ml 5% boric acid solution are added and swirled to make sure that all the sample is loosened from the bottom of the dish. Any sticking residue is loosened with a polyethylene covered rod. The dish is now heated until dense fumes evolve, without allowing the residue to dry. The dish is cooled and the residue is taken into solution with 20 ml 25% HCl and made up to 50 ml. Sodium and potassium were determined using cesium nitrate as deionizer. Copper and nickel were also determined with these solutions.

Emission Spectrochemical Analysis

A Jarrel-Ash, Model 78-090, 1.5 meter Wadsworth grating spectrogarph with a reciprocal linear dispersion of 5.4 A°/mm in the second order was used. The exposures were recorded in the second order between 2100 A° and 4850 A° using spectrum analysis No. 1 emulsion 35 mm film. The exposed films were processed for 3 minutes at 68° F in D-19 developer using a Jarrel-Ash photoprocessor. The emulsion was calibrated and attenuated using a 7 step rotating sector having a transmission ratio of 1.585 between steps.

All samples were analyzed in duplicate on separate films. Standards were burned in triplicate, spaced in between samples. Standard analyzed rocks were analyzed to check the accuracy of the procedure. Percent transmission of the lines was measured with a Jarrel-Ash microphotometer using a 12.5 micron slit. Background corrections were made for Pb, Ga, Mo, Sn, V, Ag and Co. No corrections were made for the background for Ba, B or Cr since the background level for these elements was very low at the step measured.

The total energy method was used in which only one exposure is needed for the determination of all elements. 20 mg of coal ash was mixed with 60 mg of graphite buffer mix (SP-2 graphite containing 20% LiF) in a wig-L-bug mixer. 20 mg of the arc mix was loaded into electrodes and packed. Duplicate exposures are made for each sample.

Discussion of Results

The coals studied range in rank from lignite to high volatile 'A' bituminous. Table 3 presents proximate and ultimate analyses of 20 coal samples (Rao and Wolff, 1, 2). Table 4 shows washability analyses of 38mm x 100 mesh coals, UA-107, 113 and 119 used for the study (Rao and Wolff, 1, 2).

Petrology

Vitrinite reflectance of the 20 coals studied is shown in Table 5, mean maximum reflectance varied from 0.25 to 1.04. Table 6 shows petrology of subbituminous and lignite rank coals. Total huminites in the coals range from 80% in UA-100 to 94.1 in UA-106. Corpohuminites include both phlobaphinite and pseudo phlobaphinite. Humodetrinite was highest in UA-100 and UA-101. This is explained by the fact that these two samples are from the upper portion of No. 6 seam (the uppermost seam at the lower Lignite Creek), indicative of changes in the environment causing physical degradation of humic matter and eventually ending conditions for the formation of coal.

High concentration of fluorescent huminites in UA-112 might have resulted from impregnation of liptinitic material in huminite. These coals showed highest concentration of resinite. Resinite particles up to a centimeter have been identified in the field. Suberinite was found not only in Tertiary coals, but also in samples UA-109 and UA-110 of Cretaceous age.

Samples UA-109 and UA-110 from the northern Alaska coal field are the only coals where a significant amount of alginite has been identified. First petrographic work on these two coals was reported by Dutcher, Trotter and Spackman (33). Coal samples from Lower Lignite Creek i.e., UA-100, UA-101, UA-102 and UA-119 showed the highest concentration of inertinite, in excess of 11%, and much of it as inertodetrinite.

Tables 8 and 9 show distribution of macerals in various density factions of low rank coals. Humodetrinite concentration is lowest in 1.3 specific gravity floats and increases with increasing density. This is due to the fact that processes responsible for physical degradation of humic matter also brought in detrital inorganic material that caused increase in density of coal particles.

Another observation is that suberinite is concentrated in higher density fractions. Suberinite is generally found in root tissues. The roots were coalified in place and the places roots were growing best were where there was inorganic material admixed with the original peat. Fusinite and semifusinite concentration increased for higher density fractions. The same is true for inertodetrinite. For UA-119, total inertinite concentration was 3.7% for 1.3 specific gravity float and increased to 19.7% for 1.6 specific gravity sinks, showing that beneficiation can result in substantial reduction in inert macerals, thereby concentrating reactive macerals in clean coal.

Table 7 shows the petrology of bituminous coals from Matanuska Coal field. These coals are very high in vitrinoid macerals. Table 10 shows petrology of various washability products. The concentration of pseudovitrinite is highest in lowest density fraction. Pseudovitrinite occurs in a pure form, free from admixed detrital minerals, and thus explains this phenomenon. As was the case with UA-113 and UA-119, inertodetrinite was highest in the intermediate density fractions.

Mineral Matter

Tables 11 and 12 show distribution of mineral matter in raw coals and float sink products. Quartz and kaolinite were the major minerals identified. Calcite and siderite were identified in a few instances. Bituminous coals UA-107 and UA-108 showed high concentrations of both quartz and kaolinite, showing higher degrees of crystallinity brought to the coal by coalification processes. In the upper Lignite Creek, of the two samples UA-103 and UA-104, the top seam in the series, UA-103, showed higher kaolinite. In the lower Lignite the lower No. 4 Seam UA-119 showed only 5% kaolinite. However the No. 6 Seam (the top seam) had 31% kaolinite for the upper portion (UA-100), 18% for the lowest portion (UA-102) and 15% for the middle portion (UA-101). Both siderite and calcite were found in UA-104 and UA-112. The sample UA-109 had low total ash content and thus accounted for a small portion of the total mineral matter. The balance was presumably noncrystalline that could not be detected by x-ray diffraction, as well as other clay minerals. The same is true for several other samples.

The float sink products show gradual increase in quartz with increase in density. Distribution of kaolinite is, however, different and varied with rank of coal. For bituminous coal UA-107, kaolinite was highest in lowest density fraction, and decreased with increase in density. For subbituminous "C" coals UA-113 and UA-119, the lowest density fraction showed lowest kaolinite and is presumed to be due to the noncrystalline nature of the mineral matter in the 1.3 floats of these samples.

Composition of Coal Ash

Table 13 presents concentrations of major elements in the ash of raw coals. Samples UA-115 and UA-116 are lignites with very low ash and have the lowest silica. Most of the inorganic matter in these two samples consists of alumina, calcium, magnesium and iron oxides.

UA-109, also a low ash coal, showed the lowest alumina. Siderite was the only significant mineral phase identified from x-ray diffraction patterns of LTA of the samples, and was also detected in the polished sections during petrographic analysis. The sample also showed anomalously high concentrations of MgO and Na_2O and very low concentrations of TiO_2. CaO is high in the ash of low rank coals, particularly lignites and subbituminous C coals. Coals of subbituminous B and higher rank showed considerably lower concentrations of CaO.

Table 14 shows concentration of major oxides calculated as percent of raw coals. Concentrations of SiO_2 and Al_2O_3 generally vary with ash content of the coal. Coals of subbituminous C and lower rank coals showed higher concentrations of CaO compared to higher rank coals. Coals from upper Lignite Creek, UA-103 and UA-104, showed very low concentrations on MnO compared to other coal from this field.

Tables 17, 18 and 19 show distribution of major oxides in ashes of float sink products. Concentration of SiO_2 increases with increase in density. All three coals showed higher iron in 1.3 specific gravity float ash compared to intermediate density fractions. All the coals showed highest concentrations of CaO and MgO in 1.3 float ash; concentration decreased with increase in density. CaO in 1.6 sink ash for UA-107 again increased, apparently due to the presence of CaO as carbonates. Difference in concentration of CaO in various density fractions is quite spectacular. For example, UA-113 shows 34.9% of CaO for 1.3 specific gravity float ash and reduced to 2.4% for 1.6 sink ash, indicating ash composition can be dramatically changed in beneficiation processes. On the contrary, concentrations of Na_2O and K_2O is lower in 1.3 float ash fraction (UA-113 and UA-119) compared to higher density fractions, indicating that these elements are not tied to the organic matter. Calcium was probably introduced into coal as calcium humate and explains such high concentrations of CaO in 1.3 specific gravity floats of low rank coals.

Tables 20, 21 and 22 show distribution of major elements expressed as percent float sink products. With the exception of calcium, all elements showed increased concentrations with increase in density, showing that concentrations of these elements in a washed coal would be less than raw coal. Calcium, however, showed different behavior. Low rank coals UA-113 and UA-119 showed high CaO in the intermediate density products. Major oxides analyses, however, are more useful when evaluated as concentrations of ash, since it is what matters most in predicting the behavior of ash in combustion processes and evaluating possible uses for the ash as a byproduct.

Table 15 shows the concentration of various trace elements. Anomalously high concentrations of boron were found in two seams from upper Lignite Creek, UA-103 and UA-104, and two cretaceous coals from Northern Alaska, UA-109 and UA-110. Table 16 shows concentration of trace elements as percent of raw coals. Samples from upper Lignite Creek UA-103 and UA-104, samples from Jarvis Creek UA-106. Broad Pass UA-111 and Little Tonzona UA-113 showed much higher barium compared to others.

Tables 23, 24 and 25 show concentration of trace elements in various float sink products. In general, boron, barium, cobalt, molybdenum and nickel showed higher concentration in the ash of lower density fractions.

Tables 26. 27 and 28 show concentrations of trace elements expressed as concentrations in float sink products. All elements show increase in concentrations with increase in density, showing that beneficiation of these coals will result in partial elimination of trace elements from raw coal. This finding is in agreement with the findings of Cavallaro et al., (24) for coals from other parts of the country.

Summary

Twenty samples of Alaskan coal seams, collected under a separate U.S. Department of Energy sponsored project, were used for this study. The purpose of the investigation was to conduct a general survey of basic characteristics of Alaskan coals and to determine the change in these characteristics brought about by coal preparation processes. The characteristics presented in the report include proximate analysis, ultimate analysis, vitrinite reflectance, petrology, concentration of mineral matter obtained by low temperature ashing (LTA), major, minor and trace elements in high temperature ash (HTA). In addition, washability analysis of three coals, one each from Nenana. Beluga and Matanuska coal fields, were sink floated at 1.3, 1.4 and 1.6 specific gravities and the products were analyzed for petrographic composition, minerals in LTA and composition of ash (HTA).

Conclusions

The reflectance rank of the coals studied ranged from a low of 0.22 for lignite to 1.04 for high volatile A bituminous coal.

Huminite macerals in the subbituminous coals and lignites ranged from 80 to 96.3%. Humodetrinite was highest in the top seam in a coal bearing sequence. Suberinite was found in all tertiary brown coals as well as Cretaceous coals from northern Alaska. Float sink products showed the lowest concentrate of inertinite and humodetrinite in 1.3 specific gravity floats and increased with increasing density. Petrology of bituminous coals showed very high concentrate of vitrinite macerals. LTA of bituminous coals showed a higher concentrate of kaolinite and quartz compared to brown coals. Concentration of major oxides in the ash float sink products showed major differences, particularly for CaO, ranging in one instance from 34.9% in 1.3 specific gravity float ash and falling down to 2.4% in 1.6 specific gravity sink ash. Similar major differences were observed in petrology and mineralogy, indicating that total characterization of washability products (rather than raw coal alone) is necessary in evaluating the behavior of washed coal in utilization.

TABLE 3

Proximate and Ultimate Analyses of Raw Coals

Coal Field	ASTM Rank	Thickness Meters (feet)	Sample Numbers	Basis*	Moisture %	Volatile Matter,%	Fixed Carbon,%	Ash %	Heating Value BTU/lb.	C,%	H,%	N,%	O,%	Sulfur Pyritic	Sulfur Total
Nenana															
Poker Flat Pit	Subbit.C	0.98	UA-100	1	23.61	32.80	26.54	17.05	7022	40.59	5.93	0.56	35.70	0.01	0.17
No.6 Seam		(3.2)		2		42.94	34.74	22.32	9193	53.14	4.30	0.73	19.29	0.01	0.22
Top				3		55.28	44.72		11834	68.40	5.54	0.94	24.84	0.01	0.28
Nenana															
Poker Flat Pit	Subbit.C	5.58	UA-101	1	25.23	35.71	31.40	7.66	8136	46.08	6.30	0.60	39.24	0.01	0.12
No.6 Seam		(18.3)		2		47.76	41.99	10.25	10882	61.64	4.65	0.80	22.50	0.01	0.16
Middle				3		53.22	46.78		12124	68.68	5.18	0.89	25.07	0.01	0.18
Nenana															
Poker Flat Pit	Subbit.C	1.00	UA-102	1	25.68	34.12	29.83	10.37	7516	43.87	6.05	0.59	38.99	0.01	0.13
No.6 Seam		(3.3)		2		45.91	40.14	13.95	10113	59.03	4.28	0.80	21.77	0.01	0.17
Lower				3		53.36	46.64		11752	58.60	4.97	0.93	25.30	0.01	0.20
Nenana															
Moose Seam	Subbit.C	6.58	UA-103	1	21.42	36.02	34.88	7.68	8953	51.69	6.34	0.81	33.33	0.01	0.15
		(21.6)		2		45.85	44.38	9.77	11393	65.78	5.02	1.03	18.25	0.01	0.15
				3		50.81	49.19		12627	72.90	5.56	1.15	20.18	0.01	0.21
Nenana															
Caribou Seam	Subbit.C	5.06	UA-104	1	21.93	35.88	32.85	9.34	8567	49.44	6.10	0.69	34.30	0.02	0.13
		(16.6)		2		45.96	42.08	11.96	10973	63.33	4.67	0.88	18.99	0.02	0.17
				3		52.20	47.80		12464	71.93	5.30	1.00	21.57	0.03	0.20
Nenana															
No.2 Seam	Subbit.C	8.47	UA-105	1	26.76	33.12	32.25	7.87	7966	46.41	6.42	0.63	38.50	0.02	0.17
		(27.8)		2		45.23	44.03	10.74	10876	63.38	4.68	0.86	20.11	0.02	0.23
				3		50.67	49.33		12185	71.01	5.24	0.96	22.54	0.03	0.25
Jarvis Creek															
Ober Creek	Subbit.C	3.05	UA-106	1	20.58	36.20	34.16	9.06	8746	49.83	5.84	0.80	33.42	0.31	1.05
		(10)		2		45.58	43.01	11.41	11012	62.75	4.45	1.00	19.07	0.39	1.32
				3		51.45	48.55		12430	70.83	5.02	1.13	21.53	0.44	1.49
Matanuska															
Castle Mountain	hv Ab	2.13	UA-107	1	1.78	28.23	52.20	17.78	12258	69.33	4.66	1.64	6.13	0.09	0.46
Mine		(7)		2		28.75	53.15	18.10	12480	70.59	4.54	1.68	4.62	0.09	0.47
Lower Seam				3		35.10	64.90		15238	86.19	5.54	2.05	5.65	0.11	0.57
Matanuska															
Premier Mine	hv Bb		UA-108	1	5.87	35.73	43.96	14.44	11101	63.63	5.11	1.14	15.33	0.04	0.35
				2		37.95	46.70	15.34	11794	67.60	4.73	1.21	10.75	0.04	0.37
				3		44.84	55.16		13864	79.85	5.59	1.43	12.70	0.05	0.43

TABLE 3 (continued)

Proximate and Ultimate Analyses of Raw Coals

Coal Field	ASTM Rank	Thickness Meters (feet)	Sample Numbers	Basis*	Moisture %	Volatile Matter,%	Fixed Carbon,%	Ash %	Heating Value BTU/lb.	C,%	H,%	N,%	O,%	Sulfur Pyritic	Sulfur Total
Northern				1	20.28	30.20	44.75	4.77	9292	54.79	5.71	1.13	33.32	0.08	0.28
Alaska	Subbit.B	1.5	UA-109	2		37.88	56.13	5.99	11655	68.73	4.31	1.42	19.20	0.10	0.35
Wainwright		(5)		3		40.29	59.71		12398	73.10	4.58	1.51	20.43	0.10	0.35
Northern				1	17.88	30.30	48.22	3.60	10425	60.04	5.87	1.35	28.71	0.06	0.43
Alaska	Subbit.B	1.5	UA-110	2		36.90	58.72	4.38	12695	73.12	4.72	1.64	15.61	0.07	0.53
Meade River		(5)		3		38.59	61.41		13277	76.47	4.94	1.71	16.33	0.08	0.55
Broad Pass				1	28.32	33.53	24.08	14.07	6395	38.14	6.06	0.54	41.04	0.03	0.15
Coal Creek	Lignite	2.4	UA-111	2		46.77	33.60	19.63	8921	53.21	4.04	0.75	22.16	0.04	0.21
Seam		(8)		3		58.20	41.80		11100	66.20	5.03	0.93	27.58	0.05	0.26
Little				1	21.21	37.59	30.36	10.84	7663	45.02	5.80	0.64	36.59	0.06	1.11
Tonzona	Subbit.C	38.7	UA-112	2		47.72	38.53	13.75	9725	57.14	4.34	0.81	22.56	0.08	1.40
Coal bed		(127)		3		55.33	44.67		11277	66.25	5.03	0.94	26.15	0.09	1.63
Beluga				1	23.65	35.20	33.34	7.81	8327	47.98	6.25	0.54	37.28	0.01	0.14
Waterfall	Subbit.C	9.1	UA-113	2		46.10	43.67	10.23	10907	62.84	4.71	0.71	21.33	0.01	0.18
Seam		(30)		3		51.35	48.65		12151	70.01	5.25	0.79	23.74	0.01	0.21
Northern				1	14.71	15.74	15.65	53.90	3591	20.98	3.37	0.53	21.16	0.04	0.06
Alaska	hv Cb	2.0	UA-114	2		18.45	18.36	63.19	4210	24.60	2.02	0.62	9.50	0.05	0.07
Sagwon Bluffs		(6.5)		3		50.13	49.87		11439	66.83	5.49	1.67	25.81	0.14	0.20
Yentna				1	29.80	38.26	28.61	3.33	7943	45.20	6.76	0.53	44.07	0.01	0.11
Locality 2	Lignite	3.0	UA-115	2		54.50	40.76	4.74	11315	64.39	4.87	0.75	25.10	0.01	0.15
Lower		(10)		3		57.21	42.79		11879	67.59	5.11	0.79	26.35	0.01	0.16
Yentna				1	29.86	39.29	28.43	2.42	8017	45.48	6.89	0.49	44.67	0.01	0.05
Locality 2	Lignite	3.0	UA-116	2		56.02	40.54	3.44	11429	64.84	5.06	0.70	25.89	0.01	0.07
Upper		(10)		3		58.02	41.98		11837	67.16	5.24	0.73	26.79	0.01	0.08
Tramway				1	6.38	24.29	33.54	35.79	7263	42.72	3.62	0.55	17.18	0.04	0.14
Bar	hv B	4.0	UA-117	2		25.94	35.83	38.23	7758	45.64	3.10	0.59	12.29	0.04	0.15
		(13)		3		41.99	58.01		12559	73.88	5.02	0.95	19.90	0.07	0.25
Kenai				1	23.01	35.63	32.71	8.65	8028	47.23	6.07	0.62	37.20	0.01	0.23
Cabin	Subbit.C	1.8	UA-118	2		46.28	42.49	11.23	10428	61.35	4.54	0.81	21.77	0.01	0.30
Bed		(6)		3		52.13	47.87		11747	69.11	5.11	0.91	24.53	0.01	0.34
Nenana				1	25.29	32.51	32.55	9.85	7779	45.28	6.30	1.13	37.11	0.02	0.33
Poker Flat Pit	Subbit.C	7.3	UA-119	2		43.52	43.30	13.18	10412	60.61	4.64	1.51	19.62	0.02	0.44
No. 4 Seam		(24)		3		50.13	49.87		11993	69.81	5.34	1.74	22.60	0.03	0.51

* 1 is Equilibrium bed moisture basis
2 is Moisture-free basis
3 is Moisture-ash-free basis

TABLE 4. Washability Aalyses of 38mm x 100 Mesh Coals Used for the Study.

SPECIFIC GRAVITY		ACTUAL PRODUCTS					CUMULATIVE FLOAT					CUMULATIVE SINK	
					Sulfur percent					Sulfur percent			
Sink	Float	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %	Btu/lb	Pyritic	Total	Wt. %	Ash %
Washability Analyses of Lower Seam (UA-107), Castle Mountain Mine, Upper Matanuska Valley, Matanuska Coal Field, Alaska													
Raw Coal Bed Moisture = 1.78%													
	1.30	46.49	5.46	14712	0.02	0.51	46.49	5.46	14712	0.02	0.50	100.00	18.63
1.30	1.40	23.95	12.14	13741	0.03	0.40	70.44	7.73	14382	0.02	0.49	53.51	30.07
1.40	1.60	13.46	27.75	11262	0.05	0.43	3.90	10.94	13801	0.03	0.48	29.56	44.60
1.60		16.10	58.71	5254	0.15	0.40	100.00	18.63	12492	0.05	0.47	16.10	58.71
Washability Analyses of Water Fall Seam (UA-113) Beluga Coal Field, Alaska													
Raw Coal Bed Moisture = 23.65													
	1.30	41.23	4.86	11652	0.01	0.15	41.23	4.86	11652	0.01	0.15	100.00	9.45
1.30	1.40	51.44	9.04	10877	0.01	0.24	92.67	7.18	11222	0.01	0.20	58.77	12.67
1.40	1.60	5.31	32.39	7029	0.01	0.24	97.98	8.55	10995	0.01	0.20	7.33	38.12
1.60		2.02	53.17	5031	0.04	0.20	100.00	9.45	10874	0.01	0.20	2.02	53.17
Washability Analyses of No. 4 Seam (UA-119) Usibelli Coal Mine, Nenana Coal Field, Healy, Alaska													
Raw Coal Bed Moisture = 25.29													
	1.30	21.50	5.54	11441	0.03	0.21	21.50	5.54	11441	0.03	0.21	100.00	11.27
1.30	1.40	71.29	10.88	10644	0.01	0.30	92.79	9.64	10829	0.01	0.28	78.50	12.85
1.40	1.60	6.99	32.24	7978	0.02	0.86	99.78	11.23	10629	0.02	0.32	7.21	32.28
	1.60	0.22	33.49	7771	0.13	0.51	100.00	11.27	10623	0.02	0.32	0.22	33.49

TABLE 5. Vitrinite Reflectance.

Sample No.	ASTM Rank	Mean Maximum Reflectance $\bar{R}_{0max}$	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}
UA-100	Subbit. C	0.29	4	57	23	16							
UA-101	Subbit. C	0.32	5	40	33	22							
UA-102	Subbit. C	0.33	1	31	60	8							
UA-103	Subbit. C	0.41		1	28	71							
UA-104	Subbit. C	0.42			25	74	1						
UA-105	Subbit. C	0.32	11	26	49	14							
UA-106	Subbit. C	0.39		3	51	46							
UA-107	hv Ab	1.04									20	71	9
UA-108	hv Bb	0.63				1	18	75	6				
UA-109	Subbit. B	0.57				6	59	33	2				
UA-110	Subbit. B	0.52				42	42	15	1				
UA-111	Lignite	0.28	9	63	26	8							
UA-112	Subbit. C	0.27	26	47	25	7							
UA-113	Subbit. C	0.25	3	85	11								
UA-114	hv Cb	0.54				14	74	12					
UA-115	Lignite	0.33		28	66	6							
UA-116	Lignite	0.22	46	37	14	3							
UA-117	hv Bb	0.66					14	67	19				
UA-118	Subbit. C	0.31		41	53	6							
UA-119	Subbit. C	0.25	24	58	18								

TABLE 6. Petrology of Subbituminous and Lignite Raw Coals.

Sample No.	Ulminite	Gelinite	Corpo-huminite	Humo-detrinite	Fluorescent Huminite	Total Huminite	Suberinite	Cutinite	Alginite	Sporinite	Resinite	Total Liptinite	Semi-fusinite	Fusinite	Sclero-tinite	Macrinite	Inerto-detrinite	Total Inertinite	TOTAL
UA-100	37.6	18.9	1.8	12.3	9.4	80.0	0.8	0.4	0	2.4	0.6	4.2	0.9	3.1	0.3	1.1	10.4	15.8	100.0
UA-101	49.5	12.9	1.6	13.4	6.8	84.2	0.4	0.2	0	3.6	0.4	4.6	1.0	0.7	0.2	0	9.3	11.2	100.0
UA-102	61.3	9.4	3.0	5.8	0.6	80.1	0.7	0.4	0	4.6	0.8	6.5	3.2	1.2	0	0	9.0	13.4	100.0
UA-103	80.3	11.6	0.3	2.4	0	94.6	0	0.2	0	4.2	0.4	4.8	0	0	0.6	0	0	0.6	100.0
UA-104	81.3	7.6	1.8	1.8	0.2	92.7	0	0	0	3.8	0.4	4.2	0	0.2	0.8	0	2.1	3.1	100.0
UA-105	69.7	12.4	0.9	3.8	0.2	87.0	0.4	0.1	0	4.8	0.8	6.1	1.0	0.8	0.3	0	4.8	6.9	100.0
UA-106	81.7	9.3	0.6	2.5	0	94.1	0.1	0.1	0	3.5	0.6	4.3	0	0	0.2	0	1.4	1.6	100.0
UA-109	75.2	2.3	8.8	.3	0	86.6	0	0.1	0.7	2.2	0.8	3.8	3.5	2.4	0.2	1.2	2.3	9.6	100.0
UA-110	69.3	4.0	18.6	.7	0	92.6	0	0.4	0.4	1.5	1.7	4.0	2.4	0.8	0	0	0	3.4	100.0
UA-111	29.1	35.8	0.3	8.5	17.0	90.7	0	0.5	0	4.6	0.8	5.9	0	0	0.5	0	2.9	3.4	100.0
UA-112	36.4	34.0	0.4	3.0	15.4	89.2	0.8	0.8	0	5.8	1.4	8.8	0.3	0.4	0.2	0	1.1	2.0	100.0
UA-113	65.7	18.3	2.5	3.4	0	89.9	0.4	0.3	0	3.5	0.4	4.6	0	0.5	0.7	0.1	4.2	5.5	100.0
UA-119	54.6	26.3	2.0	1.1	0	84.0	0.2	0.3	0	3.3	0.4	4.2	0.9	1.3	0	0	9.6	11.8	100.0

TABLE 7. Petrology of Bituminous Raw Coal.

Sample No.	Vitrinite	Pseudo-vitrinite	Fluorescent Vitrinite	Total Vitrinite	Culinite	Alginite	Sporinite	Resinite	Total Liptinite	Semi-Fusinite	Fusinite	Selero-tinite	Macrinite	Inerto-detrinite	Total Inertinite	TOTAL
UA-107	80.2	14.3	0.4	94.9	0	0	0.5	0.6	1.1	0.4	0.6	0	0.5	2.5	4.0	100.0
UA-108	79.5	13.2	0	92.7	1.1	0	1.2	0.7	3.0	0.3	0	0	0	4.0	4.3	100.0

TABLE 8. Washability Analyses of Sample UA-113, Crushed to 38 mm, Showing Concentrations of Macerals.

Specific Gravity Sink	Float	Ulminite	Gelinite	Corpo-huminite	Humo-detrinite	Fluorescent Huminite	Total Huminite	Suberinite	Culinite	Alginite	Sporinite	Resinite	Total Liptinite	Semi-fusinite	Fusinite	Sclero-tinite	Macrinite	Inerto-detrinite	Total Inertinite	TOTAL
	1.3	75.1	17.3	0.4	0.7	0	93.5	0	0.3	0	3.6	0.7	4.6	0	0	0.2	0	1.7	1.9	100.0
1.3	1.4	71.9	14.6	3.9	3.3	0	93.7	0.8	0	0	2.1	1.3	3.2	0.5	0	0.1	0	2.5	3.1	100.0
1.4	1.6	54.3	21.2	4.6	10.2	0	90.3	0.3	0	0	4.4	1.1	5.8	0.5	0.1	0.1	0	3.2	3.9	100.0
1.6		61.9	17.9	2.8	11.3	0	93.9	0.3	0	0	2.1	0.6	3.0	0.5	1.4	0	0	1.2	3.1	100.0

TABLE 9. Washability Analyses of Sample UA-119, Crushed to 38 mm, Showing Concentrations of Macerals.

Specific Gravity Sink	Specific Gravity Float	Ulminite	Gelinite	Corpo-huminite	Humo-detrinite	Fluorescent Huminite	Total Huminite	Suberinite	Culinite	Alginite	Sporinite	Resinite	Total Liptinite	Semi-fusinite	Fusinite	Sclero-tinite	Macrinite	Inerto-detrinite	Total Inertinite	TOTAL
	1.3	81.5	9.8	0.8	0.7	0	92.8	0	0.3	0	3.1	0.1	3.5	0.5	1.1	0.2	0	1.9	3.7	100.0
1.3	1.4	66.2	12.5	2.0	4.9	0	85.6	0.7	0.6	0	3.6	0.4	5.3	2.3	1.7	0	0	5.1	9.1	100.0
1.4	1.6	54.8	22.2	0.8	9.8	0	87.6	1.1	0.7	0	2.4	0.7	4.9	0.9	1.2	0.1	0	5.3	7.5	100.0
1.6		57.2	12.1	0.9	4.8	0	75.0	0.8	0.8	0	2.6	1.1	5.3	6.4	8.3	0.3	0	4.7	19.7	100.0

TABLE 10. Washability Analyses of Sample UA-107, Crushed to 38 mm, Showing Concentrations of Macerals.

Specific Gravity Sink	Specific Gravity Float	Vitrinite	Pseudo-vitrinite	Fluorescent Vitrinite	Total Vitrinite	Culinite	Alginite	Sporinite	Resinite	Total Liptinite	Semi-Fusinite	Fusinite	Selero-tinite	Macrinite	Inerto-detrinite	Total Inertinite	TOTAL
	1.3	62.7	35.0	0	97.7	0	0	0.3	0.7	1.0	0	0.2	0.1	0	1.0	1.3	100.0
1.3	1.4	62.9	31.3	0	94.2	0	0	0.3	0.5	0.8	1.1	0.8	0	0	3.1	5.0	100.0
1.4	1.6	76.9	19.9	0.2	97.0	0	0	0	0.5	0.5	0.4	0.8	0	0	1.3	2.5	100.0
1.6		81.6	10.8	0.7	93.1	0	0.1	0.3	5.9	6.3	0	0.2	0	0	0.4	0.6	100.0

TABLE 11. Distribution of Minerals in Low Temperature Ash of Raw Coals and Float Sink Product.

Sample No.	Product	Quartz	Calcite	Dolomite	Siderite	Kaolinite
UA-100	Raw Coal	6	0	0	0	31
UA-101	" "	6	0	0	0	15
UA-102	" "	8	0	0	0	18
UA-103	" "	12	0	0	0	26
UA-104	" "	14	4	0	4	16
UA-105	" "	8	0	0	0	9
UA-106	" "	4	0	0	0	8
UA-107	" "	10	0	0	0	39
UA-108	" "	16	0	0	0	41
UA-109	" "	?	0	0	5	0
UA-110	" "	6	0	0	0	13
UA-112	" "	7	5	0	3	12
UA-113	" "	6	0	0	0	19
UA-119	" "	4	0	0	0	5

TABLE 12. Distribution of Minerals in Low Temperature Ash of Float Sink Products.

Sample No.	Specific Gravity Sink	Specific Gravity Float	Quartz	Calcite	Dolomite	Siderite	Kaolinite
UA-107		1.3	2	0	0	1	39
	1.3	1.4	6	0	0	0	31
	1.4	1.6	8	0	0	0	27
	1.6		9	0	2	3	23
UA-113		1.3	3	0	0	0	5
	1.3	1.4	6	0	0	0	17
	1.4	1.6	10	0	0	0	38
	1.6		12	0	0	0	38
UA-119		1.3	4	0	0	0	5
	1.3	1.4	10	0	0	0	12
	1.4	1.6	11	0	0	0	24
	1.6		11	0	0	0	21

TABLE 13. Concentration of Major Elements in Ash of Raw Coals (percent).

Sample No.	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO	SO_3
UA100	55.3	19.3	7.1	2.2	9.4	0.16	1.8	1.0	0.44	3.1
UA101	37.7	22.6	9.4	3.8	22.8	0.12	1.1	0.9	0.37	5.0
UA102	39.5	21.4	6.6	2.5	24.1	0.11	1.1	1.0	0.19	3.5
UA103	34.7	25.0	5.2	7.7	16.7	0.48	1.6	1.2	0.06	7.2
UA104	43.1	21.4	9.0	5.2	14.7	0.32	1.8	1.1	0.07	5.6
UA105	47.3	20.7	8.9	2.8	12.9	0.77	1.2	0.9	0.44	6.3
UA106	42.7	16.6	11.2	2.2	20.8	0.08	0.7	1.1	0.12	21.7
UA107	53.3	25.7	4.4	1.9	3.6	0.46	2.1	1.3	0.12	1.7
UA108	53.5	28.8	6.5	2.3	4.4	0.23	1.9	1.6	0.10	2.4
UA109	41.7	5.9	18.8	13.0	13.2	5.41	1.0	0.1	0.29	13.1
UA110	43.8	23.3	6.1	3.3	4.4	1.07	1.8	1.3	0.06	2.1
UA111	45.4	29.3	4.6	1.1	9.1	0.25	2.1	1.2	0.17	3.2
UA112	29.8	19.4	6.9	3.3	22.7	0.25	1.2	0.9	0.05	17.2
UA113	41.0	28.9	6.7	1.9	16.6	0.18	2.1	0.8	0.10	7.9
UA114	66.5	20.1	3.9	2.2	1.8	0.21	3.5	1.3	0.04	.7
UA115	16.8	33.3	9.5	6.3	28.0	0.26	1.0	1.1	0.12	9.1
UA116	11.6	27.9	10.6	7.4	37.2	0.27	0.6	0.8	0.13	10.5
UA117	52.8	30.8	5.1	1.4	2.3	0.53	4.0	1.7	0.05	.9
UA118	37.4	21.0	5.7	3.6	25.3	0.11	1.3	0.9	0.11	6.2
UA119	43.4	22.7	6.7	2.7	16.6	0.93	2.2	1.1	0.21	6.5

TABLE 14. Concentration of Major Elements in Raw Coals (percent), Moisture Free Basis.

Sample No.	Ash, Percent Moisture Free Basis	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO
UA-100	22.32	12.34	4.31	1.58	0.49	2.10	0.036	0.40	0.22	0.098
UA-101	10.25	3.86	2.32	0.96	0.39	2.34	0.012	0.11	0.09	0.038
UA-102	13.95	5.51	2.99	0.92	0.35	3.36	0.015	0.15	0.14	0.027
UA-103	9.77	3.39	2.44	0.51	0.75	1.63	0.047	0.16	0.12	0.0059
UA-104	11.96	5.15	2.56	1.08	0.62	1.76	0.038	0.22	0.13	0.0084
UA-105	10.74	5.08	2.22	0.96	0.30	1.39	0.083	0.13	0.10	0.047
UA-106	11.41	4.87	1.89	1.28	0.25	2.37	0.009	0.08	0.12	0.013
UA-107	18.10	9.65	4.65	0.80	0.34	0.65	0.083	0.38	0.24	0.022
UA-108	15.34	8.21	4.42	1.00	0.35	0.68	0.035	0.29	0.25	0.015
UA-109	5.99	2.50	0.352	1.13	0.78	0.79	0.32	0.062	0.006	0.017
UA-110	4.38	1.92	1.02	0.27	0.14	0.19	0.047	0.080	0.057	0.003
UA-111	19.63	8.91	5.75	0.90	0.22	1.79	0.049	0.41	0.24	0.033
UA-112	13.75	4.10	2.67	0.95	0.45	3.12	0.034	0.17	0.12	0.069
UA-113	10.23	4.19	2.96	0.69	0.19	1.70	0.018	0.21	0.08	0.010
UA-114	63.19	42.0	12.7	2.46	1.39	1.14	0.13	2.2	0.82	0.025
UA-115	4.74	0.80	1.58	0.45	0.30	1.33	0.012	0.047	0.052	0.0057
UA-116	3.44	0.40	0.962	0.36	0.25	1.28	0.009	0.021	0.028	0.0045
UA-117	38.23	20.9	11.8	1.95	0.54	0.88	0.20	1.53	0.65	0.019
UA-118	11.23	4.20	2.36	0.64	0.40	2.84	0.012	0.15	0.10	0.012
UA-119	13.18	5.72	2.99	0.88	0.36	2.19	0.12	0.290	0.15	0.028

TABLE 15. Concentration of Trace Elements in Raw Coal Ashes (parts per million).

Sample No.	Ag	B	Ba	Co	Cr	Cu(A.A.)	Ga	Mo	Ni(A.A.)	pb	Sn	V	Zn(A.A.)	Zr
UA-100	N.D	110	N.D	N.D	150	142	36	N.D	62	23	N.D	240	57	310
UA-101	N.D	160	4,300	N.D	110	152	24	N.D	111	N.D	N.D	190	61	130
UA-102	N.D	180	4,800	N.D	160	150	26	N.D	101	150	39	280	80	180
UA-103	N.D	H	18,000	49	150	215	39	N.D	200	320	N.D	300	110	440
UA-104	1.3	1,900	12,000	40	160	150	34	N.D	130	93	N.D	300	71	360
UA-105	N.D	140	4,700	N.D	120	170	21	N.D	150	N.D	N.D	250	170	280
UA-106	1.5	130	15,000	60	140	180	22	94	145	N.D	N.D	280	160	500
UA-107	N.D	110	3,400	40	110	92	52	N.D	90	25	N.D	320	99	370
UA-108	N.D	470	N.D	260	180	86	63	N.D	200	28	N.D	380	370	260
UA-109	N.D	4,100	7,900	61	N.D	46	14	N.D	102	N.D	N.D	N.D	237	470
UA-110	N.D	H	4,800	200	81	103	100	21	260	180	N.D	270	366	580
UA-111	N.D	96	11,000	71	380	157	57	N.D	124	99	27	350	110	400
UA-112	2.9	330	12,000	73	200	434	22	79	175	57	N.D	560	403	320
UA-113	N.D	130	5,200	88	230	164	52	N.D	121	110	N.D	360	182	420
UA-114	N.D	180	N.D	N.D	150	72	32	N.D	60	21	N.D	310	101	170
UA-115	1.3	320	5,700	35	160	230	47	N.D	130	42	48	220	100	480
UA-116	1.6	370	5,500	98	170	250	31	10	165	83	28	240	120	750
UA-117	N.D	670	N.D	23	160	76	46	N.D	79	59	26	320	145	330
UA-118	N.D	380	5,500	28	170	235	27	14	105	42	N.D	400	95	410
UA-119	N.D	310	5,900	90	160	300	32	17	145	29	N.D	540	50	350

TABLE 16. Concentration of Trace Elements in Raw Coals (parts per million).

Sample No.	Ash, Percent Moisture Free Basis	Ag	B	Ba	Co	Cr	Cu(A.A.)	Ga	Mo	Ni(A.A.)	pb	Sn	V	Zn(A.A.)	Zr
UA-100	22.32	N.D	25	N.D	N.D	33	32	8.0	N.D	25	5.1	N.D	54	13	69
UA-101	10.25	N.D	16	440	N.D	11	16	2.5	N.D	9.0	N.D	N.D	19	6.3	13
UA-102	13.95	N.D	25	670	N.D	22	21	3.6	N.D	12	21	5.4	39	11	25
UA-103	9.77	N.D	H	1,800	4.8	15	21	3.8	N.D	40	31	N.D	29	11	43
UA-104	11.96	0.16	230	1,400	4.8	19	18	4.1	N.D	22	11	N.D	36	8.5	43
UA-105	10.74	N.D	15	500	N.D	13	18	23	N.D	15	N.D	N.D	27	18	30
UA-106	11.41	0.17	15	1,700	6.8	16	21	2.5	11	19	N.D	N.D	32	18	57
UA-107	18.10	N.D	20	620	7.2	20	17	9.4	N.D	18	4.5	N.D	58	18	67
UA-108	15.34	N.D	72	N.D	40	28	13	9.7	N.D	58	4.3	N.D	58	57	40
UA-109	5.99	N.D	250	470	3.7	N.D	2.8	0.84	N.D	4.9	N.D	N.D	N.D	14	28
UA-110	4.38	N.D	H	210	8.8	3.5	4.5	4.4	0.92	21	7.9	N.D	12	16	25
UA-111	19.63	N.D	19	2,200	14	75	31	11	N.D	35	19	5.3	69	22	79
UA-112	13.75	0.40	45	1,700	10	28	60	3.0	11	25	7.8	N.D	77	55	44
UA-113	10.23	N.D	13	490	9.0	24	17	5.3	N.D	19	11	N.D	37	19	43
UA-114	63.19	N.D	110	N.D	N.D	95	45	20	N.D	33	13	N.D	200	64	110
UA-115	4.74	0.06	15	270	1.7	7.6	11	2.2	N.D	4.7	2.0	2.3	10	4.7	23
UA-116	3.44	0.06	12	190	3.4	5.8	8.6	1.1	0.34	5.2	2.9	0.96	8.3	4.1	26
UA-117	38.23	N.D	280	N.D	8.8	61	29	18	N.D	26	23	9.9	120	55	130
UA-118	11.23	N.D	43	520	3.1	19	26	3.0	1.6	13	4.7	N.D	45	11	46
UA-119	13.18	N.D	41	780	12	21	40	4.2	2.5	21	3.8	N.D	71	66	46

TABLE 17. Washability Analyses of Sample 107, Crushed to 38 mm Top Size, Showing Concentration of Major Elements in Ash of Products.

Specific Gravity Sink	Specific Gravity Float	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO
	1.3	43.4	31.8	5.8	2.4	8.6	0.41	1.3	1.9	0.05
1.3	1.4	55.5	31.3	2.8	1.6	2.6	0.32	1.9	1.7	0.04
1.4	1.6	60.0	29.0	2.6	1.6	1.6	0.33	2.9	1.6	0.05
1.6		54.4	27.1	6.3	1.1	4.9	0.53	2.4	1.0	0.14
Head, calc.		54.2	28.8	4.9	1.6	4.4	0.44	2.3	1.4	0.09

TABLE 18. Washability Analyses of Sample 113, Crushed to 38 mm Top Size, Showing Concentration of Major Elements in Ash of Products.

Specific Gravity Sink	Specific Gravity Float	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO
	1.3	20.2	25.7	9.3	2.5	34.9	0.25	0.9	0.5	0.14
1.3	1.4	36.5	27.3	6.7	2.1	22.1	0.20	2.1	0.8	0.13
1.4	1.6	56.9	26.3	3.8	1.3	5.0	0.16	2.8	1.1	0.08
1.6		66.0	21.5	3.8	1.3	2.4	0.17	2.8	1.0	.07
Head, calc.		40.1	26.1	6.4	1.9	19.5	0.20	2.1	0.8	0.12

TABLE 19. Washability Analyses of Sample 119, Crushed to 38 mm Top Size, Showing Concentration of Major Elements in Ash of Products.

Specific Gravity Sink	Float	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO
	1.3	32.2	13.5	8.7	6.0	30.3	0.08	0.4	0.7	0.17
1.3	1.4	41.4	18.0	5.5	3.3	18.4	0.09	1.2	1.0	0.09
1.4	1.6	55.9	24.3	3.2	1.8	7.4	0.11	2.8	1.0	0.03
1.6		56.4	18.4	9.6	1.5	6.4	0.19	2.1	1.0	0.09
Head, calc.		41.6	18.0	5.8	3.5	18.9	0.09	1.2	1.0	0.10

TABLE 20. Washability Analyses of Sample 107, Crushed to 38 mm Top Size, Showing Concentration of Major Elements in Products (Moisture Free Basis, Percent).

Specific Gravity Sink	Float	Ash &	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO
	1.3	5.46	2.37	1.74	0.32	0.13	0.47	0.022	0.07	0.10	0.003
1.3	1.4	12.14	6.74	3.80	0.34	0.19	0.32	0.039	0.23	0.21	0.005
1.4	1.6	27.75	16.65	8.05	0.72	0.44	0.44	0.09	0.8	0.44	0.014
1.6		58.71	31.94	15.91	3.7	0.65	2.88	0.31	1.41	0.59	0.082
Head, calc.		18.63	10.10	5.37	0.91	0.30	0.82	0.082	0.43	0.26	0.017

TABLE 21. Washability Analyses of Sample 113, Crushed to 38 mm Top Size, Showing Concentration of Major Elements in Products (Moisture Free Basis, Percent).

Specific Gravity Sink	Float	Ash &	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO
	1.3	4.86	0.98	1.25	0.45	0.12	1.7	0.012	0.04	0.02	0.007
1.3	1.4	9.04	3.3	2.468	0.606	0.19	1.998	0.018	0.190	0.072	0.012
1.4	1.6	32.39	18.43	8.52	1.231	0.421	1.62	0.052	0.907	0.35	0.03
1.6		53.17	35.09	11.43	2.02	0.69	1.28	0.09	1.49	0.53	0.04
Head, calc.		9.45	3.79	2.47	0.60	0.18	1.84	0.02	0.20	0.08	0.01

TABLE 22. Washability Analyses of Sample 119, Crushed to 38 mm Top Size, Showing Concentration of Major Elements in Products (Moisture Free Basis, Percent).

Specific Gravity Sink	Float	Ash &	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	MnO
	1.3	5.54	1.78	0.75	0.48	0.33	1.68	0.004	0.022	0.039	0.01
1.3	1.4	10.88	4.5	1.96	0.60	0.36	2.0	0.01	0.13	0.11	0.01
1.4	1.6	32.24	18.02	7.83	1.03	0.58	2.39	0.04	0.9	0.32	0.01
1.6		33.49	18.89	6.16	3.22	0.50	2.14	0.06	0.70	0.33	0.03
Head, calc.		11.27	4.69	2.03	0.39	0.39	2.13	0.01	0.14	0.11	0.01

TABLE 23. Washability Analyses of Sample 107, Crushed to 38mm Top Size, Showing Concentration of Trace Elements in the Ash of Products.

Specific Gravity Sink	Float	Ag	B	Ba	Co	Cr	Cu(A.A.)	Ga	Mo	Ni(A.A.)	pb	Sn	V	Zn(A.A.)	Zr
	1.3	N.D	300	9,300	110	170	105	57	N.D	195	87	N.D	H	181	150
1.3	1.4	N.D	120	3,700	76	180	106	63	N.D	105	59	N.D	670	112	680
1.4	1.6	N.D	50	2,500	N.D	130	110	38	N.D	80	31	N.D	330	94	400
1.6		N.D	35	2,300	N.D	90	56	44	N.D	50	21	N.D	150	117	180
Head, calc.		N.D	87	3,500	N.D	100	81	48	N.D	84	33	N.D	N.D	120	300

TABLE 24. Washability Analyses of Sample 113, Crushed to 38mm Top Size, Showing Concentration of Trace Elements in the Ash of Products.

Specific Gravity Sink	Float	Ag	B	Ba	Co	Cr	Cu(A.A.)	Ga	Mo	Ni(A.A.)	pb	Sn	V	Zn(A.A.)	Zr
	1.3	N.D	97	13,000	220	230	133	45	69	190	210	N.D	510	278	450
1.3	1.4	1.1	110	6,000	100	200	150	42	28	118	110	N.D	360	212	450
1.4	1.6	N.D	89	N.D	N.D	190	147	58	N.D	72	64	N.D	400	117	440
1.6		N.D	97	N.D	N.D	220	130	44	N.D	74	76	N.D	360	110	310
Head, calc.		N.D	100	N.D	N.D	210	144	46	N.D	120	120	N.D	400	197	430

TABLE 25. Washability Analyses of Sample 119, Crushed to 38mm Top Size, Showing Concentration of Trace Elements in the Ash of Products.

Specific Gravity Sink	Float	Ag	B	Ba	Co	Cr	Cu(A.A.)	Ga	Mo	Ni(A.A.)	pb	Sn	V	Zn(A.A.)	Zr
	1.3	N.D	510	11,000	46	94	145	18	21	141	30	29	300	64	240
1.3	1.4	N.D	340	5,900	30	180	220	38	12	111	29	N.D	470	89	410
1.4	1.6	N.D	130	3,300	N.D	210	220	40	N.D	65	44	N.D	520	97	260
1.6		160	160	7,800	N.D	140	265	32	N.D	104	1,100	51	270	219	260
Head, calc.		N.D	340	6,400	N.D	170	210	35	N.D	111	38	N.D	450	87	370

TABLE 26. Washability Analyses of Sample 107, Crushed to 38 mm Top size, Showing Concentrating Trace Elements in Products.

Specific Gravity Sink	Float	Ash %	Ag	B	Ba	Co	Cr	Cu(A.A.)	Ga	Ge	Mo	Ni(A.A.)	pb	Sn	V	Zn(A.A.)	Zr
	1.3	5.46	N.D	16	510	6.0	11	5.7	3.1	N.D	N.D	11	4.8	N.D	H	9.9	8.2
1.3	1.4	12.14	N.D	15	450	9.2	25	13	76	N.D	N.D	13	7.2	N.D	81	14	83
1.4	1.6	27.75	N.D	14	690	N.D	47	31	11	N.D	N.D	22	8.6	N.D	92	26	110
1.6		58.71	N.D	21	1,400	N.D	120	33	26	N.D	N.D	29	12	N.D	88	69	110
Head, calc.		18.63	N.D	16	650	N.D	19	15	8.9	N.D	N.D	16	6.1	N.D	N.D	22	56

TABLE 27. Washability Analyses of Sample 113, Crushed to 38 mm Top size, Showing Concentrating Trace Elements in Products.

Specific Gravity Sink	Float	Ash %	Ag	B	Ba	Co	Cr	Cu(A.A.)	Ga	Ge	Mo	Ni(A.A.)	pb	Sn	V	Zn(A.A.)	Zr
	1.3	4.86	N.D	4.7	630	11	11	6.5	2.2	N.D	3.4	9	10	N.D	25	14	22
1.3	1.4	9.04	0.10	9.9	610	9.0	18	14	3.8	N.D	2.5	11	9.9	N.D	33	19	41
1.4	1.6	32.39	N.D	29	N.D	N.D	62	48	19	N.D	N.D	23	21	N.D	130	38	140
1.6		53.17	N.D	52	N.D	N.D	120	70	23	N.D	N.D	39	40	N.D	190	58	160
Head, calc.		9.45	N.D	9.5	N.D	N.D	20	14	4.3	N.D	N.D	11	11	N.D	38	19	41

TABLE 28. Washability Analyses of Sample 119, Crushed to 38 mm Top size, Showing Concentrating Trace Elements in Products.

Specific Gravity Sink	Float	Ash %	Ag	B	Ba	Co	Cr	Cu(A.A.)	Ga	Ge	Mo	Ni(A.A.)	pb	Sn	V	Zn(A.A.)	Zr
	1.3	5.54	N.D	28	610	2.5	5.2	8	1.0	N.D	1.2	8	2.0	1.6	17	3.5	13
1.3	1.4	10.88	N.D	37	640	3.3	20	24	4.1	N.D	1.3	12	3.2	N.D	51	9.7	45
1.4	1.6	32.24	N.D	42	1,100	N.D	68	71	13	N.D	N.D	21	14	N.D	170	31	84
1.6		33.49	54	54	2,600	N.D	47	89	11	N.D	N.D	35	370	17	90	73	87
Head, calc.		11.27	N.D	35	650	N.D	17	21	3.6	N.D	N.D	11	3.9	N.D	46	8.9	38

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Analysis of coal samples from the Healy, Kenai, Seldovia and Utukok River Quadrangles, Alaska

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Introduction

As part of a continuing program by the U.S. Geological Survey to collect and chemically analyze representative samples of coal in the United States, a total of 118 coal samples were collected in the State of Alaska. These samples were collected during a 5 year period by the U.S. Geological Survey and Alaska Division of Geological and Geophysical Surveys. There were 20 samples from the Healy 1:250,000 quadrangle (15 channel, 5 core); 10 samples from the Kenai 1:250,000 quadrangle (10 channel); 34 samples from the Seldovia 1:250,000 quadrangle (34 channel); and 54 samples from the Utukok River 1:250,000 quadrangle (31 channel, 18 auger, 5 cuttings). U.S. Geological Survey sample numbers, locations, thickness and sample type for all 118 samples are listed in Table 1. Location of sampled quadrangles are shown in Figure 1.

Geologic Occurrence

Healy Quadrangle

Samples collected in the Healy 1:250,000 quadrangle are from the Nenana coal field. Upper Oligocene to Late Upper Pliocene coal bearing rocks have been faulted and folded into a series of disconnected basins that extend 80 miles along the northern flank of the Alaska Range. Dips are low to moderate. Coal beds, ranging in thickness from a few inches to 60 feet, are found in 4 formations (Fig. 2). The greatest number and thickest coals are in the Healy Creek and Suntrana Formations.

Kenai and Seldovia Quadrangles

The Kenai and Seldovia 1:250,000 quadrangles lie within the Kenai coal field (Barnes, 1967). Tertiary coal beds of the Cook Inlet Region are included in the Oligocene to Pliocene Kenai Group (Fig. 3). The coal bearing rocks are within a broad structural basin modified locally by gentle folds. The deepest part of the basin is in Cook Inlet. Dips are generally less than 5 degrees. Few high angle faults are present that have displacements as much as 80 feet. The most numerous and thickest (as much as 7 feet) coals in the Kenai-Seldovia area are in the Tyonek Formation.

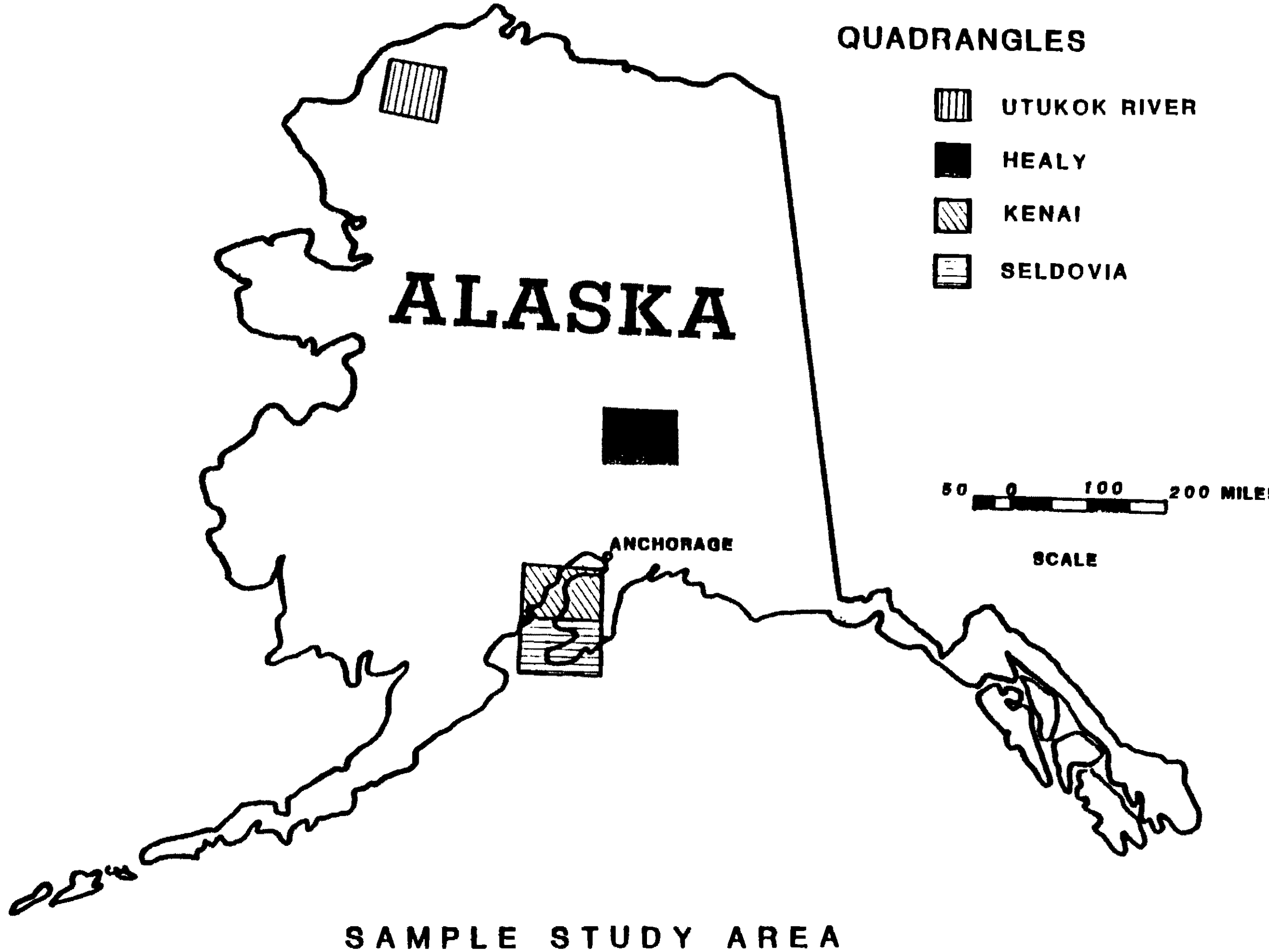

Figure 1.--Index map showing the location of the Utukok River, Healy, Kenai, and Seldovia quadrangles, Alaska, in which coal samples were collected.

Table 1.--U.S. Geological Survey sample numbers, locations, thickness, and sample type for 118 coal samples from the Healy, Kenai, Seldovia, and Utukok River quadrangles, Alaska

[All latitudes and longitudes are given in degrees, minutes, and seconds, except the Seldovia quadrangle for which only degrees and minutes are given.]

USGS Sample Number	Latitude	Longitude	Thickness (feet)	Sample type
		Healy Quadrangle		
D172389	63°55'09"	148°40'00"	5.0	Channel
D172390	---do----	----do----	5.0	Do.
D172391	---do----	----do----	5.6	Do.
D172392	---do----	----do----	3.0	Do.
D172393	---do----	----do----	5.0	Do.
D172394	---do----	----do----	5.0	Do.
D172395	---do----	----do----	5.0	Do.
D172396	---do----	----do----	5.0	Do.
D175053	63°58'12"	148°45'00"	5.0	Do.
D175054	---do----	----do----	5.0	Do.
D175055	---do----	----do----	5.0	Do.
D175056	---do----	----do----	5.0	Do.
D175057	---do----	----do----	7.1	Do.
D186043	63°54'10"	148°56'16"	10.5	Core
D186044	---do----	----do----	10.0	Do.
D186045	---do----	----do----	6.0	Do.
D186046	---do----	----do----	9.3	Do.
D186047	---do----	----do----	9.5	Do.
D186048	63°58'36"	147°16'22"	7.0	Channel
D186049	---do----	----do----	7.0	Do.
		Kenai Quadrangle		
D178628	60°01'53"	151°40'15"	4.8	Channel
D178629	60°03'39"	151°39'14"	4.0	Do.
D178630	---do----	----do----	5.0	Do.
D178773	60°00'24"	151°37'22"	6.5	Channel
D178774	60°04'17"	151°38'28"	4.4	Do.
D178775	60°04'03"	151°38'46"	4.5	Do.
D178776	---do----	----do----	7.2	Do.
D178777	60°12'11"	151°26'03"	4.3	Do.
D178778	60°12'29"	151°26'34"	4.2	Do.
D178779	---do----	----do----	2.0	Do.

Table 1.--U.S. Geological Survey sample numbers, locations, thickness, and sample type for 118 coal samples from the Healy, Kenai, Seldovia, and Utukok River quadrangles, Alaska--continued

USGS Sample Number	Latitude	Longitude	Thickness (feet)	Sample type
		Seldovia Quadrangle		
D169228	59°45'	151°00'	1.4	Channel
D169229	---do---	----do----	1.4	Do.
D169230	---do---	----do----	2.4	Do.
D169231	---do---	----do----	1.8	Do.
D169232	---do---	----do----	2.6	Do.
D169233	---do---	----do----	3.7	Do.
D169234	59°30'	151°15'	2.8	Do.
D169236	---do---	----do----	4.9	Do.
D169237	---do---	----do----	4.9	Do.
D169238	---do---	----do----	5.0	Do.
D169239	---do---	----do----	5.0	Do.
D169240	---do---	----do----	1.0	Do.
D169241	59°45'	151°15'	1.3	Do.
D169242	---do---	----do----	.9	Do.
D169243	---do---	----do----	1.3	Do.
D169244	---do---	----do----	1.6	Do.
D169245	---do---	----do----	3.4	Do.
D169246	---do---	----do----	.5	Do.
D169247	---do---	----do----	1.6	Do.
D169248	---do---	----do----	2.1	Do.
D169249	---do---	----do----	1.6	Do.
D169250	---do---	----do----	5.2	Do.
D169251	---do---	----do----	1.3	Do.
D169252	---do---	----do----	3.1	Do.
D169253	---do---	----do----	2.8	Do.
D169254	---do---	----do----	5.5	Do.
D169255	---do---	----do----	3.5	Do.

Table 1.--U.S. Geological Survey sample numbers, locations, thickness, and sample type for 118 coal samples from the Healy, Kenai, Seldovia, and Utukok River quadrangles, Alaska--continued

USGS Sample Number	Latitude	Longitude	Thickness (feet)	Sample type
		Seldovia Quadrangle		
D169256	59°45'	151°00'	5.5	Channel
D169257	---do---	----do----	3.2	Do.
D169258	59°30'	151°30'	2.0	Do.
D169259	---do---	----do----	5.9	Do.
D169260	---do---	----do----	2.4	Do.
D169261	---do---	----do----	2.7	Do.
D169262	---do---	----do----	3.6	Do.
		Utukok River Quadrangle		
D184598	69°22'56"	161°23'22"	3.2	Channel
D184599	69°22'10"	161°23'20"	2.0	Do.
D184600	69°23'08"	161°16'06"	4.8	Do.
D184601	69°26'48"	160°45'12"	5.5	Do.
D184602	69°22'00"	161°14'50"	5.2	Do.
D184603	69°21'40"	161°14'10"	4.2	Do.
D184604	69°21'42"	161°27'25"	3.3	Do.
D184605	---do----	----do----	6.2	Do.
D184606	---do----	----do----	3.9	Do.
D184607	69°20'24"	160°30'40"	5.4	Do.
D184608	---do----	----do----	4.2	Do.
D184609	69°20'44"	160°28'08"	5.4	Do.
D184610	69°20'40"	160°25'55"	4.1	Do.
D184611	69°31'43"	161°20'26"	3.0	Do.
D184612	69°21'54"	160°21'45"	5.3	Do.
D184613	69°27'58"	161°22'28"	6.3	Do.
D184614	69°28'32"	161°22'20"	1.3	Do.
D184615	69°27'08"	----do----	1.5	Do.
D184616	69°26'17"	161°20'46"	3.1	Do.

Table 1.--U.S. Geological Survey sample numbers, locations, thickness, and sample type for 118 coal samples from the Healy, Kenai, Seldovia, and Utukok River quadrangles, Alaska--continued

USGS Sample Number	Latitude	Longitude	Thickness (feet)	Sample type
		Utukok River Quadrangle		
D203122	69°15'45"	159°08'15"	12.0	Cuttings
D203123	69°41'35"	161°42'36"	25.0	Do.
D203124	69°31'15"	161°27'45"	7.0	Do.
D203125	69°31'26"	160°14'00"	15.0	Do.
D203126	---do----	----do----	20.0	Do.
D213965	69°21'10"	161°24'45"	11.8	Auger
D213966	69°22'05"	161°22'00"	4.3	Do.
D213967	69°24'00"	161°16'30"	7.5	Do.
D213968	69°23'10"	161°15'00"	8.9	Do.
D213969	69°22'05"	----do----	11.2	Do.
D213970	69°21'10"	----do----	5.6	Do.
D213971	69°23'10"	161°03'00"	7.5	Do.
D213972	69°22'50"	161°05'20"	6.9	Do.
D213973	69°23'10"	----do----	6.9	Do.
D213974	69°24'00"	161°01'45"	7.2	Do.
D213975	69°20'25"	160°34'20"	7.5	Do.
D213976	---do----	160°28'30"	11.2	Do.
D213977	---do----	----do----	12.8	Do.
D213978	69°21'10"	160°24'10"	7.2	Do.
D213979	69°23'10"	160°31'30"	13	Do.
D213980	69°27'30"	160°42'00"	5.6	Do.
D213981	69°26'45"	160°45'00"	6.6	Do.
D213982	---do----	160°47'20"	4.3	Do.
D213944	69°07'30"	161°24'40"	2.0	Channel
D213945	69°08'25"	----do----	1.6	Do.
D213946	69°06'40"	161°32'00"	8.9	Do.
D213947	69°05'45"	161°29'45"	11.5	Do.
D213948	---do----	----do----	11.5	Do.
D213949	---do----	161°20'00"	7.5	Channel
D213950	69°06'45"	161°29'45"	6.9	Do.
D213951	69°04'00"	161°27'00"	.98	Do.
D213952	---do----	----do----	3.6	Do.
D213953	69°24'45"	161°11'45"	8.2	Do.
D213954	---do----	161°06'45"	4.9	Do.
D213955	69°25'40"	160°13'00"	2.6	Do.

Series		Nonmarine Stage		Nenana coalfield
Pliocene		Clamgulchian		
		Clamgulchian		Nenana Gravel
Miocene	U	Homerian		Grubstake Formation
Miocene	U	Homerian		Lignite Creek Formation
Miocene	M	Seldovian	Upper	Suntrana Formation
Miocene	M	Seldovian	Upper	Sanctuary Formation
Miocene	L	Seldovian	Lower	Healy Creek Formation
Oligocene	U	Angoonian	Upper	
Oligocene	L	Angoonian	Lower	

Figure 2.--Stratigraphic nomenclature of the coal-bearing rocks of the Nenana coalfield, Alaska, after Wolfe and Tanai, (1980, p. 9).

ERA	SYSTEM	GROUP	FORMATION THICKNESS (in feet)	DESCRIPTION
CENOZOIC	QUAT.		Alluvium and glacial deposits	
CENOZOIC	TERTIARY	Kenai Group	Sterling Formation 0'-11,000'	Massive sandstone and conglomerate beds with occasional thin lignite bed.
CENOZOIC	TERTIARY	Kenai Group	Beluga Formation 0'-6000'	Claystone, siltstone, and thin sandstone beds, thin sub-bituminous coal beds.
CENOZOIC	TERTIARY	Kenai Group	Tyonek Formation 4000'-7700'	Sandstone, claystone, and siltstone interbeds and massive subbituminous coal beds.
CENOZOIC	TERTIARY	Kenai Group	Hemlock Formation 300'-900'	Sandstone and conglomerate.
CENOZOIC	TERTIARY		RESTS UNCONFORMABLY ON OLDER TERTIARY ROCKS	

Figure 3.--Stratigraphic nomenclature of Tertiary Kenai Group, Alaska, after Calderwood and Fackler, (1972, p. 741).

Utukok River Quadrangle

The Utukok River 1:250,000 quadrangle lies within the Kokolik-Utukok Rivers district of the northern Alaska coal field (Barnes, 1967). The Cretaceous coal bearing Corwin Formation (Fig. 4) has been folded into many east-west trending synclines and anticlines that have strata on the flanks of the fold generally dipping 5-20 degrees. Many coal beds, ranging from a few inches to more than 12 feet, are present in the Corwin Formation. Exposures are limited however, and are restricted to major drainages.

Explanation of Tables

Analytical procedures used by the U.S. Geological Survey are described in Swanson and Huffman (1976) (see Fig. 5 for flow chart showing sequence of sample preparation and chemical analysis). Twenty-two additional elements not listed in Tables 5, 8, 11 and 14 were looked for but were not found in amounts greater than their lower limits of detection (Table 2). Unweighted statistical summaries of the analytical data for all 118 Alaskan coal samples are listed in Tables 3 through 14. For statistical comparison, data summaries of coal samples from the Powder River region are included for the Healy, Kenai and Seldovia quadrangles, and Rocky Mountain Province coal summaries are included for the Utukok River quadrangle.

Arsenic content of samples summarized in this report have been determined by three different analytical methods: Samples D169228-D169234, D169236-D169262, D175053-D175057 and D172389-D172396 were analyzed spectrophotometrically (lower detection limit 1.0 ppm); samples D178773-D178779 and D178628-D178630 were analyzed by the graphite furnace atomic absorption method (lower detection limit 0.5 ppm); the other 61 samples were analyzed by instrumental neutron activation analysis (lower detection limit 0.1 ppm).

Thorium content of the samples was determined by two methods: Samples D169228-D169234, D169236-D169262, D175053-D175057, D172389-D172396, D178774-D178779, and D178628-D178630 were analyzed by delayed neutron activation analysis (lower detection limit 3.0 ppm); all other samples were analyzed by instrumental neutron activation analysis (lower detection limit 0.1 ppm).

P_2O_5 content of the samples were determined by X-ray fluorescence spectroscopy. However, due to changes in technique, the lower detection limit for samples D213965-D213982 and D213944-D213955 is 0.01 percent in whole coal; for samples D169228-D169234, D169236-D169262, and D178773-D178779 is 0.1 percent in coal ash; and for the 47 remaining samples is 1.0 percent in coal ash.

To be consistent with the precision of the semiquantitative emission spectrographic technique, arithmetic and geometric means of

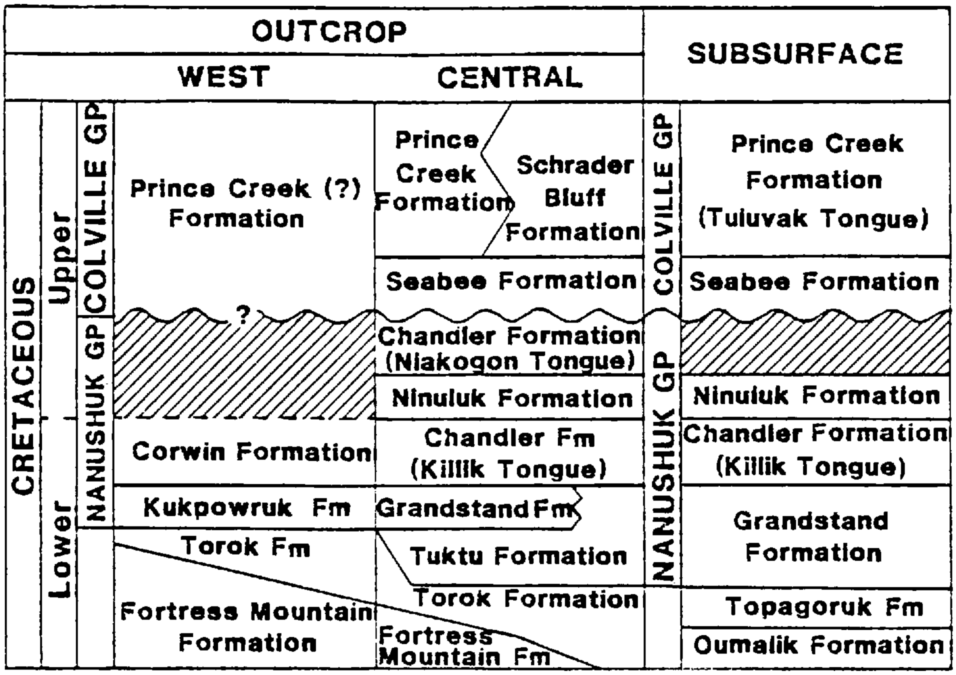

Figure 4.--Stratigraphic nomenclature of the Colville and Nanushuk Groups, Alaska, from Ahlbrandt and others, (1979, p. 14).

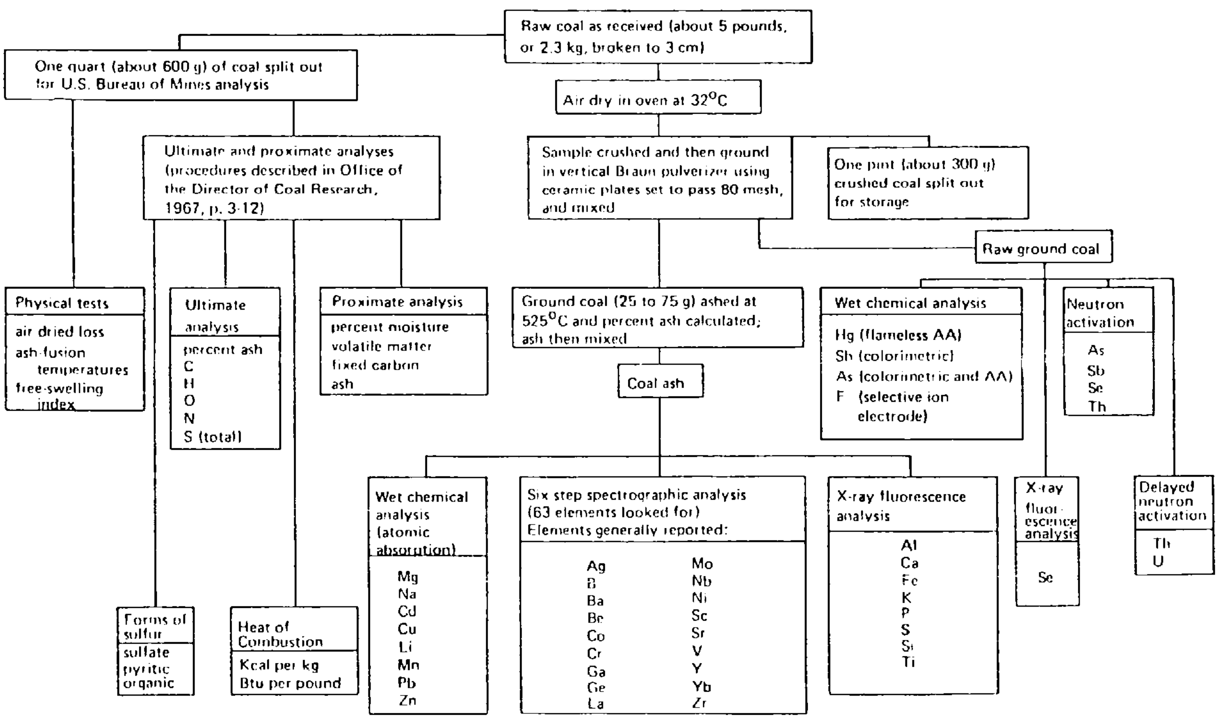

Figure 5.--Flow chart showing sequence of sample preparation and chemical analysis (modified from Swanson and Huffman, 1976, fig. 1).

Table 2.--Elements looked for, but not detected in 118 coal samples from the Healy, Kenai, Seldovia, and Utukok River quadrangles, Alaska

[Approximate lower detection limits for these elements in ash, by the six-step spectrographic method of the U.S. Geological Survey, are included]

Element name	Symbol	Lower limit of detection in ash (ppm)
Gold	Au	50
Bismuth	Bi	20
Dysprosium	Dy	100
Erbium	Er	100
Europium	Eu	200
Gadolinium	Ge	100
Hafnium	Hf	200
Holmium	Ho	50
Indium	In	20
Lutetium	Lu	70
Palladium	Pd	5
Praseodymium	Pr	200
Platinum	Pt	100
Rhenium	Re	100
Samarium	Sm	200
Tin	Sn	20
Tantalum	Ta	1,000
Terbium	Tb	700
Tellerium	Te	5,000
Thallium	Tl	100
Thulium	Tm	50
Tungsten	W	200

Table 3.--Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures of 12 coal samples from Healy quadrangle, Alaska

[For comparison geometric means for 33 samples from the Powder River region are included (Swanson and others, 1976, tables 31b and 32b. All values are in percent except Kcal/kg, Btu/lb, ash-fusion temperatures, and geometric deviations, and are reported on the as-received basis. Leaders (---) indicate no data. Kcal/kg = 0.556 (Btu/lb). °F = (°C x 1.8) + 32]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
Proximate and ultimate analyses						
Moisture	24.1	14.8	32.7	23.6	1.2	23.1
Volatile matter	35.5	27.3	38.8	35.3	1.1	32
Fixed carbon	30.1	23.4	33.4	29.9	1.1	36
Ash	10.2	5.2	34.5	9.1	1.6	7.5
Hydrogen	6.3	4.6	6.9	6.2	1.1	6.2
Carbon	46.4	35.6	52.2	46.1	1.1	50.3
Nitrogen	.7	.5	.8	.7	1.2	.9
Oxygen	36.0	24.5	44.6	35.7	1.1	32.9
Sulfur	.2	.1	.7	.2	1.6	.8
Heat of combustion						
Kcal/kg	4,465	3,410	5,120	4,430	1.1	4,860
Btu/lb	8,030	6,130	9,210	7,970	1.1	8,740
Forms of sulfur						
Sulfate	0.01	0.01	0.04	0.01	1.7	0.02
Pyritic	.08	.01	.12	.07	1.9	.29
Organic	.16	.07	.51	.14	1.7	.31
Ash-fusion temperatures, °C						
Initial deformation	1,230	1,170	1,270	1,230	1.0	---
Softening temperature	1,280	1,210	1,320	1,280	1.0	---
Fluid temperature	1,340	1,270	1,390	1,340	1.0	---

Table 4.--Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of 10 major and minor oxides in the laboratory ash of 20 coal samples from the Healy quadrangle, Alaska

[For comparison geometric means for 410 samples from the Powder River region are included (Hatch and Swanson, 1977, table 6a). All samples were ashed at 525°C; all analyses except geometric deviation are in percent. L, indicates less than the value shown. Leaders (---) indicate no data]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
(Ash)	12.6	6.5	37.5	11.5	1.5	9.0
SiO_2	35	16	51	33	1.4	28
Al_2O_3	17	8	23	16	1.4	14
CaO	20	2	37	16	2.0	15
MgO	3.3	1.6	7.3	3.1	1.5	3.56
Na_2O	.18	.09L	.53	.15	1.9	.93
K_2O	1.1	.29	2.8	.95	1.7	.28
Fe_2O_3	4.6	1.7	9.1	3.9	1.8	5.8
TiO_2	.87	.57	1.1	.86	1.2	.61
SO_3	7.0	1.0	27	5.2	2.2	14
P_2O_5	.26	.11L	1.2	.09	4.5	---

Table 5.--Arithmetic mean, observed range, geometric mean, and geometric deviation of 39 elements in 20 coal samples from the Healy quadrangle, Alaska

[For comparison, geometric means for 410 samples from the Powder River region are included (Hatch and Swanson, 1977, table 6b). All analyses except geometric deviation are in percent or parts per million and are reported on a whole-coal basis. As, F, Hg, Sb, Se, Th, and U values used where calculated from determinations made on coal ash. L, less than the value shown. Leaders (---) indicate no data]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
			Percent			
Si	2.3	0.51	8.9	1.8	2.0	1.2
Al	1.1	.44	4.6	.97	1.8	.66
Ca	1.5	.54	2.7	1.3	1.7	.98
Mg	.22	.11	.43	.21	1.4	.195
Na	.02	.007L	.077	.012	2.3	.063
K	.14	.01	.87	.091	2.5	.022
Fe	.38	.12	.84	.32	1.9	.37
Ti	.067	.022	.23	.059	1.7	.035
P	.010	.004L	.045	.003	5.3	---
			Parts per million			
Ag	.09	.07	.3	.06	2.4	---
As	3	1	10	2.6	1.8	2
B	50	15	100	30	2.1	50
Ba	500	150	1500	500	1.8	300
Be	.5	.2L	3	.2	3.2	.5
Cd	.15	.06L	.56	.07	3.2	---
Co	5	1.5	10	3	1.9	2
Cr	20	7	70	15	1.7	5
Cu	20	8.2	58	17	1.7	9.5
F	95	35	340	82	1.7	40
Ga	3	1.5	10	3	1.7	2
Hg	.07	.02	.30	.06	1.9	.08
La	7	10	20	7	1.5	---
Li	5	1.3	32	3.7	2.2	3.9
Mn	88	6.1	220	46	3.1	34
Mo	1.5	.7	3	1.5	1.5	1.5
Nb	2	1.5L	7	1.5	1.9	1
Ni	10	5	30	10	1.5	3
Pb	5.4	2L	15	4.5	1.8	5.1
Sb	1.9	.3	8.1	1.3	2.3	.4
Sc	3	1.5	10	3	1.6	1.5
Se	1.6	0.3	11	8	3.5	0.7
Sr	150	70	200	100	1.5	150
Th	4.5	.7	18	2.5	3.0	3.3
U	1.3	.4	5.2	1.1	2.0	.6
V	30	15	100	20	1.7	10
Y	7	3	20	7	1.8	3
Yb	.7	.3	3	.7	1.7	.3
Zn	14	2.3	46	8.8	2.6	12.5
Zr	15	7	70	15	1.7	15

Table 6.--Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures of 10 coal samples from the Kenai quadrangle, Alaska

[For comparison, geometric means for 33 samples from the Powder River region are included (Swanson and others, 1976, tables 31b and 32b). All values are in percent except Kcal/kg, Btu/lb, ash-fusion temperatures, and geometric deviations, and are reported on the as-received basis. Leaders (---) indicate no data. Kcal/kg = 0.556 (Btu/lb). °F = (°C x 1.8) + 32]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
Proximate and ultimate analyses						
Moisture	21.7	18.0	26.5	21.5	1.1	23.1
Volatile matter	36.5	30.0	43.2	36.2	1.1	32
Fixed carbon	27.0	20.5	33.1	26.6	1.2	36
Ash	15.3	4.8	26.9	12.7	1.8	7.5
Hydrogen	6.0	5.3	6.6	6.0	1.1	6.2
Carbon	42.6	35.4	50.3	42.2	1.1	50.3
Nitrogen	.8	.6	1.1	.8	1.2	.9
Oxygen	35.4	30.8	40.2	35.3	1.1	32.9
Sulfur	.4	.2	1.3	.3	1.7	.8
Heat of combustion						
Kcal/kg	4,070	3,430	4,770	4,035	1.1	4,860
Btu/lb	7,320	6,170	8,580	7,260	1.1	8,740
Forms of sulfur						
Sulfate	0.02	0.02	0.03	0.02	1.1	0.02
Pyritic	.06	.01	.12	.04	2.7	.29
Organic	.29	.16	1.29	.24	1.8	.3
Ash-fusion temperatures,°C						
Initial deformation	1,120	1,020	1,240	1,120	1.1	---
Softening temperature	1,180	1,040	1,290	1,180	1.1	---
Fluid temperature	1,240	1,070	1,340	1,230	1.1	---

Table 7.--Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of 10 major and minor oxides in the laboratory ash of 10 coal samples from the Kenai quadrangle, Alaska

[For comparison, geometric means for 410 samples from the Powder River region are included (Swanson, 1977, table 6a). All samples were ashed at 525°C; all analyses except geometric deviation are in percent. L, indicates less than the value shown. Leaders (---) indicate no data]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
(Ash)	15.2	5.8	25.7	13.0	1.8	9.0
SiO_2	42	16	54	39	1.5	28
Al_2O_3	16	10	21	16	1.2	14
CaO	9.1	4.1	23	7.5	1.9	15
MgO	4.9	3.3	8.1	4.8	1.3	3.56
Na_2O	3.2	.40	6.1	2.2	2.5	.93
K_2O	1.5	.39	4.1	1.3	1.8	.28
Fe_2O_3	5.3	2.2	14	4.5	1.8	5.8
TiO_2	.75	.57	.97	.74	1.2	.61
SO_3	4.5	2.3	6.8	4.1	1.5	14
P_2O_5	.84	1.0L	1.7	.77	1.5	---

Table 8.--Arithmetic mean, observed range, geometric mean, and geometric deviation of 36 elements in 10 coal samples from the Kenai quadrangle, Alaska

[For comparison, geometric means for 410 samples from the Powder River region are included (Hatch and Swanson, 1977, table 6b.). All analyses except geometric deviation are in percent or parts per million and are reported on a whole coal basis. As, F, Hg, Sb, Se, Th, and U values used to calculate the statistics were determined directly on whole coal. All other values used were calculated from determinations made on coal ash. L, indicates less than the value shown. Leaders (---) indicate no data]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
			Percent			
Si	3.5	0.45	6.0	2.4	2.5	1.2
Al	1.4	.35	2.2	1.1	1.9	.66
Ca	.76	.32	1.1	.70	1.5	.98
Mg	.41	.14	.57	.37	1.5	.195
Na	.44	.018	.68	.21	3.5	.063
K	.22	.020	.32	.14	2.6	.022
Fe	.45	.21	.74	.41	1.5	.37
Ti	.07	.02	.12	.06	1.9	.035
P	.04	.040L	.046	.04	1.2	---
			Parts per million			
As	3.5	2	5	3.4	1.3	2
B	30	10	70	20	1.8	50
Ba	500	500	700	500	1.2	300
Be	.7	.2L	1.5	.5	1.9	.5
Co	7	5	10	7	1.2	2
Cr	20	7	50	20	2.0	5
Cu	20	7.4	35	17	1.7	9.5
F	37	20L	75	31	1.8	40
Ga	5	1.5	10	5	2.0	2
Hg	.07	.01	.12	.05	2.0	.08
Li	6.5	1L	13	4	2.8	3.9
Mn	150	50	290	120	1.9	34
Mo	3	1.5	5	3	1.5	1.5
Nb	3	2L	7	3	1.8	1
Ni	15	7	20	10	1.5	3
Pb	---	---	---	---	---	5.1
Sb	0.7	0.2	1.3	0.6	1.8	.4
Sc	5	1	7	3	1.9	1.5
Se	.2	.1L	.3	.1	1.7	.7
Sr	150	50	300	100	1.8	150
Th	---	---	---	---	---	3.3
U	.7	.5L	1.2	.7	1.5	.6
V	70	15	150	50	2.0	10
Y	10	5	20	10	1.6	3
Yb	1.5	.5	2	1	1.7	.3
Zr	20	7	50	20	2.0	15
Zn	9.6	2.6	24	7.1	2.2	12.5

Table 9.--Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures of 6 coal samples from the Seldovia quadrangle, Alaska

[For comparison geometric means for 33 samples from the Powder River region are included (Swanson and others, 1976, tables 31b and 32b). All values are in percent except Kcal/kg, Btu/lb, and geometric deviations, and are reported on the as-received basis. Leaders (---) indicate no data. L, indicates less than value shown. Kcal/kg = 0.556 (Btu/lb)]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
Proximate and ultimate analyses						
Moisture	16.4	11.0	22.3	15.9	1.3	23.1
Volatile matter	40.1	38.4	41.4	40.1	1.0	32
Fixed carbon	30.2	27.1	33.0	30.1	1.1	36
Ash	13.6	8.3	23.5	12.4	1.5	7.5
Hydrogen	5.8	5.2	6.3	5.8	1.1	6.2
Carbon	47.4	45.4	50.0	47.3	1.0	50.3
Nitrogen	1.0	.9	1.1	1.0	1.1	.9
Oxygen	32.1	24.6	37.9	31.7	1.2	32.9
Sulfur	.4	.3	.4	.3	1.2	.8
Heat of combustion						
Kcal/kg	4,525	4,385	4,790	4,520	1.0	4,860
Btu/lb	8,140	7,890	8,610	8,130	1.0	8,740
Forms of sulfur						
Sulfate	0.01	0.01L	0.01	0.01	1.0	0.02
Pyritic	.02	.01	.04	.02	1.9	.29
Organic	.33	.22	.42	.31	1.3	.31
Ash-fusion temperatures, °C						
Initial deformation	---	---	---	---	---	---
Softening temperature	---	---	---	---	---	---
Fluid temperature	---	---	---	---	---	---

Table 10.--Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of 10 major and minor oxides in the laboratory ash of 34 coal samples from the Seldovia quadrangle, Alaska

[For comparison, geometric means for 410 samples from the Powder River region are included (Hatch and Swanson, 1977, table 6a). All samples were ashed at 525°C; all analyses except geometric deviation are in percent. L, indicates less than the value shown. Leaders (---) indicate no data]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
(Ash)	15.0	6.0	49.1	13.1	1.7	9.0
SiO_2	37	14	54	35	1.4	28
Al_2O_3	18	7.9	25	18	1.3	14
CaO	14	2.9	25	12	1.7	15
MgO	1.9	.75	4.0	1.7	1.5	3.56
Na_2O	1.4	.38	6.4	1.0	2.1	.93
K_2O	1.6	.48	3.1	1.4	1.6	.28
Fe_2O_3	6.5	2.6	17	5.9	1.5	5.8
TiO_2	.75	.34	1.1	.72	1.3	.61
SO_3	6.2	2.3	16	5.6	1.6	14
P_2O_5	1.3	.10L	3.1	.46	4.4	---

Table 11.--Arithmetic mean, observed range, geometric mean, and geometric deviation of 37 elements in 34 coal samples from the Seldovia quadrangle, Alaska

[For comparison, geometric means for 410 samples from the Powder River region are included (Hatch and Swanson, 1977, table 6b.). All analyses except geometric deviation are in percent or parts per million and are reported on a whole coal basis. As, F, Hg, Sb, Se, Th, and U values used to calculate the statistics were determined directly on whole coal. All other values used were calculated from determinations made on coal ash. L, indicates less than the value shown. Leaders (---) indicate no data]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
			Percent			
Si	2.9	0.47	11	2.1	2.3	1.2
Al	1.6	.31	6.3	1.2	2.1	.66
Ca	1.2	.99	1.6	1.2	1.1	.98
Mg	.15	.06	.41	.13	1.6	.195
Na	.15	.02	.47	.10	2.4	.063
K	.24	.03	1.3	.16	2.6	.022
Fe	.60	.26	2.4	.54	1.6	.37
Ti	.07	.01	.25	.06	2.1	.035
P	.06	.008L	.13	.03	3.2	---
			Parts per million			
As	8.6	2	25	7.2	1.8	2
B	20	5	70	20	2.0	50
Ba	500	150	1000	500	1.6	300
Be	.5	.2L	1.5	.3	2.2	.5
Co	5	2	15	5	1.5	2
Cr	20	2	70	15	2.2	5
Cu	22	7.1	86	18	1.8	9.5
F	72	20	290	55	2.1	40
Ga	5	1	15	3	2.1	2
Hg	.09	.03	.40	.08	1.8	.08
La	5	5	30	3	2.5	---
Li	5.9	.6	26	3.6	2.7	3.9
Mn	100	40	240	90	1.6	34
Mo	1.5	.5L	15	1.5	2.1	1.5
Nb	1	1.5L	5	.7	3.3	1
Ni	10	5	20	10	1.5	3
Pb	3.1	1.5L	11	2.0	2.6	5.1
Sb	1.2	.2	3.7	1.0	1.8	.4
Sc	5	1	15	3	2.0	1.5
Se	.9	.1	2.1	.4	3.5	.7
Sr	200	100	500	200	1.5	150
Th	2.5	1.9	6.9	2.2	1.6	3.3
U	.7	.3	3.1	.5	2.3	.6
V	50	10	200	50	2.3	10
Y	5	2	20	5	1.7	3
Yb	.7	.2	2	.5	1.7	.3
Zn	10	2.1	110	7	2.4	12.5
Zr	20	7	70	15	2.0	15

Table 12.--Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures of 24 coal samples from the Utukok River Quadrangle, Alaska

[For comparison geometric means for 86 coal samples from the Rocky Mountain Province are included (Swanson and others, 1976, table 33a). All values are in percent except Kcal/kg, Btu/lb, ash-fusion temperatures, and geometric deviations, and are reported on the as-received basis. Leaders (---) indicate no data. Kcal/ kg = 0.556 (Btu/lb). °F = (°C x 1.8) + 32]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Rocky Mountain province geometric mean
		Minimum	Maximum			
Proximate and ultimate analyses						
Moisture	10.4	1.8	25.5	8.1	2.0	10.5
Volatile matter	32.2	25	40	31.9	1.1	35.7
Fixed carbon	48.3	32.8	58.6	47.8	1.2	41.5
Ash	9.3	2.3	37.2	6.8	2.2	7.7
Hydrogen	5.3	4	5.8	5.2	1.1	5.6
Carbon	62.8	46.1	72.5	62.2	1.1	58.9
Nitrogen	1.4	1	1.8	1.4	1.2	1.1
Oxygen	22.6	11.3	36.7	21.3	1.4	22.4
Sulfur	.3	.2	.5	.3	1.3	.5
Heat of combustion						
Kcal/kg	5,990	4,505	7,685	5,915	1.2	6,180
Btu/lb	10,770	8,100	13,820	10,640	1.2	11,110
Forms of sulfur						
Sulfate	---	---	---	---	---	0.02
Pyritic	---	---	---	---	---	.11
Organic	---	---	---	---	---	.22
Ash-fusion temperatures, °C						
Initial deformation	1,240	1,140	1,600	1,240	1.1	---
Softening temperature	1,270	1,170	1,600	1,260	1.1	---
Fluid temperature	1,300	1,190	1,600	1,300	1.1	---

Table 13.--Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of 10 major and minor oxides in the laboratory ash of 54 coal samples from the Utukok River quadrangle, Alaska

[For comparison, geometric means for 295 coal samples from the Rocky Mountain Province are included (Hatch and Swanson, 1977, table 3a). All samples were ashed at 525°C; all analyses except geometric deviation are in percent. L, indicates less than the value shown. Leaders (---) indicate no data]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Rocky Mountain Province geometric mean
		Minimum	Maximum			
(Ash)	9.3	2	38.9	7.3	2.0	10.9
SiO_2	34	3.8	61	29	1.8	44
Al_2O_3	22	8.4	36	21	1.4	19
CaO	11	.80	38	8	2.1	6.2
MgO	3.8	1.0	12	3.5	1.7	1.4
Na_2O	2.2	.45	7.1	1.6	2.2	.68
K_2O	1.5	.12	4.2	1.2	2.0	.45
Fe_2O_3	8.1	1.8	33	6.8	1.8	4.5
TiO_2	1.5	.25	5.6	1.2	2.0	.81
SO_3	7.8	.34	17	4.9	2.7	5.1
P_2O_5	4.5	.05	8.9	.67	7.4	---

Table 14.--Arithmetic mean, observed range, geometric mean, and geometric deviation of 36 elements in 54 coal samples from the Utukok River quadrangle, Alaska

[For comparison, geometric means for 295 coal samples from the Rocky Mountain Province are included (Hatch and Swanson, 1977, table 3b.). All analyses except geometric deviation are in percent or parts per million and are reported on a whole coal basis. As, F, Hg, Sb, Se, Th, and U values used to calculate the statistics were determined directly on whole coal. All other values used were calculated from determinations made on coal ash. L, indicates less than the value shown. Leaders (---) indicate no data]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Rocky Mountain Province geometric mean
		Minimum	Maximum			
			Percent			
Si	1.8	0.063	11	0.93	3.1	2.3
Al	1.1	.13	4.5	.76	2.2	1.1
Ca	.50	.036	2.2	.40	1.9	.48
Mg	.17	.024	.48	.14	1.9	.089
Na	.11	.018	.27	.087	2.0	.055
K	.14	.003	1.4	.07	3.3	.041
Fe	.36	.15	1.3	.32	1.6	.34
Ti	.09	.004	.52	.05	2.8	.047
P	.07	.004	.24	.03	3.7	---
			Parts per millon			
As	2.3	.7	8.1	2	1.6	2
B	50	20	100	50	1.6	70
Ba	700	100	2,000	700	1.8	150
Be	.7	.1	5	.3	3.6	.5
Co	5	1	70	3	2.3	1.5
Cr	10	1	100	7	2.9	5
Cu	6.5	1.0	32	4.8	2.2	8.4
F	68	20	310	48	2.3	69
Ga	5	.3	20	3	2.5	3
Hg	.06	.02	.40	.04	1.8	.05
Li	15	.5	84	9.5	2.7	8
Mn	24	1.8L	170	16	2.4	20
Mo	.2	.2	1.5	.07	5.4	1.5
Nb	2	.7	10	.5	6.1	.5
Ni	15	3	30	10	1.9	2
Pb	3.3	1.0	21	1.7	3.1	4.7
Sb	.2	.05	.64	.1	3.0	.3
Sc	3	.3	20	2	2.5	1.5
Se	.5	.1	1.2	.3	2.3	1.2
Sr	200	30	2,000	150	2.4	100
Th	3.2	.3	15	1.6	3.3	2.9
U	2.2	.2	6.2	1.0	3.5	1.1
V	30	2	200	15	3.3	100
Y	7	.5	30	5	2.3	5
Yb	.7	1	3	.5	2.3	.5
Zn	11	2	67	7.7	2.3	6.8
Zr	30	2	100	20	2.5	20

elements determined by this method are to be identified with geometric brackets whose boundaries are part of the ascending series 0.12, 0.18, 0.26, 0.38, 0.56, 0.83, 1.2, etc. but reported as midpoints of the brackets, 0.1, 0.15, 0.2, 0.3, 0.5, 0.7, 1.0, etc. Precision of the spectrographic data is plus-or-minus one bracket at 68 percent or plus-or-minus two brackets at 95 percent confidence level.

Channel samples analyzed for the present study are considered to be of the same quality as outcrop samples. Preliminary investigations on Wyoming coals by J.R. Hatch and R.H. Affolter of the U.S. Geological Survey indicate significant chemical differences between outcrop and core samples. Outcrop samples have significantly higher moisture, volatile matter, oxygen and nitrogen contents, and significantly lower ash, hydrogen and sulfur contents and a significantly lower heat of combustion. At the present time, we have insufficient data to accurately determine if the same chemical differences apply to our samples of Alaska coal.

Explanation of Statistical Terms used in Summary Tables

In this report, the geometric mean (GM) is used as the estimate of the most probable concentration (mode); the geometric mean is calculated by taking the logarithm of each analytical value, summing the logarithms, dividing the sum by the total number of values and obtaining the antilogarithm of the result. The measure of scatter about the mode used here is the geometric deviation (GD), which is the antilog of the standard deviation of the logarithms of the analytical values. These statistics are used because the quantities of trace elements in natural materials commonly exhibit positively skewed frequency distributions; such distributions are normalized by analyzing and summarizing trace element data on a logarithmic basis.

If the frequency distributions are lognormal, the geometric mean is the best estimate of the mode, and the estimated range of the central two thirds of the observed distribution has a lower limit equal to GM/GD and an upper limit equal to GM GD. The estimated range of the central 95 percent of the observed distribution has a lower limit equal to GM/GD^2 and an upper limit equal to $GM\ GD^2$ (Connor and others, 1976).

Although the geometric mean is, in general, an adequate estimate of the most common analytical value, it is, nevertheless, a biased estimate of the arithmetic mean. The estimates of the arithmetic means listed in the summary tables are Sichel's t statistic (Miesch, 1967).

A common problem in statistical summaries of trace element data arises when the element content of one or more of the samples is below the limit of analytical detection. This results in a "censored" distribution. Procedures developed by Cohen (1959) were used to compute unbiased estimates of the geometric mean, geometric deviation and arithmetic mean when the data are censored.

Discussion

The apparent ranks of all 52 coal samples from the Healy, Kenai, Seldovia and Utukok River quadrangles, Alaska, were calculated using the formulas in ASTM designation D-388-77 (American Society for Testing and Materials, 1978). When calculated to a moist, mineral matter free basis, the ranges in apparent rank for each quadrangle are (see Fig. 6):

Healy quadrangle (12 samples)
Lignite A to subbituminous B coal

Kenai quadrangle (10 samples)
Lignite A to subbituminous C coal

Seldovia quadrangle (6 samples)
Subbituminous C to subbituminous B coal

Utukok quadrangle (24 samples)
Subbituminous C to high volatile A bituminous coal

A statistical comparison (student's t-test, 95 percent confidence level) of the geometric mean contents of the U.S. Department of Energy's data for 12 coal samples from the Healy quadrangle, with 33 coal samples from the Powder River region (Swanson and others, 1976) shows that coal from the Healy quadrangle is significantly higher in volatile matter and oxygen, significantly lower in fixed carbon, carbon, nitrogen, total sulfur, sulfate, pyritic and organic sulfur contents, and has a significantly lower heat of combustion. The moisture, ash and hydrogen contents are not significantly different. When compared at the 99 percent confidence level the carbon and oxygen contents are not significantly different.

A statistical comparison of the geometric mean contents of the U.S. Department of Energy's data for 10 coal samples from the Kenai quadrangle, with 33 coal samples from the Powder River region, shows that coal from the Kenai quadrangle is significantly higher in volatile matter and ash, significantly lower in fixed carbon, total sulfur and pyritic sulfur contents, and has a significantly lower heat of combustion. The moisture, hydrogen, nitrogen, oxygen and organic sulfur contents are not significantly different.

A statistical comparison of the geometric mean contents of the U.S. Department of Energy's data for 6 coal samples from the Seldovia quadrangle, with 33 coal samples from the Powder River region, shows that coal from the Seldovia quadrangle is significantly higher in volatile matter and ash, and is significantly

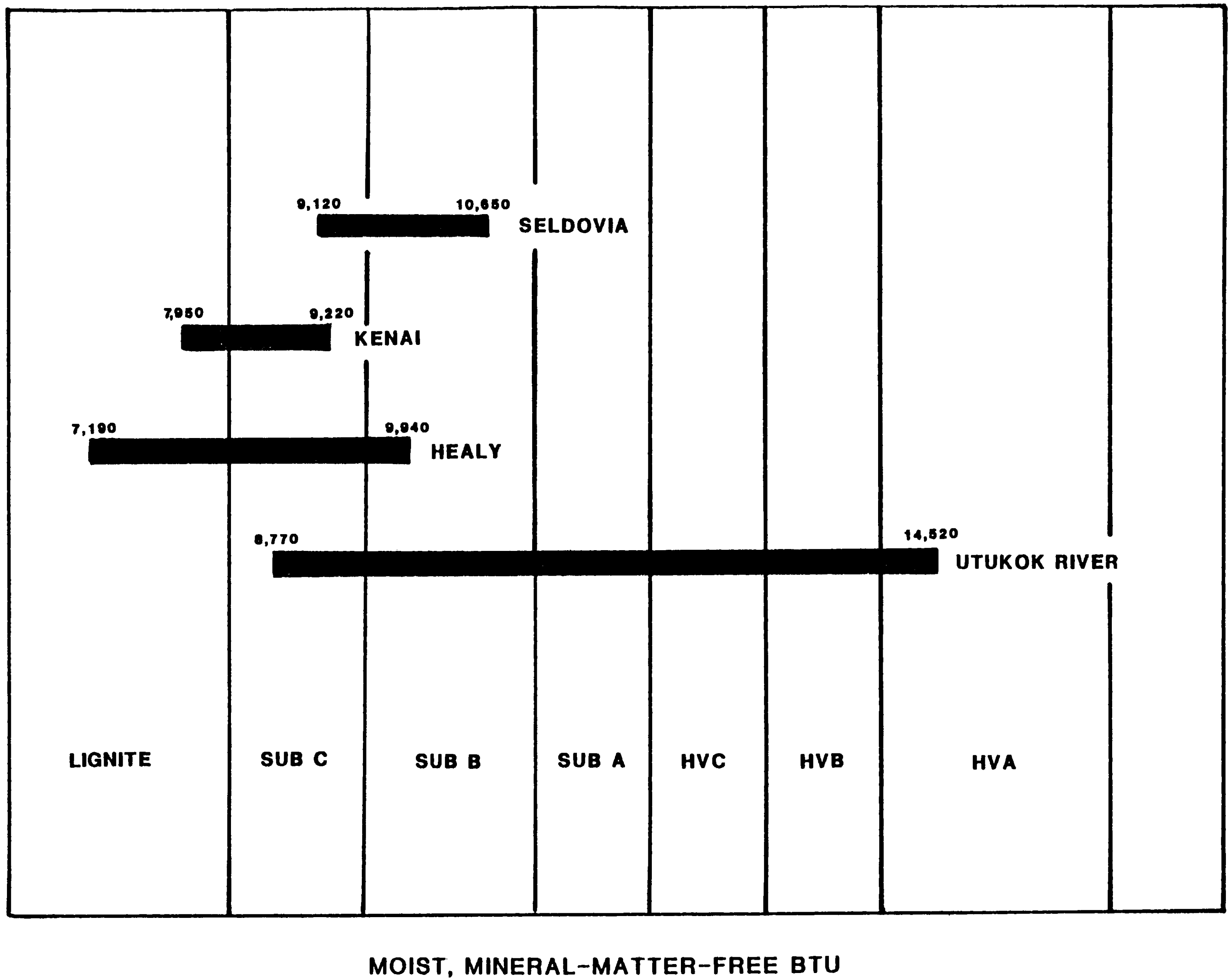

Figure 6.--Range of apparent rank determinations for coal samples from the Seldovia, Kenai, Healy, and Utukok River quadrangles, Alaska.

lower in moisture, fixed carbon, total sulfur, sulfate and pyritic sulfur contents. The hydrogen, carbon, nitrogen and oxygen contents and the heat of combustion are not significantly different. When compared at the 99 percent confidence level, the contents of ash and sulfate sulfur are not significantly different.

A statistical comparison of the geometric mean contents of the U.S. Department of Energy's data for 24 coal samples from the Utukok River quadrangle, with 86 coal samples from the Rocky Mountain Province (Swanson and others, 1976) shows that coal from the Utukok River quadrangle is significantly higher in fixed carbon and nitrogen, and is significantly lower in volatile matter, hydrogen and total sulfur contents. The moisture, ash, carbon and oxygen content and heat of combustion are not significantly different.

A statistical comparison of the geometric mean contents of coal ash and the geometric mean contents of nine major and minor oxides in the ash for 20 coal samples from the Healy qudrangle, with 410 Powder River region coal samples (Hatch and Swanson, 1977) shows that coal from the Healy quadrangle contains significantly higher ash, and that this ash is significantly higher in K_2O and TiO_2 contents and significantly lower in Na_2O, Fe_2O_3 and SO_3 contents. Contents of SiO_2, Al_2O_3, CaO and MgO are not significantly different. When compared at the 99 percent confidence level, the contents of Fe_2O_3 are not significantly different.

A statistical comparison of the geometric mean contents of nine major and minor oxides in the ash of 10 coal samples from the Kenai quadrangle, with 410 Powder River region coal samples shows that coal from the Kenai quadrangle contains significantly higher ash, and that this ash is significantly higher in SiO_2, MgO, Na_2O and K_2O contents, and is significantly lower in GaO and SO_3 contents. Contents of Al_2O_3, Fe_2O_3, and TiO_2 are not significantly different. When compared at the 99 percent confidence level the contents of SiO_2, MgO, and Na_2O are not significantly different.

A statistical comparison of the geometric mean contents of nine major and minor oxides in the ash of 34 coal samples from the Seldovia quadrangle, with 410 Powder River region coal samples shows that coal from the Seldovia quadrangle contains significantly higher ash, and that this ash is significantly higher in SiO_2, Al_2O_3, K_2O and TiO_2 contents and significantly lower in CaO, MgO and SO_3 contents. Contents of Na_2O and Fe_2O_3 are not significantly different. When compared at the 99 percent confidence level, the contents of CaO and TiO_2 are not significantly different.

A statistical comparison of the geometric mean contents of nine major and minor oxides in the ash of 54 coal samples from the Utukok River quadrangle, with 295 Rocky Mountain Province coal samples (Hatch and Swanson, 1977) shows that coal from the Utukok River quadrangle contains significantly lower ash, and that this ash is significantly higher in Al_2O_3, MgO, Na_2O, K_2O and TiO_2

contents and significantly lower in SiO_2 content. The contents of CaO, Fe_2O_3, and SO_3 are not significantly different.

A statistical comparison of the geometric mean contents of 35 elements in 20 coal samples from the Healy quadrangle, with 410 Powder River region coal samples (Hatch & Swanson, 1977) shows that the coal from the Healy quadrangle is significantly higher in contents of Si, Al, Ca, K, Ti, Ba, Co, Cr, Cu, F, Ga, Ni, Sb, Sc, U, V, Y and Yb, and is significantly lower in contents of Na, B, Be and Sr. The contents of Mg, Fe, As, Hg, Li, Mn, Mo, Nb, Pb, Se, Th, Zn and Zr are not significantly different. When compared at the 99 percent confidence level, the contents of Si, Ca and Sr are not significantly different.

A statistical comparison of the geometric mean contents of 35 elements in 10 coal samples from the Kenai quadrangle, with 410 Powder River region coal samples shows that coal from the Kenai quadrangle is significantly higher in contents of Si, Al, Mg, Na, K, Ti, Ba. Co, Cr, Cu, Ga, Mn, Mo, Nb, Ni, Sc, V, Y and Yb, and is significantly lower in contents of Ca, B and Se. The contents of Fe, As, Be, F, Hg, Li, Sb, Sr, U, Zn and Zr are not significantly different.

A statistical comparison of the geometric mean contents of 35 elements in 34 coal samples from the Seldovia quadrangle, with 410 Powder Rver region coal samples shows that coal from the Seldovia quadrangle is significantly higher in contents of Si, Al, Ca, Na, K, Fe, Ti, As, Ba, Co, Cr, Cu, F, Ga, Mn, Ni, Sb, Sc, Sr, V, Y and Yb, and is significantly lower in contents of Mg, B, Be, Pb, Se, Th and Zr. The contents of Hg, Li, Mo, Nb, U and Zr are not significantly different. When compared at the 99 percent confidence level, the contents of Ca, Na, Fe and Sr are not significantly different.

A statistical comparison of the geometric mean contents of 35 elements in 54 coal samples from the Utukok River quadrangle, with 295 Rocky Mountain Province coal samples (Hatch & Swanson, 1977) shows that coal from the Utukok River quadrangle is significantly higher in contents of Mg, Na, K, Ba, Co, Ni, Sc and Sr, and is significantly lower in contents of Si, Al, B, Be, Cr, Cu, F, Mo, Pb, Sb, Se, Th and V. The contents of Ca, Fe, Ti, As, Ga, Hg, Li, Mn, Nb, U, Y, Yb, Zn and Zr are not significantly different. When compared at the 99 percent confidence level, the content of Na is not significantly different.

Differences in the oxide composition of coal ashes and in the elemental contents of coal result from differences in the total and relative amounts of the various inorganic minerals, the elemental composition of these minerals and the total and relative amounts of any organically bound elements. The chemical form and distribution of a given element are dependent on the geologic history of the coal bed. A partial listing of the factors that influence element distributions would include chemical composition of original plants. amounts and composition of the various detrital, diagenetic and epigenetic minerals; chemical characteristics of the ground waters that come in contact with the bed; temperatures and pressures during burial; and extent of weathering. No evaluation of these factors has been made for coal from the Healy, Kenai, Seldovia and Utukok River quadrangles, Alaska.

Compared to other United States coals (Swanson and others, 1976; Hatch and Swanson, 1977), coal from the Healy, Kenai, Seldovia and Utukok River quadrangles, Alaska, are characterized by relatively low sulfur and by lower heat of combusition. The contents of elements of environmental concern, such as As, Be, Hg, Mo, Sb and Se, are low in Alaskan coals when compared with most other U.S. coals.

Quality information about Alaskan coal is dependent on an active program of geological mapping and exploratory drilling in coal field areas. However, during the past 5 years only 19 quadrangles in Alaska have been sampled for coal (Fig. 7). Most samples in these areas were of insufficient quantity and quality to be included in this report. Only the Healy, Kenai, Seldovia and Utukok River quadrangles had enough samples of sufficient quality to be adequately summarized.

There is presently no coal exploratory drilling being done by the U.S. Geological Survey, and only two geologists are currently working on evaluating coal resources in Alaska. We suggest that more intensive research be done on coals in Alaska because they may represent one of the largest resources of coal in the United States.

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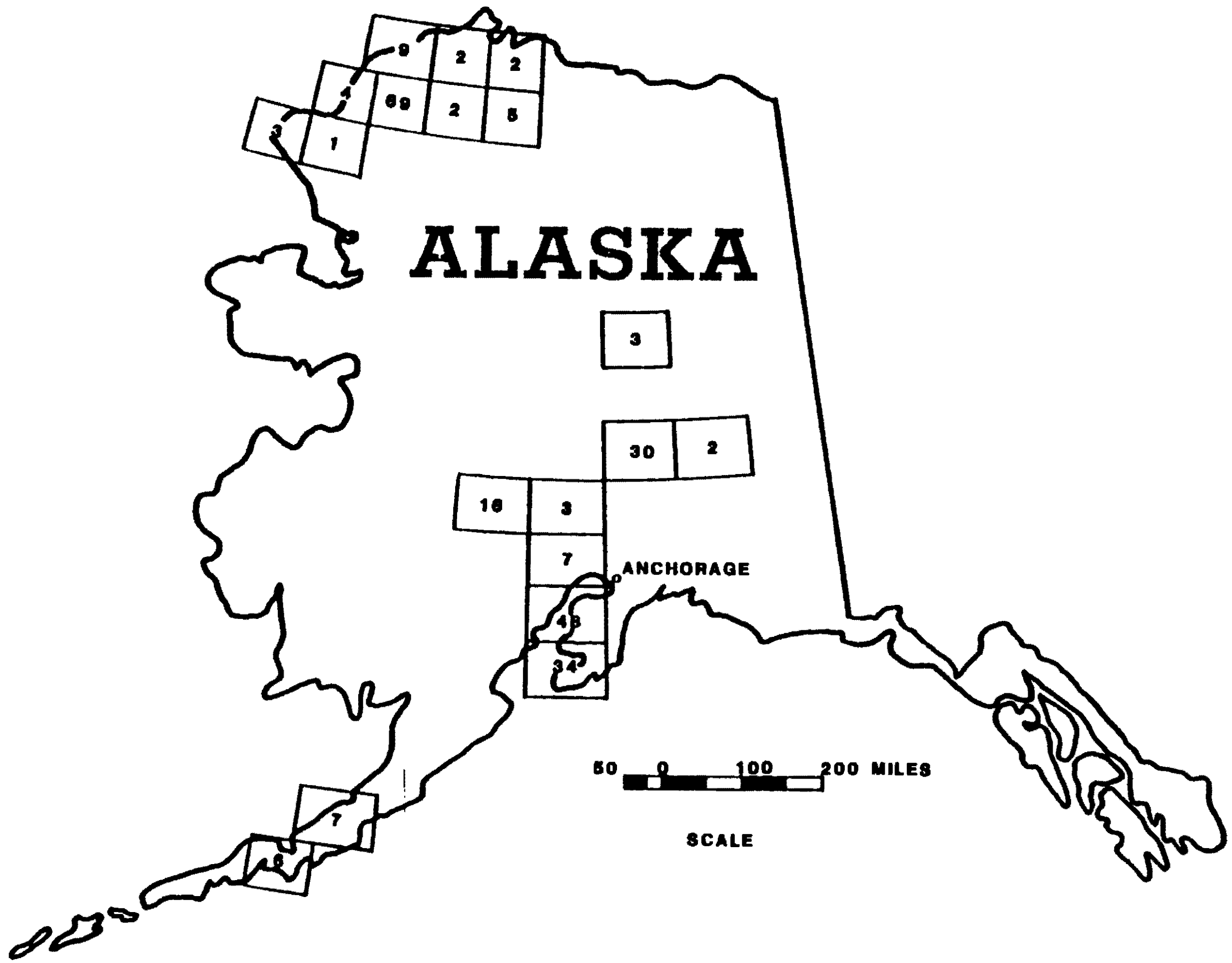

QUADRANGLES SAMPLED FOR CHEMICAL ANALYSIS

Figure 7.--Index map showing the location of nineteen quadrangles in Alaska that have been sampled for chemical analysis. Numbers inside quadrangles indicate number of samples.

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Problems and potentials for thermal drying of Alaskan low-rank coals

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Abstract

Low rank coals (LRC) contain large amounts of moisture. Removal of moisture is important to the economic feasibility of their transportation and processing. This is especially true for Alaskan coals of this type, because the State has limited major electric power transmission facilities and limited transportation facilities.

Most thermal coal drying experience in the United States is with higher rank coals. Evaluation of available drying technology and potential advanced coal drying systems must reflect the special characteristics of low rank coals. Also, the dried product requires special handling, storage and transportation.

Introduction

Demand for low rank coals (LRC)--subbituminous coals and lignites--is restricted because the high moisture content results in a low heating value per unit weight. Alaskan coals typically demonstrate this characteristic. In the lower 48 states low rank coals are used at mine mouth power plants, and some subbituminous coals are transported long distances for power generation. This is practical because of the existing electric power transmission and rail transportation infrastructure, and the large demand for electric power.

Near term conditions for Alaskan low rank coals are unlikely to justify their large-scale use for power generation in Alaska. Export markets appear more likely, but may be limited by the low heating value of the raw coal.

Export of dried coal or coal derived fuels is an alternative for marketing an upgraded Alaskan coal product. Coal derived fuels could be coal liquid mixtures, such as coal oil and coal methanol (with conversion of coal to produce the methanol) or coal derived synthetic fuels. Thermal drying of low rank coals is a necessary step for production of most coal derived fuels, and it will be an important consideration in technical and economic evaluations of the use of these Alaskan coals.

Relatively little research and development has been done on LRC drying. The potential benefits, however, indicate that work in this area should be of significant near term value to the Alaskan coal industry. Table 1 compares the characteristics of Alaskan and other coals.

Available Thermal Drying Methods

The most common method currently used for thermal coal drying is based on fluid bed dryers. However, the wide majority of U.S. experience with this equipment is with high rank coals. This experience is not directly transferable to drying coals of low rank, as will be described later. Fluid bed coal dryers are relatively simple machines and are capable of high throughput rates. However, environmental controls required by such drying techniques, which use direct heat contact, greatly complicate the total system. Also, fluid bed coal dryer operation is difficult when large amounts of fine coal (minus 28 mesh) are present. Fine coal particles become entrained in drying gases and disrupt fluid bed conditions. Dust collection requirements adversely effect economics.

The amount of fine coal produced from mining and handling low rank coals is generally larger than with coals of higher rank. This is an important factor to consider in coal dryer design and operation.

Apart from the fluid bed equipment, few other choices of proven dryer technology are available in the United States. Drum type dryers and flash dryers are in limited use with some European brown coals and with filter cake from cleaning plants for bituminous coals. More detailed investigation and development of these technologies (and possibly others) may lead to the commercial availability of practical drying methods.

Advanced Thermal Drying Methods

Advanced drying technology can be divided into two categories. The first includes development of industrial scale equipment from small-scale machines used for other purposes. Indirect dryers, where the coal is mechanically conveyed through the drying area, are one example. Spray dryers, which operate by atomizing a fine coal slurry and contacting the spray with hot gases, are another.

Results of laboratory scale tests with these types of dryers are reported by G.F. Ziesing (1). Significant technical and economic evaluation efforts are required before commercialization by the coal industry will be practical.

Table 1

COMPARISON OF TYPICAL COAL CHARACTERISTICS

TYPE OF COAL	ASH, %	VOLATILE, %	FIXED CARBON, %	BTU'S PER POUND	SULFUR, %	MOISTURE, %
CHUITNA RIVER AREA, ALASKA	7-13	40-50	40-45	10,000-11,500	0.1-0.2	25-35
NORTH DAKOTA LIGNITE	7-14	35-45	35-50	9,000-11,500	0.5-2.5	30-45
TEXAS LIGNITE	10-20	40-50	40-50	11,000-12,000	1.0-1.5	25-40
MONTANA SUBBITUMINOUS	5-15	35-40	50-55	10,500-12,500	0.4-1.7	15-25
WYOMING SUBBITUMINOUS	5-12	35-45	40-55	10,000-13,000	0.5-1.0	10-25
ILLINOIS BITUMINOUS	10-15	35-40	40-50	12,000-13,500	2.0-6.0	5-15

NOTE: ALL ITEMS ON DRY BASIS (EXCEPT MOISTURE).

Table 2

ADVANTAGES AND DISADVANTAGES OF VARIOUS TYPES OF COAL DRYERS

Type of Dryer	Advantages	Disadvantages
Fluid bed	Fully commercial High throughput Widely used by bituminous coal industry Good moisture removal efficiency	Extensive dust collection for fine coal Causes LRC size degradation Spontaneous combustion of dried LRC likely Dried LRC will reabsorb moisture from air
Flash	Commercially available Good moisture removal efficiency Works well with fine coal	Requires extensive dust and environmental controls Limited throughput Stability problems with LRC product
Spray	Low coal retention time in dryer May have potential for processes that treat fine coal	Not used by coal industry Requires coal slurry feed Fine coal product that is difficult to handle Very expensive
Indirect	Commercially available Minimum dust collection	Limited throughput Relatively inefficient Stability problems with dried LRC
Drum (Roto-Louvre, rotary kiln)	Commercially available Minimum dust collection	Limited throughput Relatively inefficient Most experience is with European coal or in noncoal industrial uses
Steam (Fleissner)	No dust problem Greatly reduced LRC size degradation Improved LRC stability Potentially most efficient	No experience with U.S. coals except for conceptual designs High-pressure vessels present technical problems for feeding and discharging coal Works best with size range of 2- to ½-inch coal.

The second major category of advanced drying has reached only conceptual levels in the United States. This category includes various techniques for steam drying. With steam drying, moisture is removed by contact of the coal with saturated steam in presure vessels. Steam drying is especially applicable to low rank coals, and works best with coals of higher moisture content. Most steam drying concepts are based on the early work of Fleissner in the 1920s. Fleissner plants were constructed in Europe as early as 1927, and several plants presently operated in eastern Europe have a maximum capacity of 600,000 tons of raw coal per year. Steam drying research in the United States has been performed by the Department of Energy for use specifically with lignites (2). Steam drying appears to have several advantages over other thermal drying methods, for reasons such as: coal size degradation is greatly reduced, less energy is consumed in drying and the dried product is more stable, thus is less subject to spontaneous combustion or moisture reabsorption.

Commercialization of steam drying will require major engineering efforts to extend laboratory results and conceptual plans to industrial scale operation. Coal handling, especially introduction to and removal of coal from pressurized vessels, may be a serious constraint. Commercial scale economic feasibility remains to be proven.

Figures 1-6 illustrate the types of coal dryers that have been discussed here, and Table 2 summarizes their advantages and disadvantages.

Thermal Drying Economics

For conventional fluid bed dryers, cost benefit evaluation for individual coals and site conditions requires extensive, but relatively straightforward, analysis. Capital plus annual operating and maintenance costs can be estimated from design data. Selected economic/financial criteria and discounted cash flow methods will provide annualized costs per ton, or per million Btus of dried coal.

Estimated costs can be compared with economic benefits to determine the project feasibility. Transportation cost savings are the simplest item to quantify. Figure 7 shows a generalized comparison of costs and benefits. On each of the three graphs, nominal transport rates (in dollars per ton mile) are plotted against incremental cost per ton of upgraded coal. This is the cost that could be incurred to break even transport savings at a ton mile rate. Three distances--500, 1,000 and 2,500 miles--and three weight reductions—10, 20, and 30 percent—are plotted.

Little information is available on the additional advantages of dried coal. We know that drying benefits coal grinding, combus-

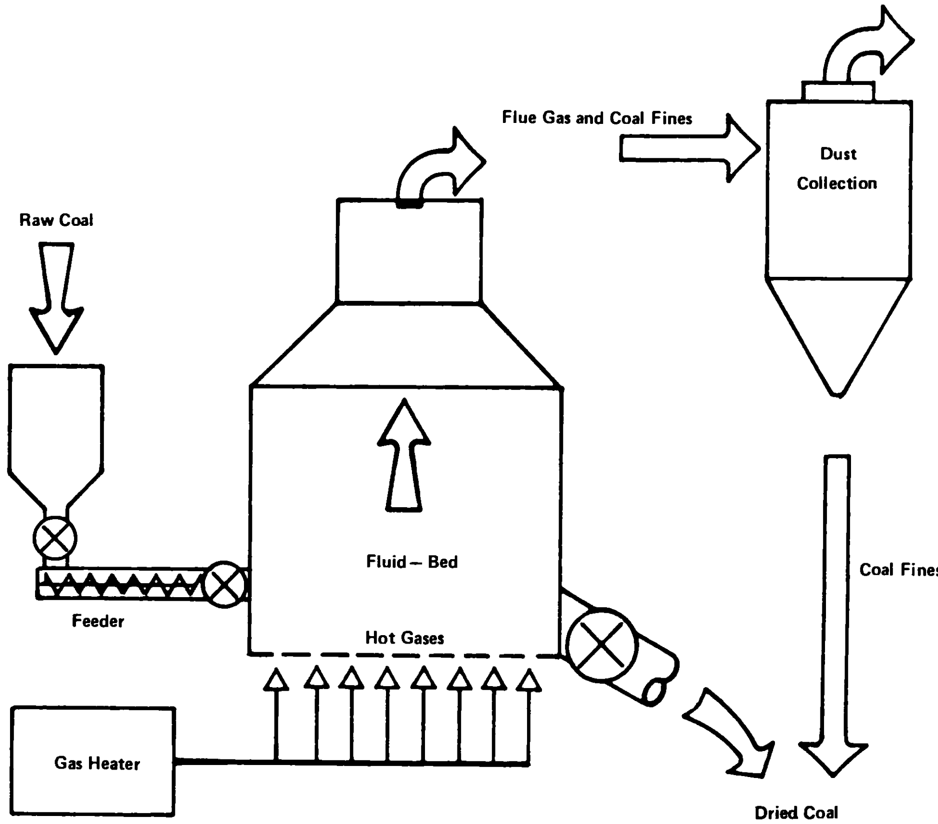

Figure 1 Fluid – Bed Dryer

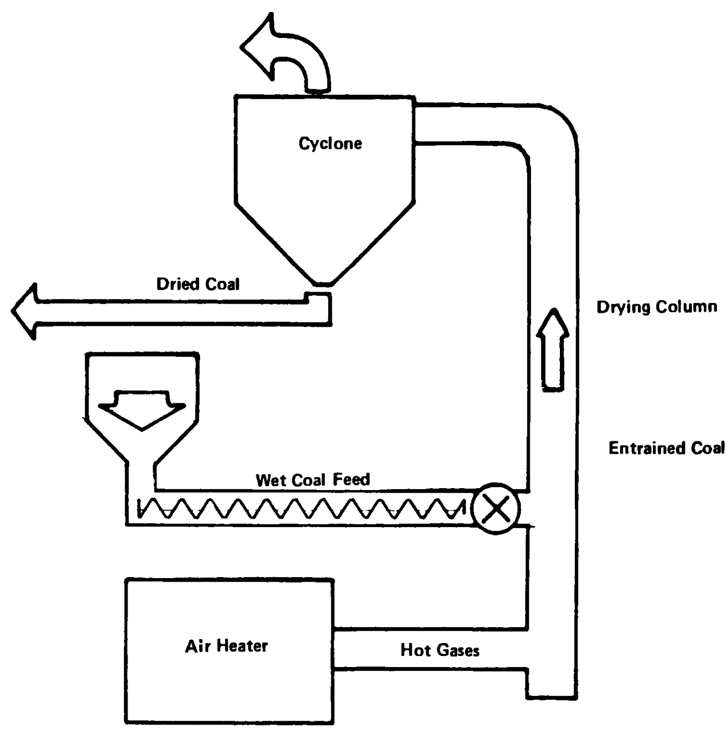

Figure 2 Flash Dryer

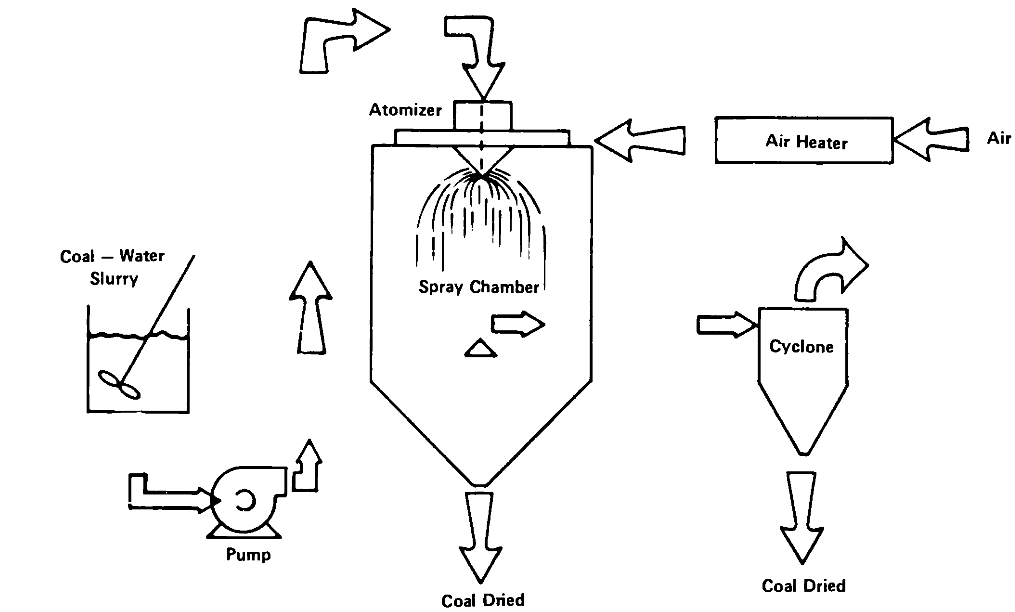

Figure 3 Spray Dryer

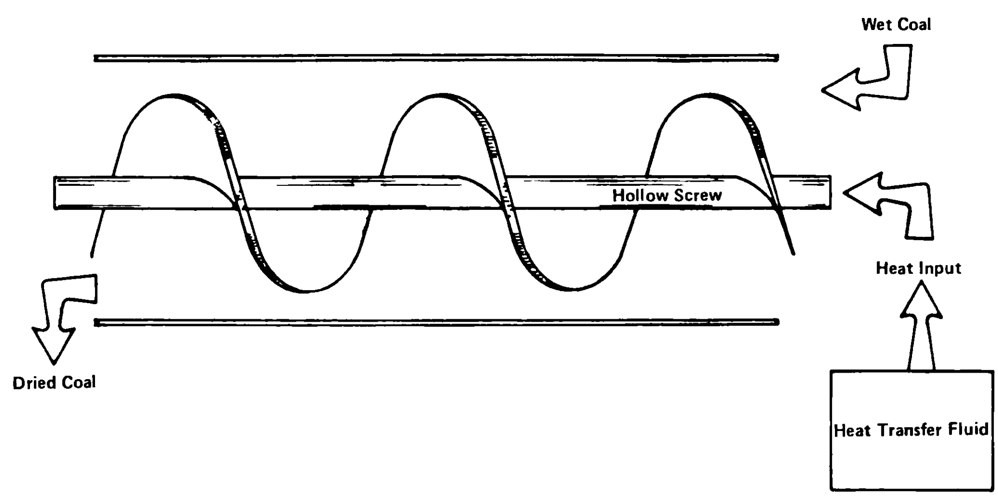

Figure 4 Indirect Dryer

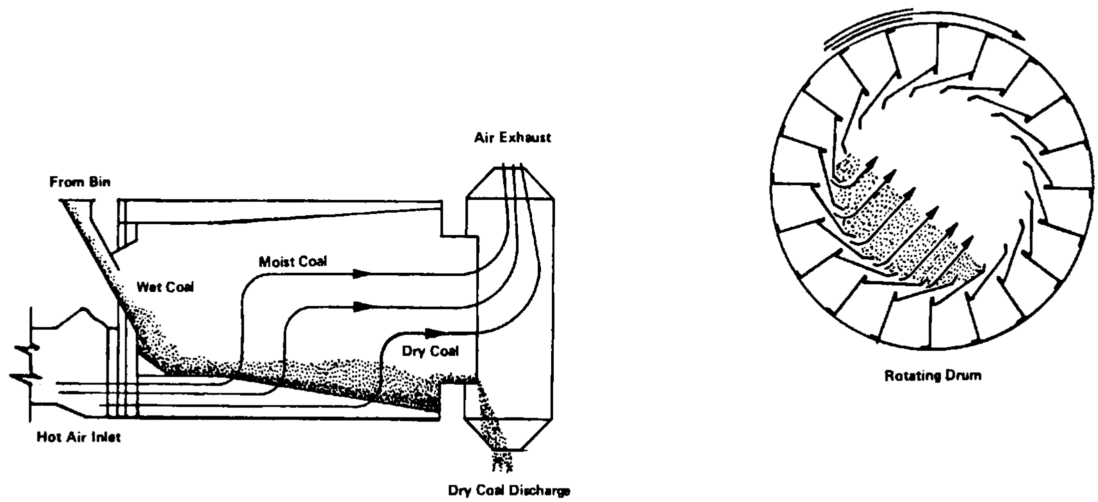

Figure 5 Drum Dryer

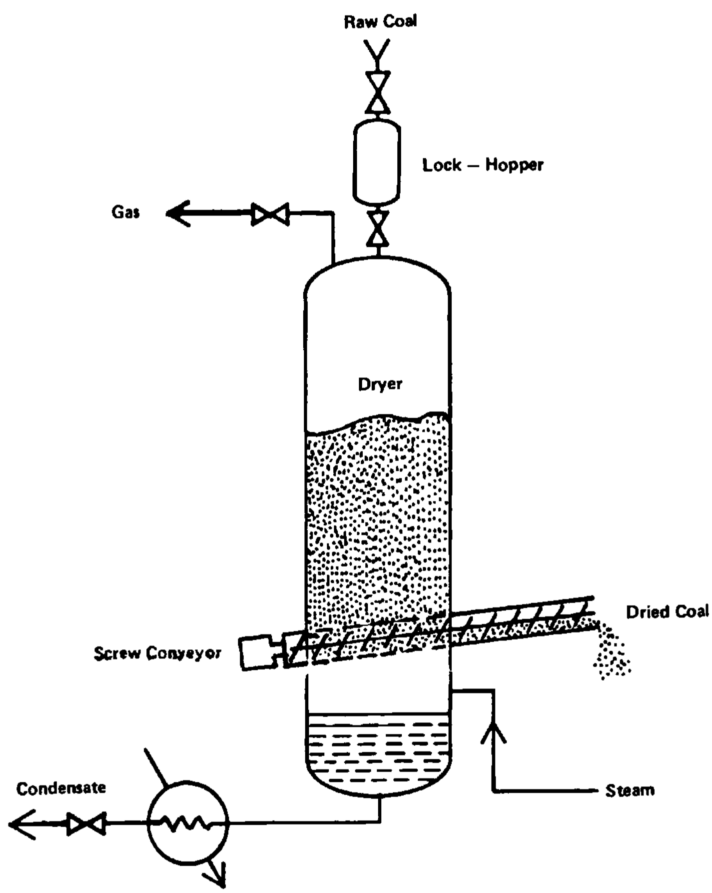

Figure 6 Steam (Fleissner) Dryer

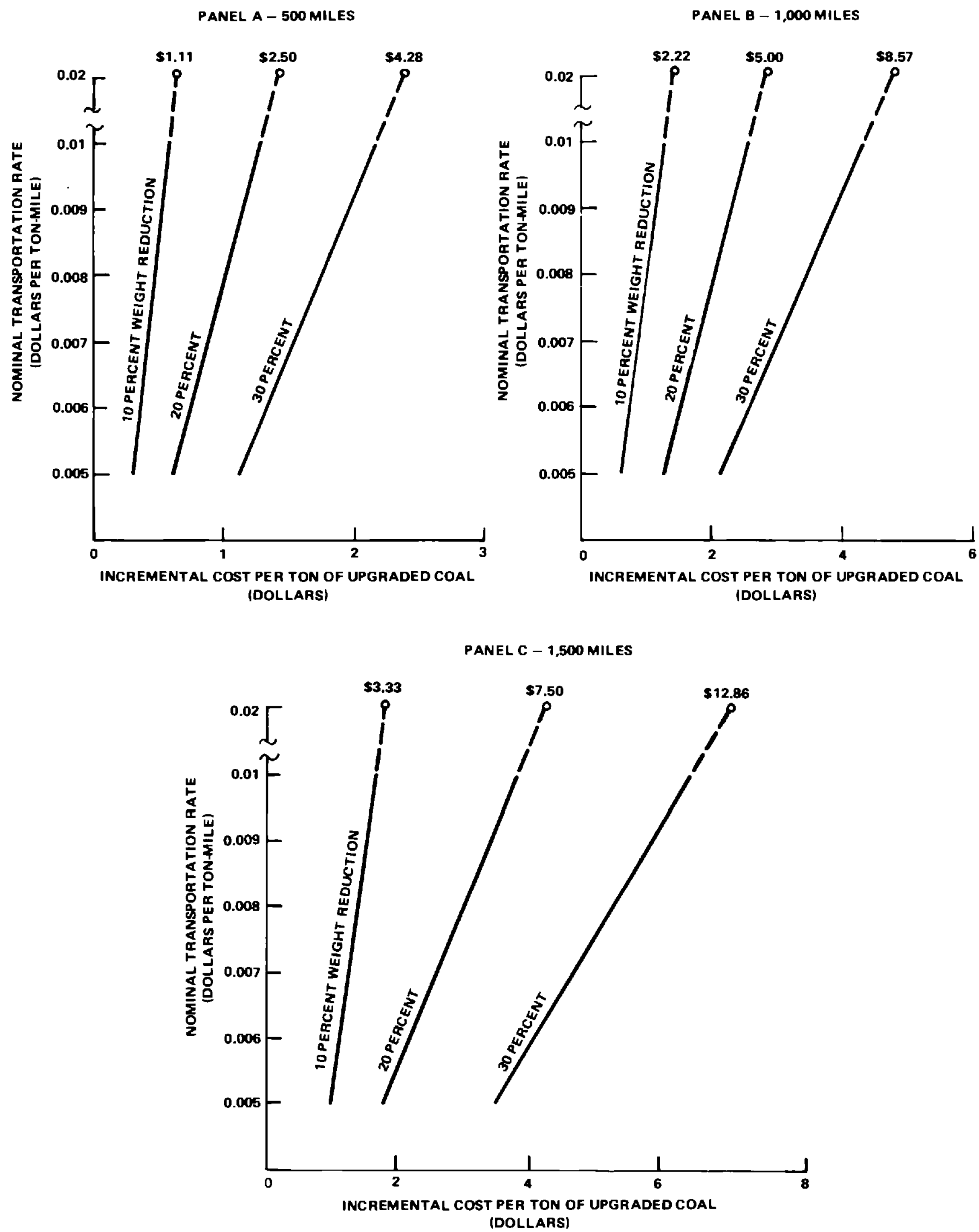

Figure 7 Comparison of Transportation Costs for Upgraded Coal

tion and conversion. These benefits, however, have not been sufficiently investigated to be quantified in this paper.

For conventional fluid bed coal dryers, annualized costs to remove a ton of water from the coal typically range from \$6 to \$10. The major cost item is dryer fuel (usually coal), which is assumed to be about \$1.25 per million Btus for the costs stated above. Actual costs are strongly site sensitive. The more advanced drying concepts require further development and design before the costs for commercial scale coal drying operations can be estimated.

Problems with Dried LRC

The problems discussed next constitute areas of opportunity for drying research and development for low rank coals (LRC). In many cases, causes of the problems are not well understood. Pragmatic solutions and more basic research are necessary to advance commercialization of drying Alaskan coal of this type.

The problem area that must first be considered is simply the large amount of moisture that must be removed. Plainly, more energy is required to thermally dry a 30 percent moisture coal than a lower moisture coal.

Equipment to handle the raw coal, the dryer itself and equipment to treat dryer effluents must all be larger. A potential benefit of drying the higher moisture low rank coals may be reduced sulfur dioxide (SO_2) scrubbing because of the coal's generally low sulfur content. Remedies to mitigate the problems associated with drying higher moisture coal include more efficient designs (insulation, heat recovery and optimization of equipment sizes), and more careful consideration of the degree of thermal drying necessary to minimize overall costs.

In addition to this basic problem, dried low rank coals exhibit several undesirable characteristics:

First, coal particle size degradation in dried low rank coals can be significant. Tests by the Department of Energy show a decrease of 40 percent in the amount of coal greater than 3/4 inch, after the coal's moisture content has been reduced from about 26 percent to 16 percent in a fluid bed dryer (3).

Second, dried low rank coals are more unstable than the raw coals, and spontaneous combustion is more likely.

Third, they are also unstable from the standpoint of moisture reabsorption. That is, the dried coal will absorb moisture from humidity in the air. Although low rank coals will not reabsorb moisture to their original level, reabsorption is rapid and could reduce much of the benefit of thermal drying.

Fourth, because of these instability problems, greater attention must be given to handling and storage of these dried coals than is needed with higher rank coals. Tests by the U.S. Bureau of Mines indicate that spontaneous combustion and moisture reabsorption can be controlled in compacted stockpiles (4). However, live stockpiles of dried low rank coals and handling and transport systems require more study.

Pragmatic solutions to the above problems appear achievable by careful engineering, based on tests with individual low rank coals. More basic research is required to better understand the drying process itself and the dried product's instability problems. The many variables of these coals such as size consist, moisture content and coal and ash analyses, must be investigated to determine their individual and combined effects on drying technology.

This is a sizeable task, but the potential benefits associated with Alaskan coals and low rank coals in general appear worth the effort.

Conclusion

Drying of Alaskan coal has the potential to reduce transportation costs and to benefit systems to produce coal derived fuels and coal conversion products.

Coal drying technology is especially important for Alaskan coals, since there is no extensive local demand for coal. Export would appear to offer a major growth opportunity.

Conventional fluid bed coal dryers are available, but they may not be optimal for low rank coals. Advanced drying systems have potential, but extensive research and development will be required before they are ready for commercialization. In addition, more research and development is needed to improve our understanding of the basic characteristics and properties of low rank coals, particularly after being dried thermally.

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Steam drying of Subbituminous Coals from the Nenana and Beluga Fields, a laboratory study

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Abstract

Samples of coal from the Usibelli Coal Mine (numbers 3 and 4 seams) and Waterfall seam of the Beluga Coal Field were dried at 250°C and 550 psia of steam pressure for varying lengths of time ranging from 5 to 60 minutes. Loss of weight ranged from 19.18 to 27.8% depending on the size consist of the sample and drying time. A weight reduction of 20% can be achieved with a 5 minute drying time for coals crushed to minus 2". Dried coals were characterized for compressive strength, size stability by drop shatter, Hardgrove Grindability Index, heating value and relation of petrology to drying behavior. The five minute steam drying process can improve heating value by more than 26% and considerably improve the grindability. Although dried coals had considerably lower compressive strength, drying did not affect size stability. Granting that dried coals regained some moisture at 98% relative humidity, weight gained is considerably less than weight lost in drying, providing net benefits due to drying. An apparatus has been designed and fabricated to enable comparison of self heating tendencies of various raw coals and dried products.

Acknowledgements

This study was conducted under the sponsorship of the U.S. Department of Energy (U.S. D.O.E) Grant Number ET-78-EG-01-12222. Laboratory investigations were conducted by David King, student in mining engineering. Edward McLaughlin was responsible for adaptation of a Parr pressure vessel for the steam dehydration system as well as for testing. He was also responsible for design and fabrication of the mechanical portion of the apparatus for testing self heating behavior of coals. Gil Mimkin designed and fabricated the electrical and electronic controls for the system. The authors wish to thank Dr. David R. Maneval for his help in the preparation of the manuscript and Dr. Earl H. Beistline, Dean of the School of Mineral Industry, for his constant support and encouragement of coal research investigation. Finally, the authors appreciate the bulk coal samples provided by Mr. Joseph Usibelli of Usibelli Coal Mine Inc. and by Mr. Benno Patsch of the Placer-Amex Company.

Introduction

Coal deposits of Alaska now being mined at the Usibelli Coal Mine and those that are in the process of being developed in the Beluga field by Placer-Amex are of Subbituminous "C" rank. The moisture in these coals varies from 22-28%. It would be economically advantageous if the moisture in these coals could be reduced so as to not have the cost of shipping the extra moisture. Also, the dried product would have superior grinding characteristics and burning qualities.

A project was funded by the U.S. Department of Energy to investigate the drying of Alaska's subbituminous coals and to characterize the products as to moisture reabsorption characteristics, physical stability and chemical stability (self ignition). The project is now complete. Work will be continued to refine the technique, which will ascertain the self heating behavior of various coals, including dried coals.

Dehydration Tests

Procedure

A Parr series 4500 two liter size pressure reactor was used for the tests (5). The tests were conducted at the University of Alaska power plant. A steam line was connected to the reactor to deliver steam at the top of the reactor. A steam outlet line was extended to the bottom of the reactor to permit elimination of any condensate from the system, as well as to establish a continuous purge of steam to maintain the highest possible temperature and pressure. A temperature of 250^{o}C and a pressure to 550 Psia were used. The samples were weighed and enclosed in stainless steel wire baskets, which were hung in staggered fashion in the reactor. Sample weights ranged from 30 gms to 120 gms depending on particle size. Steam pressure was then applied to the bomb. The steam outlet was opened sufficiently to prevent condensation of moisture in the bomb. It took 10 to 15 seconds for the pressure to reach the maximum of 550 Psia. All samples were tested for the following drying times: 5, 10, 15, 20, 30, 40, 50 and 60 minutes. At the end of the desired drying time the pressure was released. The products were weighed and stored in rubber sealed glass jars for other tests. A portion of the dried sample was crushed in a plastic bag and residual moisture was determined by the standard ASTM method at 106^{o} C (4). Samples pulverized to 60 mesh were used for determination of heating value.

For the current investigation 3 seams were studied: Nos. 3 and 4 seams from the Poker Flat pit of the Usibelli coal mine, now being mined, and the Waterfall seam in the Beluga coal field. The samples were crushed to -2" in the case of Nos. 3 and 4 seams. In the case of the Waterfall seam, only coal crushed to minus 1-1/2" was available at the time of the laboratory investigation. The samples were screened at 1-1/2", 1", 5/8" and 1/4". These sized fractions were used for the drying studies.

In another series of dehydration tests, cylinders of coal approximately one inch in diameter and two inches long were dried in the pressure reactor using the procedure described above. These cylinders were prepared by taking a diamond drill core from run of mine blocks of coal with bedding plane oriented parallel and perpendicular to the drill bit. Only sample cylinders from the Nos. 3 and 4 Usibelli Mine coals were taken.

Results

Figures 1, 2 and 3 show loss of weight in drying as a function of drying time, as well as moisture retained in the dried products for various sized particles. The data are presented in Tables 1, 2 and 3. A weight reduction of 20% can be achieved with 5 minutes residence time. Increasing residence time to 60 minutes only increased weight loss an additional 5 to 7%, depending on particle size, higher reduction being achieved for smaller particles. Moisture retained in one sample varied from 5 to 12% for different sized particles. Samples dried for the shortest period naturally retained the highest moisture. As can be expected, the smaller the particle size the lower was the retained moisture. It is obvious that 20% weight reduction can be achieved for coals crushed to -2" size and a drying time of about 5 minutes.

Tables 4 and 5 show the percentage moisture loss of core samples. The weight loss is shown to be nearly identical whether the plug had been cut parallel or perpendicular to the bedding planes.

A black aqueous liquor was collected by cooling vapors in the reactor. This material is derived from condensed steam and cognate water driven from the sample, and the color is presumably due to dissolved organic and inorganic materials. The composition of this liquor should be further investigated inasmuch as its disposal in any industrial (scaled up) plant would be necessary (10). If such disposal requires treatment prior to discharge into a receiving stream, the capital and operating cost would need to be considered in the overall treatment economics.

Dried Coal Characteristics

Several physical properties of the coal dried as described above were measured. They include unconfined compression and drop shatter, and heating values and the Hardgrove Grindability Index (HGI).

Mechanical Testing

Since coal is a nonhomogenous material, the properties determined from tests on two samples from the same mine may not be in agreement. There are a wide variety of tests to which a soil or rock specimen may be subjected. For the purpose of this project, the authors chose unconfined compression testing and modified ASTM drop shatter testing.

In the unconfined compression test, a cylindrical sample is prepared, measured and compressed in a compression apparatus. The maximum load it will carry (or the load that causes a reduction in length of 20%) divided by the end area equals the unconfined compressive strength (1). Table 6 shows comparison of compressive strengths of 1" diameter cores from No. 3 and No. 4 seams, drilled both parallel and perpendicular to the bedding. The low compressive strength of dried cores is due to severe fracturing along the bedding plane. Cores of raw coal cut parallel to bedding showed significantly lower compressive strength compared to those cut perpendicular to bedding. This was true not only for raw coals but also dried products. No 4 seam showed much higher strength than No. 3 seam for cores cut perpendicular to bedding, although cores cut parallel to bedding did not show any significant differences.

The ASTM Drop Shatter Test for coal D 440-49 has been modified to accomodate the small sample amount available for testing (4). Raw coals as well as steam dried specimens were tested and compared. The dried specimens that had been cored parallel and perpendicular to the bedding were separately dropped and tested.

Table 7 shows comparison of size stablity vs. drying time. The average stability values of all coals tested, however, indicate that dried coals are as stable as raw coals and should not present serious stability problems.

Drying has brought certain other advantages to the dried coal, particularly in grindability. Table 8 compares grindability of raw coals, air dried coals and coals dried at high temperature and pressure.

Figure 4 from "Combustion Engineering" (6) shows the relation of relative capacity of a bowl mill to Hardgrove grindability Index (HGI). The chart shows, for example, that a mill grinding a coal with 30 HGI (typical of raw Usibelli coal) to 65%-200 mesh has a capacity of 82% (not corrected for moisture). It could have a capacity of 108% when the HGI is improved to 50. Our test results show that HGI values of 50 or more are routinely achieved during the steam pressure drying process described earlier. This improvement would greatly benefit the user in that there would be reduced costs for grinding the dried fuel prior to firing.

Table 9 shows the analyses of raw coals as well as dried products. For all three coals, it can be seen that the loss in moisture resulting from steam treatment markedly improves the heating value of the dried fuel. The heating value rose 29.2%, 26.6% and 31.3% for the three seams (after only 5 minutes of heating). Further steam treatment increases the heating value to 34.5%, 34.6% and 42.5% after an hour's treatment in the reactor. Prolonged pressure treatment (exceeding 5 minutes) may prove to be less cost effective. Heating values expressed on a dry ash free basis show an increase even after a 5 minute drying period and a further increase for longer drying periods, indicative of loss of nonheat contributing functional groups due to high temperatures used in drying.

Microscopy of Dried Coals

Sections of steam dried coal were examined to analyze occurrence of shrinkage cracks and fracture patterns. After this cursory examination, the dried coals from the No. 4 seam, Usibelli mine were studied in depth. The dried coal was vacuum impregnated with epoxy and polished using the Standard Method of Preparing Coal Samples for Microscopical Analysis by Reflected Light (ASTM D 2797-72, Reapproved 1980) (4). A previous report by the author has presented results of the petrographic examination of this undried run of mine coal (this reference appears elsewhere in this publication).

The polished samples were then observed and photographed to record the number, array, orientation, nature and length of drying cracks (Fig. 5).

Microscopic observations of dried coals can be summarized as follows:

1. Fissuring develops at boundaries of banded petrographic components (Fig. 5E).

2. Suberinite, being resinous, provides a plane of weakness for fissuring. Even individual phlobaphinite cells get separated where the cell wall material is suberinite (Fig. 5E).

3. Fissures developed in huminite seem to stop abruptly when the fissures encounter thick walled fusinite, a maceral low in inherent moisture (Fig. 5B).

4. Cracks develop through fusinite when it is already cracked (such as in fusinite with bogen structure) (Fig. 5C) or when walls are too thin to offer resistance to fracturing (Fig. 5D).

5. Fissures originate at particle surface and penetrate as drying progresses (Fig. 5A).

6. As drying time is increased, fracturing is more extensive with the development of microfractures (Fig. 5F).

Moisture Reabsorption of Dried Coal

Procedure

Reabsorption: Dried coals are hygroscopic. It is important to know the amount of moisture that will be reabsorbed by the dried coal when stored under high humidity conditions. The dried coal samples, without any size reduction, were stored at 98% relative humidity over saturated potassium sulfate solution in a vacuum container. The samples were periodically weighed to determine weight gained due to moisture reabsorption.

Products from three drying times, 5, 30 and 60 minutes were chosen for this part of the study. Three particle size ranges, 2" x 1-1/2", 1" x 5/8" and 5/8" x 1/4" were tested.

Oiling: In an effort to determine the effectiveness of oil in reducing moisture pick up, several tests were conducted. Portions of the 5/8" x 1/4" coals which had been dried for 5 minutes were weighed, placed in a wire mesh basket and submerged for ten seconds in heated oil (150^{o}C). Immediately thereafter, the oiled samples were spun in a centrifuge for 10 minutes to remove excess nonabsorbed oil. The samples were then reweighed and the amount of oil adhering to the samples was determined. The oiled specimens were stored above a saturated potassium sulfate solution in a vacuum container as described above. The samples again were periodically weighed to determine weight gained (if any) due to moisture reabsorption. The oil used was "residual oil" from the North Pole Refinery, North Pole, Alaska, which had been heated to 200^{o} C to drive off lighter hydrocarbons. It would closely resemble locally available oils for use on Usibelli or Beluga coals.

Results

Moisture reabsorption without oiling: Figures 6, 7, and 8 show that although moisture reabsorption for the No. 3 seam samples was most rapid during the first 2 days, equilibrium was not reached even by the 23rd day, whereas coal from the No. 4 seam achieved equilibrium by 7-10 days (Figures 9, 10 and 11) and Beluga coal reaches equilibrium by the 17th day (Tables 12, 13 and 14). The data are shown in Tables 10, 11 and 12.

Moisture reabsorption behavior is clearly a function of particle size and drying time. For the larger sizes moisture reabsorption is greater for samples dried for longer periods of time. For smaller sizes, long period drying for 60 minutes brought out inevitable structural changes in the coal and resulted in less moisture reabsorption than those dried for say 5 minutes.

Moisture reabsorption after oiling: Table 13 shows that the steam dried coals, when dipped into hot oil and centrifuged, retained through absorption about two to three percent by weight of the oil.

Table 13 also shows the incremental and cumulative percent weight gains by the oiled dry coals over the testing period. The effect of oil on retarding moisture reabsorption was not shown in our work.

It should, however, be pointed out that the dried coals never regained their original moisture, even after being subjected to most favorable conditions for reabsorption for 3 weeks. For example, 2" x 1-1/2" coal from No. 3 seam dried for 5 minutes (Table 1) lost 19.04% in weight, but only regained 7.53% by weight after being subjected to 98% relative humidity for 23 days (Table 10). Actual pickup of moisture during transportation would be far less.

Self Heating Behavior

Procedure

It has been known for many years that coals are subject to self heating to a varying degree, and that the self heating tendency may be increased by drying. This may be caused by many factors, but principally by the increased surface area newly available for oxidation. (The drying process creates many cracks, fissures and new pores sites.) Material handling of the newly dried coal will further produce smaller particles which may lead to self heating. In order to compare the self heating characteristics of various raw (wet), air dried and steam dried coals, it was found useful to perform controlled laboratory tests to determine relative self heating properties of various raw as well as dried coals.

Kim (7) has surveyed various testing procedures useful for studies of spontaneous heating of coal. Of the four basic methods used in the past, adibatic calorimetry was chosen for this work (3, 8, 9). The coal sample is placed in an insulated container or bath, and the whole system is heated to a preselected temperature using an inert gas (nitrogen). Preheated air or oxygen is added to the system causing the temperature of the coal to rise; the material surrounding the coal is heated so that its temperature coincides with the measured temperature of the coal. Since there is no heat loss or gain to the surroundings or to the oxidizing gases, changes in coal temperature are attributable to the self heating behavior of the coal being tested. The change in the temperature of the coal in a given time, the time needed to reach a preselected temperature, or the amount of heat generated per unit of time is used to evaluate the self heating tendency of the coal.

System Description

A system has been designed and built to satisfy these requirements (Figure 15). A pulverized and sized sample of coal is loaded into a stainless steel basket which is suspended in a Dewar flask. The system requires that external air surrounding the coal is maintained at/or tracks the coal temperature. This is achieved by placing the coal in a Dewar flask fitted inside an insulated box. Further requirements are a heat source, type J thermocouples for control, type J thermocouples for monitoring, a safety cutoff and a proportional controller (Figure 15).

Thermocouples (A) (temperature of coal) and (C) (temperature of inlet gas) are used for monitoring the experiment processes on a MV chart recorder (1 chart division = 0.18° C). Thermocouples (B) and (D) are used by the temperature controller to determine the amount of heat required by the system for tracking. If (D) is less than (B) the heaters are turned on until there is no longer a difference between the two thermocouples. The amount of heating is proportional to this difference so that as the two temperatures (coal and surrounding air) approach equivalence, heating is reduced to preclude overshooting or oscillating about the desired value. An adjustable offset between (D) and (B) is built into the system. The offset is adjusted so that the temperature of inlet gases will not exceed coal temperature and will prevent bootstrapping of coal temperature.

The proportional controller design (Figure 16) utilizes a solid state relay to control power to the heater. This relay is turned on and off by a proportional controller that ensures that the heating is a function of the difference in temperature, insuring minimal thermal overshoot. The input to the controller is via a pair of type J thermocouples connected differentially. These thermocouples monitor the coal and air temperature surrounding the experiment flask. This amplified signal is applied to voltage-to-frequency converter whose pulse rate is therefore proportional to ΔT. This signal in turn drives the solid state switch. A thermal switch set for (150° C) has been located inside the heater box to prevent any possibility of a disastrous thermal runaway.

The apparatus is found to work satisfactorily. It is anticipated that various Alaskan raw coals and dried coals, along with coals known to be self heating from other parts of the country, will be tested. Preliminary results indicate that there is no substantial increase in the proclavity of coal dried by the procedure described here to self heating and compared to the run of mine coal.

Discussion and Recommendations for Future Work

As a result of these studies, a review of the literature and an analysis of drying Beluga coal done in Japan (10), a number of favorable results and useful studies have been identified. It has been shown that both Usibelli coal (seams 3 and 4) and Beluga coal (Waterfall seam) can be dewatered by steam dehydration and their weights reduced by 20%. Furthermore, the heating value is improved, rising from about 8,000 to 10,400 BTU per pound. The grindability as indicated by the HGI is improved from about 22 to 56, thus decreasing the effort (and cost) of pulverization prior to firing. Some care in handling the dried coal should minimize dusting inasmuch as the drop shatter results are good. Reabsorption does take place but never approaches even half of the original water content after 25 days, even under excessive humidity (not expected in practice).

Some of the problems that remain with the proposed steam dehydration include:

Achieving continuous rather than batch operation

Unknown effect of outside storage of dry coal

Disposition of liquor derived from steam condensation and coal dehydration

Use of agents for retarding dehydration and self heating

Larger scale tests to provide scale up date

Other approaches to dehydration, viz oil immersion

Analysis of transportation procedures for dried oiled coal

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TABLE 1

DEHYDRATION OF COAL FROM NO. 3 SEAM,
USIBELLI COAL MINE, 250°C, 550 PSIA STEAM

Particle Size	Drying Time Min.	Raw Coal Wt., Grams	Dehydrated Coal Wt., Grams	Wt. Loss in Dehydration, Percent	Moisture in Dehydrated Coal, Percent
2 x 1 1/2	60	152.48	114.67	24.79	5.78
	50	122.77	93.36	23.96	6.51
	40	115.79	87.90	24.09	6.37
	30	123.46	94.11	23.77	6.77
	20	126.85	99.13	21.85	8.80
	15	114.32	90.07	21.21	8.54
	10	118.99	93.34	21.55	8.32
	5	114.17	92.43	19.04	9.99
Raw Sample	0		-	-	26.95
1 1/2 x 1	60	99.91	74.69	25.24	5.01
	50	131.98	100.96	23.50	6.14
	40	90.50	69.06	23.69	6.65
	30	102.61	78.84	23.16	6.48
	20	122.30	95.07	22.26	7.75
	15	116.55	90.94	21.97	7.44
	10	101.47	80.20	20.96	8.11
	5	130.74	105.67	19.18	9.48
Raw Sample	0		-	-	25.19
1 x 5/8	60	80.66	60.99	24.39	5.61
	50	81.98	62.37	23.92	6.89
	40	77.44	59.57	23.08	7.08
	30	74.17	56.71	23.54	6.03
	20	65.19	50.52	22.50	4.36
	15	64.74	50.18	22.49	7.72
	10	68.39	53.54	21.71	7.03
	5	69.57	54.62	21.49	7.84
Raw Sample	0		-	-	26.41
5/8 x 1/4	60	43.19	32.96	23.69	7.48
	50	47.08	35.80	23.96	6.06
	40	44.45	33.77	24.03	5.87
	30	33.82	26.20	22.53	8.03
	20	36.65	28.46	22.34	7.54
	15	41.16	32.32	21.48	8.21
	10	39.46	30.99	21.46	8.43
	5	43.99	34.63	21.28	7.73
Raw Sample	0		-	-	25.89

TABLE 2

DEHYDRATION OF COAL FROM NO. 4 SEAM,
USIBELLI COAL MINE, 250°C, 550 PSIA STEAM

Particle Size	Drying Time Min.	Raw Coal Wt., Grams	Dehydrated Coal Wt., Grams	Wt. Loss in Dehydration, Percent	Moisture in Dehydrated Coal, Percent
2 x 1 1/2	60	170.16	128.41	24.54	6.71
	50	154.73	115.39	25.44	7.76
	40	142.61	108.92	23.62	8.00
	30	159.40	121.30	23.90	8.14
	20	157.86	122.35	22.56	7.21
	15	130.97	101.75	22.31	12.09
	10	131.61	101.47	22.90	8.59
	5	113.16	89.26	21.12	12.71
Raw Sample	0		-	-	24.55
1 1/2 x 1	60	99.35	74.54	24.97	7.02
	50	95.62	72.48	24.20	8.58
	40	114.27	86.00	24.74	6.46
	30	94.26	70.61	25.09	6.96
	20	112.38	85.47	23.94	7.40
	15	112.90	88.77	23.14	9.36
	10	113.44	87.73	22.66	10.00
	5	102.75	82.54	19.67	10.50
Raw Sample	0		-	-	25.37
1 x 5/8	60	79.71	57.53	27.80	4.29
	50	73.11	54.85	24.95	7.40
	40	75.82	57.93	23.60	8.51
	30	76.37	57.83	24.28	7.40
	20	73.81	56.40	23.59	6.69
	15	81.02	63.12	22.09	8.40
	10	70.46	54.23	23.03	7.41
	5	78.69	63.34	19.51	8.05
Raw Sample	0		-	-	25.02
5/8 x 1/4	60	47.43	34.35	27.58	5.16
	50	36.22	27.05	25.32	7.36
	40	37.00	28.50	22.97	7.78
	30	42.61	32.28	24.24	8.24
	20	34.06	26.81	21.28	9.81
	15	38.23	30.04	21.42	9.23
	10	32.17	25.66	20.24	9.77
	5	30.68	24.45	20.31	10.05
Raw Sample	0		-	-	25.69

TABLE 3

DEHYDRATION OF COAL FROM THE WATERFALL SEAM,
BELUGIA COAL FIELD, 250°C, 550 PSIA STEAM

Particle Size	Drying Time Min.	Raw Coal Wt., Grams	Dehydrated Coal Wt., Grams	Wt. Loss in Dehydration, Percent	Moisture in Dehydrated Coal, Percent
1 1/2 x 1	60	102.09	75.60	25.95	6.39
	50	100.55	77.60	22.82	5.86
	40	101.67	78.76	22.53	5.98
	30	97.94	77.31	21.06	8.62
	20	100.73	79.72	20.86	8.40
	15	101.05	81.98	18.87	10.31
	10	101.13	81.81	19.10	11.36
	5	97.85	81.42	16.79	9.44
Raw Sample	0		-	-	21.95
1 x 5/8	60	72.76	54.38	25.26	5.24
	50	70.10	53.24	24.05	5.48
	40	79.00	59.42	24.78	5.02
	30	85.67	65.61	23.42	5.25
	20	76.15	58.92	22.63	4.88
	15	72.54	56.30	22.39	6.95
	10	85.80	67.98	20.77	8.08
	5	71.13	57.13	19.65	9.18
Raw Sample	0		-	-	25.07
5/8 x 1/4	60	42.80	31.70	25.93	6.96
	50	36.72	28.08	23.53	6.66
	40	43.31	33.30	23.11	8.23
	30	77.24	58.74	23.95	5.84
	20	39.88	30.29	24.05	6.85
	15	45.94	35.30	23.16	7.03
	10	37.17	28.66	22.89	6.56
	5	37.80	29.82	21.11	7.45
Raw Sample	0		-	-	24.62

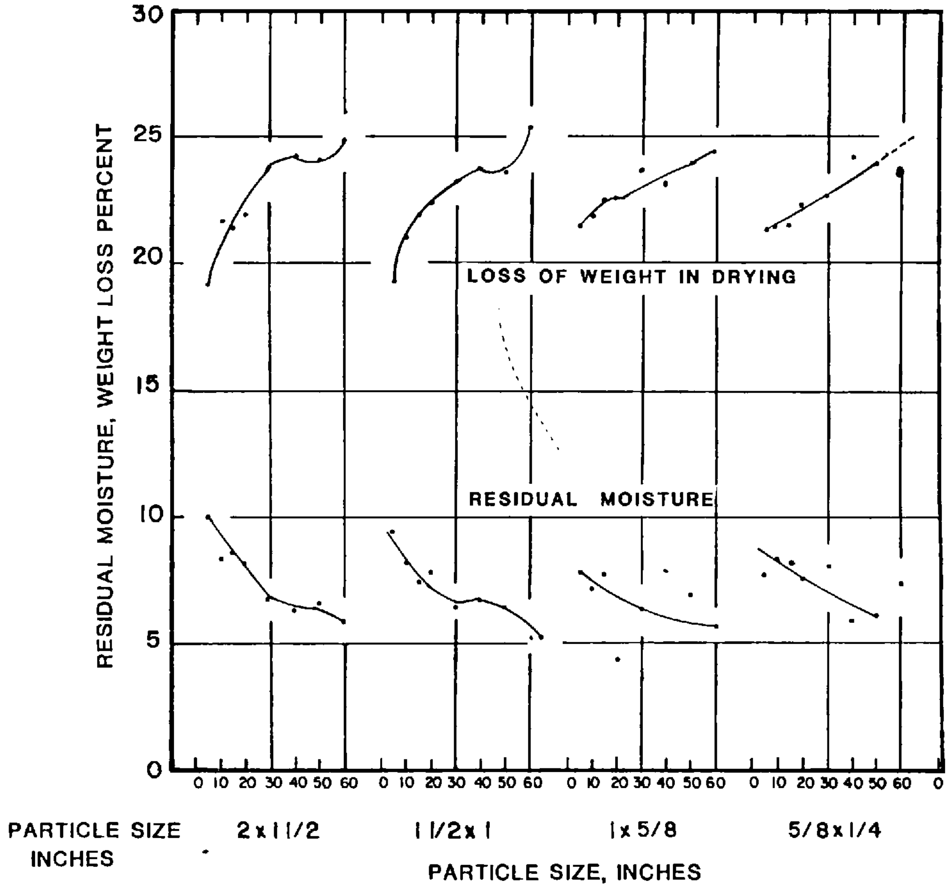


Figure 1: Loss of weight in drying as a function of drying time, and residual moisture for sized coal particles. No. 3 seam, Usibelli Coal Mine.

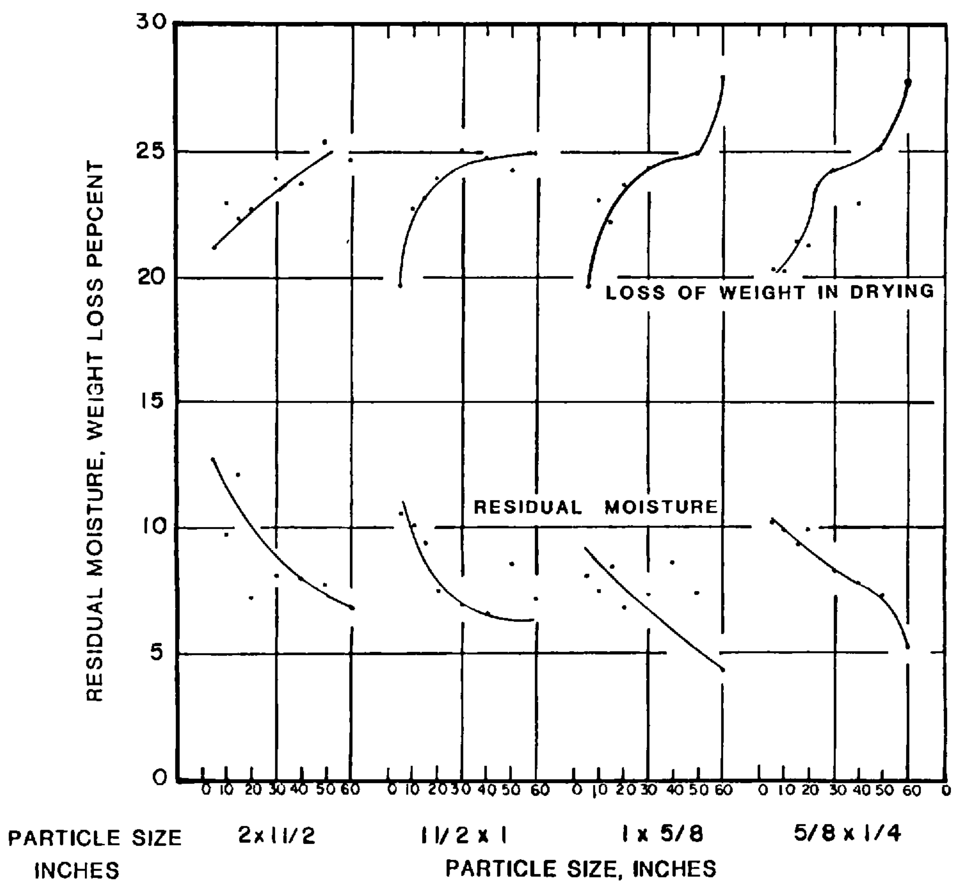


Figure 2: Loss of weight in drying as a function of drying time, and residual moisture for sized coal particles. No. 4 Seam, Usibelli Coal Mine.

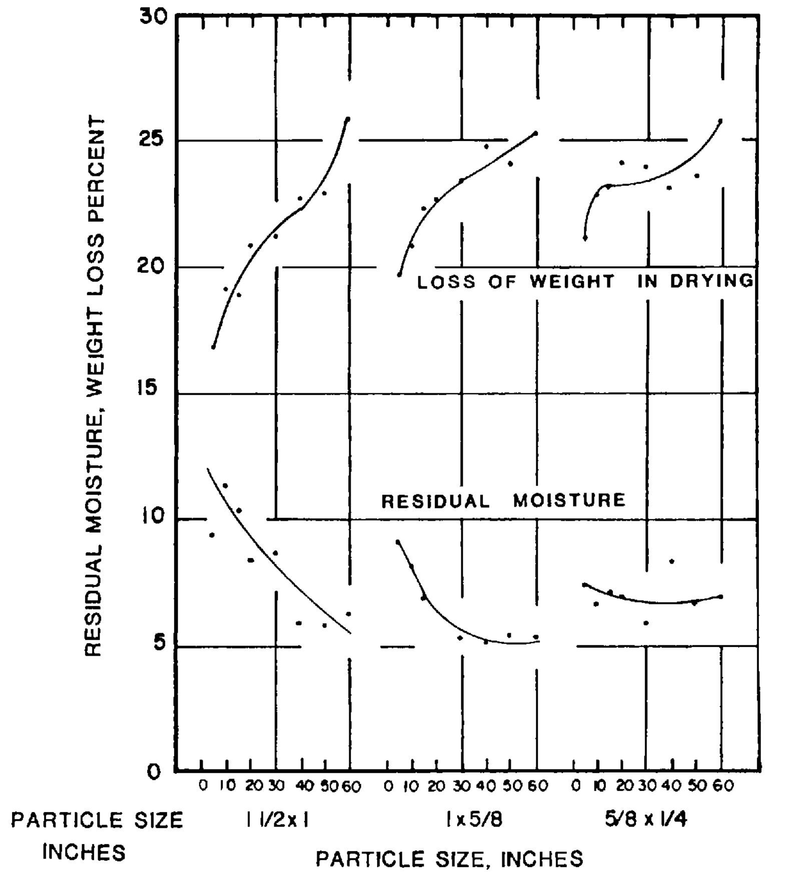


Figure 3: Loss of weight in drying as a function of drying time, and residual moisture for sized coal particles. Waterfall Seam, Beluga Coal Field.

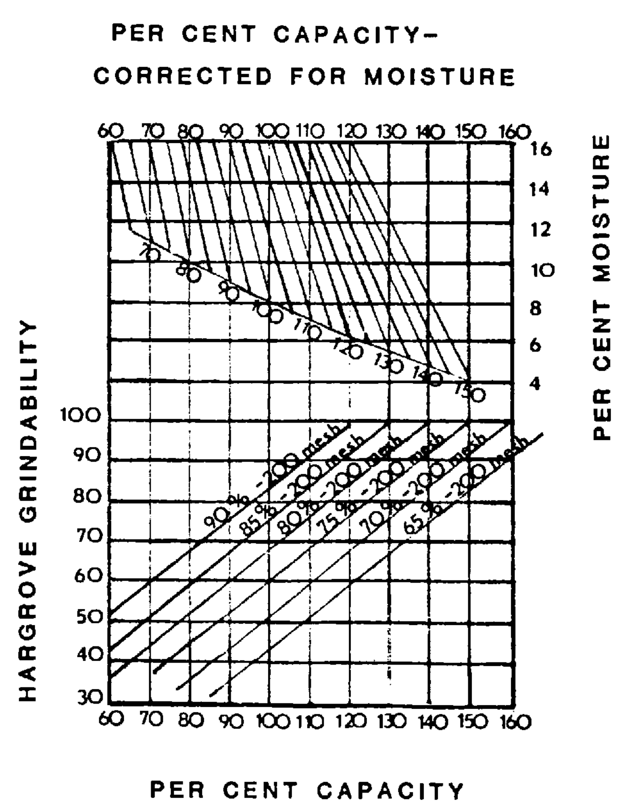


Figure 4: Relation of Relative Capacity of a Bowl Mill to Hardgrove Grindability Index.

TABLE 4

DEHYDRATION OF ORIENTED COAL CYLINDERS CUT FROM NO. 3 SEAM, USIBELLI MINE, 250°C, 550 PSIA STEAM

Drying Time Min.	Core Orientation in relation to Bedding Plane	Initial Weight of Core, Grams	Final Weight of Core, Grams	Weight Lost in drying, %
5	Perpendicular	19.80	10.12	18.58
	Parallel	20.88	17.14	17.91
30	Perpendicular	20.12	15.25	24.20
	Parallel	19.55	14.82	24.19

TABLE 5

DEHYDRATION OF ORINTED COAL CYLINDERS CUT FROM NO. 4 SEAM, USIBELLI MINE, 250°C, 550 PSIA STEAM

Drying Time Min.	Core Orientation in relation to Bedding Plane	Initial Weight of Core, Grams	Final Weight of Core, Grams	Weight Lost in drying, %
5	Perpendicular	20.03	16.00	20.12
	Parallel	17.49	13.76	21.33
15	Perpendicular	17.93	14.23	20.64
	Parallel	17.38	13.41	22.84
30	Perpendicular	16.73	13.33	20.32
	Parallel	18.16	14.39	20.76
60	Perpendicular	22.06	16.37	25.80
	Parallel	16.99	11.17	34.25

TABLE 6
COMPRESSIVE STRENGTH OF CORES OF RAW AND DRIED COALS

	Compressive strength P.S.I.					
	No. 3 Seam			No. 4 Seam		
Core Orientation to Bedding	Raw Coal		Dried	Raw Coal		Dried
	Mean	Standard Deviation	Coal	Mean	Standard Deviation	Coal
Perpendicular	1450	620	700	3250	1060	700
Parallel	930	290	300	1050	380	400

1. Raw coal cores had 1 1/32" diameter.
2. Dried cores had 15/16" diameter due to shrinkage in drying. The cores were dried for 5 minutes at 550 psia steam and 250°C.

TABLE 7

SIZE STABILITY OF RAW AND DRIED COALS
ASTM SIZE STABILITY

Sample	Size	Raw Coal	Drying time 5	10	15	20	30	40	50	60
No. 4 Seam	2" x 1 1/2"	70	61	76	76	79	75	76	64	61
	1 1/2" x 1"	90	60	72	61	76	92	87	94	74
No. 3 Seam	2" x 1 1/2"	74	91	55	79	81	94	77	56	81
	1 1/2" x 1"	89	84	78	96	91	86	70	78	87
Beluga	1 1/2" x 1"	73	93	94	88	95	83	66	89	95
Average		79	78	75	80	84	86	75	76	80
No. 4 Seam 1" diameter core Parallel		70	75		50					50
No. 4 Seam 1" diameter core Perpendicular		67	48		49		47			49
No. 3 Seam 1" diameter core Parallel		86								
No. 3 Seam 1" diameter Perpendicular		83								

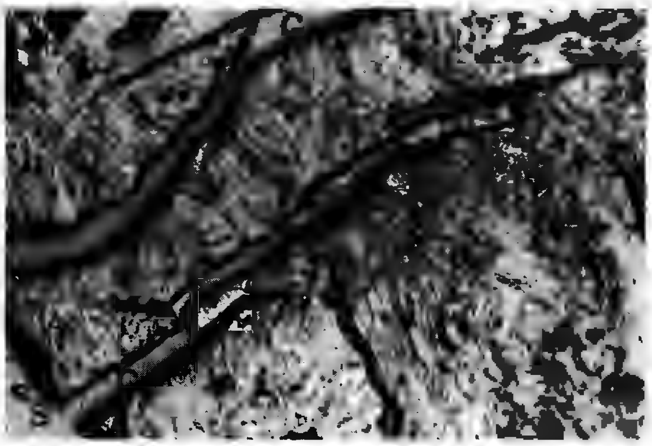
TABLE 8. Hardgrove Grindability Index of 1 1/2" x 1" Raw and Dried Coals

	Raw Coal		Air Dried Coal		Coal dried at 550 Psia at 250°C: 5 Minutes		30 Minutes		60 minutes	
	HGI	Mois. %	HGI	Mois. %	HGI	Mois. %	HGI	Mois. %	HGI	Mois. %
No. 3 Seam Usibelli Coal Mine	32	27.5	32	18.7	50	9.5	54	6.5	57	5.0
No. 4 Seam Usibelli Coal Mine	22	25.3	27	15.4	50	10.5	54	7.0	56	7.0
Water Fall Seam Beluga Field	18	22.6	23	9.8	33	9.4	36	8.6	41	6.4

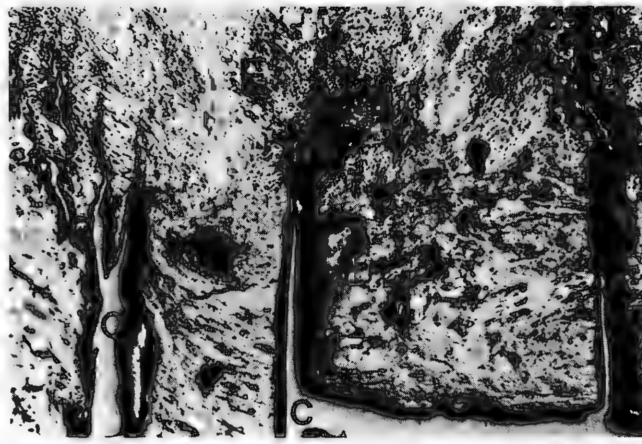
TABLE 9

CHARACTERIZATION OF DRIED COAL 1" x 5/8"

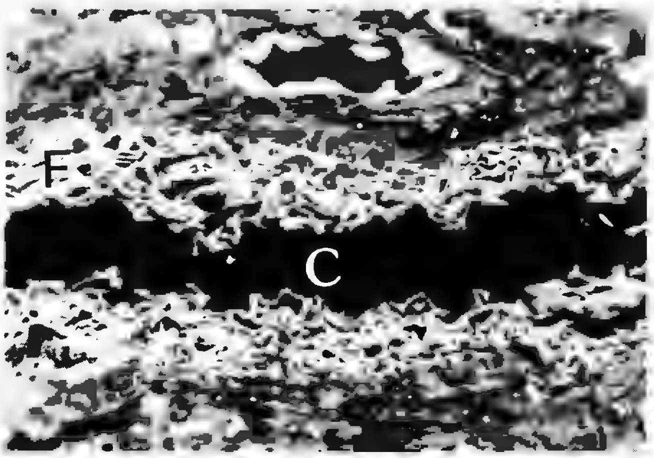
	No. 3 Seam Usibelli Coal Mine				No. 4 Seam Usibelli Coal Mine				Water Fall Seam Beluga Coal Co.			
Drying time, Min.	Mois., %	Ash, %	Heating Value, dried coal, Btu/lb	Dry Ash free basis, Btu/lb	Mois., %	Ash, %	Heating Value, dried coal, Btu/lb	Dry Ash free basis, Btu/lb	Mois., %	Ash, %	Heating Value, dried coal, Btu/lb	Dry Ash free basis, Btu/lb
Raw coal	26.41	4.26	8,061	11,626	25.02	4.71	8,074	11,490	25.07	7.92	7,717	11,517
5	7.84	4.25	10,416	11,849	8.05	5.90	10,220	11,876	9.18	5.42	10,136	11,869
10	7.03	4.10	10,583	11,908	7.41	6.47	10,328	11,992	8.08	8.14	10,066	12,015
15	7.72	4.11	10,466	11,871	8.40	6.44	10,467	12.290	6.95	5.79	10,338	11,847
20	4.36	4.13	10,944	11,960	6.69	6.51	10,276	11,838	4.88	5.87	10,878	12,188
30	6.03	4.16	10,770	11,992	7.40	5.66	10,366	11,923	5.25	7.08	10,791	12,309
40	7.08	4.04	10,602	11,928	8.51	5.28	10,224	11,868	5.02	7.87	10,601	12,169
50	6.89	4.10	10,832	12,170	7.40	4.98	10,506	11,990	5.48	6.93	10,729	12,249
60	5.61	4.10	10,841	12,007	4.29	6.13	10,867	12,131	5.24	6.30	10,997	12,432



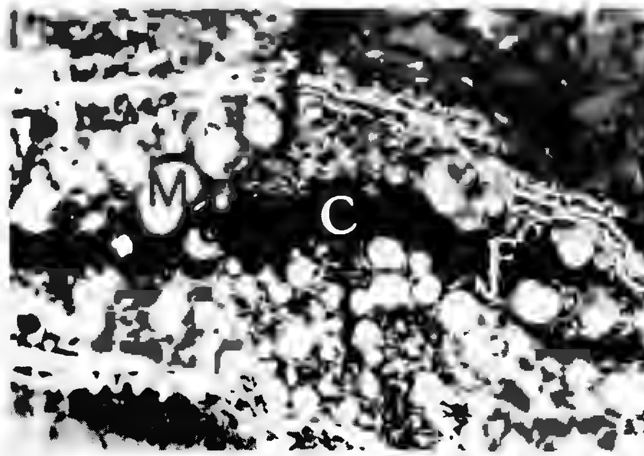
A. Development of fractures (C) from the surface (S) of coal particle
5 min. drying-50x air



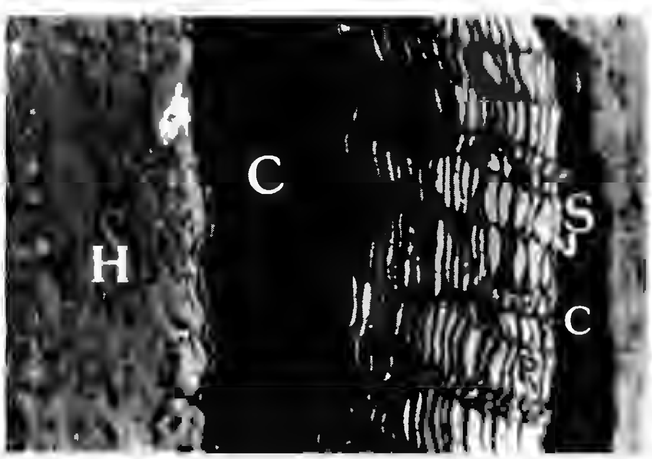
B. Fracturing (C) stops at thick walled fusinite (F)
5 min. drying-50x air



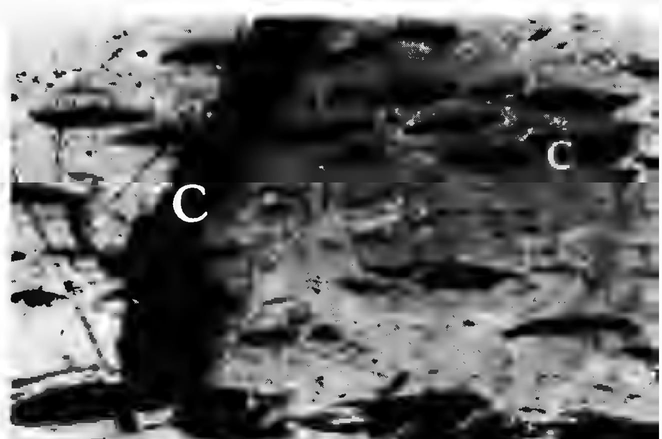
C. Fracturing (C) through broken fusinite (F) bogen structure
10 min. drying-500x oil immersion



D. Fracturing (C) of weak fusinite cells (F) filled with macrinite globules (M)
10 min. drying-500x oil immersion



E. Fissuring (C) at boundary of suberinite (S) covering phlobaphinite (P) & huminite (H) 15 min drying-500x oil immersion



F. Macro and micro cracks (C)
15 min. drying-500x oil immersion

Figure 5. Photomicrographs of dried coals from No. 4 seam, Usibelli Coal Mine. Reflected light.

TABLE 10

Reabsorption of moisture by sized coals dried for 5, 30 and 60 minutes
Sample is taken from No. 3 seams, Usibelli Coal Mine

Size, In.	Drying Time Min.	Moisture in dried Coal, %	Moisture reabsorbed, % residence time, days						
			1	2	3	7	11	17	23
2" x 1 1/2"	5	9.99	4.50	5.24	5.53	5.76	6.33	6.33	7.53
	30	6.77	6.33	7.15	7.46	7.72	8.08	8.08	9.42
	60	5.78	6.97	7.61	7.93	8.22	8.68	8.68	9.90
1" x 5/8"	5	9.48	8.09	8.53	8.53	8.97	9.07	9.36	11.60
	30	6.48	8.07	8.49	8.63	8.91	9.05	9.62	11.74
	60	5.01	7.59	8.08	8.37	8.50	8.35	9.24	10.31
5/8" x 1/4"	5	7.73	8.04	8.16	8.40	8.77	9.38	9.38	10.35
	30	8.03	7.05	7.54	7.64	7.93	8.32	8.52	9.70
	60	7.48	6.84	7.02	7.37	7.72	8.07	8.25	8.95

TABLE 11

Reabsorption of moisture by sized coals dried for 5, 30 and 60 minutes.
Sample is taken from No. 4 seam, Usibelli Coal Mine.

Size, In.	Drying Time, Min.	Moisture in dried coal, %	Moisture reabsorbed, percent residence time, days						
			1	2	3	7	10	17	24
2" x 1 1/2"	5	12.71	3.59	4.66	4.99	5.42	5.50	5.65	5.65
	30	8.14	4.38	5.88	6.24	6.82	7.00	7.16	7.16
	60	6.71	5.68	6.82	7.07	7.35	7.67	7.78	7.78
1" x 5/8"	5	8.05	5.22	6.38	6.38	6.43	7.17	7.38	7.38
	30	7.40	6.60	7.65	7.65	7.82	8.43	8.60	8.60
	60	4.29	8.17	9.08	9.19	9.40	9.45	9.82	9.82
5/8" x 1/4"	5	10.05	6.20	7.25	7.25	7.37	7.60	7.60	7.60
	30	8.24	5.33	5.85	6.00	6.30	6.37	6.67	6.67
	60	5.16	4.38	4.87	5.22	5.29	5.64	5.64	5.71

TABLE 12

Reabsorption of moisture by sized coals dried for 5, 30 and 60 minutes. Sample is taken from Waterfall Seam, Beluga Field.

Size, In.	Drying Time, Min.	Moisture in dried coal, %	Moisture reabsorbed, percent residence time, days					
			1	3	6	10	17	24
	5	9.44	2.91	2.47	3.56	3.84	4.50	4.50
1 1/2" x 1"	30	8.62	3.38	3.84	4.13	4.13	4.84	4.84
	60	6.39	4.97	5.70	6.13	6.26	6.82	6.82
	5	9.18	4.80	5.44	6.08	6.37	6.84	6.84
1" x 5/8"	30	5.25	6.78	7.59	7.93	8.13	8.60	8.87
	60	5.24	5.89	6.55	6.99	6.99	7.43	7.43
	5	7.45	5.76	6.31	6.72	6.72	7.41	7.41
5/8" x 1/4"	30	5.84	6.62	6.99	7.46	7.46	8.02	8.02
	60	6.96	6.60	6.97	7.49	7.49	7.93	7.93

Table 13

MOISTURE REABSORPTION OF OIL COATED SAMPLES DRIED FOR 5 DAYS
5/8" x 1/4"

Sample	Oil Retained Wt. %	Int. Wt., grams	Basis	Moisture reabsorbed, % Residence time, days @ 98° % R.H.				
				2	4	7	14	22
No. 3 Seam	3.0	61.2678	Increment	9.27	2.65	2.66	.46	.38
			Cumulative	9.27	11.92	14.58	15.04	15.42
No. 4 Seam	2.0	62.0300	Increment	6.09	2.46	1.11	.76	.11
			Cumulative	6.09	8.55	9.66	10.42	10.53
Water Fall Seam Beluga Field	2.1	61.2958	Increment	5.0	2.01	1.40	.52	.15
			Cumulative	5.0	7.01	8.41	8.93	9.08

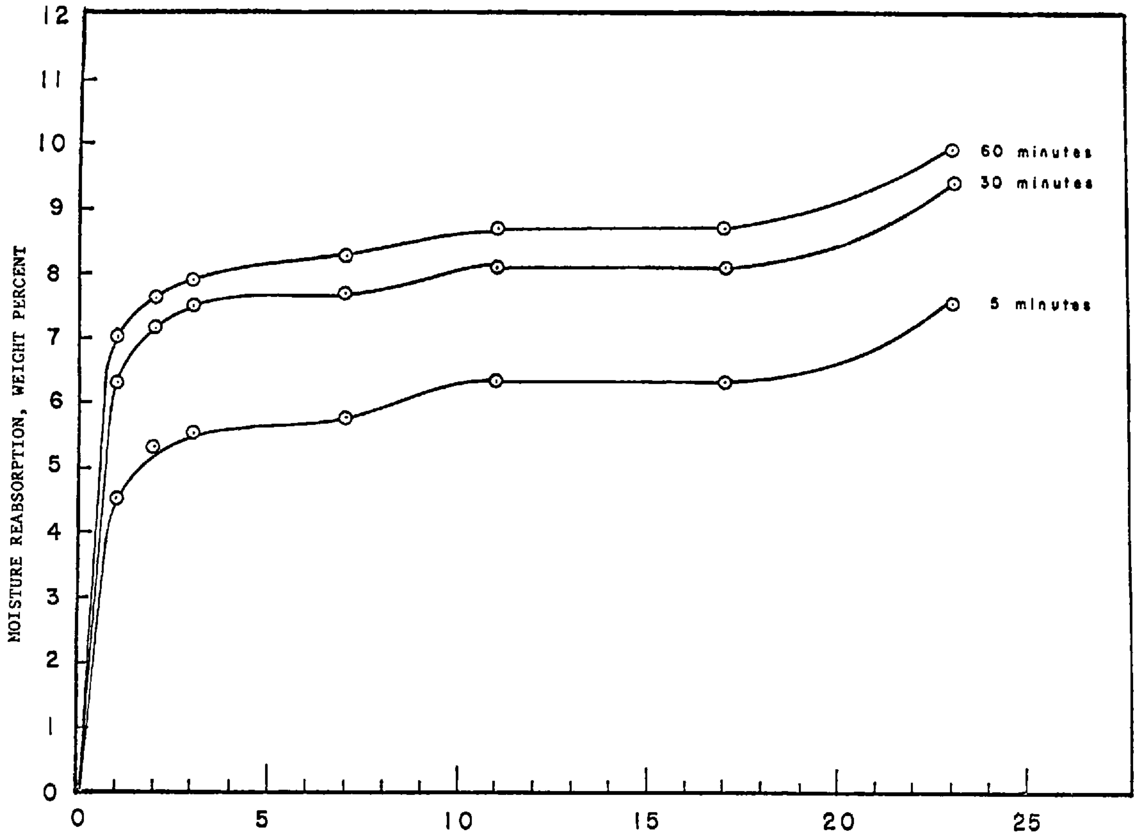


Figure 6: Reabsorption of moisture by 2" x 1 1/2" coal dried for 5, 30 and 60 minutes. Sample is taken from No. 3 Seam, Usibelli Coal Mine.

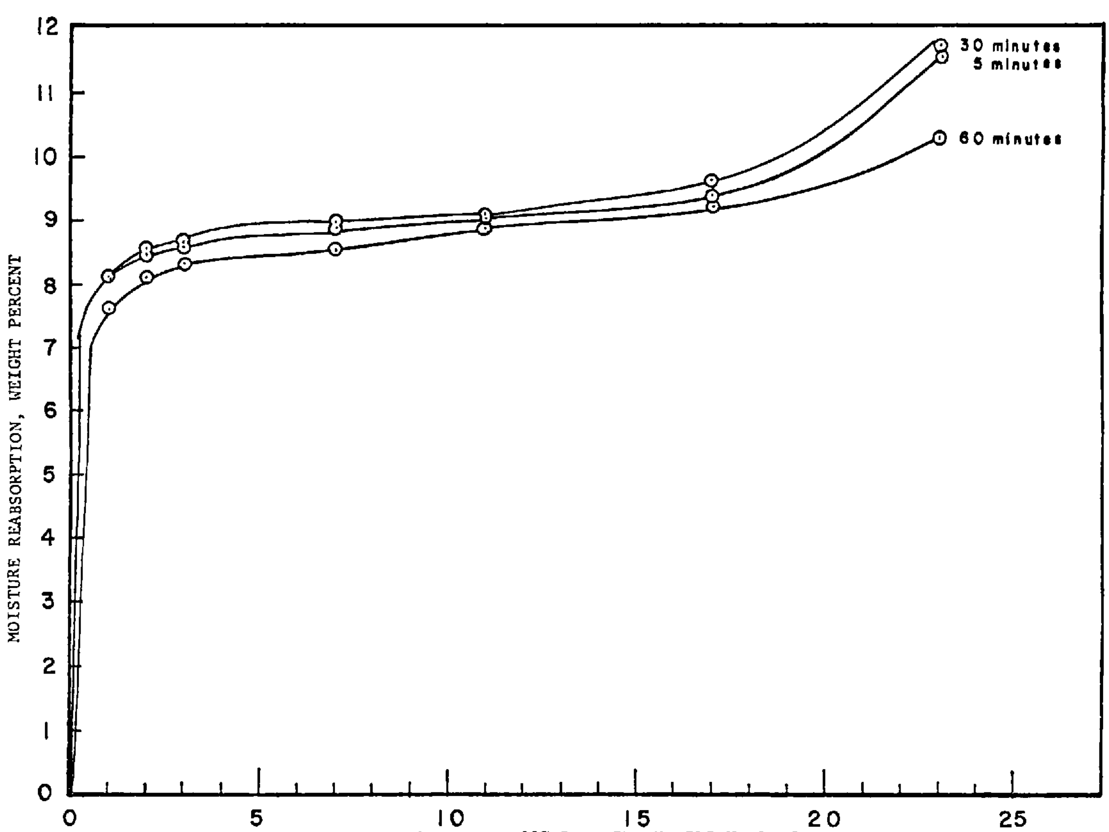


Figure 7: Reabsorption of moisture by 1" x 5/8" coal dried for 5, 30 and 60 minutes. Sample is taken from No. 3 Seam, Usibelli Coal Mine.

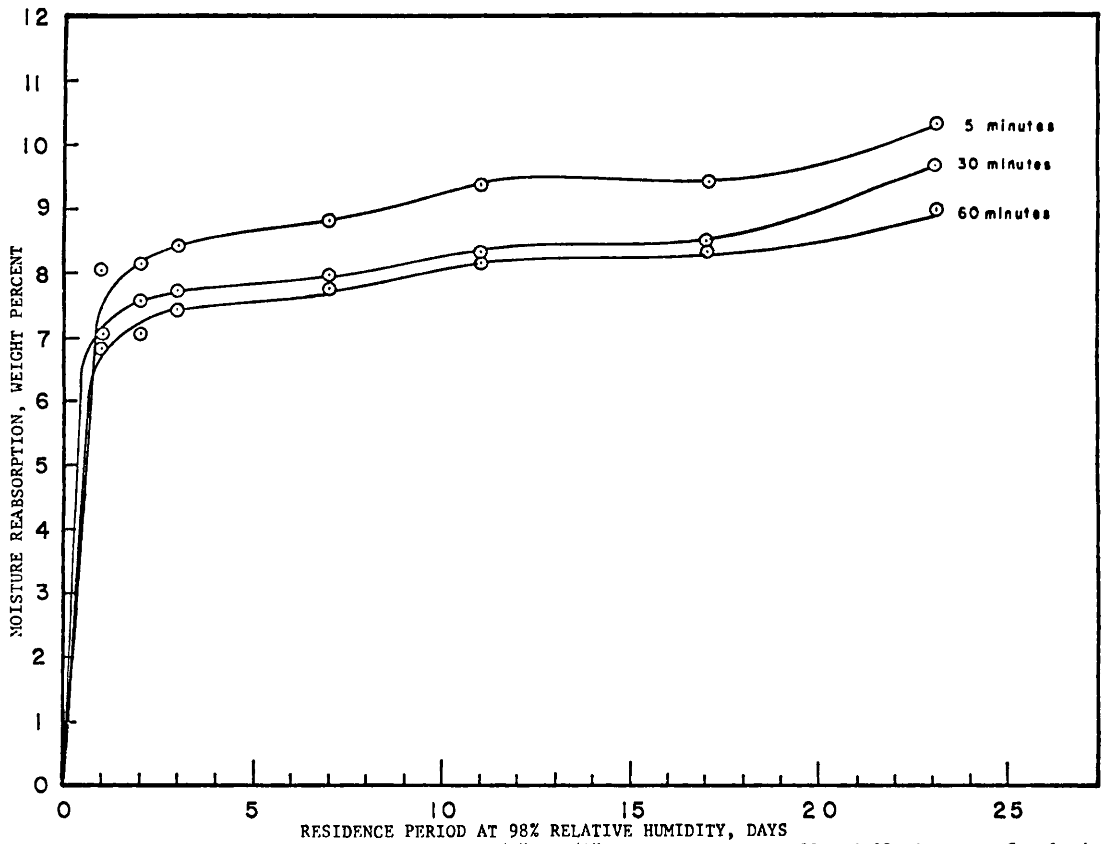


Figure 8: Reabsorption of moisture by 5/8" x 1/4" coal dried for 5, 30 and 60 minutes. Sample is taken from No. 3 Seam, Usibelli Coal Mine.

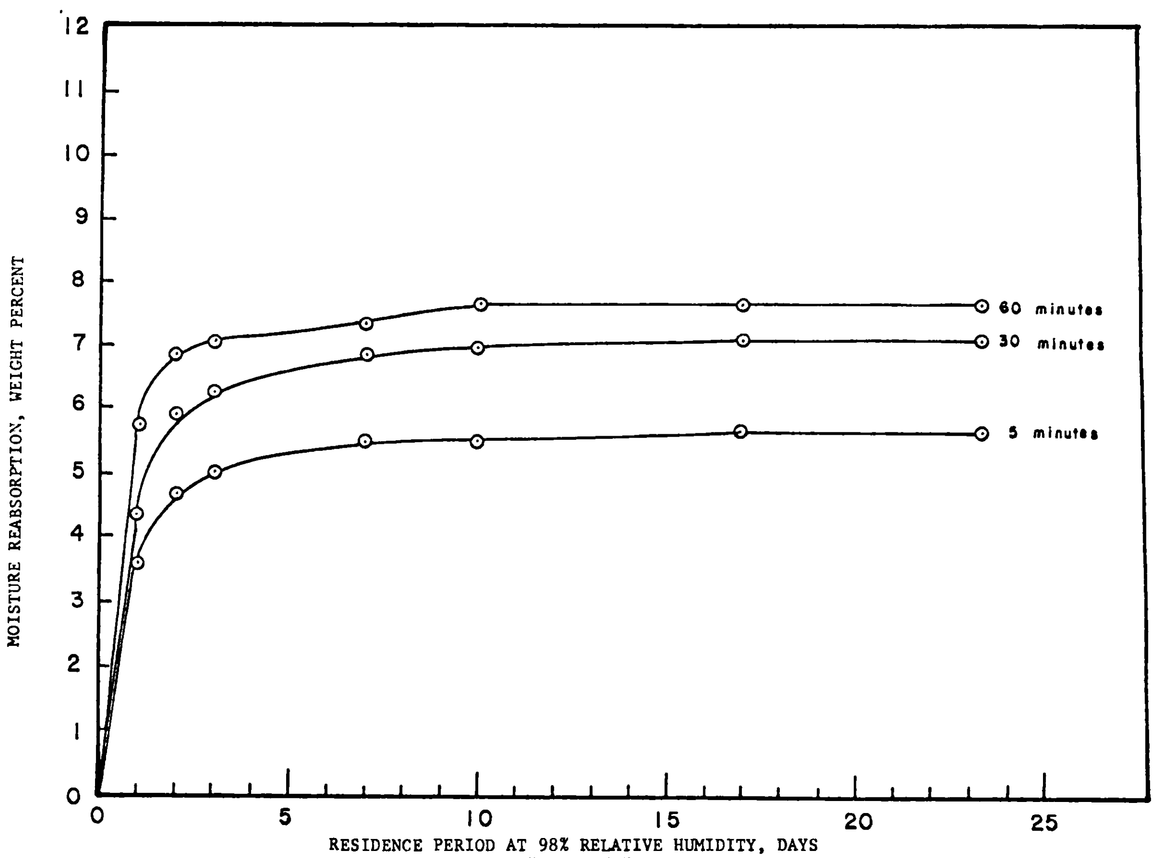


Figure 9: Reabsorption of moisture by 2" x 1 1/2" coal dried for 5, 30 and 60 minutes. Sample is taken from No. 4 Seam, Usibelli Coal Mine.

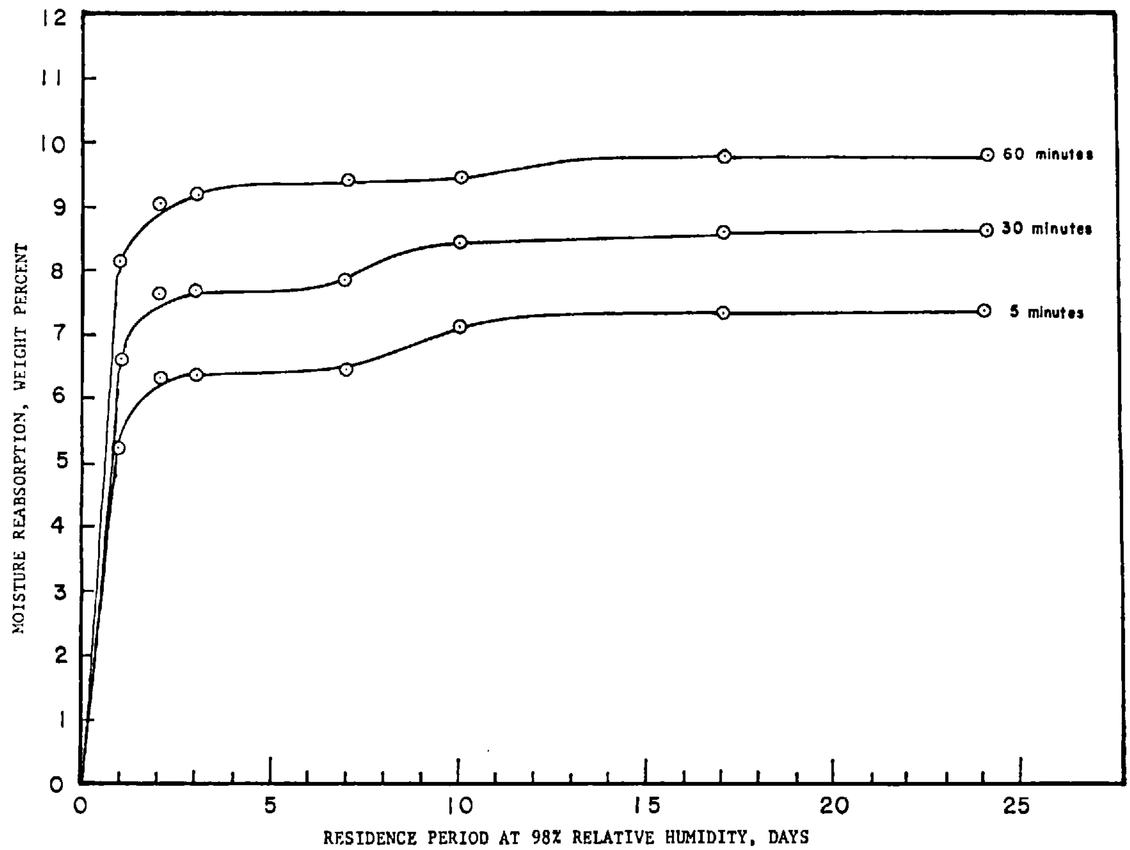


Figure 10: Reabsorption of moisture by 1" x 5/8" coal dried for 5, 30 and 60 minutes. Sample is taken from No. 4 Seam, Usibelli Coal Mine.

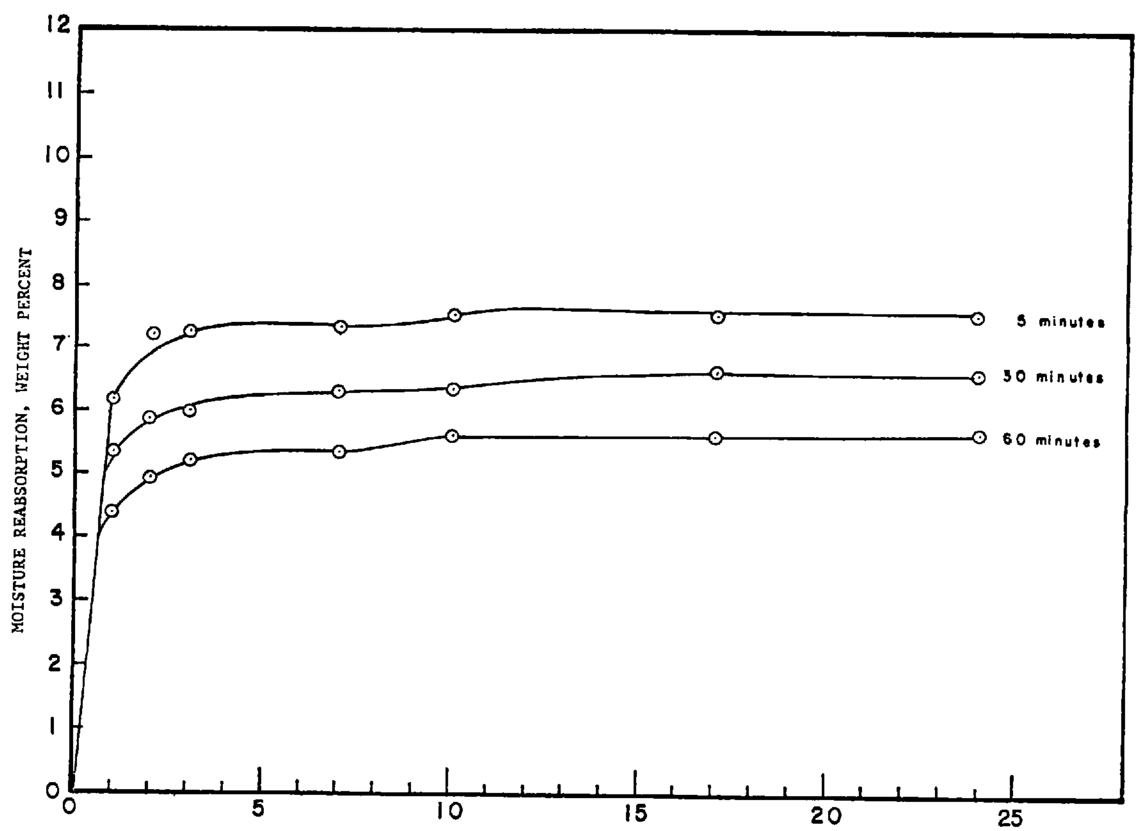


Figure 11: Reabsorption of moisture by 5/8" x 1/4" coal dried for 5, 30 and 60 minutes. Sample is taken from No. 4 Seam, Usibelli Coal Mine.

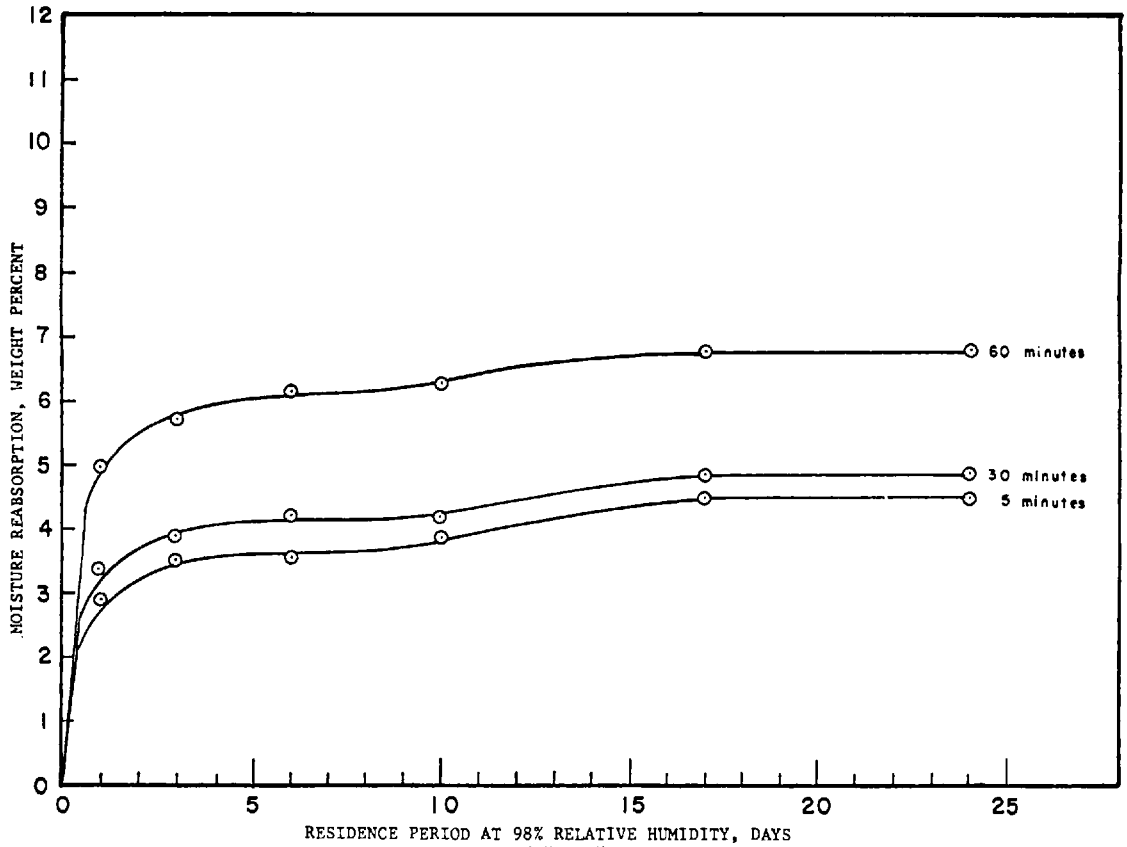


Figure 12: Reabsorption of moisture by 1 1/2" x 1" coal dried for 5, 30 and 60 minutes. Sample is taken from Waterfall Seam, Beluga Coal Field.

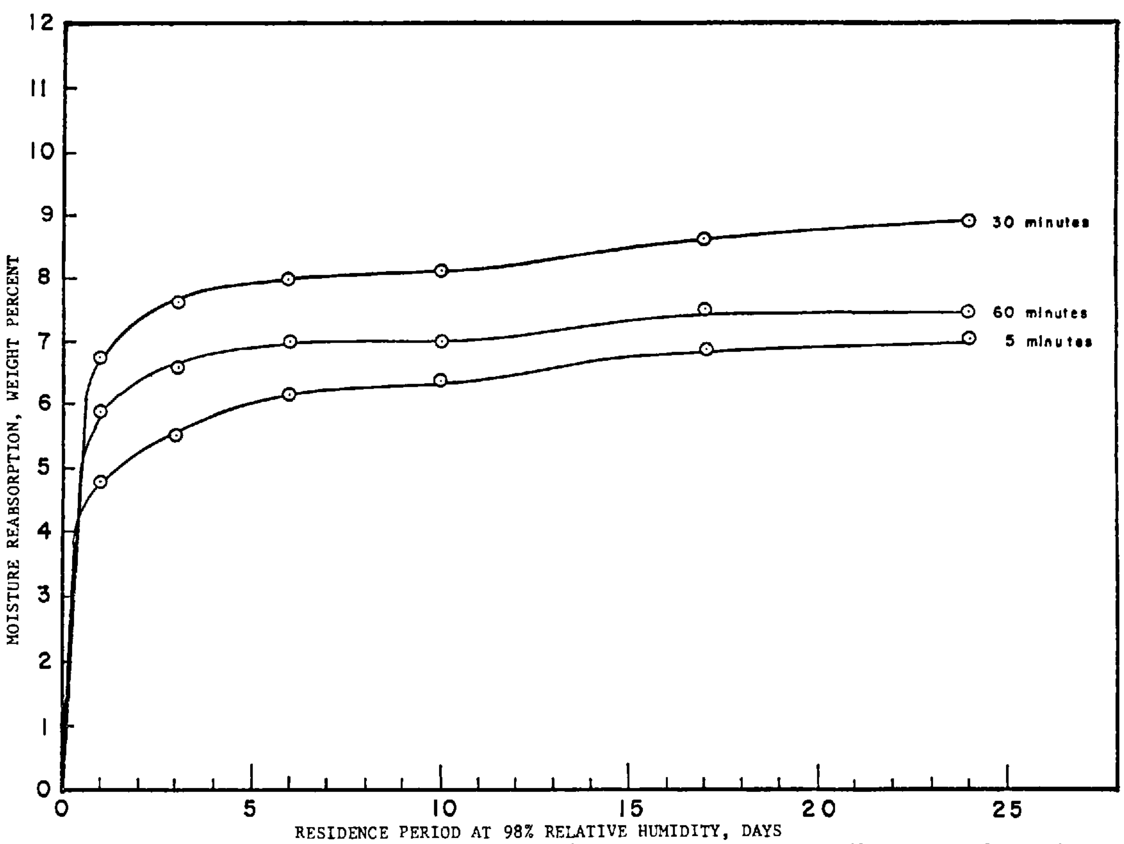


Figure 13: Reabsorption of moisture by 1" x 5/8" coal dried for 5, 30 and 60 minutes. Sample is taken from Waterfall Seam, Beluga Coal Field.

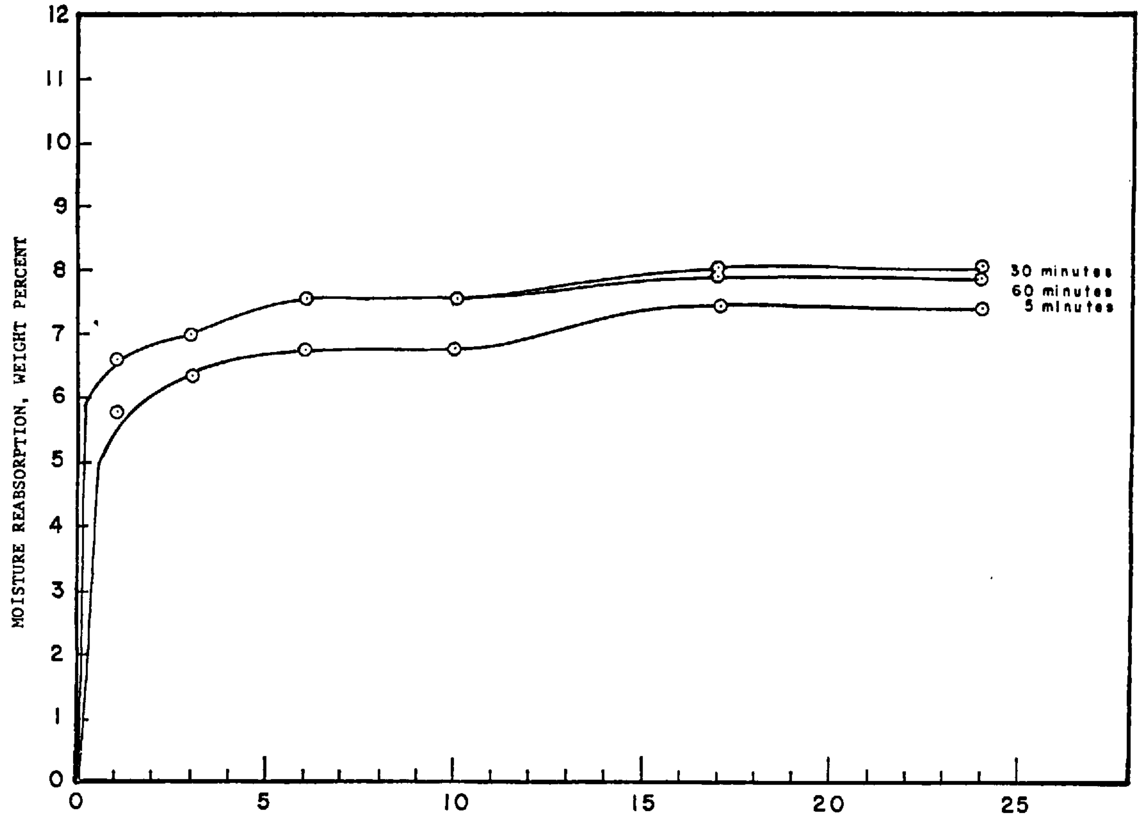


Figure 14: Reabsorption of moisture by 5/8" x 1/4" coal dried for 5, 30 and 60 minutes. Sample is taken from Waterfall Seam, Beluga Coal Field.

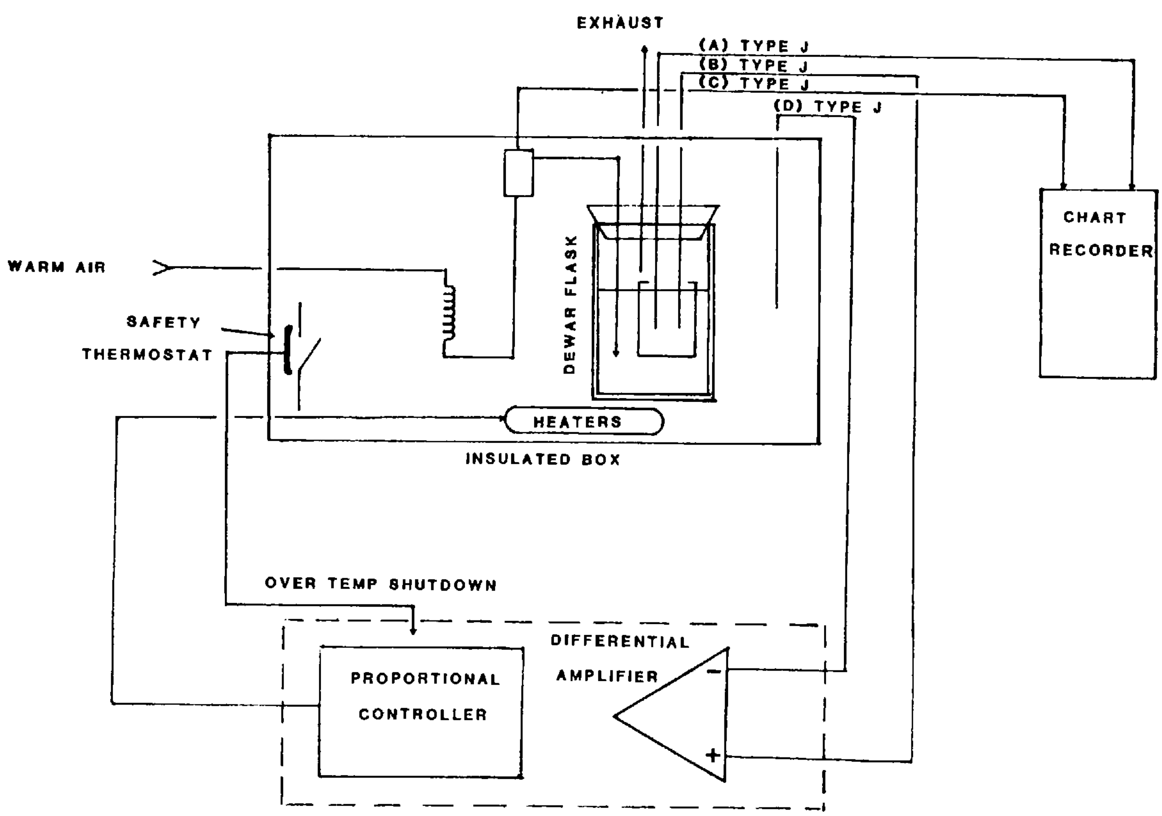


Figure 15: System block diagram.

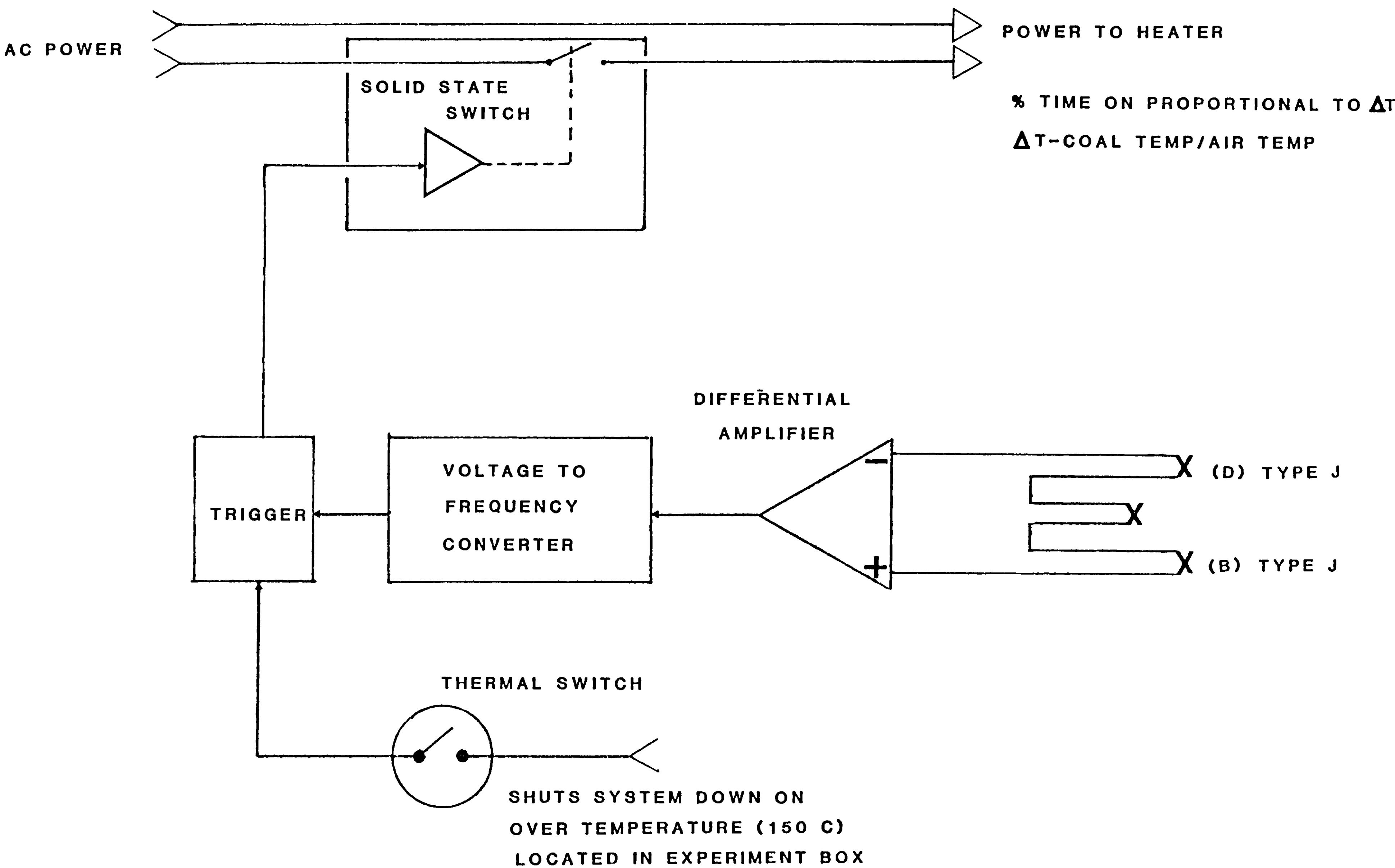


Figure 16: Block diagram proportional heat controller

K-Ar and fission-track dating of ash partings in coal seams

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Introduction

The main purpose of this paper is to call attention to the occurrence and significance of volcanic ash partings in coals. Their many geologic uses include correlation and dating of coal bearing strata, interpretation of environments of deposition and calibration of paleobotanical chronologies in nonmarine strata, as well as history and character of volcanic activity. Their practical application of this information is to measure coal resources and interpret mineral matter in coals. All these uses have been treated elsewhere (Triplehorn, 1976), so the present writing will focus on the radiometric dating of volcanic ash partings by K-Ar and fission track methods. First will be an explanation of this approach, followed by a description of our past work, then a brief discussion of future plans and possibilities.

Some comments on terminology are necessary. The partings in coal described here are assumed to be air fall volcanic ashes. Such an origin is obvious where there is glass, volcanic phenocrysts, characteristic mineralogy, absence of terrigenous detritus and lack of water laid sedimentary structures. With increasing age there is progressive alteration to clay and loss of recognizable volcanigenic features.

Volcanic ash beds, then, generally alter to some kind of clay unit. As a general term they might be called altered tuffs. In marine shales they are known as bentonites; these are usually montmorllonitic (smectitic), light colored and sticky when wet. In coals, particularly Carboniferous coals, they are known as tonsteins; these are usually kaolinitic, light colored and firm. We prefer the general term "altered volcanic ash" because there is considerable range in physical appearance, original and secondary mineralogy, as well as in the type of enclosing sediment.

Identification of Volcanic Ash Partings in Coals

Volcanic ash partings in coals are not uncommon in Alaskan and western U.S. coals. They are often not recognized, however, because geologists are not aware of their possible presence and because it may not be easy to distinguish them from the great majority of clay/shale partings that are not volcanic in origin.

In the field, the best indicators are light color combined with a thin, uniform, continuous distribution. These are not definitive, however, because some ash partings are dark colored and bedding character may vary due to irregularities on the depositional surface or compaction effects. The next best test is to disperse the clay, decant and examine any coarse fraction under a binocular microscope. Volcanic materials almost always have some phenocrysts, and the mineral suite is restricted and distinctive: beta quartz, feldspar, magnetite, biotite, zircon and apatite are most abundant. Euhedral crystals are common or even dominant. Also important is the absense of terrigenous clastic grains, such as nonvolcanic rock fragments, abraded grains, muscovite, garnet, etc.

Field and Laboratory Techniques

For reliable radiometric dating, an ash sample must consist only of primary, air fall volcanic material. Older mineral or rock fragments, from deep beneath a volcano or from older parts of a volcano, may be present. These may be difficult to detect except by scatter in the apparent radiometric ages. Their importance is also difficult to assess: overall, it is probably minor. The other, probably more important, source of contamination is streams carrying terrigenous detritus. Thus, one should avoid partings with current produced sedimentary structures such as ripple drift lamination, well-defined lamination related to grain size differences and scour features.

A coal swamp provides the ideal place for preservation of an ash fall free of the terrigenous contamination noted above. This is a major reason behind our emphasis on radiometric dating of coals: they preferentially contain the best (least contaminated) samples. The flat, vegetation choked nature of swamps makes it highly unlikely that any thin, widespread, uniform, sandy layer could be deposited by running water. In addition, such ash partings are enclosed entirely within coal, which makes it possible to collect a pure ash sample without contamination from terrigenous silicate clastics.

In general. an attempt should be made to collect the coarsest part of an ash parting. Usually this would be the lower part, because ash falls are commonly graded.

If a sample contains datable minerals, some phenocrysts should be visible with a 10 power hand lens in the field. A 20 power lens may aid in mineral identification and permit recognition of euhedral shapes. Sometimes the phenocrysts are not readily visible in the field and it may be desirable to collect a large quantity (up to fifty pounds) if there is sufficient motive to obtain a datable sample. If phenocrysts are visible, the volume may be adjusted downward according to the abundance. In remote Alaskan locations one should always collect large samples, to the limit dictated by time and ability to carry heavy loads.

Before investing in mineral separation, a preliminary examination is made to determine (1) if suitable minerals are present in sufficient quantity, and (2) if these are not so altered as to prohibit their use for radiometric dating. Ordinarily this is done by examining thin sections under a petrographic microscope. It is therefore advisable to select subsamples in the field for this purpose so that thin sections may be prepared as soon as possible. If phenocrysts are sparse, it may be necessary to test wash a small quantity to obtain adequate grains for this evaluation.

Laboratory preparation of mineral separates is a critical step. We emphasize this because it may consume large amounts of time and money, and if not done properly can result in intersample contamination. Other than to note its importance we do not want to go further into the details of sample preparation. Similarly, the specifics of the K-Ar analysis and the fission track method will not be discussed. All of these are fully described in the general literature on radiometric dating.

Summary of Previous Work

Although a few others have dated volcanic ash partings in coals as incidental parts of other studies, we appear to be the only ones concentrating on coals.

Our first effort (Triplehorn and others, 1977) was a feasibility test for Tertiary coals of the Kenai Peninsula, Alaska. This study showed the relatively common occurrence of volcanic ash partings in these coals, provided criteria for their recognition and proved their suitability for radiometric dating. As an unanticipated bonus, the samples dated bracketed the Homerian Stage-Clamgulchian Stage boundary of Wolfe (1969) and established its age at about eight million years.

Subsequent work in the same area (Turner and others, 1980) provided confirmation of the age of the Homerian Stage-Clamgulchian Stage boundary, as well as additional ages for younger parts of the section in Kachemak Bay. These results are summarized in Figures 1 and 2, taken from Turner and others, 1980. An age of about 16 million years for an older (Seldovian Stage) coal was obtained just northwest of Cook Inlet, along the Chuitna River. This, combined with a previously determined age for a coal near the base of the Homerian Stage type section, suggest an age for the Homerian Stage-Seldovian Stage boundary between about 11 and 16 million years. This is in good agreement with Wolfe's (1980) estimate of 13-14 million years for this boundary.

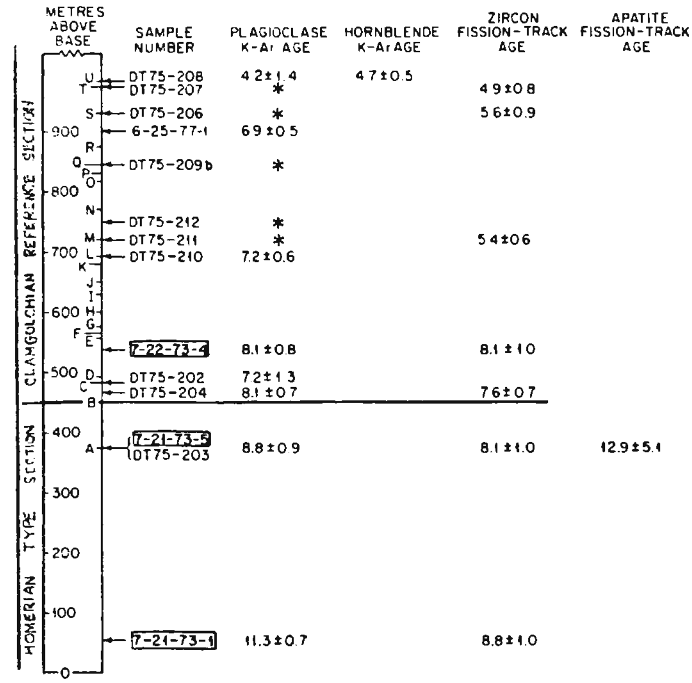

Figure 1. Estimated stratigraphic positions of dated samples, Homerian type section-Clamgulchian reference section, northwest shore of Kachemak Bay. Base of Homerian section taken as crest of anticline exposed in sea cliff about 2.1 km east of Fritz Creek (J. A. Wolfe, 1975, written commun.). Letters indicate named coal beds of Barnes and Cobb (1959). Ages for boxed sample numbers reported by Triplehorn and others (1977). Asterisks indicate ages believed to be too old owing to detrital contamination. Ages in millions of years calculated with revised decay constants recommended by IUGS Subcommission on Geochronology (Steiger and Jager, 1977).

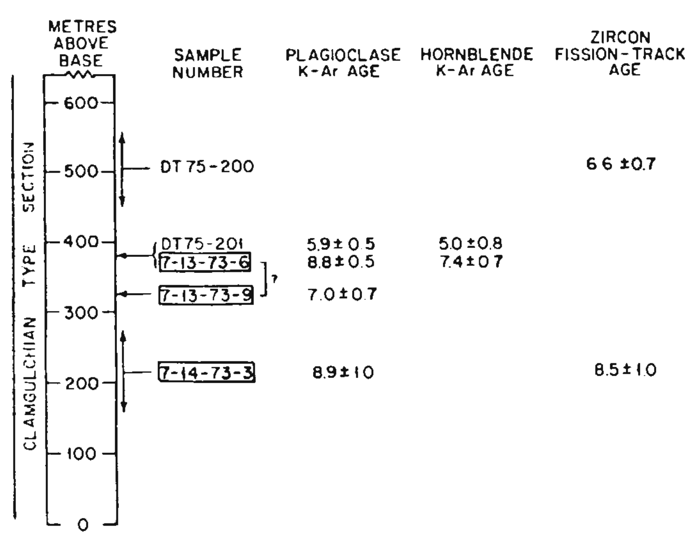

Figure 2. Estimated stratigraphic positions of dated samples, Clamgulchian type section, southeast shore of Cook Inlet. Base of section taken at Happy Creek. Ages for boxed sample numbers have been reported previously by Triplehorn and others (1977). Ages in millions of years calculated with revised decay constants recommended by IUGS Subcommission on Geochronology (Steiger and Jager, 1977). The stratigraphic positions of samples 7-13-73-6 and 7-13-73-9 may be reversed owing to structural complexities (Triplehorn and others, 1977).

To further expand the geographic and stratigraphic ranges of dated samples, we collected in earlier Tertiary rocks of western Washington, south of Seattle. The results of this work are still in preparation, but it is clear that volcanic ashes are also relatively common here and that some can be dated successfully. Our best results come from the Centralia coal mine, where six samples gave K-Ar ages of plagioclase near 40 million years with remarkably little scatter.

During 1979-1981, the first author examined a number of volcanic ash partings in coals of the Rocky Mountain region. Again, it seems clear that such partings are not uncommon but most geologists are unaware of their existence. The common feldspar here is sanidine rather than the plagioclase previously seen in Alaska and western Washington. A small number of samples have been dated, and they are from widely scattered localities in Colorado, New Mexico and Utah. The ages range from the Tertiary to Late Cretaceous. None of this work has yet been published.

Future Plans

The existence of volcanic ash partings in Cretaceous and Tertiary coals of western North America is now well established. In several cases they are so abundant as to render the coal valueless; more often they are sparsely distributed. A small percentage of these partings are datable by K-Ar and fission track methods.

Having established the presence and datability of volcanic ash partings in western coals, we can turn to some more specific objectives. A high priority is placed on the study of the Cretaceous coals of northwest Alaska. This is in a remote area and, relative to the magnitude of the resource, not wellknown. Two things are clear. however: (1) the resource is very large, and (2) delivering it to market at a profit will not be easy. Perhaps study of volcanic ash partings in these coals, including but not restricted to radiometric dating, can aid in understanding their correlations, continuity and lateral variability, a necessary basis for national development.

Elsewhere in Alaska we need more data. Only in part of the Kenai Peninsula are their sufficient dates to permit a confident interpretation of a vertical sequence. Isolated radiometric ages from other localities need to be supported by additional data. Some areas, such as northwest Alaska, can be selected as having abundant volcanic ash partings and high potential for successful study. Most areas, however, apparently contain few datable partings in their coals, so a radiometric chronology will develop slowly, if at all.

Similarly, there is little justification for seeking more isolated datable partings in western U.S. coals just to further prove their wide stratigraphic and geographic distribution. Next we need to study a few specific coal beds and coal basins in detail to evaluate the resolution of volcanic ash partings for local, intrabasin stratigraphic problems. One area in Utah is already under investigation and others in Colorado and Montana have tentatively been selected.

The paucity of volcanic ash partings in eastern U.S. coals of Carboniferous age is established. Only one such parting is known, from the Hazard #4 coal of Kentucky (Seiders, 1966; Bohor and Triplehorn, 1981). Contemporaneous European coals contain numerous tonsteins (kaolinitic clay partings) that have been studied in great detail. The senior author hopes to make a further search for such partings in eastern coals: where one has been found a few more may exist.

Acknowledgements

Early phases of this work were made possible by financial support from the Alaska Division of Geological and Geophysical Surveys, Union Oil Company and Atlantic Richfield Oil Company. More recently it has been supported by the Earth Sciences Division of the National Science Foundation (Grants EAR 76-8425, EAR 76-8425J A01 and EAR 79-22041).

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Railroads and coal

Frank H. Jones
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Railroads and coal today go together like the old saying of love and marriage. It is a real marriage, because in the coal industry transportation is extremely important--transportation is half of the coal business. In the transportation industry, rail is the most efficient mode of moving volumes of coal. Coal continues to move up as the largest or fastest growing revenue producing commodity on many railroads. That is a real love affair.

In the first quarter of 1980, railroads moved almost 118 million tons of coal, a 20% increase over the same period in 1979, and 31% above the average for the previous nine years. The Department of Energy estimates that by the year 2000, increased demand for electricity production in the U.S. that is expected to be supplied principally by coal fired systems, will require about 2 billion tons of coal. That would be about three times the annual production rate of 1978.

The demand for coal is so widely dispersed across the nation that the comparatively greater flexibility of rail transportation favors rail as the transportation mode. The railroads are keeping pace with the increasing demand for coal. But the task ahead provides a challenge to the rail industry.

When you consider that the Burlington Northern Railroad--one of the nation's leading coal transporters--originated less than 19 million tons of coal in 1970, and carried over 80 million tons in 1979, you get a feeling for the challenge ahead.

Burlington Northern's increased coal business is only a start. The Union Pacific, Santa Fe, L & N, Chessie and many other railroads are all becoming major transporters of coal. The potential for more business is there, but a number of issues have surfaced that must be resolved so that the great and vital potential for railroad services can become a reality.

The issues apply to the practical realities of more nuclear reactors, development work needed to make solar power practicable, the high cost of converting from petroleum to coal, and the economic and environmental hurdles blocking the use of coal.

As an example, although the Department of Energy identified 141 candidates for conversion from oil to coal that would burn more than 45 million tons of coal annually, the Environmental Protection Agency (EPA) proposed stiffer sulfur dioxide regulations for the conversion than are required for new coal fired plants.

As a second example, the State of Montana presently levies a severance tax that amounts to 30 percent of coal's value at the time it leaves the mine. In 1975 it was only a few cents per ton.

Pressures such as these force everyone to pay strict attention to their costs and their individual performance.

The issues have to be worked out by the railroads, the utilities, and the manufacturers of equipment and systems used in the transportation process. The involvement any participant has in the total process--mining, transporting, or burning of coal--has its effect on cost and performance factors of coal usage. All in turn ultimately bear upon the final product--the bill paid by the user of electricity.

The pressure to keep costs low in transporting coal via rail has proven to be a challenge. The unit train concept of carrying large volumes over long distances is a relatively new concept. The operation of longer hauls to transport coal has led to in-depth research that has continually improved rail technology to provide economical transportation. Cars and car components have undergone extensive testing to improve reliability and extend useful life. Maintenance-of-way techniques and track structures have been improved to insure the reliability of a rail delivery system for coal. The productivity increases that have come about because of scheduled cycling of rolling stock, maintenance programs, labor utilization, and decreased handling of coal trains have kept the cost of rail transportation competitive.

When the track, the cars, the motive power and the unit train cycles are tuned, the productivity inherent in rail transportation can carry that coal from the mine to destination at a satisfactory cost.

What does all this have to do with The Alaska Railroad and Alaska coal? It gives us a head start in developing our transportation system, because we are the beneficiaries of other railroads' experience--over 13 years experience. We can avoid the pitfalls, delays and problems encountered in the early development of coal unit train transportation. We can take advantage of the technology developed and apply the latest in the state-of-the-art when Alaska's coal is developed further.

Alaskan coal will soon become an important part of the export market. Export coal is expected to increase from 65 million tons last year to over 90 million tons by 1990. The Pacific Rim nations of Japan, Korea and Taiwan have been showing increasing interest in Alaska coal to meet their energy demands.

When large volumes of coal begin to be transported on The Alaska Railroad we will be able to implement a cost efficient, reliable transportation system. Let's take a quick look at what could be a typical unit train delivery system, either to a large coal fired plant, such as has been discussed for construction in the Fairbanks area, or a transloading point for export coal.

Begin with the coal being loaded into cars moving at one-and-a-half mph through an in motion flood loading tipple. The loading is controlled to uniform weight, scaled as it is loaded, and data concerning the car is sent to a computer for record, billing, maintenance scheduling, mileage reporting and other uses.

The car being loaded would be the latest design, either a low center-of-gravity, bathtub gondola with rotary couplers, or a rapid discharging, bottom dump hopper. The unit train would be pulled by a locomotive equipped with a "creep" device to control speed as it passes under the loading chute. Most likely there would be locomotives on the head end of the train, and a radio controlled "slave" consist in midtrain to provide smoother train handling, more tractive effort, and reduced drawbar stress.

Once loaded, the unit train would travel from the loading point to destination over trackage that has been upgraded and designed to accomodate the even axle loads of unit trains. One important lesson learned by railroads is the importance of the track structure and the effects long, heavy unit trains have on track. From this experience, we would restrict loading to 75 net tons per car to conform with our track standards, and to reduce the maintenance required by heavy use of unit trains.

At destination, the unit train would either pass through a rotary dumping facility or over an elevated trestle to dump the coal. The coal would be unloaded within several hours and the empty cars would begin their return trip for another load and repeat of the cycle.

The economics and productivity of unit train operations are a major factor in making Alaska coal competitive and in helping to hold down the cost of the final product, the bill paid by the user. Achieving productivity can dispel the thought of seeking alternate sources of energy, and increase the use of our great coal reserves.

Far Eastern export market for Alaskan coal

Steve Perles
Legislative Assistant to Senator Ted Stevens, R-Alaska

On behalf of Senator Stevens, I'd like to thank the Coal Conference and the University for extending us an invitation to participate in the Conference. It is indeed a pleasure for me to come back here to the University of Alaska, particularly as a graduate, to speak at various forums on different resources issues.

Earlier, Dean Beistline referred to those who are, as he put it, "out of the profession". I am one who is very much out of the coal profession. I'm Senator Stevens' chief legislative assistant. Most of what I do is legislative drafting, and also a lot of international trade work for Senator Stevens, which because of Alaska's geographic proximity focuses on the Pacific Rim.

I've had the good fortune of being a regular traveller to the Far East. I suspect I have made more trips to the Far East than any other present staff member of the House of Representatives or the United States Senate, or any member of that body. I go back and forth on the order of perhaps every seven, eight or nine months.

Last April, I made a trip to talk to some of our friends in Japan about the potential utilization of Alaskan coal. The principal reason I went was to see my friend, Mr. Nakabayashi, and we had a very productive set of discussions. I consider him to be one of the world's leading experts on the potential use of coal in the Far East. In many ways it's a very humbling experience for me to participate on the same panel with him.

As a watcher of Japan and other Far Eastern countries, it's my impression that Japan is presently on the verge of the greatest crisis it has seen in the postwar period. Japan has an energy problem which dwarfs the energy problem of the United States. It is virtually 100% dependent upon foreign sources of hydrocarbons for it's energy use. There is a growing nuclear capability, and some hydropower, but Japan is in a very difficult energy producing posture. If I were a government official or leader of industry in Japan, I would have difficulty sleeping peacefully at night.

The potential cataclysm for Japan's economic growth, or at least sustained economic growth as that nation has come to enjoy it, is—in my estimation—potentially in serious jeopardy. I believe that people in Japan understand the precarious situation of Japan's economy and the difficult situation that dependence on foreign oil has created. The Electric Power Development Company, for example, has begun what I consider to be a far more aggressive alternative energy program than we have yet begun in this country.

The first thing that any nation has to do if it's to convert from dependence on crude oil to coal is to secure a supply. In the case of Far Eastern countries--and we're talking principally of markets in Japan, Korea and Taiwan--those nations have three or perhaps four potential sources for large-scale coal imports. They may go to the Peoples Republic of China, Australia, the United States and perhaps Canada. The three greatest markets, however, are found in China, Australia and the United States.

China as a potential source of supply presents some rather unique political problems. Countries in the Far East have learned of the difficulties of basing a source of supply upon countries with difficult political problems. Japan now faces a crisis because of its dependence on Middle Eastern oil, particularly the oil that formerly came out of countries such as Iran. I believe that the Far Eastern countries (Japan, Korea and Taiwan) will find China to be a less than desirable source of supply for the long-term. Australia is a potential source of supply with very large coal reserves, but Australia also has very serious labor problems in its coal fields. It's also farther away from markets in the Far East than Alaskan coal is. Ultimately, I think the political considerations and the economic considerations will steer Far Eastern countries into the Alaskan coal industry.

If I dare predict, I would say by the year 2000 there are going to be thousands of people in the State of Alaska employed in the coal industry, and it will be an industry that is primarily an export market to the Far East.

What the Japanese must do now is engage in a program which is very much analogous to the coal back out program which we are now looking at in the United States. That means they must figure out how to reduce their oil dependence through the importation of coal, as well as by an increase in nuclear power. Japan has serious problems in the importation of coal which we don't find in this country, and that is distance of transportation. Here, we will be producing coal, at least from Japan's perspective, relatively close to our domestic use of that coal. In Japan, no matter where the coal comes from, it is going to have to be transported by sea for thousands of miles, so that Japan's outlook, in terms of coal back out, is really geared to technologies, at least in my impression.

The technologies needed are transportation saving technologies: from my perspective that means coal/oil mixtures or some kind of higher coal technologies, such as the methanol production which Noel is going to talk about. Both of these technologies are really transportation saving technologies. They provide a way of getting coal or coal products from a site, on board a ship of some sort, and transported many thousands of miles at a reasonable economic cost. Noel's going to talk about methanol in his speech in a few minutes; I think we share the same feelings about transportation savings which methanol conversion can provide for Far Eastern markets.

Coal/oil mixtures are an interesting technology, the one which the govenment of Japan seems to be investigating in earnest, and one which I believe they will come to utilize within the next five to six years. Coal/oil mixtures are essentially the pulverization of coal, the dewatering of that coal, and then the creation of a suspension of coal in a heavy residual fuel such as heavy oil # 6, i.e. a slurry.

The advantage of a system like that is that a fine coal/oil mixture such as the one just described can be fired in a converted, conventional oil firing power plant. It is a liquid fuel, not a solid fuel. That helps on the back out problem which countries such as Japan and the Far East face. It also means that the fuel can be transported at lower cost because it can be handled as a liquid during the transportation phase.

Bunker fuel or heavy oil # 6 has a very high flash point, so using a coal/oil mixture many of the serious transportation problems and safety problems that are related to dust explosion are eliminated. Because the coal is dewatered on site, you're not shipping water great distances.

Now we in Alaska are really in a unique position of all of the potential sources of coal around the world for Far Eastern markets, to provide coal/oil mixtures. We have an abundance of coal, an abundance of oil, and we are going to be building a refinery in Valdez, called Alpetco. One of the byproducts of cracking oil is a residual fuel. In this country we crack oil because we wish to consume the light end of the barrel. In fact, we are going to have a surplus of heavy oil in this country through the year 1990; many people project that we will have a growing surplus of residual fuel.

It's quite possible that a rather handsome marriage of resources will occur here in the United States. We may find ourselves with an abundance of coal to export and a surplus of residual fuel, and we can mix those together in a coal/oil mixture. This export product will be of great use in Japan, Korea and Taiwan, and will substantially contribute to reduction of the United States' balance-of-trade deficit. Alaska can become one of the leading producers of coal and coal/oil mixtures and methanol for use in the Far East.

Mr. Nakabayashi, as I mentioned earlier, is truly the expert in this field. When I was hosted in Japan by the Electric Power Development Company, I had the good fortune of going to the Mitsubishi Heavy Industries Plant where coal/oil mixture research is done. I came away convinced that coal/oil mixture technology is real. The government of Japan believes that it can use coal/oil mixture technology both in public utilities and industrial boilers. There is an enormous market potential which can be filled by the State of Alaska since we have the raw materials.

It is in the best security interests of the United States and of free countries in Asia to engage in joint technological exchanges, which will result in commercial coal sales between Alaska and the Far East. The sales may be as coal transported on the Alaska Railroad and sold in bulk in Japan, or be as coal/oil mixtures, or be as methanol. Dependence by free world countries on Middle Eastern sources of oil leaves us in a very precarious position, and our allies in the Far East are in a far worse and more precarious position than we are here in the United States. The development of joint technology programs leading to joint commercial development is in the best security interests of both countries. Senator Stevens would like to see these kinds of programs go forward, and he hopes in the future he'll be able to work with the Alaskan industry and with our good friends from the Far East to develop these programs. He certainly looks forward to the day when we will see a real commercial exchange between the Far Eastern countries, such as Japan, and our Alaskan coal industry.

Again on behalf of Senator Stevens, thank you.

The feasibility of Beluga coal as fuel for the power industries of Japan

Y. Nakabayashi
Electric Power Development Company, Ltd., Japan

Necessity of Studying Subbituminous and Brown Coals as Power-Generating Fuel in Japan

With the 1980's setting in there is a strong tendency toward use of coal, the so-called "Coal Fever". This tendency is noted not only in Japan, but all over the world.

At this moment only bituminous coal is being imported to Japan, and it is therefore expected that sooner or later the supply and demand situation of coal will make it difficult to secure long-term stability of price and supply (Fig. 1).

Subbituminous and brown coals account for a considerable portion of the world's coal reserves. However, because of such problems as high moisture content, low calorific value and spontaneous combustion, these types of coal are currently used for very limited purposes, e.g., as a fuel for thermal power generation in the coal mining area. Because of their geological origin, subbituminous and brown coals are deposited abundantly in one area, and they often permit open cut mining. These features allow us to anticipate a low mining cost (Figure 2).

For these reasons, it is becoming important in Japan to promote technological development concerning transportation and storage of subbituminous coal.

Feasibility of Beluga Coal as Fuel for Power Generation in Japan

As stated above, we intend to use subbituminous and brown coals as fuel for power generation in Japan through technological development efforts in the future. Beluga coal is a promising candidate to achieve this goal, and we are now studying it, with the following quantitative data:

<u>Points considered to be advantages for Japan</u>

a. Relatively short distance between Alaska and Japan (oceanic transportation).

Fig. 1 Fundamental Problem on Importing Coal to Japan

— Bituminous Coal —

(a) Increasing Demand for Bituminous Coal

(b) Difficulty of Stable Supply

(c) Increasing Cost

Fig. 2 Comparison of Coal Characteristics

	Usual Coal Imported	Sub-Bituminous	Brown Coal
Heat Value (Kcal/Kg)	6.000 ~ 7.000	3.500 ~ 4.500	1.500 ~ 2.000
Total Moisture (%)	5 ~ 15	20 ~ 30	60 ~ 70
Ash (%)	5 ~ 15	8 ~ 20	1 ~ 5

b. Short distance of inland transportation; this is especially advantageous when future inflation is taken into account.

c. Large amount of reserves.

d. Open cut mining is expected to be possible.

e. Year round ports are anticipated despite the cold weather in winter.

f. Low sulfur content.

Demerits of Beluga coal

a.	Low heating value	3,500-4,500 Kcal/kg
b.	High moisture content	20-30%
c.	Relatively high ash content	8-20%
d.	Possibility of spontaneous combustion	
e.	Cold weather in winter	

If these demerits are overcome by technological development, the import of Beluga coal for use as fuel in Japan will become possible in the future. With this in mind, we are currently promoting the technological development stated below:

The achievement of this goal will not only benefit Japan, but will also contribute to the economic and social development of the State of Alaska, and the improvement of the Japan-U.S. economic relations.

Present Status of Research and Development on Beluga Coal in Japan

As stated above, technological development is a key to using subbituminous and brown coals as Japan's imported fuel. Technological development is basically classified into the following categories:

1. Development of dewatering technology which is safe and reliable, and which gives the highest economic advantages.

2. Development of technology allowing the transportation of large quantities of coal, and storage for a long period without spontaneous combustion in any stage of the process. Technology to prevent spontaneous combustion is classified into the four following types: sealing technology, oil coating on coal

surface (Coarse COM), coal water slurry technology and coal oil mixture technology (Fine COM).

3. Combustion technology.

Schedule of Research and Development

Since 1976, the Electric Power Development Company (EPDC) has been promoting technological development for the utilization of subbituminous and brown coals according to the schedule shown in Figure 3. Two items are under development; one is brown coal produced in Victoria, Australia and the other is Beluga coal from Alaska.

The following cases are expected to occur when importing Beluga coal to Japan; for each case a feasibility study is carried out, followed by the development of necessary technology (Figure 4). So far, the dewatered (dehydrated) coal technology for Cases 1 and 2; tests to prevent spontaneous combustion; and coal oil mixture (COM) pilot plant tests for Case 4 have been finished.

Fine COM Technology

Here I would like to give a brief explanation on the fine coal oil mixture (COM) and coarse COM technology.

As snown in Figure 5, the fine COM technology comprises mixing 50% of #6 oil and 50% of pulverized coal of about 70% minus 200 mesh at a COM preparation plant. The mixture is kept liquid, without separation of the solid from the liquid, for a long period so it can be handled in a liquid form, as with fuel oil. The large portion of fuel oil poses a problem, and in this respect Fine COM is more suitable as a fuel for converting existing power plants operating on fuel oil than for newly constructed power plants.

The U.S. and Japan are leading other nations in the technological development of fine COM; each of the two is now at the stage of a demonstration test, having finished both bench scale and pilot plant tests. In Japan, the Electric Power Development Company is the prime mover of this program; we have carried out tests on COM manufacture, transportation, storage and combustion. Figure 6 shows the research and development schedule for fine COM. The 350MW oil design test, in particular, is attracting world-wide attention.

Although the fine coal oil mixture (COM) technology offers an effective means of overcoming Beluga coal's spontaneous combustibility, we do not currently consider importing fine COM using Beluga coal, since producing fine COM in Alaska for Japan would result in the import of large amounts of oil. There is the possibility that imported Beluga coal will be used as a raw material at

Fig. 3 R & D Schedule of Brown Coal Utilization

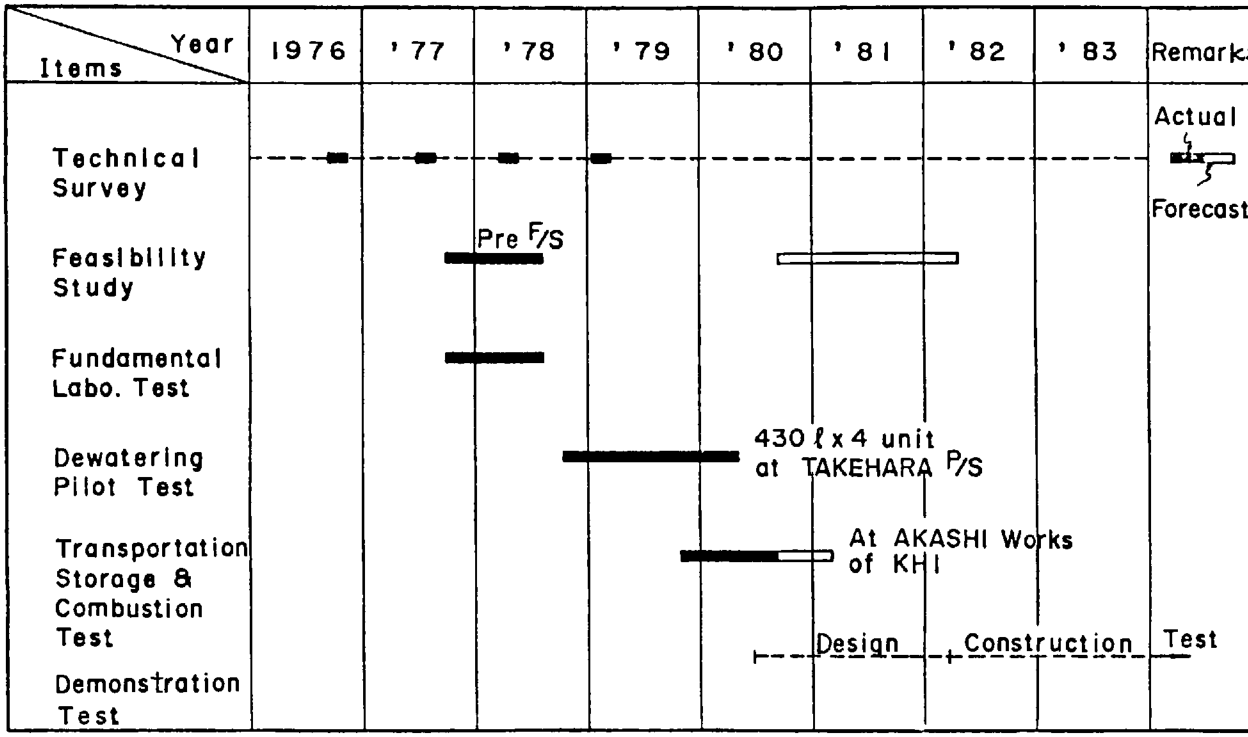


Fig. 4 Base Case

	ROM Coal	Dewatered Coal	Remarks
Sealing System	Case 1	Case 1'*	*: Pilot Test was Finished
Coarse COM	2	2'*	
Coal Water Slurry	3	3'	Not Recommended in Case of Beluga Coal
Fine COM	4	4'*	Only Application to West Coast in USA

Fig.5 Fine COM Flow

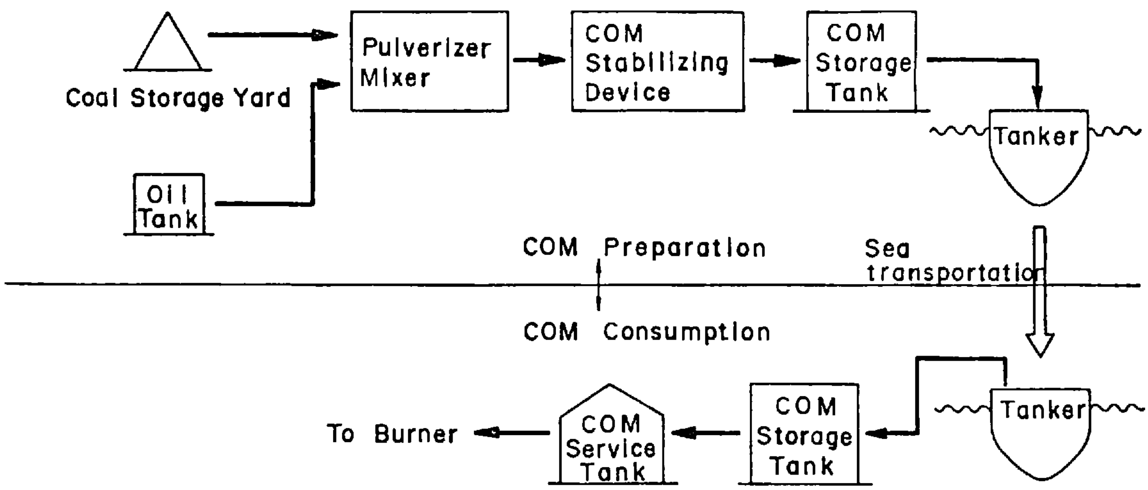
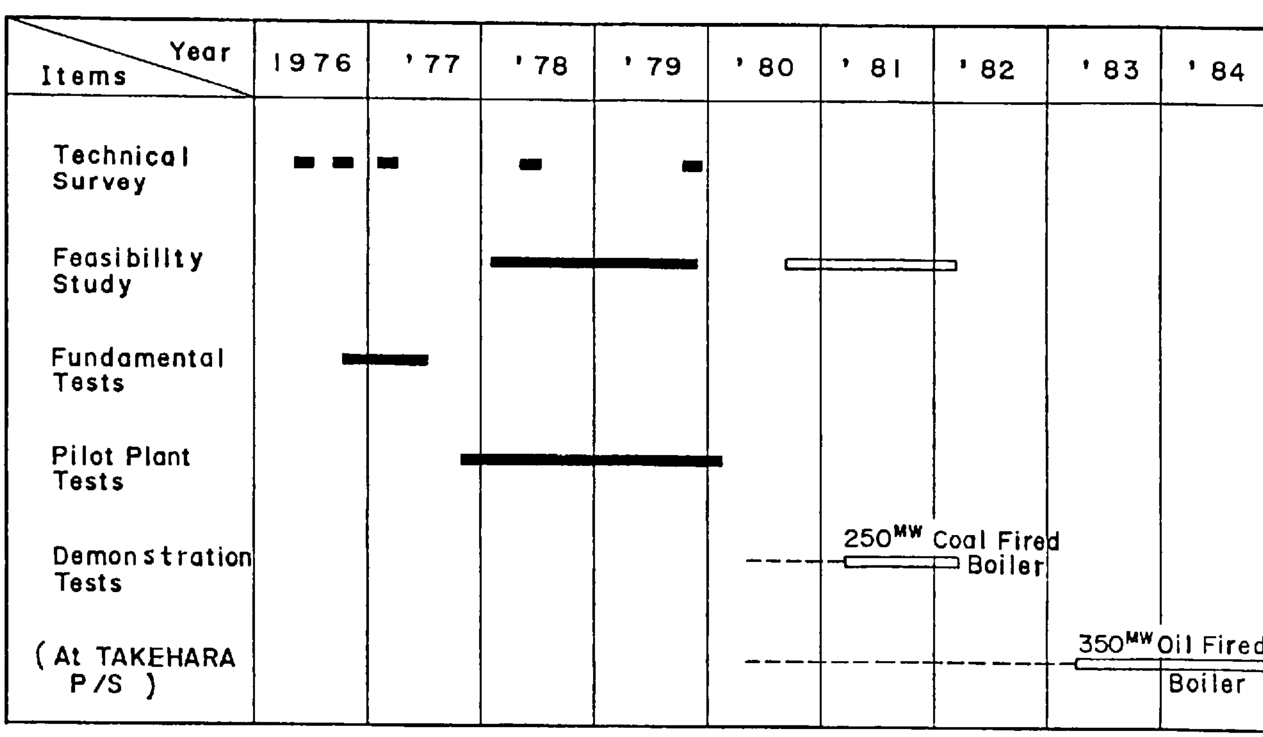


Fig. 6 R & D Schedule of F COM



fine COM plants in Japan. When fine COM is produced in Alaska, we presume that the product will have to be destined for the west coast of the U.S. and Hawaii. The details of the fine COM technology are published in the reports of the 1st and 2nd Symposia, sponsored by the U.S. Dept. of Energy.

Coarse COM Technology

Figure 7 shows the idea of the coarse coal oil mixture (COM) technology. Coarse COM features the improvement to serve as fuel for newly constructed power plants. It permits pipeline transportation in the form of oil slurry when unloaded from ships in Japanese ports. The fuel can be deoiled to reduce the oil content at the time of combustion. With these features, coarse COM is produced to have a particle size distribution of several millimeters.

This system prevents spontaneous combustion by coating with a small amount of oil before shipping from Alaska; it is a promising technology for Beluga coal. As with the fine COM technology, it has passed the stage of pilot plant test.

Dewatering Technology

Dewatering technology (dehydration) is a key to the effective utilization of subbituminous and brown coals. After comparative study on the fluid bed dryer, roto louvre dryer, rotating steam drum dryer and other dryers to be used for Australia's Victoria brown coal, the Electric Power Development Company decided on the D-K process (Fig. 8). The merits of this process are:

1. Batch type steam heating.

2. Nonevaporation dewatering process.

3. Simple system.

4. Dewatered coal is in a lump form, thus making handling easy and minimizing dusting.

5. The components of the ash dissolve to some extent, thus improving the ash's properties.

6. Considerable improvement of the Hardgrove Grindability Index (HGI).

7. Although a relatively high installation cost is required, the nonevaporating process promises a high dewatering thermal efficiency and low dewatering cost.

Fig. 7 Coarse COM Flow

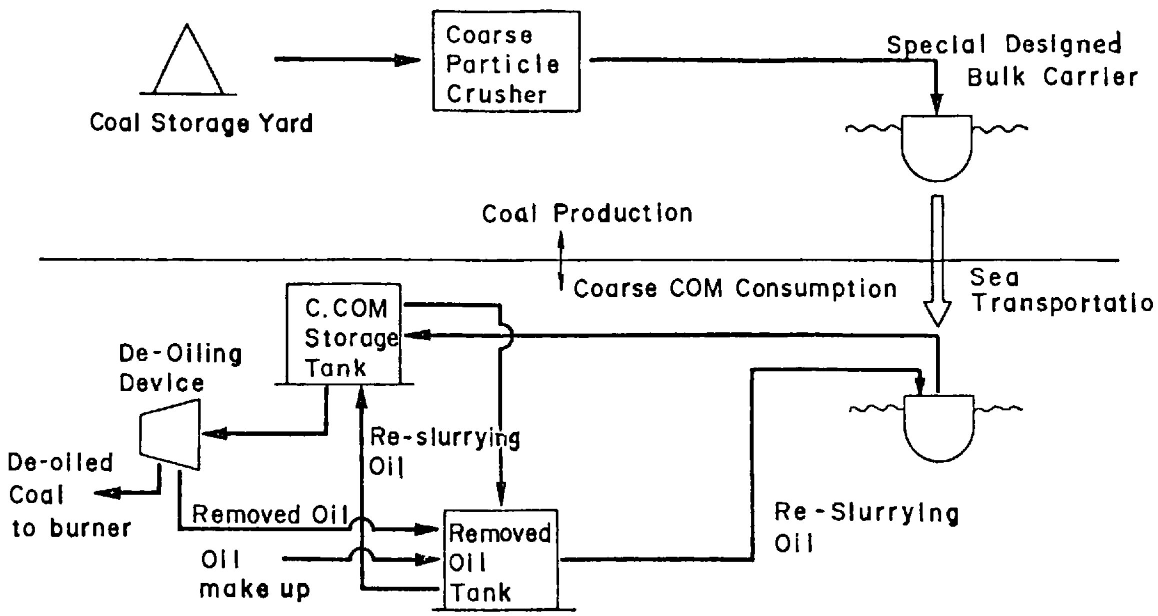
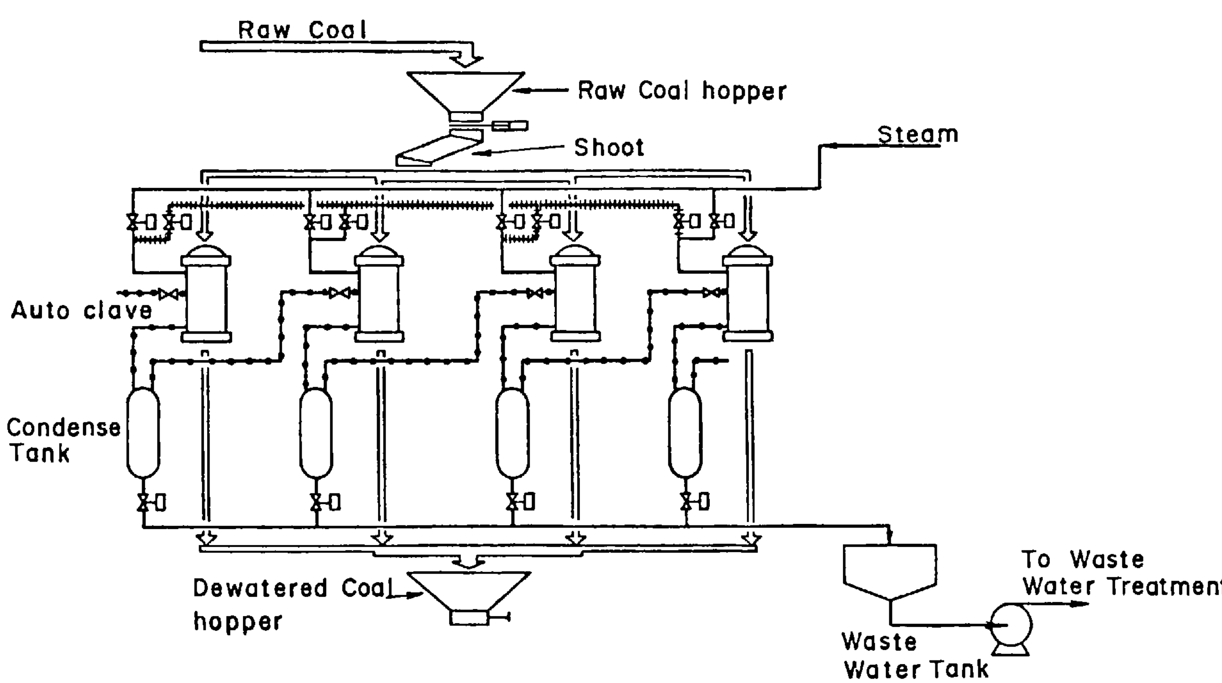


Fig. 8 D-K Process Flow



A 430 L/unit x 4 capacity pilot plant was established in the site of the Takehara Thermal Power Station of the Electric Power Development Company, and 200 tons of Victorian brown coal was dewatered. After that, a dewatering test was carried out on 150 tons of Beluga coal in 1979. The major results of the test are as follows:

1. The best rate of dewatering is from 25% to 8%.

2. The thermal efficiency of 0.8 kg steam/kg H_2O is higher than those of other processes.

3. Almost all of the heat energy of the raw coal remains in the dewatered coal. The fuel ratio (F.C/V.M) however, changes from 0.8 to 0.9. This means that carbonization progresses in the D-K process.

4. The dewatered coal has higher spontaneous combustibility than the raw coal. This is not the case with Victorian brown coal.

5. The resulting water requires wastewater treatment.

A main problem to be solved in the future is to carry out a detailed study as to whether the D-K process or the fluid bed dryer is better for Beluga coal.

Spontaneous Combustion Test

A $10m^3$ capacity test silo and other facilities were installed at the Akashi Research Laboratory of Kawasaki Heavy Industries, a manufacturer carrying on joint research with the Electric Power Development Company, and there have been tests since 1979 on the spontaneous combustibility of dewatered Victorian brown coal, dewatered Beluga coal and raw Beluga Coal (Figure 9). Main results obtained so far are as follows:

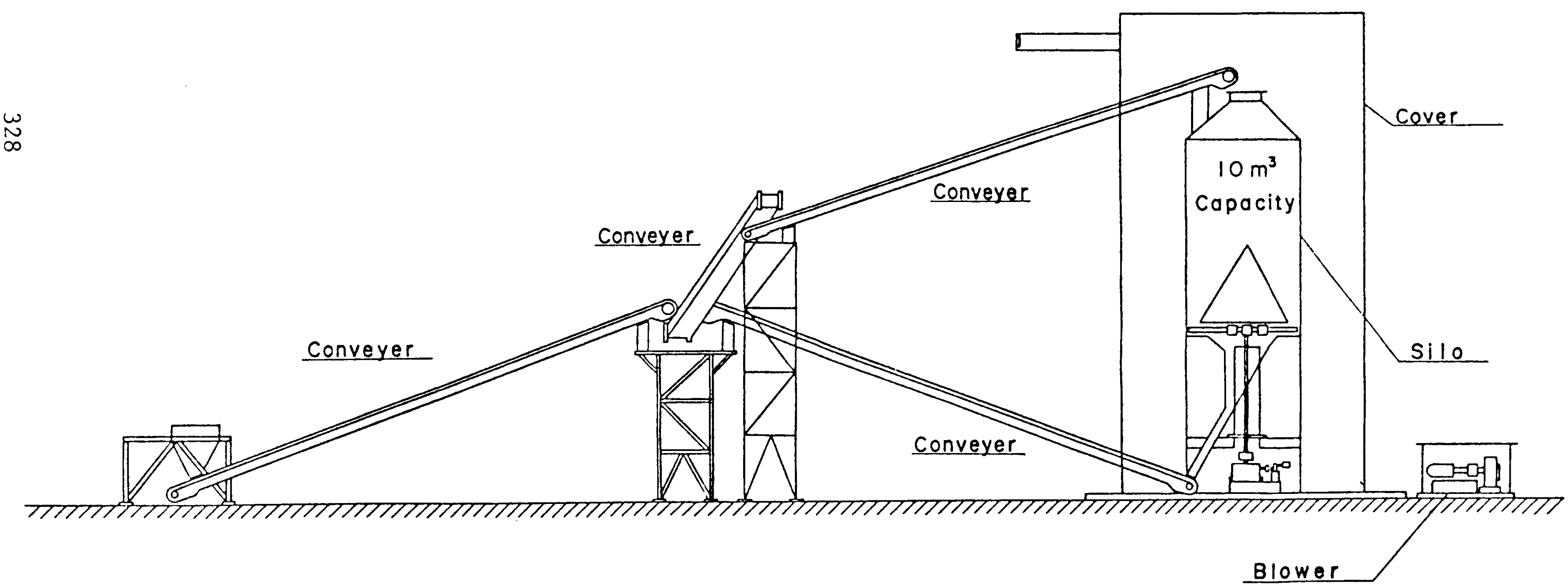
1. Dewatered Beluga coal may show very high spontaneous combustibility, as do many others; a test carried out under a natural ventilation condition in a $10m^3$ test silo has confirmed oxidation heating from $10^{o}C$ to $70^{o}C$ in one week.

2. The enclosed storage system offers an effective countermeasure for spontaneous combustion, but the oxygen concentration within the system must be kept at 5% or less.

3. Spontaneous combustion can be controlled by using 3-5% of coating oil (with respect to the coal).

A problem to be solved in the future is to study methods of outdoor storage of coal and to determine the best method of bulk transportation and storage (raw coal 1000t or more).

Fig. 9 Spontaneous Combustion Test Facilities



Combustion Technology

From 1979 to 1980, four heavy industrial companies, carrying on joint research with the Electric Power Development Company, have been performing fine COM combustion tests on Beluga coal, using the combustion test furnaces (capacity 1 - 3t/hr) which each of the manufacturers has in its research laboratory or factory.

Main results of the tests are as follows:

1. The flame has a shape similar to that encountered in the combustion of fuel oil.

2. The burner tip can be operated continuously over 5,000 hours by using friction resistant materials and hardening processing.

3. The atomizer nozzle diameter must be set to several milimeters because of the problem of clogging with pulverized coal.

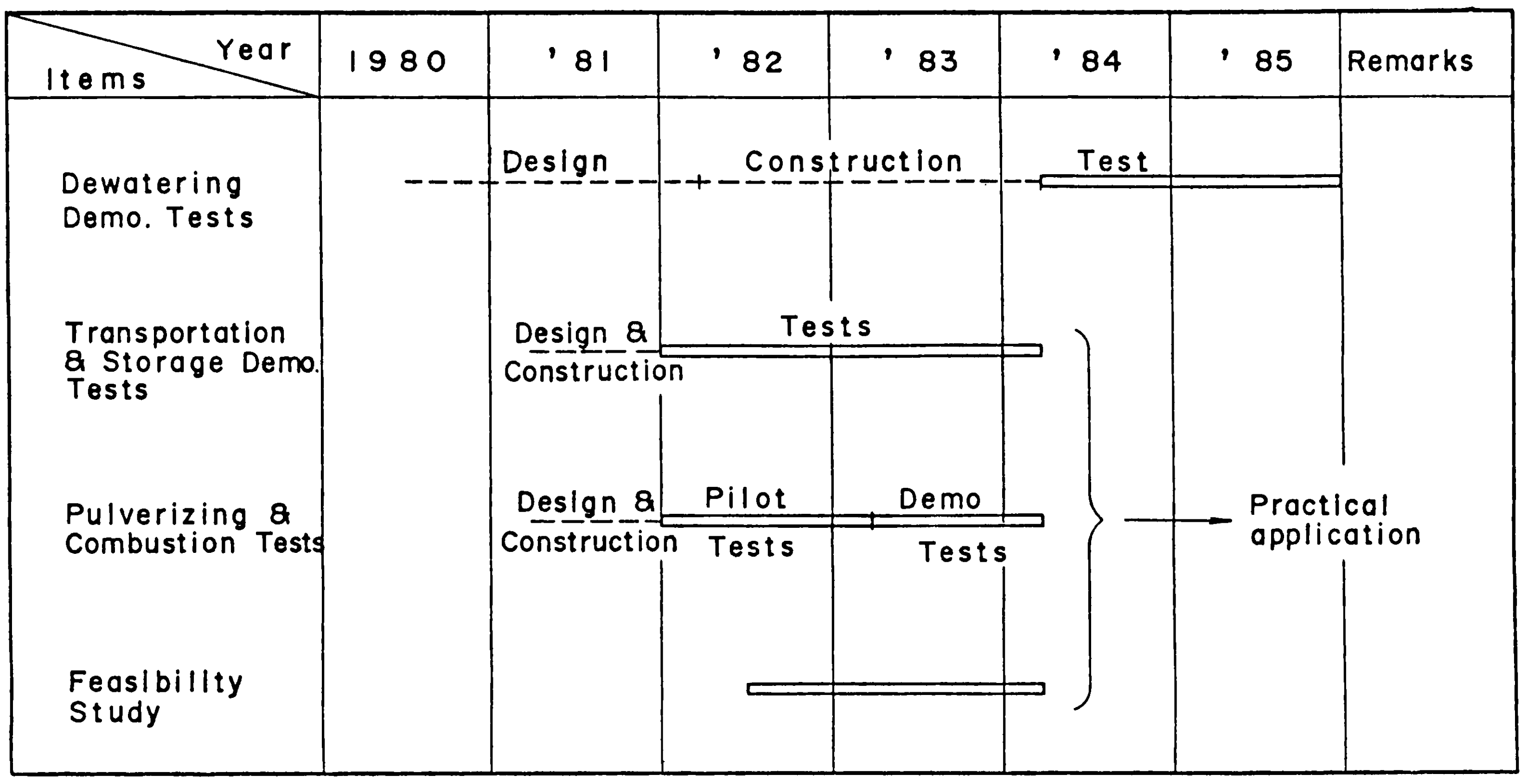
4. The amount of unburned components of the ash can be adjusted to a level similar to that in pulverized coal combustion.

Determination of the best process for Beluga coal pulverizing, and determining the best combustion systems are problems requiring future testing.

Future Problems and Plans

Figure 10 shows major areas of study requiring future solution and a 6-year schedule. Carrying out research and development, while in parallel promoting feasibility studies, we expect to become possible Beluga coal importers to Japan after 1985.

Fig.10 Future Tasks & Schedule



Industrial fuel gas demonstration plant

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Abstract

The Memphis Light, Gas and Water Fuel Gas Demonstration Plant concept comprises an installation engineered to generate and distribute industrial fuel gas of approximately 300 Btu/SCF. From 3,158 tons of coal per day, the plant will produce 175 million cubic feet of industrial fuel gas daily, the equivalent of 50 billion Btus, or equivalent of 40 million cubic feet per day of natural gas. The Institute of Gas Technology's U-GAS[R] Process, which utilizes a fluidized bed gasifier, will be used to gasify the coal and make a medium Btu fuel gas.

The overall project is being conducted in three phases over an 8 year period. An initial 26 month Phase I includes process studies, development work, definitive design and project cost estimates. Final engineering design and construction will be accomplished in Phase II, spanning 48 months. Plant operations and testing in Phase III will be conducted over a 20 month period. The plant will then be operated as a commercial unit for 20 years.

The estimated cost of the project is $441 million (1979 dollars) of which Phases II and III will be cost shared. Memphis Light, Gas and Water's share of the cost will be financed with revenue bonds. The U.S. Department of Energy (DOE) has recently begun negotiations for Phase II Final Design and Construction, and Phase III Operations.

On February 22, 1980, DOE approved Phase II Final Design and Construction, and Phase II Operations. Negotiations have been completed and the contract was signed on May 21, 1980, in Memphis.

Introduction

The constantly changing world conditions clearly indicate that there is a need for new energy sources which are not affected by world political conditions. New and dependable energy sources are especially needed for industrial growth. One of the many new sources that is most plentiful is from coal gasification. Unlike some other substitute fuels, coal gasification has a very large source of raw material. It is clean burning and environmentally acceptable.

At the present time coal gas is not being produced in amounts large enough to contribute much to our energy requirements. Coal gasification has made some tremendous steps in the last few months. This paper will discuss the U-GAS[R] Process and coal gasification.

Memphis, Tennessee has an energy shortage. The Memphis Light, Gas and Water Division's Coal Gasification Plant is a joint effort on the part of a utility, the U.S. Government and industry to produce a medium Btu gas from coal. The plant will add a new dimension to the future of energy in Memphis.

The Memphis Light, Gas and Water Division has the responsibility of supplying electric, gas and water utilities to the customers of Shelby County. Tennessee

In 1970, Memphis residences and industry used 93.4 billion cubic feet of gas per year, as shown in Figure 1. Curtailment from the pipeline supplier, Texas Gas Transmission Corporation, decreased the supply to 62 billion cubic feet by 1977. Approximately 70 billion cubic feet of gas is projected for the Memphis allotment in 1980. When natural gas supply becomes tight and supplies are curtailed, industrial customers are the first to be curtailed under federal guidelines. This proposed Industrial Fuel Gas Demonstration (IFG) Plant is to provide a substitute fuel for these industries.

The plant will make the equivalent of 50 million cubic feet of natural gas per day from 3,158 tons of coal. The medium Btu gas will consist mainly of hydrogen, carbon monoxide and carbon dioxide and will have an estimated heating value of 300 Btu/SCF.

Construction and operation of the plant will advance the state of the art of producing industrial fuel gas from coal; permit detailed evaluation of the costs and benefits of the expanded technology; and allow identification of environmental and social impacts, and regional and national economic benefits.

The Industrial Fuel Gas Plant and distribution system will supply industrial customers in the Shelby County area. The facility would also provide energy for Memphis to offer to new industry--energy that most other cities in the country do not have.

The facility would provide enough fuel to meet the needs of eight more large employers such as Firestone Tire and Rubber Company, which employs 2,800 people.

Consequences of Delay

Few potential Industrial Fuel Gas (IFG) customers in the Memphis area have the physical, economic and/or technical capability to convert directly to coal for their energy needs. In addition,

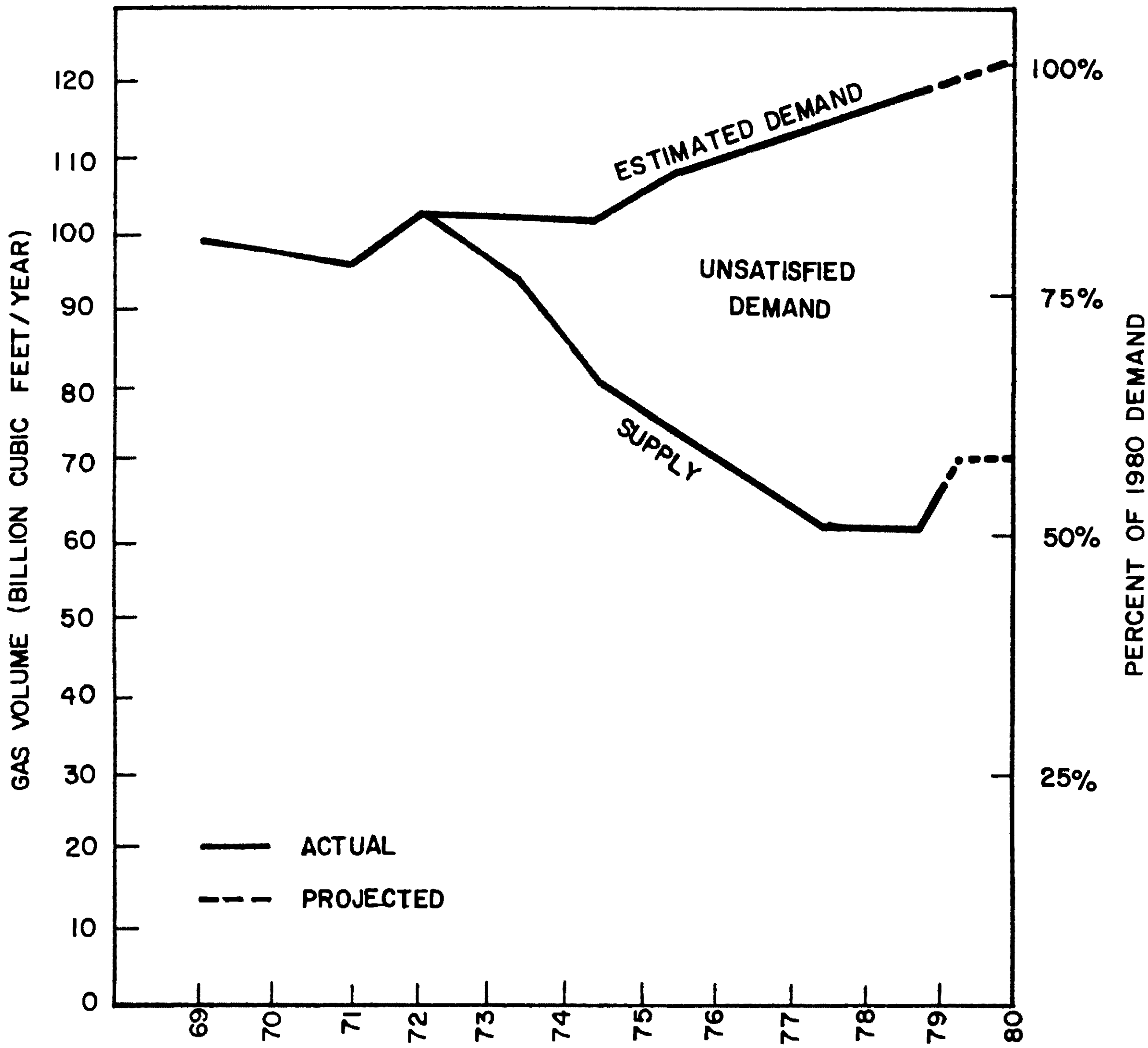


FIGURE 1 MLGW NATURAL GAS SUPPLY AND ESTIMATED DEMAND

there are regulatory constraints which pose further problems to potential coal users. These potential customers will continue to rely on natural gas and fuel oil for their operations, unless there is a suitable alternative that can provide a reliable, long-term energy supply. Reliance on either natural gas that is subject to potential availability and curtailment problems over the long-term, or on fuel oil--much of which comes from imported sources--poses supply concerns for the future. Alternative energy resources for Memphis and for the United States must clearly be developed and proven. Failure to expeditiously provide IFG in the Memphis area will, therefore, result in greater fuel oil use. the possible suspension of business activity by some industries in the event of curtailments. or the lack of reliable energy availability for stimulating the growth of the Memphis economy.

Participants and Functions

Organization

DOE - The Department of Energy issued a request for proposals on Low Btu Fuel Gas demonstration plant projects. The response to this request included six proposals, of which Memphis Light, Gas and Water (MLGW) and W.R. Grace Company were selected to enter into separate negotiations for an Industrial Fuel Gas Plant with DOE. The Department proposed to cost share one of these projects in hopes of providing supplemental energy for the United States. MLGW has been selected to construct and operate an Industrial Fuel Gas Plant.

MLGW - The Memphis Light, Gas and Water Division is a municipal utility that distributes electric, gas and water to Shelby County, Tennessee. MLGW is the prime contractor for the Industrial Fuel Gas Plant to be located in Memphis, Tennessee as shown in the organizational chart in Figure 2.

FWEC - Foster Wheeler Energy Corporation in Livingston, New Jersey is the architect, engineer and construction manager. FWEC is an internationally recognized corporation that has large engineering projects all over the world.

IGT - The Institute of Gas Technology in Chicago, Illinois is the developer of the U-Gas® Process. IGT is an independent not-for-profit educational and research organization. Test results have been obtained from a pilot plant in Chicago.

DRC - Delta Refining Company in Memphis, Tennessee is an oil refining company that will provide operations and safety experience. DRC will also be a customer of the Industrial Fuel Gas Plant.

EIA - Energy Impact Associates, Inc. in Pittsburgh, Pennsylvania did the Environmental Report for the project. EIA is a subcontractor to Foster Wheeler Energy Corporation. Memphis State University and Ramcon assisted in the collection and analysis of the environmental data.

ORNL - Oak Ridge National Laboratory in Oak Ridge, Tennessee has prepared the preliminary draft Environmental Impact Statement and will be writing the final statement for the Department of Energy.

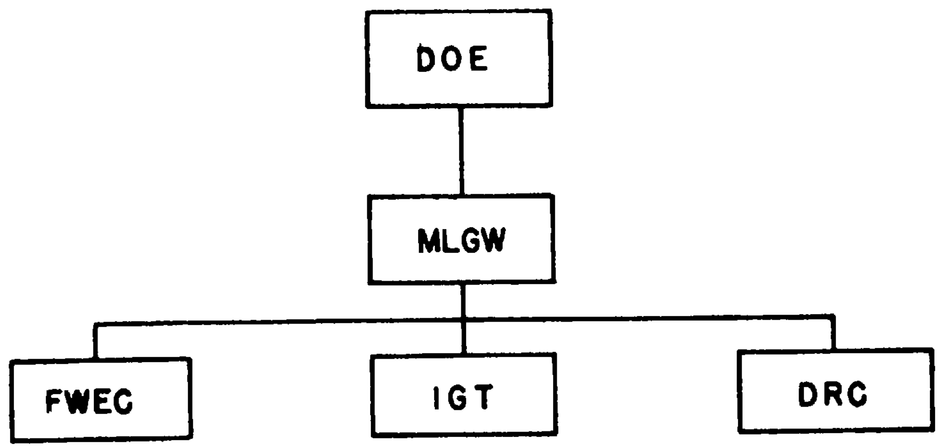


FIG. 2 ORGANIZATION CHART

Project Plan and Schedule

The project is divided into three phases, which are shown in Table 1. Phase I Conceptual Design lasted 26 months and the cost was $11.0 million, which was 100% funded by the Department of Energy. Phase II Final Engineering Design and Construction of the plant is to be completed in 48 months at an estimated cost of $450 million. Phase III Operations and Testing will be conducted for 20 months at an estimated cost of $80 million. The total project is scheduled to be completed in 94 months at an estimated cost of $541 million (1979 dollars). Phases II and III will be cost shared by the Department of Energy and Memphis Light. Gas and Water. Table 2 lists the Phase I tasks.

Plant Location

The Industrial Fuel Gas Plant is to be located in Memphis, Tennessee at a site shown in Figure 3.

The location of the plant will be adjacent to the Tennessee Valley Authority's Allen Steam Generating Plant, south of President's Island and near the Mississippi River port facilities and industrial parks.

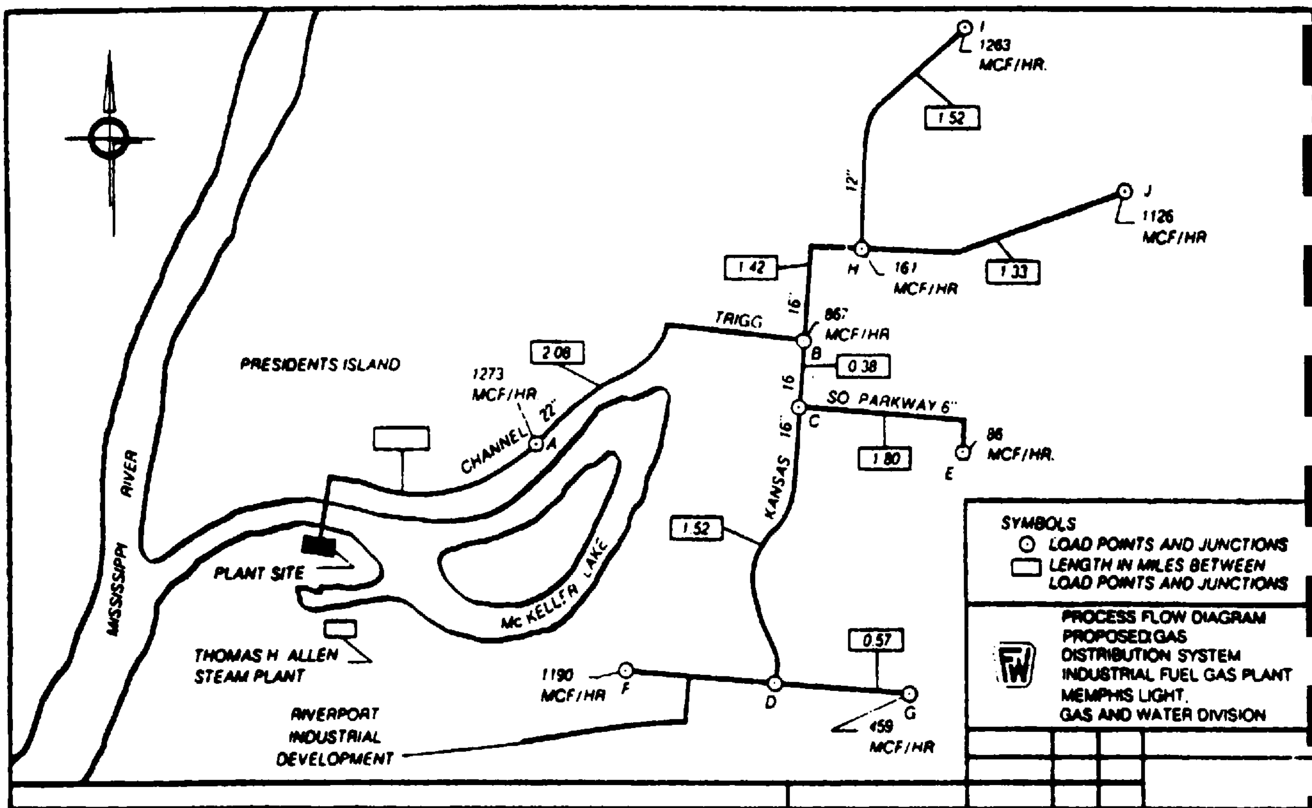


FIG. 3 DISTRIBUTION SYSTEM

Mains will be installed to economically serve the customers who sign contracts. Since the fuel gas has a lower Btu measurement and cannot normally be mixed with natural gas in present gas mains, a separate gas distribution system must be installed to carry the fuel gas to industrial customers.

Project Status

Pilot Plant

Successful tests have been conducted at the Institute of Gas Technology's U-GAS[R] Pilot Plant in Chicago. These tests have generated sufficient data to allow adequate design work for the commercial plant. Much design data has been obtained for the Demonstration Plant, but additional tests are needed for more detailed data.

Design

All of the items in Phase I tasks, which are listed in Table 2, have been completed. The conceptual design for the commercial plant, the demonstration process design and the demonstration

TABLE 1 - PHASES OF PROJECT

PHASE	DESCRIPTION	COST MILLIONS $	GOV. FINANCING MILLIONS $	GOV. %	MLGW FIN.	MLGW %	TIME
I	Design	11	11	100	0	0	26 Mo.
II	Construction	450	441	98	9	2	48 Mo.
III	Operation	80	0	0	80	100	20 Mo.
		541	451	83	89	17	94 Mo.

TABLE 2 - PHASE I TASKS

Task I	Conceptual Design and Evaluation of Commercial Plant
Task II	Demonstration Plant Process Design
Task III	Demonstration Plant Process and Mechanical Design Package
Task IV	Demonstration Plant Evaluation and Selection
Task V	Demonstration Plant Environmental Analysis
Task VI	Materials, Agreements and Licenses for the Demonstration Plant
Task VII	Planning for Final Design, Construction and Operation
Task VIII	Economic Assessment
Task IX	Technical Support
Task X	Long Lead Time Items
Task XI	Program Management

plant mechanical design are deliverables that have been submitted to the Department of Energy.

Site

Phase I research work on the proposed site and a site selection has been completed. Memphis Light, Gas and Water owns the proposed site and has worked out a satisfactory arrangement with the Tennessee Valley Authority on a prior lease agreement.

Environmental

A meeting was held in June, 1979 to determine the scope of the project, and the issues to be analyzed in depth in the Environmental Impact Statement. All interested agencies and persons were invited to participate in this scoping meeting, which was conducted by the Department of Energy. With support from the industrial team, the Environmental Report was completed in August 1979 and submitted to the Department of Energy and Oak Ridge National Laboratory (ORNL) in September, 1979, to be developed into an Environmental Impact Statement. The preliminary draft of the Statement has been completed. The ORNL schedule shows the final Statement will be completed in February, 1981, and a record of decision in March, 1981. If this schedule is achieved, the ground breaking could begin in April, 1981. At the present time it appears the plant design will meet all the environmental regulations, and no major environmental problems are foreseen.

Contract Negotiations

Negotiations have been completed on the prime contract and three major subcontracts for Phase II and Phase III. Many items had to be resolved, since this is the first contract that the Department of Energy has entered into that has a cost sharing arrangement and payback provisions.

Costs (May, 1981, Base)

Phase I has been completed at a cost of approximately $11 million. The plant costs are estimated at $450 million, with an additional $80 million for 20 months operation and testing. The estimated cost of the gas for the Demonstration Plant is between $5-6. Approximately $50 million is available from the Department of Energy for FY80 funding.

Schedule

The project is on schedule and has made all the required deliverables to the Department of Energy. If the present schedule is met, the Memphis Industrial Fuel Gas Demonstration Plant will be the first major synfuels plant on line producing Industrial Fuel Gas in 1985, as shown on the following schedule.

Phase II and III Schedule

The following dates are on the proposed schedule.

December 1, 1979	MLGW to submit Phase I to DOE in Chicago.
December 15, 1979	Decision by MLGW Board on proceeding into Phase II.
January 1, 1980	Submit Phase I package to DOE Washington with Chicago recommendations.
February 22, 1980	Decision by DOE Washington to proceed.
May 21, 1980	Contract signing and begin Phase II Final Design.
March, 1981	Record of Decision.
April, 1981	Break ground for Phase II construction.
March, 1984	Begin testing and shakedown.
November, 1985	Complete operation and tests on Phase III.

Technical Support Program

U-GAS^R Process

The U-GAS^R Process has been selected by Memphis Light, Gas and Water and the U.S. Department of Energy for the demonstration plant program. The U-GAS^R Process has been developed by the Institute of Gas Technology to produce a medium Btu (300 Btu/SCF) fuel gas from coal in an environmentally acceptable manner.

The Process shown in Figure 4 accomplishes four important functions in a single stage, fluidized bed gas gasifier. It decakes coal, devolatilizes coal, gasifies coal and agglomerates and separates ash from char.

In the process, washed coal (1/4 inch x 0) is dried only to the extent required for handling purposes. It is pneumatically injected into the gasifier through a lock hopper system. Within the fluidized bed, coal reacts with steam and oxygen at a temperature of 1750^o to 1900^{o}F. The temperature of the bed depends on the

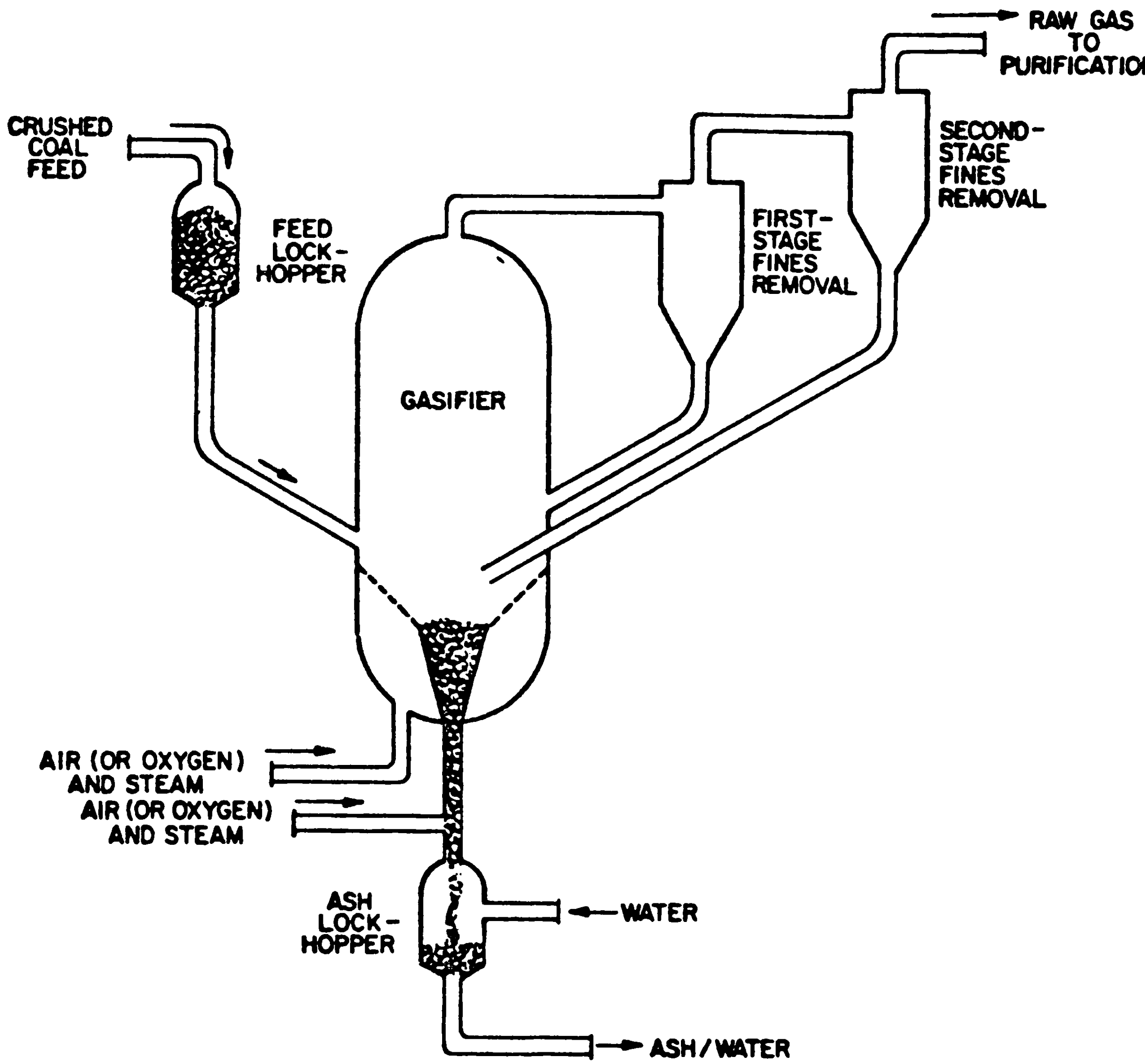


FIGURE 4. FLOW DIAGRAM FOR U-GAS® GASIFIER

type of coal feed and is controlled to maintain nonslagging conditions for ash.

The operating pressure of the process depends on the ultimate use of product gas and may vary between 50 and 350 psi. The pressure must be optimized for a particular system; for production of an industrial fuel, a minimum pressure of 80 to 100 psi is desirable. At the specified conditions, coal is gasified rapidly, producing a gas mixture of hydrogen, carbon monoxide, carbon dioxide and a smaller percent of methane. Because reducing conditions are always maintained in the bed, nearly all of the sulfur present in the coal is converted to hydrogen sulfide.

Simultaneously with coal gasification, the ash is agglomerated into spherical particles and separated from the bed. Part of the fluidizing gas enters the gasifier through a sloping grid. The remaining gas flows upward at a high velocity through the ash agglomerating device, and forms a hot zone within the fluidized bed. The temperature within the hot zone is greater than at other locations in the bed. High ash content particles agglomerate under these conditions and grow into larger and heavier particles. Agglomerates grow in size until they can be selectively separated and discharged from the bed into water filled ash hoppers, where they are withdrawn as a slurry. In this manner, the fluidized bed achieves the same low level of carbon losses in the discharge ash that is generally associated with the ash slagging type of gasifiers.

Coal fines elutriated from the fluidized bed are collected in two external cyclones. Fines from the first cyclone are returned to the bed, and fines from the second cyclone are returned to the ash agglomerating hot zone, where they are gasified, agglomerated with bed ash, and discharged with ash agglomerates. The raw product gas is significantly free of tar and oils, thus simplifying ensuing heat recovery and purification steps dictated by the end use of the product gas.

Pilot Plant Program

Most of the U-GAS^R Process development work has been performed in a pilot plant which was put into operation in 1974. The pilot plant is located at test facilities of the Institute of Gas Technology in southwest Chicago; the same facilities also contain the HYGAS^R pilot plant. The U-GAS^R plant consists of a gasifier and all required peripheral equipment, with utilities and other support services provided by the HYGAS^R plant. The U-GAS^R pilot plant consists of a drying and screening system, feed storage silos, a lockhopper system (weighed) for feeding a dry pulverized material at rates up to 3000 lb/hr, a refractory lined fluidized bed reactor with a special agglomerate withdrawal system in its base, a product gas quench system, a cyclone system for removal and recycle of elutriated fines, a product gas scrubber, a product gas incinerator and all necessary instrumentation and controls.

The U-Gas^R Process development work is divided into three separate parts: Part I, during which the process feasibility was demonstrated using metallurgical coke and char as feed; Part 2, during which the pilot plant was modified to feed coals and trial tests were made with coal; and Part 3, during which process feasibility was proved (using coal as feed), and data were developed for scale-up of the process and design of the demonstration plant. The Part 3 operations were conducted with Western Kentucky No. 9 coal. The objective was to provide mechanical, operating, environmental and process data for the preliminary design of the demonstration plant, using Western Kentucky No. 9 coal. A total of 16 test runs were conducted over the period of 15 months beginning with January, 1978.

A summary of the U-GAS^R pilot plant tests are shown in Table 3. The properties of the coals tested in the pilot plant are shown in Table 4.

The highlights of test operations were as follows:

1. The pilot plant tests firmly established process feasibility and provided a strong data base for completing the preliminary demonstration plant design.

2. Four consecutive, extended period tests of up to 200 hours were conducted, during which good quality raw product gas (285 Btu/SCF) and high ash content (80 to 90 weight percent) ash agglomerates were produced from Western Kentucky coal.

3. A technique of feeding caking coals directly into the gasifier without pretreatment was perfected. Over 400 tons of caking coal with a free swelling index (FSI) of 4 to 7 were fed.

4. Stable operability of the gasifier while recycling entrained coal fines back into the gasifier under continuous agglomerating conditions was demonstrated.

5. Data related to environmental aspects of the U-GAS^R Process, particularly wastewater characteristics, which indicated the presence of only trace quantities of tar and oils were provided.

6. The pilot plant operated for more than 100 hours at pressures of up to 60 psia (gasifier design pressure is 65 psia), proving applicability of the ash agglomeration technique and the ash agglomeration discharge mechanism at moderate elevated pressures.

7. A broad operating window for the major operating variables of temperatures, superficial velocity and bed ash content was established.

TABLE 3 SUMMARY OF PILOT PLANT TESTS

TEST RUN	FEED MATERIAL	DATES	OPERATING PERIOD,* Hrs.	COAL FEED tons	COAL CONVERSION** ATTAINED,%
124	Run-of-mine Western Kentucky bituminous coal	6/78	168	84	81
130	Washed Western Kentucky bituminous coal	11/78	106	88	76
131	Washed Western Kentucky bituminous coal	12/78	104	70	94
132	Washed Western Kentucky bituminous coal	1/79	74	47	89
133	Washed Western Kentucky bituminous coal	2/79	153	104	92

* Total hours of operation with coal (coke in No. 51) during the run.

** Based on moisture, ash-free coal feed to the gasifier.

Table 4 - PROPERTIES OF COALS TESTED IN PILOT PLANT

(Western Kentucky No. 9 Coal)

	Washed	Unwashed
Proximate		
Ash	12.0	19.9
Volatile	35.8	34.4
Fixed Carbon	49.1	45.1
Ultimate		
Carbon	72.2	64.3
Hydrogen	4.5	4.4
Oxygen	6.8	6.2
Nitrogen	1.2	1.1
Sulfur	3.1	4.6
Chlorine	0.13	0.19
Ash	12.1	19.9
Initial Deformation Temperature, ^{o}F	2270	2160
Free Swelling Index (FSI)	4-7	5-6
Higher Heating Value	12,498 Btu/lb.	11,570 Btu/lb.

8. Suitable materials of construction were tested, and the design for the internal components of the gasifier was established.

In addition to the pilot plant activities, support studies have been conducted on 1) ash chemistry to better understand the principle of ash agglomeration, 2) bench scale tests to determine the main operating variables affecting the formation of ash agglomerates, 3) cold flow model tests to define the mechanism of selective separation of agglomerates and obtain scale up information, 4) computer modeling to predict the performance of the gasifier and 5) combustion experiments to determine utilization characteristics of Industrial Fuel Gas.

Additional coal candidates for the demonstration plant are being tested in the pilot plant to verify the utilization and to determine the design requirements. At the end of April satisfactory tests were completed in the pilot plant, using Pittsburgh #8 coal. The pilot plant is shown in Figure 5.

Environmental Program

Environmental Report

The objective of the environmental work for the Memphis Light, Gas and Water Plant is to prepare an Environmental Report containing the necessary background information (field analyses and assessments), so that an Environmental Impact Statement can be written by the Department of Energy in compliance with the National Environmental Policy Act. The schedule for the Environmental Impact Statement is shown in Table 5.

The field activities on the existing environment have already been completed. The engineering and design data contained in the Environmental Report represent the information available as of August, 1979 and are consistent with the description available from the conceptual design activities of the plant designers. The Industrial Fuel Gas Demonstration Plant will be designed, constructed and operated to meet all applicable environmental permits and laws.

Agency Coordination

In order to address the concerns of the city, county, state and federal regulatory agencies, an active agency coordination program is being conducted. This enables these agencies to make constructive suggestions, which will strengthen the environmental program.

FIGURE 5 VIEW OF THE IGT PILOT PLANT

TABLE 5

SCHEDULE FOR ENVIRONMENTAL IMPACT STATEMENT

ITEMS	DATES
Environmental Report Completed	August 1979
DEIS to EPA	October 17, 1980
DEIS Notice of Availability	October 24, 1980
Public Hearing	December 3, 1980
End of Public Comment Period	December 8, 1980
FEIS Available for Public Review	February 1981
FEIS (Record of Decision)	March, 1981

Demonstration Plant Design

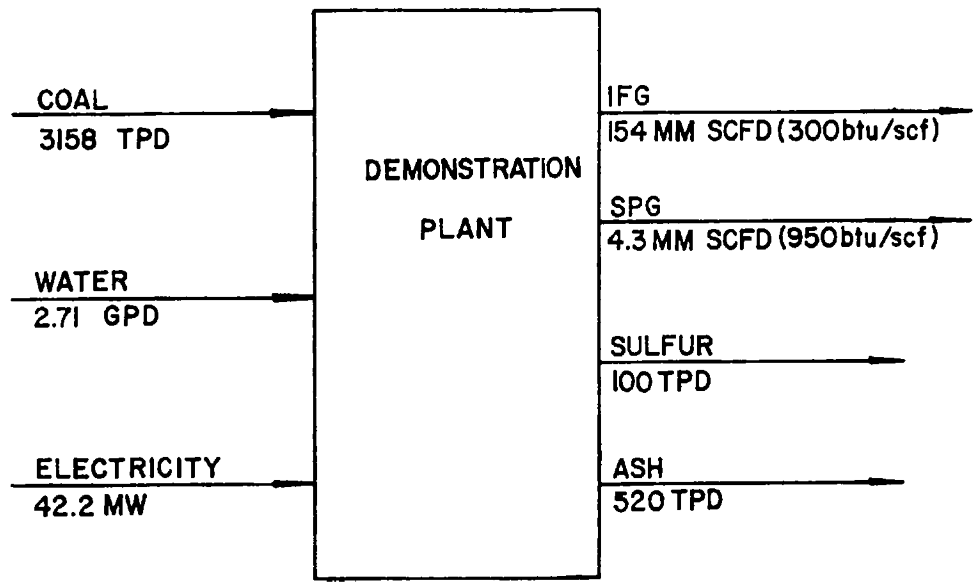
The Industrial Fuel Gas (IFG) Demonstration Plant produces a nominal 50 billion Btu/day of product gas, which is equivalent in energy output to approximately a 10,000 barrel/day oil refinery. The overall plant balance is shown in Figure 6. The coal feed rate to the plant is 3158 ton/day of Western Kentucky #9 coal. The product gas has a heating value of 300 ± 30 Btu/SCF. 45 billion Btu/day of this gas is available as send out gas to IFG customers. The remaining 5 billion Btu/day of this gas is further processed to pipeline quality (950 Btu/SCF) and deposited in the Memphis natural gas distribution system to generate Btu credit. The Btu credit can be withdrawn and used to satisfy IFG customer demand when the U-Gas production facility is totally or partially down for maintenance. By the use of the credit generation system the demand of IFG customers can thus be assured. The demonstration plant design has been prepared by Foster Wheeler Energy Corporation.

Figure 7 is the plant block flow diagram showing the process sequence and process related support facilities of this demonstration plant. Each process unit, as well as each process related support facility, is described briefly in the following summary.

Section 310, Air Separation Plant - Compresses intake air and separates it into oxygen and nitrogen. The oxygen is compressed and sent to the gasifiers. A small portion of the nitrogen is returned for plant use. Liquid oxygen and nitrogen can also be produced to keep their respective storage tanks filled, in order to provide the necessary reserve for an outage of the air separation plant.

Section 320, Coal/Coke Treating and Feed - Coal is crushed from 2" x 0" to 1/4" x 0" and dried to 2.5% moisture in a dryer mill. The dried, sized coal is stored in a coal silo. Sized coke received by the plant is also dried by a separate dryer and stored in a coke silo. Coal or coke is conveyed to the gasifier feeding systems from either the coal or coke silo. Dual conveying systems are provided to fill the gasifier feeding systems, with one serving as a spare. Each gasifier has its own feeding system. The gasifier feeding system is a multifeed hopper system, each consisting of a receiving hopper, two lock hoppers and two injection hoppers. Each injection hopper feeds into three pneumatic injection lines which transport coal or coke into the gasifier.

Section 330, Coal Gasification - Contains the coal gasifiers where steam and oxygen react with the coal in a fluidized bed at about 1875° and 75 psig to produce hot, raw gas (CO, Co_2 and H_2). Within the reaction zone of the fluidized bed is an ash agglomerating zone. The ash agglomerates drop into a water quench. Fines carried over with the hot, raw gas are returned to the gasifier through external cyclones.



THERMAL EFFICIENCY = 69.3 %

FIGURE 6. DEMONSTRATION PLANT OVERALL BALANCE

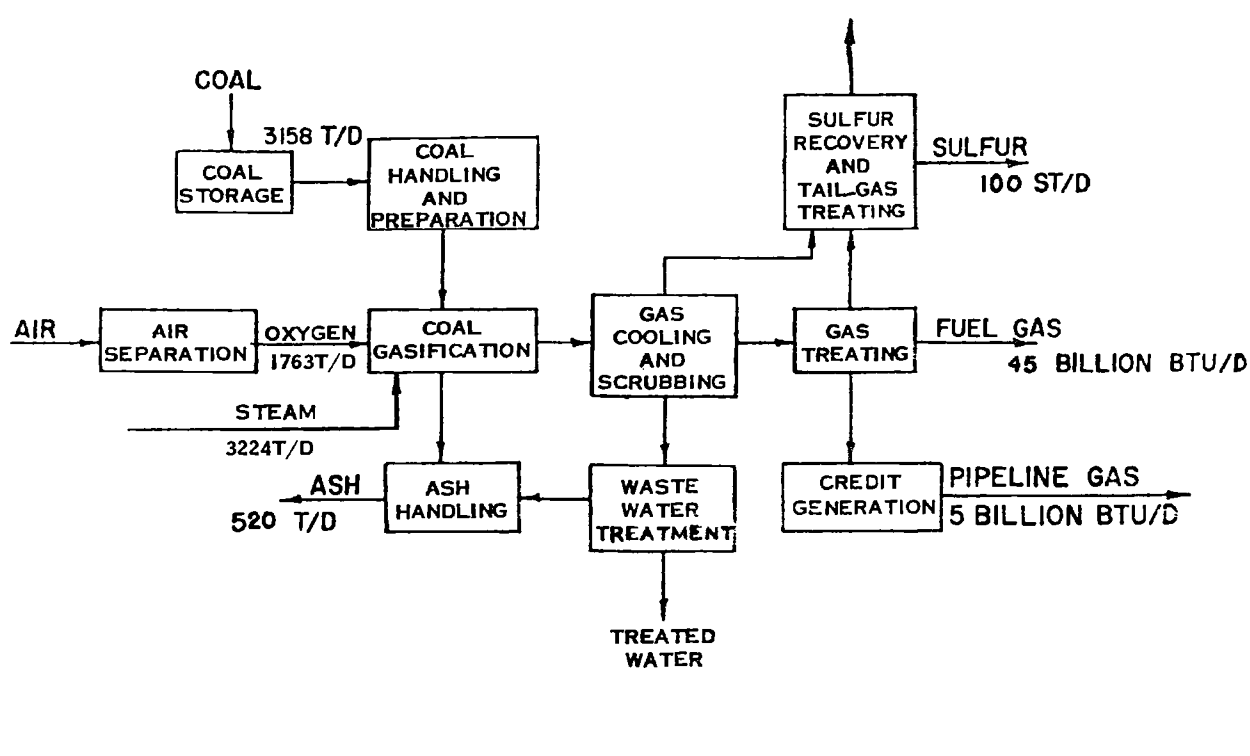


FIG. 7 DEMONSTRATION PLANT BLOCK FLOW DIAGRAM

Section 410, Coal/Coke Handling - Receives the incoming washed coal (2" x 0") from barges and transports it to a 14 day live coal storage pile. From there coal is transported to Section 320.

Section 420, Ash Treatment - Receives the agglomerated quenched ash slurry from the gasifiers (Section 330) and conveys it hydraulically to the dewatering bins. The dewatered ash is then discharged into trucks for disposal to the ash pile. The water from the dewatering bins is collected in the clarifier where clean water overflows into a sump tank, while the underflow is pumped back to the dewatering bins. The clean water is then recycled to the gasifiers. A start up pump is provided for initial transport of slurry to the dewatering bins when the gasifier pressure is too low for conveying.

The nonprocess sections to support the process and to provide utilities to the process include the following functions:

Section 430, Utility Area which includes:

Steam Generation
Raw Water Storage
BFW Treatment

Section 440, Waste Water Treatment

Section 450, Cooling Tower

Section 460, Flare

Section 470, General Facilities which include:

Long-Term Coal Storage for 90 days
Long-Term Ash & Solid Waste Storage
Interconnecting Piping
Roads and Fences
Firewater System
Power, Lighting and Communication
Sewers

Section 340, Gas Cooling and Scrubbing - Cools the gas from 1875° to 450°F. For purposes of heat recovery, the gas pases in sequence through a high pressure steam generator, high pressure steam superheater, another high pressure steam generator and a boiler feedwater preheater. After heat recovery the raw gas is quenched to saturation and passes through scrubbers. In the scrubbers particulate matter is removed by scrubbing with water. Sections 330 and 340 are four parallel trains and the balance of the plant is one train.

Section 350, Gas Compression - Scrubbed gas is cooled, compressed to sufficiently high pressure and cooled again to go through gas treating and deliver the gas at 150 psig to the industrial fuel gas distribution header.

Section 360, Gas Treating - Receives the cooled gas from gas compression, Section 350. It then passes to a Selexol unit where H_2S and COS are removed to meet the product gas sulfur specification, and enough CO_2 is removed to obtain a constant heating value product gas. The product is then odorized and metered before being discharged to the industrial fuel gas distribution system.

Section 370, Sour Water Stripping - Receives sour water from Sections 340, 350 and 360. The major portions of ammonia and hydrogen sulfide are removed by means of steam stripping.

Section 380, Sulfur Recovery - Receives sour gas from Section 370 and acid gas from Section 360. It converts the sulfur compound in three catalytic stages of Claus type sulfur recovery unit to achieve 96% recovery. Sulfur goes through condensers, seal pit, rundown pit and storage tank before being loaded into tank trucks.

Section 390, Tail Gas Treating - Receives the tail gas from Section 380. It then goes to a Beavon unit package, where remaining sulfur is converted to H_2S and then removed to a Stretford Unit. The tail gas is reheated to achieve satisfactory buoyancy and discharged to the atmosphere.

Section 220, Credit Generation - Treats from 10% to 30% of the product gas from Section 360 to produce pipeline quality gas, which will be deposited into the Memphis pipeline gas distribution system to generate a reserve of credit. This reserve can be withdrawn during U-gas plant outage. Pipeline gas withdrawn from the Memphis pipeline gas distribution system will be adjusted to the U-gas heating value prior to its distribution to the U-gas customers.

Commercial Plant Economics

During Phase I, a commercial plant conceptual design and a cost estimate were prepared by Foster Wheeler Energy Corporation. The commercial plant is defined as a plant built after experience gained from construction and operation of the demonstration plant. Therefore, there are quite a few differences between the demonstation plant and the commercial plant design.

The commercial plant produces 50 billion Btu/day of industrial fuel gas from a total coal feed of 2792 tons/day of Western Kentucky No. 9 coal. Approximately 175 million SFC/day of product gas with a heating value of 300 $\pm$ 30 Btu/SCF is produced. Unlike the demonstration plant, the commercial plant does not have a credit generation system to produce pipeline gas. Other major differences are use of product gas as boiler fuel, catalytic hydrolysis of carbonyl sulfide, sparing and back ups philosophy and gasifier carbon conversion efficiency.

Using the commercial plant conceptual design, erected plant cost estimates were prepared on a process unit basis. Costs were obtained both from process licensors and vendors whenever possible. Other costs were based on Foster Wheeler Energy Corporation's in house information. The economic analysis and calculation of gas costs presented here are based on C.F. Braun Utility Financing Method. The total capital replacement is estimated to be $197.4 million expressed in Fourth Quarter, 1979 dollars. The breakdown is shown in Table 6. The annual operating cost based on 20 year plant life and 90% stream factor is $45.29 million. Table 7 shows the itemized operating cost. Using the utility financing method, the average cost of gas is $4.25 per million Btu.

Marketing

Studies

A burner study on the combustion ability of medium Btu gas has been conducted by the Institute of Gas Technology. No major problems are foreseen, based on tests conducted on industrial burners.

A marketing study was conducted by SRI International on medium Btu gas for Memphis Light, Gas and Water. The study shows that a potential market exists and the utility with a reliable supply and a good load factor can deliver the medium Btu gas at the most economical price.

Another marketing study "Analysis of Industrial Markets for Low and Medium Btu Coal Gasification" by Booz, Allen and Hamilton, Inc. or the Office of Resource Applications, U.S. Department of energy, also completed in July, 1979 the major conclusions that medium Btu gas plants that have 1) multiple uses, 2) reliable supply, 3) utility financing, 4) less environmental problems, 5) operating experience, 6) coal supply region, 7) natural gas curtailment and 8) shortage of alternate fuels are the most attractive configurations.

Based on the above items, Memphis can meet all of these conditions and would be an excellent place to build a medium Btu coal gasification plant.

Reliability

The main selling point of the Fuel Gas Demonstration Plant is the reliability and the assurance of supply. In order to increase the attractiveness of this fuel gas to potential industrial customers, the reliability of supply must be insured, even during periods of plant shutdown or repair and maintenance. The plant is designed to enhance reliability by the use of modular gasifier trains and several back up systems, but is not cost effective to build complete redundancy in the plant. For the present, reliability is of special concern because only one plant, rather than several independent plants, as would be the case for an already developed system, will be available to produce gas for customers.

Credit System

The reliability is to be obtained by using the existing natural gas system as back up and establishing a credit system. As the fuel is produced in excess of the system demand, the excess fuel gas can be injected into the natural gas system in small quantities to dilute the natural gas. Another alternative is to consider a propane air mixture, and a third alternative is to methanate a portion of this excess U-GAS[R].

During fuel gas operation, up to 30% of the product gas from the Industrial Fuel Gas Demonstration Plant can be methanated to natural gas quality and introduced into the existing Memphis natural gas system, thereby accruing "credit" against periods of time when the plant is not operating. During these periods the "credited natural gas" will be withdrawn, diluted with air to the proper medium Btu heating value and distributed to the industrial customer. These conditions are shown in Figures 8, 9, 10 and 11.

This plant would supply industry the supplemental fuel that is needed and also provide a ready and available fuel for new industry in the area. The industrial fuel gas is expected to be competitive with fuel oil and other alternate forms of energy replacing natural gas.

Also, as part of the marketing effort, surveys on customers' burners, processes and uses will be conducted. Technical assistance, conversion procedures and estimated costs will be presented to each customer. Distribution pipe sizing, metering and operation procedures will be suggested in the proposal to the customer.

The market of existing customers consists of 25 to 125 potential customers, depending on their usage and distance from the proposed plant. Three large industrial parks are being planned within the proposed industrial fuel gas distribution system. The industrial fuel gas will be a tremendous asset in developing these idustrial sites.

Economic Benefits

The future of Memphis lies in the ability of this community to provide jobs for its people. According to the Tennessee Valley Authority's 1977 Annual Report, only 154 new industries came to Tennessee, of which only three came to Shelby County. It's unbe-

TABLE 6 COMMERCIAL PLANT CAPITAL REQUIREMENT

(Fourth Quarter, 1979 Dollars)

	$ Million
Erected Plant Cost	129.2
Contractor's Charges	21.3
Start Up Costs	9.1
Working Capital	8.4
Interest during Construction	29.4
Total Captial Requirement	197.4

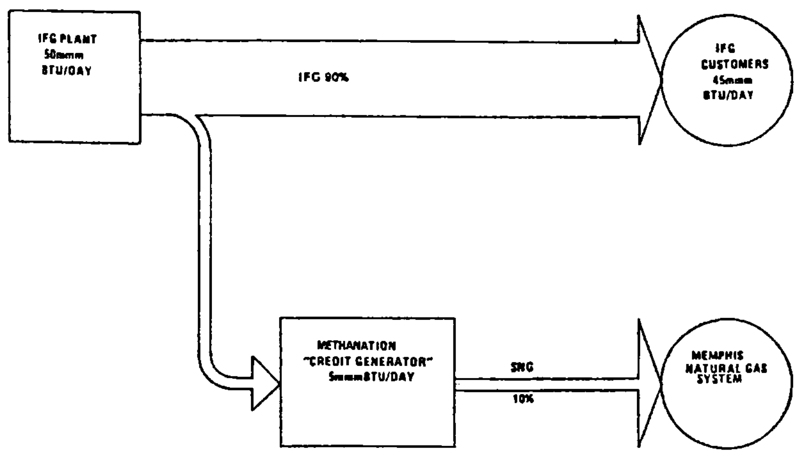


FIGURE 8 "CREDIT SYSTEM" - PLANT NORMAL OPERATION

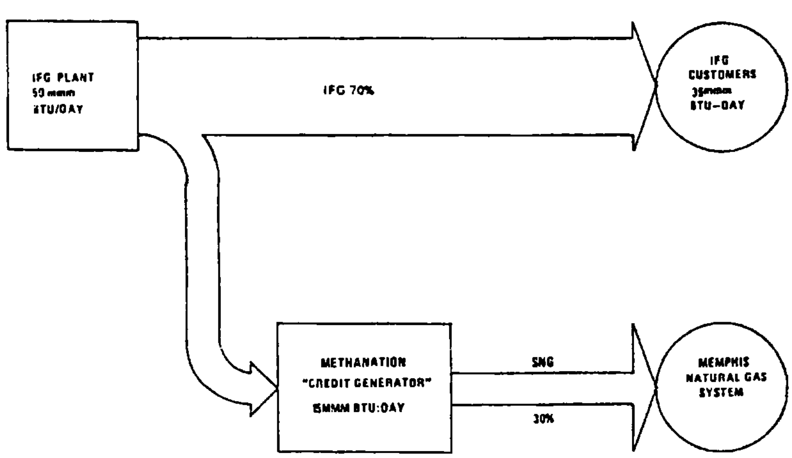


FIGURE 9 "CREDIT SYSTEM" REDUCED DEMAND OPERATION

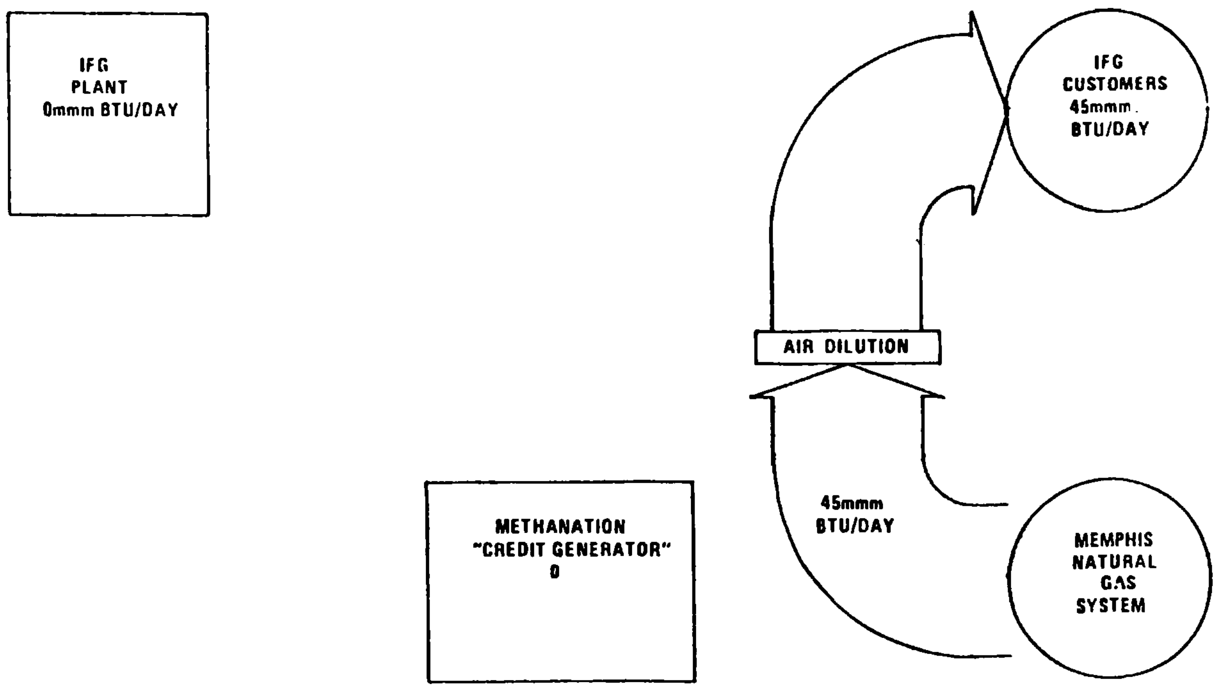


FIGURE 10 "CREDIT SYSTEM" – OPERATION DURING PLANT OUTAGE

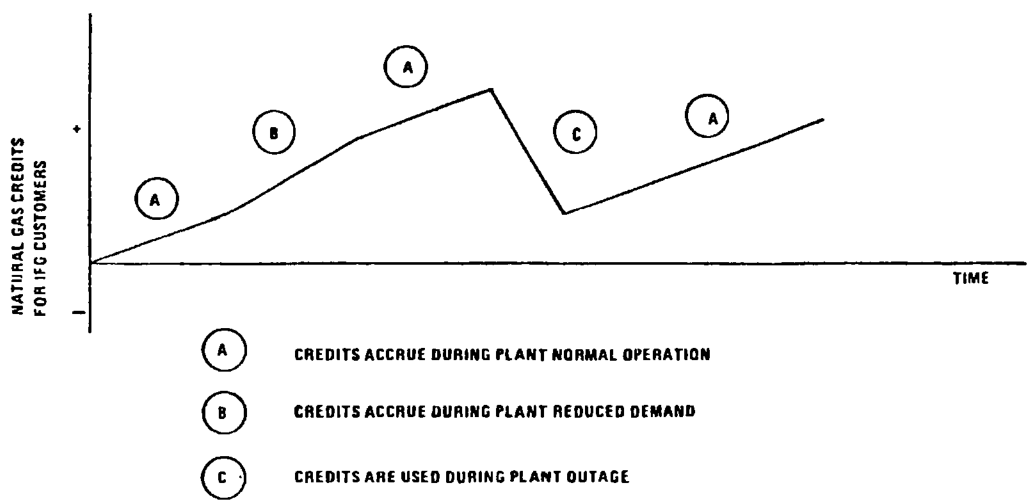


FIGURE 11 "CREDIT SYSTEM" - SUMMARY OF OPERATION lievable that the largest county in the state received only 2% of the industries. The shortage of energy is the most crucial problem facing the city. Without energy, there are no jobs. Without supplemental energy, the city will not be able to maintain the status quo, much less grow and prosper. The Industrial Fuel Gas Plant is a major step in providing supplemental energy for industrial customers.

Besides serving existing industry, the project would help the industrial economy of Memphis. The project has been hailed by a local bank official as the "ticket to at least 15,000 industrial jobs". According to industrial leaders, industrial fuel is the missing element in attracting new industry. By adding this important ingredient to Memphis' good climate, pool of ready labor, low electric rates and excellent distribution facilities, the city would greatly benefit.

Labor and Capital

The facility will be constructed at a capital cost of approximately $350 million based on 1979 dollars. The on site construction work force will consist of about 3.0 million job site hours over 36 months, with a peak level of about 700 workers. This will represent a payroll of over $50 million. The vast majority of the workers required to build the plant are expected to come from the Memphis area work force. The capabilities and skills required are presently available in sufficient numbers from the metropolitan area. The annual operating staff for the Fuel Gas Plant will be about 270 persons, involving an annual payroll of $6.4 million. While many of these workers are expected to be drawn from the Memphis area, the specialized requirements of some jobs may result in some of the operating staff coming from outside the area.

The objective is to provide a supplemental fuel at a competitive price. with assurance of supply and reliability. The proposed Memphis Light, Gas and Water Division's coal gasification project provides a solution to the business, the technical, socio-economical and environmental problems associated with coal conversions in the United States. With the solution of these problems, along with proof of a working system, Memphis Light, Gas and Water can significantly improve the city's future and act as a model for other cities to follow in developing similar energy sources for their needs.

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Mason, David M. and Patel, J.G., Chemistry of ash agglomeration in the U-GAS[R] process: Paper presented at American Chemical Society Annual Meeting, Fuel Chemistry Division, September 9-14, 1979, Washington, D.C.

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Beluga coal export market study

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Within this conference's overall appraisal of Alaska's coal resource, we report on a study of the marketability of Beluga coals, conducted for the Office of the Governor.[1] Our study's objective was to estimate if and when the Beluga region should be developed. The scope of the study was limited to the export market for coal (including the "Lower 48" states); it did not consider the demand for coal to be used in synthetic fuels (synfuels) production or the potential for in state use.

We have focused on six general areas of study. The first is a general market outlook, in which we have emphasized analysis of the overseas Pacific Rim market and briefly considered the domestic "Lower 48" market. Secondly, we analyzed the competitive position of Beluga coal; i.e., who are the competitors and what contributes to their position? Third, we separately estimated transportation costs because they can be a major factor in the delivered costs to the consumer and because these costs vary so widely among suppliers. Fourth, we estimated competitors' prices and examined what will determine those prices in the future (through 2000). Fifth, we addressed the issue of coal quality and attempted to quantify it from the consuming industries' point of view. Finally, we recognize that price will not be the only factor in the future development of Beluga coal, and thus briefly note what we believe will be the most important nonmarket factors--most of which will work in favor of the marketability of Beluga coals.

We first reviewed a number of forecasts to come up with a general market outlook for the "Lower 48", West Coast and East Asian markets. General agreement prevails among these many forecasts, although many done by consumer groups tended to be higher; this may be due to the natural inclination of consumer groups to bias their forecasts to promote competition.

There are a number of important points to be made about the "Lower 48", West Coast market, which can be divided into the California and the Pacific Northwest (Oregon and Washington) markets. First

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[1] For more detailed information, the reader is referred to the report: Ward Swift et al., Beluga Coal Market Study, prepared for the Division of Policy Development and Planning, Office of the Governor, Juneau, Alaska, November 1980.

and most important, the electric utilities, which would of course form the major market, have already initiated plans (including coal supplies) that will extend until at least 1990. Further, most of the Northwest's plans are for the use of Wyoming coals, with a small indigeneous coal contribution, and 98% of California's coal requirements are scheduled to be met by Utah coals. About 60% of California's coal demand will be "coal by wire"; that is, the power plants will be sited outside the state and electricity will be transmitted to the state over power lines. This means that, in effect, the potential of the California coal requirement that can be captured is equal to about 38% of the total requirements (including "coal by wire").

Secondly, our study suggests that because this market is fragmented, it will not provide the critical mass necessary for the initial development of Beluga coals; nor is this area growing rapidly enough to absorb this new supply. Finally, however, we think that the West Coast could, after 1980, form a potential market for expansion once the Beluga fields and related facilities are in operation, but only for that part of the market that is actually burnt in California. It is difficult to predict conditions beyond that time, although it would seem clear that West Coast utilities would welcome another fuel and siting option near the coastal load centers.

East Asia will most likely be the major market for the Beluga coals. This market is characterized by extraordinarily rapid growth from essentially a zero base. Japan is clearly the principal market, followed by Korea, Taiwan and others such as the Philippines, Singapore and Hong Kong. The driving force behind this market's growth is of course the marked increases in the cost of crude oil. Figure 1 depicts the East Asian market for steam coal, expressed in short tons per year. The heating value is expresed as 9,000 Btu/lb, which is approximately the heating value of a higher rank or beneficiated Beluga coal. This forecast is plotted on the semilogarithmic scale, which underplays the explosive growth of this market.

The forecast represented by Figure 1 illustrates the one overriding reason for the improved outlook for Beluga coals; i.e., the rapid increase in demand for steam coal in East Asia. In fact, three years ago, the point on the scale for that period would be off the scale to the lower left (i.e. near zero). The 21% per year growth rate forecast for the 1985-1990 period is truly impressive, and this is the low forecast of the several we reviewed.

Alaskan coals will have a number of competitors for these East Asian markets. Austrailia's exportable coal supply regions are primarily in New South Wales and in Queensland on the East Coast (Figure 2). New South Wales has the lowest mining and transportation costs of Australia's coal regions. Queensland, just to the north, follows, but Queensland coals will increasingly have to come from the interior regions, with some additional overland transportation charges. The major sources of incremental produc-

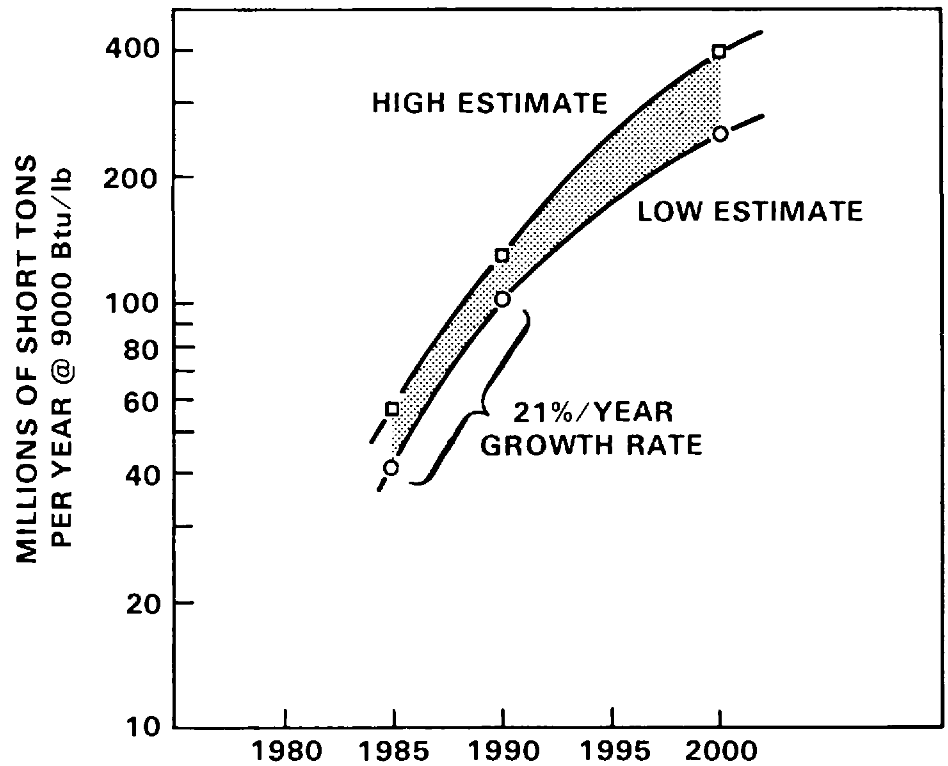

FIGURE 1. East Asia Steam Coal Market Outlook

tion are expected to come from Queensland II, which is in the interior and beyond the Great Dividing Range.

Among Canada's coal supply regions (Figure 3), Southeastern British Columbia will be the principal source of competition. The coal would be moved westward by rail out through Vancouver, or through an expanded Robert's Bank facility. Canadian costs are higher than Australian costs, and geological conditions limit the amount that coal production can increase. British Columbia's current coal exports consist almost exclusively of metallurgical coal, which does not compete with the steam coal market. Canada is discussing the possibility of developing a new coal port at Prince Rupert to allow delivery of northeastern British Columbia coals, which are not currently being mined; however, the rail transportation costs could be quite high. The Alberta Plains coals, which are further east, could contribute to Canada's exports but their high rail haulage costs would probably prevent them from being competitive.

South Africa (Figure 4) is currently a major exporter of steam coal. Our reviews of cost information available for South Africa showed coals from the Southern Transvaal region to be the principal competitors, with their reference port at Richards Bay. The Southern Transvaal area currently has the lowest mining and overland transportation costs of all the competitors; but, their ocean

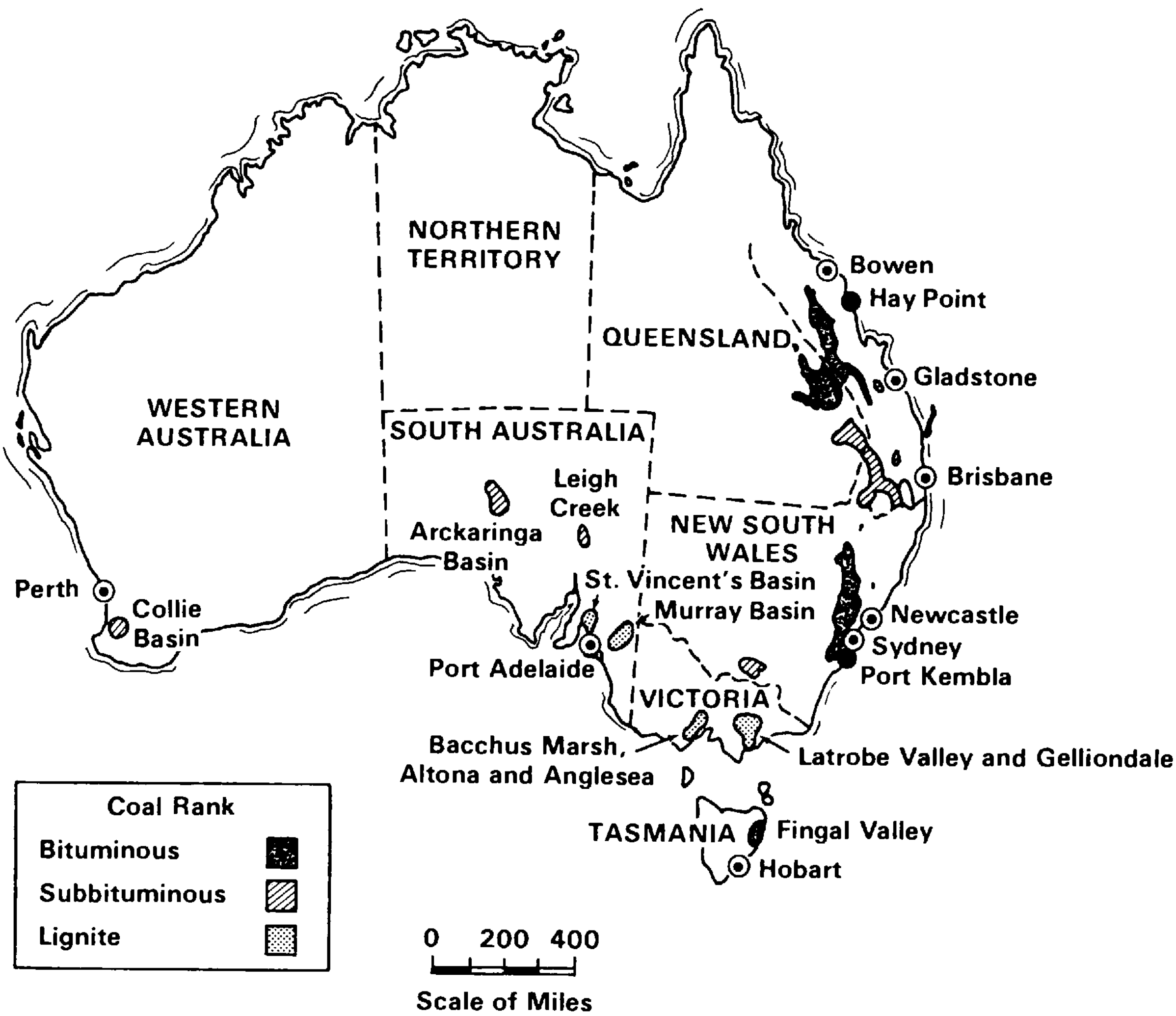

FIGURE 2. Australia Coal Supply Regions

transport costs to the East Asian markets are much higher than those for Australia, Canada or even the contiguous United States.

The western United States could compete for this East Asian market, although lack of ports somewhat limits the movement of both Utah and Wyoming coals, the major suppliers for this region. While Utah has a high quality coal, its development requires expensive underground mining, followed by about 800 miles of rail transport to a port such as Long Beach, California. Wyoming's mining costs are low, but so is the quality of its coal in terms of Btu per pound. Wyoming's bid for this market is further hampered by high overland (about 1000 miles) and ocean transport costs. Wyoming coal for export most likely will have to move down the Columbia River corridor by rail to new ports on the river's lower reaches. The Columbia River Bar constrains the size of ships that can get in and out, and hence increases shipping costs. Utah coal might be shipped out of California in ships of larger deadweight tonnage (DWT).

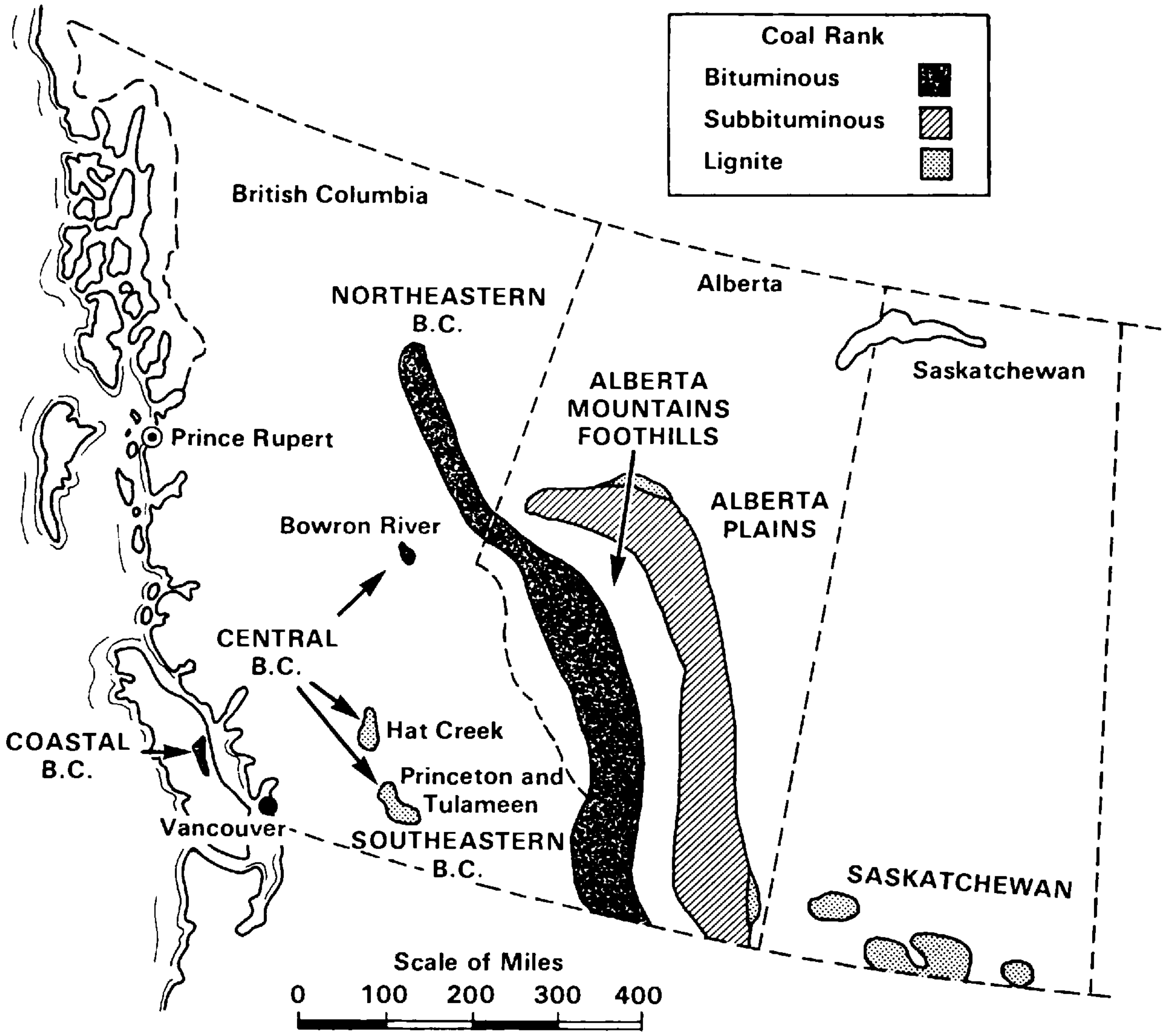

FIGURE 3. Western Canada Coal Supply Regions

We have no clear picture for the People's Republic of China. We know only that they have a lot of coal. Their announcements regarding their intentions to develop their coals change almost weekly. As far as we know, they currently have no major ports to handle a large volume of exports but are considering their construction. While it is possible that the People's Republic of China could eventually become a major supplier, it can currently be regarded only as a dark horse.

Transportation costs vary so widely, depending upon supplier and route, that we analyzed them separately from the overall estimates of competing prices. Figure 5 illustrates the ocean freight distances relevant to the East Asian markets in round trip nautical miles. The longest round trip distance is clearly from South Africa to Japan (14,500 miles); the shortest is from Cook Inlet to the "lower 48" West Coast at 6,300 miles. Australia and lower

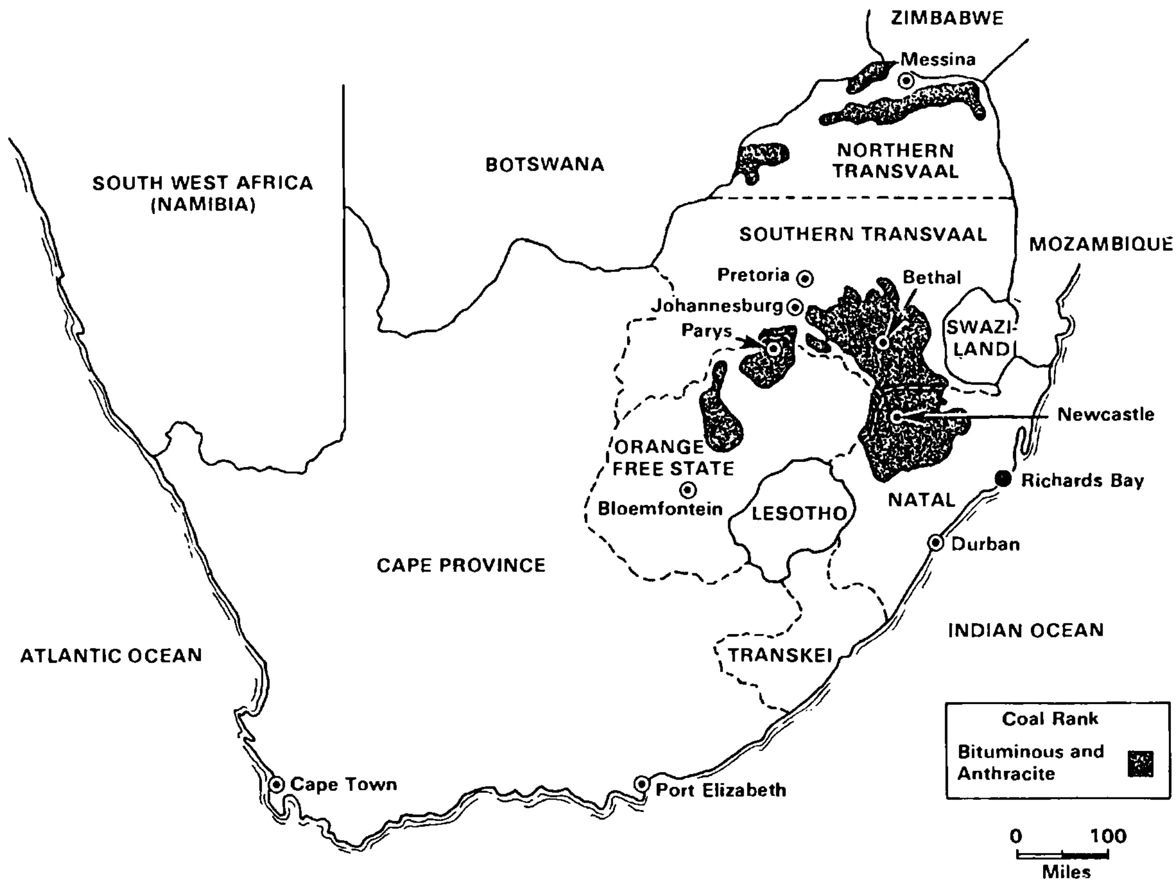

FIGURE 4. South Africa Coal Supply Regions

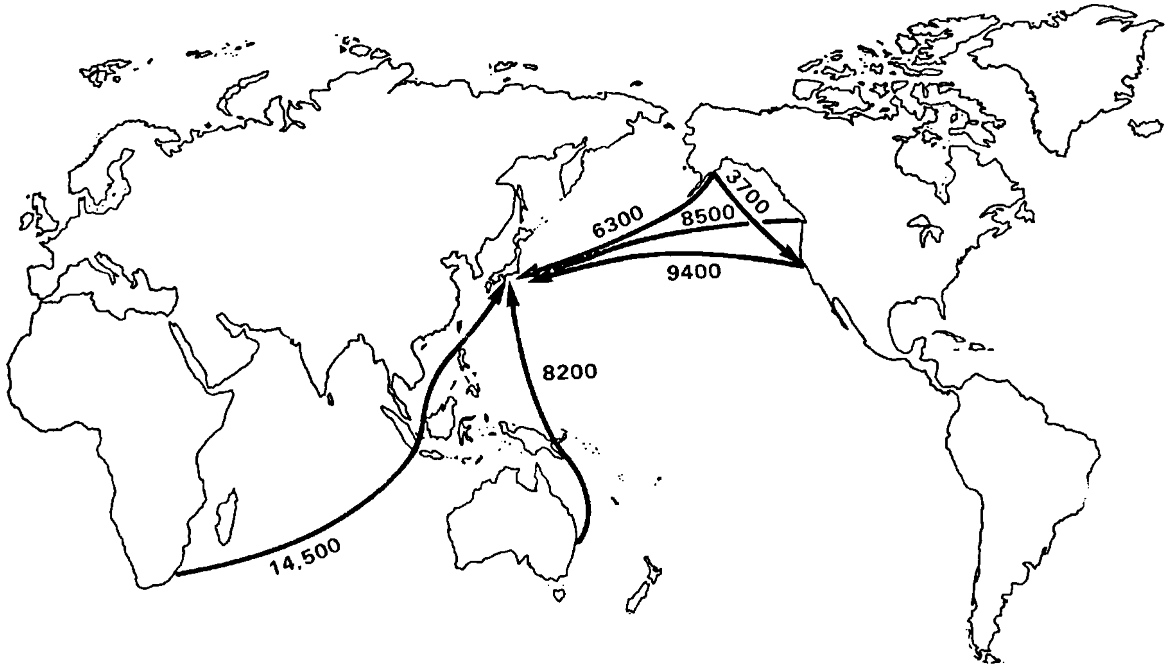

FIGURE 5. Ocean Freight Distances--Round Trip Nautical Miles

North America are at intermediate distances. Given the nature of the trade routes and markets, it appears that coal carriers are likely to return in ballast, and thus coal shipments must bear the full cost of the round trip. Any additional overland haulage costs must be included in consideration of trade routes.

Transportation costs comprise capital recovery, operating costs (other than fuel), fuel costs and port costs, as well as variables such as trade route, flag of operation, deadweight tonnage (DWT) and financial structure of ship ownership. Figures 6 and 7 illustrate the levelized ocean freight rates calculated for a Japan destination and a California destination, respectively. These rates are for ships of 110,000 deadweight tonnage, using a 3% real rate of escalation in fuel costs, and sailing under foreign flag. The costs are expressed in levelized dollars per million Btu for various coals that might be available from the locations shown on the graph for the year of initial fleet operation, i.e., export contract initial fulfillment.

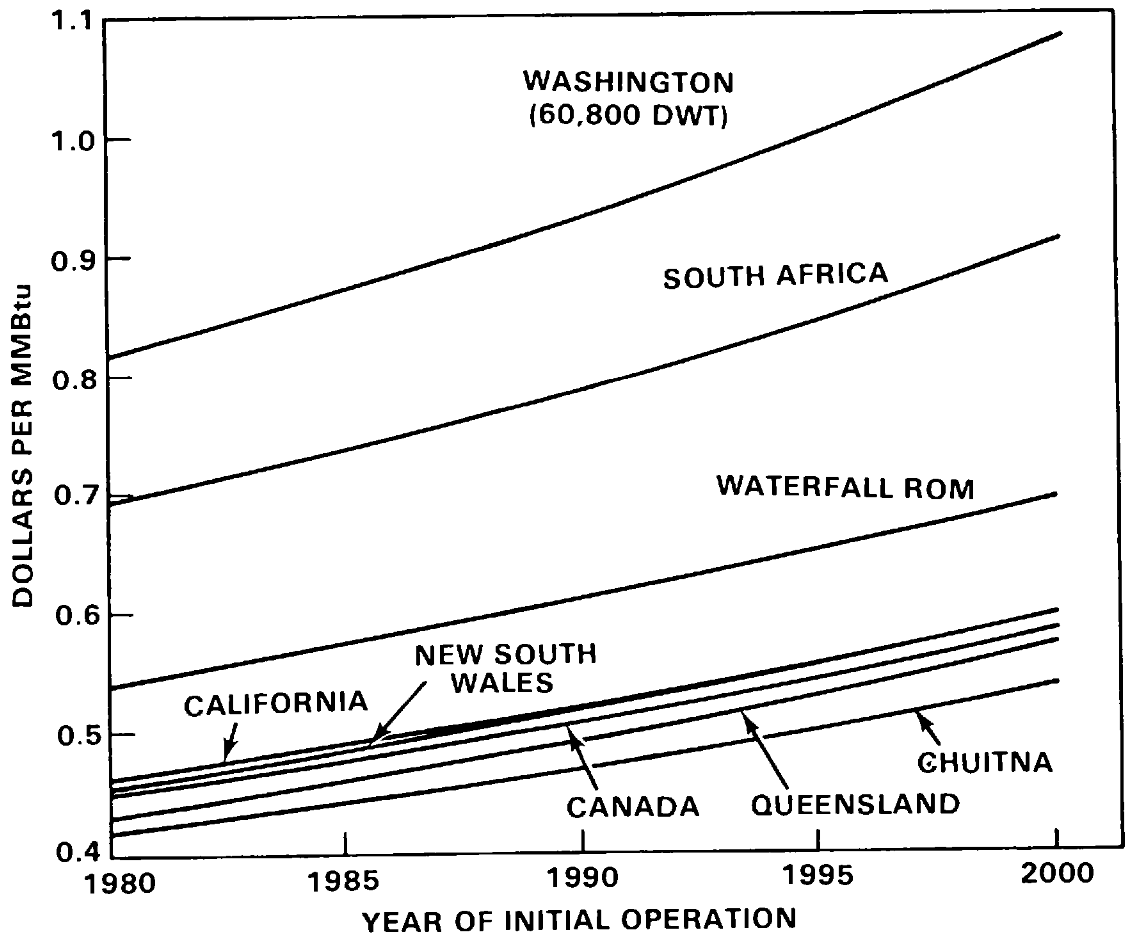

FIGURE 6. Levelized Ocean Freight Rates to Japan

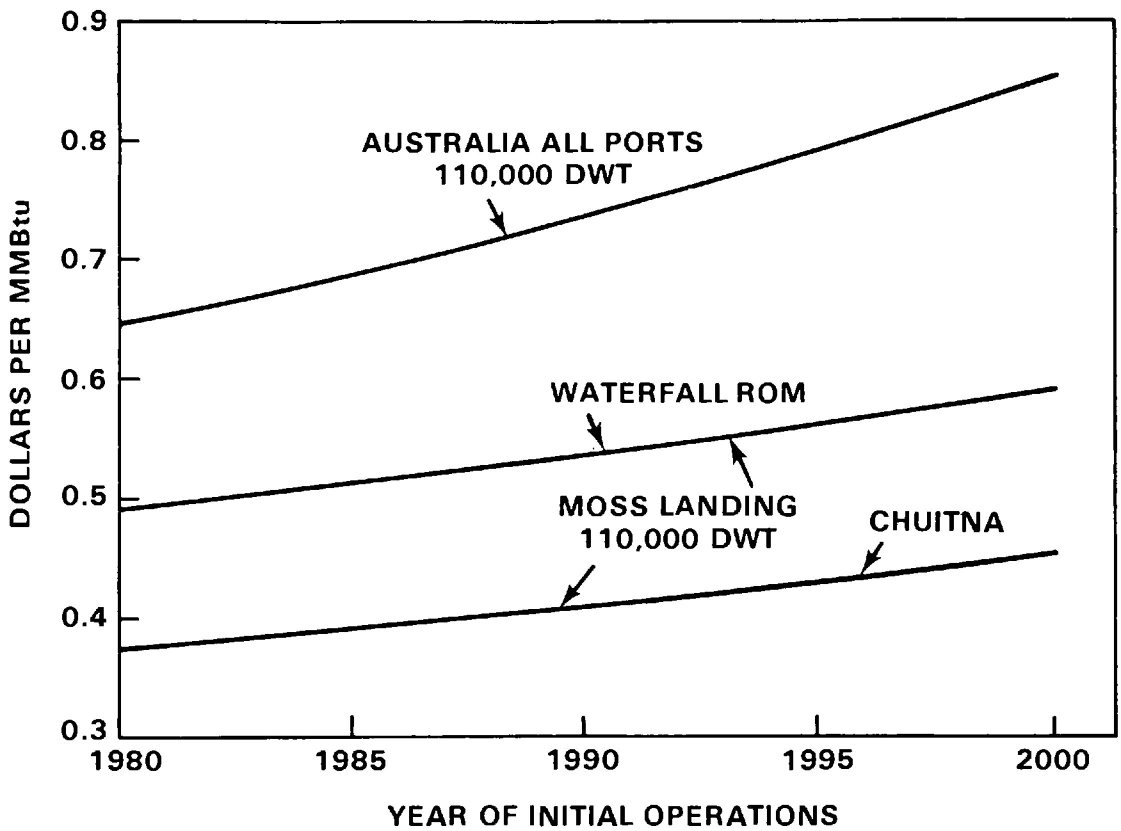

FIGURE 7. Levelized Ocean Freight Rates to California

Wyoming coals shipped via Washington State represent the highest costs, primarily because of the ship size limitations imposed by the Columbia River Bar, higher overland tariffs and the low heating values of those coals. South African coals, though of high heating value, suffer from a much longer trade route. The bottom line on the curve is for Chuitna coal dried to about 10% moisture. It is clear that it enjoys an advantage of several cents per million Btu over its nearest competitor, primarily because of low overland and ocean freight charges. Figure 7, which gives similar data for a California destination, assumes the use of large bulk carriers that might be accommodated at sites such as Moss Landing (although a new port facility would be required), the use of U.S. flag vessels employed under the Jones Act, and operation of the shipping system by private corporations.

Having briefly described the possible competitors and analyzed transportation costs, we present the methods used for estimating the price of steam coals competing with Beluga coals for the East Asian markets. Estimating these prices is difficult for a number of reasons. First, explosive growth in steam coal use is forecast for this area. Because the demand for such coal here has historically been very low, no real trading patterns have been established. Finally, even where price quotations are available, they tend to refer to the spot market and not to the long-term market that we would anticipate prevailing in the future. (For example, given the forecasted rapid growth rate of the East Asian market, we expect that new reserves will have to be developed.)

Despite these factors, we believe that price will be determined largely by the cost of production and transportation plus economic rents obtained by producers and host governments. First of all, long-term contracts will prevail as markets expand. In fact, it is highly likely that the customers for coal will wish to take a significant equity position in the coal development, to assure some control over supply and price.

Secondly, we expect the market to be highly competitive; there is no cartel as there is with oil, and the geographically and politically diverse nature of the supply system renders cartel development unlikely. There is at least one case in which price may not be determined solely by production and transportation costs: where the potentially lowest cost producer or the host government will extract an economic rent to raise his price to that of the nearest competitor. This might be the case for coals from New South Wales, Australia.

Our method for estimating competing prices was to employ supply curves based on expected mining conditions and basic cost components of mining and transportation.[2] These curves show the minimum additional costs for incremental production. In essence, the supply curves provide the marginal costs for developing the next unit of coal production. Based on the concept of net present value and on managerial finance considerations, this method yields the minimum acceptable selling price for incremental production. This includes an acceptable rate of return on investment (ROI) in real terms.

Figure 8 shows three supply curves[2] for coals that might compete with Beluga coals. These curves represent the minimum selling price necessary to encourage additional production. These supply curves include most fees, all royalties and all transportation costs as we know them. They do <u>not</u> include export fees or loading costs because we lacked the data. Nor do they include any provision for new investment or supporting infrastructure costs such as will be necessary for the Beluga coal fields. Therefore, these supply curves should not be compared to those presented for Beluga coals (Figure 9). Further, the estimates shown in Figure 8 are based on a 5 to 9% real return on investment, whereas typical investment analysis--and the analysis of Beluga coals--uses a 15 to 20% real return.

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[2] ICF, Inc., May 1980. Draft Report. Coal Supply Curves for Australia, Canada and South Africa. Washington, D.C.

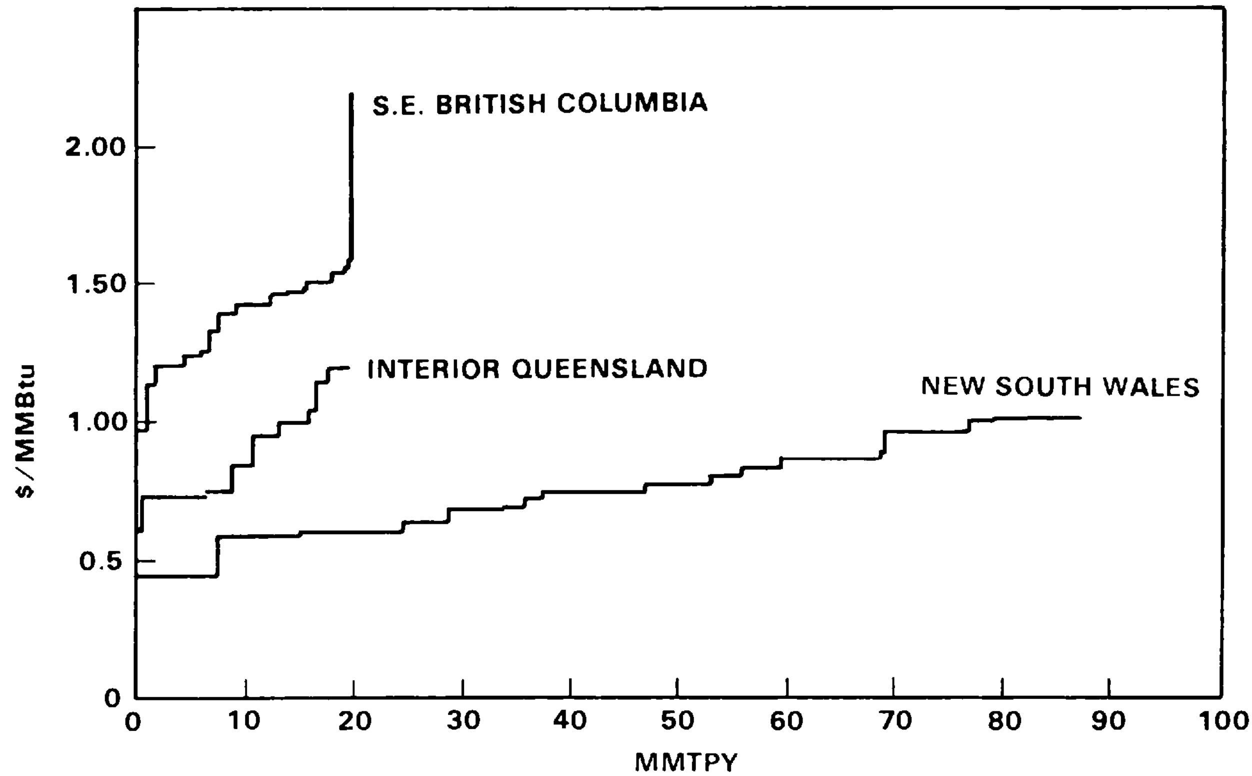

FIGURE 8. Typical Supply Curves--FOB Dock

A sample supply curve for Beluga coal uses the Chuitna field with coal dried to 10% moisture (Figure 9).[3] This estimate, which is based on a 75% debt and 25% equity, illustrates the effect of production rate on price. This supply curve differs significantly from those shown in Figure 8 because it includes a high degree of initial infrastructure costs. As production and shipment rates increase, the effect of these costs is diluted. The estimate includes all costs for mining, drying, overland transport, port and handling facilities and town site and other infrastructure charges. As previously mentioned, these estimated costs are biased higher than those shown in Figure 8, primarily because of the difference in basis for return on investment and because the port costs (5 to 10 cents per million Btu) were not included in the costs estimated for the other supply sources. Thus the prices shown for Beluga coals are for F.O.B. trimmed vessel in December, 1979 dollars.

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3 Bechtel Corporation. April, 1980. "Executive Summary - Preliminary Feasibility Study Coal Exports Program." Study conducted for Marubeni Corporation, San Francisco, California.

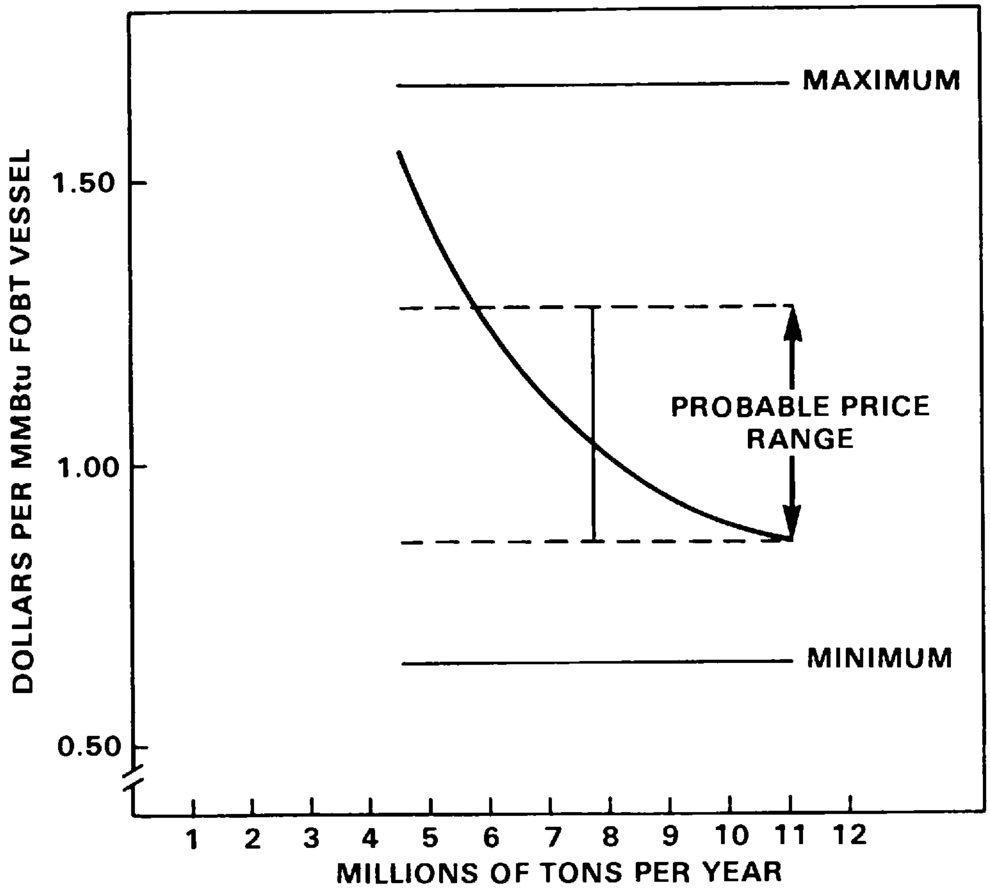

FIGURE 9. Effect of Production Rate on Price--Chuitna Field, 10% H_2O

Figure 10 shows our estimates of the CIF (cost, insurance, freight) price for seven steam coals delivered to Japan under production and market conditions that are likely to prevail in the mid to late 1980s. The prices are expressed in 1980 dollars per million Btu. The figure does not show the minimum delivery cost of steam coal from New South Wales, as this lowest cost (estimated) producing region is expected to effectively price its coal near that of its closest higher priced competitor, i.e., to Queensland coals, which are the lowest of those shown here. We also believe that our comparative analysis may be biased against Beluga coals for two reasons: 1) loading port costs are not included, because of lack of data, for foreign and western U.S. coals but are for the Beluga coals; and 2) a 20% real return on investment was used by Bechtel for the Beluga coal, versus a 5 to 9% real return used by ICF for the other coals. Table 1 summarizes this information on competing prices.

We briefly addressed the effect of coal quality on operating and plant capital costs as might be judged by a prospective purchaser, such as an electric power utility. The effect of coal quality on a power plant's operating costs can be reasonably indicated by the heat rate in Btu per kilowatt-hour of power generated (Figure 11).

Table 1. Example of Minimum Delivery Cost (CIF) for Steam Coal to Japan, 1985 Conditions in $1980, Exclusive of Port Costs, $/Million Btu.

Source	FOB Mine (M) or Port (P)	Overland Freight	Ocean Shipping	Delivered Price CIF
Queensland	1.00 (P)	--	0.46	1.46
South Africa	0.70 (P)	--	0.78	1.48
Utah via California	1.25 (M)	0.48	0.49	2.22
Wyoming via Washington	0.55 (M)	0.84	0.87	2.21
Western Canada	1.20 (P)	--	0.48	1.68
Beluga Fields (a)				
Chuitna Dried to 10% H_2O	1.05 (P)	--	0.45	1.50
Capps ROM	1.15 (P)	--	0.58	1.73

(a) Beluga field FOB port price includes ship loading costs which are not included for other coals. This differential is on the order of $0.05 to $0.10/million Btu. Chuitna costs are based on Bechtel base case.

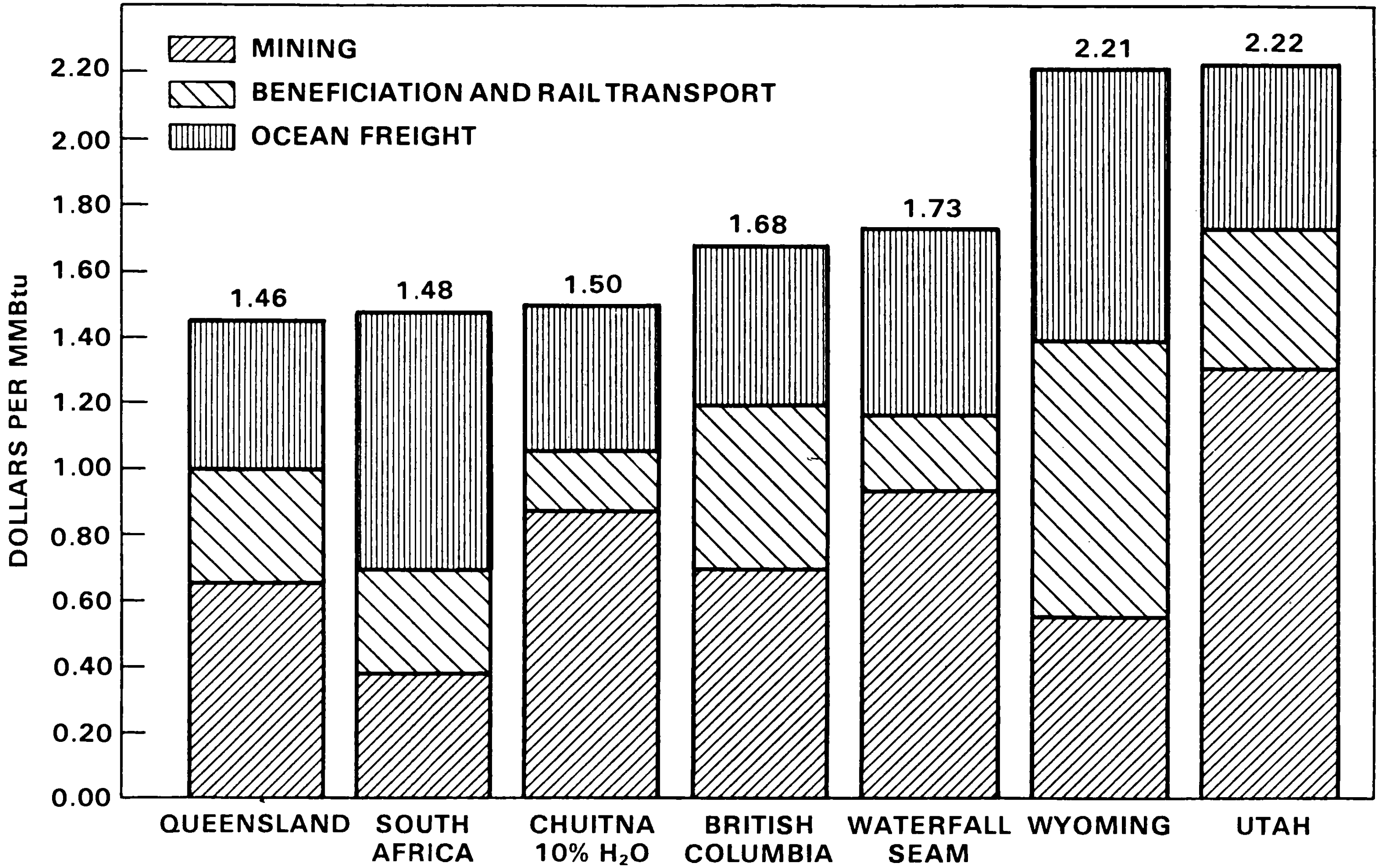

FIGURE 10. Steam Coal Prices-Cost Insurance Freight (CIF) Japan-1985 Conditions

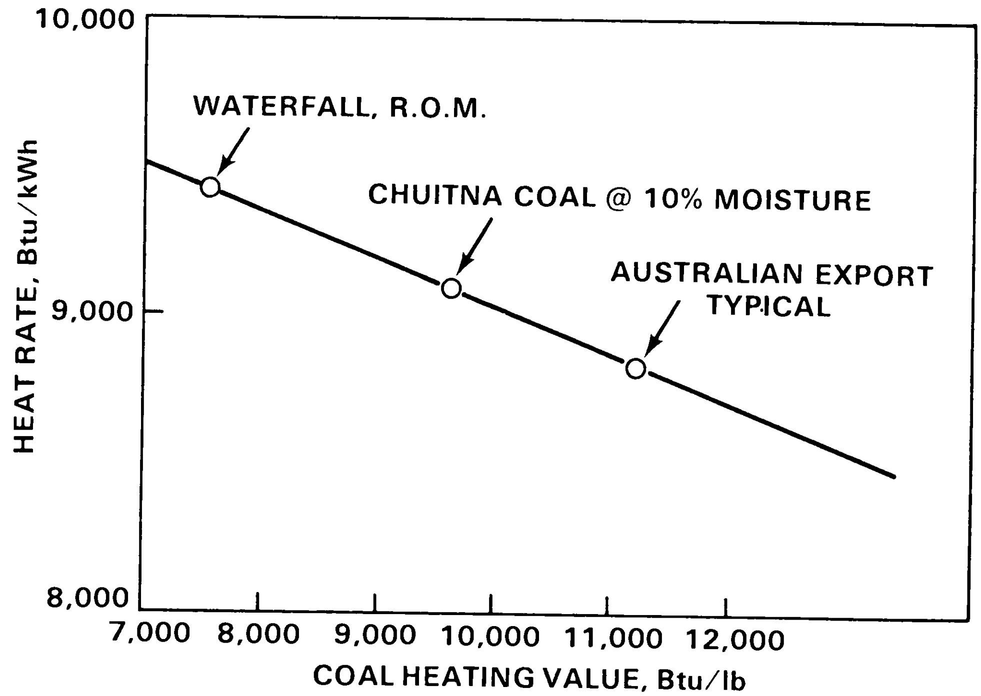

FIGURE 11 Effect of Coal Quality on Power Plant Heat Rate

As heating value declines, more coal must be handled at constant plant output, all other things being equal. As a result, more energy is consumed in the coal handling, grinding, ash handling and draft system operation. For a point of reference, we used the tentative specifications developed by Japan's Electric Power Development Corporation (EPDC) for the Matsushima Plant and calculated heat rates for this and two representative Beluga coals. Chuitna coal, dried to 10% moisture, incurs about a 3% penalty on a Btu basis; Waterfall seam coal run-of-mine from the Capps area incurs about a 7% penalty.

Figure 12 illustrates the effect of coal quality on electrical power generation plant capital costs. These estimates are based on a 1,000 megawatt plant, constructed under U.S. conditions and to come on line in 1985. The analysis considers corrections for heating value, ash content and characteristics, grindability, and about five primary power plant construction cost centers. Again, the Electric Power Development Corporation's Matsushima plant specifications are used as a point of reference. The Waterfall seam suffers about a 2% penalty for its run-of-mine coal; the Chuitna field (dried to 10% moisture) coal actually gains about 1%, primarily because its ash content is lower than that of the specification. These Figures (11 and 12) suggest that the quality of Beluga coal is not as significant a factor as might previously have been thought.

Finally, as we suggsted earlier, we must recognize that price will not be the only factor that determines the future development of the Beluga coals. We have identified five nonmarket factors that

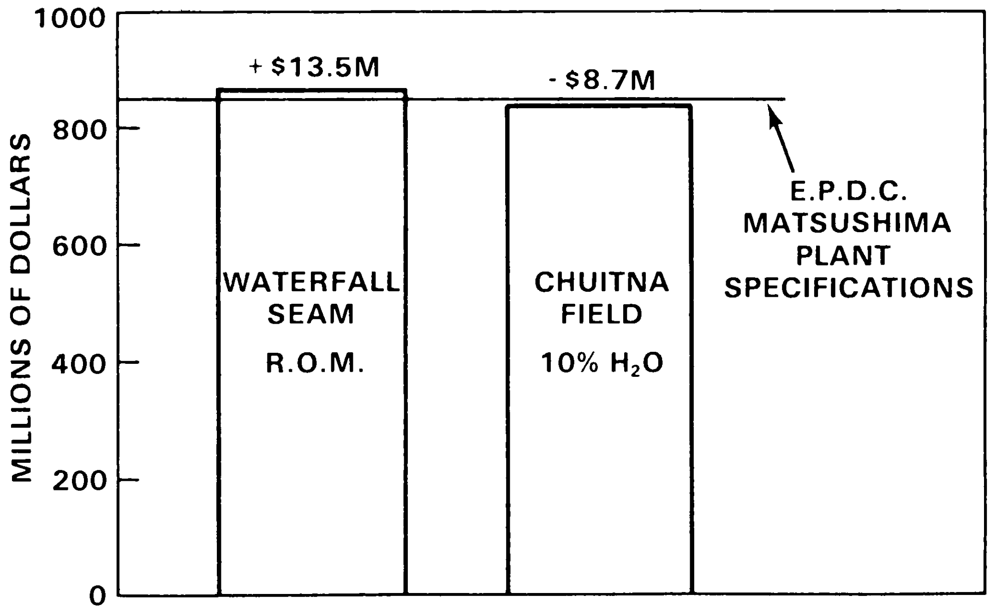

FIGURE 12. Effect of Coal Quality on Plant Capital Cost (1,000 MWe, 1978 dollars)

we believe may be important in decisions to open the Beluga coal fields. The first is the desire for diversity of supply sources. We expect this to become increasingly important as international steam coal trade increases; security of supply will be a major factor in the minds of prospective customers.

Secondly, we believe that the acceptance of foreign investment by the producing host country will be a strong consideration on the part of the prospective customers, as they will wish to establish significant equity participation for assuring some long-term price stability. This factor is liable to be detrimental for both Australia and Canada, but may be an advantage for U.S. coals, where restrictions on foreign investment may be less confining.

Third, political stability will be a very strong consideration. Similarly, stability in labor relations will be important. Customers have been severely hurt by work stoppages in the past and are understandably very sensitive. This is a particularly significant problem in Australia, which is known for its tumultuous labor relations problems.

Finally, we believe that prospective customers will be searching for what might be called a "positive attitude" on the part of the producing countries. By this we mean a display of willingness to negotiate openly and with guarantees that there will be no surprises in the future. It also means that the host countries will provide support in working through the institutional problems, such as regulations and licensing.

All of these nonmarket factors should work to the advantage of Beluga development vis-a-vis the competition. Clearly, the U.S. is considered politically stable and allied to the East Asian markets. Foreign investment is not discouraged, although there are some restrictions on direct investment in mineral resource extraction. Labor problems exist in all countries, but likely less so in the U.S. where mediation procedures are well established.

A preview of the Beluga methanol project

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Abstract

A coal-to-methanol plant with a capacity of 54,000 barrels/day (7,500 ton/day) is proposed for a site close to the Beluga coal field, near Cook Inlet, Alaska. The extensive proven reserves of coal, abundant water and favorable environmental conditions are complemented by an existing liquid transportation system, and marine shipping for efficiently serving markets in all Pacific Coast States. Commercially proven technology, using large size Winkler gasifiers and low pressure Imperial Chemical Industries (ICI) process for methanol synthesis provides assurance of technical success and economical production. Principal markets for the methanol are expected to be as fuel for electric power generation and for motor vehicles. A study is now in process to ascertain the technical and economic feasibility of this project.

A Preview of the Beluga Methanol Project

Despite the announced intent of the United States to utilize more fully its coal resources, the coal industry remains stagnant with unused capacity. The Pacific Coast in particular has moved but little towards the use of coal. In the five Pacific Coast states, there are several reasons why the conversion to coal, and the use of coal, have lagged:

1) Reluctance on the part of major West Coast markets, the electric utilities, to consider this "new" fuel because of environmental constraints. 2) Distance of Pacific Coast markets from the large, producing coal fields of the Rocky Mountain and Plains states—and attendant high transport costs. 3) Need for liquid fuels—especially those which are clean to handle and clean to burn.

Production of methanol from the Beluga coal field adjacent to Cook Inlet would surmount each of these obstacles, and employing this large resource for clean fuel production would lead the way for coal to be a significant energy source along the entire West Coast.

A Brief History of the Beluga Coal Resource*

The Beluga coal field has confirmed reserves of over one billion tons of very low sulfur content subbituminous coal, and more as yet unexplored and at depth. It is located about 60 miles west of Anchorage, Alaska. A noteworthy feature of its location is the proximity of tidewater and low-cost ocean transport (Fig. 1). The detailed location map (Fig. 2) depicts the three areas where the Beluga Coal Company, a wholly owned subsidiary of Placer Amex, Inc., holds seven coal leases. Five are from the State of Alaska and two are from Cook Inlet Region, Inc. (one of the Alaska Native Regional Corporations).

Prospecting permits were first obtained by Placer Amex in 1967; since then the company has continued to explore these coal leases, and to conduct studies of mining feasibility, environmental impact (6), transportation and marketing (Fig. 3).

Like other subbituminous coals, the Beluga coal can be: 1) direct shipped (or washed) for use in steam powered electric generating plants or, 2) converted to synthetic fuels and chemicals by various existing or developing processes.

Studies indicate that an export market for direct shipped or washed coal would have to amount to five or 6 million tons per year in order to amortize the expense of the mine, the infrastructure, and, principally, the costly port development (7). More modest operations, however, would suffice to supply a local electric generating plant (8).

Although direct burning is the most efficient means to utilize the energy contained in coal, it is cleaner and more convenient to use when converted to gaseous or liquid fuels. Alaskan coal can certainly be considered as a raw material for gasification if shipped to a site near potential markets for the gas and then processed; or the coal can be made into liquid products near the resource and shipped by tanker to various markets. Thus, several other possible forms in which Beluga coal could be used have been considered. Following the 1973-74 international petroleum crisis, the U.S. Office of Coal Research, Nissho-Iwai American Corporation and Placer Amex, Inc. sponsored a study to evaluate the technology and economics of producing solvent refined coal (SRC) products from the Beluga coals by the Pittsburg and Midway process (9). Since about 1975, consideration has been given to upgrading of the coal before shipment and producing coal oil mixtures. Investigation of this concept is continuing, and last year a sample of 350 tons of coal from the Capps area of the Beluga coal field was shipped to Japan for testing. The paper presented by Mr. Nakabayashi at this conference (10) describes some of the coal oil

*Previous papers have covered the history and geology (1,2,3) of the Beluga coal field, mining (4) and transportation (5).

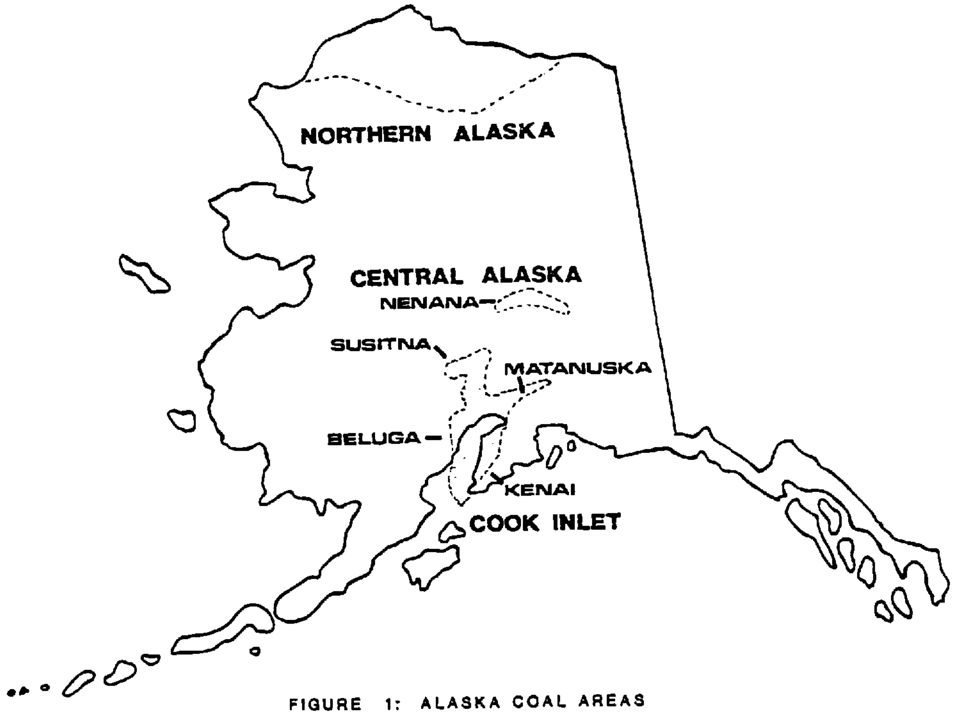

FIGURE 1: ALASKA COAL AREAS

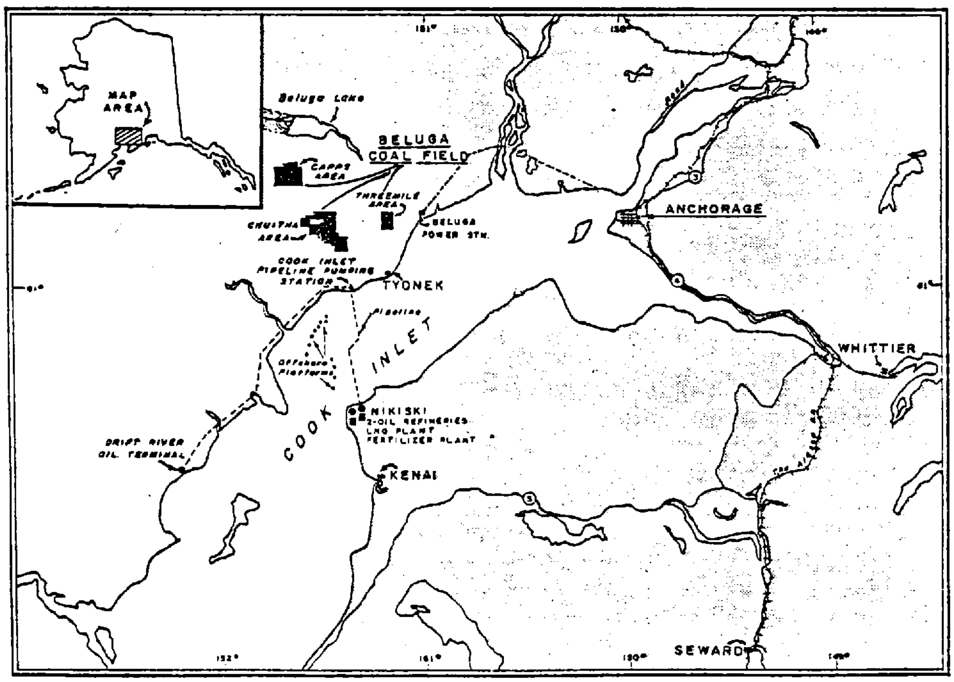

FIGURE 2: LOCATION MAP

BELUGA ACTIVITY CHART

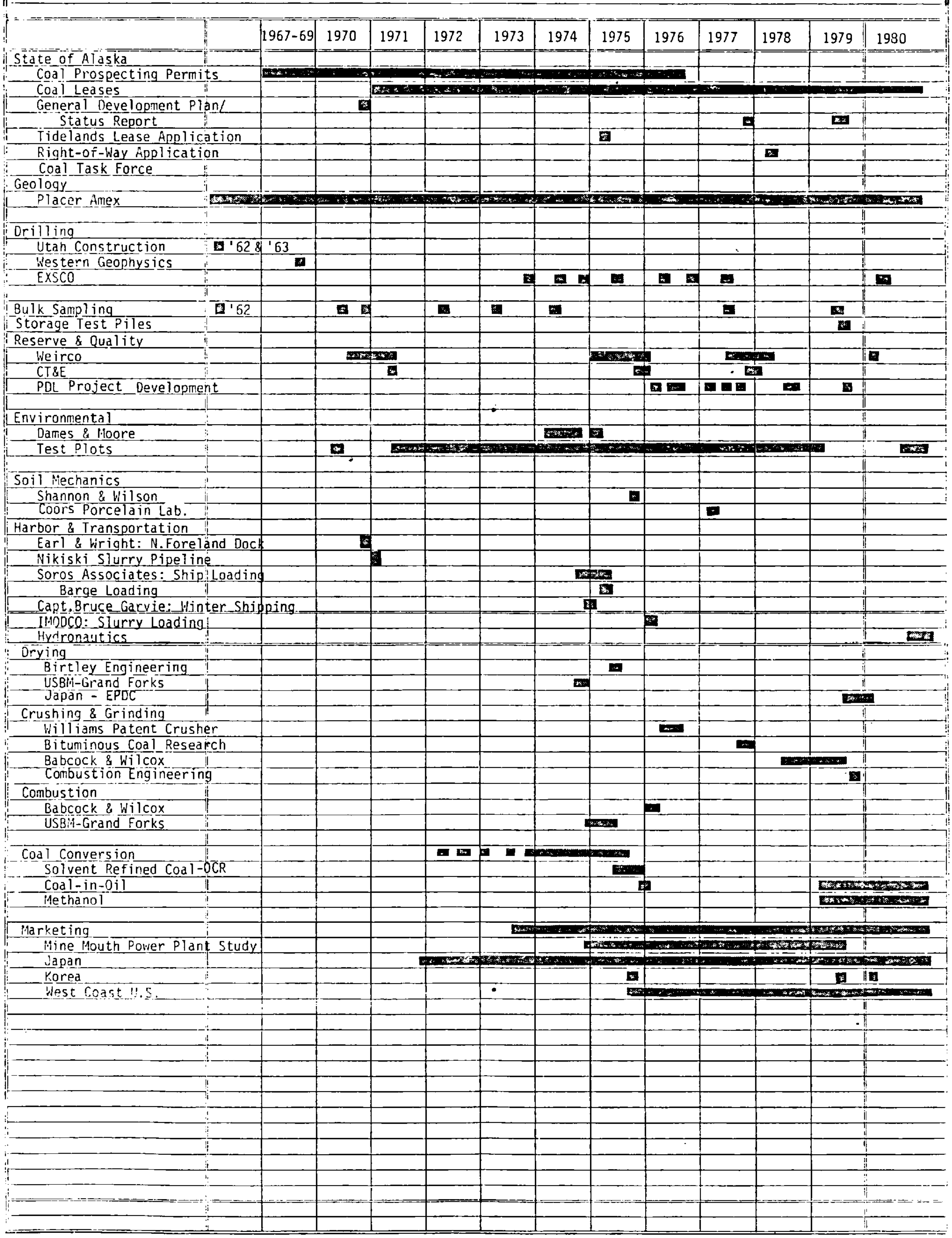

FIGURE 3

mixture (C.O.M.) technology that has been pursued in Japan, and how certain aspects may fit in with Beluga coal development.

Most recently, since the West Coast petroleum product shortages of 1979, much of our attention has been directed to conversion of Beluga coal to liquid fuels, specifically to the production of methanol (methyl alcohol).

The Beluga Methanol Project

Early this year the Department of Energy solicited proposals for feasibility studies of "alternate fuels", advising that repayable grants of up to four million dollars each were available to those submitting proposals for the production of such fuels (e.g. coal liquids, shale oil, biomass, unconventional natural gas, etc.). Placer Amex, Inc. and Cook Inlet Region, Inc. jointly submitted a proposal under the category of coal liquids to study the feasibility of producing 7,500 tons per day (54,000 barrels per day) of methanol from Beluga coal (11). The Beluga project was officially awarded the Dept. of Energy grant on August 28, 1980.

The Beluga proposal was deemed to satisfy the various criteria established by the Department of Energy, among them being:

1. Availability of Specific Resources

The only raw materials needed for the process are coal, water and air. The drill proven coal reserves of the Beluga coal field total a billion tons, with a resource base estimated by the U.S. Geological Survey to be four billion tons or more (3). Water is available in abundance.

2. Readiness and Suitability of Technology

The Beluga Methanol Project will utilize commercially proven, well-established technology. The processes selected are suited to the particular coal and to the site of operations, are simple, have minimal environmental impact and investment cost, and use equipment of proven size. An important criteria of the Dept. of Energy in awarding grants was that a project get underway expeditiously without preliminary research and development. Moreover, the process technology for the Beluga methanol project can be utilized for other types of coals, and therefore can have widespread application.

3. Site Suitability and Environmental Considerations

The project site has several environmental advantages as a location for construction of a synthetic fuels plant. The long summer growing season will aid revegetation of the mined areas. Environmental monitoring and assessment of the region, undertaken as part of the feasibility study, will insure that discharges and emissions will in no way be detrimental. The coal derived fuel has no ash nor sulfur and produces a notably small amount of nitrogen oxides following combustion—important environmental advantages in the market areas where the product will be ultimately consumed.

4. Capability of Proposers

Complementing the coal mining and resource experience (including Alaskan coal operations) of the proposers is the technical and business expertise of the team engaged for the study. This includes the Davy McKee Corp., an international engineer/contractor having extensive experience in the proposed technology. This firm is responsible for engineering the largest methanol plants ever ordered (2,760 short ton per day units now being built in the U.S.S.R.), the largest plant in operation (Celanese at Clearlake, Texas, 2,200 short tons per day) and was involved in most of the plants in the world producing in excess of 1,000 tons/day.

5. Regional Benefits from Plant Operation

This synthetic fuels project can benefit nearby Cook Inlet communities as a source of full time employment, both directly at the mine, the methanol plant and the ship loading facility; and indirectly in support activities which would require materials and services from other areas, including the Anchorage region. Native land owners will have a management role in the development of resources on their lands, and a significant presence in the study team. The project can provide an additional local source of electric power, a natural complement of the methanol plant's self-sufficiency in electric power.

Basic Process Technology of the Proposed Plants

Coal liquefaction processes can be characterized as either direct or indirect, with production of methanol from coal being accomplished by indirect liquefaction. Direct liquefaction is not yet a commercial reality, although considerable effort has already been spent in research and development. Such processes would typically use coal that is crushed and ground to a fine size, mixed with liquids from the process, and then reacted with hydrogen at high temperature and pressure. The solvent refined coal (SRC) test facility located at Fort Lewis, Washington, is an example of such a project.

Indirect liquefaction of coal has been commercially used for many years. The process is "indirect" because the crushed, dried coal is first gasified with steam and oxygen in a reaction vessel. The product gases ("synthesis gas") are then purified and reacted catalytically to form such products as liquid hydrocarbons or methanol, as shown in Figure 4. The world's largest operation of this type is South Africa's Sasol which, with a coal input of up to 90,000 tons per day, uses Lurgi gasification and Fischer-

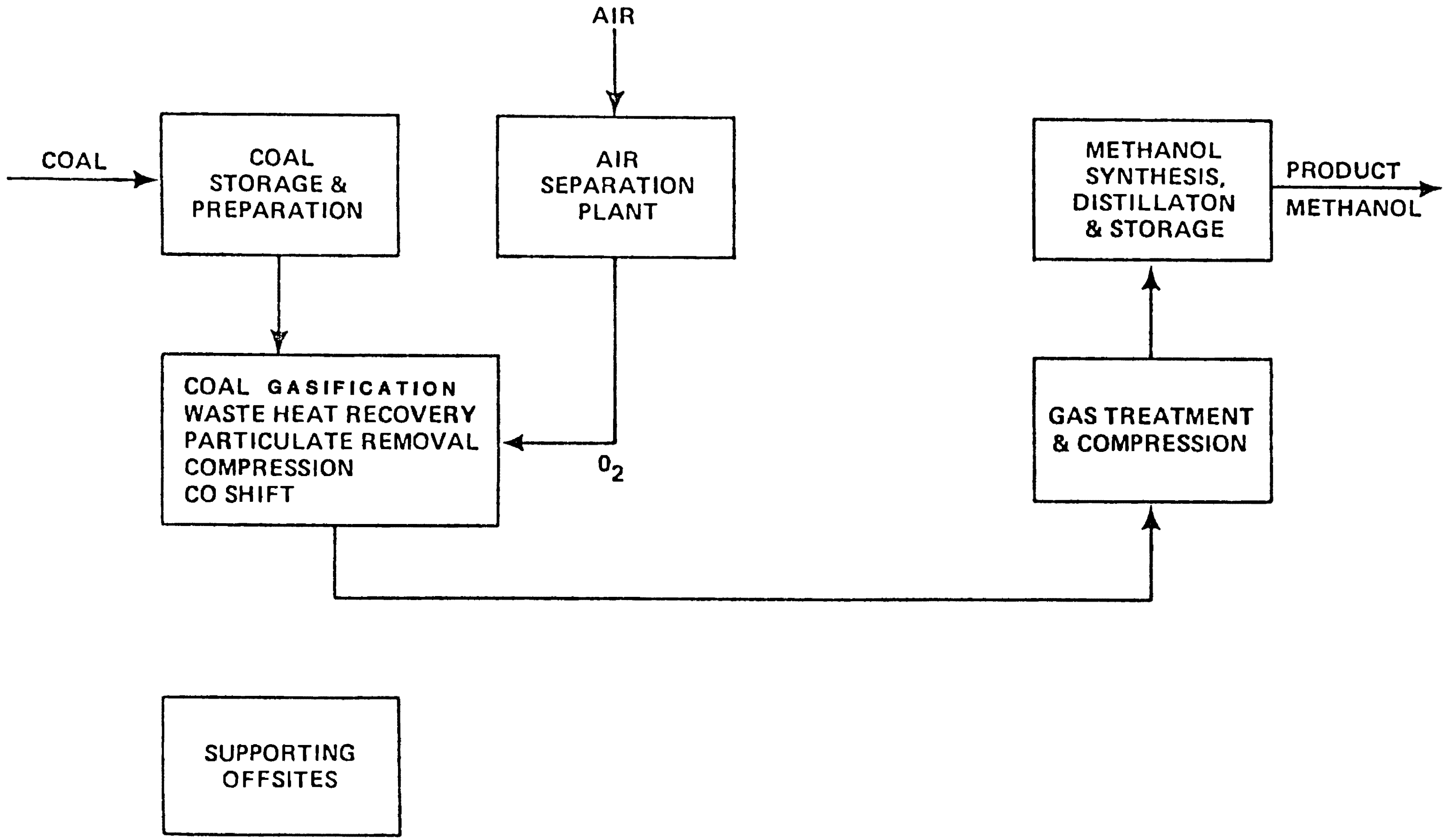

FIGURE 4: COAL TO METHANOL

Tropscn synthesis to produce a wide variety of products. Another South African firm, African Explosives and Chemical Industries, has produced methanol from coal at Modderfontein for twenty years and plans to substantially expand this operation.

Selection of System

A major decision for our project was the selection of the type of coal gasification system to be used. A comparison of the principal commercially proven systems proved instructive for the selection:

Lurgi Gasification: A fixed bed gasifier, requiring sized coal, preferably of low ash content. This process produces fuel gases and low value byproducts, such as tar and ammonia; although such byproducts can be worthwhile commodities in the appropriate locations, in a remote site distant from markets they would impair the logistics of the operation and marketing.

Koppers Totzek: An entrained bed system, requiring coal to be pulverized to 70% under 200 mesh, preferably with low ash content, and a fluid ash at the operating temperature. Synthesis gas or medium Btu gas is produced without byproducts.

Winkler Gasifier: A fluid bed system which can accept crushed coal up to 3/8 inch in size and in which fines are satisfactory. Synthesis gas (or medium Btu fuel gas) is produced without byproducts. Medium and high ash contents are acceptable. Fuel source for the plant boilers is coal and the reactive char withdrawn from the gasifiers along with ash. The gasifier has considerable potential for future capacity increase when developed for operation at elevated pressure.

Among the above outlined characteristics of these processes are several that fit the requirements of the Beluga project very well.

The Beluga coal seam varies in ash content, and therefore a process accepting higher ash coal is desired so as to maximize utilization of the resource*; the low Hardgrove grindability of much of the Beluga coal suggests a coarse size feed to the gasifier;

*Unburned carbon in the char from the gasifiers will be utilized in the boilers to be used for generating power at the plant.

byproducts should be avoided and environmental effects minimized; a low capital cost is desirable. All of these factors pointed to the selection of a fluid bed gasification system, the Winkler gasifier, which has operated commercially since 1926 in Europe.

The synthesis gas leaving the Winkler gasifier will consist of hydrogen, carbon monoxide, carbon dioxide and small quantities of methane, nitrogen and oxygen. Sulfur containing compounds are removed from the gas mixture before the gas enters the converter.

Converters can produce methanol from synthesis gas regardless of the source of the gas mixture, i.e., whether derived from steam reforming of methane or naphtha, or from the partial oxidation of oil or coal. The synthesis reaction of hydrogen and carbon monoxide to form methanol requires a catalyst and is favored by low temperature and high pressure. The rate of reaction is, however, retarded by the low temperature. The zinc/chrome catalysts origially used proved so unreactive at the low temperatures that favor the equilibrium, that it was necessary to raise the temperature. This action had an adverse effect on the yield, so it was necessary to operate at very high pressures--typically 4,500 pounds/square inch (psi)--to obtain economic production.

Before World War II, a copper catalyst was developed which provided high reactivity at low temperatures (typically 400 to 550° F) and at modest pressures (750 psi). However, the copper catalyst could not become a commercial reality until the 1960s, when gas purification techniques enabled the removal of the trace quantities of sulfur which poisoned this catalyst.

Nearly eighty percent of the world's methanol productive capacity built during the past decade has used the same low pressure process as selected for the Beluga methanol project. This low pressure process is used for:

The largest single stream methanol plant in operation

The largest plant being built

The methanol plant currently in operation which uses coal as the raw material.

The Beluga project will use three production trains (i.e., parallel units of equipment), each with a capacity of 2,500 tons of methanol per day, allowing equipment to be used in the largest sizes readily available and minimizing costs.

Looking toward the future, the gasifier will be structurally designed to operate at slightly higher than the intial four atmosphere operating pressure. This will enable improved production efficiencies to be achieved as permitted by actual operating experience. The coal handling equipment will be designed to accommodate increased feed rates, and additional downstream processing capacity can be added as needed. Thus the process selected will demonstrate a major commercial technology, while providing the means to test and utilize innovative improvements.

Plant Construction and Infrastructure Development

During the planning of the proposed project, Cook Inlet Region, Inc. and Placer Amex will work closely with native village representatives, the Kenai Peninsula Borough and the various governmental agencies involved. A grass roots industrial complex and its supporting community and infrastructure can be developed in a manner that can serve as a model for future similar projects elsewhere.

The proposed plant site is near the shore of Cook Inlet, a distance of about 25 miles by rail, or less by conveyor from the source of the coal and close to tidewater. Barge transport can deliver supplies and even entire preconstructed modules of the plant. The construction season will be limited, but a combination of conventional and modular methods should minimize costs and time of construction. Fabrication in the Pacific Northwest of modules for the plant will be considered.

The proposed plant location is also adjacent to an existing pipeline which has sufficient capacity to carry the methanol produced, on a batch or intermittent basis. This pipeline extends about forty miles to an existing shiploading facility in Lower Cook Inlet where tankers as large as 80,000 dead weight ton (DWT) are currently handled. This pipeline and marine operation will be studied during the initial stage of the feasibility study, to ascertain what modifications may be necessary to enable the existing system to carry methanol and to store and load it on ships.

Markets for Beluga Methanol

Marketing of the product will benefit from the low-cost marine transportation used to ship the product from Cook Inlet to receivers in the various Pacific Coast states. Year round shipping in both Upper and Lower Cook Inlet is practicable (5), as verified by the now routine service provided to Anchorage by several marine carriers. As distinct from the fixed nature of pipeline transport, and from projects having major markets adjacent to the plant site, the transport system for the Beluga methanol project will provide a highly flexible, relatively low-cost method of product delivery.

We anticipate that the principal markets for methanol from the Beluga project will be in electric utility fuels, motor vehicle fuels and the chemical industry. The selling price of the product is obviously a major consideration in marketing, and one of the principal objectives of the feasibility study is to develop and confirm sufficient data to determine costs and price of the product.

Electric Power Generation

Methanol has been tested in gas turbines at Florida Power Corporation (1974) and at Southern California Edison Co. (1978-79) (12). Because of the favorable emission characteristics (13) (no sulfur dioxide or particulates and very reduced oxides of nitrogen (NO_x) levels as compared with natural gas combustion), there is special interest in methanol in such pollution prone regions as exist in Southern California. Methanol has also been tested in a boiler (New Orleans Public Service Co., 1972), and tests are proposed at a Southern California Edison Co. boiler unit.

A very large potential exists for fuel methanol use in combined cycle power generation, where it can produce power at a heat rate comparable to best commercial practice. Where peaking units are installed, methanol satisfies the Power plant and Industrial Fuel Use Act which mandates use of alternate fuels, if available. Inasmuch as exemptions to burn gas or oil are not allowed for more than 1500 hours per year, new combined cycle plants are not being implemented in this country. Availability of an alternate fuel would enable such plants to operate as a base--or intermediate--load producer and could thereby enable the efficiencies of combined cycle operations to be achieved. For power production in combined cycle plants there are more than ample markets for the entire plant capacity. One base load plant of 400 megawatts would require one half the plant's production of methanol. Because of their much higher (i.e., poorer) heat rate, an even smaller capacity of simple cycle combustion turbines would use the plant capacity for an equivalent amount of power output.

Combustion turbines provide an excellent opportunity for introducing methanol into a market of substantial size; existing distribution systems and this type of generating unit can be easily accommodated to this fuel. Combustion turbines currently use gas or distillate fuel, and thus can be more likely candidates for methanol use than are boilers where residual fuel is currently used. Nevertheless, repowering of existing steam boilers with methanol-fired turbines to obtain combined cycle units is feasible and may be attractive, especially if legislation is passed to "back out" oil and gas from the boiler units.

Among the factors favoring introduction and use of methanol into the electric utility market are:

1) Technical capabilities of electric utility personnel. 2) Relatively small number of applications (generating stations) compared to potential users such as motor vehicles, thereby minimizing possible distribution problems. 3) Regulation by federal and state governments, both of which have made efforts to encourage (or mandate) use of such fuel.

Motor Vehicle Fuels

The transportation fuel market provides methanol its best opportunity to be competitive at an early date without subsidy. Methanol can be used:

for gasoline blends
for gasoline replacement
as a denaturant for gasohol
as a feedstock for MTBE
as a feedstock for "synthetic" gasolines

Automotive fleets using fuel containing about 90 percent methanol already exist and gasoline/methanol blends analogous to gasohol are under development. Methanol is currently available at about one half the price of ethanol, although tax benefits currently available for ethanol serve to reduce the effective price of the latter.

Approval has been given by the Environmental Protection Agency (EPA) for MTBE additions as a high octane blending component in gasoline. Each ton of MTBE requires about 0.37 ton of methanol for its manufacture. Formerly MTBE was not expected to be produced in quantity on the West Coast because of limited supply of isobutylene from ethylene plants; however, it has been found that butenes from catalytic cracking stream of refineries can be used with methanol to produce MTBE.

Conclusion

It may be seen that methanol produced from Beluga coal can readily overcome each of the obstacles to coal use in the Pacific Coast States that was mentioned in the Introduction. Methanol will help satisfy the need for liquid fuels; it is clean to handle and clean to burn. Methanol from the large reserves of the Beluga coal field can be delivered to widespread markets by an economical and highly flexible marine transport system.

Consummation of the Beluga Methanol Project will be in the interests of the State of Alaska, the several states where the product will be marketed and the nation, which will benefit from reduced consumption of imported petroleum.

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Alaskan coal to west coast kilowatts

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Introduction

The U.S. Department of Energy, through its Regional Office in Seattle, recently completed a Draft Study, the Transportation and Market Analysis of Alaska Coal. The Draft Study has been made available to the newly organized Interagency Coal Export Task Force in Washington, D.C., where it has been favorably received. President Carter charged the Task Force with finding ways to substantially increase U.S. coal exports. The expanded export and domesitc use of coal is one of the cornerstones of the Administration's energy policy. The Department of Energy Draft Study, which will be printed and distributed in January 1981, found, in part, that:

(a) Alaskan coal could be delivered as steam coal to primary market areas (Puget Sound, Northern California, Japan, Taiwan and Korea) for a cost of between $1.87 and $3.31 per million Btu ($28 to $53 per ton) depending on the coal source and the destination. In this price range it would be competitive with coal from other sources (both domestic and foreign) in Far East markets but probably not competitive in U.S. West Coast markets.

(b) By converting Alaskan coal into a synthetic fuel (e.g., methanol) which has clean burning characteristics, Alaska coal could provide a valuable energy source to serve U.S. West Coast markets. This would be particularly so in those urban areas close to electric load centers, which are in Clean Air Act "nonattainment" areas.

Today I will concentrate on the second finding of the Draft Study because the concept needs to be more widely discussed, and because there appear to be mutually reinforcing relationships between the desire to market Alaskan coal, the need for rapid construction of additional electric generation capacity in the Pacific Northwest, the need to reduce consumption of foreign crude oil and the continuing need to protect the environment.

Need for Power

The Pacific Northwest is currently experiencing electrical shortages. The Pacific Northwest Utilities Conference Committee forecast that such shortages, in the range of 2,000 to 4,000 MWe, will continue until the early 1990's, when some of the nuclear power plants currently under construction are expected to come on line (2). There appear to be only three ways which, used alone or in combination, would effectively meet this shortage:

1. Encourage strong conservation programs (much stronger than those now in effect);

2. Bring on line those alternative power plants that can be quickly constructed, e.g., combustion turbine or wind turbine driven electric power generators, or small hydroelectric additions; and

3. Perhaps import supplemental electric power into the region--if and when it may be available.

Combustion Turbines

It is my view that combustion turbine powered generators, fueled with methanol (CH_3OH) derived from Alaska coal, may prove to be both an economically and technically sound alternative to burning imported oil. The technologies, costs and management of combustion turbine powered generators are well understood. The equipment may be ordered by electric utilities, essentially as catalog items.

For example, the Puget Sound Power & Light Company was recently granted an exemption from the Fuel Use Act to use petroleum or natural gas as a primary energy source in two planned 81 MWe oil or gas fired combustion turbine peak load power plants in Whatcom County, Washington (3). These two power plants will be on line this coming spring. It is my further view that these two turbines may be only the harbinger of many more to come in the Pacific Northwest, much like those now being used on the East Coast.

I also believe that had coal derived methanol been available at a reasonable price, it would have been specified for the two Puget Power turbines. In fact, there is an almost automatic temporary exemption from prohibitions of the Fuel Use Act, which would allow new and existing power plants to use oil or natural gas pending availability of synthetic fuel.

Methanol

Methanol, being a simple hydrocarbon molecule without troublesome elements linked into it, has the attractive property of being very clean burning. Southern California Edison recently burned methanol for 500 hours in one of its existing natural gas fueled turbines, which is used for peak loading purposes. Particulates and

SO_2 emissions were found to be zero and NO_x was measured at 40 to 50 ppm (4), a very acceptable level under the requirements of the Clean Air Act.

All parts of the U.S. are subject to the Clean Air Act. Administratively, the most significant differences in application of the Act occur between areas where National Ambient Air Quality Standards have been attained, and areas where they have not.

In general, urban areas are "nonattainment" for one or more "criteria" pollutants,* which means that it is most difficult to obtain permits to construct new industrial facilities that have a pollution potential in such areas. These same urban areas have the heaviest electrical loads. Because of transmission loss and for reasons of reliability, electric utilities prefer to locate new generating facilities near such load centers.

It is in precisely these same urban areas that combustion turbine powered generators logically would be located, provided such facilities burn a clean fuel.

Aside from the requirements of the Clean Air Act, I am persuaded that the public will not willingly accept a major industrial fuel using facility any place in the coastal strip west of the mountains along the West Coast in the "Lower 48" states, unless it will burn a clean fuel. Methanol is such a fuel.

Proven Technology

The technology for producing methanol from coal is in commercial use. In general, the process calls for the gasification of the coal and then conversion to methanol with the aid of catalysts. In the process, pollutants such as ash, sulfur and heavy metals are removed. The resultant methanol is clean burning.

In support of the prospective use of this technology, in July, 1980 the Department of Energy awarded a $3.9 million grant to Placer Amex, Inc. and the Cook Inlet Native Corporation, Inc. to study the commercial feasibility of producing 54,000 BPD of methanol from Beluga coal.

Transportation

According to the U.S. Coast Guard, methanol may be transported by tanker or pipeline by using similar equipment and precautions used to transport gasoline. Therefore, it can be transported to conventional docks or tank farms. It can also be stored for rela-

*Sulfur dioxide, nitrogen oxides, total suspended particulates, carbon monoxide, ozone, volatile organic compounds (hydrocarbons), and lead.

tively long periods of time without deterioration. For example, methanol could be stored in tank farms near combustion turbine facilities during the off season, and drawn down during the peak usage period. The fact that methanol transport can make use of conventional transportation facilities and systems could translate into major savings.

Economic Situation

Our knowledge of the economics of the "Alaskan Coal to West Coast Kilowatts" concept is admittedly scanty, and preliminary at best. But, based on what we do know, I am optimistic that it could prove to be economically competitive in its own right. Should this be so, the other advantages of such a concept would be compelling reasons for use of private industry. We trust that the feasibility study just mentioned will provide specific answers to most of our economic questions. However, there are some alternatives, about which we do have good economic data, that may be used for indirect comparison.

The Washington Public Power Supply System has estimated in a 1979 study that new coal fired power plants and nuclear fired power plants would produce electricity at a bus bar cost of 51.3 to 62.0 mills/KWH, and 54.8 to 59.0 mills/KWH respectively in 1989 dollars (15).

The Puget Sound Power & Light Company has estimated that the cost of producing electricity using the combustion turbines previously mentioned, fueled with natural gas or oil, would be 63.3 and 72 mills/KWH respectively in 1980 dollars (16).

Based on the above, we estimate that methanol could directly compete with the Number 2 distillate fuel oil, which may be used in the Puget Sound Power & Light Company's combustion turbines, if the methanol could be produced and delivered to the combustion turbine site for $6.01 per million Btu or less in 1980 dollars. Current cost estimates for methanol production from coal range from approximately $3.25 to over $11.00 per million Btu, depending upon the location and capacity of the plant, the process used and the quality of the coal (7).

While we do not know the precise costs for transportation of methanol from Alaska to lower 48 markets, it appears certain to be less than transportation costs for coal. Further, it is expected that the Placer Amex/Cook Inlet Corp. feasibility study referred to earlier, and ongoing Maritime Administration studies will provide credible answers to methanol transportation cost questions. However, we must not lose sight of the fact that methanol is both clean burning and free from foreign control. Therefore, it could be competitive even at prices somewhat higher than OPEC oil prices.

Conclusion

Today I have discussed one possible scenario for the use of Alaskan coal. We need more concrete answers before we can definitely conclude that it is a viable alternative, but, conceptually, it has many things going for it. It is an example of the kind of coal using system that national policy supports. Presently, the U.S. Department of Energy is implementing this policy, in part, by funding industry directed feasibility studies, and by supplementing these studies with in house analyses of the socio-economic and technical issues.

As a Nation, we need to consider such options as "Alaskan Coal to Pacific Coast Kilowatts", recognizing that social and technological changes may suggest better choices tomorrow. In short, while there is no single technology that can be guaranteed to solve an energy problem today or tomorrow, I believe methanol has a bright future. The Nation needs initiative, enterprise and willingness to take risks--well-known characteristics of Alaskans--to help solve our energy problems and reduce our vulnerability to the political and economic policies of the oil exporting countries.

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Mining methods at Usibelli coal mine using dragline

Joseph Usibelli
President, Usibelli Coal Mine, Healy, Alaska

Since a lot of you are going to be visiting the mine tomorrow, I'm going to cover a couple of areas in our mining program that will need a little explanation before you get there; or that will not be readily apparent because of the time of year and are not current activities.

The areas I'm going to cover in detail are the use of the dragline and the planning thereof, and some of the reclamation work we do. Now our mine is located in a very beautiful area, with an abundance of wildlife and an occasional outcrop of coal. The start of the stripping sequence starts with the planning. Survey and geological work is done on the outcrops, followed by an extensive drilling program. There is a very extensive drilling program, logging of the holes, followed by plotting and engineering work, which results in cross sections. Our dragline is a standard of the industry and we've learned a few things.

Your planning has to be much more precise because you're very limited in scope. You're limited to the length of reach of the dragline and, therefore, you'd better have your ducks in a row before you get started or you're going to find yourselves in real trouble, probably spoilbound with dirt to move and no place to put it.

The purpose of the dragline is to move the overburden only. It does not handle the coal, contrary to what a lot of people have envisioned. It is strictly a method for moving the dirt. The way we do that is by making a cut, in this case a 4,000 foot long cut, approximately 100 feet wide, sidecasting the overburden. Cut number one starts with the original ground surface, taking that amount of overburden and sidecasting it.

Cut number two, which would be when you got into the next seam, would then place the overburden from the upper seam into the hole that you've already mined. Now, obviously, that means that you have to move the coal out of the way first.

Unfortunately, tomorrow we may not see the dragline in operation because we've come to the end of a pit. We have to shut down the dragline in order to get the coal out of the way, so that we can start back and take advantage of this hole. In some cases we have a little longer distance between number three and number four seams, so we actually took two cuts on three prior to getting to the four seam, We are starting back on our first cut of four seam at the present time.

With the dragline you're limited by the height it can dump, the depth it can dig and the distance it can dump out. These are the constraints that you have to design in.

Our initial work with the dragline was to cut an access slot which is used primarily to road network. The original outcrop parallels Lignite Creek. The first cut, obviously we don't have a nice straight edge to work with, and let me tell you it is nice to have straight pits with draglines. You definitely do not want inside curves, because you immediately run out of spoil room. We found that out the hard way. You are limited in your ability to straighten out these curves by how far you can reach maximum with a minimum of how much room you need to place the dragline. So your first cut on the high points, you would take a maximum reach, narrowing down on the others. Our solution at a very deep gully was to take overburden and actually construct a dam or a walkway across that, walk the dragline across and dig itself out behind it. We then continued on, roughly paralleling the surface, but with still a few curves in it.

By the time we get to our third cut back our pit will be straight. We are now at this point with the dragline moving the top cut. My crewmates surprised me a little bit. They may have moved that pole out of the way. Maybe we will be in production. I certainly hope so. I've been gone two weeks, so I'm not sure where things stand.

With a very mature pit we have the full depth of overburden. The top overburden is somewhat shallow. In actuality, when we get to a completely mature pit we will have a top overburden of about 150 feet in depth, approximately 20 feet of coal, 85 feet of interburden and 17 feet of coal. Now that is very deep for most surface mines: that's almost 300 feet of total pit depth.

Once these things are all laid out on paper, you go out into the field and stake the pits. That's followed by ditch preparation with tractors, blast hole drilling and loading of the holes. As a point of interest, now we're drilling 9 inch holes and we have the capability of going 120 feet. We use ammonium nitrate fuel oil mixture for our explosive. Each hole is primed with a high explosive primer, using primacord as a detonating agent. then filled with the ammonium nitrate. The truck carrying ammonium nitrate is licensed just like DuPont, because we buy fertilizer grade ammonium nitrate. It is mixed with fuel oil and becomes an explosive at that point.

These are then shot. The ground is leveled for the dragline, because draglines do not work very well on slopes. The overburden is then moved.

Figure 1 shows the sequence of operations in the mining system. When working from the top bench, removing the overburden above 4 seam, the dragline casts the overburden into the previous, adjacent cut where 3 seam and the 3-4 parting had been removed. The coal of 4 seam is removed and the the dragline ramps down to the lower bench. From this bench it removes the 3-4 parting above 3 seam, stacking it on top of the overburden just moved from above 4 seam. The coal of 3 seam is removed and vacates a place for the dragline to cast the next strip of overburden from above 4 seam.

The machine is self-propelled and obviously can't do all its digging from one place, so these machines do not work on crawlers, they are walking draglines. These shoes on the side are operated by cam mechanisms, which actually pick up the back of the machine and slide it back, a step at a time. The step is seven feet. It picks the machine up and repositions for the next step. It's not very fast, taking about 43 seconds to make a seven foot step, but it corners like it's on rails. Quite often the machine is used to prepare its own pad ahead; in this case you see it dumping on the pad. This is done in permafrost conditions. We remove the thawed permafrost and backfill with dry material. Actually, we use the bucket to help level the pad and then finish it up with a tractor. In most cases the overburden is sidecast into the previous hole.

The machine is electric and powered from this substation, getting 25,000 volt power out through this extension cord, which we call a trailing cable, at 6,900 volts, 6,000 feet of power cable to the machine. It really has only four functions. The hoist drum has two cables, paired, all cables are paired. These are 2 5/8 inch cables which lift the bucket. The drag drum positions the bucket laterally. There is a swing mechanism. Actually there are three of these units which control the rotation of the machine. Then of course, the fourth function is the walking. In normal digging, you're only using these three.

The machine is completely automatically lubricated. It is a fairly efficient machine. We find that we're getting about 2,000 cubic yards per hour when we're digging. We have averaged an availability of about 80% and a usage factor of about 80% of that. We're running almost 1,200 yards per scheduled hour. Now in order to keep that up you have to do some pretty intense maintenance. The largest area of maintenance is bucket repair. This thing is in the dirt all the time, and it wears itself out rather rapidly. As a matter of fact, we find we have higher wear rates than anywhere in the country, possibly in the world. We get as little as 600 hours of digging before we have to switch buckets. Fortunately we have two of them. This is a preventative type maintenance, repairing cracking and wear on the bottom of the bucket. We have a forklift that can handle the 47,000 pound bucket, positioning it in the shop where it is repaired by welders. We have one man, full time, doing nothing but welding on dragline buckets.

We also get a lot of wear in the chains and so we have extra sets of those, which are also constantly under repair. We have a

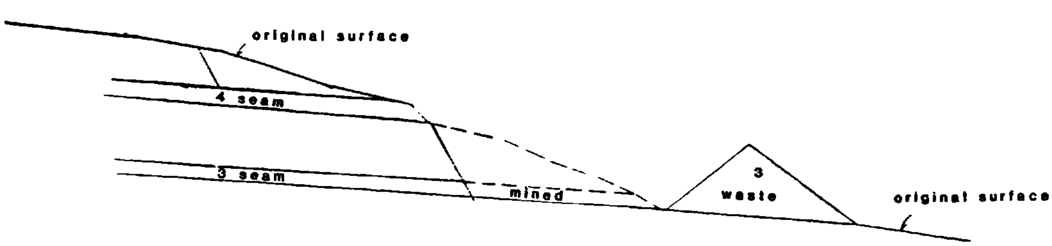

FIG. 1a) PROFILE SHOWING 3 SEAM MINED AND 4 SEAM HIGHWALL

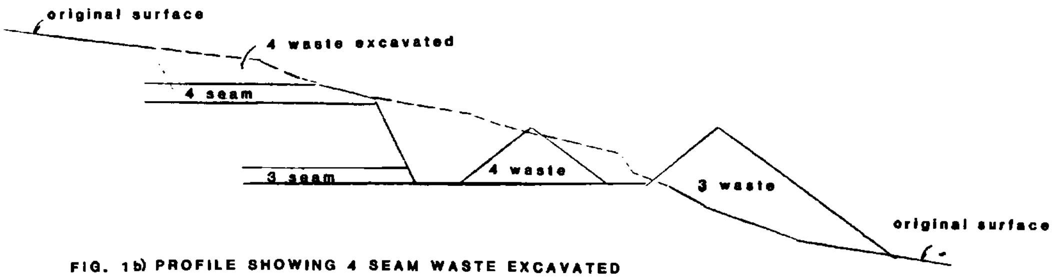

FIG. 1b) PROFILE SHOWING 4 SEAM WASTE EXCAVATED

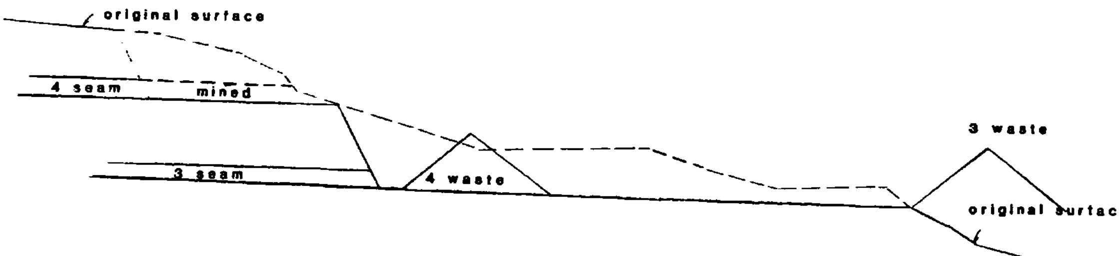

FIG. 1c) PROFILE SHOWING 4 SEAM COAL MINED

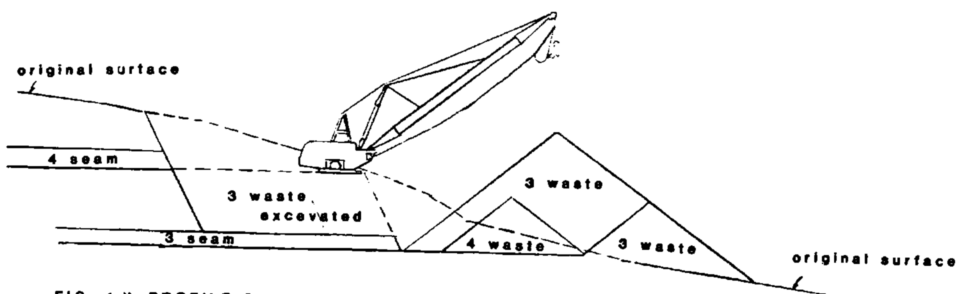

FIG. 1d) PROFILE SHOWING 3 SEAM WASTE EXCAVATED

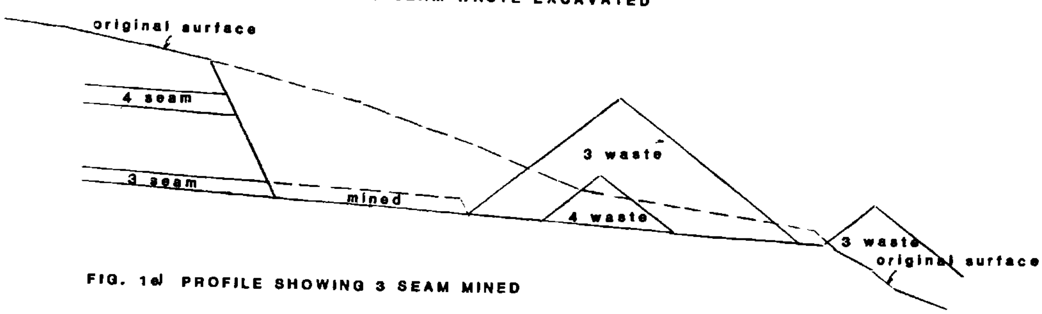

FIG. 1e) PROFILE SHOWING 3 SEAM MINED

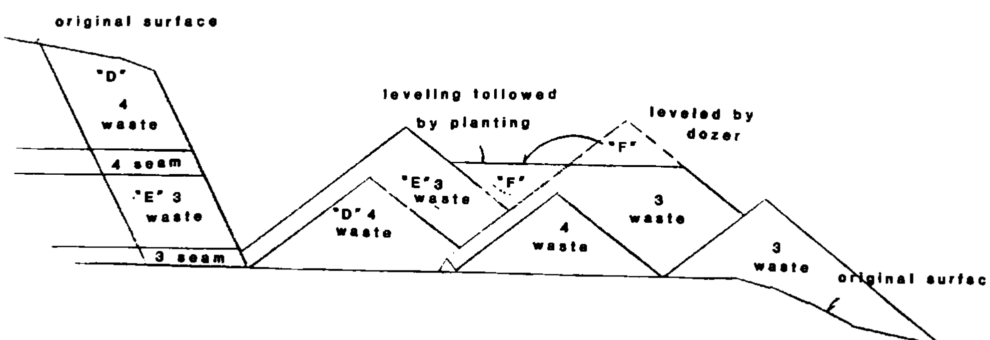

FIG. 1f) PROFILE SHOWING NEXT PROPOSED STEP TO SOUTH WITH RECLAMATION FOLLOWING

little bit of unscheduled maintenance. In one case we lost a bearing on one of the 1,300 horsepower drag motors, and this is just the brake assembly which had to be removed before the rotor could be taken out, trucked up in the lathe and the bearing ground off. It had welded itself to the shaft because of overheating.

After the overburden is removed and sidecast, the coal is exposed. It is loaded in the trucks by rubber tired front end loaders and hauled to our preparation plant, the tipple, as it is known in the industry. In this case we're hauling it over the top of a mountain, about a 40 minute round trip haul. We will soon have a new tipple, and I'll discuss that this afternoon. The coal is dumped in the tipple where it is crushed, crushed again, screened in this case, and loaded into rail cars for shipment to our customers.

Now we get into the portion of the reclamation which follows the stripping. The total reclamation starts from day one. You may have noticed in one of the early diagrams of the pit, we actually had the reclamation planned in there with the repositioning of the spoil, to leave the approximate original contours. We then seed it. Our reclamation has been rather successful (Figures 2a, 2b, 3a and 3b). The reclaimed areas are returned to the wildlife (Figures 4 and 5).

Thank you.

Figure 2a. Before (1977).

Figure 2b. After (1977).

Figure 3a. Before June 15, 1979.

Figure 3b. After August 25, 1979.

Figures 2 and 3. Effectiveness of new seeding of reclaimed land showing advance in growth in one season.

photo by Malcolm Lockwood

Figure 4. Caribou in Usibelli Coal Mine area.

photo by Malcolm Lockwood

Figure 5. Moose in Usibelli Coal Mine area.

Coal mining and exploration under permafrost conditions at Spitzbergen, 78° N

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Abstract

The annual mean temperature at Spitsbegen is -5°C (+23° F). Maximum thickness of the permafrost is 450 meters--almost 1500 feet.

Mining coal within the permafrost zone does offer some advantages. Most important is the improved mechanical behavior of the rocks in frozen state and the effect of this on roof stability. When mild air ventilates the mine during summer the stability of roof and walls is reduced. Under unfavorable stress conditions this effect may be noticeable as far as 800 m. from the mine opening.

When using conventional mining techniques, like undercutting and blasting, the dry environment of permafrost at the coal face is favored. With introduction of full face shearers and large drill rigs this changes. Such equipment requires very good dust suppression, that is to say a surplus of water right at the face.

Thus, modern mining in permafrost is faced with a major problem: how to deliver and use ample water at the face, and at the same time avoid clogging of wet coal enroute through the mine, or freezing at subzero surface temperatures.

There is no single solution to these problems, however, preheated ventilation air reduces some of them.

Special attention is given when mining in the region just below the permafrost. Pockets of Artesian water and methane may be encountered here.

Mapping of the coal reserves is severely hampered by the Arctic climate and rigid countryside. The sensitive environment also requires special considerations to avoid pollution and damage.

Picking surface samples, or samples from test adits, the effect of weathering must be considered. For sulfur, volatile matter and ash content this effect is measurable more than 50 m. from the surface.

Brine, diesel and heated water have been used as drill fluids. If the permafrost is less than 150 m., heated water may be the most economical. However, it requires absolutely continuous circula-

tion. Brines or diesel, preferably cooled below $0^{o}C$, offer greater flexibility. On the other hand, they are corrosive and polluting. Stabilizing muds, cement and fresh water/ice are used to stop large losses of fluid on fissures.

Horizontal, deflected wire line drilling have been tested. Using this method in the mine may replace surface boreholes through permafrost, and hence be advantageous.

The cost of mining and exploration in the Arctic is very high. The coal product must therefore have a favorable market value. Realization of this fact in mining means to emphasize uniform, stable production. In exploration, great efforts are made to predict mining feasibility and product quality at the earliest possible stage. One of the key factors in these assessments is the distribution of permafrost.

Introduction

At the Norwegian archipelago of Spitsbergen (Svalbard), two Russian and two Norwegian coal mines are in operation. These mines represent the northernmost industrial activity of the world (Fig. 1).

The mining was started by the American J.M. Longyear in 1906. Later several other nationalities began mining, but during the difficult economic times of the 1920s most settlements were abandoned.

Today the Russian company Trust Arktikugol ("Arctic Coal") employs 2200 people, and have a total annual production of 0.4 million tons from their two settlements, Barentsburg and Pyramiden.

Longyearbyen is the administrative center for the islands, and is also the center for the Norwegian mining company Store Norske Spitsbergen Kukkompani.

The total population of Longyearbyen is 1200. The annual coal production is 0.4 million tons.

50 km SE of Longyearbyen a new mine, Svea, is now being developed. Small scale production and larger exploratory works are carried out, while plans for a 0.25 million tpy production in 1983 are being considered.

There are several coal formations on Svalbard. However, only the coals from the Carboniferous period (north of Isfjorden) and the lower Tertiary in the central basin, are of any importance. The Tertiary coals represent the most promising reserves for the future, and they outcrop along the rim of the large central trough. So far explorations and mining have only been done along

Fig. 1 Svalbard (Spitsbergen) location of present coal mines

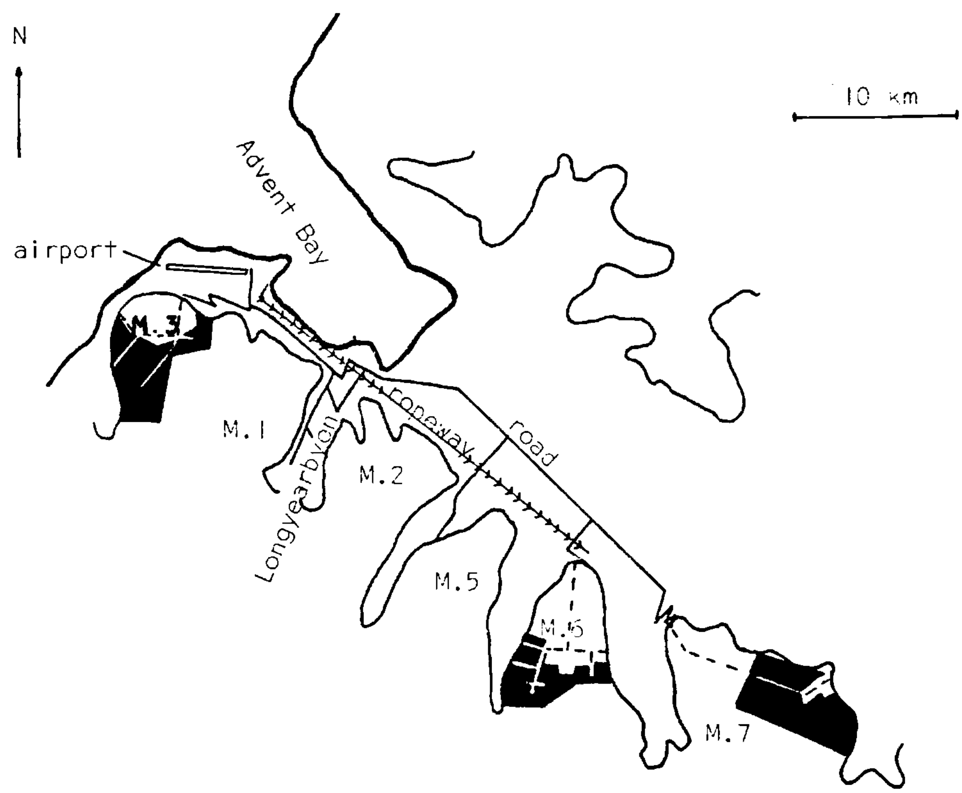

Fig.**2** Location of mines by Longyearbyen
Coal reserves in black.

the outcrop. The whole basin, and in particular the eastern part from Longyearbyen to Svea, has favorable conditions for coal.

There are five coal seams in Longyearbyen, but only one of them, the Longyear seam, has satisfactory thickness and quality for extraction. It is subbituminous with low ash and sulfur content, well-suited both as metallurgical coal and steam coal. The thickness varies between 0.8 m. and 1.8 m. The main seam at Svea has a maximum height of 5.5 m. with quality similar to the Longyear seam.

Climate

The annual mean temperature at sea level is -5°C. During summer the temperature rarely exceeds +15°C. At its coldest it may get as low as -45°C, but only for a few days. Precipitation varies considerably, in Longyearbyen it is less than 300 mm. (11.8 in.) per year.

In the mountains the permafrost goes down as far as 400-450 m. from the surface. In lower lying broad valleys the thickness is 100-130 m. On south facing slopes, covered by black shale, the permafrost is greatly reduced.

Glaciers, which cover 50% of the potential coal resources, also reduce the underlying permafrost.

During periods of somewhat milder climate, far-reaching frost actions took place. Fissures, now filled with frozen surface water, have been encountered 150 m. below present surface.

Today the only evident frost action takes place in the active layer of the permafrost. The thickness of this active layer varies from 0.5-1.5 m., depending on the type of vegetation and soil.

The coldest area of the ground, throughout the year, is found at 10 m. below the surface. The temperature here reflects the annual mean surface temperature.

Mining

The mines in Longyearbyen are drift mines, 150 to 500 m. above sea level (Fig. 2). Today the production of coal comes from mines 3 and 6. The seams here are 80 to 90 cm thick.

At the face only coal is extracted. This is traditionally done in a 3 shift cycle, each shift engaging 3 men. The first shift undercuts the coal bed and blasts the coal to a width of 1.5 m. along the total face length of 180 m. During the second shift, coal is scraped into mine cars in the crosscut. The scraper box is pulled back and forth along the face by a two drum slusher haulage winch. On the third shift, to complete the cycle, the steel friction roof supports are moved parallel to the advancement of the face.

From the crosscuts the mine cars are hauled to the mine portal by means of trolley locomotives. The main haulage roads and crosscuts are driven both in the seam and below it, so that the top of the mine car is level with the scraper boxes on the face.

In the gateroads roof supports are steel girders, wooden props and 2 meter expansion bolts. From the mines the coal is transported by ropeway and trucks to a dry cleaning plant. During the winter (Nov. to June) the coal is stockpiled. As long as the height of the stockpile is less than 8 meters, spontaneous combustion does not occur.

In Mine 7 the average thickness of the seam is well over 1 m. It is therefore possible to use mechanized equipment, and a face with hydraulic roof supports and shearer loader was installed in 1977. The productivity here is 50 t/ms, more than double that of Mines 3 and 6.

With a seam thickness of 1.5 to 5.5 m., work in the Svea Mine is also mechanized. Continuous miners are used and the coal is transported on rubber conveyor belts.

Mining and Permafrost

In Longyearbyen the mines are within the permafrost zone (Fig. 3), while the greater part of the Svea Mine is below the permafrost table (Fig. 4). In both areas the thickness of permafrost is 350-400 m., but the coal seam has a larger overburden in Svea than in Longyearbyen. These circumstances reflect one of the key issues for coal mining at Spitsbergen, whether to "fight" the permafrost, or to "exploit" it.

When using the traditional methods of production (Mines 3 and 6), the advantages of being within the permafrost are obvious, and probably vital to a successful mining.

If full face shearers are being used, or if the mining takes place below the permafrost table, the subzero temperature in parts of the mine is disadvantageous. When evaluating how the permafrost will effect mining, the following must be considered:

roof stability	dust suppression
dry conditions	coal handling
water drainage	gas accumulation

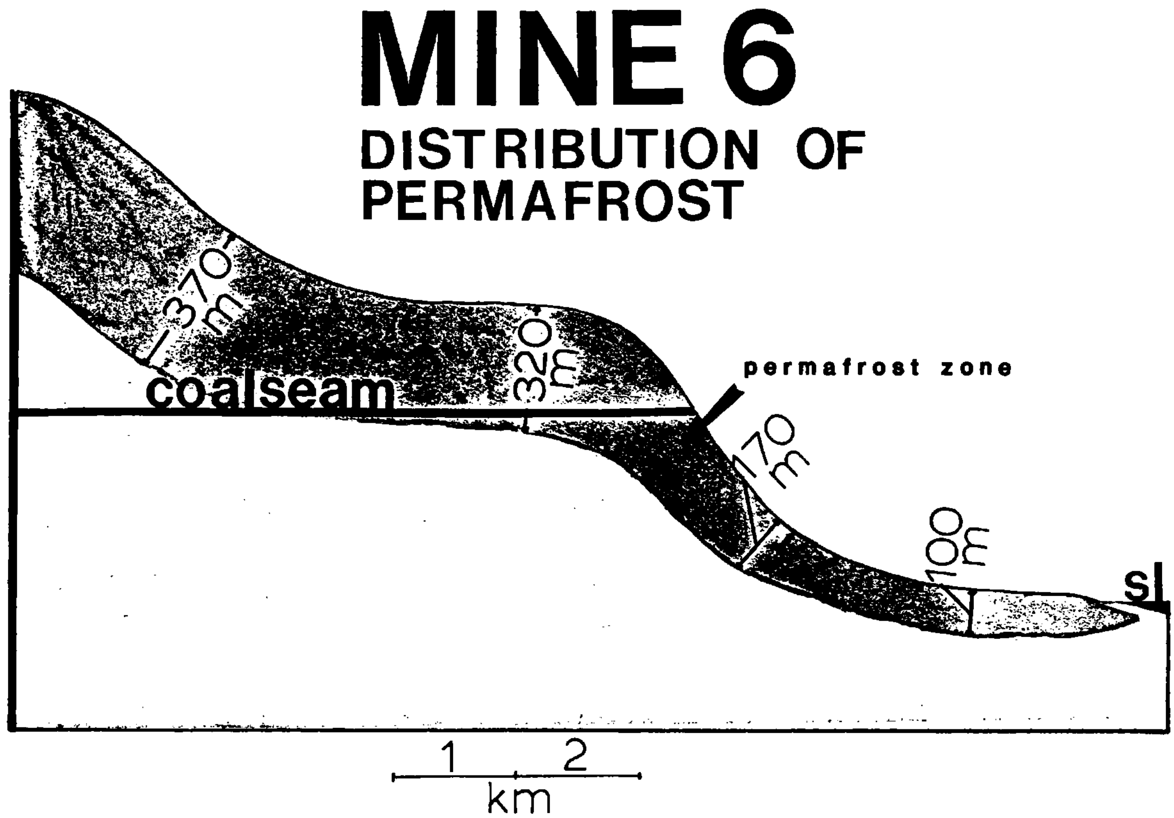

Fig. 3 Distribution of permafrost

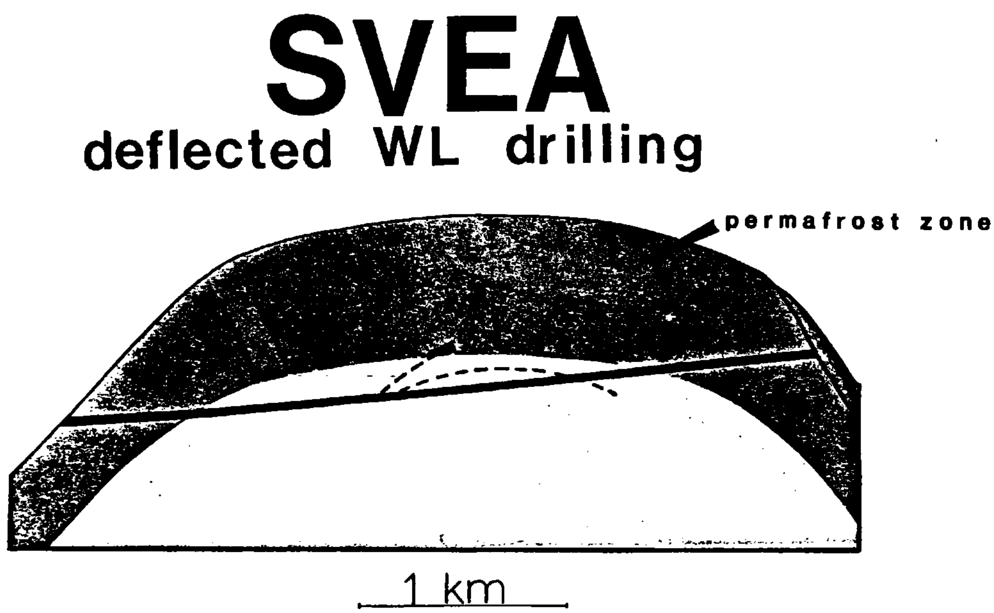

Fig. 4 Deflected WL drilling

Roof Stability

The mechanical strength of the rocks is generally improved in the frozen state. Partly this is due to a more uniform strain situation in the rock. In particular this is evident in soft shales. In the unfrozen state, they will crumble and disintegrate under pressure, e.g. under roof supports. However, when the rock is frozen, each thin layer of shale is held together by the frozen water, and the shale acts like one uniform, solid block of rock.

Stability of roof and walls is also improved because all water on fissures and joints is frozen. Thus, the ice hampers movement along fissures.

Consequently, the permafrost does improve the mining conditions to a great extent. However, one must bear in mind that this is a comparatively unstable condition. When mild summer air ventilates the mine, or in areas of heat sources like large motors or restrooms, the rock is constantly exposed to heat, and the permafrost recedes. The outer part of walls and roof will then achieve normal mechanical properties. Unless extra precautions are taken rockfalls will eventually occur.

The effect of ventilation in summertime may reach as far as 800 m. from the mine portal. Rebolting of the roof and picking off loose rocks on the walls are annual activities in this area.

Dry Conditions

Traditional mining requires that the men work in a kneeling position right at the face, and the method is laborious. It is rather obvious that a cool and dry climate is greatly favored among the men.

Admittedly, the equipment they use produces some dust, but this can be countered by wearing face masks. As far as possible, all workers position themselves so that the ventilation carries the dust away from them.

Where drilling in sediments over or under the coal is needed, e.g. roof bolting and driving of headways, all rigs are equipped with vacuum dust collectors.

Water Drainage

Below the permafrost zone very high water pressure develops as a form of Artesian well. The permafrost will act as a tight lid, giving rise to high pressure and rapid inflush of water in the mine. However, the permafrost will also prevent any surface water from sustaining the pressure, and within a few weeks the water pressure will have dropped considerably.

One problem is that the quantities of water may at first be very great, thus exposing the mining equipment, especially electric material, to far more water than it is constructed for. In general, the biggest problem is how to drain the water out of the mine. The best solution has been to use insulated double walled heated PVC pipes. These are easily put together, when and where they are needed. One particular problem using these pipes has been that they are not constructed for the great temperature differences experienced in the mine, where the outer tubing is at air temperature of -30°C, while the inner tubing has water running through at +0°C.

Dust Suppression

The measures in dealing with dust under dry conditions are not satisfactory when using mechanized equipment. This is presently the major concern of coal mining in the Arctic. The only way of suppressing the dust is to spray with water.

In order to keep the water consumption at the lowest possible level, the water may be "atomized" by mixing with high pressure air at the nozzle. The direction of the waterspray in relation to the rotating cutting bits is adjusted to give maximum effect.

Foam additives have not been tried, as there is uncertainty as to how they will react at low temperatures.

Introducing water to machines at subzero temperatures requires several precautions. To avoid ice forming in pipes and nozzles, the water may either be kept constantly flowing, or all pipes drained whenever circulation is stopped. In Spitsbergen the problem is approached by adding antifreeze solution to the water, and by heating the water. Thus, during brief stops for maintenance, etc. the water will not freeze. For standstills of more than several hours, all pipes are drained.

In the main supply pipe, water is kept constantly flowing in a closed circuit by having a thin return pipe back to the pump or reservoir.

Coal Handling

From a quality and preparation point of view, a constant drizzle of water or excess use of water for dust suppression is never ideal. When working in the Arctic, high moisture content causes more severe problems.

Whether the coal is produced within the permafrost zone or below that, the product must pass through this zone on its way to the surface. Run-of-mine coal consists of large percentages of both coarse and fine grain sizes. Moisture content above 6-8% will cause clogging or freezing of this mixture. However, to achieve satisfactory dust suppression, the dust must hold at least 10% "atomized" water. Consequently the degree of moisture has to be well balanced within narrow limitations.

Above ground the coal is exposed to air temperatures down to -40°C on its way to the preparation plant and during stockpiling. Coal cleaning in Longyearbyen is done by a dry air process. The yield of this process is considerably reduced if the coal is wet. For this reason a wet preparation process is now being proposed, both for Longyearbyen and at the new mine at Svea. This process will then require a thermal drier for the fines to bring the moisture below 7% before stockpiling. The coarser coal (+12 mm) may hold as much as 10% moisture without freezing, and thermal drying of this coal will probably not be required.

Gas Accumulation

The lower permafrost level acts as a trap for methane accumulation where an inclined coal seam enters the zone of permafrost. In Spitsbergen the gas concentrations are low, and advancing roadways through the lower permafrost level have not met with serious problems. However, in cases when gas concentrations are high, extra boreholes for gas ventilation may prove necessary in these regions.

Future Mining

Most of the coal reserves within the permafrost have now been extracted. Future mining will therefore be faced with the problem of mining both frozen and temperate rock.

Acknowledging this fact, the mine at Svea is now run with pre-heated ventilation. Using oil furnaces at the mine portal, the intake air is heated to at least 0°C. Furnace capacity is sufficient for air temperatures down to -30°C. By this means, mechanized equipment, dust suppression, wet coal and water drainage do not create any particular problems. The drawbacks are, of course, the cost of heating air, and the loss of stabilized frozen rock in roadways.

It is important to hinder the heat from gradually penetrating deeper and deeper in the walls. To achieve this, the walls are bolted using horizontal resin bolts made from oak. These bolts are somewhat flexible, but will keep loose blocks of coal in place. The part of the walls effected by thawing thereby act as insulation to prevent further penetration of the 0° isotherm.

Usually coal mining equipment is not manufactured for subzero conditions. To assess how new ideas will respond to lower temperatures is therefore one of the major considerations in planning. The need for a frost restraint emulsion for the hydraulic roof supports in mine 7 at -10°C, or resin components that would mix satisfactorily at -5°C, are illustrations of unexpected problems of this type.

Exploration

Quite a few factors determine the success of exploration in the Arctic. Difficult logistics, unstable weather conditions, rigid terrain and vulnerable flora and fauna that require special precautions all increase the costs of any program. Without doubt permafrost causes the main problems for any coal exploration at Spitsbergen. It effects core drilling and seismic surveys and has, so far, excluded any attempt at borehole geophysics. For trenching or small adit workings the permafrost represents both advantages and drawbacks.

Core Drilling

One of the most important intentions when drilling through permafrost is to keep the wall of the borehole frozen. This will keep ice filled fissures stable, and wedging is not likely to occur. At the same time, with most fissures closed great losses of drilling fluid are reduced.

To maintain the stable permafrost in the wall it is necessary to use brine (salted water) or other liquids with freezing point below the lowest temperature in the ground, i.e. -8°C. Any such available liquid will be a polluter, toxic and corrosive, and is therefore not very desirable. To realize their full effect, those liquids should also be kept below zero on entering the ground. This is not always easy to accomplish.

Thus, more than 50% of the boreholes at Spitsbergen suffer from great losses of drilling fluid (Fig. 5). To sustain a proper fluid composition may become a major challenge when everything has to be air-lifted to the drill site.

In this situation it is tempting to use heated water rather than brine. This could cause wedging, although in fairly soft but stable sediments this can be avoided. However, more severe problems will occur if, for any reason, the circulation is hindered. As Fig. 6 shows, the temperature curve for water is satisfactory for drilling short holes (150 m.). Indeed, when drilling short

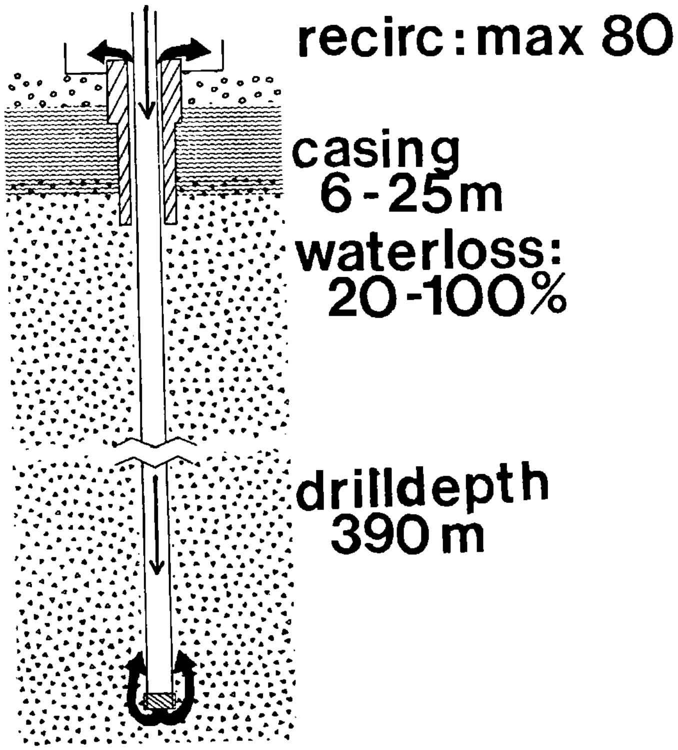

Fig. 5 Technical values from core drilling

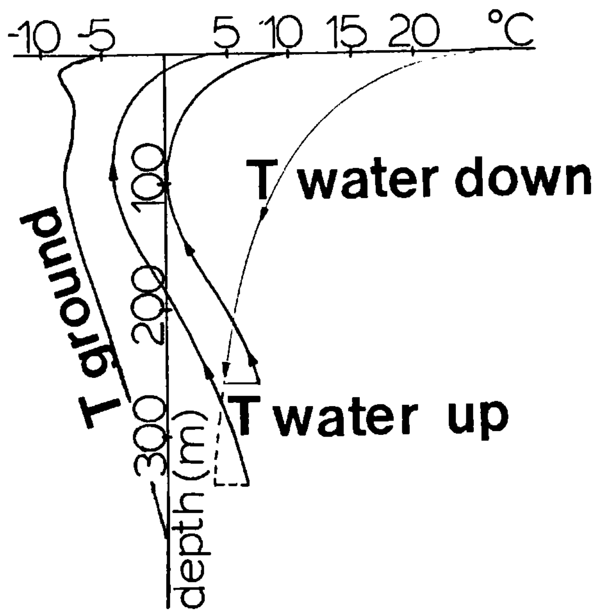

Fig. 6 Temperature curve for ground temperature and fluid temp at different drill depths

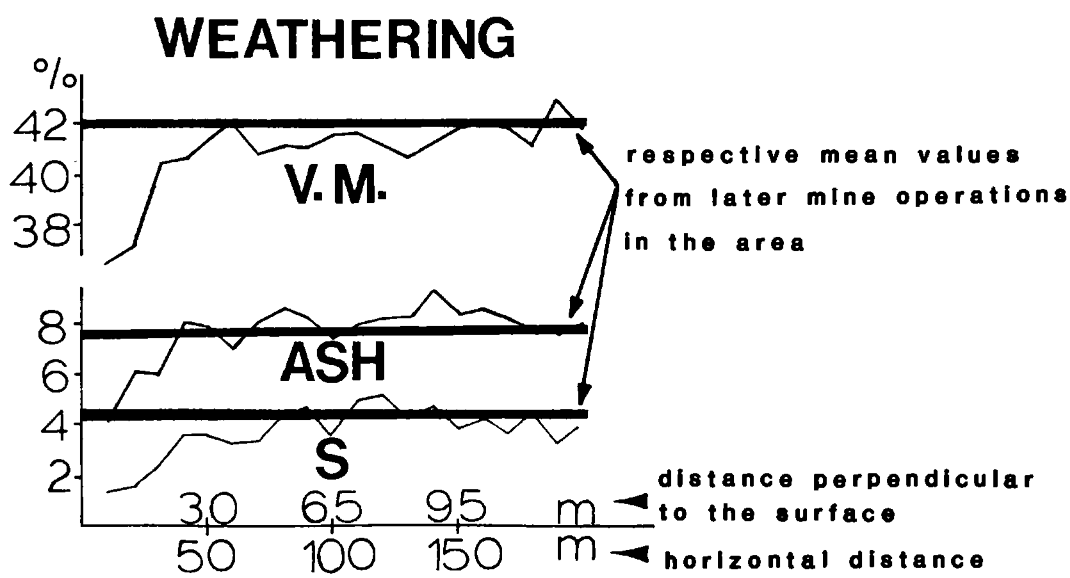

Fig. 7 Effect of weathering on outcrop samples from adits in coal

holes, heated water may be the most economical provided there is great awareness from the drillers, and sufficient back up equipment if any vital part fails.

However, as the hole gets deeper the water is cooled more, and eventually reaches subzero temperature. If circulation is stopped, instant freezing will occur. One particular deceiving factor in this picture is heating of the returning water close to the surface, caused by the warm water entering the borehole. There is, therefore, no way the driller can keep control; quite often it happens that the rods suddenly are stuck.

The selection of drill sites is important. Quite often a satisfactory water supply, expected shallow overburden and environmental and logistic considerations are more decisive factors than the optimal geological grid pattern. If at all acceptable, locations close to creeks or on the brinks of small gorges are chosen. However, these are the areas where one might expect to encounter high pressure water and gas below the permafrost.

Great losses of drilling fluids have successfully been reduced or stopped by using A1 cement, commercial muds or even fresh water/ice. In the latter case the ice is cored, and whatever is left on fissures will keep walls tight for a short while. If it is a question of completing the last 20-30 m. of the borehole, using ice is an inexpensive and easy method.

Wire line drilling has been tested. Due to the slower penetration for the first critical 300 m., and larger fluid requirements to obtain the same core diameter (46 mm.), this technique is not desirable at Spitsbergen.

Seismic Surveys and Borehole Geophysics

The first attempt to apply high resolution seismic surveying at Spitsbergen was done last summer, and an assessment of the method is not complete. However, the lower level of the permafrost and the subsoil, and the active layer on top are expected to cause great problems. In order to obtain the necessary accuracy in the reflected signal, high frequencies are used. It is not possible to transmit these frequencies with very high energies, and most of the signal may be absorbed in the upper layers.

Geophysics in the borehole will probably function satisfactorily. On the other hand, due to the permafrost the chance of retrieving equipment lowered down into the borehole is not good, and no tests have been carried out.

Trenches and Adits

Besides core drilling, trenches and adits made along the outcrop of the seam are the major exploration methods.

Working the adits during spring or autumn makes it possible to take advantage of the stabilizing effect of permafrost without severe thawing due to ventilation.

The weathering of frost action can be seen both in proximate and ultimate analysis (Fig. 7). Inorganic as well as organic sulfur and the ash content are all reduced by 30% in the outer part of the adit. Measuring the distant perpendicular to the surface, the effect can be seen more than 50 m. from the surface.

Volatile matter and calorific value are effected as far as 100 m. from the surface.

Exploration Future

Three different concepts are now being considered:

1) Taking more careful note of the available results from coring and adits.

2) Larger, heavier equipment.

3) Wire line deflected drilling from the mine.

The first of these points is rather obvious. It is, however, also true that the many technical problems due to permafrost and Arctic conditions tend to dominate the geological results of exploration. Accurate core logging, and all kinds of sample analysis and interpretations can hardly be more justified than in the Arctic, where every coal sample is collected under considerable strain. Consequently, different approaches to correlative analysis of trace elements, core logging and quality are being tried.

Larger, heavier equipment would in many instances perform better compared to what is now being used. However, there are logistic, environmental and financial considerations to be made.

In most cases the chances of success are better with larger equipment, but the amount of work accomplished in one summer season is reduced.

Deflected wire line drilling has been tried at Svea (Fig. 4). For local exploration within 600 m. of advancing headings this method will be used extensively. The method offers two great advantages: work is done underground, thus no climatic problems; and the drillhole is below the permafrost, thus no fluid problem, so water can be used. The most serious problem encountered when the method was tested was the rod pulling and pushing. No diamond drill rig has so far been made for use in long inclined pushes. However, due to the problems when drilling from the surface, and because modern equipment requires more complete and advanced planning, it is hoped to solve this problem soon.

Conclusions

There are satisfactory solutions to most of the problems caused by the permafrost.

The traditional method of mining at Spitsbergen has been to "exploit" the frozen ground. However, with the introduction of mechanized equipment dust problems become more serious. Consequently, water has to be used, but only to a limited degree.

Below the surface, preheated ventilation seems to offer a fairly complete solution to many different problems, but also causes new ones.

The move towards modern equipment coincides with the extraction of the last coal reserves solely within permafrost. As mining continues in areas below the zone of permafrost, water and wet coal will be major daily considerations. Even in areas below the permafrost the temperature will still be fairly low, and not all equipment is readily adaptive to these environments.

With production moving further underground, so will the exploration tasks, with more emphasis put on core drilling. This is a technique severely hampered by permafrost. For deeper holes drill fluids must be of types with freezing point below 8°C, but these normally have properties undesirable for the equipment and the environment.

In local exploration and in early planning for production, deflected wire line drilling underground will play an important role.

Soil characterization of Alaskan coal mine spoils

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Introduction

Reclamation of surface mined land requires close attention to spoil manipulation for optimizing the establishment of vegetation. Approaches include topsoiling, mulching and surface manipulation, which is aimed at increasing moisture status, water infiltration, tilth and nutrient availability and retention. Topsoiling is highly desirable but is not feasible or practical in all situations. Thus, plant must be established in spoils made up of a wide range of mixtures of coal and overburden materials.

Selective versus random placement of overburden materials during mining operations generally results in greater benefits for future land use (8). However, even with selective placement by mine operators, overburden materials deposited on the surface will be largely devoid of organic matter, and deficient in certain essential plant nutrients. Additional characteristics may include low moisture and nutrient holding capacity, poor tilth, compaction, the presence of phytotoxic substances and other physical and chemical characteristics which may inhibit biological growth.

Problems with coal spoils and overburden materials elsewhere in the U.S. range from general nutrient deficiencies to severe toxicities, as well as physical soil problems due to dispersive effects of high exchangeable sodium concentrations. In the eastern part of the nation, spoils from high sulfur coal are acidic and often result in aluminum and heavy metal toxicity to plants (1). In the arid west there are saline and/or sodic spoil materials; without some method of amelioration, they result in specific ion toxicity or general salt (osmotic) effects on plant growth (3, 7). Nutrient deficiencies frequently include nitrogen (N), phosphorus (P) and sometimes potassium (K). Secondary nutrients, calcium (C), magnesium (Mg), sulfur (S) and micronutrient deficiencies are less common in revegetation trials.

Very little information is available on the physical or chemical properties of Alaskan coal spoils and overburden materials. Alaskan coal is generally low in sulfur content; therefore, sulfur oxidation and resultant acidification of spoil material should not be a major problem. Climatic conditions at locations of immediate interest would not generally be considered conducive to accumulations of excess soluble salts. However, local incidence of salt accumulation and high sodium in substratum materials cannot be ruled out.

Knowledge of the chemical and physical nature of the spoil and undisturbed overburden is essential in predicting its suitability as a growth medium, in determining necessary ammendments for plant establishment and for initiating and sustaining the soil forming processes.

Methods and Procedures

Preliminary sampling of spoil and overburden material was initiated in the summer and fall of 1979 at the Usibelli Mine at Healy, at the Capps Lease in the Beluga field, at an abandoned strip mine in the Matanuska Valley near Sutton, and at an abandoned site at Meade River. Composite samples were taken to a depth of 15 cm at all locations. At Healy, in situ overburden material was sampled down to the coal seam.

All samples were air dried and sieved through a 2 mm stainless steel screen. Chemical analyses were performed according to methods recommended for mined land spoils and overburden in western United States (6) and according to methods used for soil testing (2). These included extraction of ammonium and nitrate ions (NH_4 and NO_3N) with 2N potassium chloride and analysis using a Technicon Autoanalyzer. Potassium, calcium, magnesium and sodium were extracted with 1N ammonium acetate (NH_4OAc) and determined using atomic absorption spectroscopy. Phosphorus was extracted using a Bray P-1 solution and analyzed on the Autoanalyzer.

Micronutrient cations were extracted with DTPA-TEA buffered to pH 7.3 and determined by atomic absorption. Saturation extract analysis involved saturating a 200 g soil sample with deionized water, and extracting the soil solution under vacuum. Total soluble salts (E.C.) were measured with a Beckman conductivity bridge, and soluble cations were determined by atomic abbsorption. The sodium absorption ratio (SAR) was calculated by the modified Gapon equation:

$$SAR = (Na) / \sqrt{\frac{(Ca \pm Mg)}{2}}$$

where sodium (Na), calcium (Ca) and magnesium (Mg) concentrations are expressed in meg/1.

Results and Discussion

Extractable nutrient concentrations in surface spoil material at five sites are given in Table 1. Values reported are the means of three or more samples.

The Healy A site was exposed substratum material overlying a coal seam but containing no coal, while the Healy B site was from a spoil bank containing significant amounts of coal and shale material. The Sutton site was a relatively old (perhaps 15 years) spoil bank containing appreciable amounts of both coal and shale material. The Beluga site represented recently disturbed and shallow overburden material containing little coal or shale. The Meade River sampling was from an abandoned disturbance of unknown age and had a high shale content.

Spoil (pH) ranged from 5.5 at Beluga to 8.3 at Sutton. The lower end of this range at Beluga would indicate a serious acidity problem, and sulfur content of the coal in the Beluga field (approximately 0.2%) should not adversely affect pH. The high pH at Sutton could adversely affect availability of phosphorus and certain micronutrients; field studies currently underway should confirm or deny this possibility.

Extractable nutrient concentrations would indicate probable growth response to nitrogen, phosphorus and potassium fertilizer application at most of the sites tested. Soil test calibration work on agricultural soils indicate probable response to phosphorus when Bray extractable phosphorus is less than 10 ppm. All sites except Meade River fall in that category.

Similarly, growth response to potassium application has been observed on Alaskan soils when exchangeable potassium levels fall below 50 ppm. Both Healy sites and the Beluga site are definitely marginal with respect to potassium supply. Soil test nitrogen is more difficult to interpret because of its many forms and high mobility in the soil. However, Healy A. Sutton and Beluga are clearly deficient in both the ammonium ion (NH_4^-) and nitrate (NO_3^-N). Healy B and Meade River sites demonstrated relatively high ammonium levels and slightly elevated nitrate levels. Overall, the Beluga and Healy A sites were least fertile and should show response to a complete N, P, and K (nitrogen, phosphorus and potassium) fertilizer. The other sites will perhaps show less response to one or more nutrients, but will require some level of fertilization. Optimum application rates and N, P and K ratios must await results of field trials which are now underway. Calcium and magnesium levels were adequate on all sites with the possible exception of Beluga, which demonstrated a very low exchangeable magnesium level. The unusually high magnesium level at the Healy A site, in combination with marginal potassium levels, could interfere with potassium uptake by plants.

Saturation extract analysis (Table 2) showed a range in soluble salts from 0.05 to 2.90 mmhos/cm. While the upper value would be considered high for surface soils in Alaska, it should not affect plant establishment or growth. Sodium levels ranged from 0.21 to 6.13 meq/1; however, as sodium increased, concomitant increases in calcium and magnesium resulted in sodium adsorption ratios (SAR) well below levels that would cause serious soil physical problems (9). High pH at Meade River are explained by relatively high CO_3 levels, indicating the presence of free calcium and magnesium carbonates. The even higher pH at Sutton would appear to be controlled by a HCO_3 system. High spoil pH and the presence of free carbonates raises serious questions with respect to the availability of phosphorus and certain micronutrients. Micronutrient metal cations such as zinc, manganese, copper and iron are involved in complex chemical reactions in the soil, which affect their availability; one characteristic common to all is that their concentration in the soil solution decreases with increasing pH and concentration of free carbonates (4).

The chelating agent diethylenetriaminepentaactic acid (DTPA) has proven an effective extracting solution for assessing the availability of micronutrient cations in the soil (5). Concentrations of DTPA extractable zinc (Zn), manganese (Mn), copper (Cu) and iron (Fe) along with an interpretive guide are given in Table 3. With the exception of zinc at the Healy A and Beluga sites, all locations exhibited trace metal concentrations in the "adequate" range. Generally, the values reported are equal to, or greater than, those obtained on a wide range of agricultural soils in Alaska.

In view of this, and of the fact that micronutrient deficiencies have not been documented for forage grasses in Alaska, it is unlikely that micronutrient deficiency will be a major problem in mine spoil revegetation.

Additionally, these preliminary results would not indicate problems of metal phytotoxicity or accumulation of metals in plant tissue that might be toxic to wildlife. Field trials are currently underway to test for possible zinc response in barley at Healy and zinc, manganese, copper and iron response in barley at Sutton site.

Since spoil materials are often a heterogeneous mixture of overburden strata, it is desirable to know the chemical characteristics of these horizons as they occur in situ before the mixing process takes place. Samples were taken with depth down to a relatively shallow coal seam in the Lignite Creek area at Healy. Results of these analyses are summarized in Tables 4 and 5.

The primary differentiation with depth occurred between upper soil horizons and the underlying alluvial parent material. Finer soil texture and presence of organic matter are reflected in the higher cation concentrations in the upper soil horizons. These generally decreased with depth. Phosphorus concentrations increased with depth, probably in response to a lesser adsorption and fixation capacity in the coarser textured alluvial deposits. Extractable nitrogen concentrations were unaffected by depth. Saturation extract analysis (Table 5) showed no zones of salt accumulation, nor sodium adsorption (SAR) values that would be detrimental to the establishment of plants in these materials.

Anticipated problems with a mixture of these materials would be infertility and certain physical problems related to low water holding capacity of the coarse textured parent material. Additional *in situ* sampling of overburden materials was made in 1980 at Beluga, however, analytical results are not yet available.

The preliminary sampling for overburden characterization was restricted to sites (with the exception of Meade River) where revegetation studies are currently underway. In addition to providing background information, these data will be used to determine initial amendment treatments in the revegetation work. The data presented is representative only of the sites thus far sampled. Because of the heterogeneous nature of coal spoil materials, and because of variations in soils, climate and geologic formations between locations within the state, chemical characteristics far different from those reported here are possible.

Summary

Coal spoil and overburden materials from existing and potential strip mining sites were characterized for chemical properties. The Alaskan spoils were generally found to be infertile with respect to the major plant nutrients sodium (Na), phosphorus (P) and potassium (K). With the possible exception of magnesium (Mg) at Beluga, the secondary cations, calcium (Ca) and magnesium appeared to be at satisfactory levels. Of the micronutrient cations zinc (Zn), copper (Cu), manganese (Mn) and iron (Fe), only zinc at one Healy site was marginal according to DTPA soil test values. High acidity (pH) values at Sutton, however, may limit plant availability of one or more of these nutrients. Soil reaction at all sites was above the level normally associated with aluminum and manganese toxicity. No elevated levels of manganese were observed in DTPA soil tests. Saturation extract analysis showed no potential for high levels of salt or sodium accumulation. Sodium adsorption ratios were below the range commonly associated with poor soil structure and resultant effects on plant growth.

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Alaska surface coal mining study – Public Law 95-87

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Authority and Objectives

The authority for the Alaska Surface Coal Mining Study is Public Law 95-87, August 3, 1977, 95th Congress, known as the "Surface Mining Control and Reclamation Act of 1977". This Act is to provide for the cooperation between the Secretary of the Interior and the states with respect to the regulation of surface coal mining operations, the acquisition and reclamation of abandoned mines and for other purposes. Section 102 of the Act states the 13 major purposes of the Act and these may be summarized generally as making surface coal mining compatible with society and the environment; to reclaim mined areas as soon as possible; to obtain a realistic working approach involving environmental protection, agricultural production and the need for coal, and to give information for the basis of formulating effective and reasonable regulations for surface mining operations.

The specific reference for the Alaska study is in Title VII - Administrative and Miscellaneous Provision, Section 708 "Alaskan Surface Coal Mine Study". This section states:

Alaskan Surface Coal Mine Study

Sec. 708. (a) The Secretary is directed to contract to such extent or in such amounts as are provided in advance in appropriation Acts with the National academy of Sciences - National Academy of Engineering for an in depth study of surface coal mining conditions in the State of Alaska in order to determine which, if any, of the provisions of this Act should be modified with respect to surface coal mining operations in Alaska.

(b) The Secretary shall report on the findings of the study to the President and Congress no later than two years after the date of enactment of this Act.

(c) The Secretary shall include in his report a draft of legislation to implement any changes recommended to this Act.

(d) Until one year after the Secretary has made this report to the President and Congress, or three years after the date of enactment of this Act, whichever comes first, the Secretary is authorized to modify the applicability of any environmental protection provision of this Act, or any regulation issued pursuant thereto, to any surface coal mining operation in Alaska from which coal has been mined during the year preceding enactment of this Act, if he determines that it is necessary to insure the continued operation of such surface coal mining operation. The Secretary may exercise this authority only after he has (1) published notice of proposed modification in the Federal Register and in a newspaper of general circulation in the area of Alaska in which the affected surface coal mining operation is located, and (2) held a public hearing on the proposed modification in Alaska.

(e) In order to allow new mines in Alaska to continue orderly development, the Secretary is authorized to issue interim regulations pursuant to section 501(b) including those modifications to the environmental standards as required based on the special physical, hydrological and climatic conditions in Alaska but with the purpose of protecting the environment to an extent equivalent to those standards for the other coal regions.

(f) There is hereby authorized to be appropriated for the purpose of this section $250,000: provided that no new budget authority is authorized to be appropriated for fiscal year 1977.

Study Committee Procedure

The National Academy of Science and the National Academy of Engineering, through their Board on Minerals and Energy Resources, appointed a committee composed of 16 persons recognized for their professional competence in associated disciplines. Seven members were from Alaska and others had considerable Alaskan experience. Disciplines included permafrost, agriculture, coal mining, mining consultants, State and Federal agencies, forestry and wildlife management, environmental concerns, economics, biobehavioral sciences and earth sciences.

The committee had a number of meetings, two of which were in Alaska. Members viewed the Usibelli Coal Mine operation in subzero temperatures in February of 1979, and later visited and viewed the Beluga field, the Matanuska field and coal outcrops on the North Slope. Many consultants, including Joe Usibelli and staff, Cole McFarland of Placer Amex, and other knowledgeable people from Alaska and from other states provided the committee with realistic pertinent information on topics such as Alaskan coal mining, Alaskan physical and socioeconomic characteristics, land laws and regulations and environmental concerns. Discussions with North Slope Borough personnel at Point Barrow were included on coal mining, the environment and subsistence hunting.

Using this information and their background knowledge, members of the committee prepared reports on subjects in their areas of competence. An editorial committee did an outstanding job of consolidating the material into the final draft report. This final draft had the approval of the members of the Study Committee. The report was then sent to a group of specialists in the disciplines for individual review, their comments were rceived and incorporated in the report by the Editorial Committee. The final report was submitted to the National Research Council for review and was approved by the Governing Board of the Council. Excellent staff support for the entire project was received from the staff of the Academies. Publishing of the report is now underway and hopefully a limited number of copies will be "off the press" within the next two weeks!

The channel of communication as visualized is that the report will be transmitted to the Secretary of Interior for his consideration, and then recommendations will be made to Congress.

Basic Considerations

The committee recognized a number of basic points as it developed its report, which has since been reprinted by the Mineral Industry Research Laboratory, University of Alaska, Fairbanks. These included:

1. The vast coal resources in Alaska which may well be equal to those of other states in the Nation.

2. The great and increasing importance of coal in the nation's energy picture of the present and future.

3. The need for appropriate consideration of environmental conditions, reclamation and pollution.

4. The large size of Alaska (1/5 the United States), and the wide variety of natural conditions which have a great bearing on coal mining and reclamation, and which are considerably different than those in the other states.

5. Some of these conditions are unique to Alaska because of the extreme northern latitude, and some occur more often than in other states and are more severe.

6. Such conditions include:

a) Permafrost occupying about 3/4 of the state's land area;

b) Tundra vegetation occupying large treeless regions of the state;

c) Extremely cold weather and short summer season in many parts of Alaska;

d) Hydrologic conditions that are considerably different than in the other states;

e) Much of Alaska's coal is low in sulfur;

f) Major streams fed by heavily silt laden meltwater from glaciers that contain sediment load concentrations greater than efficient discharge limits permitted under Federal regulations for coal mining;

g) The location of some coal deposits in areas subject to frequent earthquakes (Beluga);

h) The need to consider three different regions within Alaska because of the great differences in natural conditions. These, as established by the committee, are:

(i) The Arctic Region (North Slope) (with vast coal resources, continuous permafrost, tundra vegetation, long periods of severe cold, limited daylight in winter and limited water supply).

(ii) The Interior Region, which lies between the Brooks and Alaska ranges (with modest coal resources, discontinuous permafrost, tundra and boreal forest vegetation, severe winter weather, summer and winter extremes in temperature and limited ground water supplies).

(iii) The southcentral region, south of the Alaska Range (with large coal resources, generally free of permafrost, tundra and boreal forest vegetation, generally ample ground water supplies, moderately cold winters and warm summers, and some areas subject to seismic risk).

7. Socioeconomic and Environmental conditions that are different in Alaska than in other states, including:

a) Subsistence aspects of the economy of many Native Alaskans;

b) Limited surface transportation systems.

(i) Desire of some to restrict access to coal areas.

(ii) Difficulty of constructing roads in permafrost zones.

c) Division of land ownership among Federal, State and private ownership.

8. The realization that overall the law did not seem to be as unreasonable as the regulations that came from the laws.

9. That flexibility must exist in procedures to accomplish overall intent because of the wide variation of natural, socioeconomic and environmental concerns and conditions.

10. The inadequacy of scientific data about much of Alaska to comply with permit requirements, and the relatively limited experience of surface coal mining and reclamation in parts of the state.

11. The Commitee considered Alaskan conditions from the broad viewpoint of potential increase of coal development and production, and not of production limited only to local use.

Report Format

The organization and content of the report is described in the report as follows:

"The report begins with a summary that presents the essential findings and recommendations of the Committee. Chapter 1 provides background information on the objective of the study and the procedures used to carry it out; an overview of unique or unusual environmental conditions in the major coal bearing regions of Alaska; and a brief history of mining in Alaska, from both an environmental and socioeconomic perspective. Chapter 2 describes the geography and geology of the coal bearing regions of the State. Chapter 3 discusses the environmental, socioeconomic and regulatory conditions that have a special bearing on coal mining and reclamation in Alaska. As a matter of convenience, these conditions and some relationships among them are described under separate headings. Combinations of conditions, and especially fluctuations of conditions between summer and winter, may have a far greater impact on coal development in Alaska than any one environmental factor by itself. This discussion, together with an understanding of conditions analogous to those in the conterminous United States, provides the basis for analysis of the Act's suitability for Alaska and for suggestions with respect to alternative approaches to control surface mining and reclamation in the State. Chapter 4 discusses criteria for evaluating the Act. Chapter 5 analyzes the suitability of the Act for mining and reclamation conditions in Alaska, and suggests alternative procedure for dealing with these conditions. The text is followed by an annotated Bibliography of selected references on Alaska.

Appendix A analyzes the provisions of the Act for their applicability to Alaska and suggests where the Act may need to be modified for Alaskan conditions. Appendix B discusses Federal, State and local law for control of the environmental and general health and safety impacts of coal mining in Alaska. The information was obtained from a comprehensive review of the pertinent laws and from interviews conducted primarily in Alaska with persons concerned with the administration of these laws.

Following the appendices is a Glossary which includes, in addition to technical terms, a description of commonly referenced legislative acts and regulatory bodies."

Summary of Findings & Recommendations

The summary of the report presents both main findings and then principle recommendations. Each finding and recommendation is referenced to the pertinent sections of the report for more detailed information. In addition, a table is presented that relates the recommendation to specific Alaskan conditions as well as to specific provisions of the Act.

The summary of findings and recommendations are stated on about 17 pages and consequently cannot be stated in a meaningful way in this presentation because of lack of time.

My further consolidation of the summary of the findings are that unique conditions exist in Alaska and create special problems for coal mining and reclamation. These conditions include: climate, permafrost, hydrology, wildlife, geologic hazard, geographic diversity of Alaska for three major coal basins, limited coal mining and reclamation experience in some areas (North Slope), unique Native economy, low population - large area, lack of a sophisticated transportation network, influx land status, and understanding of acceptable post mining land use.

Again a consolidation of the summary of major recommendations given are:

1. Appropriate standards for mining and reclamation are yet largely to be defined, but can be expected to vary in the three major geographic coal areas. Thus, on the North Slope, much is to be learned about acceptable mining of coal; however, private industry, if given a variance for a commercial mining operation, could provide a considerable amount of information about mining and reclamation technologies in arctic areas.

2. Regulations pertaining to hazard and nuisances such as that of blasting should exercise levels of control appropriate to local or regional conditions. The same overall thought applies to wildlife and water discharge regulations.

3. Designation of prime coal lands to prevent their being classified as lands precluding mining. Such classifications would prevent development of a major energy resource important to the State and Nation.

Use of the Report

1. Basis for information and recommendations by the Secretary of the Interior to Congress to allow a dynamic coal industry to develop in Alaska in an environmentally acceptable manner.

2. A source of pertinent Alaska physical, socioeconomic and environmental information for numerous other affiliated reports being prepared.

3. Hopefully a helpful source of information for the preparation of "The Alaska Surface Coal Mining Program" being prepared by the State Division of Minerals and Energy Management. Pedro Denton will be making a presentation on this topic later in this Section.

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Overview - abandoned mined land reclamation

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Introduction

At one time, the need to reclaim mined lands was not as accepted as it is currently. At present, however, post mining land is of continuing concern in a number of areas in the nation. What follows is a brief statement on the current status of this concern, and the resources and approaches now available to address the problem.

Status of Reclamation

Abandoned mined lands are being restored under two situations: first, as an integral part of active mining of coal located both vertically below and horizontally adjacent to previously mined areas and; second, as land use restoration targets to be addressed under dedicated programs and funds specifically designed to abate or control undesirable effects of past mining.

Examples of both approaches to reclamation of abandoned areas have occurred under the auspices of a number of states, on their own initiative. Federal involvement has also been a pertinent part of the U.S. Bureau of Mines, Department of Housing and Urban Development, predecessor agencies of the Environmental Protection Agency, and regional economic development commissions, most particularly the Appalachian Regional Development Commission. The activities of these agencies are varied; for example, they are involved in research and demonstration, site correction, site development and general improvement of the environment. Many handicaps had to be overcome, such as: incomplete understanding of the range of the problems, the size and relative costs of curative work; the interaction between problem, cure and results; and the economic, social and developmental impacts of the project or program.

Recently the interest in mining and reclamation work was heightened through passage of the Surface Mining Control and Reclamation Act of 1977 (SMCRA 95-87). This legislation provides for a partnership to be established between the states and the Department of the Interior's Office of Surface Mining. On one hand, a permanent program for mine planning, inspection and enforcement ensures that current mining will result in reclaimed lands suitable for a variety of post mining land uses. On the other hand, a special reclamation fee is collected to establish a fund to reclaim certain previously mined lands to a useful purpose not now possible for lands affected by mining activity that occurred before the passage of SMCRA 95-87.

Not all lands and water are eligible for reclamation work under this Act, but only those that meet one of the following tests:

1977 Surface Mining Control and Reclamation Act

Eligible Lands and Water:

Sec. 404. Lands and water eligible for reclamation or drainage abatement expenditures under this title are those which were mined for coal (or which were affected by such mining, wastebanks, coal processing or otner coal mining processes) and abandoned or left in an inadequate reclamation status prior to the date of this Act, and for which there is no continuing reclamation responsibility under state or other federal laws.

The Regulations:

5.1 Eligibility requirements for reclaiming lands and water affected by mining for noncoal minerals and materials.

5.11 Applicability - The eligibility requirements apply to reclamation activities under a state or Indian program. Monies from the fund can be used for reclamation of lands that were mined or affected by mining for noncoal minerals, and minerals and materials if the findings set out below are met.

5.12 Findings - The Director or Regional Director must make a finding in writing that:

1) The lands and water were mined or affected by mining for noncoal minerals and materials and abandoned or left in an inadequately reclaimed condition prior to August 3, 1977, and that there is no continuing responsibility to reclaim under state or other federal laws (determine this by using the same procedures that were used for coal above; get legal opinion);

2) The governor of the state or head of the tribal governing body has requested the reclamation;

3) All coal mined lands within the state or reservation have been reclaimed, <u>or</u> the particular noncoal reclamation effort is necessary for the protection of the public health or safety (if the latter is the basis for the request it must be substantiated by facts);

4) The monies are available for the reclamation of the noncoal mined lands from the state's/tribe's allocation (it would not be possible, therefore, to have a noncoal reclamation project in a state where there is no coal production, although it is possible

to have a coal reclamation project in a state where there is no current coal production). Some examples are as follows:

a. A coal producing state with no state plan in existence, but with the state actively pursuing the goal of a state plan, can use monies that are part of that state's allocation. These monies can be used for reclaiming lands that have been affected by mining of noncoal minerals and materials, even if all abandoned coal mined lands have not been reclaimed, if the requirements in (1) and (2) above are satisfied, and the proposed reclamation of the noncoal mined lands is for the protection of the public health or safety.

b. A coal producing state with an approved reclamation plan, which includes projects for reclaiming abandoned coal mined lands, as well as lands adversely affected by mining for noncoal minerals and materials, can use grant monies to reclaim noncoal abandoned mine lands before all coal reclamation is completed. In such cases, the requirements in (1) and (2) above must be satisfied and the proposed reclamation of the noncoal mined lands is for the protection of the public health or safety.

Elgible lands will also be subject to the following priorities:

Surface Mining Control and Reclamation Act of 1977.

Sec. 403. Expenditure of monies from the fund on lands and water eligible pursuant to section 404 for the purpose of this title shall reflect the following priorities in the order stated:

1) the protection of public health, safety, general welfare and property from extreme danger of adverse effects of coal mining practices;

2) the protection of public health, safety and general welfare from adverse effects of coal mining practices;

3) the restoration of land and water resources and the environment previously degraded by adverse effects of coal mining practices, including measures for the conservation and development of soil, water (excluding channelization), woodland, fish and wildlife, recreation resources and agricultural productivity;

4) research and demonstration projects relating to the development of surface mining reclamation, and water quality control program methods and techniques.

5) the protection, repair, replacement, construction or enhancement of public facilities such as utilites, roads, recreation and conservation facilities adversely affected by coal mining practices;

6) the development of publicly owned land adversely affected by coal mining practices, including land acquired as provided in this

title for recreation and historic purposes, conservation and reclamation purposes and open space benefits.

Although the range of opportunities for reclamation are very broad, what amount of money can be expected for the program and how much reclamation can be anticipated?

Funding Level of Abandoned Mine Reclamation Program

The Surface Mining Control and Reclamation Act of 1977 (SMCRA 95-87) provides for a collection authority in the Office of Surface Mining to handle a fifteen year reclamation fee. Fees are paid by coal operators, at the rate of 35 cents a ton for surface mined coal, 15 cents a ton for underground mined coal and 10 cents a ton for all lignite mined and sold. Current estimates of total income expected is $4 billion by 1992, the end of the currently authorized collection period. A preliminary estimate for reclamation demands is $30 billion, to be applied to the eligible portion of 1 million acres of land affected and presumed abandoned prior to the passage of SMCRA 95-87. Obviously, if only one in ten of the dollars needed are to be available, then a policy for program strategy and project priority setting and selection must be constructed by the states, tribes and Office of Surface Mining.

Those decisions will be made by the appropriate jurisdictions responsible for allocations of the fund. Exact oraganization and procedures will vary somewhat among individual tribes and states and there will be periodic variations in the guidelines applicable to the federal share of the fund. Basically, however, they will conform to the legislated allocations of the fund.

Under the law, money in the abandoned mine land reclamation fund is earmarked as follows:

50 percent goes to the state and Indian tribe where the fee is collected, once they have OSM approved regulatory and reclamation programs.

Up to 20 percent goes into the Rural Abandoned Mine Program (RAMP), run by the Department of Agriculture's Soil Conservation Service, to reclaim rural lands. The rural land owner can apply for these funds through the local soil conservation district.

Up to 10 percent, or $10 million, goes to assist small coal mine operators (those producing less than 100,000 tons of coal a year) in obtaining mining permits. The funds are used to help pay laboratory and consulting fees to collect and analyze soil and water data needed before a permit can be issued.

The remaining 20 percent is used by the Office of Surface Mining to handle emergency and high priority projects, and to administer the reclamation program.

An accounting of the fund as to the most recent quarterly report shows substantial fund growth in the last several years.

Reclamation Fee Collections, Region V

CY Qtrs. Ending 31 Dec. '77 - 31 Mar. '80

State/Indian Tribe[1]	Tonnage	Monies Collected
Alaska	1,854,295.04	$ 649,003.23
Arizona[2]	-	-
Colorado	37,787,201.61	10,655,177.18
Crow (MT)	10,391,522.00	3,637,032.70
Hopi (AZ)	3,139,016.00	1,098,655.60
Navajo (AZ, NM)	40,626,281.14	14,075,517.09
New Mexico	13,588,414.50	3,953,076.67
North Dakota	36,285,700.04	3,422,323.17
Utah	24,190,940.44	3,622,427.56
Wasnington	12,152,920.50	4,253,522.18
Wyoming	164,957,634.91	57,143,245.35
TOTAL	407,661,725.74	$123,975,747.65

1 Indian tribe figures are not included in state totals.
2 All figures for Arizona are Indian tribe totals.

Although it is not yet known how large or expensive the reclamation needs of the nation will be, it is possible to predict the nature of expenditures.

Application of the Reclamation Fund

Several expenditures have occurred since the reclamation fees have begun to accrue.

One type of expenditure is reclamation planning. At the national level, a nationwide inventory of mined lands' problems is underway. Approximately four states and tribes are working on inventories with federal funds specifically designated for that purpose. The inventories of abandoned mine lands for the remainder of the states and tribes are underway in various stages of contracting. Alaska is in this stage and a contract to do the work is being considered.

At the regional level reclamation planning is underway in five states and two tribes. This planning essentially establishes the framework for selecting projects, conducting control and improvement work, evaluating the results and coordinating the multijurisdictional interests in reclamation activities.

A second type of expenditure provides for potential project investigations, analysis and preliminary selection of probable curative measures. These expenditures are handled by both the Office of Surface Mining through its regional structure and in other instances by states and tribes. To date this work has been limited to the more extensive and complex conditions caused by mining. For example, under mined urban areas, interfingering of underground areas and their drainage, inadequate mine maps, mine discharges from indistinct sources and coal mine fires whose burn boundaries, direction and rate of combustion are uncertain.

A third type of expenditure is reclamation work to alleviate or eliminate undesirable effects of mining. This type of work is also being done through the regional Office of Surface Mining, in states desiring it, through their appropriate abandoned mine land agency. Projects are underway currently where there is a need to counter a threat to life, health and property. These emergency situations receive immediate and expeditious attention. For example, a cavity opening in a family's yard at their very doorstep. In other hazard situations the usual routine and timing of contracting and construction are applied.

To date $61,000 has been applied to 19 emergencies and $2,217,000 to 31 projects. An additional $686,000 for nine projects is in various stages of application, approval, funding and contractual obligation in Region V.

There have been 32 projects completed to date; they have controlled such adverse conditions as mine openings, surface subsidence, highwalls and pits, and unstable mine facilities. In the near future there will be projects involving mine drainage and radiation hazard related to coal mining.

An overview of the progress to date of reclamation activities in the western Region V of the Office of Surface Mining is shown on the following page.

Progress in Reclamation - Region V

Program Participation

Participate in National Inventory	State Reclamation Planning (Underway)	1st Year's Annual Reclamation Work Plan	Emergency Projects	Other Projects	Fee Collection
					X
X	X	X	X	X	X
X	X	Pending		X	
X	X	Pending		X	X
X	X		X	X	X
				Pending	X
			X	X	X
Pending	X		X	X	X
Pending	X	Pending			X
Pending	X				X
Pending	Pending			Pending	X
Pending					

New Program Entrants

Although Alaska and other states and tribes are not participating in this program currently, there have been several expressions of interest in future involvement. When the timing is appropriate the following flow chart establishes a guide to the general route and milestones to follow, which should provide resources for abandoned mined land reclamation assistance where desired and needed.

References

Public Law 95-87, August 3, 1977, Surface Mining and Reclamation Act of 1977.

AML Fee Compliance 62713-62716, December 13, 1977, 30 CFR 837.

AML Final Rules 49932-49952, October 25, 1978, 30 CFR 800.

AML - 1st Annual Work Plan (Cooperative Agreement) 67057, November 21, 1979, 30 CFR 872.

AML Final Guidelines 14810-14819, March 6, 1980.

Final E.I.S. Title IV, March 1980.

Office of Surface Mining, Operations Manual.

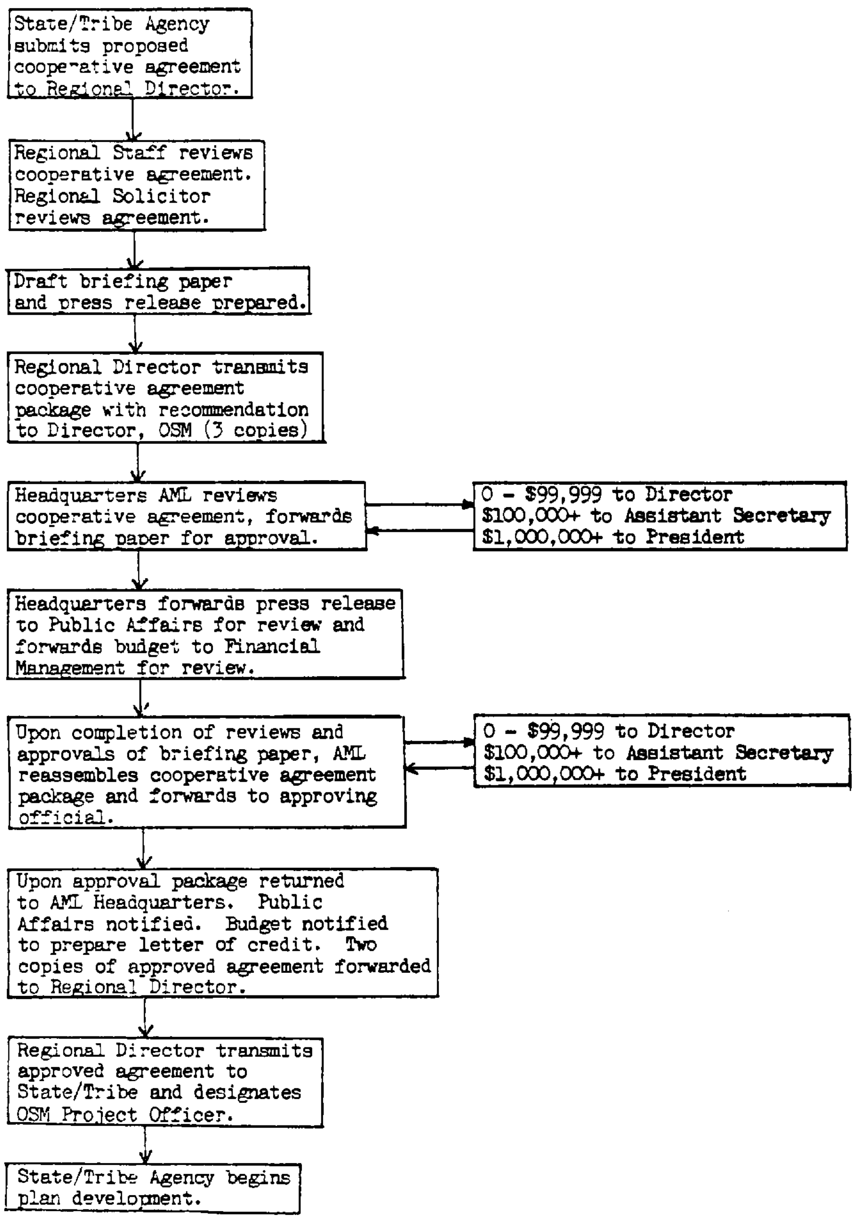
RAMP 44748-44756, September 28, 1978, 30 CFR 632.

AML Recordkeeping and Reporting 60285, 1979.

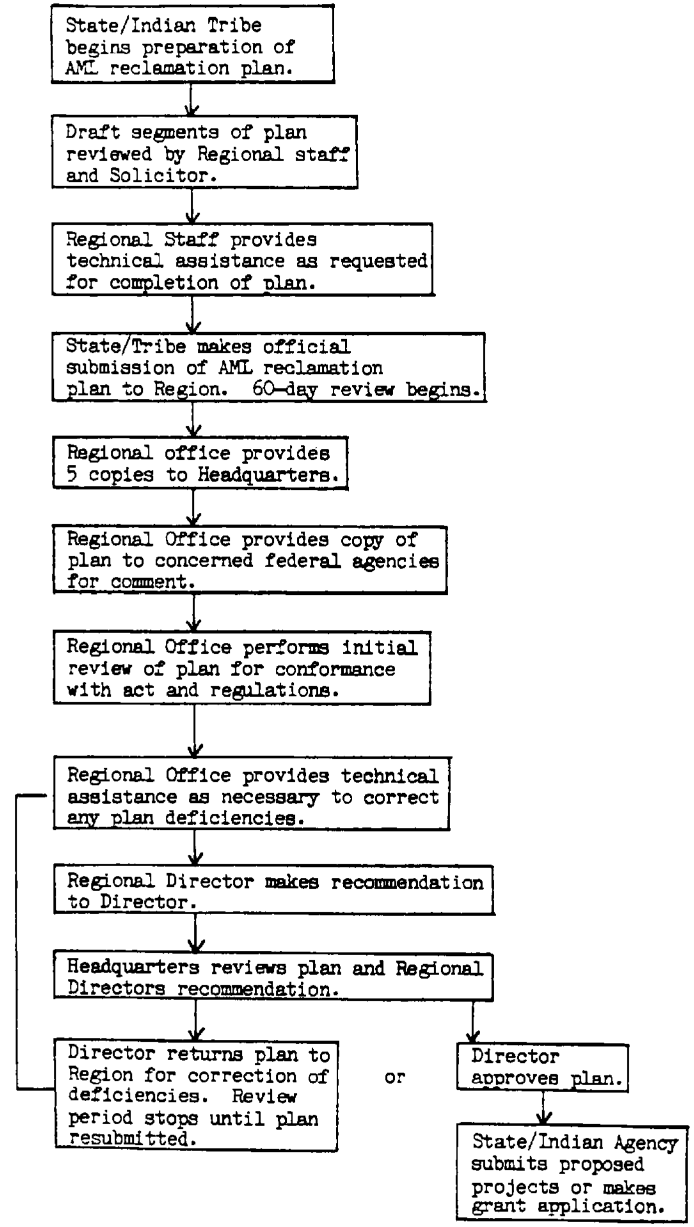
Federal Assistance (AML) Impact - Public Facilities, Natural Gas/Petroleum Conservation 58006, August 29, 1980, 30 CFR 886.

Grants: Mining & Mineral Resources Research Institutes and Mineral Research Projects, 38556, 1978.

FLOW CHART FOR REVIEW OF THE COOPERATIVE AGREEMENT FOR DEVELOPMENT OF THE RECLAMATION PLAN



FLOW CHART FOR STATE/INDIAN RECLAMATION PLAN REVIEW



Alaska surface coal mining program

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Introduction

Almost everyone recognizes that coal mining in Alaska requires different technology than in the other coal producing states. Alaska's remoteness, climatic extremes and sparse population obviously pose conditions not common to the other states. The differences were recognized by congress when it commissioned, in Section 708 of Public Law 95-87, a special study to determine if any of the provisions of the law should be modified because of unique conditions in Alaska.

Partly in anticipation of the results of this study, and also to accurately assess a program by which the state could assume jurisdiction over surface coal mining in Alaska, the Department of Natural Resources started preparing a draft program early in 1980. A preliminary draft of this program is nearly complete, and is ready for legislative, public and federal review. The purpose of this paper is to give an overview of Alaska's program development progress to date.

The opinions and interpretations in this paper are the author's and do not necessarily represent the opinions of the state or the Department of Natural Resources. The paper has not been reviewed by the state. The author has served as program development coordinator for the program since early in 1980 on a special project basis and is not a permanent employee of the state.

Federal Act and Regulation

The Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87, 91 Stat. 445 (30 U.S.C. section 1201 et. seg.)) is essentially an environmental law designed to regulate surface coal mining on a national scale. Its primary purpose is to prevent water and air pollution and other adverse environmental impacts, and to require that disturbed areas be reclaimed to an appropriate post mining use. It pertains to all coal mining regardless of whether the coal is on federal, state or private lands.

The Act recognizes that "the primary governmental responsibility for developing, authorizing, issuing and enforcing regulations for surface mining and reclamation operations" should rest with the states. The Act took the power to regulate coal mining from the states and provided a mechanism by which this power can be partially returned to the states, upon approval (by the federal Office of Surface Mining (OSM)) of a state program incorporating minimum federal standards.

OSM reported in a news release dated March 5, 1980 "Twenty four states, including all of the nation's major coal producers, have submitted plans to assume primary responsibility for regulating the surface effects of coal mining". States submitting plans were Maryland, Pennsylvania, Virginia, West Virginia, Kentucky, Tennessee, Alabama, Mississippi, Illinois, Indiana, Ohio, Arkansas, Iowa, Kansas, Missouri, Oklahoma, Texas, Louisianna, Colorado, Montana, New Mexico, North Dakota, Utah and Wyoming. Georgia, Washington and Alaska, none of which are considered major producers, did not submit plans by the March 3, 1980 deadline for state program submittal.

In this same news release, OSM Director Walter N. Heine noted that "The bottom line is approval by January 3, 1981. Where programs are not approved by that date a federal program is required". The foregoing statement would seem to indicate that federal regulations will be applied to Alaska on Jan. 3, 1981. But Alaska has argued that the special study by the National Academy of Sciences-National Academy of Engineering required by Section 708 of the Federal Act would dictate a different time frame for Alaska. This was noted by OSM in the May 16, 1980 Federal Register, which states on page 32330:

> Alaska did not submit a program and has asserted it does not have to do so at this time because the study of surface coal mining in Alaska being carried out by the National Academy of Siences pursuant to Section 708 of the Act is not complete. OSM is currently examining what action should be taken with regard to Alaska.

The issue has not been resolved, but obviously Alaska cannot design a final program until the results of the 708 study are made available. Even then the uncertainty of what changes will be made to the federal act could further complicate the time schedule.

The time frame for submittal under the Act is important for Alaska because the deadline for program submittal (March 3, 1980) has passed and OSM's position is that if a state fails to meet the deadline, a federal program must be imposed befor the state can apply for program approval. This is an extremely narrow and impractical interpretation of 30 CFR 731.12, but so far the state has been unable to change the OSM position. It apparently does not matter that the 708 study is already over a year late, and that both Alaska and OSM consider the 708 study a critical element in developing an Alaska program.

The following excerpt from OSM's 1979 annual report is a good indicator of OSM's recognition of the importance of the 708 study to developing Alaska's program:

> A number of outstanding issues related to Alaska's program may have to await formulation and resolution until after completion of the Alaska Study and Departmental response mandated by the Act. Study scheduled for completion by May 31, 1980.

It should be noted that the Act required the study be completed no later than two years after the date of enactment, or by Aug. 3, 1979.

The Federal Act is one of the most complex and detailed statutes ever written. If Alaska adopts a companion law, which it must if it wishes to regulate coal mining in Alaska, it will be one of the longest statutes on the books for such a special purpose, containing over 50 pages. For comparison, the Statute which regulates oil and gas operations in Alaska, AS 31, contains only 25 pages. But it is the regulations and their seemingly endless detailed requirements for procedural matters that has caused the most criticism. These regulations and their program submittal requirements are extremely tiresome to read and work with and require a very cumbersome and unwieldly process for approval of a state program.

Alaska's draft of the regulations is nearly 350 single spaced pages, and this includes many consolidations which OSM may not approve. The section on bonding alone contains over 40 pages. In addition, there will probably be two to three hundred additional pages of explanatory materials. In comparison, the Alaska Oil and Gas conservation regulations contain only 35 pages.

Much of the problem that the other states have had is in getting variations from the federal regulations. The federal act provides in section 101(f) that "because of the diversity in terrain, climate, biologic, chemical and other physical conditions in areas subject to mining operations, the primary governmental responsibility for developing, issuing and enforcing regulations..... should rest with the states."

OSM has implemented this policy by regulations under 30 CFR 731.13 (called the state window), which provides for detailed state justification for any state variations to the federal regulations. Many states have complained that the window is closed, but one of the most interesting characterizations was by the United States Court of Appeals in a July 10, 1980 decision on the Peabody Coal Company case. In a footnote to a statement that the statutory scheme "leaves broad discretion in state officials while ensuring, through federal oversight, that the minimum requirements of the Act are achieved." they made the following comment:

"The Secretary insists that he has left this discretion intact through the so-called "state window" provision in the regulations. This section allows states to propose alternatives that are "consistent with the regulations" the Secretary has issued, 30 CFR 731.13(c)(1). The language of this provision, however, is deceptively comforting. Elsewhere, the regulations define "consistent with" as meaning "no less stringent than and meet(ing) the applicable provisions of the regulations" the Secretary has issued. Id 730.5(b). Thus there is little room for states to maneuver. The "window" would be more accurately described as a one way mirror."

These characterizations could be alarming for Alaskans, knowing that mining in Alaska will require different mining practices than in the other states if it were not for the 708 study. The 708 study could provide an open "window" for Alaska that will allow variations from the federal program to adjust to the unique conditions in Alaska. In this respect, Alaska could have it easier than some of the other states, but to accomplish this it must aggressively follow through on the 708 study to be sure there is appropriate rsponse by the Secretary of Interior and Cogress.

Program Development Progress

Alaska received a $100,000 program development grant from OSM on March 11, 1980. The actual monies were received on April 8, 1980. The grant required that the state contribute $25,000 to the program. The grant application was the beginning of the formal process to determine whether Alaska would assume control of surface coal mining in Alaska. Under this grant, the Department of Natural Resources hired the author full time early in the year to coordinate development of a state program including regulations, statute and other program submittal elements. Prior to that time several individuals had, on a part time basis, closely followed OSM activities and had analyzed how the program might impact Alaska. There was also considerable participation in the NAS-NAE hearings in Alaska, and most of the general problems in applying the act and regulations were identified.

The program development grant provided for accomplishing the following:

1. A comprehensive review of existing Alaska statutes and regulations to identify current authorities relevant to the regulation of surface mining.

2. Draft legislation and regulations necessary to comply with PL 95-87.

3. Recommendations for a process by which lands could be determined to be suitable or unsuitable for surface mining.

4. Recommendations for the coordination of review and issuance of permits for surface coal mines among all state and federal permitting authorities.

5. Assembly of all the elements into a program submittal for the purpose of assuming state jurisdiction.

The proposal provided for an advisory committee to be appointed by the Governor, to guide the Department of Natural Resources in developing a program and in deciding whether or not the state should assume jurisdiction over surface coal mining. The committee was appointed by the Governor in early April 1980, and consists of Earl H. Beistline of the University of Alaska; Richard Douglass of the Alaska Conservation Society, Cole E. McFarland of Placer Amex, Inc., Margaret Sagerser of Cook Inlet Region, Inc., Joseph E. Usibelli of Usibelli Coal Mine, Inc. and Philip Waring of the Kenai Peninsula Borough.

Since Earl Beistline was chairman of the NAS committee on Alaskan Coal Mining and Reclamation and to avoid any possible conflict of interest, Ernest N. Wolff has served on the committee on his behalf to the present time. Now that the report is complete, Mr. Beistline is back on the Advisory Committee. The first committee meeting was held on May 13, 1980 and two meetings have been held since then.

Perhaps the major task in developing the program was in identifying the specific federal standards and regulations which were not applicable to Alaska, and determining what change would be necessary for Alaska. To accomplish this objective, the Department of Natural Resources invited all state coal lessees to a workshop in Anchorage on March 18, 19 and 20, 1980 to go through the federal regulations with the state section by section, identifying the specific sections requiring a variance and the need for the variance.

A state team composed of members of the Departments of Natural Resources, Fish and Game and Environmental Conservation was formed to participate in the workshop and to develop recommendations for a state position on the proposals. The proposals developed at this meeting and in subsequent meetings of the state team were reviewed by the involved state departments and the advisory committee, and have been accepted for review purposes.

The proposals are the basis for the Alaska Regulations proposals, which are presently nearly complete in review draft form. It was decided to closely follow the federal regulations, except where substantive changes were necessary, or where necessary to conform to style requirements of Alaska legislation. It was felt that this procedure would minimize explanations to OSM and would considerably shorten preparation time.

A key to the success of this approach is the extent to which the 708 study will justify the need for the variances in Alaska, and will provide the data necessary by the regulations to support in variance from the federal regulations. A summary of the substantive variances to the federal regulations is attached.

In a somewhat backwards process, a proposed Alaska statute is also being drafted which would conform to the regulation variances and the federal requirements. This is, of course, a variation from the normal procedure, but in this case it may be justified by the strict federal standards which leave very little latitude for statute or regulation drafting.

There are numerous other program elements which must be developed as a part of the program submittal, 30 CFR 731.14. The most important of these relates to the organizational structure of the surface mining authority and how it will function, the process for determining lands suitable or unsuitable, a compilation of existing state laws and regulations, a section-by-section comparison of proposed state laws and regulations with the federal, and the permit coordination and review process. The other submittal elements are largely narrative explanations of the regulatory process provided by the proposed state regulations, and statistical information on Alaska's past and projected coal activities.

It has been proposed and endorsed by the Advisory Committee that the surface mining authority be in the Department of Natural Resources. The authority would be with the Commissioner and he could delegate this authority to an appropriate director. The director would be supportd by a technical advisory team of experts from other Departments, or from within the Department of Natural Resources. The proposed team would consist of a hydrologist, a geological engineer, a habitat biologist, an environmental engineer, an air quality engineer, an agronomist, an attorney and a coal mining engineer. The team would be available for permit review as well as special problems in enforcement and administration. The members would serve on an as needed basis. The coal mining engineer would be in charge of enforcing and administrating the program. Total costs of such a program are estimated at about $125,000 a year, half of which would be funded by the federal government under program administration grants. The Department of Environmental Conservation has countered this proposal with a proposal that the authority be in their Department.

The unsuitability process required by Section 522 of the Act has been one of the most troublesome to develop. The requirements of the law and regulation are difficult to understand, and people working with it generally have a problem in separating the planning process required by the Act from a process that would be used in leasing considerations. The data base and inventory requirements are also troublesome, primarily because of the lack of detailed data in Alaska.

The proposed process allows for petitions patterned after the federal regulations. In addition, a process is provided by which coal lessees or other coal owners can petition the authority to have lands declared suitable for mining. The primary objective of this provision is to provide a process by which determinations can be made as soon as possible, so that long-range land use and mine planning can be done with as much certainty as possible. Alaska already has programs in the Department of Natural Resources which can be adapted to this process. Also additional program development funds have been requested from OSM to refine the process and to develop a data base and inventory system.

The permit coordination and review process is not complete, but it probably will be patterned after existing programs requiring detailed review.

A preliminary draft of the section-by-section comparison of the regulations is nearly complete. This should considerably facilitate review of the program by the public and others.

Alaska's program development has been easier than other states' in several respects. First, Alaska has not been on the same time schedule. This has allowed the utilization of other state programs as guides. The Texas and Montana programs, already approved, have served as models for much that has been done. Litigation by the National Coal Association/American Mining Congress (NCA/AMC) and others may also resolve many of the issues that would cause problems for Alaska.

A long series of issues have been decided at the U.S. District Court and Court of Appeals level in industry's favor, and generally in favor of more flexible regulations. The exact number is difficult to determine because of the interrelationship of so many of the issues, but a figure of 38 regulations withdrawn and 44 invalidated has been used by NCA/AMC. These issues have not been finally decided, and how many of the federal regulations will be redrafted to address the court decision is not known. This problem is often characterized as a "shifting target". Allowing the "target" to settle down will make it easier in Alaska.

Summary

A preliminary draft of a program for Alaska to assume jurisdiction over the surface mining of coal is nearly complete. Within a few weeks, a complete package will be sent to the involved agencies for final review, before going to Alaska's Surface Mining Advisory Committee for their review and help in resolving any differences. A complete program package should emerge ready for pulic, federal or legislative review. It is difficult to determine how the draft program will be adjusted as a result of this process, or what final decisions will be made. The issues are complex and understanding is complicated by extremely detailed procedural regulations; but the decisions that will be made could have considerable impact on the development of Alaska's coal resources.

Proposed Significant Modifications to Federal Surface Coal Mining Regulations

Federal Reg No.	Summary of Change to Federal Concept
700.11(c)	Allow groups of individuals to mine cooperatively without permit, in excess of the 250 ton limitation where approved by the regulatory authority.
701.5	Allow exception from classifying waters with pH of less than 6 as "acid drainage" where a lower pH is natural for the area.
764.13(b), Part 765	Special procedures for determining lands unsuitable for mining in Alaska.
779.13(b)(3) 783.13(a)(3)	Allow exception in Alaska for requiring all hydrologic data in all cases.
780.15 816.95	To provide for Air Quality control in Alaska to be based on state and federal air quality standards.
785.14(c)(1)	Allow wildlife habitat as postmining use which could qualify for exceptions from restoring to original contour.
785.16(c) (4)(i)	To allow returning watershed to original condition as standard for getting exception to return to original contour, rather than requiring improvement (the regulation and statute standard).
785.19(a)	Limits application of "alluvial valley floor" standards based on lack of agricultural potential. ALVs would not apply in the Northern, Nenana, Yentna, Susitna, Beluga and Matanuska fields.
786.25(b)(1)	Allow longer time for commencement of operations than provided by statute and regulation.
815.15(c)(1), (c)(2)	Provide special standards for exploratory roads.
815.15(f)(1)	To allow other than native species for revegetation for areas disturbed in exploration.
815.15(i)(3)	To allow leaving exploration equipment in the field where it will facilitate future exploration.

Federal Reg No.	Summary of Change to Federal Concept
816.11(a)	To allow reduction of marker requirements where area is inaccessible.
816.21(b)	To allow mixing of topsoil with overburden where it will not be used in revegetation.
816.22(e)(1)	To allow exception from requirement to seek out separate "best" material even if other material is adequate for revegetation.
816.22(e)(1)(ii)	To not require trials and tests of topsoils being certified by a laboratory unless required by the state.
816.22(e)(1)(iii)	To allow the state to use practices proven in other areas as guide in approving use of topsoil substitutes.
816.22(f) 816.71(c)	To allow leaving topsoil and vegetative cover in place where needed as insulating layer.
816.42(a)	To allow alternate sediment control methods to sedimentation ponds, and to rely on federal and state water quality standards rather than OSM effluent standards.
816.42(c)	To allow exception from treating all waters as "acid water" where natural conditions are less than a pH of 6.
816.57(a)	To allow exception from the requirement to restore all streams to original channel without regard to importance.
816.64(a)	Remove the requirement to publish blasting schedule and rely on notice to residents and agencies.
816.65(a)	To relate blasting time to time of day rather than "sunrise" and "sunset".
816.71(a)	To allow excess spoil to be placed in mined area to limit disturbed area.
816.83(a) 816.89(b)	Allow alternative to the requirement to make all waste banks impervious.
816.97(b)	To allow discretion in reporting requirements for eagles because of numbers of eagles in some areas.

Federal Reg No.	Summary of Change to Federal Concept
816.97(d)(2)	To clarify that some interference with wildlife is inherent in any structure in remote areas and allow recognition of this in Alaska.
816.104(a)	Remove the numerical relationship of final thickness to initial thickness because of difficulty in determining in permafrost areas.
816.104(b)	To prevent redisturbance of storage areas in permafrost areas where material condition is not adaptable to temporary storage methods.
816.106	Allow discretion by regulatory authority in requiring repair of revegetated areas.
816.150-176	Special road building standards for Alaska.
825, New Section	Special performance standards for Alaska areas with natural cliffs and highwalls.
843.12(c)	Allow more time for abatement actions where needed because of remoteness or weather.
845.18(a)	To allow more time for service by mail.

Alaska's coal-leasing program

Laurel A. Murphy
Division of Minerals & Energy Management, Anchorage

Introduction

Five years ago, the Director of the Division of Lands placed a "temporary suspension" on the issuance of new coal prospecting permits. Although the problems involved with public notice were the immediate cause of the suspension, the need for reform in the state's coal management program has continued the moratorium to the present day. It should be noted that all of the state's most accessible prospective coal areas were already under lease or permit prior to this "moratorium".

In recent years, many efforts have been made to remedy the situation. In 1978, portions of the coal leasing regulations were revised and public hearings were held in Anchorage, Fairbanks and Juneau. These revisions, however, were not formally adopted. In the spring of 1979, House Bill 420 was introduced to amend the leasing and royalty provisions of the present coal statute, AS 38.05.150. That bill was withdrawn by Representative Bill Miles.

In November of 1979, the Department incorporated many of the 1978 revisions, along with comments from public hearings, into a more extensive rewriting of the regulations. These proposed regulations were held in abeyance pending the possible action on House Bill 955, introduced last spring by the House Resource Committee. That bill would have codified many of the coal leasing regulations. House Bill 955 was considered and died in the House Resources Committee.

The Department of Natural Resources' position with regard to the 1980 legislature was that if no bill was passed, the current coal leasing statute, AS 38.05.150, would allow the Department to adopt any necessary changes in coal management through regulation. To fulfill that commitment, regulations will be adopted after additional public hearing.

In addition, the Division of Minerals and Energy Management is adjudicating the 415 coal prospecting permit applications which have accumulated during the past five years. It is hoped that valid permits can be issued as soon as the new regulations are adopted.

The Current Leasing Program

	Number[1]	Acreage*
State Coal leases[1]	52	102,989
State Coal Prospecting Permits Pending Conversion . .	6	15,849
State Coal Prospecting Permit Applications	415	1,989,555[2]

1 - As of October, 1980
2 - The leases are located in the Healy, Yentna, Beluga, Kenai and Matanuska areas.
3 - Further information, including maps, on these permits and leases is available from the Division of Minerals and Energy Management, 703 W. Northern Lights Blvd., Anchorage, Alaska 99503.

The royalty rate on the current coal leases ranges from 5 to 35 cents per ton. (2 leases at 5 cents, 20 at 10 cents, 9 at 15 cents, 3 at 20 cents, 1 at 30 cents, 17 at 35 cents.) Royalty rates have not been adjusted for any of these leases, although several leases were issued prior to 1960 and could be readjusted.

The 6 permits under request for conversion to lease have been examined and recommendations made. These conversions will be subject to the new regulations.

Of the 415 permit applications which have been received, 90% are located in the Yentna-Susitna area. Approximately 25 permits are located in the Beluga area and the rest are scattered throughout the Matanuska, Kenai, North Slope and Herendeen Bay coal areas. These applications have been examined to ascertain any defects which could prevent issuance of a permit. For example:

33 applications are for land which has never been opened to non-competitive coal leasing.

55 applications are totally, and 28 applications are partially, for lands which were previously under coal lease or permit. This land is not available for an over-the-counter permit.

9 applications are for lands within Denali State Park.

1 application is for land partially within the area of the proposed Willow Capital site.

1 application is for land in an area which is restricted to competitive coal leasing.

The applications are currently being reviewed to determine the compatibility of surface uses and classifications with coal mining actvity. For example, one of the applications is for an area on which the Skwentna airfield is located. Other applications in the Susitna Valley are located on areas chosen for public land disposal and critical habitats areas. In some cases, incompatible land use may prohibit the issuance of a permit and in other cases, special permit stipulations will be established.

In addition, the Division of Geological and Geophysical Surveys is currently studying Alaska's coal resources. Based on these findings, the Commissioner may determine that some of these areas contain commercial quantities of coal. Such a determination would mandate competitive leasing, and prospecting permits would not be issued.

Finally, each permit area will have to be carefully examined prior to issuance, for any surface and subsurface title conflicts.

The Coal Leasing Regulations

Although the proposed coal leasig regulations have not yet been put into draft form, a number of issues have been identified and analyzed. The following list of issues, although not all inclusive, represents current thinking of the Dept. of Natural Resources. These regulations will encourage the establishment of a Coal Mining Unit (CMU), based on the federal government's logical mining unit, in order to achieve more efficient and orderly operations. Under this concept, lessees of adjoining coal leases may establish a coal mining unit or the Commissioner may require a lessee to become part of a unit. In such a case, the Commissioner could modify the terms and conditions of the individual leases, to ensure that all leases within the unit were equitable and governed by substantially the same requirements. Lease terms for diligent development and work commitment could also be modified and applied to the unit rather than to each individual lease.

1. Competitive Leasing

State land may be offered for competitive coal leasing if the Commissioner of Natural Resources determines that:

a) The land contains commercial deposits of coal. The determination of comercial quantities will be based on estimates of the quantity and quality of coal derived from sample analysis, measurements,and from geologic projections.

b) There is substantial geological or geophysical evidence to indicate the probable existence of significant commercial deposits of coal in the land.

c) There is interest in competitive leasing of the land for coal exploration or development.

2. Noncompetitive Leasing

State lands may be offered for noncompetitive coal leasing if:

a) The Comissioner determines that the land does not qualify for competitive leasing.

b) No bids are submitted for land offered for competitive coal leasing, and the Commissioner determines that it is in the best interest of the state to offer the land for noncompetitive leasing.

3. Competitive Leasing Method

a) The Commissioner may choose any appropriate coal leasing method for tracts to be leased by competitive bidding. This could include, but is not limited to, a combination of a cash bonus, royalty share or net profit share as the bid variable.

b) For noncompetitive lands, prospecting permits will be issued for a two year period in accordance with the existing regulations.

4. Lease Term

Leases will be issued for an indeterminate period of time, as long as there exists diligent development and continuous operation.

Diligent development means that the coal mining unit (CMU), of which this lease is a part, must be producing coal in commercial quantity by the end of the 15th year from the effective date of the lease.

The Department is considering adopting a variation of the federal definitions for commercial quantity and continuous operation. In that case, commercial quantity would be defined as an amount of production equal to 1% of the CMU reserves, and continuous operation would mean the production of coal equal to 1% of the CMU reserves. The average amount would be computed on a three year basis (the year in question and the two proceeding years).

The requirement of production of coal in commercial quantities from a lease may be suspended:

a) If operation of the mine is delayed or interrupted because of force majeure, (i.e., strikes, climatic conditions, administrative delays, litigation or other unavoidable or unforeseeable circumstance not within the control of the lessee); or

b) For up to 5 years, the lessee may make payments in place of production in an amount determined by the Commissioner, if the

Commissioner finds that the public interest would be served by a suspension of the condition.

5. Royalty

Royalty shall be not less than five percent of gross value at mine mouth.

6. Royalty Adjustment

The royalty payment is subject to adjustment at intervals of no more than 20 years from the start of coal production. The specific period for adjustment, as determined by the Commissioner, shall be provided for in the lease.

7. Rental

Each coal lease shall provide for a reasonable escalated rental. Although the Department has not decided on the specific sum, rental will be higher than the minimum contained in the statute. (25 cents/A for the first year, 50 cents/A for years 2 through 5, and then not less than $1.00/A.) The rental payment for each year shall be credited against the royalty due the state as it accrues for that year once production has begun.

8. Rental Adjustment

Each coal lease shall provide that the annual rental payment is subject to adjustment at intervals of no more than 20 years. The amount will be determined in the lease.

9. Work Commitments

In a coal lease, the Commissioner may include terms imposing a minimum work commitment on the lessee. These terms may include penalty provisions, to take affect if the lessee fails to comply with the work commitment requirements.

10. Termination

If the lessee fails to comply with provisions of the lease, or of the statutes and regulations in force at the effective date of lease, and the failure continues for 90 days after the lessee is served with written notice, the Commissioner may suspend activity on the lease until compliance is achieved, or may terminate the lease.

11. Conversion to Lease

A coal prospecting permittee is entitled to a coal lease upon showing, to the satisfaction of the Commissioner, that the land covered by the permit contains coal in commercial quantities, and submits a satisfactory mining plan.

The term "commercial quantity" is defined as a combination of quality and quantity sufficient to induce a prudent person, under present and reasonably anticipated conditions, to invest effort and capital towards the development and operation of a producing mine. Evidence of commercial quantity may include:

a) Qualitative data supported by proximate and ultimate analyses of the coal beds on which the reserve calculations are based.

b) Data regarding the thickness and continuity of the coal beds on which the reserve determinations are based.

c) Reserve calculations indicating degree of accuracy as, for example, "measured," "indicated" and "inferred" of U.S. Geological Survey/U.S. Bureau of Mines definition.

d) Estimation of market value of the coal.

The term "satisfactory mining plan" is a conceptual outline of the mining methods contemplated for us, and the feasibility of the envisioned operation. It may include:

i) A sketch map on topographic base showing location of portals, pits, facilities, haulage way, transportation routes, slurry lines and other significant features both within and outside of the permit area.

ii) Estimation of the recovery factor anticipated.

iii) Estimation of mining costs on a per ton basis.

iv) Description of post mining and reclamation plans.

Conclusion

Coal development in Alaska is almost at a standstill because of numerous issues facing the three major landowners--the Native Corporations, the State of Alaska and the Federal Government.

The State of Alaska is attempting to resolve its problems so that the approximately 20 percent of known coal reserves that are located on state land can be explored and developed. Hopefully, the state and industry can work together to create simple, consistent and predictable regulations and policies, which will encourage the development of the state's coal resources.

Luncheon Speech - October 22

Honorable Terry Miller
Lt. Governor of Alaska

Thank you very much J.P. for the generous introduction. I'm delighted to be back in Fairbanks to have an opportunity to, first of all, officially greet those who are new to the state, or have invested here but reside elsewhere. Welcome to Alaska, we're glad to see you here. I'm glad the weather has put on a great face for us, and for those of you who live here, hello again. Before making some extemporaneous remarks, I would like to introduce very briefly some important people from the audience, because whether or not what I'm about to say ever comes about will depend for a large part on their actions.

First, very quickly a few key members of the Alaska legislature who are in the audience. The reason I'm doing that quickly is because during the rest of the conference you'll have an opportunity to meet and talk with them.

I'd like to first introduce Representative Sally Smith from Fairbanks. A former colleague that I served with during my years in the State Senate, Mr. Brad Bradley of Anchorage. Another Fairbanks product, Representative Bob Bettisworth. A member of the State Senate, also from the Fairbanks area, Senator Don Bennett. We've also got several key candidates for the state legislature, many of whom I'm sure will be, after a week and a half from now, members of the legislature elect. There are too many to introduce. If you're running for the legislature would you stand up?

I contemplated what I was going to say today, and, of course, the great temptation is always to talk about the great potential for coal development in Alaska. But upon reflection, I decided we really don't need to tell you what you already know and you probably know a lot better than I do. Let me say that as I understand it, of the several hundred years supply of coal which is available in the United States, at present levels of energy consumption, approximately one half of it resides within the borders of Alaska. I think that's a staggering statistic which should be remembered not only here, but throughout the United States.

Other than to just say that, I would like to talk a bit more broadly about Alaska. Where we are, and what we can be. The Statehood Commission was authorized by a narrow vote in the last election to assess all kinds of things. I called them to a meeting in a building not too far from here to assess exactly what they ought to do. It seems to me that one of the appropriate things the commission can do is to sit back, because they have the luxury of so doing. They're not involved in the hurly-burly of everyday politics. They can assess where we are, or how far we've come and where we have to go. Maybe use that as a vehicle to communicate to the people of the United States what Alaska is.

We talk about these vexing problems and federal, state issues. I'll not go into them, because I don't want to put a pall over the conference, other than to say that much of what you're discussing today will depend on the success of our federal-state relations. It seems to me that Alaska is really--and I know you've heard this, every generation says it--really at the crossroads. We're at the threshold. Several things are happening in Alaska.

First of all, we're on the verge of some kind of settlement, and I fervently hope it's a good settlement, of the Alaska Lands Claim in Congress. As a result of that, for the first time in the history of this state, in the history of the territory, state residents, either through Alaska Regional Native Corporations, or through land held by the State of Alaska, will own substantial tracts of Alaska's land. Obviously, the people who control Alaska's land will control Alaska.

The second thing that's happening, and all of you are no doubt aware of it, is Alaska's sudden so-called oil largesse, where we're talking about receiving over the next several fiscal years several billion dollars each year. So we have indigenous capital for the first time. I submit to you, with those two tools, land and capital, we are going to change Alaska, and I hope we're going to change it for the better.

That's one of the things maybe the commission meeting over there can talk about. What is Alaska to the rest of the United States, and indeed to the world? It seems to me that with the new tools that we now have, which will be controlled by Alaskans, we can step forward and offer Alaska's manifold bounty to the people of the United States.

It will come as no surprise to you that over the last several years the standard of living in the United States has declined, and is continuing to decline. The American economic pie is getting smaller, and I defy anybody, anywhere, including in this room, to challenge that.

It seems to me that the people of Alaska, with their resources, their manifold bounty, can contribute to the bucking up of the American economy, to raising the standard of living. Not only we can, we have a permanent obligation to do that. When you hear national economists saying we've got to lower expectations and tighten our belt, I submit to you, that's a little bit like the dentist when he's in there and he says, "This may be a little sensitive". Usually, it will hurt like blazes. That's what's going to happen in this country. I think we need to aggressively go to the American people and tell them what we've got for them, and why we need them.

We need to tell them that as part of this natural bounty, for example, we've got splendid scenery; wilderness values that ought to be preserved in perpetuity for the American people.

Coal task-force policies of the State of Alaska for coal development

Richard Eakins
Director, Division of Economic Enterprise, Juneau

The purpose of my remarks is to inform the symposium on the role and function the Alaska State "Coal Task-Force" has in developing Alaska's coal resources.

Earlier this month, Governor Hammond reasserted his policy for using petroleum resource revenues for expanding and diversifying other sectors of Alaska's economy. The Governor said, in a Chicago address, "Alaska's basic challenge in the years ahead is to convert the state's nonrenewable oil wealth into a viable, continuing economic base which will contribute to both the state's and the nation's well-being".

For the past two years, it has been a major policy tenet to direct hydrocarbon wealth into the building-up of other economic sectors of the economy. The two prime examples to date are the program for locating a bottomfish industry in Alaska; and the Delta Barley Project, a program to develop a major agriculture industry in the state.

The Department of Commerce and Economic Development has taken the Governor's economic policy directive and used it to structure a long range economic development assistance program for diversifying the state's economy.

This program is predicated upon some basic assumptions:

First, Alaska's economic growth for the next two-to-three decades will occur due to resource extraction.

Second, future growth will also occur through the development of the state's power and energy resources.

Third, resource development and energy power development in themselves will not provide the economic diversification and viable economic base addressed in the Governor's policy. For this to occur, a modern, technical industrial base, using a combination of resources and power energy, needs to be established in Alaska. This industrial base could take the raw resource material and use local power sources for processing and manufacturing, thus adding value to the resource material prior to its export out of Alaska.

Fourth, the State of Alaska will continue to have a powerful influence and direction upon the economy for the foreseeable future. The influence and direction will come through fiscal policy measures, such as annual budget expenditures, public works and infrastructure construction.

The administration's economic development program presently centers on fisheries, agriculture, tourism, international trade and reverse investment, coal development and petrochemicals. In the long-range it is considering minerals development as an important plank in the state's future economy.

The increasing importance that Alaska coal is to have on the world energy market was recognized by the Department of Commerce and Economic Development several years ago. The development stage of Alaska Coal was perceived by the Department to have advanced to where tidewater coal production would undoubtedly occur in the mid-1980's. The administration agreed with this analysis and the Governor designated coal development as a priority program. The concern was for state agencies to become prepared for the significant impact that coal development would have upon the state, both economically and environmentally. Direction came from the Governor that the state begin serious preparation for coal development activities. As a result, an Interagency Coal Task Force was formed in June 1978, with the Department of Commerce and Economic Development designated to chair the task force.

The purpose and objectives of the Coal Task Force were:

First, to organize a cooperative effort between state and local agencies.

Second, to prepare and make policy and program recommendations to the administration.

Third, to interface and cooperate with the private industry sector.

Fourth, to anticipate, prepare and bring the public sector program requirments for coal development to the stage of private industry development and keep pace with them.

The coal task force has met periodically over the past two years to carry out its assigned function. To date, activities of the task force have included:

1. Preparing an inventory, by agency, of each and all questions and problems that need to be addressed for new coal development to occur.

2. Preparing a program, by agency, to cover those problem areas of a general nature and for those problems identified for specific developments, such as the Beluga field.

3. Addressing the need for a tidewater bulk loading facility.

4. Preparing policy formation on the state's role for providing infrastructure support.

5. Entering into a support and cooperative effort with the Cook Inlet Native Corporation and Placer Amex Corporation, and their Methanol Feasibility Study funded by the Department of Energy.

6. Communicating with other private developers and buyers interested in coal.

7. Contracting with the Battelle Northwest Laboratories to analyze and prepare base data on the market situation for exporting Beluga coal through the Governor's Division of Policy and Planning.

The Department of Commerce and Economic Development has for several years been working with private enterprise to encourage the opening of new coal mines, and the industrial development that would accompany it.

The prospect of new coal development in Alaska has presented some difficult problems which have delayed and retarded that development. To begin with, Alaska coal reserves near tidewater have several unknowns that have caused potential users to look elsewhere first. Since the coal is located in an undeveloped wilderness location, costs associated with development and delivery price are estimated and not production proven. Users tend to disclaim statements of price competitiveness, given Alaska's reputation for high costs. The coal is in an undeveloped state, three to four years away from production stage. Users tend to look to operating coal fields first.

The estimated infrastructure costs associated with opening a new mine would require a minimum of six million tons annual production. It has been difficult to find one user, or to put together a package of users having a need for that amount of coal.

The world energy situation and Middle East political conditions have certainly worked to Alaska's favor. A surprising problem has been the lack of information or knowledge about Alaska's coal among what would be considered very sophisticated industries and countries. These are industries having world-wide operations and markets but no knowledge or awareness of Alaskan coal. At times their information bordered on the ludicrous. So there has been a problem of educating the world about Alaska.

Despite the above problems, the Department of Commerce and Economic Development's policy has been a belief that coal will generate a very important economic contribution to Alaska's economy and expanding industry. It is believed that the formulative stage of an expanding coal industry would occur in the decade of the eighties and, therefore, fit into the Administration's program for economic diversification.

The Department composed a scenario of what were believed to be development alternatives within competitive economic conditions. These development alternatives were grouped under three general usages of coal:

1. Coal exported in lump form for steam coal.

2. Coal converted into electrical power for industrial users in proximity to the mine area.

3. Coal converted into processed or manufactured fuels for export.

The Department has made extensive marketing efforts and contacts with every utility company on the West Coast regarding the first use, steam coal. Given the world interest in coal, the Department has also determined power requirements and the policy for coal importation for Japan, Korea, Taiwan, Germany and Denmark. A promotion effort for Alaska coal has been made to government and industry officials in each of those nations. The success of that effort is obvious when you count up the numer of trade teams and industry contracts from these different countries that are occurring in Alaska each month.

We believe the second use, power for industry, is the key to providing an industrial base in the State of Alaska. It would appear from some studies that electrical power generated from Alaska coal will be cost competitive with new power in the Lower-48 produced from fossil fuels. If other Alaskan cost disadvantages can be overcome, Alaska power available on long-term contracts may appear attractive to industry for future plant site location. A combination of resource materials and power will be a powerful incentive to offer industry in the coming decades. Discussion is being held with aluminum processors, iron ore reduction and steel companies and magnesium processors.

The Cook Inlet area contains every important energy source needed to establish an industrial base. There is coal, gas, oil and the potential for hydropower. With our added resource wealth, it should be possible to establish a specialized industrial base in that area.

The third possibility for using Alaska coal is conversion into synthetic fuels. The Department has kept informed with developments in this field and has been in contact with industry leaders. The state has given direct support to the Beluga Methanol Feasibility Study and views this project as making an important contribution to Alaska coal development. We believe methanol fuels will make real economic sense if the federal government ever forms a realistic future energy development program.

The Department has followed with interest the industry exploration study on Coal Oil Mixture (com). While there appeared to be strong interest in this fuel in earlier stages, the inability to use North Slope oil has posed a problem.

While there are many problems for coal development, nevertheless the opportunities are unlimited. It is our belief that coal has an important role to play in Alaska's development, and a long-range economic contribution to make to the state's economy.

Environmental constraints to coal development

Dave Sturdevant
Alaska Dept. of Environmental Conservation, Juneau

This paper presents a summary of the major environmental regulatory programs which may serve as constraints to coal development. Each of these regulatory programs is clearly mandated by state and federal legislation to protect the quality of environmental resources which have been degraded by past development activities. These programs may nonetheless be perceived as constraints because compliance with them entails substantial commitment of time, money and effort by industry.

The development of coal resources comprises a sequence of activities beginning with mining and continuing through processing, conversion, transportation and combustion to final waste disposal, including secondary aspects such as community and industrial development. The chain may be as short as a small mine serving a local power plant, or it may span all of these activities over two continents. As for the impacts, some are local and temporary and some are global--among the most serious environmental concerns faced on the planet. Now that world scale coal development is on the horizon for Alaska, our focus must expand to include these greater concerns.

The State of Alaska has begun to develop a surface mining regulatory program, pursuant to federal statute. The surface mining program, whether under state or federal administration, is a comprehensive program for environmental control of surface mining and reclamation. The nature of the program which will evolve in this state is uncertain, depending on litigation, the Office of Surface Mining and the Congress. However, the major aspects of the surface mining program can be identified.

Any operator is required to obtain a permit for surface mining, issued in accordance with the regulatory program. The permitting process covers three phases of activity--environmental assessment, mining and reclamation.

An environmental assessment must be detailed in the permit application. Topics which must be addressed include: geology, ground water hydrology, surface water quantity and quality, climate, vegetation, soils and land use. The requirement to include fish and wildlife resources has been remanded by the courts to the Office of Surface Mining for revision.

The mining phase is controlled by the performance standards contained in the Act and in the federal regulations. These standards provide detailed procedures for nearly every aspect of mining activity, including the following primary items: stream diversion, sediment control, acid forming and toxic forming spoil, ground water protection, surface and ground water monitoring, stream buffer zones, effluent limitations, coal utilization, spoil disposal, coal processing wastes, air resources, fish and wildlife protection, road design and construction and the removal, storage and redistribution of topsoil.

The reclamation phase must also be detailed in the permit application. Reclamation must restore the land to a condition capable of supporting uses existing prior to mining, or to "higher or better" uses, and must comply with the performance standards of the mining phase. The reclamation plan must describe: capacity for alternative land uses, how the proposed land use is to be achieved, earth moving, revegetation, handling of acid forming and toxic forming materials, compliance with the Clean Air Act and Clean Water Act, protection of water quality, sedimentation ponds and impoundments, waste banks, stream diversions, disposal of excess spoil and transportation facilities.

Air quality regulation creates perhaps the tallest and broadest hurdles that must be crossed in the development and use of coal resources. The presence of this regulation indicates the severity of air quality degradation that can be associated with coal development.

There are three main programs which govern air emissions, pursuant to the Clean Air Act. First, the "National Ambient Air Quality Standards" program establishes the maximum pollutant concentrations which can legally exist in the outdoor air. No source of air pollutants may cause those standards to be violated.

Second, the "New Source Performance Standards" program regulates actual pollutant emissions from stationary sources. These standards are set based on the emission levels which can be achieved through the best control technology available. Standards have been developed specifically for coal preparation plants and coal power plants. It is this program, well-known to many Alaskans, which requires the scrubbing of at least 70 per cent of the sulfur dioxide from power plant emissions, despite the extremely low sulfur content of most Alaskan coals. The additional cost of this scrubbing equipment may be unnecessary to protect air quality in Alaska.

Third, the "Prevention of Significant Deterioration" program sets substantially more stringent ambient air quality standards than the above in most regions of the U.S., and requires a detailed impact analysis for permit issuance. The purpose of the program is to maintain air quality where it is currently better than the national ambient standards.

This program probably is commonly perceived as the greatest constraint upon many kinds of development because the impact analysis requires, at considerable cost, field monitoring and modelling of emissions impacts over a period of one to two years, and because there can be no significant impact in certain national protected areas. In Alaska, these areas are four--Mt. McKinley National Park, Tuxedni National Wildlife Refuge in lower Cook Inlet, Bering Sea National Wildlife Refuge and Simeonof National Wildlife Refuge, south of the Alaska Peninsula.

Coal mining has long been associated with water pollution caused by massive earth moving, alteration of surface and ground water flows and exposure of acid forming and toxic materials. Processing, conversion and combustion facilities may also affect water quality through wastewater or thermal discharges. The huge water quality problems of the past, however, are now controlled through a variety of regulatory programs. Alaska's low sulfur coals probably eliminate major acid drainage problems.

The federal surface mining program requires collection and treatment of all on site water according to standards which have been mutually adopted with the federal Environmental Protection Agency (EPA). The program also requires earth moving operations to be stabilized against erosion and leaching.

All waters discharged must receive a permit from the Environmental Protection Agency, which imposes pollutant limitations. The state has a double role in discharges--it must certify that a discharge receiving a permit complies with state laws and regulations, and it adopts the federal permit as a state permit.

The state also maintains "Alaska Water Quality Standards", which specify allowable pollution limits in receiving waters.

Thus, there are three levels of control of water pollution from surface mining--control of the mining process, control of discharges and control of receiving water quality.

A wastewater discharge from any other phase of coal development also requires the federal discharge permit and state certification, if the dishcarge will reach a navigable water. This permit may require six months to a year for issuance.

A final authority respecting water quality, which may apply to many aspects of coal development is the U.S. Army Corps of Engineers' jurisdiction over construction affecting navigable waters, including wetlands. As with wastewater discharge, the state must certify that an activity to be permitted will comply with state water quality laws and regulations before a permit can be issued. The Corps permit may be issued in three months in ordinary cases and six months or more in complex cases.

Solid wastes produced by surface mining are controlled by the surface mining program and do not require separate regulatory action. Their control is most important in terms of water quality protection.

The cleaning of coal and its combustion produce considerable solid wastes, which are controlled through permits issued by the state. The regulatory burden should not be great, so long as suitable disposal sites can be found. There is the potential, however, for toxic materials to be present in coal ash.

The "Alaska Coastal Management Program" may serve to constrain coastal development, although it can equally serve to identify areas where development may be promoted. The heart of the program is a set of environmental guidelines and standards which require protection of key features of coastal ecosystems. In the organized borough, the coastal program is applied through planning programs adopted by municipalities, and in the unorganized borough it is applied by the state based on the guidelines and standards.

Fish and wildlife concerns may be addressed by a number of regulatory programs. The federal surface mining program contained a section, now remanded by the Courts, requiring a study of fish and wildlife and a plan to minimize adverse impacts. The Alaska Coastal Management Program requires maintenance of fish and wildlife habitat. The Alaska Department of Fish and Game issues permits for any disturbance of anadromous fish streams. The "Endangered Species Act" requires protection of identified endangered species. The "Fish and Wildlife Coordination Act" requires consultation with the U.S. Fish and Wildlife Service and the Alaska Department of Fish and Game. Regulations of the Corps of Engineers also require consideration of fish and wildlife values and compliance with the Fish and Wildlife Coordination Act.

Protection of historic and archaeological resources is required both by the "National Historic Preservation Act" and by the "Alaska Historic Preservation Act". Major projects on state and federal lands generally require agency clearance before commencing.

Finally, the "environmental impact statement" must be mentioned. Where federal resources are involved, an environmental impact statement may be required, and the period of preparation may be measured in years rather than months.

In conclusion, while environmental regulation may serve as a constraint upon development, each regulatory program clearly has a beneficial public purpose. The complexity and extent of regulatory programs reflect the complexity of the interaction between humanity and environment, and the extent to which past actions have degraded the quality of environmental resources. It is our obligation to attempt sensible and equitable application of those programs.

Coal program of the Alaska Division of Geological and Geophysical Surveys

Gilbert R. Eakins and Cleland N. Conwell
Alaska Division of Geological and Geophysical Surveys

The Alaska Division of Geological and Geophysical Surveys (DGGS) has a mandate by law (Alaska Statute 41.08.010) "to determine the potential for production of metals, mineral and fuels". Coal qualifies as the most abundant fuel in Alaska and is widely distributed throughout the state.

Other responsibilities of the Survey, by both law and regulation, include coal conservation (AAC-46-) and the examination of mine foremen for competency is required by federal law. State regulation formerly provided for safety inspections, but these have been taken over by the U.S. Department of Labor. The total result of changes in laws at the state and federal levels leaves the Alaska Division of Geological Survey with a primary responsibility to assess Alaskan coal resources.

During the territorial years and early years of statehood, the U.S. Bureau of Mines and the U.S. Geological Survey work centered on the development of coal as a fuel for the Alaska railroad, and later for the military establishment. The principal development areas were in the Matanuska Valley and near Healy. However, an assessment of the resource continued on a broader scale, including drilling in the north slope, at Susitna and in the Kenai fields. From available literature and other sources, the U.S. Geological Survey published a coal resource map of Alaska in 1967, which illustrated the extent of coal fields in Alaska.

Alaska DGGS research during the last several years has added to the literature and knowledge of coal in the state, and in 1977 the division published an updated energy resource map. Other projects by the state, sometimes in cooperation with the U.S. Geological Survey or the University of Alaska, have been to explore individual coal fields in greater detail, including the Herendeen, Chignik, Cape Lisburne and Healy fields.

The State Geological Survey presently is initiating a long-range program to help determine the coal resources of Alaska. The goal is to eventually compile a coal atlas on each of the coal fields, which will include a set of maps and all available information on the coal: extent of known coal bearing units, depths and thickness of coal beds, coal analyses, land status, reserves, geology and environments of deposition. This would be the ideal product but its progress will depend upon funding and the amount of information that can be obtained from industry and federal agencies engaged in coal investigations. A major effort will be made to correlate the latest geological information with the best available coal data, and to fill gaps by field exploration.

The results of this program will be used by the state in resource and energy inventories, proper management of state lands, coal leasing and prospecting permiting, and by industry and Alaska's Native corporations for feasibility studies. Laboratory work on coal and sediments will be largely performed by P.D. Rao's Mineral Industry Research Laboratory at the University.

During the past summer, the Alaska DGGS was engaged in two coal projects: one in the general area of the Susitna lowlands and one at the old Chicago Creek coal mine on the Seward Peninsula.

The Susitna lowlands have been a prime area for the leasing of state lands. The reasons are the relatively thick seams (up to 50 feet) suitable for strip mining, and the close proximity to tidewater where shipping facilities could be constructed. This year, field work concentrated on the Susitna lowland region near known important coal reserves and many pending state coal prospecting permits. Currently geologic and land status maps are being compiled for the region. Two short field trips were made to acquaint the investigators with projects being conducted by industry in the Capps-Beluga area and to study the geology. A final report is due July 1, 1981.

The second major project is an assessment of the old Chicago Creek coal field on the Seward Peninsula. Coal was mined in the area intermittently from about 1904 to 1937. The total production is unknown, but old reports indicate over 100,000 tons were hauled overland to Candle. Coal could be an excellent substitute for the very expensive oil used in Alaskan villages for space heating and for power generation. A preliminary field survey and literature research have been completed by the State Survey. The next phase will be contract drilling and trenching to determine the reserves, quality and mineability of the coal. The final phase will be a feasibility study for developing a mine (open pit or underground) in this area. This should be completed by the summer of 1981.

Because of the growing need for additional energy sources and the present high cost of petroleum products, the State Survey believes coal research and coal development should have high priorities. Indications are that the state will expand its efforts in this field.

Potential impacts of coal development on fish and wildlife in Alaska

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Introduction

Coal mining, whether in West Virginia, Montana, or Alaska, is a subject surrounded by controversy. Environmentalists and the industry have long engaged in heated debates over various aspects of coal mining, and in recent decades the volleys leveled by both sides have escalated considerably in virulence. The controversy is likely to continue as the U.S. tries to meet its ever increasing demands for energy through the exploitation of coal. To some extent, such conflicts are inevitable. We need the coal. We also need a healthy environment. The extent to which we can avoid conflicts over these two requirements depends upon our ability and willingness to address environmental problems before they get out of hand.

A question some of you may be asking yourselves is, need we be concerned about fish and wildlife? With Alaska's vast cornucopia of pristine habitat, with the relatively small land area that is currently being disrupted by coal mining, and given the relative success of past reclamation efforts, is there really anything to worry about?

At the present state of development, the answer is probably no, there is not immediate cause for serious concern. Development in Alaska in the past has been relatively localized, and disruption has not been widespread. However, with large scale coal exploration on the horizon, we must begin to assess and evaluate the possible effects this development will have on our fish and wildlife resources. It is my aim here to briefly outline some of the potential problems and impacts associated with surface coal extraction.

Coal development impacts on fish and wildlife can result from water quality degradation, air pollution, and disturbance of the land. Impacts can be directly related to mining operations themselves, or can result from the development and maintenance of community support facilities associated with the mining.

Water Quality

1) Erosion. Erosion can have severe impacts on aquatic organisms through resulting sedimentation of water courses. Sources of erosion include: areas exposed by excavation; spoil piles; improperly contoured or revegetated backfills; areas that have undergone slumping, subsidence, or landsliding as a result of the degradation of ice rich permafrost; general construction activities; and improper road building and maintenance. Erosion may also result from the construction of housing, airports, and other support facilities.

Besides obvious siltation of rivers that are normally clear, erosion can cause excessive siltation above and beyond normal sediment loads in glacial streams, rivers, and lakes. Siltation from mining activities may also occur during biologically important periods when natural siltation is at a minimum. It is important to remember that aquatic organisms have adapted themselves over centuries to natural silt cycles in glacial waters. The timing or quantity of additional sediment loads resulting from mining activities may upset the delicate interrelationships between these physical and biological factors that have evolved together over long periods of time.

Siltation can have a severe impact on fish. The eggs of salmon, grayling, and other fish depend upon dissolved oxygen supplied by water flowing through and over streambed gravel. When silt overlays the streambed, the availability of dissolved oxygen is reduced dramatically. Salmon and grayling eggs are extremely sensitive to this smothering effect, and are often among the first fish to disappear from even slightly silted streams.

Siltation can also affect a variety of other aquatic organisms. Insects and other invertebrates, on which fish depend for food, can suffer severe population reductions as a result of siltation. As excess sediments reduce the amount of light available for plant photosynthesis, aquatic vegetation may suffer. The vital functions of adjacent or downstream wetlands--which are important spawning and nursery areas for fish, and provide essential habitat for a variety of other animals--may also be impaired.

Erosion can be controlled to a large extent by proper engineering techinques and prompt revegetation. Erosion control should be planned for and implemented before it becomes a serious problem.

2) Chemical contamination. Salts, trace elements, dissolved organics, and acid forming substances can leach from spoil materials, coal piles, and exposed surfaces in the mine. These substances originate from the shales, siltstones, and other overburden materials that are associated with coal formations, as well as the coal itself. If the mine intercepts the flow of surface or subsurface water, the threat of water quality degradation becomes

more severe. Contamination may continue long after the mine is closed, due to the excessive vertical permeability of spoil backfills.

Human sewage and waste associated with the mine and suport communities can also create water quality problems. Coal fired power generation facilities yield fly ash, desulfurization sludge, and bottom ash, which, along with coal storage dumps, can leach trace elements, salts, and acid forming materials into surface and ground water.

High concentrations of trace elements, including heavy metals, are known to be toxic to fish, wildlife, and humans. Trace elements associated with coal that are particularly toxic to aquatic organisms include mercury, cadmium, beryllium, cobalt, copper, arsenic and antimony. The information presented by Dr. Mitchell in an earlier paper indicates that some of these elements may not pose significant problems in the areas tested.

Reductions in water pit can increase the toxicity of various compounds, and affect the availability of nutrients. Alaska has been blessed with predominantly low sulfur coal, and acid generation should not be a serious problem in most areas of the state.

The presence of excess quantities of salts may sufficiently degrade surface and ground water to the point where they are no longer able to support certain species of aquatic organisms. But again, preliminary data presented in an earlier lecture indicated that this may not be a problem in many areas of Alaska. The effects of large amounts of dissolved organic hydrocarbons are not well understood, and more research is needed before impacts on fish and wildlife can be assessed.

When considering water quality impacts, or any other environmental degradation, it is important to keep in mind that any damage sustained by lower members of the aquatic food chain will have repercussions at higher trophic levels, interfering with normal food supplies. Thus, the disappearance of even the most "minor" species, such as insects or other invertebrates, must not be viewed lightly. It is also important to remember that bioaccumulation of toxic materials may cause problems in animals further up the food chain. Visible damage or decimation of populations resulting from food chain disruption or bioaccumulation may occur only at advanced stages of degradation. Visual inspection, therefore, is generally not a reliable indicator of environmental damage.

Air Quality

Particulate emissions in the form of coal dust generated in mining and crushing can be a problem, especially in winter. Emissions from crushing operations can be controlled through the use of various types of particulate pollution control equipment, but dust associated with excavation may be more difficult to control. Road dust can also be generated in considerable quantities during the summer months, but is fairly easily minimized by watering or paving. Chemical pollutants generated by coal fired power plants, heating plants, and vehicles in many cases have had a greater impact on air quality than activities directly associated with mining.

The extent to which birds, mammals, and other wildlife species are directly affected by air pollution is not well understood. The most significant impact may be the effects of air pollution vegetation. Plant communities subjected to continued long term air pollutant loading may or may not suffer observable damage. However, long-term exposure may alter the structure and composition of plant communities by selecting against those species that are less able to tolerate emissions. The ability of communities to withstand the stress imposed by air pollution depends on the amount, type, and duration of exposure; the response of individual species; and the particular environmental factors at work at the site, such as the buffering capacity of the soil. Any alterations in vegetative communities can be expected to affect wildlife species that depend on such communities to carry out their life functions.

Land Disruption

Large scale coal development will create obvious disruptions of large areas of land, and result in temporary--and in some cases permanent--loss of habitat. Habitat loss will also result from the construction of housing, roads, airports, etc., associated with the development of support facilities and communities. Migration routes of animals such as moose, caribou, and migratory waterbirds may also be disrupted by mining and associated development. It is essential that reclamation and habitat restoration efforts be initiated as soon as possible after mining is completed, so as to relieve the population pressures on adjacent lands caused by the dispersion of wildlife away from the mining area. If revegetation is not performed promptly, wildlife populations may suffer declines.

Changes in the species composition of, or the growth form of plant communities that result from mining activities or reclamation efforts can be expected to cause a shift in the composition, distribution, and density of wildlife species. This may be desirable or undesirable, depending on the species affected. Strictly topographical changes wrought by mining, backfilling, or subsidence of degraded ice rich permafrost should not be a major problem, unless improper engineering results in erosion or landsliding.

Interception and/or alteration of surface drainage and ground water flow patterns by mining activities will have obvious effects on fish and other aquatic organisms. In addition, changes wrought in surface patterns can also affect the density and distribution of terrestrial wildlife. The avoidance of surface streams and rivers can circumvent problems that may arise from disrupting surface water drainage patterns, but ground water flow disruption caused by mining may be a more difficult problem to solve. Whether or not the latter will seriously disrupt wildlife distribution and density depends on the availability of water in the region being mined, the extent to which density and distribution have been determined by ground fed surface water supplies, and the degree to which changes in water table levels affect the availability of surface water.

Coal extraction may create problems in areas where frozen soil or ice has perched the water table and led to the establishment of wetlands communities. If permafrost is degraded in such areas as a result of mining, the functional perch will be removed, and the water table will drop. Wetlands vegetation may be replaced by plants adapted to drier conditions, changing the nature of the habitat and resulting in a shift in animal populations. Moose, waterbirds and other wetland species may be affected, especially in areas where patches of permafrost have created isolated pockets of wetlands on which these animals rely for food, cover, or breeding areas.

Associated with land disturbance is disruption caused by human activity. An increase in human population will tend to spread human disturbance over large areas. Hunting and fishing will directly affect fish and wildlife, and those species that are sensitive to human activities will disperse out of the area, putting pressure on adjacent ecosystems and possibly resulting in population declines.

Conclusions

Coal mining in Alaska can have essential adverse impacts on fish and wildlife. While it is not possible to prevent all damage and disruption to fish and wildlife populations, impacts can be minimized through the use of available pollution control technologies, adherence to state and federal mining and environmental standards, and prompt reclamation. Environmental protection, in many instances, may not be easy or cheap but the stakes are high. We cannot afford to ignore them.

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Coal development: What is and what should be the role of state and local government

Frederick H. Boness
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Since a number of participants in this conference have already discussed in some detail specific aspects of government involvement in coal development, I have decided to discuss government's role in a broader, more policy oriented way. First, I would like to discuss briefly the various government activities which make up a total state policy. After that, I would like to offer a few suggestions for making changes in what I perceive that policy to be.

Let us begin by asking what are the different roles the state has in coal development? First, there is the regulatory responsibility. This is applicable to all coal development whether it occurs on state or private lands. The principal regulatory responsibility is environmental protection, but there also are regulatory responsibilities concerning health and safety and even labor matters. The state's regulatory responsibilities are, to some degree, overshadowed by federal regulatory activities of the same nature. As others at this conference have indicated, the working out of the respective state and federal responsibilities is something which is not yet fully resolved.

A second area of state involvement concerns the actions of the state as an owner of coal. Essentially, there are two aspects of state activity in this area. The first is the making available of developable coal lands. The decisions in this area, at least in theory, are guided by overall state resource development and economic growth policy. In practice, I believe the policy for making coal lands available has been amphorous. I do not, however, mean this as a serious criticism, as I do not believe the unavailability of state land has imposed a constraint upon coal development.

The second aspect of state activity related to state ownership involves the terms upon which state owned coal land is made available for development. In particular, the term of the lease, the rental and royalty provisions, and development requirements all determine whether a particular development is feasible. Lease terms are also a factor in judging whether the state, as seller of a non-renewable resource, is receiving its "fair share".

The third role of the state in coal development is its taxation policy. At the present time, direct state taxation of coal development is limited to a mining license tax of 7% of net revenues over $100,000.00, and state income taxes applicable to all businesses in Alaska. Coal operators may also be required to pay a property tax if their operations are located in an area where the local government imposes such a tax. There is not, however, a severance tax or statewide property tax similar to the taxes imposed upon oil and gas operators.

The fourth and final area of state involvement which I want to identify is what I shall call infrastructure support. This might take the form either of direct state appropriations for the provision of various support facilities such as docks, roads or railroads, or it might include more indirect methods such as favorable financing arrangements and tax credits or tax holidays for certain types of facilities.

How these different elements are combined, either conciously and deliberately, or by chance, constitutes a state "policy" on coal. Approached in this manner we can ask, "What is the state's policy on coal development?"

Critics of our state government, I expect, would be quick to answer that there is no state policy, or perhaps that the state policy is to inhibit development by imposing onerous and unnecessary environmental regulations. Such answers would, in my opinion, contain an element of truth, but they are far too simplistic to be meaningful.

First, I suggest that prospective developers must recognize that within the executive branch, no single agency or department has responsibility for, or control over, all of the aspects of state involvement discussed above. One department has responsibility for leasing, several others have responsibility for environmental protection and yet another is charged with helping to promote development.

The executive branch has responded to this situation by creating task forces and interagency working groups, and by locating central coordinating and planning responsibilities in the Governor's office. These efforts have been sincere and instructive, and many of the individuals who have been involved in such efforts are here and have reported on them. However, speaking candidly, I believe we must also acknowledge that such efforts, at least to date, have not been successful in defining a consistent, rational policy towards coal development. Nor do I believe these efforts will succeed even if undertaken with renewed dedication. I say this because I believe development of a consistent policy—at least a policy which supports coal development—can only come about after a discussion of the advantages and disadvantages of such development and adoption of a <u>legislative</u> program.

Some efforts toward this end have been made by the legislature recently, but I believe these discussions were too narrowly focused—looking principally only to state lease terms—and lacking in broad public participation.

I would now like to turn briefly to a suggestion for a state policy on coal. I begin this discussion by stating my belief that among the many different development opportunities available to Alaska, I believe coal development should rank very high. I take this position for several reasons.

I believe world demand for coal will be very good over the next 20 to 50 years and that those companies (and states) which start development today will be in the best position to meet future demand increases. Additionally, coal development will do a far better job of diversifying the Alaskan economy than will development projects based upon refining or processing Alaska's oil and gas resources. Furthermore, coal development, at least in comparison with other forms of development being promoted, is relatively labor intensive and should therefore provide good employment opportunities. Finally, coal development may benefit many Alaskans directly by providing aleternative energy sources. From all of these reasons I believe the state should adopt a policy of encouraging coal development.

Having said that, let me say I do not wish to join ranks with those who argue that environmental regulations are the culprit holding up coal development. I believe waging a battle against environmental regulation is unwise and fruitless. There are many in Alaska who support coal development, but only if such development includes thorough protection of the environment.

In my opinion, constant complaints and disputes over environmental regulations create serious doubts about whether the industry is really concerned about the environment. I suggest the proper approach to environmental regulation is to accept the fact that society can choose any level of environmental protection it wishes. But since such protection is for the good of society as a whole, then it seems to me logical that society should participate in the cost of that protection.

Perhaps the most significant concern state officials have addressed themselves to in the past is the defining of a state policy for the leasing of state owned coal, which would ensure that the state receives a "fair share" from its non-renewable resource. While I support the objective, I believe much of the effort has been too narrowly focused.

I suggest the state should not treat coal as a resource from which it expects a significant <u>direct</u> financial return, at least initially. My comment in this regard can be put into perspective by considering a few numbers. In 1977 Alaska produced about 665,000 tons of coal. If the state received \$1.00/ton royalty--which it did not--the contribution to the state treasury would barely be noticeable. Even if we assure that a project is undertaken which results in production of 5 to 6 million tons/year (which is the size project some have said is necessary to be viable), again royalties, even at \$1.00/ton, are barely more than a drop in the bucket.

Even if these numbers are doubled or tripled, we are still not talking about significant revenues by Alaska's present standards. I suggest the state could afford to forego these revenues in the next 10 or 15 years in order to secure the benefits derived from creation of employment opportunities, economic diversification and the making available of alternative energy sources in Alaska. Furthermore, with more creative taxing and leasing terms, I believe the state could recover even these foregone revenues.

I suggest the state's role should be to work to establish the industry through short-term assistance or incentive, if necessary. Such incentives should be regarded as an investment which will be returned at a later date. There are many mechanisms by which this could be done. For example, a leasing policy which required substantial royalty participation (20-30%), but <u>after</u> the developer has recovered capital is one way. Another would be a tax moratorium of 10 or 15 years, after which time significant taxes might be assessed. As I suggested above, I think even subsidies for environmental protection can be justified.

Such a state policy, I believe, is desirable because the risk of a serious mistake and resulting loss of the public wealth and resources is low. I say this because I do not believe coal developers will ever find themselves in the enviable position where market scarcities for coal create very large returns to producers. However, even if I'm wrong about this, the alternative leasing and taxation policies available to the state will enable the state to receive its "fair share" of any unanticipated windfalls. On the other hand, coal has a good long-range outlook and the dollars the state foregoes initially should be returned over the long run. At the same time coal development might provide midterm benefits in the areas of employment and low-cost energy.

I suggest it is not sound public policy to argue that coal development will necessarily and automatically happen when its time has come, and state encouragement before that time will result in revenue losses to the state. There are legitimate public objectives other than maximizing state revenues, which will not be achieved by a strictly passive policy. Furthermore, I believe Alaska's overall economic policy should itself reflect a diversified portfolio. If Alaska always pursues only the most risk free economic develoment policies possible, then Alaska must expect only the smallest returns. Coal development, I believe, creates only a relatively small risk of loss should an aggressive policy turn out to be unnecessary, yet offers a reasonably good overall long-term return. <u>That</u>, I think, is the kind of investment we all like to have.

Panel Discussion

Moderator: William R. Wood
Mayor, City of Fairbanks and
President Emeritus, Univ. of Alaska

I know that time at this session is of the essence. There are some people who have a plane to catch, it's been a long day and this, I believe, is the final session. I'm going to move it along as promptly as possible, so that we can have some time for discussion and then be sure that we get Mr. Eakins and Mr. Mueller out of town today. Nothing personal, just a good thing to get them back to Juneau.

If you would look at the line-up, all the names and numbers are listed therein, I don't think there's much need of my repeating the information that you find there. I'm going to call upon these gentlemen in order. They have approximately five minutes each to enlighten us, with pearls of wisdom and stimulating commentary, looking toward the future of production. Then we are going to turn it over to you, the audience, to ask them searching questions.

We start with none other than the Dean of the School of Mineral Industry at the University of Alaska, Fairbanks, Earl Beistline, who was a part of the land grant for that institution.

Coal research needs

Earl H. Beistline
Dean, School of Mineral Industry, Univ. of Alaska, Fairbanks

Critical developments in the nation's and world's energy supply has focused interest on the increased use of coal, both to conserve oil and gas as well as to use these materials as a source to manufacture more valuable products such as petrochemicals. The vast resources of Alaskan coal offers the opportunity to supply additional energy resources on a state, national and international basis, which will be beneficial to the State's economy (including more jobs for Alaskans), have a favorable influence on the nation's balance of trade, and will be of value to the society receiving Alaska's exported coal.

For the better utilization of Alaskan coal, numerous questions must be answered and problems solved such as those pertaining to coal resources, characteristics of coal, mining techniques for coal in arctic, subarctic and temperate areas, upgrading of coal for various uses, use of coal byproducts, and appropriate coal transportation methods and facilities.

Coal research in the School of Mineral Industry, University of Alaska, Fairbanks, has been underway since 1963, and was greatly enhanced by a grant of money given by Joe Usibelli to establish the Usibelli Memorial Coal Laboratory in 1964, in memory of his father, Emil, who mined in the Healy coal field for many years and unfortunately lost his life in a mine accident.

Since then, funds, grants and contributions have been received from varius agencies and industries, including the U.S. Bureau of Mines, U.S. Geological Survey, U.S. Department of Energy's Office of Surface Mining, Canadian Superior Exploration Company, Alaska State Legislature and the Usibelli Coal Mine. There has also been excellent cooperation from other individuals and companies interested in Alaska's mining industry. Through this assistance, a limited but continuous viable coal research program has been, and is, underway. Projects completed and underway are listed in the handout that has been previously distributed.

Public Law 95-87, 95th Congress, authorized funding for creation of 13 University Research Centers in various parts of the nation. Unfortunately, even though a number of universities, including the University of Alaska, Fairbanks, submitted detailed proposals for such a Laboratory, funding for establishing the Coal Laboratories was not approved by the Congress. The State Legislature, in anticipation of federal approval, provided a sum of $150,000 to be used specifically as a matching portion for research projects in

1979-80, but this amount was returned when the Federal portion was not forthcoming.

This year the Legislature provided $150,000 for coal research, which has allowed the Laboratory to increase its research efforts directed toward obtaining more information about Alaska coal, and hence, ultimately contribute to the development and utilization of this excellent resource.

In discussions with Dr. Rao and his associates, coal research that is needed includes the following topics:

1. Basic studies on: a) Organic chemistry of coal macerals from various coal fields of varying geological times, b) Inorganic chemistry of coals, and the affinity of major oxides and trace elements to the organic material, c) Reflectance rank and petrology of all significant seams in Alaska and d) Mineral matter in coal - quantitative analysis of minerals associated with coal.

2. Studies related to the formation of coal: depositional and postdepositional environments for various coal fields.

3. Bench scale study of liquefaction behavior of all significant coal seams of Alaska, and correlation extraction yields with petrology, rank and nature of mineral matter, etc.

4. Mining of coal in the Arctic: to have an experimental underground mine at Wainwright, Ataksuk or similar locations.

5. Dry beneficiation systems suitable for year round operation of coal preparation plants.

6. Palynology and paleobotany of Alaskan coals.

7. For immediate application—design of ship loading facilities and cost of transportation of Alaskan coals--an engineering study.

8. Beneficiation of Alaskan coal to make low ash - low sulfur products.

9. Make pelletized low ash - low sulfur - devolatilized coal for use by home owners to offset high energy costs.

10. A plan to mine remaining coal resources of the Wishbone Hill.

11. A mine plan for recovering multiple small seams in Kenai Peninsula.

12. Development of a fluidized bed coal furnace for small business or home use.

13. Economics of methanol production from Alaskan coals.

14. Applications of slurry transportation for remote coal fields.

15. Blending of various Alaskan coals for coke making.

16. Rehabilitation of mined land.

17. Drying of coal for domestic use and export.

18. Utilization of coal and oil for complimentary use.

Other speakers on the panel will discuss various facets of coal development and hopefully the foregoing list will be expanded by ideas that may come forth from their presentations, as well as from members of the audience. In this way, working together, we can further enhance Alaska Coal Research for the benefit of industry, the state, the nation and the world.

Transportation and market analysis for Alaska coal

Jack Robertson
U.S. Department of Energy, Seattle

Our department, working through the Seattle office, recently completed a draft study of transportation and market analysis of Alaska coal. We essentially updated a lot of past studies to bring them up to 1980 dollars, and 1980 technology. There were some eight findings, nine conclusions and six recommendations, but because of time I'm just going to talk about one aspect. That is: there is a mutually reinforcing relationship between the desire to market Alaska coal and the need for rapid construction of additional electric generation capacity in the Pacific Northwest. There is also a need to reduce consumption of foreign crude oil, and to continue to protect the environment.

The forecast shows that in the Pacific Northwest during the decade of the 80s the shortage of electrical energy will run about 2,000 to 3,000 megawatts. There is no way that this can be made up, short of some rather short range moves, such as stronger conservation programs. Or, for example, by the installation of combustion turbines and wind turbines, and the importation of electrical energy from outside the region, which would be very expensive.

What I want to concentrate on is the combustion turbine aspect. Because it appears to me, and it appears to us in the office, that Alaska coal converted to methanol, which can be carried down to the Pacific Northwest in tankers and put in conventional pipelines to combustion turbine sites, looks like a good solution. We do not know enough about the economics of it, yet, but the study which Placer Amex is working on is going to give us more information on that. I point out that in the urban areas, which are the greatest load centers, there is no way that we can put a major burning fuel facility in unless it is clean burning, and methanol is a clean burning fuel. Also, in those urban areas you can locate combustion turbines, and the utility companies like to locate the generating facilities next to the load centers simply for reliability reasons.

So that's the message we want to leave with you today. We think that it will turn out to be a viable alternative and that it will be price competitive. It appears to be so now, based on some preliminary work, at least based on imported petroleum. We think it's the technology and the concept that needs to be discussed. Thank you.

Coal for power generation

Robert Hufman
General Manager, Golden Valley Electric Association

I appreciate the opportunity to submit our views regarding utilization of Alaskan coal resures for the generation of electrical energy.

Coal is a most attractive fuel cost wise when compared to the oil alternative in interior Alaska. However, it carries with it extremely heavy environmental constraints, resulting in long lead times of 8 to 10 years for completion of conventional coal fired facilities and excessive associated costs. Today an estimated 33% of the project's total cost is expended to comply with numerous environmental regulations. Without a drastic change in the complexion of the United States Congress and a corresponding change in the Environmental Protection Agency (EPA) administration, it is my opinion that costly constraints will become even more excessive in the near future.

EPA has yet to formally issue its regulations covering disposal of fly ash classed as a special category hazardous substance. Doug Costle, EPA's administrator, has publicly stated his intentions to act promptly regarding regulations to abate the so-called "acid rain" problem. This in spite of the fact that a short time ago EPA testified at a House Committee hearing that 3 to 5 years of research would be required before a judgment could be made as to whether new air quality regulations would be required to control acid rain. In EPA's opinion older existing utility coal fired facilities are major contributors to the acid rain problem. Therefore Mr. Costle may shortly impose retrofit abatement requirements on existing facilities amounting to millions upon millions of dollars, ultimately to be absorbed by utility customers. As a matter of interest, acid rain is caused by gases in the atmosphere that form acids when they dissolve in water. Such gases include carbon dioxide which is naturally present in the atmosphere, as well as pollutants such as sulfur dioxide and nitrogen dioxide produced by combustion. When rain falls on areas where the soil lacks minerals to neutralize the acid, lakes may become too acidic to support life.

EPA's proposed visibility regulations are due to be promulgated soon. A portion of their proposed visibility regulations are based on concern for emission drift into a class 1 area from an outside source such as a power plant. However, they say that while protection of vistas "within the boundaries of a class 1 area is clearly required, vistas outside the class 1 area must also be protected if they can be viewed from the class 1 area".

EPA does note that Congress apparently failed to protect urban and other vistas not integral to the viewing experience, therefore, criteria must be shaped to determine which out-of-area vistas should be protected for a viewer standing, say, on a mountaintop and gazing beyond the class 1 area.

Mt. McKinley Park is a class 1 area and the mountain provides quite an expansive view from 20,3000 feet. EPA's current view is that manmade visibility impairment is any visually perceptile change in visibility from that which would have existed under natural conditions. I hasten to add at this point, it is not impossible to build a conventional coal fired plant today. It is simply an extremely expensive, frustrating and seemingly never-ending experience.

However, I believe a viable future for coal utilization by utilities will be realized during the late 1980's. Such a future will come about as a result of improved burning technologies such as pressurized fluidized bed combustion. That process shows great promise. We note the recent announcement of our country's first commercial scale coal gasification plant in Mercer County, North Dakota. The $1.4 billion dollar plant will process 14,000 tons of coal into approximately 125 million cubic feet of gas every day. This is the energy equivalent of 20,000 barrels of fuel oil a day.

The South African Coal, Oil and Gas Corporation uses the LURGI process to gassify coal yielding substitute natural gas, sulfur, pheonols and ammonia. The gas is further refined by a Fischer-Tropsch process followed by an exclusive synthol process producing gasoline, diesel, jet fuels, alcohol and ketones. Advanced technology in this field has made South Africa over 75% energy independent. This was attained in spite of the fact that the country has no domestic oil or natural gas. The United States, West Germany and Japan recently signed agreements to fund a 1.4 billion dollar project in West Virginia, to convert coal into synthetic liquid fuels suitable for refining to make gasoline and heating oil or boiler fuel.

In anticipation of new future availability of coal derived fuels, major manufacturers such as General Electric Company are offering gas turbines capable of easy, expeditious conversion to as many as seven different coal derived fuel categories, thereby offering maximum flexibility in the planning process.

So there is a bright future for coal and Alaska has an abundance of this valuable resource. We should actively support prompt commercial development of advanced coal technologies and vigorously resist the promulgation of unduly restrictive regulations, and those that would obstruct development of these promising technologies.

Thank you.

Past and future coal mining in Alaska

Cole McFarland
Vice President Operations, Placer Amex, Inc., San Francisco

As mentioned in earlier papers, Alaska is positioned to make a meaningful contribution to this national policy of increased coal utilization.

The widespread nature of Alaska's coal resource resulted in early use of coal for heating and cooking by Natives and early settlers, where stream erosion or tidal action provided natural and easy access. Early mining efforts were undertaken in various such locations in the state, with most significant operations on the Kenai Peninsula by Russian engineers and West Coast entrepreneurs. The first significant and continuous coal mining operations were begun when the U.S. Government constructed the Alaska Railroad. Development of Matanuska coal to provide a West Coast supply for the U.S. Navy as well as the Alaskan Railroad, and development of the Nenana Field to supply fuel for Fairbanks were the main objectives.

A single 10,000 ton shipment of Chickaloon coal moved in a navy collier in 1922 was the first and last navy shipment. However, the Jonesville operations in the south and the Suntrana and later Usibelli operations in the north served the railbelt domestic and commercial needs well. The military installations in both areas constructed power plants to conform to respective coal characteristics of the two regions.

Conversion of the Alaska Railroad to diesel in the 1950s and subsequent conversion of the Anchorage utility and military installations to natural gas in 1967 resulted in the shutdown of major Matanuska coal operations. The OPEC crunch in 1973-74 and subsequent rapid escalation of oil prices have once again placed the energy spotlight on coal.

A broad world concensus concludes that world oil supplies will peak and begin to decline before the turn of the century. While removal of artificial price constraints and reopening of lands to modern exploration techniques will extend petroleum reserves, the world community must begin the transition to alternate fuels. In addition to increased conservation, a number of promising methods of electrical energy production, such as fusion and solar power, are on the horizon. However, the principal alternatives to meeting the projected oil shortfall by the year 2000 are nuclear energy and coal. Greatly expanded world production, transport and use of coal will be a cornerstone in the transition from fossil fuels to more advanced energy systems.

The United States, with its high level of energy consumption must, for reasons of national security and economic well-being, move aggressively to reduce its dependence on foreign oil. The congress is considering additional steps that will expedite expansion of the nation's coal production for conventional central power generation, production of coal sourced synthetic fuels and coal export to western bloc nations. While there may be some moderation to what many of us consider excessive regulatory constraints, a major expansion in coal utilization will still be governed by stringent environmental safeguards. As mentioned earlier, Alaska is positioned to make a meaningful contribution to this national policy of increased coal utilization. Coal will play as important a part in meeting the nation's future energy needs as oil does today (and natural gas soon will).

Large subbituminous reserves within the Nenana coal field on the railroad, and the Beluga field located near navigable Cook Inlet tidewaters, are well situated to be used for bulk export and chemical conversion to liquid products. Economic evaluation on a cost-per-delivered-Btu will determine whether or not a drying/moisture stabilization step is warranted for bulk coal shipments. The most likely approach to chemical coal conversion is coal gasification and synthesis to the alcohol fuel methanol by commercially proven processes; with pipeline transport to coastal harbors and shipment by conventional oil tankers to market.

Studies are now underway to determine the environmental, technical and economic feasibility of both of these approaches to marketing Alaskan coal.

Looking to the future, I agree with Lt. Governor Miller that new oil discoveries will be made. The existing and planned pipeline systems to move North Slope petroleum products to coastal sites and Lower 48 markets can be used in the future when, oil and gas production decline, to transport coal liquids produced from central Alaska and the huge Arctic coal resource. Interim test mines to supply local native villages with fuel for heating and electric generation will serve to develop acceptable mine and reclamation methods in the Arctic environment. New methods, such as in situ gasification of methanol/coal slurries, may be feasible by that time. Coal conversion plants in the Nenana and Beluga fields will have demonstrated the environmental impacts to be expected.

In Alaska, as in the rest of the world, the coal mining and processing base constructed for transitional energy production will be available to supply world needs for transport fuels, and hydrocarbons for manufacturing of chemicals and foodstuffs well into the 21st century.

Environmental constraints

Ernest Mueller
Commissioner, Alaska Dept. of Environmental Conservation, Juneau

Environmental Constraints

Thank you. I'm not going to take the time to duplicate what Dave Sterdevant and Elizabeth Speer said in the earlier session. I think they covered the environmental issues. I'm sure many of you who are not associated with the regulatory process were somewhat amazed at Dave's admittedly cursory, but nevertheless extremely complex rundown on the steps that are necessary to go to for coal development. I think Bob Hufman's comments are well taken also.

I think it will be helpful, however, to explain a little bit about what our role is in the development of an industry in Alaska, particularly, coal development. Our agency, working under federal and state law, has set ambient standards for pollutants in the air. In terms of coal, that's primarily sulfur oxides and articulate matter, and maybe other types of heavy metals or other pollutants that might show up. Those standards are transmitted in some cases into emission standards. Not only do we regulate how much of a particular pollutant can be in the air but also, how much a particular industry, a particular process may dispose of into the air, depending upon the process or industry involved.

In Alaska, of course, as I mentioned, sulfur oxides are not only a pollutant that comes from the coal burning industry, but also from pulp mills and other industries. We also are heavily involved in the process that Mr. Hufman mentioned--the development of national policies--primarily by the Environmental Protection Agency but also by the Congress, who passed Clean Air Act amendments, for example. They established some of the constraints that this industry has to work under in terms of the kind of sulfur removal processes that are required. We spend a substantial amount of our time lobbying the Congress, testifying before committees and working directly with EPA, to try to make national regulations flexible enough to allow for Alaska's unique conditions.

I'm sure everybody's heard of Alaska's unique conditions thousands of times, but when you're talking about the Ohio Valley versus the Tanana Valley there's a substantial difference in the kind of airshed we're working in. We need to make the regulations on the federal side flexible enough to address the needs of Alaska. EPA, on the other hand, tries to make them apply nationally in as rigid a format as they can. So we're constantly battling with them on those ends. We spent many months in Washington during the development of the Clean Air Act. I think we did make some changes, particularly in terms of the prevention of significant deterioration regulations. At one point in time, we were faced with a mix of the D-2 bill versus the Clean Air Act amendments as originally drafted, in which Alaska would have been virtually impossible to develop because of the overlap of the wilderness areas and the restrictions on development near wilderness areas. These were problems that Mr. Hufman mentioned on visibility, as well as the fact that these are so-called mandatory Class I air pollution areas. We managed to develop a lot of flexibility in that, so that none of the eventual D-2 areas will be fixed in that kind of sequence. They have a lot more flexibility in the Clean Air Act in that case.

One of the things that we have been doing in the last few years is working directly with project sponsors of major projects, such as the Alpetco project, in determining what the environmental issues are and how they can best be addressed. We generally work as we did in the Alpetco process, within the framework of the EIS program (Environmental Impact Statement), and under the state's Permit Simplification Bill that passed the legislature several years ago. We can provide a service through each of our regional offices to work directly with the developer, to identify which permits he needs for a particular project and to expedite those through the state and federal system. We find that service working quite well, and this last month we opened our third Permit Information Center in Fairbanks. We have one in Juneau and Anchorage as well.

In summary, we look at our job as not only setting environmental standards, but also as working directly with industry and the public in developing ways and means by which those standards will be met, and ways in which Alaska industry and future Alaska industry can meet those standards. Our object is to try to develop as flexible and as adaptable a program as possible, so that industry has room to work and so the needs of Alaska's environment and the public health of the people are met as well.

Thank you.

Coal for central home heating in Fairbanks

Bob Sundberg
Councilman, City of Fairbanks

The use of coal as the primary fuel, for both electrical generation and district heating, is not a new concept in Fairbanks. Research done by Mr. Keith Sworts, Superintendent of the Fairbanks Municipal Utilities Power Plant, reveals that district heating was successfully being used in Fairbanks during the early 1930's.

The Northern Commercial Company built and operated this district steam heating system. The thermal energy was supplied from a power plant owned by the Northern Commercial Company, located at Second Avenue and Turner Street. Concrete utilidors were built in what was then most of the downtown area, (Cushman to Lacey on 2nd and First to Ninth on Cushman) and steam lines were placed in these utilidors. A report prepared in 1979 states in part "The steam lines that have been in service for over 40 years in these utilidors are still in good shape".

An agreement was made on October 31, 1949, whereas the City of Fairbanks would purchase from the Northern Commercial Company the electric, water and district steam systems. On July 30, 1950, the sale was completed, and the City has owned and operated these utilities to this day.

Important milestones, since acquiring the system, were the building of a new coal fired power plant at the end of State Street on the south bank of the Chena River, and the installation of 3,500 feet of steam line from the new plant to the existing district steam heating system. On December 15, 1951, the Northern Commercial Company built power plant was shut down. The City has continued since that time to provide electricity and steam to its citizens from the State Street power plant. Over the years other major improvements have been made, but these improvements have centered on increased electrical production. The District Steam Heating System, which had 183 customers in 1960, has 140 today.

In response to an invitation from the Hammond Administration, about one year ago, the Fairbanks City Council submitted a capital projects "wish list", which the Council called "Programs for Progress". Governor Hammond indicated that the projects his administration would look favorably on were those that did not represent high operating and maintenance costs that would have to be borne by the taxpayers.

Two of the projects chosen by the City Council to be included in "Programs for Progress" addressed the priority of conserving energy and reducing consumer costs through improvements to public works and utilities.

The first project, estimated to cost $2 1/2 million, is titled "First Avenue Reconstruction and Steam Facility Replacement and Upgrading". The second, titled "District Heating Demonstration", is estimated to cost $2 million.

Through the good efforts of our representatives in Juneau, both of these programs were funded at the requested levels; because the First Avenue Reconstruction does not represent a new concept of district heating in Fairbanks, my comments will focus on the District Heating Project. Certain assumptions have been made by the City Council, which may or may not prove valid as work progresses on the District Heating Program. They are in part:

1. That coal will be the most economical fuel in the Fairbanks area for the foreseeable future.

2. That hot water, rather than steam, is the better thermal medium because it is cheaper, permits higher cogeneration efficiencies and greater geographic reach.

3. Air quality will improve as small, inefficient, uncontrolled heating plants are replaced.

4. Fairbanks will become more competitive by retaining and expanding its tax base and employment base.

5. District heating will help stabilize heating costs and may reduce heating costs as much as 50% compared to heating with oil.

6. Hot water district heating systems require less maintenance than steam systems.

7. Annual operating and maintenance costs will be covered by user fees.

There may well be other important considerations, but the examples cited, if proven correct, make this a very attractive venture.

Since the requested funding was approved for the District Heating Project, the city requested proposals from interested persons and firms to act as consultant for the planning and engineering of the project. Twenty-eight proposals were received. After committee review and selected organization presentations to the City Council, ACRES American Incorporated was chosen as Managing Consultant. Stefano & Associates, Inc., and Stutzmann Engineering and Associates, Inc., were chosen as Associate Consultants.

ACRES American Incorporated, a Maryland based firm and a recognized international consulting organization, has undertaken planning, engineering and project management in many diversified fields. Because district hot water systems are not common in the

United States, ACRES had brought to this project the firm of Brunn and Sorenson, a Danish firm, who are members of the Danish Board of District Heating. Brunn and Sorenson are recognized in Europe as leading experts in district hot water heating systems.

Stefano and Associates, Inc., is an Alaskan firm with recognized expertise in the power generation field.

Stutzmann and Associates, a Fairbanks firm, are experts in soil conditions and right-of-ways.

The scope of work has been determined for the pilot or demonstration district heating project. Work will be done in phases, the first of which is an engineering report. The objective of this phase is to prepare a report which considers the technical and economical feasibility of developing a district heating system to supply heat to all areas of the city and certain facilities outside the city limits.

That area outside of the city limits specifically addresses the feasibility of feeding hot water to the airport from the university and city heating systems. Phase I is scheduled to be completed on December 31, 1980.

Phase II is the "pilot district heating system preliminary design". Identified tasks in this phase are:

1. Pilot system site selections.

   A. At a work session of the City Council on Monday, October 20, 1980, site selection was made.

2. Preliminary design of district heat source.

   A. Scheduled September 10, 1980 - November 15, 1980.

3. Preliminary design of the heat distribution system.

   A. Scheduled October 1, 1980 - November 15, 1980.

4. Preliminary design of pilot user hookup.

   A. Scheduled October 15, 1980 - November 30, 1980.

5. Prepare technical specifications and select bidder for long lead hardwear.

   A. Scheduled November 1, 1980 - November 30, 1980.

6. Prepare construction specifications.

   A. Scheduled November 15, 1980 - December 15, 1980.

7. Preliminary cost estimate - pilot district heating system.

A. Scheduled December 2, 1980 - December 31, 1980.

Phase III - Pilot district heating system final design and construction supervision, scheduled for 1981. The pilot system to be operable and supplying heat to about 80 residences by the fall of 1981.

In a letter dated April 29, 1980, to Dr. John Sawhill, Deputy Secretary, Department of Energy, Washington, D.C., from Robert C. Embry, Jr., Assistant Secretary, same organization, Embry states in part, "From a National Energy Policy perspective, district heating is a way, and perhaps the only practical way, of converting the heating system of vast numbers of urban based buildings to coal without severe environmental and social disruptions".

Embry further states, "modern district heating is widely used in Europe, the Soviet Union and recently Japan. As yet, there is no major urban hot water district heating system in this country".

I am sure that the reference to "major urban" meant cities much larger than Fairbanks, but I feel that our direction is proper and Fairbanks has an opportunity to be a leader in this country in modern hot water district heating. Because of the large amount of capital necessary to install a city-wide system, we will continue to look to our representatives in Juneau for this needed capital.

Of the many worthwhile projects proposed and funded by the last legislature, none, in my opinion, have the potential of the lasting benefits that district heating offers. We can and we must provide hot water district heating to all possible users. It is truly a program for progress.

Current and future mining activities at Usibelli coal mine

Joseph Usibelli
President, Usibelli Coal Mine, Healy, Alaska

Well, I agree with Cole, let's not look at the past. As far as I'm concerned this is the past, so let's look at the future. A little bit on our philosophy as a company and how we view the immediate and maybe not too immediate future.

We feel we have a maximum philosophical limit of our production of about 4 million short tons a year. Philosophical, based on a number of factors, number one being a unique position in the market that we are currently, at least, the sole source of coal in the interior of Alaska. Because of that, we have to extend our reserves beyond what a normal mining company might consider for a time period. Most mines are designed around a 40 year life, so that brings us to about 4 million tons a year. Also, having visited a lot of mines in this country, it appears to me that mines in our position, doing our type of mining, reach a point of inefficiency at about 4 million tons a year. For a very small closely held company such as we are, you get above that point and bureaucracy starts growing. I know how much we hate to deal with bureaucracies. We sure would hate to become one. So 4 million looks about our maximum.

Now obviously we can't produce that 4 million currently. But amazingly, with our present equipment and with equipment which we are already committed to construct in the next year, we will have a capacity of somewhere around 2 million tons a year--roughly three times our current production. So obviously we're looking for markets and we're not alone. One third of the coal capacity of this country is unused at this point. Many mines are sitting idle. Most mines operate at much less than capacity.

We think that that two million tons is going to be used, and we think it's going to be used very shortly. Otherwise we wouldn't have made committments to expand our capabilities. There is a strong possibility it will be used within the immediate vicinity of interior Alaska, with possible small growth in existing facilities, and some possible short-term major facilities going in. It's interesting to me that all the speakers talk about export coal and they all seem to say Beluga is the only way to go. I don't believe that for a minute. I think we're going to beat you guys into production by ten years.

We have a few advantages on this that they don't have. We have the infrastructure. That is a major structure for them. Ours is there. We're on a railroad which is now under very aggressive management that wants very, very badly to get some unit trains so that they can make some money. That's money for all of us because it's our railroad, and anytime they turn a profit that means the cost of service into Fairbanks can be reduced and we like that. Now we think that's a possibility. We are dealing with a number of companies for export of coal.

We don't think it's going to have to be dried, contrary to some of the things you hear. We don't think it's going to be gone to methanol. We know how to dry coal. You throw it in the furnace, light it and it dries every time. It's all a matter of economics. Whatever is the cheapest to get Btu's into a furnace so that you can get electricity out the end is what it's all about.

Another advantage is that we don't need to go to six or seven million tons a year to start a mine. As a matter of fact, if you'd like to buy a couple hundred pounds tomorrow, bring a basket with you, we'll be glad to sell it to you. We can produce at any level over and above what we currently are, so that means we can get into a market on a trial basis. Nobody's having to take our guesses on what our costs are going to be. We know what our costs are. The railroad says they know what their costs are, so we have a pretty good idea of what we can land coal for in any Far Eastern country.

One of the advantages we see for ourselves is the very aggressive and positive attitude of the governments of the Far Eastern nations. Some of it has been forced upon them, because they're a lot more vulnerable in their energy situation than this country is. We have some alternates. We have a lot of good alternates. Number one, we waste more energy than they do, so we have more capability of cutting back on our usage and we've done a lot of that. An amazing amount.

They are vulnerable because their energy is imported, and they have all taken the stance that they will increase their use of coal for power generation. They have no alternative and that's what they're going to do and they're very aggressive about it. They're building new power plants, converting old power plants and they are going to be buying a lot of coal. They would very much like to be in business with a U.S. coal source because they look on our government as being a stable government. (I don't necessarily agree with them sometimes, but nevertheless that's the way they see it.) So that gives us an advantage.

All in all, I think we're going to be in the export market. I think we're going to be in shortly. I think we're going to see a growing industry using coal in the interior. If everybody would believe me when I talk about how we could back out of some of the oil we're using now, and sell it—quit burning it up here and use coal instead--then we could be up to our 4 million tons pretty quickly.

Discussion

Moderator: William R. Wood

Mayor, City of Fairbanks and President Emeritus, Univ. of Alaska

Dr. Wood: I wonder if all of you would join me in a round of applause for Dr. P.D. Rao for bringing together so knowledgeable a panel as this. Let's give him a round of applause.

This panel has been very forthright in presenting the coal research needs of Alaska: the state policies for coal development; the environmental constraints; the transportation and market analysis for Alaska coals, which was particularly informative, I think, for all of us. The coal for power generation; coal for central home heating in Fairbanks and the future mining activities at Usibelli Coal Mine. I don't think I've left out anything, and I don't believe our speakers left out very much either.

We're now open for questions and any of you that has a question, there's a mike and you can address anyone of the panel specifically or the whole panel in general. Who would like to ask a question? ...

I was afraid there was a lawn mower effect here. All the rough spots have been trimmed off.

Charlie Parr: Somebody should break it loose. I have two questions which I think are related and I think each one has been partially answered. One is, what is being done to improve consumer acceptance of coal, instead of the much more convenient and cleaner fuels people are presently using. Maybe the district home heating concept is part of that answer, I'm not sure.

The second question is, what about value added in Alaska, or what we call in state processing? In other words, something more than simply mined coal coming out of the ground and going directly out of the state without the extra value that Alaska could get from more processing. Perhaps the methanol that was mentioned may be a partial answer to that question. I think the two questions are related, and I'd be very much interested in hearing any comments.

Dr. Wood: Thank you Mr. Parr. Who would like to tackle that one? I think he answered part of it himself. That in one case district heating is a partial answer and the other is the methanol project, is a partial answer, but I think his questions merit further comment. Mr. Usibelli.

Joseph Usibelli: Actually, a couple of things are being done to increase acceptance. The district project is an excellent one for a concentrated area like Fairbanks. But I think we're getting other things. Number one, coal is becoming more attractive just because of price. I've observed over the years--the old philosopher speaking here--that when it comes to any situation of change, the person or the group that reacts the most quickly is the individual. There are a number of reasons for that. It's kind of an inertia effect, and we see that now. I'm not kidding when I say we get people coming in buying a couple hundred pounds of coal or a pickup load or a ten ton truckload. We've seen a lot of that in the last year; it's a function of price. The price of oil is just too high. So that's happening.

Secondarily, after a long period with no development work being done at all, in home coal burning technology there now has been some done. First, there are some new units out that kind of give you the advantage of both. They're either combination units where you can use coal or select oil, or select electricity if you don't happen to want to fuss around with coal.

Another concept is some fairly free standing units that handle everything themselves. Actually, you pour the coal into a bin somewhere and it actually puts the ashes in your trash can for you. You really don't have to mess around with it too much. That takes a lot of the fuss and bother out of it.

The second question, the processing. I think that maybe people don't realize that the mining of coal is a very labor intensive industry. We did a very rough calculation that if the oil that were coming out of this state were coming out in equivalent Btu's in coal there would be 80,000 coal miners working in the mine at our rates of labor, which are pretty efficient.

Dr. Wood: Mr. McFarland, you wanted to have a shot at these questions.

Cole McFarland: Just briefly, I think Joe covered the domestic. There's quite a bit going on. There are a few more exotic things such as pelletizing, and some processes that might give you a little cleaner burning fuel, but generally it's a matter of price when you're trying to heat your home. I think it will gravitate towards modern stokers. You have to get a hold of the ash, though, Joe, to spread on the driveway.

But as far as methanol goes I think we're strictly looking at very highly populated centers that have a distinct air pollution problem, and they're in need of a clean burning fuel and are going to pay the premium for it. I don't see that necessarily being the case here.

Dr. Wood: Any other questions, please?

Ovie Weeks, Alaska Railroad: First, I'd like to add a little bit on what Joe has said as far as use in the home. We are now hauling coal from Joe's mine at Healy into the Matanuska Valley.

People down there that don't have the natural gas available in Anchorage are faced with either high electric energy costs from Matanuska Electric or the high cost of diesel fuel. They found that coal is the way to go down there.

Second, I'd like to ask a question of our two state government officials up there. What is your reaction to the comment that was made earlier about having the state pay part of the cost of the environmental constraints that are put on the development of the coal mines?

Dr. Wood: Who wants to address that?

Ernest Mueller: I guess what you're suggesting is that the state should provide some kind of economic incentive, either as a direct grant or low interest loan or something like that to offset some of the costs of meeting environmental standards. As a practical matter, the state has provided through the Alaska Industrial Development Authority some low interest loans for meeting environmental standards, particularly at the two pulp mills in Alaska. Dick can correct me if I'm wrong. But I'm not sure what the reception would be to meeting environmental standards with a grant program. Well Dick, do you have anything to add to that?

Richard Eakins: I think Fred has a good point and I think we need to look at it very seriously. The question is, how are we going to use the oil royalty revenues to increase the other sectors of the economy? Adding value on to the product, as Mr. Parr suggested, is one way. Another option is to stick it in financial institutions and make more money. Then what do you do with that money?

In my personal, humble opinion, a good way to use a portion of that money would be infrastructure support and transportation. As Mr. Hufman pointed out, if one of the heavy costs of that is going to be environmental, it's in the public interest to use a portion of those monies.

The policy that our department has espoused is that we can have a viable growing economy and industry and we can have the best environmental industry in the world, because we can afford to pay for it. If that's what the public wants, it seems to me we are in a very enviable position. We can have that and we can afford to pay for it. Then let's pay for it.

Dr. Wood: It occurs to me that the bottom line, regardless of which approach is followed to offset the costs of the environmental protection, the same people pay for it--the consumers. Because the government has no money, and neither do companies except as it's derived from consumers. Our tax payers, if you want to call them that. Therefore, I'm always astonished that the zeal to regulate is not tempered by the consideration of the ultimate payer. Another question?

Sandra Stringer: I have a question of our first speaker, Earl Beistline. Earl, you mention that Public Law 9587, which would have set up 13 regional coal research labs throughout the country, fell through. The state legislature appropriated matching funds, but the federal government failed to come through. At the conclusion of your statement, you jestingly commented that you were looking for some sort of a state grant. Are you looking for the state to back an entire coal research lab here in Fairbanks? If so, do you have the personnel at present to staff such a facility?

Earl Beistline: Sandra, first of all, the coal laboratory situation looks as though it's dead, but there's always a chance that it can be revised. Now, we had the matching money up to $150,000. We had another program under the same public law, where we were able to match with our people that are here. This is for the Mineral Institute that we do have. For that we get federal money coming in to supplement the state money. Now then, the last legislature provided $150,000 without any string for coal research, and that is what we have now. This allows us then to move ahead to expand our program and to acquire additional individuals. In other words, part of our problem is to have funding to bring people in so you have a good solid core. As we go down the road, once we have this core we can acquire money not only from the state but from the federal government--from various agencies--for research proposals, private industry and that type of thing.

Sandra Stringer: I guess, specifically, my question is exactly what is it that you want out of the next legislature?

Dr. Beistline: Well, Sandra, it boils down, I think, to one word. We feel that we could use additional money for coal research because of the importance of the program. It isn't just an idle statement such as we we were bantering back and forth here. But it is a program that we fully justify, in our opinion, for additional resources for coal research. The listing that we showed on the screen will give an idea of some of the areas where research is needed. Now in this conference there have been many ideas thrown out by a number of individuals for areas where research is needed. Realize also that a university can do only a certain amount of work in these fields, and that a lot of research is going to be done by other, more sophisticated units in the states and that type of thing.

Yesterday, in the luncheon speech given by Dean Leonard, he pointed out the importance of research, and gave several examples of that. One pertained to the iron mining in Minnesota. The University of Minnesota had done a great deal of research on the iron mineral known as taconite. In the meantime the conventional iron ore had been pretty well depleted, and it appeared that the mining industry as far as iron was concerned was on its way out. But the basic research that had been done on the taconites and other type of iron ore was such that industry could continue major mining in the state.

It's that type of thing that we feel is so important. There is so much not known about Alaskan coal. I don't mean only the characteristics, but the utilization and this infrastructure that is needed.

Dr. Wood: We have the combination of the University of Alaska and the Alaska Energy Center now being formed, as the result of legislative action last session. Both of them are here in Fairbanks, and I think we've opened up tremendous opportunity for investment of risk capital, and a major contribution to the well-being of the nation as a whole. Other questions, please?

Nilo Koponen: I have a question, I think for Bob Hufman. I'm not sure that I understood quite your whole point, but I believe you were essentially saying that you were not recommending the increased use of coal for power generation at this time. I was wondering what sort of policy changes or economic incentives that would be within the scope of the legislature to provide, that would make it perhaps more feasible.

Robert Hufman: Well, I'm sorry if I was misunderstood. I certainly would recommend the optimum utilization of coal for the generation of electricity at this time to displace as much oil as we can, Nilo. It's simply a question of economics when we look to conventional coal fired plants today. I explained some of the constraints, or rather the existing constraints were outlined by the gentleman from DEC. I added an additional list of constraints that are in the offing coming from EPA, indicating that the situation as I see it, when it comes to burning raw coal, isn't going to get better, it's going to get worse unless, again as I see it, the complexion of Congress and the EPA administration changes.

Our position right now is to maximize the utilization of the existing coal fired facilities in interior Alaska that are interconnected through Golden Valley's transmission system, primarily the Fairbanks Municipal Utilities System. The University of Alaska will have a new unit on a 7,500, hopefully sometime early this winter. I believe that you know, because it's been made public numerous times, that we've been attempting to purchase excess energy from both military plants--Eielson and Wainwright--and it's going to take an Act of Congress. We're halfway there, past the congress. I talked to Congressman Young's office today. He indicated that it looks like it's pretty well greased on the House side, and hopefully when they reconvene following the election it will be in the forefront, as far as legislation is concerned. We have negotiated contracts with MUS; we negotiated a new contract with the University, all designed to allow us to back off the existing oil fired generation, and replace it with coal fired. Once that legislation passes we intend to go back to Clear AFB, and that facility probably has more excess power spinning around the clock than the other two military plants combined. So, armed with that legislation this is what we plan to do.

As far as assistance from the legislature is concerned, outside of an outright subsidy such as suggested here, with the state picking up a portion of the cost of the environmental constraints and regulations for new facilities, that would be the only relief, as I see it, with one exception. It was brought up earlier today that legislation was introduced at the last session to make it more costly to utilize coal by increasing the severance tax and the assessments on the leases. Now as far as I'm concerned, that's counter productive; raising the cost of coal, while at the same time saying you should burn coal to displace oil. We're doing that to replenish a treasury in a state that's already overflowing. I don't think the state needs that money. It's going to be directly passed through to the customers. Joe Usibelli certainly isn't going to eat that tax. He's going to pass it through, and I would if I was Joe. So it means that the people that are in fact utilizing coal are going to be paying more. Now it would be different in my mind if we were exporting the majority, say, of the coal production in the state. Then in my estimation at that point in time I would be willing to pay a little bit more, because it would be worthwhile. But to impose that tax at this point in time on the customers that are in fact utilizing coal to me is ridiculous, because the state doesn't need the money.

Dr. Wood: Thank you, Bob. Underscoring once more concerns for the consumer. Let me raise one other concern, which comes to me every week from leaders in the villages, where the cost of fuel now is so exorbitant that they're having to cut down on their usage of oil. They're reverting to cutting down the trees for the necessary heat for their homes and their businesses. Frankly, the very environment that they're wishing to preserve to stabilize their way of life is being destroyed, simply because they have to resort to cutting the wood, cutting down their forests, their timber, since they can no longer afford the cost of fuel. We've not talked about that very much in this conference. But it's a very real problem in Alaska, and I'm confident that the legislature this year is going to address it.

Joe Usibelli: Bill, could I comment just a little bit further on what Bob said. I don't know if you caught it, but when Laura Hardy gave her talk she was talking about the change in the regulations, and it came out to no less than 5% royalty on the coal. Now this I find a little frightening. Not because of the 5% number, which I think is too high, but because that was addressed in the legislature last session at 5% and was defeated. It never even made it out of committee. But now coming out of the Dept. of National Resources, through what I consider a back door approach, they are now going to just change it by a regulatory change at no less than 5%, bypassing the legislative process. I think that is basically wrong. I don't see it as a revenue measure, because if you're talking about an additional dollar a ton, which is about what it comes out to, you're only talking about maybe $700,000 a year into the treasury. As was stated earlier that's nothing. We're wasting that much every day in most departments in the old state system. So I don't see it as a revenue measure. Or even if you're talking ten million tons a year coming out of this state it's not a revenue measure. The question then becomes, what is it and why is it? I don't really have the answer to that.

Dr. Wood: Thank you, Joe. Mr. Karella?

Andy Karella: Joe just raised one question. I was about to say that after two days, my head's overflowing. All the questions I have are answered one way or the other if I wait long enough. On the severance tax, we do not need it. Industry does not need it to get off the ground even for export. Because I believe that we have to get into a competitive position, and I'm not at all sure that we are. Adding $1.00 per ton is going to reduce our competitive edge. That question arose since I stepped up here. Thanks a lot for a good program.

Dr. Wood: Thank you, Andy. The question was asked, I believe, by Sandra, to what can the legislature do that would be helpful in getting the utilization of our coal resource. I think it's been mentioned by two or three speakers. The basic thing is the infrastructure, the transportation system, the loading facilities and the docking facilities if it's for export. Certainly the transportation system. If we're trying to address how you get help out to the villages, you've got a major transportation problem. Fuel now is something like $5.00 a gallon in some of the villages in this state. $5.00 a gallon. It's less than $1.00 in Fairbanks and about $1.00 in Anchorage. There's a difference. Transportation is the reason for the difference. Yes, sir, your question.

Jim Sheppard: I'm with the railbelt school district, and our main office is in Healy, next to Joe Usibelli, so coal and transportation is not too big a problem for us. I've heard a lot about production and marketing Alaskan coal, but I've only heard a few proposals for in state utilization of this resource on a small scale. Dean Leonard, from the University of West Virginia, at the Tuesday luncheon talked about the West Virginia coal miners using fuel oil to heat their houses, and everyone's desire to see the coal burned in someone else's backyard, preferably miles away. It is obvious to me that local utilization of this resource in our homes, businesses and public buildings is both financially and environmentally possible. At present the Railbelt School District is building a prototype electric-to-coal conversion project at Healy. We are using federal and state matching funds under a Dept. of Energy grant. Our payback period estimates are very good. We have had some technical and financial problems, but by this time next year we hope to have a model system on line operating at 20% of our previous fuel expenditures. If Alaska wants to sell its coal resources, first it must be sold to itself. The Railbelt School District is sold and we request your continued support.

Dr. Wood: Thank you very much. We're going to take one more question and then we're going to close it with some remarks from Earl Beistline.

Senator Brad Bradley: This question is probably for Joe. Would it expedite the development, utilization and sale of our coal resource if we gave a tax credit for each ton of coal? I think Joe would probably like that.

Joe Usibelli: Boy, I like that concept. I don't really know about the economics of that. It would probably do more psychologically to focus people's attention on it, because there are a lot of people that are very worried about their bill, but it never really occurs to them to think about coal as one of the solutions. As I said earlier, you get into this inertia effect and there are a lot of individuals that are doing that way and it's now starting to ripple into bigger things, such as the Healy project. Now that's kind of a natural. there, because we kind of live cheek by jaw with those folks. But another one that was very interesting to me is that the McKinley Park is also thinking about going to a coal fired central system. That just tickles me no end, but we're seeing it all over. I think maybe the economics are there, just in existing systems. I tend to get away from a lot of these subsidies and things. I think the best thing the government could do is just get off our back.

Dr. Wood: Let me turn it over to Earl, now. But just one reflection, that nowhere in this conference did I hear mention of an energy source which was much used in my boyhood days on the farm in the Midwest--buffalo chips--Earl, would you ...

Congressman Nick J. Rahall

Thank you and good evening.

I cannot express enough my delight in returning to our nation's largest state and to the land of the midnight sun.

Last year I had the pleasure, as a member of the Interior and Insular Affairs Committee of the U.S. House of Representatives, to tour this scenic state, along with my good friend and your fine congressman, Don Young.

During that visit I was also honored in being named to the Order of the Alaska Walrus, a distinction I duly note to visitors to my Washington D.D. office when pointing out the certificate.

I have never experienced a more beautiful place on earth than this great state, and am sure I never will. I was thrilled by the majestic grandeur and vast wilderness, and was warmed by the people I met.

Already, this visit has been just as good as the first, and I thank the University of Alaska and the Dean of the School of Mineral Industry, Earl Beistline, for providing me the opportunity to come back.

I am pleased to be here, and am honored to join all of you in a discussion of what we call in West Virginia, "King Coal".

It is hard for someone from the lower 48 to grasp the size of Alaska. More than twice as large at Texas, the state spans four different time zones.

Most of Alaska still belongs to nature; it remains the home of caribou and perhaps an occasional Eskimo hunter.

One thing my previous visit proved to me is that development and growth have not harmed this state and will not harm this state as many have said. The caribou roam along the pipeline, as I have seen from the air, and nature and technology seem to have reached an equilibrium.

What Alaska has experienced in the way of environmental protest to future growth and development, my own State of West Virginia has experienced and still is to this day.

There are a great many individuals in this wonderful land of ours who believe that the earth must remain chaste and smog free. Legislation and regulation has been advanced, with little or no regard to the harmful effects. To these individuals, whose thinking I believe is totally unrealistic, I say, "Consider the consequences of America's future. Freedom and energy independence on one hand, or domination and control by oil exporting nations".

A country that is dependent on other nations for its energy is not the master of its own destiny.

The majority of Americans generally believe that when one discusses the mineral resources of Alaska, they are only referring to oil. The North Slope has of course provided a boost to our supply of domestic oil, but we are rapidly realizing that oil alone will not fulfill America's future energy appetite. Such a realization turns us to coal as the answer, and I am sure many Alaskans are beginning to ask the same question that is asked each day by West Virginians, "Why not coal?"

Alaska has vast coal resources, particularly near Anchorage, in the Copper River area, and in the National Petroleum Reserve, I am told.

I would like to relate some facts about coal that carry true for Alaska as well as the entire United States. Facts that give further credence to the question, "Why not coal?"

Of all the energy potential available to this country, coal comprises nearly 82 percent, the largest of any one reserve. With one third of the world's entire coal supply beneath our own soil, America is not energy poor, it is energy rich.

Coal costs less than half the price of imported oil as a fuel for producing electricity. Consider just how large the price differential has become. A typical American utility spends roughly $35 for a ton of coal delivered and another $25 to meet existing air and water pollution standards, a total cost of $60. The equivalent amount of crude oil would cost $165.

Coal is not imported. It does not weaken the dollar. It is not a drain on our balance of payments.

Coal can now be burned cleanly, contrary to some environmental claims. At the present time modern technology is advancing new methods to allow for the greater utilization of coal in a clean and efficient manner. Coal washing, wet and dry scrubbers, precipitators and a fluidized bed combustion process being developed at Georgetown University in Washington, D.C., will enable industrial and utility users of coal to reduce sulfer emissions and meet current E.P.A. standards.

Most important of all: coal is available now. The industry has a current surplus of over 100 million tons. This alone, if utilized, could replace the equivalent of 12 percent of our current oil imports.

Ten days ago I attended a meeting of the West Virginia Coal Commission in my state's capital city, Charleston. The commission was founded and is chaired by West Virginia's Governor, Jay Rockefeller, who also headed up President Carter's Commission on Coal.

Attending the session also were Governor Hugh Carey of New York, and Governor Ed King of Massachusetts. Both of these men represent large northeast industrial states that rely heavily on imported oil for industry and the creation of electricity.

They stressed their desire to burn coal, to replace oil with coal, and to develop coal in synthetic fuels. As Governor Carey so aptly put it, "Coal is this nation's freedom fuel".

Throughout the discussions, there was a great deal of emphasis on legislation presently pending in the Congress that would force around 80 utility plants to convert from oil to coal to produce electricity. This legislation would be a major boost to regions of the the country that mine coal with a lower heat content. Such regions include northern West Virginia and southwestern Pennsylvania.

In my own congressional district located in southern West Virginia, the coal is of a lower sulfer content, and most used to produce coke for the making of steel.

Alaska's coal is of the subbituminous nature. This array of coal provides special problems in its use, for the cheaper grades are less likely to be moved from their source to markets elsewhere.

This fact brings me to another aspect of the West Virginia Coal Commission's meeting last week, which included a presentation by former assistant Energy Secretary John Sawhill who, following the meeting in Charleston, returned to Washington, D.C. to take up the reins of the new Synthetic Fuels Corporation. Dr. Sawhill was appointed by President Carter to head this massive technological undertaking that equals--if not exceeds--the space program, and that may be the light at the end of the tunnel for coal--especially Alaskan coal.

In 1975, a similar conference to this one was held here at the University, and at that time, the hope was expressed that new technology would be developed and in turn benefit Alaska as a potential coal supplier. The Syn-fuels effort just may be that hope.

The creation of the sythetic fuels industry has achieved wide bipartisan support and substantial momentum in the past year. That momentum is continuing, I am happy to say, and there is no doubt that coal will be a major beneficiary.

So far this year, we have seen the start up of two coal liquefaction pilot plants, and contracts have also been signed for two solvent refined coal demonstration plants. Another effort is about to get underway for a coal gasification facility.

Now I don't need to tell you that so far none of these plants are located in Alaska, and being fully aware of the transportation problems producers here face, I indeed see the need to have one of these facilities located here in this state. I can only say that these initial steps are only the tip of the iceberg in this field, and Alaska should be considered in the future.

The Syn-fuels Corporation has already issued solicitations for $5 billion in loan guarantees and purchase commitments for the actual construction of commercial scale facilities.

Over the next four years, $20 billion will be made available in financial incentive, and ultimately $88 billion will be expended.

The corporation should be viewed as an investment bank whose purpose is to serve as a catalyst for the new syn-fuels industry. It is evident that we cannot wait for traditional market forces alone to provide the incentives for this effort. That luxury was removed by our continuing vulnerability to oil supply disruptions, and by the high cost of oil imports.

The synthetic fuels corporation will also play a major role in research and development measures to allow private industry and utilities to produce and use coal more efficiently and more cleanly. The expenditure in this regard will be $1 billion.

The success of these research and development efforts will give coal consumers and the public greater confidence in coal's ability to meet future energy needs in economical and environmentally acceptable ways.

With this thought in mind, it is the hope of all of us who are supporters of coal to see the use of coal in utility facilities increase nationwide and right here in Alaska. Already I am told that the Golden Valley Electric Co-op burns coal at one of its' power plants. In time hopefully, such use will spread to other regions of the state.

The syn-fuels program is off the ground, but the coal conversion bill still faces a tough fight in Congress.

I am optimistic that next year, if not this year, will mark the passage of this legislation, because we can wait no longer to move in this direction--indeed our nation's security may be on the line.

From the topic of utilization, I would like to move now to a discussion of coal production. Unlike the Appalachian region of the lower 48, Alaska's coal comes from surface mining. We of course are seeing surface mining now comprising about 51 percent of the total production of coal, but in southern West Virginia, deep mining is still predominant.

Just as your state is embroiled in the fight for its land, my state has long battled the anti surface mining groups. When I was elected to Congress in 1976, my first major legislative activity was to be a member of the House-Senate Conference Committee that worked out the final version of the Surface Mining and Reclamation Act of 1977.

I was pleased with the careful balance this legislation set, but in time grew extremely disappointed with the way the Office of Surface Mining interpreted Congress' intent and wrote highly restrictive regulations.

After a number of oversight hearings, held by the Interior and Insular Affairs Committee, it became evident that changes either had to be made in the regulations or in the law. So far, it has been difficult on both counts to bring about change.

Late last year I advanced a proposal that would amend the surface mining law, to allow the states to set their own program into operation. while still working within the federal guidelines set up by the original law.

I am sorry to say that these endeavors have hit upon a very strong roadblock, in the form of Interior Committee Chairman, Congressman Morris Udall of Arizona.

The Senate has passed this amendment, but Mr. Udall has blocked any movement of it in the House, or for that matter in a House-Senate Conference Committee.

I do not need to tell you that this opposition is just another in the long, well organized environmental attempts to block the expanded use of coal. For too long, coal has had a dirty reputation as an energy source that kills miners and pollutes the air. This effort has been hard to fight, but we can see some progress from time to time, as even the New York Times editorialized in May of this year, "It now seems clear that all of us had better take another look at coal. Coal may be good for the world and especially good for America...In effect, the United States could become the Saudia Arabia of coal".

Alaska's economic stability is very similar to that of West Virginia's. Your history is one of the boom-bust cycle. We have the same experience. As one form of energy is pushed, jobs are created, money is made and the economy booms. But when the demand is gone, the bottom falls out.

Unemployment is widespread throughout the Appalachian coal fields. Alaska has one of the highest unemployment rates in the nation.

If coal again comes to the forefront we all stand to gain, and will gain over the long-term.

My optimism is not tainted in any way, shape or form. I am bullish on coal, just as I am bullish on this country. I want to see America strong just as each and every one of you do. I can see that the only way for this to come about is for the United States to become reliant on its own energy resources, not someone elses.

Alaska and West Virginia can form a bond, a strong bond--east and west--north and south--for the greater production and utilization of coal.

We can do it, but we have to work for it. I have no intention of giving up, and I know your congressman, Don Young, is in this fight also. With all of you joining this effort, we will win, for the betterment of Alaska, for the betterment of West Virginia, and for the betterment of America.

Thank you.

Usibelli Coal Mine, Poker Flat pit area.

Mr. Usibelli explaining maintenance schedule on Dragline bucket.

Participants at Luncheon.

Luncheon speaker, Lt. Governor Terry Miller, seated are Raymond Lasmanis (left) and J.P. Tangen (right).

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