Environmental Assessment of the Alaskan Continental Shelf

Annual Reports of Principal Investigators for the year ending March 1979

Volume X. Hazards
Data Management

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF INTERIOR
Bureau of Land Management

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Outer Continental Shelf Environmental Assessment Program
Boulder, Colorado

October 1979

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DISCLAIMER

ACKNOWLEDGMENT

These annual reports were submitted as part of contracts with the Outer Continental Shelf Environmental Assessment Program under major funding from the Bureau of Land Management.

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HAZARDS

CONTENTS

Annual Report

Contract #03-5-022-55
Research Unit #271
Reporting Period: Annual Report Period Ending April 1, 1979
Number of Pages: 30

BEAUFORT SEACOAST PERMAFROST STUDIES

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April 1, 1979

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I. SUMMARY

The objective of this study is to develop an understanding of the nature and distribution of permafrost beneath the ocean and barrier island along the Alaskan Sea Coast. Marine seismic refraction equipment the primary tool used in this study has shown submarine permafrost to be present at relatively shallow depths to distances of at least 20 km from shore. To put these observations into perspective, three principal points discussed at the Barrow Synthesis Meeting in January, 1978, are listed as bounds on the distribution of offshore permafrost.

On the basis of bathymetry and sea level history:

(1) Shallow, inshore areas where ice rests directly on the sea bottom are underlain at depths of a few meters by ice-bonded equilibrium permafrost. Ice-rich permafrost must be anticipated where ever the water is less than 2 m deep.

(2) Ice-bonded permafrost was once present beneath all parts of the continental shelf exposed during the last low sea level interval, and consequently relict ice-bonded permafrost may persist beneath any part of the shelf inshore from the 90 m isobath. (Depths to relict permafrost have been observed by members of this research unit to range from 10 m or less to depths greater than 100 m. Similar depth data gathered along the Canadian coast range from 10 m to 250 m.)

(3) Ice-bonded permafrost is probably absent from parts of the Beaufort Sea shelf seaward from the 90 m isobath, although subsea temperatures are probably below 0 C.

In addition to these general guidelines, some specific conclusions resulting from the current studies can be listed along with their possible implication of offshore oil and gas development:

a. From (2) above, we conclude that in some offshore areas where permafrost is relatively far from the ocean bottom it is possible to bury hot oil pipelines beneath the ocean.

It may not be possible to bury hot oil pipelines in near shore areas where permafrost can be ice-rich and located within a few meters of the ocea bottom.

b. Seismic studies outside of the barrier islands have shown that the depths of ice-bonded permafrost are not simply related to their distance from shore. In the Prudhoe Bay area shallow ice-bonded materials have been mapped offshore of the islands while nearer to shore these materials are considerably deeper.

c. The barrier islands are not uniformly underlain by ice-bonded permafrost. Areas with no ice bonding have been observed. In these cases, it should be possible for hot oil gathering lines to cross the island areas with no adverse effects from ice-bonded materials.

d. Also from (2) above, we conclude that cold gas lines can be buried in the offshore regions where a non-frozen layer exists but that the problem of freeze-back must be dealt with. The presence of salt brine complicates this problem beyond the onshore freezing problem.

e. Former thaw lakes and old river valley which contribute to the variability of the upper permafrost surface can be found in subsea permafrost of land origin. It may be possible to utilize these areas for offshore structures and avoid ice-bonded materials if desired.

II. INTRODUCTION

A. General Nature and Scope

This project is particularly concerned with the comparatively unknown areas offshore and along the barrier islands where subsea permafrost has been shown to exist. A high priority was established for mapping the distribution of offshore permafrost.

The study, which utilizes seismic refraction techniques to probe the ocean bottom along the Alaskan Beaufort Sea coast, was initiated in April of 1975. Because of the nature of the geophysical tool the primary data gathered are depths to the upper surface of the subsea permafrost. The study will provide information relevant to task D-8 in NOAA's proposal to BLM.

B. Specific Objectives and Relevance to Problems of Petroleum Development

Using the equipment purchased by the program, data are being gathered which enable determination of the distribution and nature of offshore permafrost. The most important parameter to be determined in this study is the distribution of offshore permafrost. Also, the depth to the top of the bonded permafrost beneath the ocean floor is to be determined. Another objective is compilation of the above parameters for use by other principal investigators and appropriate agencies and industries.

The Prudhoe Bay area and adjacent offshore islands is the primary focus of this study. The truncation of permafrost beneath the ocean is of interest, particularly the shape of the frozen-nonfrozen boundary. Thus, the second major objective is the determination of the shape of the boundary. One important facet of this objective is determining the nature and extent of permafrost beneath the barrier islands. These results will provide valuable information for refinement and testing of thermal models as well as for determining operational methods for offshore oil and gas development.

The third major objective is to provide information to support reconnaissance drilling programs including those of the University of Alaska, CRREL, and the USGS. Drilling provides information on bottom conditions only near the drill hole. It is possible, using the seismic technique, to extend such site specific information to areas remote from the drill site, by correlating seismic data at the drill site and at the remote locations. Also, seismic information can be used to suggest areas for future drilling investigations.

Specific and detailed relevance to problems of offshore petroleum development have been addressed in the synthesis document developed by the Earth Science Study Group at Barrow in January, 1977. The reader is referred to the section on permafrost-induced problems from that report.

III. CURRENT STATE OF KNOWLEDGE

The sea floor along the Arctic Coast is known to be underlain by permafrost. At this time, although relatively little is known about offshore permafrost properties including its distribution and the dynamics of its formation and destruction, definite progress toward more understanding is being made. Several of the problem areas needing investigation have recently been discussed in "Priorities for Basic Research on Permafrost" and also in a position paper for the National Science Foundation titled: "Problems and Priorities in Offshore Permafrost."

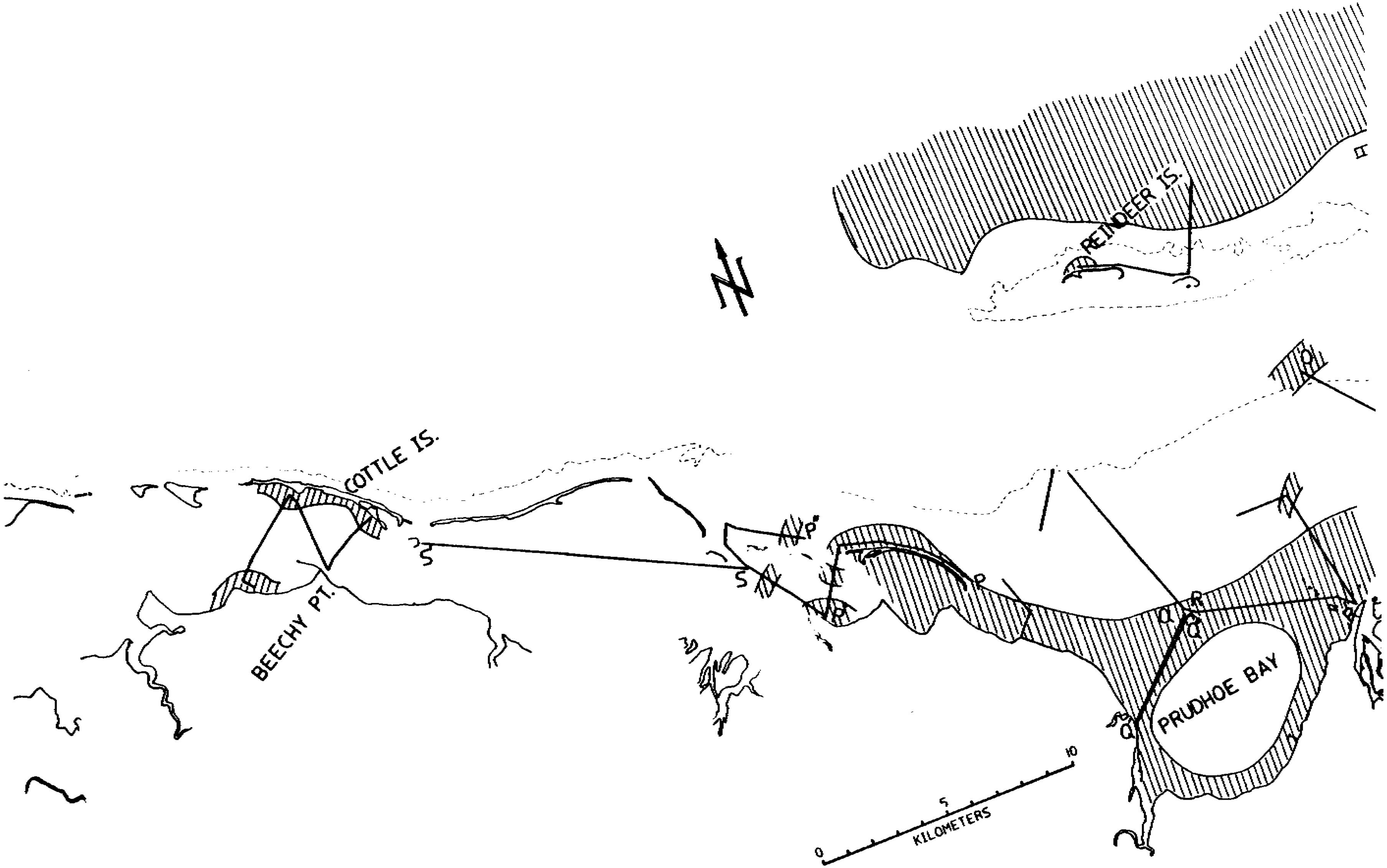
Extensive permafrost has been reported beneath the Canadian Beaufort Sea (Hunter, et at, 1978) and beneath the water of Prudhoe Bay, Alaska (Osterkamp and Harrison, 1976, 1977). Some of the physical processes involved in the degradation of relict permafrost are beginning to be understood and in addition to temperature, the porosity of the sediments and the salinity of the interstitial liquids have been shown to be important. Current data are available in the annual reports of research units 253, 255, 256, by Harrison and Osterkamp. Some details of the processes involved are also found in Harrison and Osterkamp (1976). The results reported here are in agreement with the drilling results obtained by the Joint USACRREL/USGS drilling program (R.U. 105) as reported by Sellman et al. (1976)(see also Chamberlain et al, 1978). In last years annual report a close correlation between their drilling and our geophysical results was shown. Also, the geophysical results are in general agreement with those of Osterkamp and Harrison. The depth of the permafrost upper surface is currently known along several transects made both inside and outside of the barrier islands. Widespread aerial distribution and depth information remain to be determined although it is possible to make some general statements regarding offshore permafrost, (see the summary section of this report), and to sketch regions of known shallow permafrost (see area map later in this report).

IV. STUDY AREA

The area investigated during this study is shown in Figure 1. Several vessel track lines shown in the figure and identified by letters were run during the 1978 summer field season. Past reports by this research unit have shown other lines in the area covered by Figure 1. The reader is referred to those reports to complete a listing of all lines run to date.

V. SOURCES AND METHODS

Shallow seismic refraction techniques have been documented by Grant and West (1964) and their application to the detection of subsea permafrost has also been described (Hunter, 1974; Hunter and Hobson, 1974). The seismic refraction data taken in and near Prudhoe Bay were collected using two 40 cubic inch air guns as a acoustic source and the refracted signal was detected along a hydrophone line towed behind a 21' vessel.


REINDEER IS.
COTTLE IS.
BEECHY PT.
PRUDHOE BAY
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KILOMETERS

Figure 1a

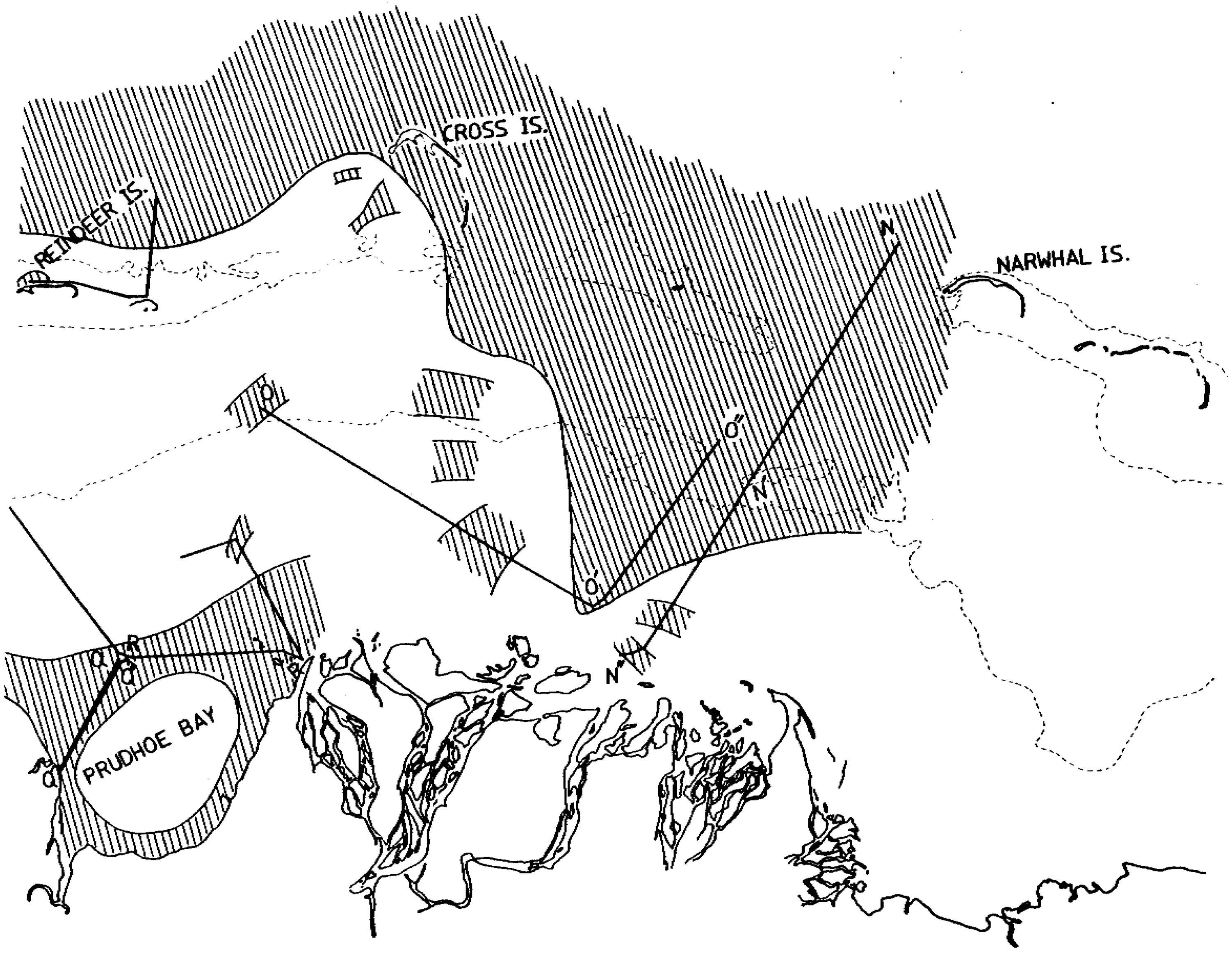

Figure 1b

The air guns were fired simultaneously and the 24 channels of hydrophone output were recorded in analog form by a chart recorder. These data were gathered at several points along the ship transects, scaled and reduced to time-distance plots. Over 300 of these plots were made last season along 120 km of vessel track.

The time-distance plots are used to determine seismic velocities in the sub-bottom material and depths to various layers. The velocities are then used to determine whether the bottom materials are frozen. Permafrost velocities in the materials near Prudhoe Bay are typically between 2500 m/s and 3000 m/s while similar materials in the nonfrozen state typically have velocities ranging from 1600 m/s to 2000 m/s (Rogers _et at._, 1975). Significant velocity contrasts such as these, which are typical of coarse sandy materials, allow easy classification of materials into the frozen or unfrozen state.

VI. RESULTS and VII. DISCUSSION

We have compiled the results of all of our marine refraction lines in Figure I. The shaded areas on the chart have been sketched to indicate areas of observed shallow surmarine permafrost. In all cases the observed permafrost is 40 meters or less _beneath the water surface_ and in most cases it is 30 m or less beneath the water surface. Areas where refraction lines have consistently shown high velocity refraction (velocities greater than 2500 m/s) have been connected together to indicate probable regions of continuous bonded permafrost at depths less than 40 meters. The area north of Reindeer Island is an example of such a region. Where refraction lines have only sporadically shown bonded materials, local shading has been used to indicate the sporadic nature of the observation. The shaded patches south of Cross Island are an example of this interpretation.

No correlation has yet been made with geological information. A recent shallow offshore drilling program sponsored by the conservation division of the U.S. Geological Survey will provide a great deal of new information on shallow bottom materials. When these data become available they will be compared with the geophysical results gathered to date.

Regions where bonded materials occur at depths greater than 40 meters have not been included because we have little information at these depths. (The present refraction system is depth limited due to energy limitations.) However, deeper permafrost is known to occur in the area between the West Dock and Reindeer Island (see the April 1, 1978 Annual Report).

Several vertical sections have been prepared which show the water depth and depth to ice bonded materials observed by the refraction measurements. Figures 2 through 9 represent vertical sections through the vessel track lines identified in Figure 1. Other vertical sections have been given in past reports and are not reproduced here. The figures indicate the permafrost surface relief is often on the order of 15 meters over a 10 km line. In some locations the surface relief is probably much greater than 15 meters. Figure 5 shows locations where high velocity refractors were not observed along line 0-0" at distances of 11 to 13 kilometers from the start of the line. It is quite possible that a refractor was located below the observation depth of the refraction system (approximately 40 m). If this were the case the surface relief could be in excess of 30 meters over the distance of one kilometer.

Range of Observed Velocities:

Differentiation of ice-bonded materials from non-bonded materials as shown in Figures 2 through 9 depends upon a significant velocity difference between these states. Figure 10, taken from a report by Rogers et al., 1975, shows a clear separation of velocities observed near Point Barrow, Alaska. The low velocity group, velocities below 2000 m/s corresponds to non-frozen sandy gravels while the high velocity groups, velocities above 2500 m/s, corresponds to those same materials when ice bonded. All of the refraction lines used to produce the figures were reversed so effects of sloping layers have been removed from the velocity data.

Figure 11 is a histogram of velocities observed near Prudhoe Bay. The observed velocities are not clearly separated as was the case for the previous figure. However, there is an apparent bimodal distribution with one significant grouping below 2200 m/s and another grouping above 2600 m/s. Two factors probably account for the lack of a clear separation of the high velocity group from the low velocity group. None of the refraction velocities were determined from reversed lines; consequently effects of sloping refractors have not been removed from the data. Also, the later velocity data were taken from a wider geographical area than that of Figure 10 and the materials are known to vary from sandy gravels to silts and clays. Virtually all material encountered in these seismic

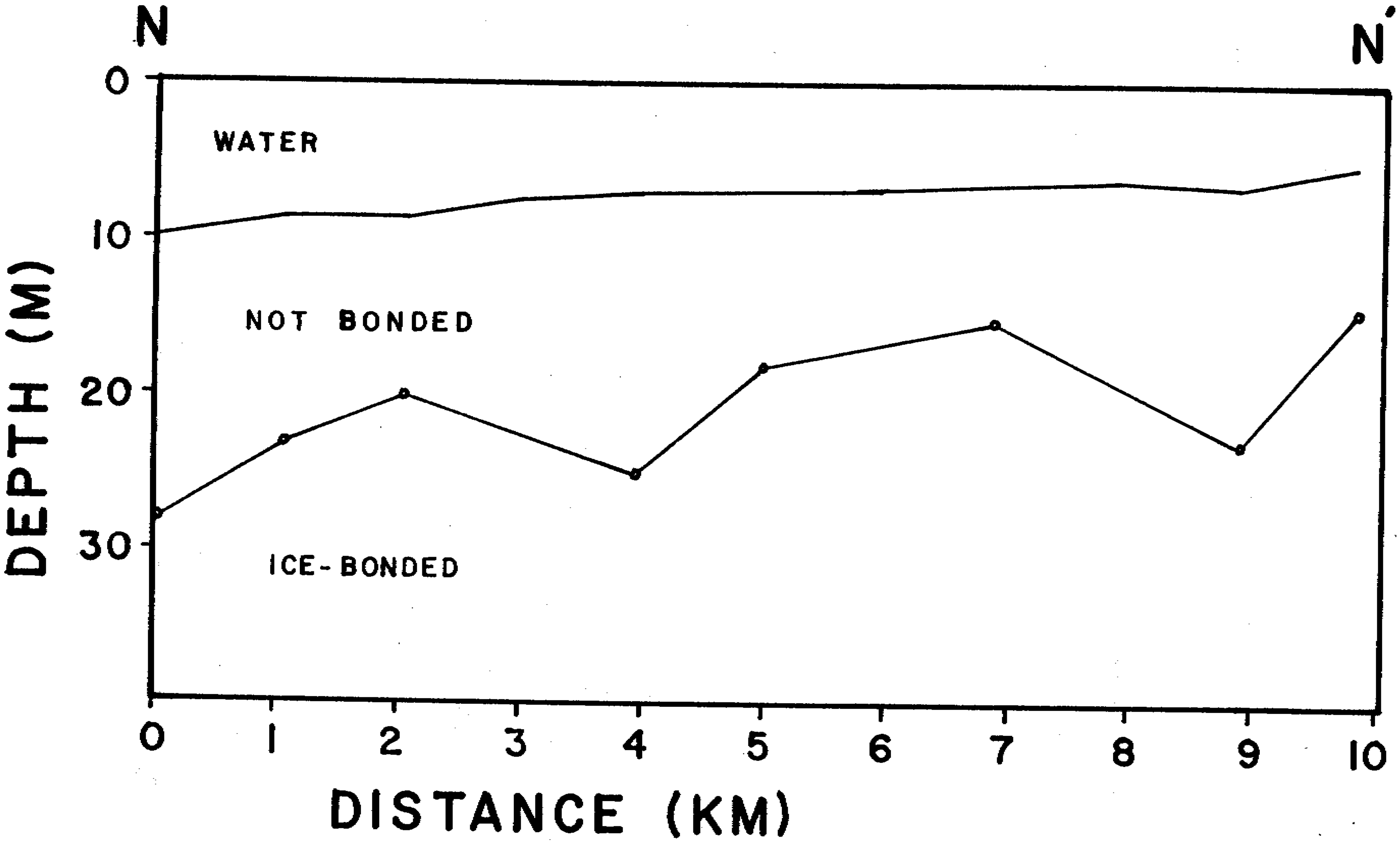

Figure 2: Vertical section through line N - N'

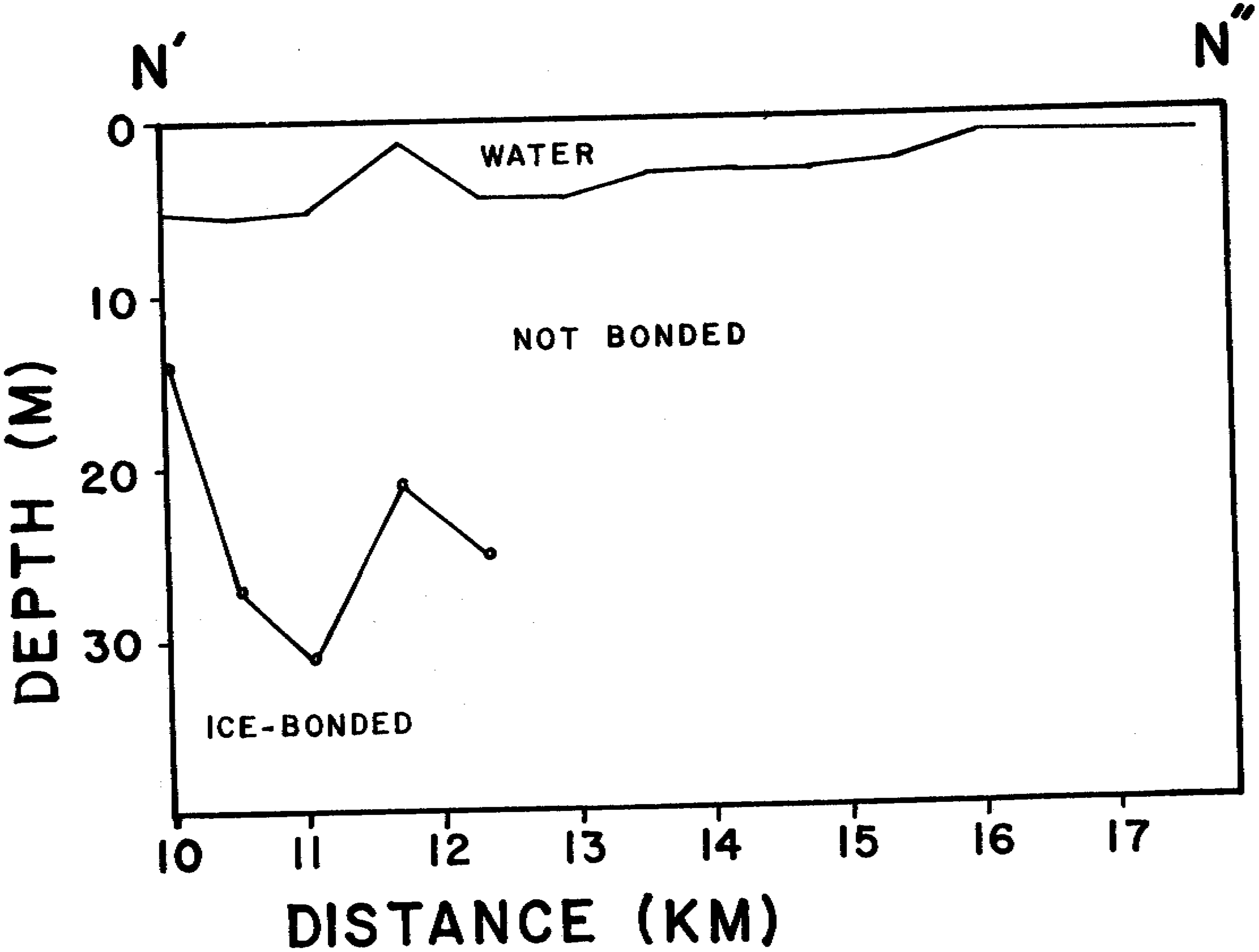

Figure 3: Vertical section through line N' - N"

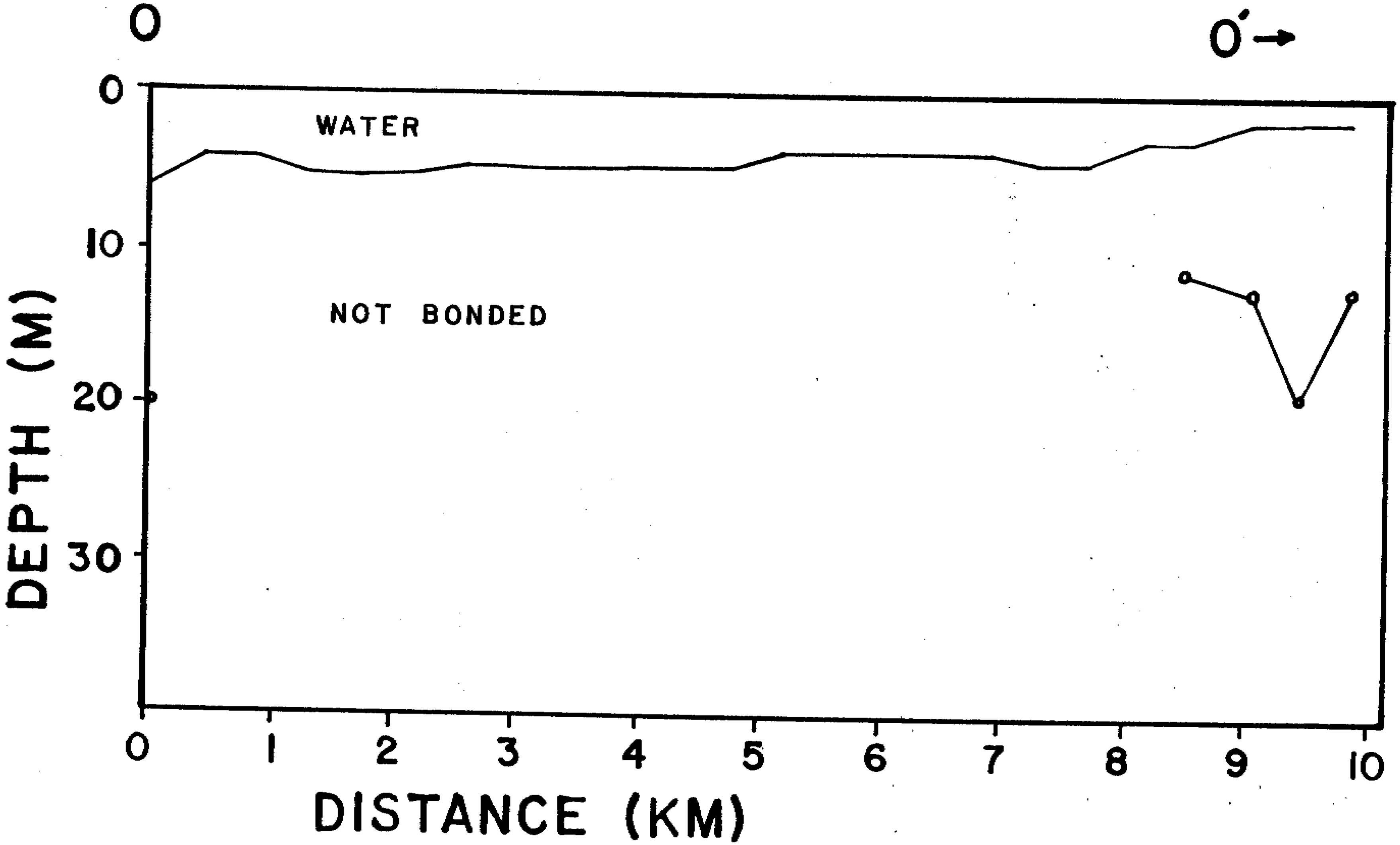

Figure 4: Vertical section through line O - O'

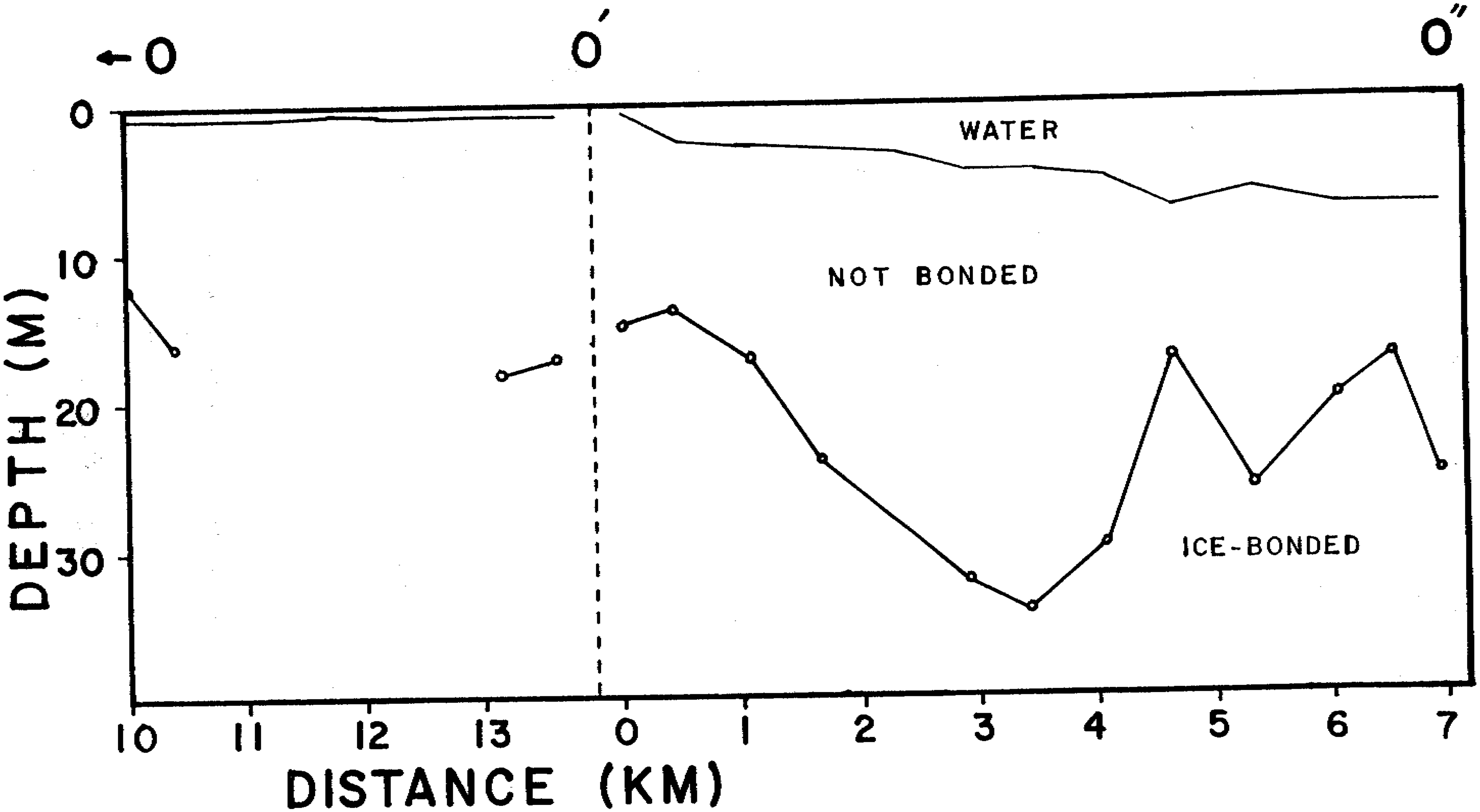

Figure 5: Vertical section through line O' - O"

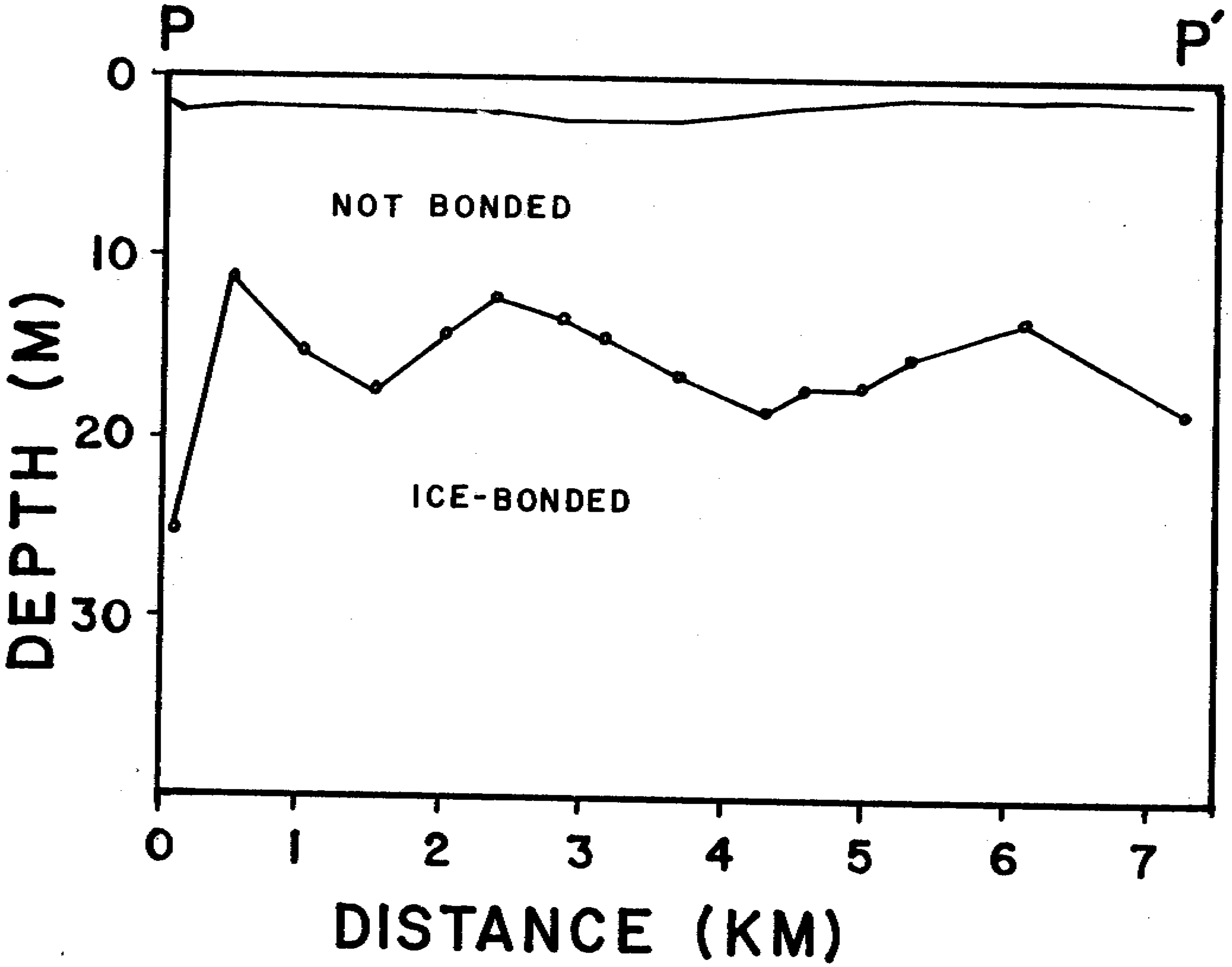

Figure 6: Vertical section through line P - P'

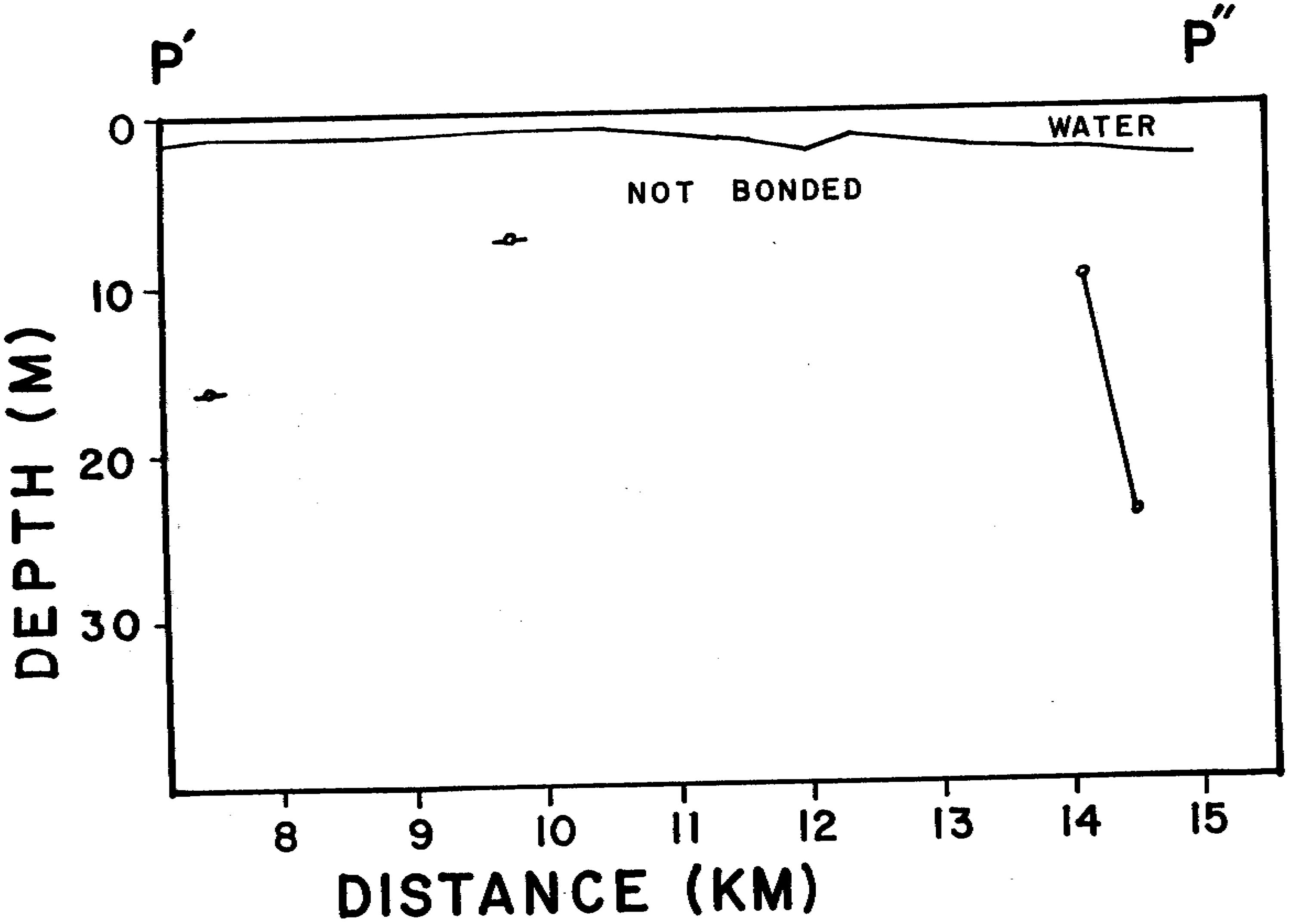

Figure 7: Vertical section through line P' - P"

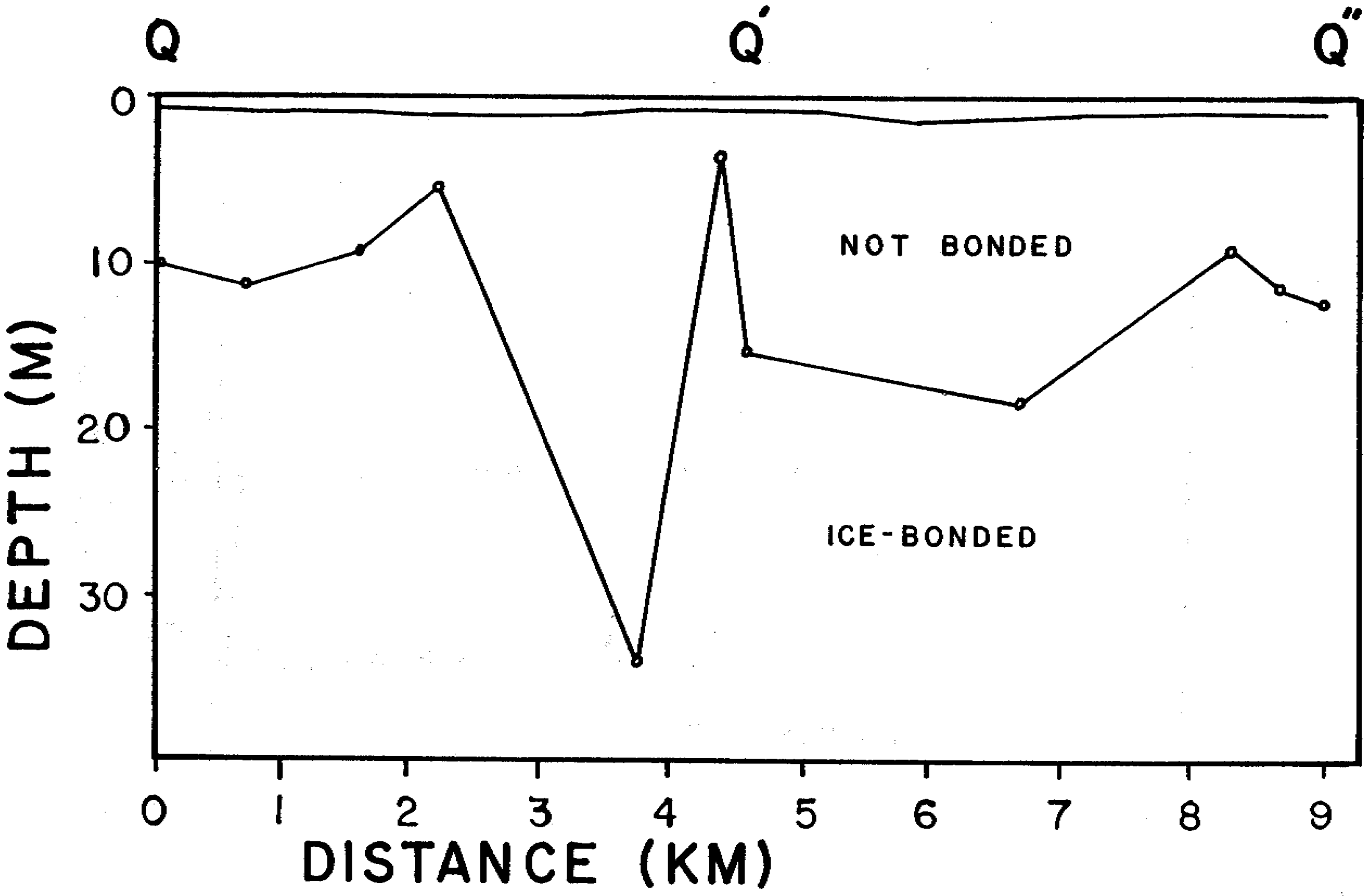

Figure 8: Vertical section through line Q - Q"

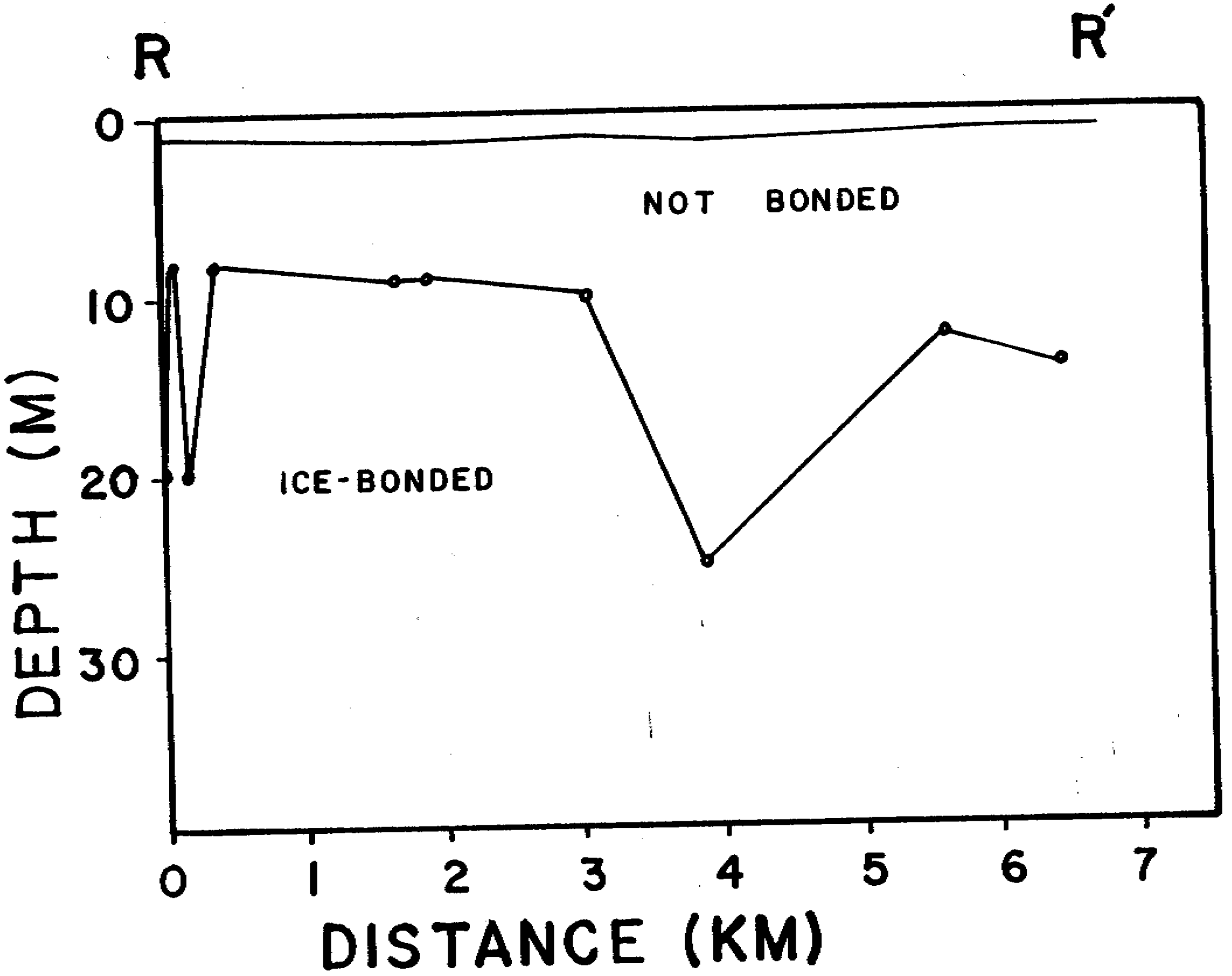

Figure 9: Vertical section through line R - R'

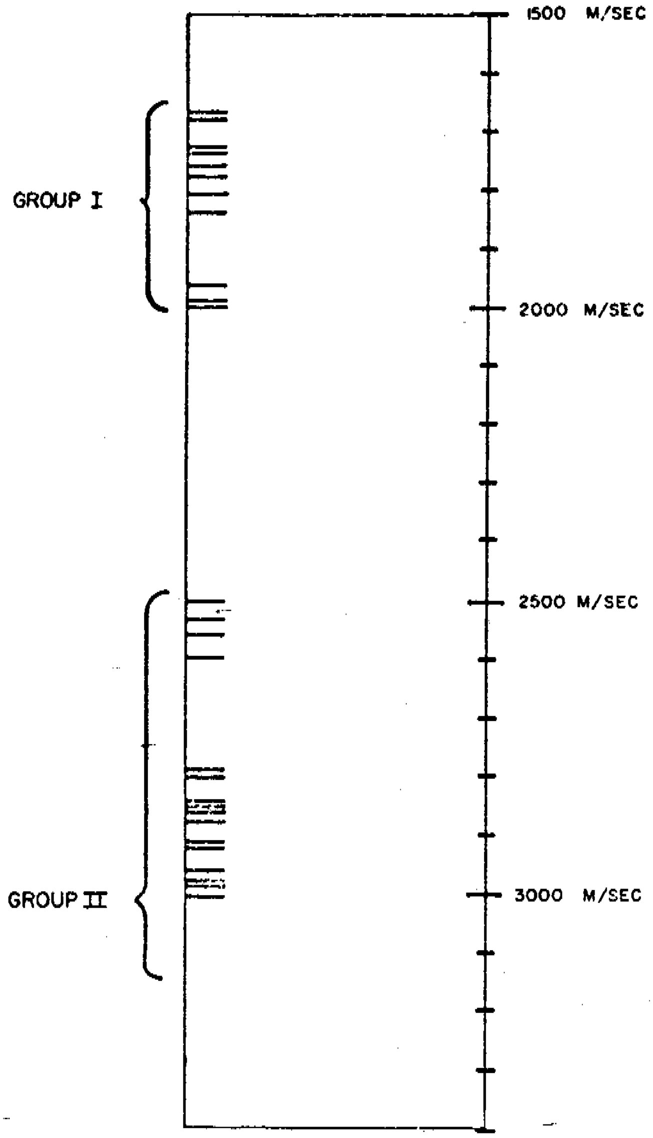

Figure 10: Refraction velocities measured near Pt. Barrow, Alaska. In all cases, group I corresponds to velocities in non-frozen sandy gravels, while those in group II correspond to similar materials in the frozen state. Velocities measured in the Prudhoe Bay area compare well with these data and generally velocities of 2000 ms^{-1} and 3000 ms^{-1} correspond to the non-frozen and frozen states.

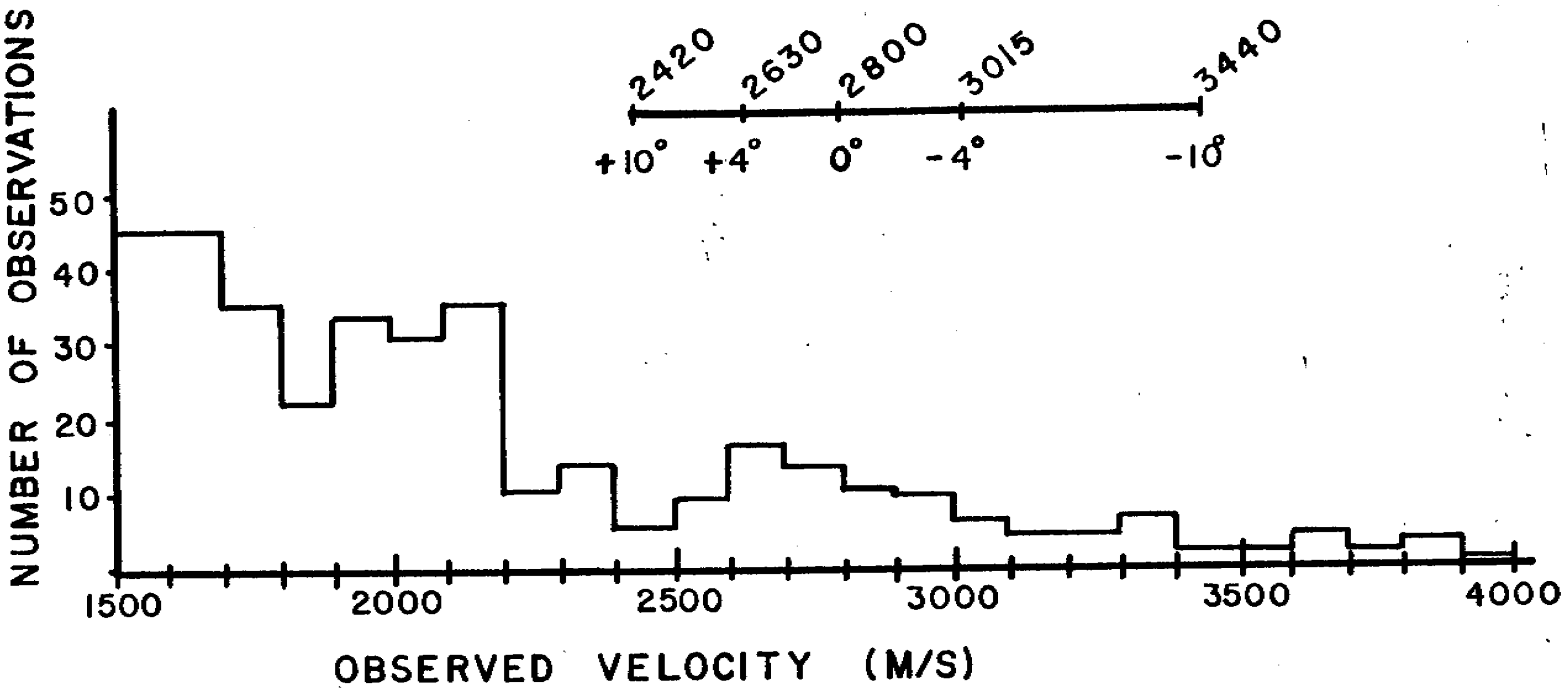

Figure 11: Histogram of seismic velocities observed in Prudhoe Bay area.

surveys are expected to show a significant velocity difference between the frozen and non-frozen state. However, non-frozen coarse materials generally have higher velocities than fine grained non-frozen materials. This fact will tend to broaden the two velocity groups and to obscure their separation. One can estimate the effects of a dipping refractor for the velocities encountered in the Prudhoe Bay area using known relations (see Grant and West, Pg. 150). Figure 12 shows the relationship between observed velocity and refractor dip calculated for dip angles ranging from +10° to -10°. Tha assumed refractor velocity is 2800 m/s and it is seen that the observed velocity of this refractor varies from 2420 m/s to 3440 m/s. The significance of this variation on the observed velocities is shown in figure 11 by the horizontal line. A ±10° dip variation is seen to vary the observed velocity from -14% to +23% of the actual velocity. It is thus possible that refractor dip is responsibile for a significant part of the variation in observed refractor velocities. It should be noted that for a series of random dip angles the average of the apparent velocity data will be shifted above the actual average velocity. Using the velocities calculated for ±10% it is seen that the average velocity is 2920 m/s or 120 m/s higher than the actual velocity.

The relatively large number of velocities observed below 1800 m/s are believed to result from the fact that in shallow water the effects of the water layer is not taken into account. The result of this approximation is that a sizeable number of velocities are observed that are slightly above the velocity of sea water (approximately 1500 m/s). This "average" velocity observed represents the combined effects of the shallow water and the materials near the sea bottom.

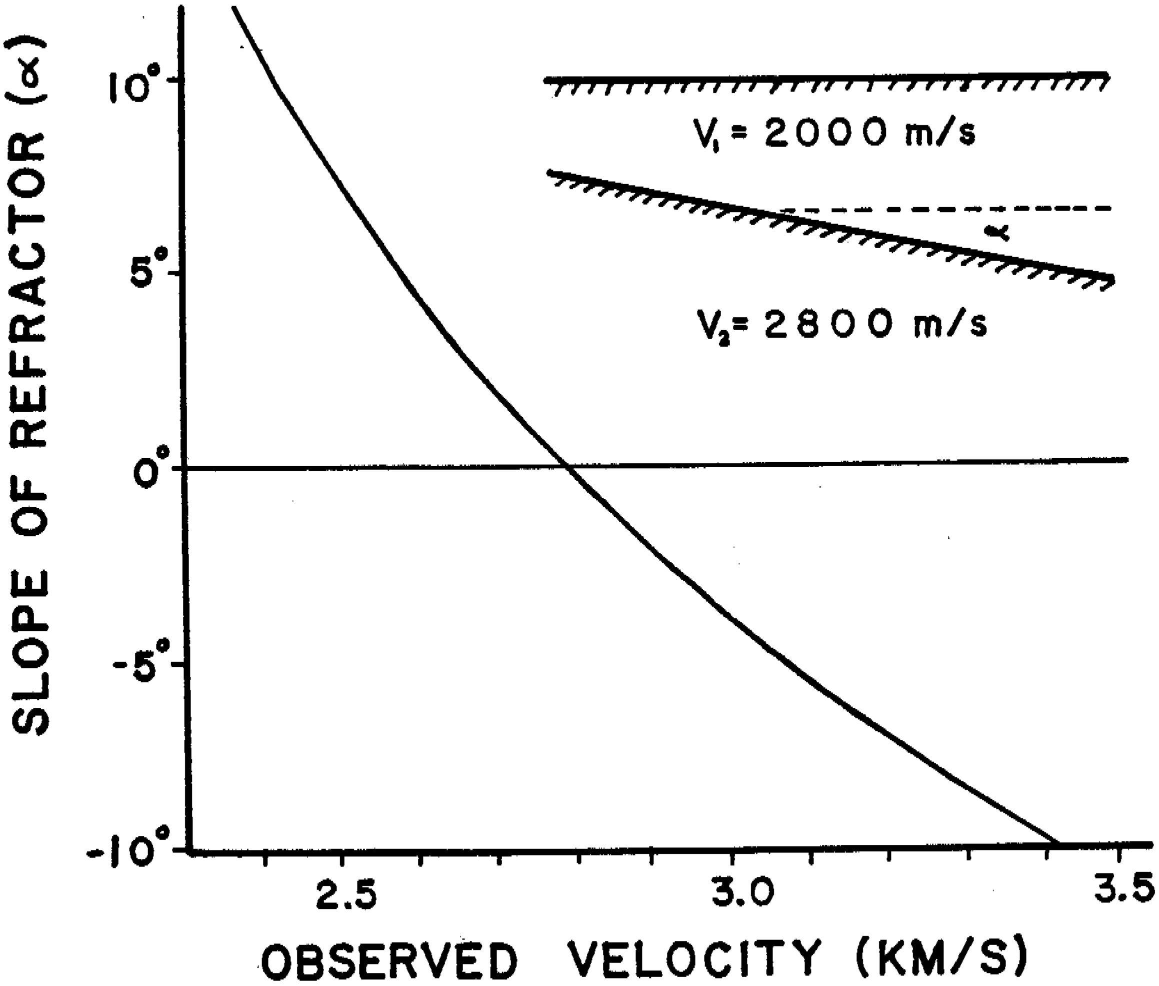

Figure 12: Observed velocity for a sloping refractor. Upper material velocity is assumed to be 2000 m/s and lower material velocity is assumed to be 2800 m/s.

VIII. CONCULSIONS

In an attempt to summarize conclusions to date, we list below a series of conclusions from past reports with appropriate modifications resulting from more recent data. It must be remembered that the rather limited geographical coverage to date means that the conclusions are perhaps regionally limited. However, the conclusions are certainly appropriate to the very important offshore area adjacent to existing Prudhoe Bay oil fields.

A. In past reports we suggested that one possible way to deal with shallow permafrost near shore is to extend a causeway from shore to regions offshore where the ice-bonded permafrost is sufficiently deep so that any thaw bulb from a hot oil pipeline would not affect the permafrost. At least two occurences of relative shallow submarine permafrost (7 m and 8 m beneath the ocean bottom in water depths of 10 m and 6 m respectively) have been observed at distances up to 18 km from shore. Thus the surface of the bonded materials is seen to be highly irregular.

B. Seismic reconnaissance on three barrier islands indicates that they are not all completely underlain by bonded permafrost, but that some may be free of ice-bonded permafrost. Certainly this conclusion is dependent upon the history of the islands; whether it is a fragment of a former shoreline or whether it is a constructional feature. Also, the width of an island, its migration rate and soil types are important. We have observed continuous bonded materials beneath Stump

Island along its entire length. In contrast, no high velocity refractors have been observed on Reindeer Island. Jet drilling on the island indicates a highly variable material beneath this island some frozen and some not frozen (conversation with Will Harrison). We have observed high velocity refraction on portions of Cross Island. Islands such as Flaxman Island which are land remnants can be expected to be underlain by thick permafrost. Thus, the islands seem to be highly variable with regard to their permafrost conditions.

C. Prudhoe Bay appears to be an old thaw lake (see the 1978, 1977 annual reports) and therefore presents a large dip or possibly a window in the surrounding bonded permafrost surface. This is site specific information, but it seems unlikely that there are not other old thaw lakes offshore along the Beaufort Seacoast. Also, Dave Hopkins has suggested the existance of paleo valleys which may present large depressions in the permafrost surface or the absence of permafrost in these areas (Hopkins, 1978). Knowledge of such sites could provide permafrost free locations for bottom founded structures or, if such locations are not desirable for a particular application, old thaw lakes could be avoided.

D. Several island sites have been studied where seismic velocity data and drilling data seem not to agree; drilling evidence indicated frozen material, but refraction velocities were not high. Our conclusion is that ice-bearing materials should be distinguished from ice-bonded materials. Brine inclusions depress the freezing point of a material and tend to spread the freezing point from a discrete temperature to a range of temperatures corresponding to various stages of freezing. Thus a material may have ice inclusions but may not be ice-bonded and hence present a relatively low velocity compared to the totally bonded material. The distinctions between ice bearing and ice-bonded is important from the standpoint of material properties. For example, an ice-bonded material may have a high resistance to shear stress, but the same material when not ice bonded may have little shear resistance. An important parameter affecting offshore permafrost is temperature; in contrast to permafrost on land it is relatively warm and consequently more thermally fragile. This fact coupled with the presence of salt water accounts for some of its local variability.

IX. NEEDS FOR FURTHER STUDY

An extensive drilling program conducted during February and March 1979 by the U.S. Geological Survey, has resulted in a wide spread shallow coring program. There is a good opportunity to correlate seismic velocities with the soil types and with frozen materials. Refraction lines will be run in the locations of many of these drill holes and information about the state of the permafrost which has been determined locally by sampling and temperature measurements will be extended by the seismic lines.

Another feature requiring further investigation is the possible existance of paleo valleys. The permafrost distribution in these areas is expected to vary significantly from adjacent areas.

X. SUMMARY OF LAST QUARTER

FIELD WORK:

During the last week in March the site of one of the U.S.G.S conservation division drill holes were visited and sonic velocity measurements were made as a function of depth into the drill hole. The site visited was Tract 129 of the proposed State-Federal Beaufort Sea Lease Sale. James Rogers and John Morack conducted the field work.

DATA COLLECTED:

Several dozen records were taken of the sonic travel time from the ocean bottom where an air gun was discharged to a hydrophone located at varying depths in the drill hole.

ANALYSIS:

The travel time data are being reduced to velocity data. This reduction will result in sonic velocity as a function of depth and will provide useful information for the marine refraction work. This is the first data that have been obtained in this region where the sonic waves travel in the vertical direction rather than in a horizontal direction. Thus the data should provide better information on the vertical variation of velocities and in some cases they should help resolve the question of how thick a frozen layer must be to be observed by the refraction method.

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Annual Report
1978-1979
Research Unit #327

Shallow faulting, bottom instability, and movement of sediment in lower Cook Inlet and western Gulf of Alaska

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April 1, 1979

I. Summary of Objectives, conclusions and implication with respect to OCS oil and gas development.

Lower Cook Inlet: Our work in lower Cook Inlet in 1978 had seven major objectives: study the migration of large bedforms, conduct detailed observations on bedforms in a small area where the GEOPROBE was located, obtain ground truth for side scan sonar records collected over different types of bedforms, collect additional coverage of an east-west strip through the inlet to study boundary characteristics of bedform fields, determine the surface characteristics of the "smooth" area north of Cook Ramp, obtain data on sediment transport over the bottom and conduct a pilot study of volcanic deposits off Augustine Island.

The study of the migration of large bedforms was a continuation of a similar investigation done in 1977 under poor sea state conditions. The idea was to rerun a number of selected lines obtained in 1973 and 1974 by industry. Careful rerunning, utilizing preplots, provided us with overlapping high-resolution seismic profiles and sonographs. Comparison of the industrial data with ours shows that no observable change in identity, size and position could be noted over a 4 to 5 year period. This does not deny that motion has occurred, but indicates that migration is less than the accuracy of positioning.

A small area close to the 1977 OCEAN RANGER site was selected for deployment of the GEOPROBES (see R.U. #430). Due to the availability of reconnaissance lines run by Cacchione and Drake we continued our investigations in that area utilizing high-resolution seismic profiling, side scan sonar, bottom television and camera, and profiling current meter. The large bedforms with heights up to 8 - 12 m are highly three-dimensional with large lateral variations of crestal heights.

The interpretation of side scan sonar can be very difficult and differences in darkness on the record can easily be interpreted wrongly, as we discovered with the bottom television/camera investigations. The smaller or lower bedforms, such as small sand waves and sand ribbons, are especially much less in height than measurements from sonographs suggest. Often the sand bodies are in the order of 10-20 cm high with wide bands of lag deposits in the troughs or adjacent to the sand ribbons. Measurements on sonographs are based on the assumption that angles of incidence are measured rather than materials with different reflectivities. Originally it was thought by us, and others who looked at our results, that such sand bodies were on the order of 50 to 150 cm high.

In 1977 we started to collect a dense coverage of high-resolution seismic profiles and sonographs in an east-west oriented rectangle to study the variation in bedforms and their boundary characteristics. Part of the results were poor owing to sea state conditions. In 1978 we added several lines to this study segment. No detailed plots and analyses have been conducted at this time.

The "smooth" area north of Cook Ramp, bounded in the south by the ramp face and to the north by bedforms, puzzled us with respect to its nature. Bathymetric profiles show that it represents a shallow depression. Bottom television and camera indicate that it is covered by a variety of small ripples and an abundance of sessile plants and animals, and by molluscs. Although we lack current information this area may represent a zone of low current activity preventing construction of larger bedforms. It is difficult to see it as an area of bypassing due to high currents when comparing this area to other depressional areas. The steering effect of the ramp on the incoming tide may indeed cause a low velocity zone at the top of the ramp.

We have undertaken a number of observations on the movement of sand grains by combining vertical current profiles, bottom television/camera, and dispersal studies. The results show that significant active movement takes place only during spring tide during the last few hours of each ebb and flood cycle. It is assumed from these point observations that this is representative for the area.

A brief pilot study of offshore volcanic deposits was conducted on the east side of Augustine Island to observe the feasibility of using a large vessel and our equipment. The shallow water with local peaks in the seafloor is too threatening for a large-sized vessel, and definition of our high-resolution seismic records is insufficient to observe possible lava flows due to the multitude of multiples off the hard bottom. Television observations show heavy overgrowth by sessile plants obscuring the bottom characteristics, and considerable turbidity in the water column.

In conclusion, our observations in lower Cook Inlet thus far indicate that sand transport over the bottom exists but is less severe than thought originally However, the loose nature of the sand, combined with the strong bottom currents, can provide anchoring difficulties for drill ships and semisubmersibles, and may cause severe erosion of pipelines. We observed that small amounts of fine material (clay and organic matter) appear to inhibit transport when threshold velocities are reached. Stirring up the sand may cause removal of such fines and erosion may become more severe.

Kodiak shelf: Our work on the Kodiak shelf in 1978 had three major objectives: 1) detailed study of a seafloor fault to possibly determine the recency of movement, 2) search for sediment slides on some steep portions of the shelf, and 3) reconnaissance study of gas-charged sediment.

Study of the seafloor fault proved generally unsuccessful. A detailed seismic-reflection and side-scanning sonar survey showed insufficient quality of fault-related features to guide subsequent television observations and sampling.

A seismic-reflection survey in and around Sitkinak Trough, where seafloor gradients reach $8\frac{1}{2}^{\circ}$ and are some of the steepest on the Kodiak shelf, failed to record any evidence of sediment slides. So far we have found no indication of significant slope instability on the shelf, although major slides have been found on the adjacent continental slope.

Sediment cores containing gas-expansion voids and showing high methane concentrations were recovered at four locations in Chiniak, Kiliuda, and Sitkinak Troughs Acoustic anomalies appear in seismic reflection records at these and several other localities. No hazardous features such as sediment slides or low strength have so far been found associated with this sediment.

II. Introduction

A. General Nature and Slope of Study: Assessment of the environment geologic hazards, sediment types and sediment distribution in lower Cook Inlet and on the Kodiak shelf, western Gulf of Alaska.

B. Specific Objectives: The identification of active surface faults, areas of sediment instability, the relation of sediment types to bottom morphology and circulation patterns, and types and movement of bedforms.

C. Relevance to problems of Petroleum Development: Active faulting and sediment instability are potential dangers to offshore structures. The relation between morphology and sediment characteristics will identify the presence of areas where erosion is more active than deposition and areas that are sediment traps and consequently may act as sinks for pollutants as well as nutrients. Transport of sand over bedforms likely will increase once the sediments are stirred up by anchoring and trenching activities thereby removing fine clay and organic matter that presently decreases the natural erodibility.

III. Current State of Knowledge

Lower Cook Inlet: Field studies conducted during the summers of 1976, 1977 and 1978 show that no significant recent faulting can be detected within the lease area (sale C1) in spite of the high seismic activity of the area. A few faults with vertical offsets at the surface have been detected in Kamishak Bay and around the Barren Islands.

The influence of volcanism is poorly understood as far as the open-water area is concerned. Volcanism may have severe secondary effects on land, especially mudflows in the Iliamna area. Nuees ardentes are characteristic for Augustine but their distance of travel over water is unknown. Juergen Kienly (RU #251) addresses the volcanic problems.

The nature of the surficial sediments (semiconsolidated pebbly mudstones of possible late Pleistocene age, locally overlain by a thin blanket of sand) does not show slumping on any of the local slopes. Liquefaction of sand may occur under dynamic loading conditions but no evidence has been observed. Sand, ranging in thickness from a few centimeters to 15 meters (crests of very high bedforms), does not occur on many slopes except for Cook Ramp. If liquefaction takes place there may be insufficient thickness available to be a significant threat of consolidation or flow.

Gas-charged sediments have not been observed in records collected on board the R/V SEA SOUNDER. However, the USGS Conservation Division in Anchorage claims evidence for the presence of such gas-charged sediments south and southeast off Augustine. Conservation Division also found water column bubble indications on 3.5 kHz records. We have not seen those proprietary records and can only state that a few abnormalities exist in that area on our records, possibly indicating gas-charged sediments. However, the record characteristics differ from SEA SOUNDER records in other areas where gas-charged sediments do occur.

Sediment distribution and composition has been reported in previous reports. We are still adding data points but no change in the overall patterns are evident.

Considering the objectives given under point I, the only adverse effect on OCS oil and gas development are the bedforms present in the sand blanket that overlies the pebbly muds. The thickness ranges from a few centimeters in the north and at the eastern and western boundaries up to 15 meters as crestal heights of the largest bedforms. Repetitive surveys of a number of selected lines show that, within the accuracy of Mini-Ranger navigation, no conclusive indication can be obtained as to the migration of 6 to 15 m high sand waves over the period 1973 to 1978 (Appendix I). Additional complications became apparent from our detailed survey that shows that these large bedforms are highly three-dimensional referring to the rapid variations in elevation of crests (Appendix II). Consequently, when an orginal survey line is repeated and they are not coincident within 20 to 30 m over the previously run line, one may obtain measurable differences that can be interpreted incorrectly. The study, described in Appendix I, in collaboration with John W. Whitney and Dennis Thurston of the USGS Conservation Division in Anchorage and with William G. Noonan of Marathon Oil in Anchorage, clearly demonstrates that the large bedforms do not move measurably over a period of 4 years. However, sand movement has been observed on bottom television and via time-lapse photography from the GEOPROBE. The latter also showed that asymmetry of ripples reverses from ebb to flood tides and vice versa, and that a minor storm in October 1978 had a significant influence on the bottom. In addition, we showed last year that drill cuttings from the C.O.S.T. well were incorporated in the sediment at least to the depth of the core (13.5 cm) with concentrations at 4.5 to 6 cm and 10.5 to 11.5 cm, two depths that correspond to ripple and small sand wave heights. This incorporation took place during the summer after a drilling period of 100 days.

We also discovered (Appendix II) that velocities higher than the threshold velocity for the particular sand size has to be obtained to really move sand. Preliminary analyses indicate that a small amount of fine clay and/or organic matter protects the sand from moving at threshold velocities.

The interpretation of sonographs is still in a state of infancy. When bottom features are sufficiently high to be identified on bathymetric profiles, a certain ground truth for the sonographs is provided, and the combination of both types of records can lead to a three-dimensional morphological interpretation. It has to be kept in mind that a sonograph displays nuances in acoustic reflectivity that can result either from different types of materials or from differences in angles of incidence. Material differences can only be determined by bottom television/ photography and by sampling. Often, certain characteristic patterns show up on sonographs that provide an interpretive answer. However, when bottom features are of low relief and cannot be identified on bathymetric profiles, it is easy to obtain an incorrect interpretation (Appendix III). For example, it is impossible to distinguish on a sonograph the difference between a flat bottom with no sedimentary features, gravel or shells, small ripples, or a rocky bottom with heavy overgrowth of algae. Bottom television and camera observations are the only present means to characterize such bottoms. A difficulty is that the size of the smallest object identifiable on a sonograph varies, based on ship's speed and height of the side scan sonar fish off bottom. When currents are strong a minimum ship's speed is required to maintain a desired heading. In reality the smallest object identifiable on a sonograph is often still larger than can be seen at any time on the television or on a bottom photograph. Consequently, long television/camera observations have to be made to obtain sufficient data to identify the sonograph feature properly. This is well illustrated when dealing with small sand waves. The light and dark patterns on a sonograph clearly show the overall shapes and directions. Normally it is assumed that the dark bands represent slopes facing the side scan sonar fish and heights can then be calculated. Our television observations showed that the assumed flanks of 50-150 cm height in reality represent wide bands of highly reflective shells and shell fragments, and that the sandy part between those shell bands are not more than 10-20 cm high (Appendex III). Television observations also show the patchy nature of sediment types and biota, which in turn demonstrates the danger of interpretation and of local classification based on one or a few samples. A combination of high-resolution seismic profiles, sonographs, some television/camera coverage and a few samples normally is sufficient for geological purposes but may lead to wrong conclusions when quantifying biological aspects or trying to obtain an accurate pipeline corridor survey.

Kodiak Shelf: The current state of knowledge about geological and geophysical environmental conditions on the Kodiak shelf have recently been summarized by Hampton and others (1979; see Appendix IV). The geo-environmental concerns are associated with the seismotectonic regime and the physical properties and dispersal of sediment. Included are the distribution of earthquake epicenters, tectonic segmentation, occurrence of shallow folds and faults, texture and composition of sediment, gas-charging of sediment, bedforms, slope stability, and sediment dispersal patterns.

The 1978 cruise program included three main objectives on the shelf: 1) detailed study of some major surficial faults to determine recency of movement, 2) reconnaissance survey of Sitkinak Trough to determine the nature of its sedimentary fill and to search for areas of slope instability, and 3) evaluation of the occurrence of gas-charged sediment using geochemical and geophysical methods. Notes on the tracklines, sampling stations, and data collected on the cruise are being compiled for an upcoming Open-File Report.

The faults chosen for detailed study trend across the landward edges of northern Albatross Bank, Kiliuda Trough, and middle Albatross Bank. Seismic-reflection records across the faults show that they offset the seafloor, suggesting activity that post-dates late Pleistocene time. In particular, they appear to trend across sediment that infills Kiliuda Trough from the sides and was probably deposited during the last marine transgression. The 1978 program was designed to examine in detail the relationship between the faults and this lateral infill using high-resolution seismic reflection, side-scanning sonar, and underwater television systems. We especially wanted to determine if the lateral infill had been offset by the faults, and to take sediment samples for dating. Thereby, the maximum time since last movement could be determined. Unfortunately, the seismic-reflection and side-scan surveys did not show any obvious features that could be used to guide subsequent television observations and sampling efforts. Insufficient time was available for further surveying work, and the project was terminated.

Three seismic-reflection lines were run across the head, middle, and mouth of Sitkinak Trough. Three cores were collected; two near the mouth of the trough (one on the eastern side at 56°08'N/153°29.6'W and one near the axis at 56°05.6'N/153°31.3'W) and one in the middle (near the axis at 56°07.6'N/153°38.4'W). The walls of the trough have some of the steepest gradients found on the Kodiak shelf, ranging up to 8½° and typically being on the order of 3°-4°. The trough contains a thick, stratified fill spanning up to 400 miliseconds of two-way travel time in the seismic profiles (somewhat less than 400 meters). The geometry of the sediment body suggests that infill has been mainly from the southwest. The sediment cores are composed of greenish to bluish mud, with sand and siliceous microfossils. This sediment fill is different from that in the other troughs on the Kodiak shelf in that it is much thicker (400 ms vs. 20 ms) and contains less volcanic ash. Vane-shear strength measurements on a core from Sitkinak Trough are generally of lower magnitude than for those on several cores from Kiliuda Trough (Appendix VI).

The main purpose of the Sitkinak Trough work was to search for occurrences of sediment slides along the steep margins. No evidence of slides was detected in any of the records.

Gas-charged sediment was recovered in cores at four localities (Fig. 15 in Appendix IV). These cores contain gas-expansion voids where methane levels were measured in excess of a few 10^6 nl/l (Appendix V). They also typically contain abundant layers and patches of black material that apparently are concentrations of ogranic matter. At three of the four localities (excepting the one in Sitkinak Trough) plus several others, distinct acoustic anomalies occur in siesmic-reflection records and can be traced for significant distances (Fig. 15 in Appendix IV). These anomalies appear as variations in the strength of the return acoustic signal from particular reflectors or intervals; varying from acoustic transparency to opacity. Thus, the anomalous areas are characterized by abrupt lateral variations in seismic-reflection signature. The gas-charged sediment shows no sign of sliding where it occurs on sloping sections of the seafloor (up to 1 3/4°), and vane shear measurements show no obvious strength differences from cores that are not gas-charged (Table 1 in Appendix IV). The environmental significance of the gas-charged sediment cannot yet be fully assessed, but no hazardous features have been found associated with it at this time.

New data on the physical properties of Kodiak shelf sediment include grain size and textural parameters, bulk density, water content, grain specific gravity, void ratio, and porosity (Appendix VI). Much of these data are from a recent Masters thesis by Burbach (1977). The grain-size data support earlier conclusions that sediment from the main portions of the banks is coarse (gravel to sand) and particularly sparse in silt and clay. It typically contains abundant shells and has high bulk densities (1.7 - 2.0 g/cm^3). Sediment from broad, shallow depressions on the banks is finer grained than that on the main parts of the banks and contains abundant volcanic ash. Moderate to high porosities (45-76%) and low grain specific gravities (2.40-2.66) are characteristic, reflecting the abundance of ash. Trough sediment is also fine grained and ash-rich. Porosities are high (57-73%), and bulk densities (1.30-1.74 g/cm^3) and grain specific gravities (2.38-2.69) are low.

Burbach defines a fourth sedimentary environment, the "basal trough", which includes the areas of the troughs seaward of the sills that occur across their mouths. The sediment characteristically has a poorly sorted, polymodal grain-size distribution, with sizes from boulders to clay. Porosities are low and occur in a narrow range (37-44%), and bulk densities are high (1.62-2.09 g/cm^3). Burbach concludes that the basal troughs contain a mixture of bank and trough sediment.

Physical property data are still being collected and analyzed, and is the major lab effort at this time. Whole-sediment grain-size distributions are being measured, as are water contents, bulk densities, and grain specific gravities.

IV. Study Area

1. Lower Cook Inlet between Shelikof Strait at latitude 58°40'N and Cape Ninilchik at latitude 60°00'N, mainly encompassing OCS lease-sale area CI.

2. Kodiak shelf between Amatuli Trough at latitude 59°00'N and to Chirikof Island at latitude 56°50'N, mainly encompassing OCS lease sale area 46.

V. Sources, Methods, and Rationale of Data Collection

Data were collected during a 20-day cruise in August, 1978. Previous cruises were during June and July, 1976 and September and October, 1977, all aboard the R/V SEA SOUNDER. Some additional data came from copies of a 1976 Petty-Ray Geophysical, Inc. survey made under contract to the U.S. Geological Survey, Conservation Division in Anchorage. Additional high-resolution seismic records were collected by R. von Huene aboard R/V S.P. LEE during his 1976 survey off Kodiak.

Seismic and sampling methods have been discussed by Bouma and Hampton (1976) and Hampton and Bouma (1976). The rationale for collecting data with the instruments and equipment described in the above-mentioned U.S. Geological Survey Open-File Reports is that such procedures are the only ones generally recognized to achieve the proposed objectives.

VI, VII, VIII Results, Discussion, and Conclusions

It has to be kept in mind that the 1976 cruise aboard the R/V SEA SOUNDER was a reconnaissance due to lack of public information related to environmental geohazards. The field data were reported by Bouma and Hampton (1976a) and Hampton and Bouma (1976). The plans for the 1977 field season to study details pertaining to the geohazards could not be sufficiently realized owing to weather and sea state conditions, and as a result the quality of many of the high-resolution seismic records was such that adequate interpretation was often impossible. None of these problems faced us during the 1978 field season, and the excellent data are still being worked. Their quality makes it possible to restudy and reinterpret many of the 1977 and 1976 observations. Our navigational base is on the Mercator projection and replotting is required to provide graphical output in UTM projection.

The high-energy hydraulic environment in lower Cook Inlet has an inpact on the bottom. Where sufficient unconsolidated sand-size material is available, the bottom is characterized by different types and sizes of bedforms, such as sand waves, sand ridges and dunes. Where such unconsolidated material is scarce or absent one finds sand ribbons, sand tails, sand patches, small ripples, boulder fields, or a bare bottom (Bouma and others, 1976b, 1977a,b, 1978a,b; Hampton and others, 1978; Appendices II and III). The nature of the smooth as well as the underlying bottom is assumed to be of glacial origin and locally may contain fluvio-glacial deposits. The subbottom is variable according to seismic records. Up until now we have not been able to obtain proper data on this material. As discussed earlier we observed sand transport during the last hours of each ebb and flood tidal cycle and then only during spring tide. The GEOPROBE data show reversal of ripples under ebb and flood tides, and they show a significant influence on resuspension and transport during a storm. Sediment transport threshold velocities have to be bypassed to obtain effective sand movement due to the inhibitive action of minor amounts of clay and organic matter. It is concluded that sand transport is taking place, presumably in significant quantities, during the winter, as based on comparison of sonographs of small bedforms collected in successive years. Migration of bedforms therefore takes place. However, to move and/or change the morphology of large bedforms measurably, a very large amount of material has to be transported. Either the environmental conditions in the period 1973 to 1978 were insufficiently strong to cause migration, or the volume of a large bedform requires a longer observation time than four years to produce conclusive evidence.

We do not have any winter observations. Attempt to deploy a rotating side scan sonar device off a drilling vessel operating in the sand wave failed due to lack of industrial cooperation. Sufficient summer observations have been carried out to have an understanding about the sand transport during that period but any total quantification can only be realized when either long term measurements are carried out or can be obtained with the deployment of a relative side scan sonar and a GEOPROBE over the winter months.

Long-term studies during the summer, such as the incorporation of drill cuttings after 100 days drilling at the C.O.S.T. well site, have already shown that even during the summer transport takes place although lack of sufficient cores make any quantitative statement impossible.

The Kodiak shelf experiences strong tectonism, which poses environmental problems. Possible tectonic segmentation of the shelf, into two relatively active and one relatively inactive segments, has been identified by combining seismological and geological data. The severity of tectonic hazards, such as seafloor deformation and strong shaking, might vary between the segments.

Another recent conclusion about the Kodiak shelf is that gas-charged shallow sediment is widespread. Gas-saturated samples (at atmospheric pressure) have been recovered from Chiniak, Kiliuda, and Sitkinak Troughs, and acoustic anomalies from these areas as well as nearby on adjacent banks have been observed. No potentially hazardous features, such as slope instability or low strength, have yet been found associated with this gas-charged sediment although such problems have been documented in other geographic areas.

Other geo-environmental concerns on the Kodiak shelf, reported previously, include:

1. Shallow faulting with probable present-day activity and future seafloor offset.

2. Storage sites for fine-grained sediment (and possibly pollutants) in Kiliuda, Chiniak, and Amatuli Trough.

3. Localized transport routes of sediment (and possibly pollutants) across the shelf break, especially on northern Albatross Bank and in Stevenson Trough.

4. High-energy sediment transport, with possible scour and fill problems, in Stevenson Trough.

5. Localized deposits of volcanic ash in Kiliuda, Chiniak, and Amatuli Troughs, with possible abnormal compaction during loading.

6. Coarse-grained unconsolidated and muddy semiconsolidated sediment on Albatross and Portlock Banks that appear to be stable foundation material but may pose some problems to drilling because of the presence of boulders.

7. Lack of sediment slides on the shelf except for some apparently localized occurrences reported by Self and Mahmood (1977, Marine Geotechnology, v. 2, p. 333-347).

IX. Needs for Further Study

Lower Cook Inlet: It is anticipated that the fieldwork planned for the summer of 1979 will provide sufficient information on geo-environmental hazards in lower Cook Inlet for OCSEAP purposes. Only two major issues are lacking to provide adquate quantitative information:

1. We need information about sand transport and bedform migration during the winter season when storms are more abundant and more severe than during the summer. Sea state conditions prevent adequate vessel operations and costs would be prohibitive if data collection over a long period is attempted. The only successful approach is the utilization of the rotating side scan sonar tower and one GEOPROBE deployed off a drilling platform that operates in the sand wave field.

2. To repeat the survey we conducted over the 1973 industrial lines to measure possible migration of large bedforms. Such study should be taken either 5-8 years from now or after a period of abnormal severe storms.

Kodiak shelf: The main outstanding work on the Kodiak shelf is to extend our mapping of gas-charged sediment and to determine the environmental significance. An adequate job would require use of a pressurized coring device and analysis under hypobaric condition's. These techniques are presently available but are judged to be unfeasible.

A good general knowledge of geo-environmental problems is at hand for most of the shelf. Completion of the areal coverage is planned in 1979. Significant advancement beyond this stage requires long-term site specific or process-oriented studies, especially for detailed quantitative or predictive information.

X. Summary of January-March Quarter

No cruises or field projects were conducted during this quarter. This period was utilized to continue our examinations of seismic and side scan sonar records, and studying the bottom television and camera data. In addition we started to convert our tracklines and data points from the Mercator projection to UTM projection. We also made a classification system of bedforms and developed a system to present sonograph data on maps.

Measurement of mass physical properties of Kodiak shelf sediment is ongoing during this period. Also, analysis of seismic records and sediment samples pertaining to gas-charged sediment and to the sedimentary environment of Sitkinak Trough, has been accomplished.

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Appendix V. Methane levels in sediment cores. Measurement by gas chromatography, on board ship, immediately after core recovery. Analyses by George Redden and Keith Kvenvolden.

Station Number	Location	Water depth, m	Distance below top of core, cm	Methane content x10^6 nl/l
329	57°39.0'N 151°57.8'W	218	0-10	0.301
			50-60	42.070
			100-110	32.093
			200-210	36.250
343	56°40.0'N 153°05.5'W	153	0-10	0.003
			65-75	0.073
			110-120	0.112
			187-197	0.237
344	56°39.6'N 153°05.6'W	155	0-10	0.022
			50-60	0.640
			117-127	2.075
			200-210	31.300
347	56°36.6'N 153°17.8'W	138	0-10	0.003
			50-60	0.105
			100-110	0.227
348	56°37.3'N 153°18.6'W	143	0-10	0.002
			50-60	0.148
			100-110	0.443
			200-210	2.110
349	56°38.0'N 153°19.4'W	145	0-10	0.001
			50-60	0.034
			100-110	0.127
			197-207	0.288
			300-310	0.696

Station Number	Location	Water depth, m	Distance below top of core, cm	Methane content $\times 10^6$ nl/l
355	56°08.8'N 153°29.6'W	314	0-10	0.011
			50-60	0.002
			206-216	0.004
			348-358	0.039
356	56°05.6'N 153°31.3'W	250	56-66	0.439
			175-185	51.492
			310-320	29.375
357	56°07.6'N 153°38.4'W	233	0-10	0.005
			50-60	0.011
			129-139	0.026
358	56°47.2'N 153°11.6'W	122	0-10	0.003
			48-58	0.004
			100-110	0.005
			150-160	0.008
359	56°46.6'N 153°10.7'W	152	0-10	0.002
			56-66	0.049

APPENDIX VI

Mass Physical Properties of Kodiak Shelf Sediment

A. Table of Values for Statistical Sedimentary Parameters and Geotechnical Properties (from Burbach, 1977)

Sample No.	Median (ϕ)	Mean (ϕ)	Skewness	Standard Deviations (ϕ)	Kurtosis	Bulk Density (g/cc)	Water Content (%)	Specific Gravity	Void Ratio	Porosity (%)
73(B)	-0.24	-0.93	-0.42	1.95	0.91	1.91	34.57	2.71	0.92	47.77
74(B)	-0.04	-0.14	-0.14	1.74	1.26	1.89	36.13	2.68	0.94	48.48
81(T)	-0.50	-0.36	0.25	1.18	0.92	1.52	73.26	2.38	1.73	63.41
85(B)	-0.25	-0.46	-0.20	1.54	1.42	1.84	40.19	2.71	1.09	52.24
86(B)	0.74	0.40	-0.21	2.05	0.99	1.85	36.29	2.61	0.93	48.13
-87(T)	3.27	3.58	0.41	1.26	1.06	1.49	73.71	2.40	1.80	64.27
-88(T)	0.17	0.41	0.40	0.92	2.08	1.40	111.95	2.44	2.70	73.00
90(B)	0.18	-0.19	-0.25	1.97	0.85	1.73	49.31	2.67	1.30	56.71
91(B)	1.46	1.14	-0.27	1.51	0.65	1.75	42.67	2.59	1.12	52.81
92(T)	6.40	6.73	0.27	1.65	0.94	1.44	96.18	2.46	2.36	70.21
93(T)	2.39	2.69	0.57	0.97	2.12	1.54	73.58	2.49	1.82	64.52
94(B)	0.32	-0.14	-0.21	2.40	0.71	1.91	31.87	2.70	0.86	46.48
95(T)	-2.40	-0.84	0.86	3.13	2.47	1.74	43.97	2.58	1.14	53.28
96(T)	6.96	7.67	0.31	2.56	0.62	1.30	84.23	2.41	2.43	70.88
97(T)	3.50	4.20	0.55	2.60	1.43	1.39	117.91	1.92	2.01	66.83
98(T)	7.00	7.37	0.24	2.00	0.82	1.52	72.81	2.38	1.73	63.31
113(BT)	0.83	-0.06	0.39	3.00	1.02	2.03	24.55	2.70	0.66	39.68
114(BT)	-2.00	-0.10	0.71	3.73	0.91	1.62	63.72	2.59	1.63	41.98

B = bank
T = trough
BT = basal trough
BD = bank depression

Burbach, S. P., 1977, Depositional environments of the Kodiak shelf, Alaska: Master of Science Thesis, Texas A & M University, 92 p.

Sample No.	Median (ϕ)	Mean (ϕ)	Skewness	Standard Deviations (ϕ)	Kurtosis	Bulk Density (g/cc)	Water Content (%)	Specific Gravity	Void Ratio	Porosity (%)
115 (BD)	2.76	2.54	-0.24	1.02	1.72	1.66	51.46	2.40	1.30	56.42
127 (BT)	0.37	-0.39	-0.35	3.47	1.05	2.05	23.43	2.70	0.62	38.44
128 (BD)	3.81	3.11	-0.20	3.61	1.24	1.69	53.51	2.61	1.38	58.07
130 (BD)	3.80	3.80	0.35	1.38	2.39	2.08	21.91	2.69	0.58	36.74
131 (BT)	1.17	0.73	-0.16	2.71	1.03	1.95	30.45	2.70	0.81	44.70
132 (BT)	3.99	4.91	0.24	4.32	1.31	1.73	50.11	2.69	1.34	57.23
134 (BT)	0.80	0.43	0.12	4.18	1.21	1.78	45.86	2.71	1.23	55.13
135 (BD)	3.30	3.57	0.39	1.26	1.17	1.92	30.85	2.66	0.82	45.00
136 (BD)	7.10	7.26	0.13	1.71	0.88	1.34	136.24	2.40	3.27	76.60
137 (B)	1.28	0.008	-0.54	2.95	1.22	1.97	26.88	2.62	0.69	40.97
140 (B)	-0.87	-1.83	-0.39	3.90	0.89	1.91	32.39	2.69	0.86	46.26
141 (B)	1.57	0.85	-0.39	2.61	0.95	1.72	48.92	2.61	1.26	55.83

B. Vane shear measurements, S8-78-WG Kodiak Shelf

Station Number	Location	Water depth, (m)	Distance below top of core (cm)	Undrained strength (kg/cm^2)
329	57°39.0'N 151°57.8'W	218	18	0.167
			30	0.046
			40	0.102
			71	0.065
			77	0.093
			84	0.130
			92	0.102
			123	0.111
			136	0.093
			155	0.148
			165	0.093
			184	0.167
343	56°34.8'N 153°08.4'W	119	29	0.125
347	56°36.6'N 153°17.8'W	138	30	0.065
			75	0.120
			91	0.150
			124	0.145
			153	0.220
348	56°37.3'N 153°18.6'W	143	35	0.045
			75	0.100
			120	0.150
			170	0.215
			220	0.250

Station Number	Location	Water depth (m)	Distance below top of core (cm)	Undrained strength (kg/cm^2)
349	56°38.0'N 153°19.4'W	145	38	0.007
			82	0.030
			124	0.100
			172	0.115
			176	0.140
			238	0.120
			275	0.220
			334	0.200
			347	0.200
350	56°46.4'N 153°10.4'W	154	55	0.035
			85	0.260
351	56°46.7'N 153°10.8'W	125	55	0.280
			100	0.320
			200	0.380
355	56°08.8'N 153°29.6'W	314	35	0.070
			100	0.035
			200	0.040
			250	0.080
			340	0.105
357	56°07.6'N 153°28.4'W	233	30	0.040
			90	0.070
			120	0.090

C. Grain size distributions of the epiclastic component of sediment samples from the Kodiak shelf.

Station Number	>2 mm(%)	2-0.062 mm(%)	0.062-0.004 mm(%)	<0.004 mm(%)
201	73.9	25.3	0.8	0.0
202	0.5	65.7	13.5	20.3
215	52.1	41.4	6.5	0.0
216	0.0	71.7	28.3	0.0
217	91.4	7.3	1.3	0.0
219	100.0	0.0	0.0	0.0
227	0.0	58.3	41.7	0.0
232	32.6	65.7	0.6	1.1
233	0.0	2.6	69.4	28.0
234	85.3	14.7	0.0	0.0
242	0.0	68.1	0.0	31.9
244	19.8	66.3	13.9	0.0
245	14.9	53.3	11.9	19.9
246	89.3	10.6	0.1	0.0

FAULTING, SEDIMENT INSTABILITY, EROSION, AND DEPOSITION HAZARDS OF THE NORTON BASIN SEAFLOOR

ANNUAL REPORT OF THE PRINCIPAL INVESTIGATOR FOR THE YEAR ENDING MARCH, 1979

HANS NELSON

Research Unit 429

U.S. GEOLOGICAL SURVEY

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Faulting, Sediment Instability, Erosion, and Deposition Hazards of the Norton Basin Sea Floor - Annual Report 1979

Hans Nelson, Devin R. Thor, and Matthew C. Larsen

I. SUMMARY

Studies of potential geologic hazards on Norton Basin sea floor in northern Bering Sea were conducted by the U.S. Geological Survey (USGS) to evaluate oil and gas lease tracts preparatory for Outer Continental Shelf (OCS) leasing. The data base for this evaluation included 9000 km of high-resolution geophysical tracklines, (Nelson, Hans, Holmes, M.L., Thor, D.R., and Johnson, J.L., 1978; Thor, D.R., and Nelson, Hans, 1978; Larsen, M.C., Nelson, Hans, and Thor, D.R., 1979) 1000 grab samples, 400 box cores, and 60 vibracores; in addition, hundreds of camera, hydrographic, and current meter stations have been occupied during the past decade by USGS, National Oceanic and Atmospheric Administration (NOAA), and University of Washington oceanographic vessels. Figure A1shows the northern Bering Sea, and summarizes the types and distribution of potential geologic hazards. Figure A2shows a summary of cruise tracklines run for environmental research by the USGS in northern Bering Sea.

The northern Bering Sea is a broad, shallow epicontinental shelf region covering 200,000 km^2 of subarctic sea floor between northern Alaska and the U.S.S.R. The shelf can be divided into four general morphologic areas: (1) the western part, an area of undulating, hummocky relief with glacial gravel and transgressive-marine sand substrate (Nelson, Hans, and Hopkins, D.M., 1972); (2) the southeastern part, a relatively flat, featureless plain with with fine-grained, transgressive-marine sand substrate (McManus, D.A., Kolla, V., Hopkins, D.M., and Nelson, Hans, 1977); (3) the northeastern part, a complex system of sand ridges and shoals with fine- to medium-grained sand substrate (Nelson, Hans, Field, M.E., Cacchione, D.A., and Drake, D.E., 1978); and (4) the eastern part, a broad, flat marine reentrant (Norton Sound) with Holocene silt and intercalated very-fine-grained storm-sand substrate underlain by gas-rich, peaty Pleistocene mud (Nelson, Hans, and Creager, J.S., 1977). A detailed discussion of bathymetry and geomorphology of northern Bering Sea is given by Hopkins and others (Hopkins, D.M., Nelson, Hans, Perry, R.B., and Alpha, T.R., 1976). Bathymetry of the study area is shown in figure A-3.

The northern Bering sea is affected by a number of dynamic factors: winter sea ice, high winds, storm waves and strong currents (geostrophic, tidal, and storm). The sea is covered by pack ice for about half the year, from November through May. A narrow zone of shorefast ice (sea ice attached to the shore) develops around the margin of the sea during winter months; around the front of the Yukon River Delta shorefast ice extends 50 km offshore (Thor, D.R., Nelson, Hans, and Williams, R.O., 1978). During the open-water season, the sea is subject to occasional strong northerly winds, and in the fall strong south-southwesterly winds cause high waves and storm surges along the entire west Alaskan coast (Fathauer,T.F., 1974). Throughout the year a continual northward flow of water is present with currents intensifying on the east side of strait areas (Coachman, L.K., Aagaard, K., and Tripp, R.B., 1976). Although diurnal tides are very minor (less than 0.5 m), intense tidal currents are found in shoreline areas and within central Norton Sound (Fleming, R.H., and Heggarty, D., 1966; Cacchione, D.A., and Drake, D.E., 1978).

Potential geologic hazards discussed in our report include faulting, thermogenic gas seepage, biogenic gas-charged sediment and cratering, sediment liquefaction, ice gouging, current scouring, storm sand migration, and mobile bedform dynamics. These geologic hazards may pose problems for the future development of offshore resources in Norton Basin.

GEOLOGIC HAZARDS OF NORTON BASIN

Tectonism- Surface and nearsurface faults are prominent along the entire north margin of Norton Basin, but Holocene fault activity is difficult to determine because strong current scour may be preserving or exhuming old scarps (Johnson, J.L., and Holmes, M.L., 1978). Seismicity (N.N. Biswas, oral commun.) and active migration of gas along some faults suggest that recent movement has occurred on fault segments in the gas seepage area of northern Norton Sound. Surface and nearsurface faults are rare in west-central Norton Basin but become more common along the southwest margin, particularly in strait areas northeast and north of St. Lawrence Island. Determination of the magnitude and the periodicity of recent fault activity depends mainly on completion of studies of seismicity; Norton Basin, hosever, is seismically more active than previously thought (Biswas, N.N., Gedney, L., and Huang, P., 1977). Fault traces and seafloor scarp relief in Norton Basin are shown in figure A-4.

Sediment Instability- Gas-charged sediment and sediment susceptible to liquefaction create potentially unstable surficial-sediment conditions in Norton Sound. There are two types of gas-charged sediment: (1) thermogenic, occurring in a local area 40 km south of Nome, Alaska and (2) biogenic, occurring in a wide area of north-central Norton Sound. The surficial, Holocene, coarse-grained silt and very fine-grained sand sediment that cover Norton Sound are susceptible to liquefaction due to cyclic-wave loading (CLukey, E.C., Cacchione, D.A., and Nelson, Hans, 1979).

Geophysical, geotechnical, and geochemical evidence indicate that hydrocarbon gases of deep subsurface thermogenic origin migrate into the nearsurface sediment along fault zones 30-40 km south of Nome (Nelson, Hans, Kvenvolden, K.A., and Clukey, E.C., 1978). Subbottom reflector terminations and the absence of coherent reflections (or "acoustic turbidity") on 120-kJ profiles indicate a large zone of anomalous acoustic response, about 9 km in diameter and 100 m below the sediment surface, probably is caused by an accumulation of gas. Acoustic anomalies in nearsurface sediment, seen on high-resoltuion seismic profiles, occur in the area of large subsurface gas accumulation as upward extensions of "chimneys" of this accumulation. Vibracorer samples (6 m long) of nearsurface sediment that display acoustic anomalies showed signs of gas saturation; such as expansion pockets and cracks, disrupted bedding, gas-streaming features, and gas-cavity honeycomb structures (Kvenvolden, K.A., Nelson, Hans, Thor, D.R., Redden, G.D., and Rapp, J.B., 1979). The presence of gas in the vibracorer samples indicate that bubble-phase gas in the sediment is the cause of nearsurface acoustic anomalies and therefore also of the deep subsurface acoustic anomaly. Penetration of the vibacorer into sediment at sites with acoustic anomalies in nearsurface sediment was three times more rapid than at sites without acoustic anomalies ((Nelson, Hans, Kvenvolden, K.S., and Clukey, E.C., 1978). High-resolution seismic profiles also show linear and V-shape patterns in the water column over the area of acoustic anomalies, features indicating that bubbles are rising through the water. Gas-bubble trains emanating from the sea floor are observed on underwater television and confirm the active seepage of gas.

Sediment from vibracores taken at the seep site contained gas cavities, expansion voids, a dominance of carbon dioxide gas, unusually high concentrations of hydrocarbon gases heavier than methane, and significant quantities of gasoline range hydrocarbons (Nelson, Hans, Kvenvolden, K.A., and Clukey, E.C., 1978; Kvenvolden, K.A., Nelson, Hans, Thor, D.R., Redden, G.D., and Rapp, J.B., 1979). The composition of the gas in nearsurface sediment above a thick underlying sediment section with acoustic anomalies suggests both a potential petroleum source at depth and a possible hazard for any future drilling activity in this area. Any articficial structures penetrating the large gas accumulation at 100 m or intersecting associated faults that cut the gas-charged sediment may provide direct avenues for uncontrolled gas migration to the sea floor. Gas-charged substrate also displays a lower shear strength than gas-free sediment (Clukey, E.C., Nelson, Hans, and Newby, J.E.,1978). Figure A5shows the location of thermogenic gas-charged sediment and seep site.

Small (3-8 m diameter), shallow (<0.5 m deep), circular craters observed on sonographs over a large area of north-central Norton Sound appear to be caused by present-day gas venting (Nelson, Hans, Thor, D.R., and Sandstrom, M.W., 1978). The craters are associated with nearsurface peat layers, gas-rich sediment, and acoustic anomalies in high-resolution seismic reflection profiles. Nearsurface peaty-mud layers from 1 to 2 m below the sea floor and several meters thick have been vibracored throughout northern Bering Sea. The peaty mud is a nonmarine pre-Holocene deposit with abnormal amounts of organic carbon (3-7 percent) and biogenic methane generated from buried organic debris (Nelson, Hans, Kvenvolden, K.A., and Clukey, E.C., 1978; Kvenvolden, K.A., Nelson, Hans, Thor, D.R., Redden, G.D., and Rapp, J.B., 1979). This gas-charged nearsurface sediment causes sporadic acoustic anomalies by attenuation of sound waves in the low-density peaty mud and gas-charged sediment. Both acoustic anomalies and gas craters occur only where freshwater mud is now covered by a relatively thin (1-2 m) layer of Holocene mud. Where Holocene mud is thicker near the Yukon Delta or grades into sand in Chirikov Basin, craters are absent. Areal extent of the gas-crater field and isopachs of Holocene mud are shown in figure A-5.

During non-storm conditions, the nearsurface gas may be trapped by a 102-m-thick layer of impermeable Holocene mud. Apparently the gas escapes and forms craters during periodic storms that cause rapid changes in pore-water pressures and sediment liquefaction because of sea-level setup, seiches, storm waves, and unloading of covering mud. Gas venting and sediment craters or depressions, apparently formed during peak storm periods, may be a potential hazard to offshore facilities because of rapid sediment collapse. The upper several meters of sediment also has reduced shear strength because of the gas and organic content (Clukey, E.C., Nelson, Hans, and Newby, J.E., 1978).

The fine-grained sand and coarse-grained silt which form the substrate of Norton Sound are highly susceptible to liquefaction by wave-induced or seismically-induced cyclic loading (Clukey, E.C., Cacchione, D.A., and Nelson, Hans, 1979). Normal yearly storm waves propagating through the full fetch of Bering Sea intersect the shallow Yukon prodelta area and seem to be capable of inducing sufficient loading to liquefy Norton Sound sediment to a depth of 1-2 m. Liquefaction of sediment to this depth may contribute to the formation of gas craters and surficial slumps, and enhance erosion in prodelta sediment. The interaction of these processes needs to be taken into account when offshore facilities are designed, because unusual stresses may be encountered if the top few meters of the substrate were to liquefy during a major storm, like the unusual November, 1974 surge (Fathauer, T.F., 1975).

Erosion and Deposition Hazards- Ice scour in bottom sediment is found everywhere throughout northeastern Bering Sea beyond the shorefast ice zone where water depths are less than 20 m, but has also been noted occasionally in water depths of 30 m (Thor, D.R., Nelson, Hans, and Williams, R.O., 1978). Ice-gouge furrows cut into bottom sediment a maximum of 1 m and occur most commonly and ubiquitously as single gouges. Pressure-ridge "raking" (numerous parallel gouge furrows) is most common around the shoals of the Yukon Delta because a well-developed ice shear zone is there. Most of Norton Sound is affected to some degree by ice gouging, as are the margins and sand-ridge shoal areas of Chirikov Basin. Gouge distribution and density and shorefast ice limits are shown in figure A-6.

Much gouging in Norton Sound is probably caused by pressure ridges formed along shear zones as pack ice moves west past stationary shorefast ice (Dupré, W.R., 1978). The combination of pronounced Yukon prodelta shoals with ice convergence offshore from the delta area accounts for the high density of gouging in this area. Because ice gouging is a pervasive scouring agent, design of offshore facilities should take into account the intensity and depths of potential gouge penetrations.

Large-scale bottom scour is associated with strong bottom currents and some areas of densely-spaced ice gouges. Large (25-150 m diameter), irregular, shallow (as deep as 1 m) depressions in Yukon-derived silty, sandy mud occur along the southwest margin of the Yukon prodelta area and on the flanks of an extensive shallow trough in north-central Norton Sound (Larsen, M.C., Nelson, Hans, and Thor, D.R., 1978). These depressions are usually associated with increased bottom steepness and areas of higher bottom-current speeds. Some northern depressions are found near sea-floor scarps of unknown origin; depressions west of the prodelta front expand progressively outward from ice gouge furrows. Apparently, in regions where current speed is increased because of constriction of water flow along the flanks of troughs, shoals, or prodelta fronts, any further local topographic disruption of current flow by slump scarps or ice-gouge furrows initiates scour of the Yukon River-derived sediment to form large shallow depressions.

Scour depression distribution, shown in figureA-7,indicates areas where artificial structures that disrupt current flow may cause extensive erosion of Yukon-derived silt or very fine-grained sand and create potentially hazardous undercutting of the structures. Even buried structures may be subject to scour because strong currents may greatly broaden and deepen naturally occurring ice gouges and thus expose the buried structures. Full assessment of this geologic hazard requires long-term current monitoring in specific localities of scour to predict current intensity and periodicity, especially during major storms, when combined storm-tide and wave currents may be several times greater than normal. Current monitoring over several months has shown speeds as high as 30 cm per second during fair weather and as high as 70 cm per second during typical stormy seather (Cacchione, D.A., and Drake, D.E., 1978).

Strong currents caused by storm waves and sea-level setup transport large amounts of sand onto the Yukon prodelta. Fine-grained sand, apparently originating from sand bars off the Yukon River Delta, is deposited as well-sorted clean sand as far as 75 km from the delta shoreline. Sand-beds range from 5 to 20 cm thick within 30 km of the shoreline and vary from 1 to 5 cm thick 30 to 75 km from the shoreline. The widespread distribution of these storm-sand layers (fig. 7) shows that significant quantities of sand are transported across the Yukon prodelta during storms; sand movement may be a potential hazard to underwater facilities that would act as a barrier to inhibit sediment movement.

In sandy substrate, especially in constricted passages such as strait areas, strong bottom currents create migrating fields of mobile bedforms. Sand waves 1 to 2 m high with wavelengths of 10 to 20 or 150 to 200 m, and ripples 4 cm high with wavelengths of 20 cm, occupy the crests and some flanks of a series of large (2-5 km wide and as much as 20 km long) linear sand ridges lying west of the Port Clarence area (Field, M.E., Nelson, Hans, Cacchione, D.A., and Drake, D.E., 1977; Nelson, Hans, Cacchione, D.A., and Field, M.E., 1977; Cacchione, D.A., Drake, D.E., and Nelson, Hans, 1977). Ice gouges are found in varying states of preservation on several ridges. Active sandwave modification and recent bedform movement is indicated because ice gouges are annually recurring features. Survey tracklines of the 1976 cruise were replicated in 1977, and local changes in bedform type and trend further substantiate recent bedform activity. Bedload transport and small-scale sand waves move during calm weather; maximum change of large-scale sand waves, however, may take place only when northerly current flow is enhanced by sea level setup from major south-southwesterly storms. Strong northerly winds from the arctic reduce the strength of continuous northerly currents and thereby reduce bedload transport and the activity of mobile bedforms near Bering Strait. Distribution of bedform fields throughout Norton Basin is shown in figure A-3; details of the Port Clarence sand-wave field dynamics, which are given by Nelson and others (Nelson, Hans, Field, M.E., Cacchione, D.A., and Drake, D.E., 1978), are pertinent to any future development of this single large natural harbor area north of the Aleutians.

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II. INTRODUCTION

A. General Nature and Scope of Study

This research addresses geological hazards that may result from surface and near-surface faulting, sediment instability, and erosion and deposition processes in the Norton Basin region (Fig. A2). Geological baseline parameters and process information also are generated that provide valuable ancillary information for other interdisciplinary studies. For example, data on sediment texture is presented that is crucial to understanding sediment dynamics questions encountered in RU 430 or benthic organism distribution. Opportunities to collect baseline information on trace metals, and light and heavy hydrocarbon fractions in surface and subsurface hydrocarbons also have been provided. These data are important inputs for RU 413 and for NOAA studies of light hydrocarbon gas seeps.

B. Specific Objectives

To meet our objective of defining recently active faults we are reviewing all old sparker and airgun records to trace fault origins. These are then compared with new reconnaissance data on surface and near-surface faulting observed in high-resolution records. Our goal for sediment stability problems is to characterize soils engineering index properties of the sediment and compare this with other near-surface sediment parameters of gas content, seismic acoustic anomalies, mass movement evidence, and storm sand and peat stratigraphy to determine areas where sediment failure is possible. By studying bedforms on side-scan sonar records, thickness of Holocene sediment on high-resolution seismic records, and stratigraphy of storm sand layers, we hope to determine regions where currents and waves cause excessive disruption of the sea bed. Detailed analysis of the side-scan sonar records also permits assessment of regions of intense ice gouging and bottom current scour.

C. Relevance to problems of petroleum development

In this extremely shallow epicontinental shelf area similar to the North Sea (Fig. A3), the stability and maintenance of drilling rigs, production platforms, pipelines, and shoreline based facilities in the Norton Basin area are all threatened by potential hazards of active faulting, thermogenic gas charged sediments, thixotropic sediment, ice gouging, and sediment scour caused by current and wave erosion. Potential problems of biogenic gas venting and sediment collapse during storm wave interaction with the bottom must be understood prior to construction and installation of sea-floor structures for petroleum development.

III and IV. CURRENT STATE OF KNOWLEDGE IN THE STUDY AREA

A significant number of sediment studies and some deep-penetration seismic profiling had been accomplished in the Norton Basin region prior to the advent of OCS studies in the summer of 1976[1]. Reconnaissance studies with high-resolution geophysical systems and sampling for cruise S5-76-BS Cruise S5-77-BS concentrated on the western portion of Norton Sound, and on Chirikov Basin, again employing high-resolution geophysical systems, and sediment samplings.

The cruise being addressed in this report, S9-78-BS, was devoted to topical studies at several selected sites in Norton Sound and Chirikov Basin (Fig. A-1). The S9-78-BS cruise consisted of three weeks of field work in September 1978, and covered 2500 km of geophysical tracklines. Data were collected using 3.5 kHz, 12 kHz, 200 and 7 kHz, Uniboom, side-scan sonar, and 160 kJ single-channel sparker (Fig. A-8). Twenty nine stations were occupied, where 30 vibracores and 2 Van-Veen grab samples were collected (Fig. A-8).

V. SOURCES, METHODS, AND RATIONALE OF DATA COLLECTION

The nature of previous work in this large geographical area dictated the rationale for the study methods. Regional broad reconnaissance of the northern Bering Sea was accomplished in 1976 and 1977 cruises. For this reason the 1978 cruise concentrated on topical studies which evolved from this reconnaissance work. High-resoltuion geophysics, side-scan sonar, and new sediment vibracoring (6-m cores) techniques were employed. The topical studies included the sand wave fields west of Port Clarence, the thermogenic gas seep south of Nome, the biogenic gas craters in central and eastern Norton Sound and the scour depression areas west and northwest of the Yukon delta.

Specific methods for each facet of the study are outlined in detail in the results section. The research results are subdivided into four topics, each of which comprises a separate sub-report with different authors.

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[1] See summary bibliography in Nelson et al., 1974; Oceanography of the Bering Sea, Occasional Publication No. 2, edited by Hood, D.W. and Kelly, E.J., Institute of Marine Science, Univ. of Alaska, Fairbanks, AK, p. 485-516. (note insert paper b)

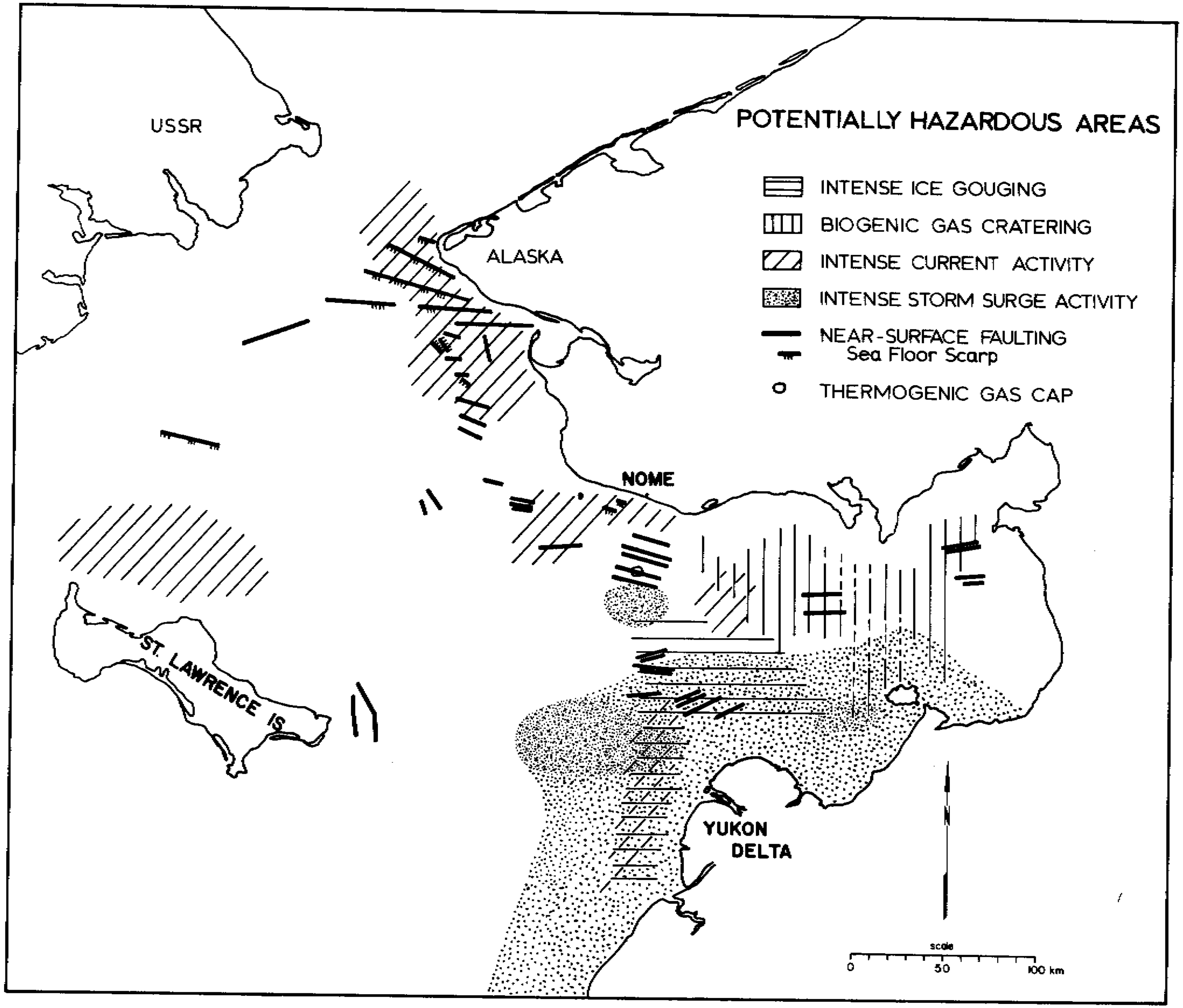

Figure A-1. Summary of potentially hazardous areas of northern Bering Sea.

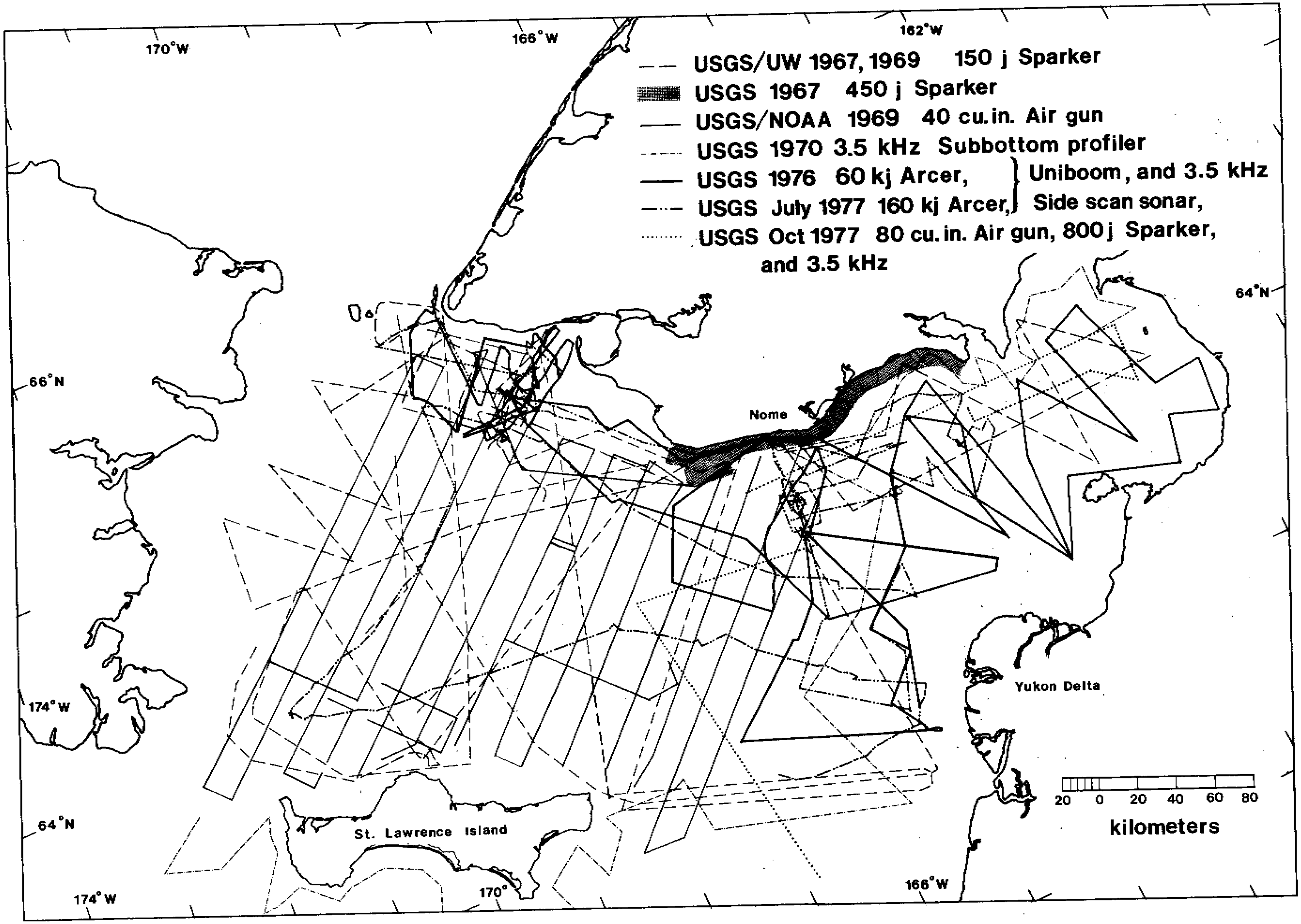

Figure A-2. Coverage of geophysical surveys in northern Bering Sea.

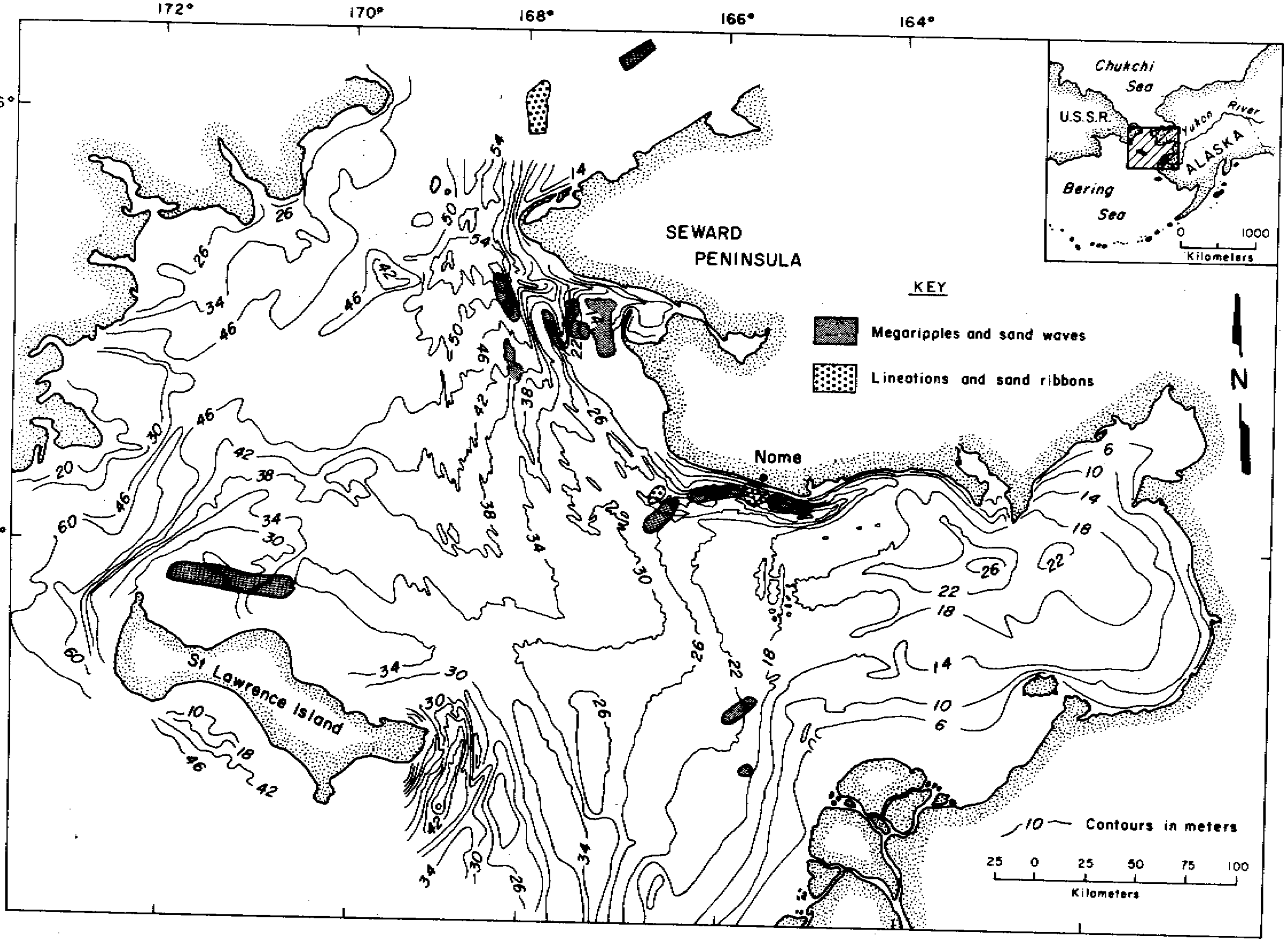

Figure A-3. Bathymetry of northern Bering Sea showing distribution of major areas of mobile bedforms.

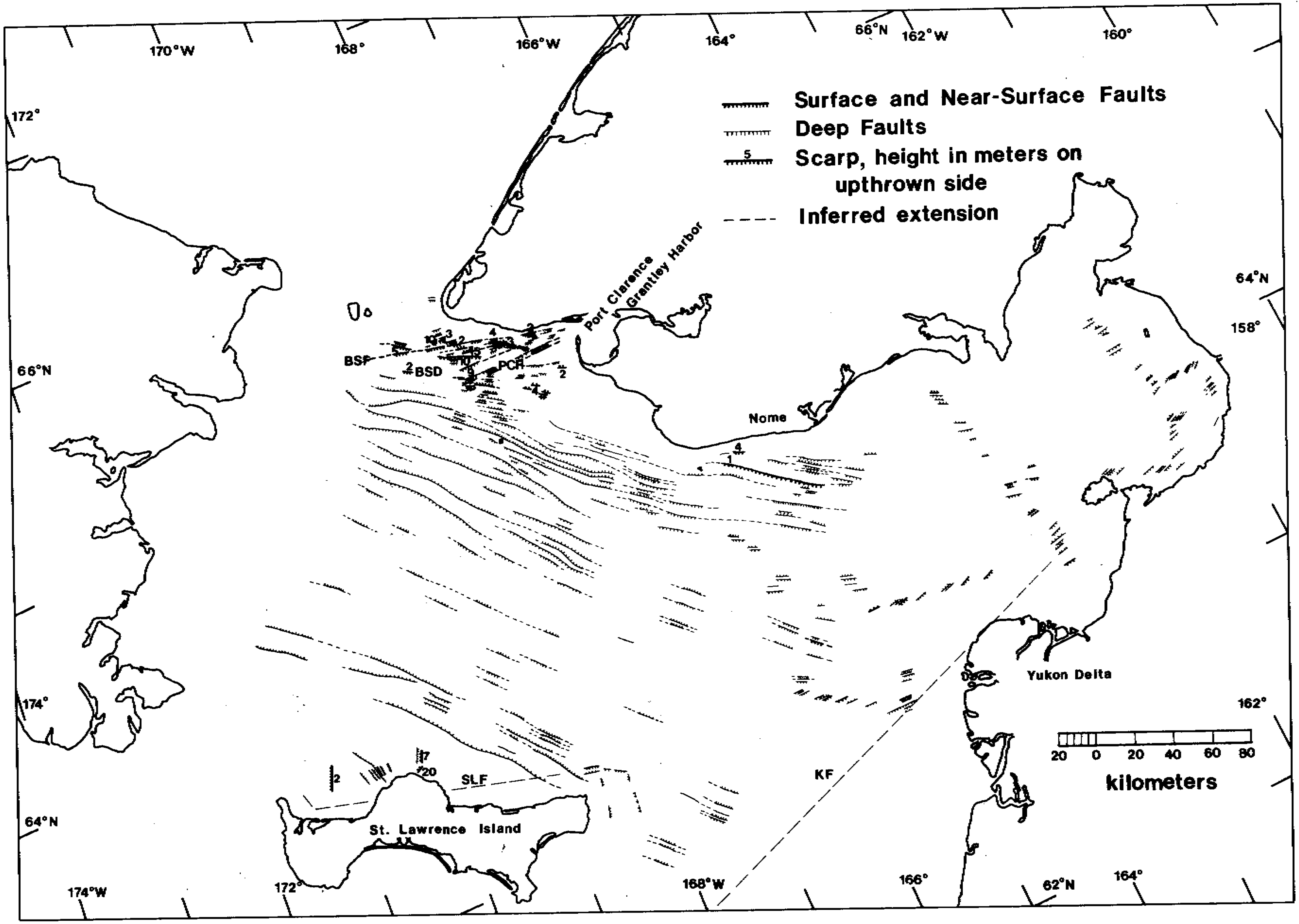

Figure A-4. Faults in Norton Basin

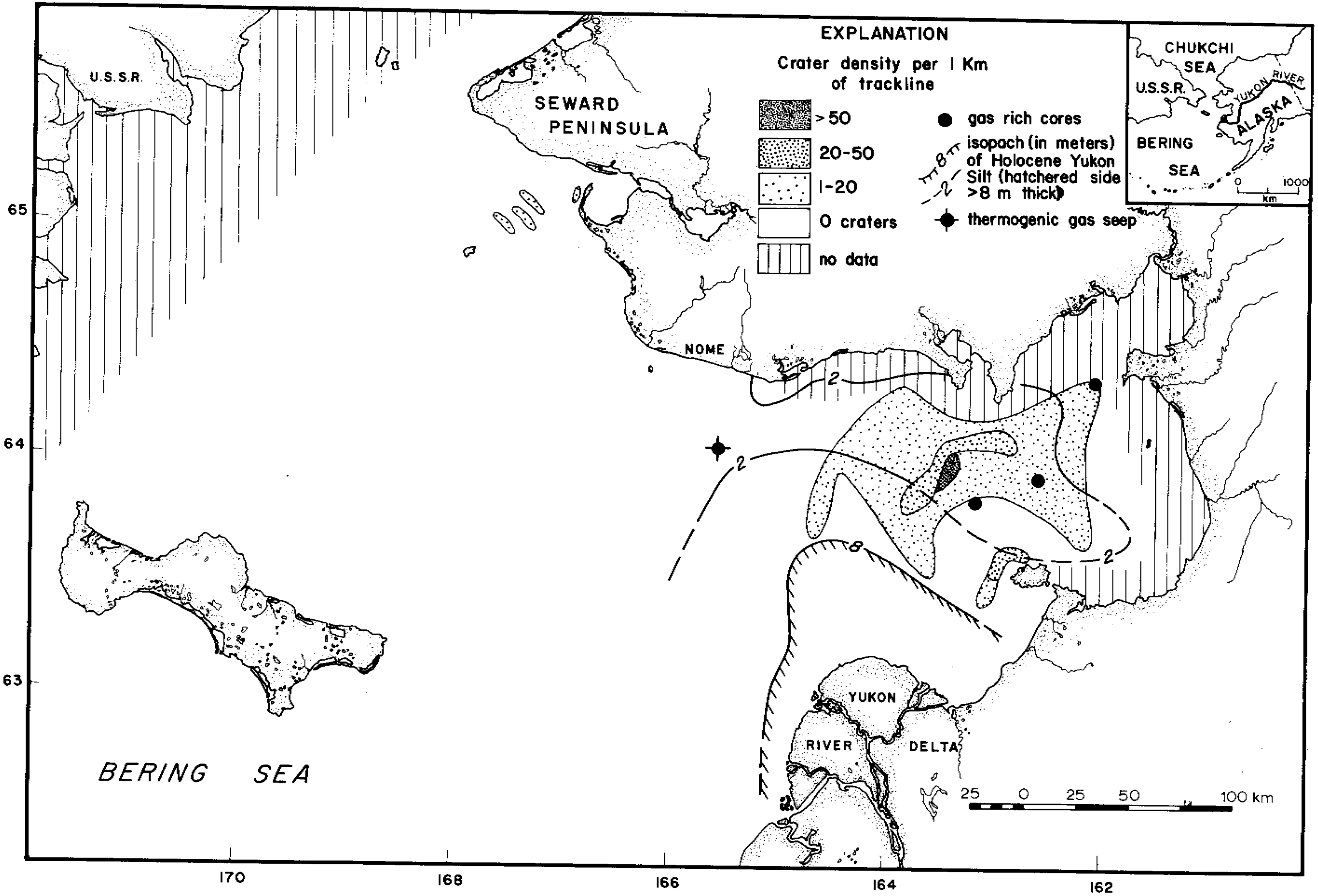

Figure A-5. Distribution and density of craters on sea floor of Norton Sound, showing isopachs of Holocene mud derived from Yukon River and deposited since Holocene postglacial sea-level rise.

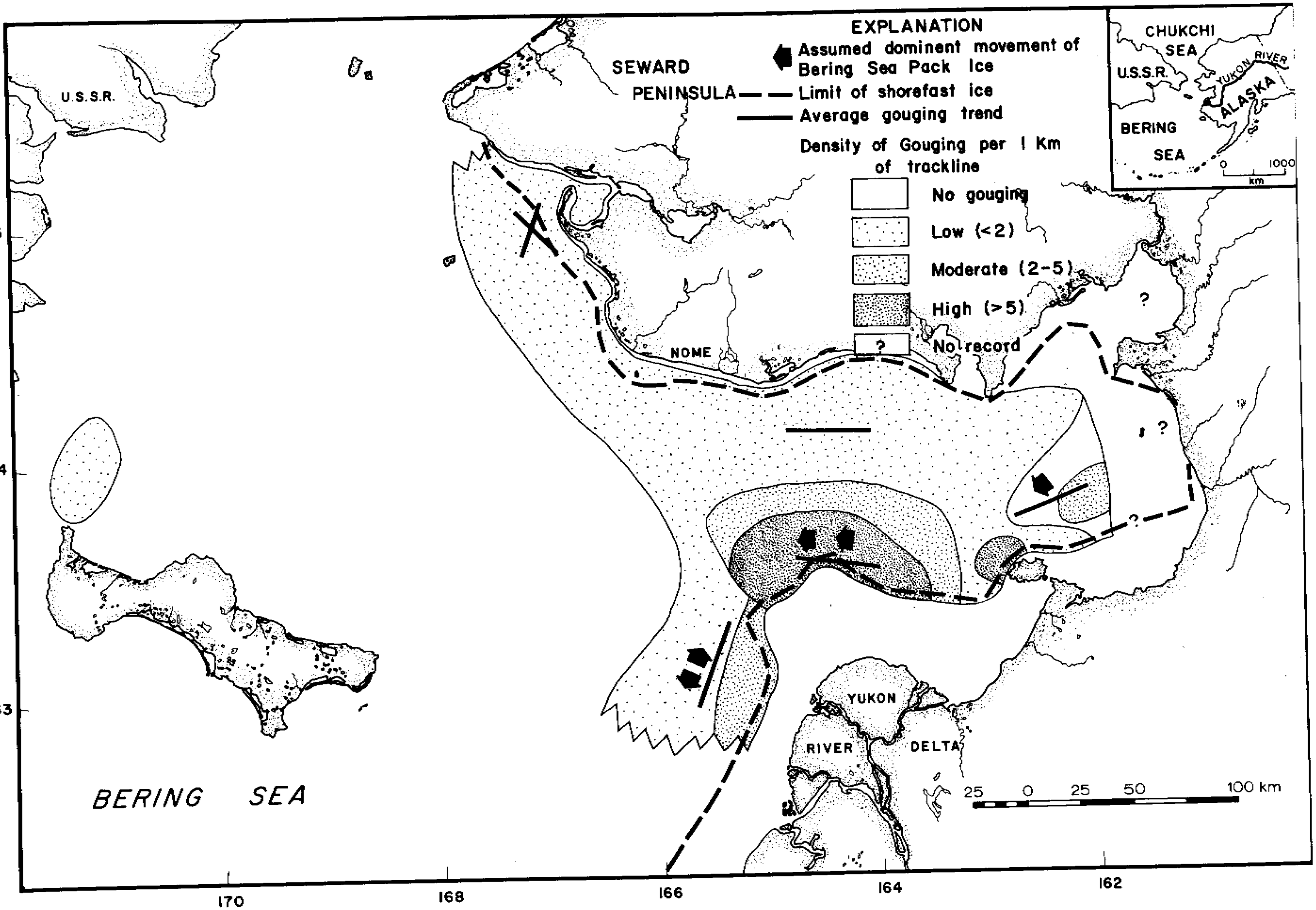

Figure A-6. Distribution and density of ice gouging, movement directions of pack ice, and limits of shorefast ice in northern Bering Sea.

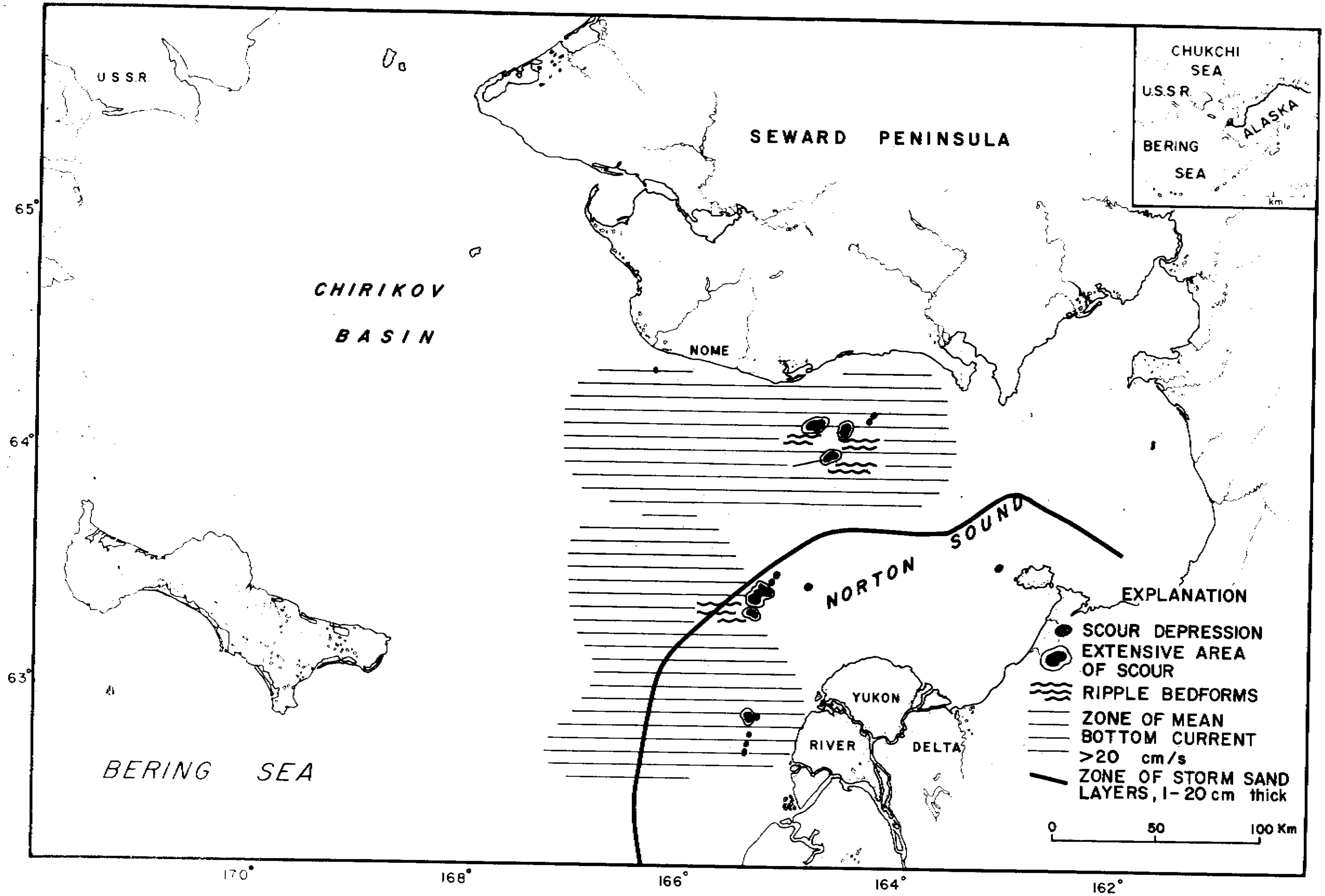

Figure A-7. Location of scour depressions, extensive scour and ripple zones, and strong bottom currents in Norton Sound, showing area of storm-sand deposition.

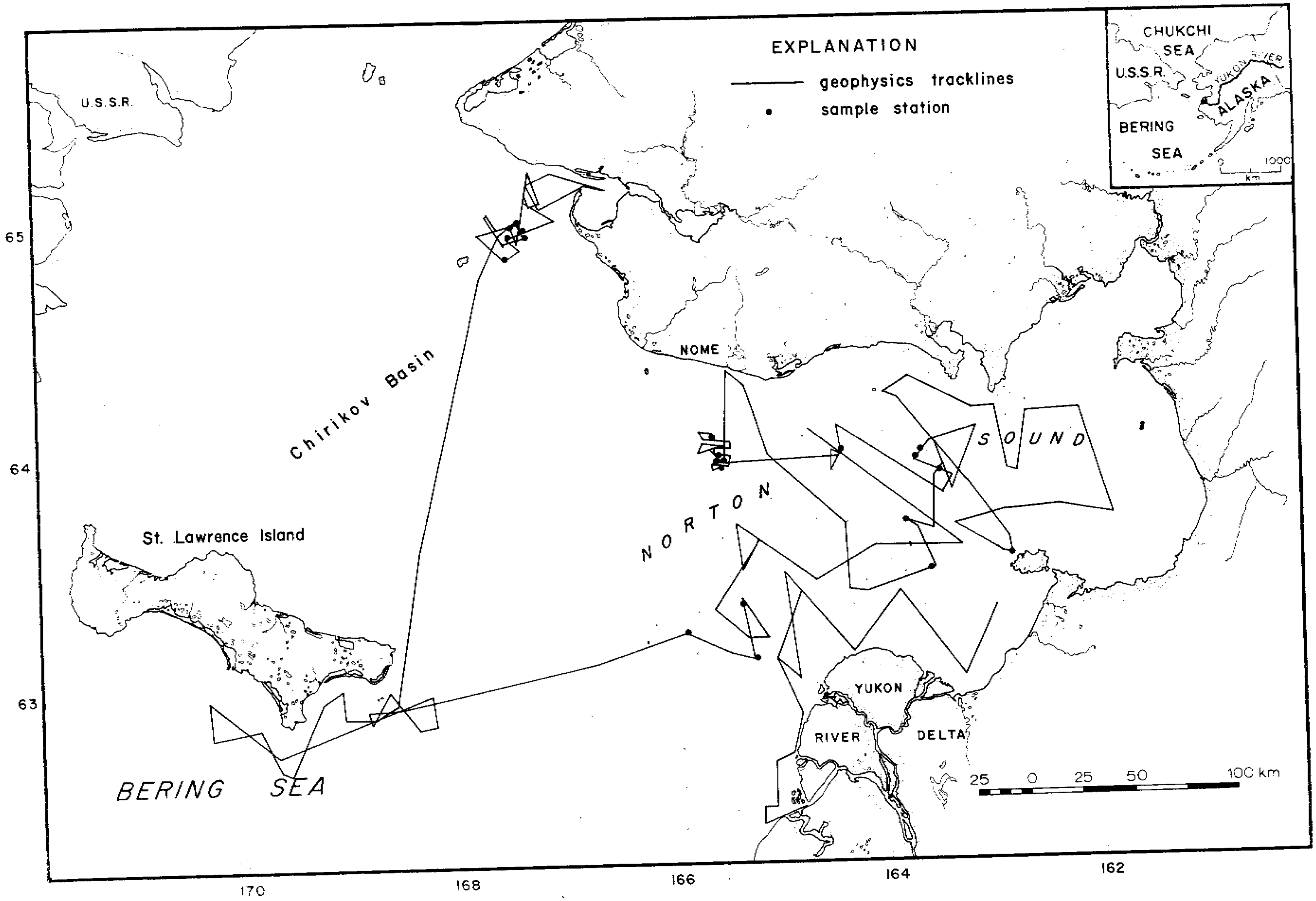

Fig. A-8. High resolution seismic profile tracklines and sampling stations from S9-1978 cruise.

VI. RESULTS

B. DISTRIBUTION OF GAS-CHARGED SEDIMENT IN NORTON SOUND AND CHIRIKOV BASIN

Mark L. Holmes

Discovery of the submarine seepage of natural gas south of Nome, Alaska, in 1976 (Cline and Holmes, 1977) prompted a comprehensive review of seismic reflection data from the Norton basin area. The same types of anomalous acoustic responses associated with the seep zone (Cline and Holmes, 1977; Holmes and Cline, 1978; Nelson et al., 1978) were first encountered by Grim and McManus (1970) in the course of a high-resolution seismic study of the northern Bering Sea in 1967. They interpreted the zones of acoustically impenetrable reflectors on their sparker records as representing a Yukon River deposit very near the surface of the present-day sea floor. The highly reflective nature of this surficial deposit was thought to cause the sudden termination of deeper reflectors observed along portions of the seismic track. Air gun reflection records collected in Chirikov basin during a cruise by NOAA (then ESSA) in 1968 (Walton et al., 1969) also crossed a few of these reflector termination anomalies, and revealed that these zones were more widespread than Grim and McManus (1970) had suspected.

Cline and Holmes (1977) first suggested that these acoustic responses were caused by the presence of bubble phase gas in the near-surface sediment; Holmes and Cline (1978), and Nelson et al. (1978) presented detailed analyses of the deep penetration and high resolution seismic reflection records collected over the seep zone on two USGS cruises in 1977. An additional 3500 km of single- and multi-channel airgun records were obtained by the USGS in August 1978, from both Norton Sound and Chirikov basin. This comprehensive geophysical study further emphasized the widespread occurrence of the acoustic anomalies.

Figure 1 shows the distribution of these acoustically anomalous zones along more than 20,000 km of seismic reflection lines in Norton basin. Two distinct types of acoustic anomalies are observed on the seismic reflection records: Reflector pull-downs and reflector terminations (Holmes and Cline, 1978). Both types could be caused by the presence of gas in the near-surface (upper 150 m) sediment. Reflector pull-downs similar to those shown in Figure 2 have been observed and described by several other investigators from both deep and shallow water areas (Lindsey and Craft, 1973; Cooper, 1978). The low compressional velocity in gas-charged subsurface horizons causes the recorded time section (seismic record) to be distorted relative to the true depth section. The greater travel time through the gassy sediment produces a zone of pulled down reflectors beneath it on the seismic record. The gas does not necessarily have to be in the free state (bubble phase) to produce this phenomena; gas-water or oil-water solutions have compressional velocities less than water alone (Craft, 1973), although the decrease is much greater if gas is present in the sediment interstices. The strong horizontal reflector exhibiting a 180° phase shift which is associated with the observed pull-downs (Figure 2) could be the result of reflections from interfaces between gas-charged zones and strata where water alone fills the pore spaces. The decrease in both compressional velocity and density due to the presence of gas in the sediment results in a large negative reflection coefficient at the top of the gas-charged layer (Craft, 1973; Savit, 1974). Such a condition would produce acoustic responses similar to the strong horizontal reflectors above the reflector pull-downs (Figure 2).

The extensive reflector termination anomalies observed throughout Norton basin (Figure 1) are probably also caused by a subsurface accumulation of gas in sufficient quantity that attenuation and scattering of the seismic signal, even from large sources, is virtually complete. Crossings of the acoustic anomaly associated with the gas seep south of Nome are shown in Figures 2 and 3. The anomaly covers an area of about 50 km^2; it is characterized by a sudden termination of subbottom reflectors, and by a dramatic pull-down of the reflectors at its margins (Fig. 3). The depth to the top of the feature causing the anomalous acoustic signature appears to be quite shallow, on the order of 50-200 m. In places the surface of the acoustically opaque zone rises abruptly to within a few meters of the sea floor (Nelson et al., 1978). These zones may indicate the locations of the active seeps.

Calculations by Cline and Holmes (1977, 1978) indicated that the concentrations of the low molecular weight hydrocarbons which had accumulated in the sediment beneath the seep zone were far below theoretical saturation values. This finding was in conflict with the seismic reflection data, which strongly suggested the presence of bubble phase gas in the sediment. The paradox was resolved by the recent discovery that the seep consists primarily of CO_2 rather than hydrocarbons, and that CO_2 is present in the free state in the sediment interstices (Kvenvolden et al., in press).

An acoustic feature identical to the reflector termination anomaly over the Norton basin gas seep (but smaller in areal extent) was recorded over the Attaka oil field off southeastern Kalimantan using a multi-channel seismic reflection system (Schwartz et al., 1974). Here the acoustic anomaly is caused by a gas cap approximately 450 m thick covering an area of 20 km^2. Laterally continuous velocity analyses of the seismic data suggested a compressional velocity of about 750 m/sec in the gas sands, and this was confirmed by subsequent velocity surveys in wells drilled on the structure (Schwartz et al., 1974).

Examples of other reflector termination anomalies observed in Norton basin (Figures 4 and 5) are quite different from the one associated with the gas seep. They exhibit only slight reflector pull-downs at their margins, and lack the dramatic "wipe-out" appearance of the seep anomaly. The same mechanism, however, gas in the near-surface sediment, provides the most plausible explanation for their occurrence. Indirect evidence indicating abnormally low compressional velocities in these shallow zones is provided by the multi-channel seismic reflection data collected by the USGS in August 1978. An oscillographic camera is used to monitor the signal from the hydrophone streamer every 50 shots. A "normal" shot record is shown in Fig. 6. This is not a "gather" in the true sense of the word, but merely a recording of the output from each of the 24 streamer channels for one shot from the 1326 cubic inch (21.7ℓ) air gun array. Refracted arrivals (head waves), the water wave, and reflected arrivals are clearly visible.

In sharp contrast is a shot record over the gas seep reflector termination zone (Fig. 7). Virtually no reflected energy is returned to the streamer over the gas-charged zone. A shot record over a more typical Norton basin reflector termination zone is shown in Fig. 8. Severe attenuation of the reflected arrivals is still apparent, though not to the same spectacular degree as over the gas seep area. Even more surprising is the degree to which the direct water wave is attenuated; in fact it is almost totally absent over the seep zone (Fig. 7).

These phenomena can easily be explained by invoking the model of near-surface gas-charged sediment. Not only will attenuation of the reflected arrivals be pronounced (Mavko and Nur, 1979), as in the case of Figs. 7 and 8, but the combination of a long (2,800 m) streamer and shallow (20 m) water produce another interesting effect. In such shallow water the direct arrival consists of a complicated train of events, most of which involve rays which have been reflected at least once at wide angle from the sea floor. Normally this would have little noticeable effect on the apparent amplitude of the water wave, but when gas is present in sufficient quantity to lower the compressional velocity of the near surface sediment below that of the water, then quite a different result is observed. Any ray impinging on the sea floor is refracted downward instead of reflected upward, and so energy is progressively lost as the water wave is transmitted to and along the streamer.

This drastic reduction in apparent amplitude of both the reflected and direct arrivals was observed over virtually all of the reflector termination anomalies crossed in the course of the 1978 survey. It is indicative of a significant reduction in compressional velocity in the near-surface strata; the most likely explanation is the presence of free (bubble-phase) gas in the sediment.

The distribution of acoustic anomalies (Figure 1) suggests that near-surface accumulations of gas are most common in the central part of Norton basin northwest of the Yukon River delta. The apparent gas-free zones along the southern and eastern shores of Norton Sound are due to the absence of data from these very shallow water areas. Such is not the case for western Norton basin, however. Seismic reflection coverage is good; there are simply few occurrences of acoustic anomalies.

The possible sources of the gas are still being investigated. The gas seep south of Nome is the only well-substantiated source of hydrocarbon gases indicative of a deep petroleum source (Cline and Holmes, 1978; Nelson et al., 1978; Kvenvolden, 1979, personal communication). The location of many of the other reflector termination zones, especially in Norton Sound, coincides with known occurrences of buried tundra-derived peat deposits which were formed during low sea-level stands in the Quaternary (Nelson and Creager, 1977). Biogenic methane and carbon dioxide generated in these peat beds could cause the observed anomalous acoustic responses; the peat layers themselves could also act to trap upward migrating petroleum-derived gases. The absence of acoustic anomalies (gas-charged sediment) in western Norton basin (Chirikov basin) is probably due to the different types of Quaternary deposits. Chirikov basin was extensively glaciated during the Pleistocene (Grim and McManus, 1970); the boundary between the glaciated and unglaciated terrain corresponds closely with the western limit of acoustic anomalies in Fig. 1. The Quaternary glacial and glacio-marine sediments deposited in Chirikov basin do not have a high potential for biogenic gas generation because advance and retreat of the ice sheets evidently destroyed or prevented the growth of tundra-derived peats common to Norton Sound. Also, the relatively thin Tertiary sedimentary section beneath Chirikov basin has not attained sufficient thickness to subject the basal sediments to the temperatures and pressures required for the generation of hydrocarbon gases.

The distribution of acoustic anomalies (Figure 1) suggests that almost 7000 km^2 of seafloor in Norton Sound and Chirikov basin is underlain by sediments containing sufficient gas (biogenic and/or thermogenic) to affect sound transmission through these zones. Further detailed processing and analysis of the seismic data will possibly permit quantitative estimates to be made of the amounts of gas present in these acoustically anomalous zones.

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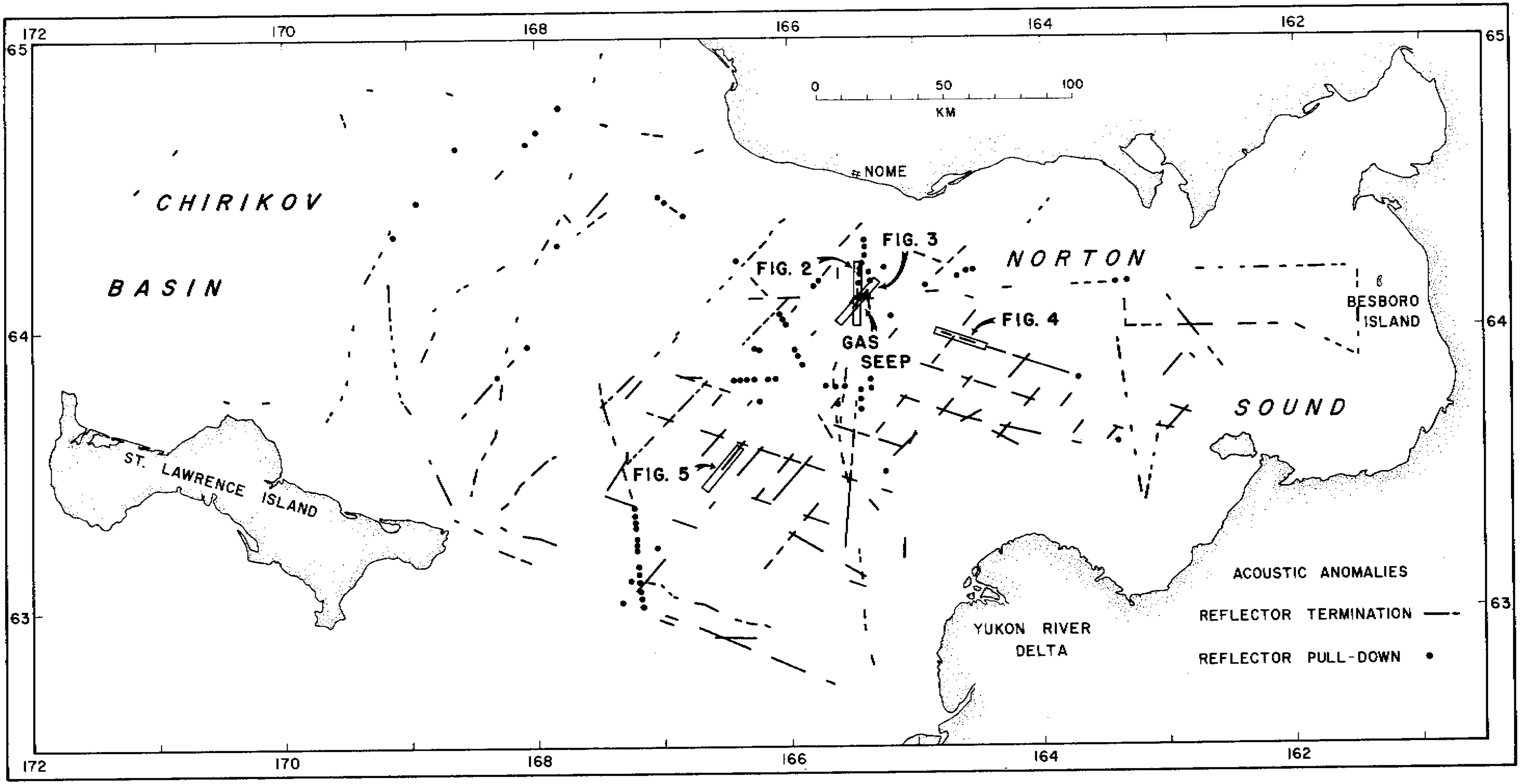
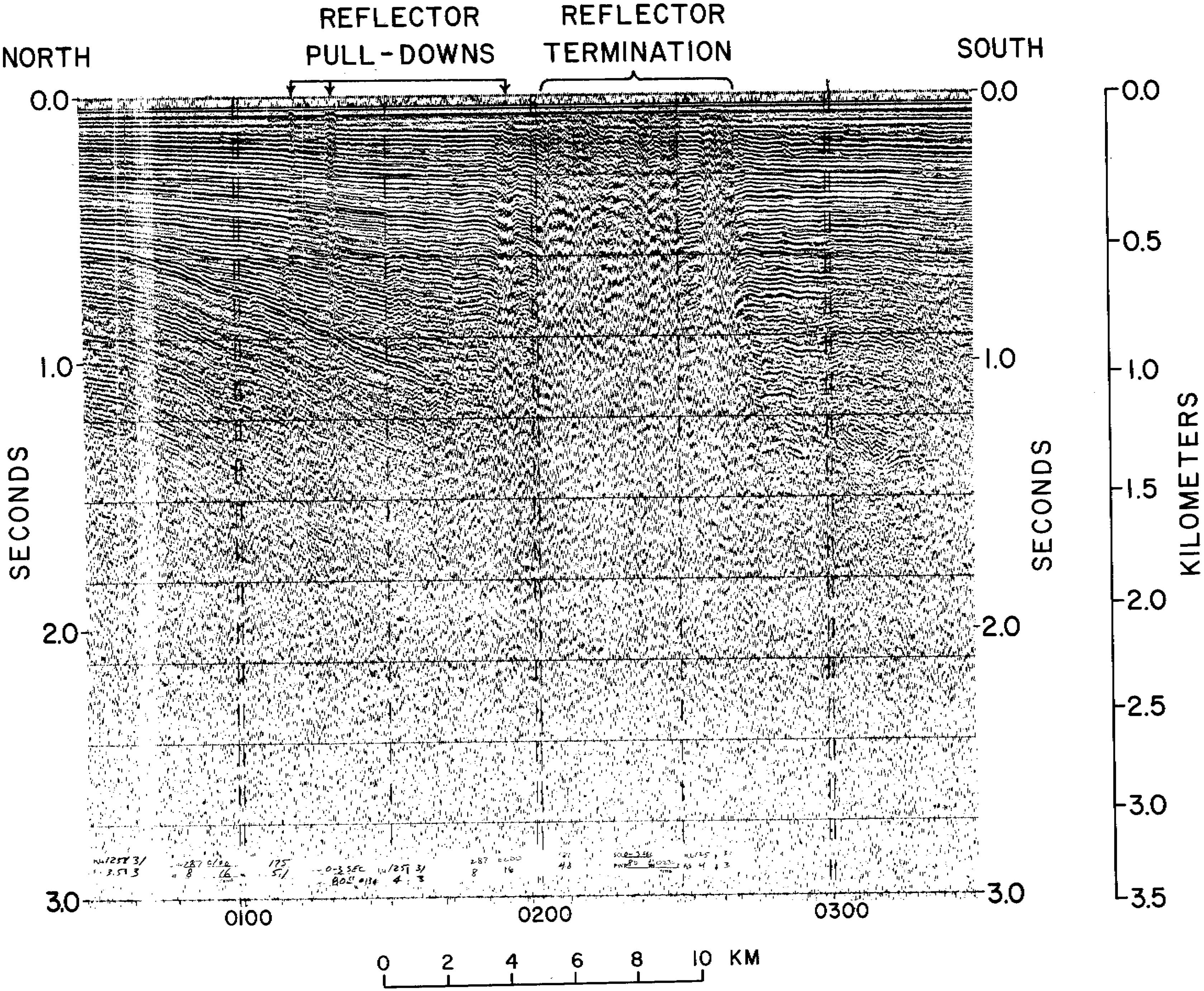


FIGURE B-1 Location of anomalous near-surface acoustic responses observed on single channel seismic reflection records from Norton Sound and Chirikov basin. The acoustic anomalies are due to the presence of bubble phase gas in the sediment. Also shown are the locations of the Norton basin gas seep (Cline and Holmes, 1977), and the seismic record sections shown in Figures 2-5.

FIGURE B-2 Seismic reflection record across the Norton basin gas seep zone. Location of line shown in Figure 1. This record shows two types of acoustic anomalies indicative of gas in the sediment: Reflector terminations and reflector pull-downs.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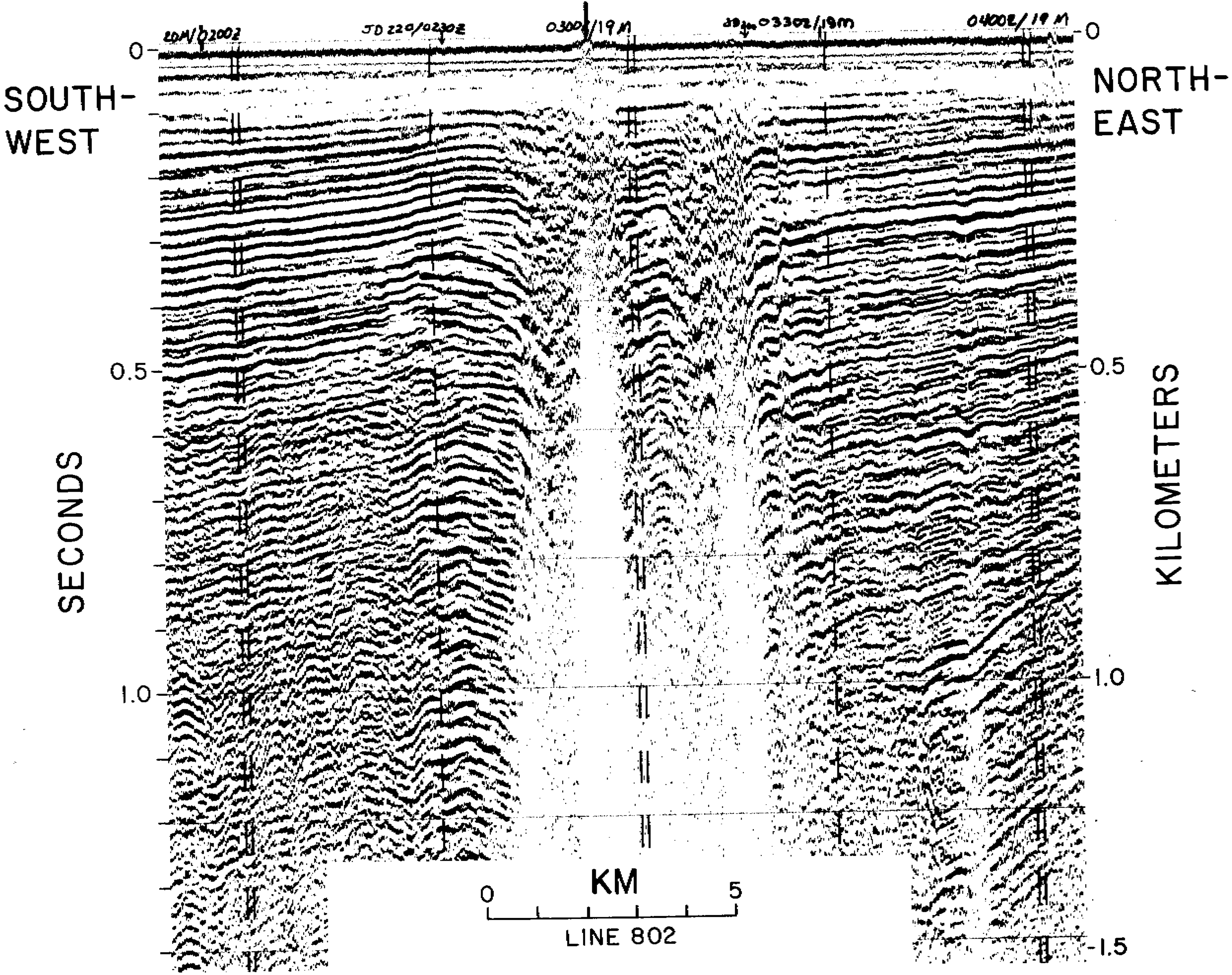
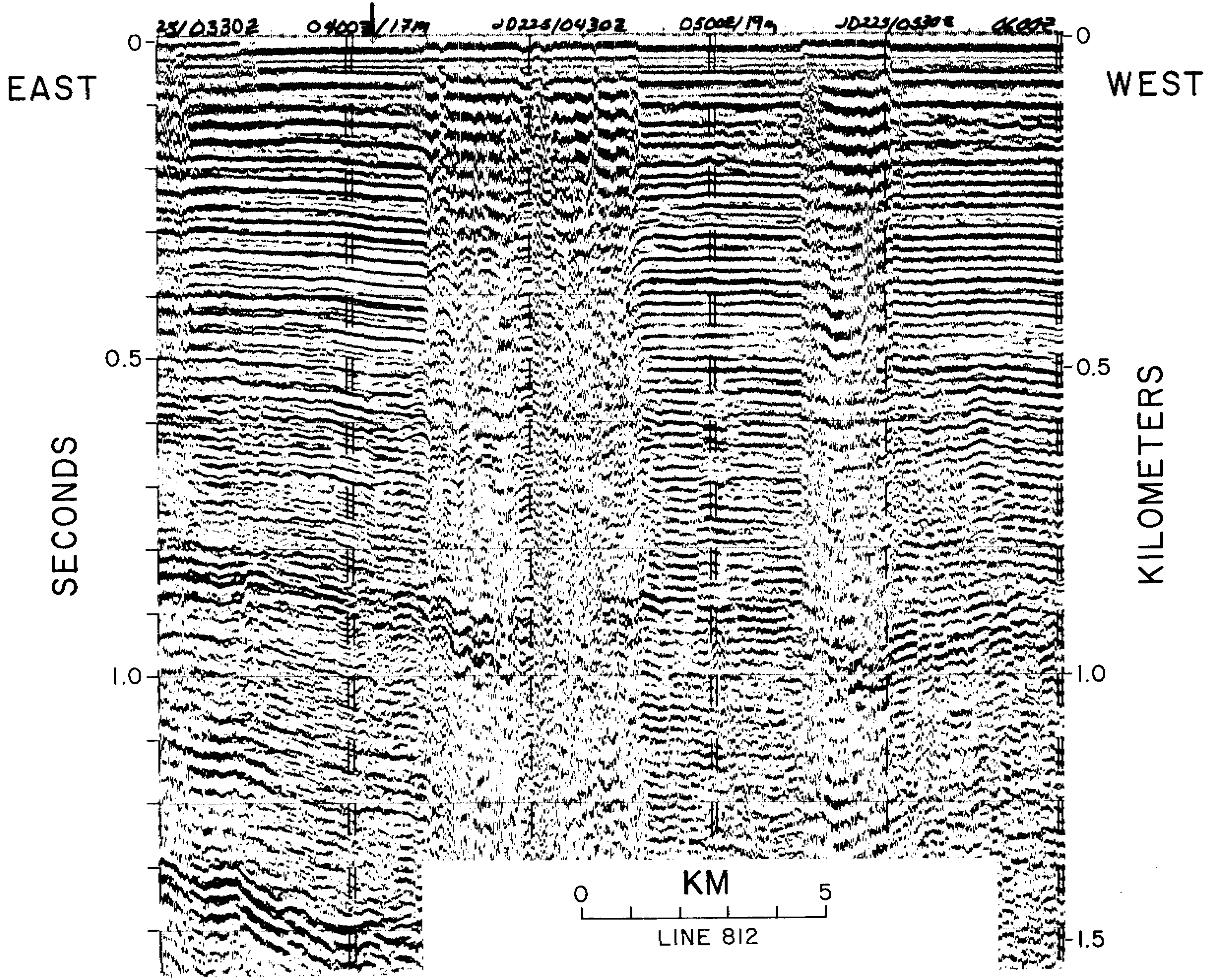
2.0
3.0
SECONDS
SECONDS
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
KILOMETERS
0100
0200
0300
0
2
4
6
8
10
KM

FIGURE B-3 Single channel reflection record across the Norton basin gas seep area. Location of line shown in Figure 1. Reflector termination zone and marginal pull-downs are clearly shown. The 0254 multi-channel shot record is shown in Figure 7.



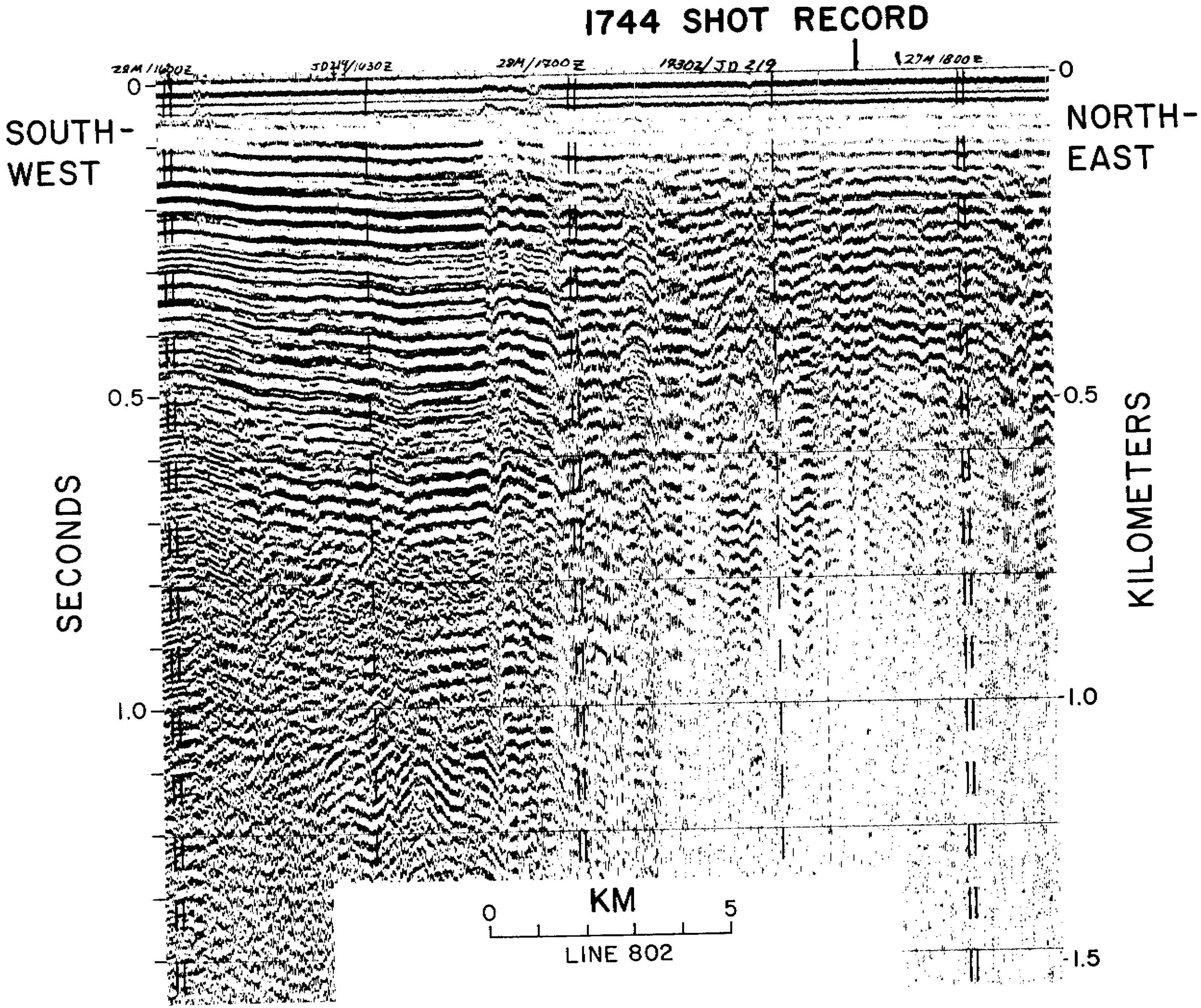
0254 SHOT RECORD

FIGURE B-4 Single channel seismic reflection record from eastern Norton basin showing "normal reflector zones and typical reflector termination anomalies. Location of line is shown in Figure 1. The 0404 multi-channel shot record is shown in Figure 6.



0404 SHOT RECORD

FIGURE B-5 Single channel seismic reflection record from southern Norton basin showing "normal" reflector zones and a typical reflector termination anomaly. Location of line is shown in Figure 1. The 1744 multi-channel shot record is shown in Figure 8.


1744 SHOT RECORD
28M/1600Z
JD219/1430Z
28M/1700Z
1930Z/JD 219
27M 1800Z
SOUTH-
WEST
NORTH-
EAST
0
0.5
1.0
1.5
SECONDS
KILOMETERS
0
KM
5
LINE 802

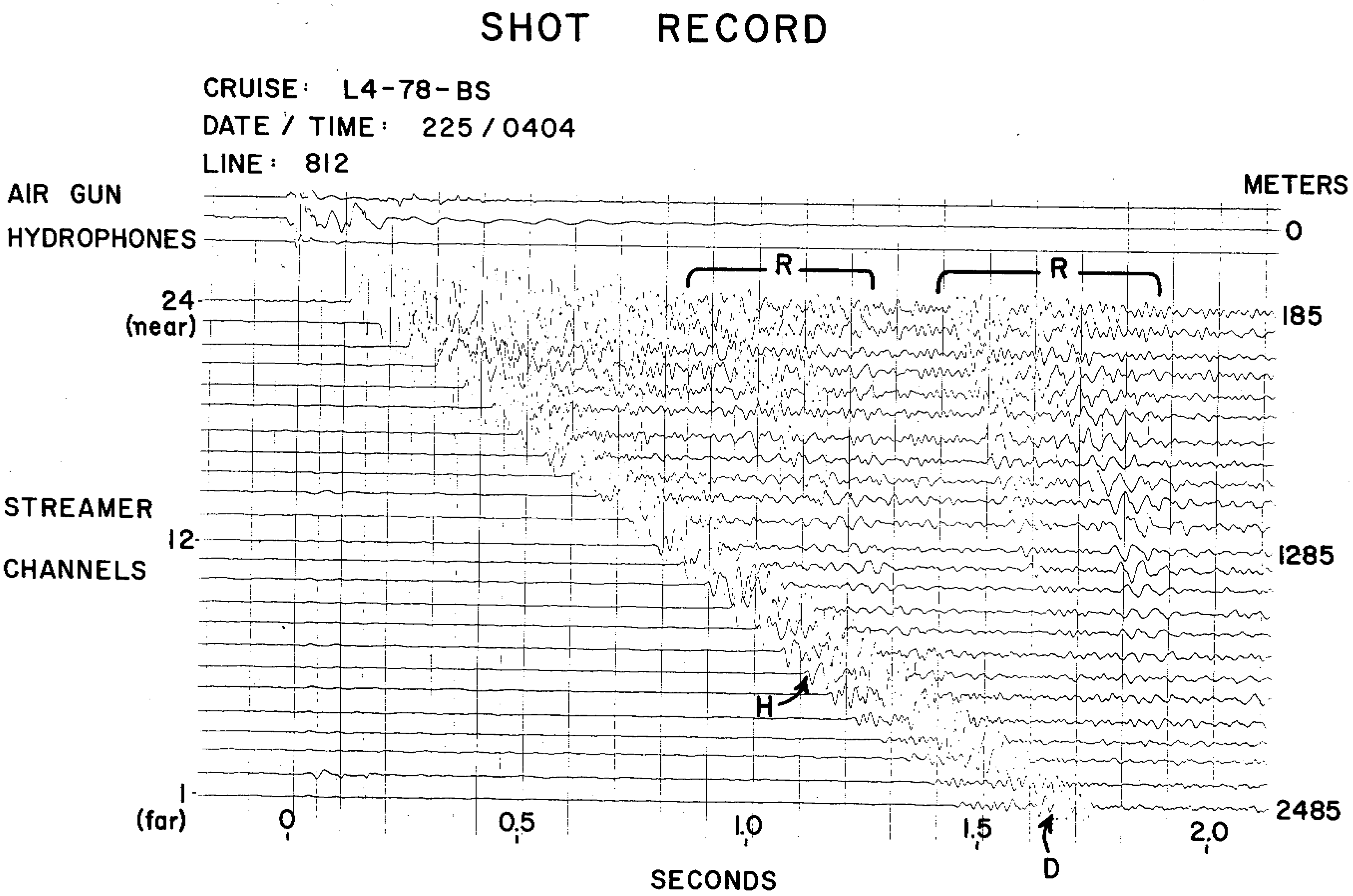


FIGURE B-6 Multi-channel shot record over "normal" reflector sequence shown in Figure 4. Refracted head waves (H), the water wave (D), and reflected arrivals (R) are clearly visible.

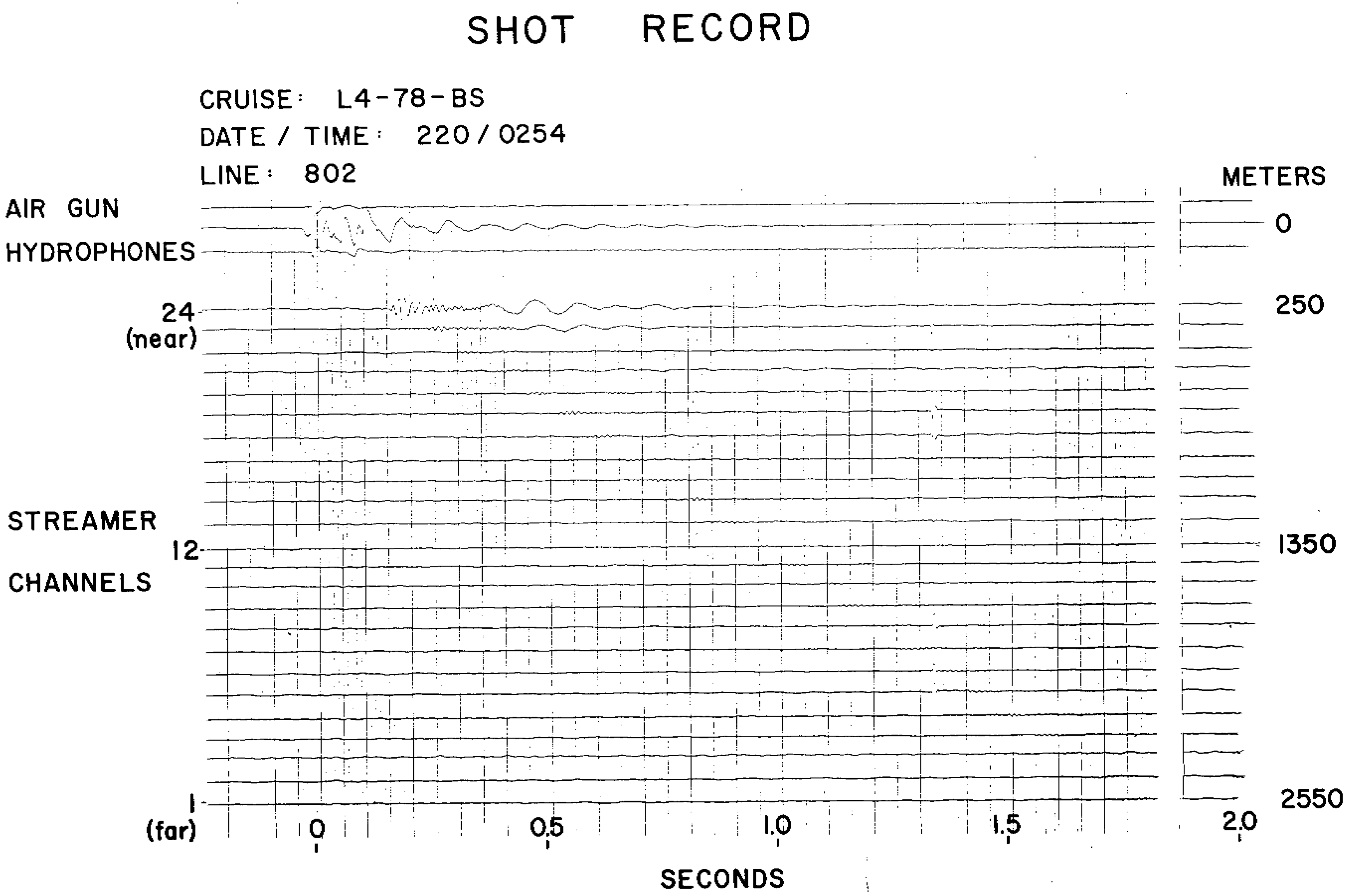


FIGURE B-7 Multi-channel shot record over the gas seep reflector termination anomaly shown in Figure 3. All arrivals are markedly attenuated as a result of gas in the near-surface sediment.

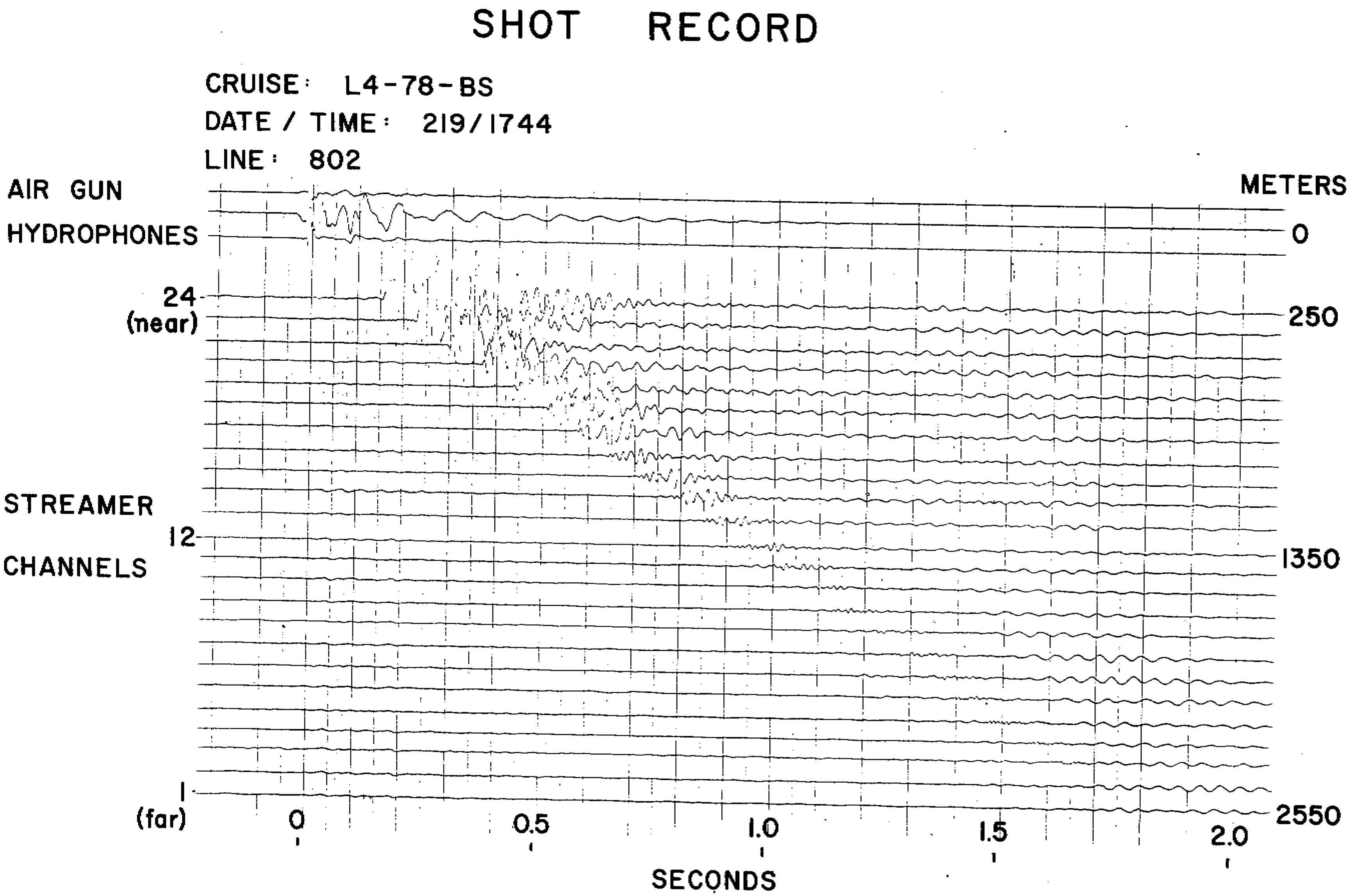


FIGURE B-8 Multi-channel shot record over a typical Norton basin reflector termination anomaly shown in Figure 5. Attentuation due to low velocity gas-charged sediment is still apparent, though not to the same degree as in Figure 7.

VI RESULTS

C. BIOGENIC AND THERMOGENIC GAS IN GAS-CHARGED SEDIMENT OF NORTON SOUND, ALASKA

Keith A. Kvenvolden, C. Hans Nelson, Devin R. Thor, Matthew C. Larsen, George D. Redden, John B. Rapp and David J. Des Marais

INTRODUCTION

Previous investigations in Norton Sound describe acoustic anomalies that are attributed to the presence of near-surface gas-charged sediment, (Nelson, C.H., Kvenvolden, K.A., and Clukey, E.C., 1978; Holmes, M.L., Cline, J.D., and Johnson, J.L., 1978; Cline, J.D., and Holmes, M.L., 1977, and 1978). One anomaly in particular has been studied in detail because of the discovery in 1976 of submarine seepage of petroleum-like gaseous hydrocarbons into the water column, (Cline, J.D., Holmes, M.L., 1977). The gas seep comes from sediment that is inferred to be saturated with hydrocarbons, (Nelson, C.H., Kvenvolden, K.A., and Clukey, 1978; Holmes, M.L., Cline, J.D., and Johnson, J.L., 1978; Cline, J.D. and Holmes, M.L., 1977, and 1978). In the summer of 1977 a geochemical investigation of the seep site showed that near-surface sediment contains petroleum-like gas and gasoline-range hydrocarbons (Nelson, C.H., Kvenvolden, K.A., and Clukey, E.C., 1978). However, the measured concentrations of hydrocarbons in the sediment, although unusually high, were well below saturation. The contradiction between geophysical evidence suggesting gas-saturated sediment and the geochemical analyses showing concentrations of hydrocarbons greatly below saturation led to the work described in this paper.

A major objective was to determine the chemical composition and concentration of the gas in the sediment and to indicate possible sources for this gas. We focused on two areas (Fig. C1) where geophysical, geological and geochemical information indicates that the sediment is charged with gas. One area, approximately 50 km south of Nome, is designated Site 3 from the core number of our 1978 survey. This area corresponds in location to the seep mentioned above, (Nelson, C.H., Kvenvolden, K.A., and Clukey, E.C., 1978; Holmes, M.L., Cline, J.D., and Johnson, J.L., 1978; Cline, J.D., and Holmes, M.L., 1977, and 1978), About 12 km northwest of Site 3 we investigated a second area, designated Site 4. At Site 4 there is evidence of gas-charged sediment, but there is no indication of surface seepage of gas. At both sites the depth of water is 19 m. The geophysical, geologic and geochemical results obtained at these two contrasting sites have explained the earlier contradictory evidence from the seep area.

METHODS

The following high-resolution reflection-profiling multisensor system defined the acoustical responses of the anomalies: (1) 800-J boomer; (2)3.5-kHz subbottom profiling system; (3) 12-kHz echo sounder tuned to detect bubbles in the water column; and (4) 200-kHz echo sounder also tuned to detect bubbles. In addition to the high-resolution systems, deep-penetration reflection profiling was obtained with a 120-kJ sparker system. Side-scan sonar with a 100-m sweep was used to detail the seafloor. About 200 km^2 of seafloor surrounding Sites 3 and 4 has been crossed by about 400 km of geophysical tracklines. The multisensor acoustic system obtained a sequence of acoustic profiles from which we constructed a detailed grid of geologic cross sections, (Larsen, M.C., Nelson, C.H., and Thor, D.R., in press; Nelson, C.H., Holmes, M.L., Thor, D.R., and Johnson, J.L., 1978; Thor, D.R., and Nelson, C.H., 1978).

Geologic observations consisted of underwater television and photography and detailed examination of sediment cores. A sled carrying a 70 mm underwater camera and a television camera was deployed at Site 3 (the seep site)to obtain a direct view of the features on the bottom. Time constraints prevented underwater camera and television coverage at Site 4. Sediment cores were taken with an air-driven vibracorer which monitored its rate of sediment penetration. The vibracorer had a barrel 6 m long and contained an 8.5-cm diameter plastic core liner. From every meter of core, segments about 9 cm long were removed for gas analysis. Also, where a gas expansion pocket developed within the core, analyses were made on gases directly removed through the core liner. The remaining core segments were preserved for later engineering studies. A duplicate core was split, described geologically and sampled for organic carbon, moisture content, and radiocarbon dating.

Geochemical studies consisted of analyses for hydrocarbons and CO_2 on board ship and measurements of total gas composition and of carbon isotopic compositions of CO_2 and methane in shore-based laboratories, (Kvenvolden, K.A., Weliky, K., Nelson, C.H., and Des Marais, D.J., (in press). One gas expansion pocket in the core at Site 3 was sampled as follows: the core liner was partially penetrated with an awl, and a rubber septum was strapped over the partial penetration with a hose clamp. Gas samples were recovered by penetrating the septum, with a needle on a gas-tight syringe and with double-ended needles, to fill 20-ml vacutainers. Also, sediment from the samples removed from the cores were extruded from the liners into 1-qt. paint cans. Each can was immediately filled with helium-purged water. From each can 100 ml of water was withdrawn and the can was sealed. The resulting headspace was purged with helium through septa-covered holes in the can. The can was shaken for 10 minutes in a paint can shaker to release interstitial gas into the headspace. One-milliliter samples of the gas mixture from the gas pocket, the vacutainers and the paint can headspace were analyzed on a gas chromatograph having both flame ionization and thermal conductivity detectors. More detailed compositional information on the gas in the vacutainers was obtained by shore-based gas chromatography. Methane and CO_2 from the vacutainers were separated in a vacuum-line combustion apparatus and their carbon isotopic composition determined by mass spectrometry using methods modified after Craig (Craig, H., 1953). Results are reported relative to the PDB (Peedee Belemnite) standard. ($\delta^{13}C^{o}/oo$ =

$$\left[\frac{{}^{13}C/{}^{12}C\ (\text{sample}) - {}^{13}C/{}^{12}C\ (\text{standard})}{{}^{13}C/{}^{12}C\ (\text{standard})}\right] \text{x } 1000$$

GEOPHYSICAL RESULTS

Geophysical studies have defined the general geologic setting for the area where Sites 3 and 4 are located, (Holmes, M.L., Cline, J.D., and Johnson, J.L., 1978). The sites are on the northeastern side of Norton Basin, a major subsurface northwest-southeast-trending synclinorium. The upper stratigraphic section of the basin fill consists of folded and faulted Tertiary rocks unconformably overlain by horizontally bedded Quaternary units, (Nelson, C.H., Hopkins, D.M., Scholl, D.W., 1974). Tertiary strata dip generally southwest by several degrees or less into the synclinorium. Broad anticlinal arches within the Tertiary section are formed by dip reversals of less than 0.5° toward the northeast.

The geology of the area is characterized by faults, folds, acoustic anomalies, and gas seepage. Faults are subparallel, trend northwest-southeast, and dip southwest (Fig. C1). These faults occur in zones which splay from deeper master faults that offset the acoustic basement, (Holmes, M.L., Cline, J.D., and Johnson, J.L., 1978). The fault system displaces Tertiary and Quaternary units but does not seem to cut through surficial sediment.

Near-surface acoustic anomalies on seismic profiles are common in the area of this investigation. Two types of anomalies are recognized on sparker records. One type of acoustic anomaly, seen at Site 3, is an acoustic-termination anomaly, characterized by sharp termination of subbottom seismic reflectors with an intervening zone lacking coherent reflections (Fig. C2A). The other type of anomaly, observed at Site 4, is characterized by near-surface "pull-downs" of seismic reflectors. The pull-down effect continues to depth (Fig. C2D). The anomalies are attributed to the attenuation and scattering of seismic signals due to gas bubbles in the sediment (Nelson, C.H., Kvenvolden, K.A., Clukey, E.C., 1978).

The 120-kJ sparker profile over Site 3 (Fig. C2A) shows dipping reflectors terminating at regions where the acoustic return signals are highly attenuated. This anomaly is probably caused by a large continuous gas accumulation about 100 m below the surface (Nelson, C.H., Kvenvolden, K.A., and Clukey, E.C., 1978; Holmes, M.L., Cline, J.D., Johnson, J.L., 1978). The boomer profile (Fig. C2B) shows an apparent near-surface extension of the large gas accumulation (Nelson, C.H., Kvenvolden, K.A., and Clukey, E.C., 1978). The 12-kHz (Fig. C2C) and 200-kHz profiles show gas bubble trains in the water column that indicate active gas seepage above the near-surface acoustic anomaly.

At Site 4 the 120-kJ sparker profile (Fig. C2D) reveals a series of reflector "pull-downs". The source of acoustic disturbance is very near the surface. The anomaly on the boomer record at Site 4 is patchy (Fig. C2E) in contrast to the more continuous response shown on the record at Site 3 (Fig. C2B). The 12-kHz (Fig. C2F) and 200-kHz profiles at Site 4 show a clear water column with no evidence of gas bubbles.

GEOLOGIC OBSERVATIONS

The presence of active gas seepage at Site 3, as indicated on the 12-kHz and 200-kHz profiles, is documented by underwater television and photographs. Intermittent and rapid streams of bubbles come from small vents. Bubbles are easy to see on television but difficult to see in plan-view photographs (Fig. C3A). Apparent gas vents were videotaped in 1977, but no bubbles were seen (Nelson, C.H., Kvenvolden, K.A., and Clukey, E.C., 1978). These vents, plus those seen in 1978, range from 5 to 40 cm in diameter, are too small to appear on side scan sonar records, and are conical in shape with depth to width ratios about 1:1. This shape differs from the shapes produced by biological activities which tend to be infilled and much smaller in size (Nelson, C.H., Rowland, R.W., Stoker, S.W., and Larsen, B.B., (in review). Gas seep vents sometimes occur at the crest of ripple fields (Fig. C3B). There is no mounding around small vents. The vents do not resemble mud volcanoes that have been described at other places and that have generally been attributed to gas venting with mixtures of liquid and mud, (Newton, R.S., Personal Communication, 1978). The Norton Sound seep vents are quite different from the apparent biogenic gas craters commonly found elsewhere in the sound (Nelson, C.H., Thor, D.R., and Sandstrom, M.W., 1978).

Relations between sediment ripples and vents indicate that dynamic processes are operating at Site 3. Sediment at the two sites consists of very fine sand and coarse silt derived from the Yukon River. This material can be worked into small ripples (Figs. C3A and C3B) by either intermittent storm waves or strong bottom currents that reach speeds of up to 30 cm/s during daily tidal fluxes (Cacchione, D.A., Drake, D.E., 1978). Photographs taken in 1977 show a generally smooth, highly bioturbated seafloor at the seep site (Nelson, C.H., Kvenvolden, K.A., and Clukey, E.C., 1978). In 1978, however, the seafloor was rippled. The ripples were well preserved and generally symmetrical, like ripples attributed to wave effects. Some of the ripples, however, were modified by bottom currents and were formed into more asymmetric bedforms. The presence of gas vents superposed on these dynamic mobile bedforms suggests that vents form quite frequently. Furthermore, the absence of bubble emanations at most vents indicates that gas movement in near-surface sediment is episodic and rapidly changes pathways to the surface.

Gas in the sediment significantly changes sediment geotechnical properties and internal structures. When the 2-m vibracorer penetrated gas-charged sediment in 1977, rates of penetration were much higher than at locations that did not show geophysical evidence of gas-charging (Nelson, C.H., Kvenvolden, K.A., and Clukey, E.C., 1978). With the 6-m long-vibracorer used in 1978, penetration was as much as three times faster at Sites 3 and 4 than at locations where no anomalies exist. These data on rates of penetration emphasize the loss of shear strength in near-surface, gas-charged sediment.

When cores in gas-charged sediment are removed from the seafloor, the gas begins to expand rapidly and causes a number of secondary phenomena in the sediment core. At Site 3 the core expanded in an explosive manner so that nearly a meter of sediment was blown out the end of the liner when it was removed from the vibracorer. In addition, several 5-10-cm gas pockets formed in the core from the bubble phase gas (Fig. C3C).

The rapid expansion of the core disrupted internal sedimentary structures. Cores at both sites showed a number of cracks (Fig. C3D) which have been noted in other cores affected by gas expansion. The core at Site 3 contained a number of gas cavities in the lower part, so that the sediment resembled a honeycomb (Fig. C3E). The gas apparently streamed rapidly up through the core causing longitudinal gas streaming structures in the lower part of the core (Fig. C3D, top). A large honeycomb structure then formed above where this gas became trapped beneath a cohesive peat layer. At Site 4 sediment expansion cracks also were observed in the core; however, no large gas expansion pockets developed, and the core extruded only a few centimeters out of the core barrel.

Seismic profiles suggest that the region near Sites 3 and 4 is characterized by 1-2 m of Holocene sediment (Nelson, C.H., Holmes, M.L., and Thor, D.R., 1978; Thor, D.R., and Nelson, C.H., 1978; Larsen, M.C., Nelson, C.H., and Thor, D.R., (in press); Nelson, C.H., Creager, J.S., 1977) and lithologic studies indicate that the sediment is coarse silt derived from the Yukon River (McManus, D.A., Venkataratham, K., Hopkins, D.M., and Nelson, C.H., 1974). The stratigraphy in the vibracore shows Holocene sediment slightly over 3 m thick at Site 3 and about 1.5 m thick at Site 4. Because of necessary compensation for gas expansion, the true thickness of the overlying Yukon mud in this area is probably like the

2-m thickness found elsewhere in Norton Sound. Yukon mud, 1.5 to 2 m thick, overlies Pleistocene freshwater peaty mud deposited before the Holocene marine transgression (Nelson, C.H., Creager, J.S., 1977). The peats or peaty muds that characterize Pleistocene sedimentation contain large amounts of organic carbon (8 to 34 percent). This organic-rich mud may generate high quantities of methane as observed at several places in Norton Sound (Nelson, C.H., Thor, D.R., Sandstrom, M.W., 1978).

GEOCHEMICAL ANALYSES

The gases extracted from sediments at Sites 3 and 4 (Table 1) were analyzed by gas chromatography on board ship. The measurements should be considered semiquantitative because our standards required large multiplication factors to calculate the unusually high concentrations of gases found at both these sites. At Site 3, CO_2 is the dominant gas being about 4 to 5 orders of magnitude higher in concentrations than methane, which is the most abundant hydrocarbon gas. Of special interest is the fact that the hydrocarbon gases heavier than methane, namely ethane, propane, and the butanes, are especially abundant relative to methane. The ratios of methane/ethane + propane $(C_1/(C_2 + C_3)$ are all less than 10 and in fact, in one sample, this ratio is less than 1. Ethene and propene are also present but always in lower concentrations than their saturated homologues. Gas chromatograms also show that gasoline-range hydrocarbons are present. Generally, the overall concentrations of hydrocarbons appear to decrease with depth in the vibracore.

The dominant gas in sediment at Site 4 is methane and CO_2 is usually subordinate by a factor of about 3. Hydrocarbons heavier than methane are present, but their concentrations relative to methane are small. For example, the ratios of $C_1/(C_2 + C_3)$ range from about 1000 to 24,000. Near the surface ethene and propene are in greater concentrations than ethane and propane but at depth saturated hydrocarbons are more abundant. The concentration of hydrocarbons increases with depth. Methane reaches concentrations near saturation in the interstitial water.

Geochemical analyses of the gases present in a gas expansion pocket (Fig. C3C) in the core at about 178-187 cm depth provided a good estimate of the bubble-phase composition of the gas at Site 3. Carbon dioxide constitutes about 98% by volume of the total gas mixture. Other gases measured are: N_2, 1.9%; O_2, 0.5%; Ar, 0.3%; H_2, 0.1%; and H_2O, trace. Only 0.04% of the mixture is hydrocarbons. Concentrations of individual hydrocarbons in parts per million by volume of total gas are: methane, 362; ethane, 39; propane, 18; n-butane, 4; and isobutane, 20. Ethene and propene were not detected. The ratio $C_1/(C_2 + C_3)$ is 6.4, in the same range of values shown in Table 1 for Site 3.

Carbon isotopic compositions were determined for CO_2 and methane from the gas expansion pocket and for organic carbon at 325 cm in the core at Site 3. For Site 4, carbon isotopic compositions were measured for CO_2 and methane from the headspace of the canned sample from 190 to 199 cm and for organic carbon from Pleistocene sediment at 212 cm in the core. The results, summarized in Table C-2, clearly show that the sources of the gases at Sites 3 and 4 must be distinctly different. On the other hand, the organic carbon in the Pleistocene peaty mud has the same isotopic composition at both sites, and, therefore, the peat probably is of the same source.

DISCUSSION

Our geophysical and geologic observations indicate that gas is present at high concentrations in the sediment at Sites 3 and 4. The geochemical data confirm these observations but show that the gas composition differs at the two sites, with CO_2 leaking into the water at Site 3 and methane trapped in the Pleistocene sediment at Site 4.

Many of the geophysical features at the two sites are similar, but there are a few differences between the sites. Similarities between Sites 3 and 4 include (1) a thin veneer of Holocene sediment covering Pleistocene peaty mud; (2) higher rates of vibracorer penetration at both sites than at adjacent locations not exhibiting near-surface acoustic anomalies. (These penetration data help substantiate that the acoustic anomalies at Sites 3 and 4 indicate gas-charged sediment); and (3) gas expansion cracks in cores from both sites. The core from Site 3 also exploded at the top and developed large gas pockets within the core liner, suggesting a higher sediment gas content at Site 3 than at Site 4.

Differences between the two sites appear mainly in geophysical records. For example, the sparker records for Site 3 show an acoustic anomaly at about 100 m depth that has sharp terminations of subbottom seismic reflectors with an intervening lack of coherent reflections; high-resolution records indicate bubbles leaking from the sediment into the water column. At Site 4 the sparker records show near-surface pull-downs of the seismic reflectors, and high-resolution records indicate no bubbles in the water. The acoustic anomaly at Site 3 is interpreted to be caused by an accumulation at 100 m and deeper of gas, mainly CO_2. Some CO_2 apparently is escaping from the accumulation and breaks through the seafloor as a seep. At Site 4 the acoustic anomaly is believed to be due to trapping of gas, mainly methane, generated in the near-surface sediment.

The chemical and isotopic compositions of the gases at Sites 3 and 4 provide information for interpreting possible sources. Bernard et al. (Bernard, B.B., Brooks, J.M., and Sackett, W.M., 1976) utilize two parameters, the ratio of $C_1/(C_2 + C_3)$ and the $\delta^{13}C$ value of methane, to determine the origin of natural hydrocarbon gases in submarine seeps. They point out that microbial degradation produces hydrocarbons with $C_1/(C_2 + C_3)$ ratios greater than 1000 and with methane having $\delta^{13}C$ values less than -60 °/oo. On the other hand, thermal sources produce hydrocarbons with $C_1/(C_2 + C_3)$ ratios of 0 to 50 and $\delta^{13}C$ values of methane heavier than -50 °/oo. The hydrocarbon gases at Site 3 where $C_1/(C_2 + C_3)$ ratios are less than 10 and the $\delta^{13}C$ value of methane is -36 °/oo, clearly are from thermogenic sources according to the criteria of Bernard et al. (Bernard, B.B., Brooks, J.M., and Sackett, W.M., 1976). The dominant CO_2 at this site has a carbon isotopic composition of -2.7 °/oo. This value suggests that the CO_2 is probably derived from the thermal decomposition of marine carbonates, which are believed to underlie large parts of the Bering Sea Shelf (Patton, W.W., Jr., and Dutro, J.R., Jr., 1969). Thus, the isotopic evidence for both organic and inorganic carbon indicates that thermal processes are involved in the formation of gases at Site 3. In contrast, the gases from Site 4 are dominated by methane and are apparently produced by microbial activity as suggested by the $C_1/(C_2 + C_3)$ ratios ranging from 1000 to 24,000 and by the $\delta^{13}C$ of methane of -80 °/oo. The CO_2 at Site 4 has a $\delta^{13}C$ value of -14 °/oo that is in the range consistent with biologically produced CO_2 but we do not know if the method of collecting samples from canned sediment affects the isotopic fractionation of the CO_2. Carbon isotopic compositions of bacterially generated CO_2 and methane in sediment from the Deep Sea Drilling Project (Claypool, G.E., Presley, B.J., and Kaplan, I.R., 1973) however, are similar to isotopic compositions at Site 4. The presence of high concentrations of methane in Norton Sound sediment is fairly common (Nelson, C.H., Thor, D.R., and Sandstrom, M.W., 1978), but the occurrence of a CO_2 seep at Site 3 is unique.

At Site 3 the predominant gas, CO_2, carries with it a small component of gas and gasoline-range hydrocarbons. These hydrocarbons may be related to petroleum. As an example, in the petroleum province offshore southern California, submarine gas seeps are common. At two of these seeps the chemical and carbon isotopic compositions of hydrocarbon gases have been determined. The results are similar to those we obtained for gas at Site 3. For example, seeps at Coal Oil Point and Carpenteria have $C_1/(C_2 + C_3)$ ratios of 36 and 10 respectively and $\delta^{13}C$ values of methane of -38.7 ‰ and -40.3 ‰ (Claypool, G.E., Presley, B.J., and Kaplan, I.R., 1973). Thus, the hydrocarbons at Site 3 may be derived from processes similar to or the same as those involved in the origin and maturation of petroleum. Even if these hydrocarbons are derived from petroleum, they probably constitute less than 0.1% of the gas in the accumulation at 100 m depth indicated by the sparker records. We cannot yet define precisely the sources and processes by which CO_2 and the hydrocarbon gases are produced at Site 3 but a number of alternatives have been considered and are discussed elsewhere (Kvenvolden, K.A., Weliky, K., Nelson, C.H., and Des Marais, D.J., (in press)).

The occurrence of near-surface sediment charged with biogenic or thermogenic gas has direct implications for sediment stability (Whelan, T., Coleman, J.M., Roberts, H.H., and Suhayda, J.N., 1976). The presence of high concentrations of gas in the sediment of Norton Sound causes a reduction in stability as suggested by the rapid rates of vibracorer penetration into the gas-charged sediment. Areas with near-surface, gas-charged sediment may be potentially hazardous to any engineering developments requiring firm and stable footings.

CONCLUSIONS

Geophysical, geologic and geochemical evidence all indicate that gas-charged, near-surface sediment is present in Norton Sound, Alaska. Some sediment is charged with methane that is probably derived from microbial processes operating on Pleistocene peaty mud beneath a thin veneer of Holocene sediment from the Yukon River. At Site 3 sediment is charged with CO_2, which seeps into the water column. This CO_2 carries with it a minor component of hydrocarbon gases and gasoline-range hydrocarbons. The chemical and isotopic compositions of the sediment gases indicate that they are derived from thermal sources operating at depth within Norton Basin. The gases probably migrate up faults eventually reaching the surface as a seep. The hydrocarbons apparently are derived through processes similar to or the same as those that produce petroleum. Our data do not indicate whether a significant accumulation of petroleum is present at depth. The ease of penetration by the vibracorer into the gas-charged sediment suggest that the presence of gas reduces the stability of the sediment. Areas where sediments are charged with biogenically and thermogenically derived gas may be hazardous for any future engineering developments in the area.

ACKNOWLEDGMENTS

We thank the scientific staff and crew of the R/V SEA SOUNDER for assistance in collecting and processing samples at sea. Particularly we are grateful to E.C. Clukey for geotechnical information, W.C. Evans for compositional analysis of the total gas mixture, K. Weliky for help in preparing samples for carbon isotopic measurements, and J. Henning for typing and assembling the manuscript.

C-8.

The cruise was supported jointly by the U.S. Geological Survey and by the Bureau of Land Management through an interagency agreement with the National Oceanic and Atmospheric Administration, under which a multiyear program responding to the needs of petroleum development of the Alaskan continental shelf is managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office.

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Table 1 - Content of Gases in Sediment
nL/L of Interstitial Water*

	Interval (cm)	Methane	Ethane	Ethene	Propane	Propene	n-Butane	Isobutane	CO_2	Methane / Ethane+Propane	Ethane / Ethene
Site 3	110 - 119	68×10^3	7300	63	220	48	50	640	61×10^6	9	120
	200 - 209	4.0×10^3	3000	290	9300	200	5600	24000	110×10^6	< 1	13
	300 - 309	2.1×10^3	500	56	330	56	280	240	47×10^6	3	9
	400 - 409	1.5×10^3	340	180	440	130	240	94	52×10^6	2	2
Site 4	0 - 9	69×10^3	28	81	35	68	14	-	$.072 \times 10^6$	1.1×10^3	0.4
	50 - 59	220×10^3	66	170	45	66	-	-	1.4×10^6	2.0×10^3	.4
	90 - 99	3500×10^3	820	99	320	28	34	40	4.6×10^6	3.1×10^3	8
	190 - 199	33000×10^3	830	62	560	30	170	400	11×10^6	24×10^3	13
	290 - 299	41000×10^3	1100	330	760	140	290	640	17×10^6	22×10^3	3
	390 - 399	38000×10^3	1000	330	910	230	170	230	12×10^6	20×10^3	3

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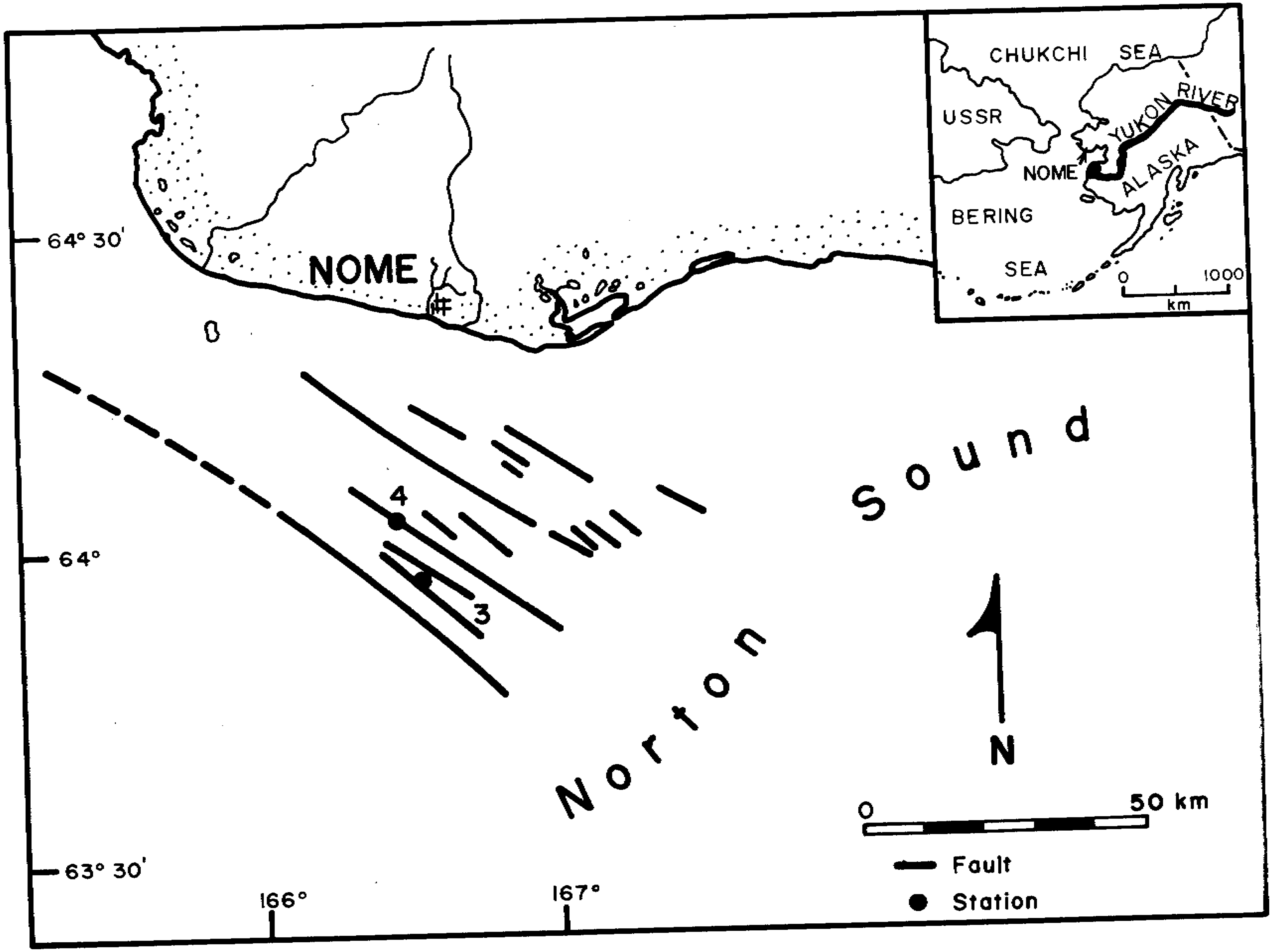
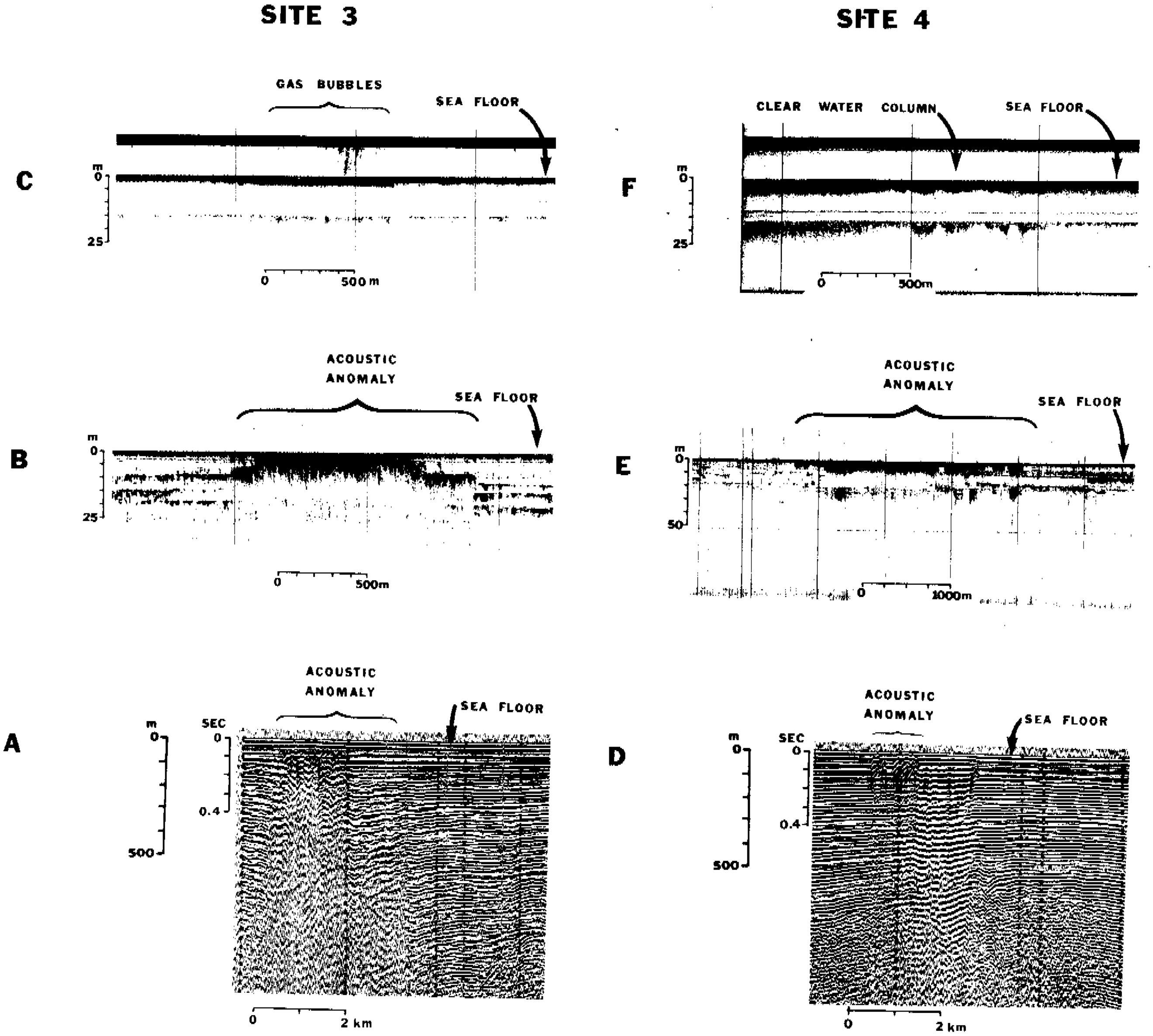
*Concentrations are calculated on the basis of interstitial water determined from moisture content. Hydrocarbons are corrected for partitioning effects between the headspace and the sediment-water mixture in the paint cans.

Table 2 - Carbon Isotopic Composition of Gases and Organic Carbon in Sediments of Norton Sound ($\delta^{13}C°/_{\circ\circ}$)

	Site 3	Site 4
CO_2	-2.7±0.1, -2.6±0.1	-14.0±0.1, -14.4±0.1
Methane	-37±2, -35±2	-80.5±0.2, 80.4±0.2
Organic Carbon	-27.9, -27.4	-27.8, -27.8



FigureC1. Location map of Sites 3 and 4 in Norton Sound, Alaska. Near-surface fault traces are mapped near these sites.



FigureC2. Geophysical profiles taken over Site 3 (A-C) and Site 4 (D-F). A -- 120-kJ sparker record showing reflector terminations and intervening lack of conherent reflections. B -- Boomer record showing reflector terminations and continuous zone lacking acoustic definition. C -- 12-kHz record showing V-shaped gas bubble trains in the water column. D -- 120-kJ sparker record showing reflector "pull-downs". E -- Boomer record showing reflector terminations and patchy acoustic response. F -- 12-kHz record showing a clear water column without bubble trains.

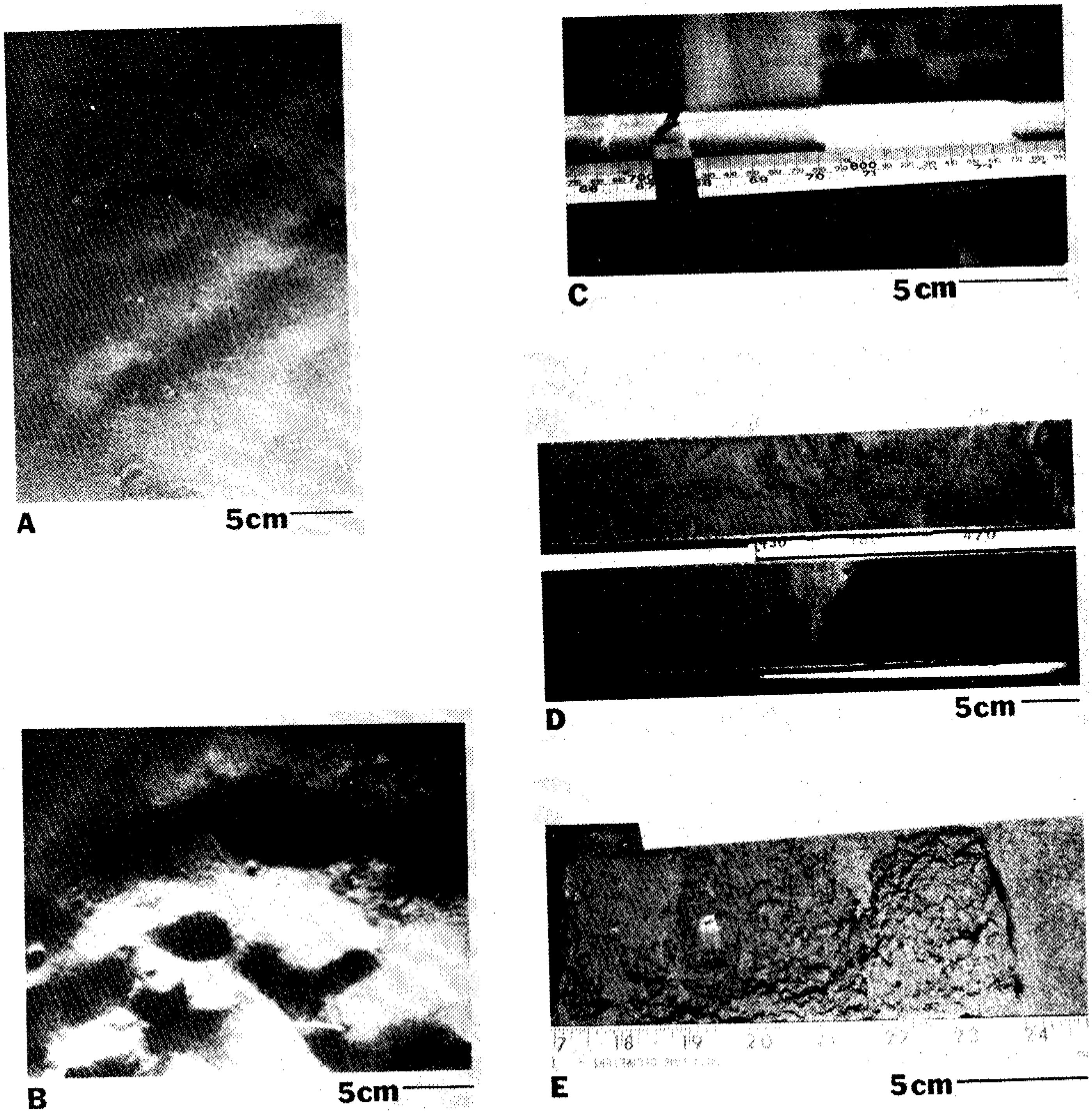


Figure C3. Gas escape features at Site 3. A -- Seafloor with a circular gas vent and active bubbling (arrows). B -- Rippled seafloor disrupted by circular gas vents. C -- Core in liner exhibiting gas expansion cracks on the left side and a large expansion pocket filled with gas that was sampled by syringe and vacutainer. D -- Internal sedimentary structures with gas streaming features in top core half. Core half at bottom is located stratigraphically above the other core and shows undisrupted peat layers that may trap some gas below. E -- Honeycomb of gas cavities in core half just below black peat layer (at left edge).

VI. RESULTS

D. MODERN BIOGENIC GAS-GENERATED CRATERS (SEAFLOOR "POCKMARKS") ON BERING SHELF, ALASKA

Hans Nelson, Devin R. Thor, and Mark W. Sandstrom

INTRODUCTION

We have observed widespread occurrences of small (1-10 m diameter) circular pits or craters in north-central Norton Sound of the Bering Sea epicontinental shelf; a few similar craters are also present near Port Clarence (Fig. 1). These features resemble so-called "pockmarks" observed on numerous other broad shelf areas (King and MacLean, 1970; Offshore Engineer, 1977; Platt, 1977). The origin of these sea-floor depressions has been ascribed to diverse processes such as permafrost melting, meteorite showers, and gas and fluid escape (Offshore Engineer, 1977).

We postulate that the craters in Bering Sea are formed by present-day venting of biogenic gas generated and trapped in buried peaty mud. This paper describes this new occurrence of craters or pockmarks and shows the geological, geophysical, geochemical, and geotechnical evidence in favor of our hypothesis.

Methods

This paper is based partly on analysis of 2,800 km of high-resolution profiles from Uniboom and 3.5 kHz systems and 2,200 km of side-scan sonar trackline collected onboard the R/V SEA SOUNDER during 1976 and 1977 (Fig. 1). The Uniboom system utilized four hull-mounted E.G. and G. transducer plates with a total power output of 1,200 joules. The Raytheon 3.5 kHz CESP II system used a hull-mounted transducer array consisting of 12 Tr-109A units. The 105 kHz E.G. and G. side-scan sonar sysem recorded at 50-m and 100-m sweeps (scales). The altitude of the transducer fish was maintained at approximately 10 percent of the scale being used.

Surface sediment samples were obtained with a 60-cm stainless steel box corer or a frame-supported Soutar Van Veen grab sampler that was free of hydrocarbon contamination. Subsurface samples were obtained with a 2 m Kiel vibracorer. Sediment subsamples were collected as soon as possible after the sampling device was brought on deck; the sediment was placed into 600-ml paint cans, and the cans were filled with distilled water to maintain a constant headspace of approximately 50 ml and then flushed with helium before sealing the can. Low-molecular-weight hydrocarbons (LMWHC) were determined by static headspace analysis of the canned samples using gas chromatography (Nelson and others, 1978). The cans were shaken, punctured, and 1-ml samples of the gas headspace were injected into the gas chromatograph. A Carle #311 Analytical Gas Chromatograph, equipped with a flame ionization detector, utilized a series of columns that allowed complete separation of C_1 through C_4 alkanes and alkenes. The chromatograph was calibrated with 1-ml samples of a gas standard.

Gas remaining in the can after shipboard gas analysis was collected in 20-ml vacutainers and stored for mass spectrometric analysis. Methane in the gas samples was purified from carbon dioxide and other hydrocarbons by passing it through a trap held at -180°C and collecting it on activated charcoal held at -180°C. The methane was quantitatively converted to carbon dioxide for mass spectrometric analysis by combustion in an oxygen atmosphere at 900°C using the method of Kaplan and others (1970).

Geologic Setting

Norton Sound is an elongate, east-west trending marine reentrant in northwestern Alaska, bounded on the north by the Seward Peninsula and on the southwest by the Yukon Delta (Fig. 1). The floor of the sound is nearly flat, lacking topographic irregularities except a broad, shallow trough in the northern part. Most of the sound is between 10 and 20 m deep (Fig. 2).

Sea-level lowering in late Pleistocene time caused Norton Sound to be subaerially exposed (Nelson and Hopkins, 1972). During this time, fluvial processes and tundra vegetation characterized the area (Hopkins, 1967) and peaty, organic-rich mud was deposited over much of the region (Fig. 2). This fluvial freshwater sediment contains 2.5 to 7 percent organic carbon as compared to the overlying marine sediment, which contains 0.5 to 1.0 percent organic carbon (Nelson, 1977). The carbon-14 ages of the uppermost part of the nonmarine sediment range from 10,120 to 16,400 years B.P. and confirm its pre-transgressive history and origin as non-marine deposition on an emergent landmass (Steve Robinson, written communication, 1978; USGS Radiocarbon dates W-2686, 155, 157, 159, 357 and 352).

The sea flooded most of Norton Sound, initiating marine sedimentation during the period between 12,000 and 9,000 years B.P. (Nelson and Creager, 1977). In Holocene time 0-10 meters of fine-grained sandy silt derived from the Yukon River has prograded over Norton Sound (McManus and others, 1977; Nelson and Creager, 1977). The Holocene marine sediment typically is less than 2 m thick in the region of the sea-floor craters (see cores 121, 126, 131 in Fig. 2; Nelson and Creager, 1977).

CRATER AREA CHARACTERISTICS

Crater Morphology and Distribution

Small circular pits occur on the seafloor over a large area of central and eastern Norton Sound (Fig. 3). These craters range from 1 to 10 m in diameter, average 2 m in diameter, and area probably less than half a meter deep because their relief is not evident on the horizon line of sonographs or 200-kHz fathograms (Fig. 4). Neither rims nor mounds around the craters have been observed on sonographs. Their absence also is characteristic of other pockmark occurrences (King and MacLean, 1970; Per Stokke, written communication, 1978). The cross-sectional shapes of the craters cannot be determined because of the lack of visible relief in the records. Most of the craters,however, probably are relatively shallow and flat floored. If they were funnel-shaped, geometry would dictate depths greater than 0.5 m, and such shapes should be evident on records. The fairly smooth, concave saucer shape of craters probably results because (1) after the crater forms the soft sediment flows from the sides toward the center, and (2) the constant oscillatory pounding of wave motion on the bottom induces shear failure in soft sediment (Henkel, 1970), thus causing crater sides to collapse toward the center of the crater.

Although we lack side-scan data in the central area of the crater field, crater density seems to decrease outward from two areas of greatest concentration in east-central Norton Sound (Fig. 3). Concentrations reach a maximum of 134 craters per kilometer of trackline or over 5,000 craters/km^2; typical concentrations, however, range from 200 to 1000 per km^2.

Geophysical Characteristics of Crater Areas

High-resolution seismic profiles in Norton Sound are characterized by parallel horizontal reflectors, commonly with acoustic anomalies except in the Yukon prodelta area (Figs. 1 and 4). The acoustic anomalies represent acoustically impenetrable near-surface zones in the sediment and occur as (1) total termination of subsurface reflectors with weak or absent multiples (Fig. 4), or (2) hyperbolic forms just below the surface, replacing normal reflectors, but with strong multiples. Anomalies range from sporadic features a few meters long to continuous features several kilometers long. Both types of anomalies occur throughout the Norton Sound area and in many cases are associated with specific locations of the small circular craters or pockmarks.

Two possible causes for the acoustic anomalies in Norton Sound are (1) sharp contrasts in sediment type or (2) presence of gas-charged, peaty Pleistocene mud. Gravel beds in buried channels may act as a multifaceted, dense reflector surface and thus create a hyperbolic anomaly (Nelson and others, 1978). Peat or gas-charged sediment may act as an acoustic sponge, absorbing all reflective energy because of the large density difference between gas-rich peat and sediment (Kepkay and

Barrett, 1977; Schubel and Schiemer, 1973; Keen and Piper, 1976). The extensive reflector-termination anomalies and occurence of peat with high gas content in east-central Norton Sound suggest that gas-charged sediment is a major cause of acoustic anomalies in sediment of the crater field area.

Organic Geochemical Characteristics of Crater Areas

Low-molecular-weight hydrocarbons (C_1-C_4) (LMWHC) are present in the sediment of Norton Sound (Table 1). These hydrocarbons may be generated from microbial degradation (biogenic gas) of organic material or from thermocatalytic alteration (thermogenic gas) of organic material. Biogenic gas is usually characterized by $C_1/C_2 + C_3$ ratios greater than 50, C_1/ C_1-C_4 ratios greater than 0.99, and ^{13}C values lighter than -50 $^{o}/oo$ (Bernard and others, 1976; Stahl, 1974). Thermogenic gas usually has $C_1/C_2 + C_3$ ratios less than 50, C_1/ C_1-C_4 ratios less than 0.95, and ^{13}C values heavier than $-50^{o}/oo$ (Bernard and others, 1976).

Gas chromatographic analysis of the LMWHC in Norton Sound sediment shows the gas is predominantly methane (>99%) with small amounts of ethane, ethylene, propane, propylene, and iso- and n-butane (Table 1). The $C_1/C_2 + C_3$ and C_1/ C_1-C_4 ratios (>1000 and >0.99, respectively) and ^{13}C values (-69 to $-75^{o}/oo$) for the gases in these sediments substantiates that the LMWHC are generated by biogenic processes. High concentration of organic carbon in the peaty mud (3-7 percent) suggests that abundant organic material is present for microbial anaerobic decomposition and methane production to occur.

The chemical composition and ^{13}C values of the LMWHC (Table 1) in these sediments rule out the possibility that high methane concentration in the sediment is related to the thermogenic gas seep in western Norton Sound reported by Cline and Holmes (1977) and Nelson and others (1978). Cline (1976) detected relatively high C_2 and C_3 concentrations in the water column, yet no methane anomalies were detected in bottom waters or the gas seep area of central Norton Sound.

Methane content in surface sediment and bottom water is not anomalous (Fig. 5); subsurface values, however, increase by several orders of magnitude in Pleistocene peaty mud in the crater area (see core locations 121, 125, 131 in Figs. 2 and 3). In samples at the base of the vibracores in the crater area, measured methane content was very close to saturation or bubble phase as calculated by the method of Yamamoto and others (1976). Both Holocene marine and Pleistocene freshwater sediment contain much less methane in non-crater areas (see cores 137 and 15 in Figs. 2 and 3).

The variation in organic carbon content correlates with methane content and may predict the presence of high methane concentration in the Port Clarence crater area where methane measurements are not available. In contrast, organic carbon content is significantly lower in Pleistocene freshwater mud in areas where no craters are found, yet the basic stratigraphy is similar to that of other crater areas (see 15 in Fig. 2; Nelson, unpublished data).

RELATIONSHIP OF CRATERS TO SEA-FLOOR GEOLOGY, GEOPHYSICS AND GEOCHEMISTRY

The craters in the northern Bering Sea are very recent features as shown by their presence within modern ice-gouge grooves and by the fact that relict, buried craters have not been observed in seismic profiles (Fig. 4). Bering shelf craters are found only in areas with a thin (1-3 m) cover of Holocene fine-grained mud, generally Yukon silt (McManus and others, 1977). Where the mud is thicker, craters and acoustic anomalies are absent. No craters have been found on the Chirikov Basin seafloor, which is covered by transgressive gravel and fine sand (Nelson and Hopkins, 1972; McManus and others, 1977). However, mud-covered swales between sand ridges off Port Clarence do contain craters (Fig. 2).

The areas of sea-floor craters occur where the near-surface peaty mud is rich in organic carbon (greater than 3 percent) and consequently, contains a high quantity of methane. The methane content is saturated or in bubble phase at many places in the peaty mud of Norton Sound and thus causes absorptive acoustic anomalies (Schubel and Schiemer, 1973). The lack of anomalies under some crater areas may be due to the loss of gas in subsurface sediment through recent outgassing. Failure to measure methane saturation in crater areas probably is best explained by loss of gas and pore water during coring and sample processing of short vibracores without core liners. [1]Methane saturation was measured in 1978 sediment from samples enclosed in core liners. Samples in which methane content close to saturation were measured had been vibrated out of the sea floor and then split. This procedure exposed them to atmospheric conditions before analysis, and considerable gas could have escaped. The high methane content remaining at the time of analysis suggests that the <u>in situ</u> sediment was saturated with methane, and the high methane content could cause the observed acoustic anomalies. Because measurements of both organic carbon and methane vary

[1] Methane saturation was measured in 1978 sediment from vibracore samples enclosed in core liners.

stratigraphically down section and from place to place, it is likely that *in situ* variation of organic carbon and bacterial methane production may in part explain the sporadic occurrence of acoustic anomalies (Reeburgh and Heggie, 1977).

CRATER GENESIS

All evidence from research elsewhere (Claypool and Kaplan, 1974; Reeburg and Heggie, 1977) indicates that high methane concentration in the area studied can result from microbial decomposition of organic detritus in the subsurface Pleistocene peaty mud. Martens and Berner(1977) and Martens (1976) have noted that methane concentration sometimes reaches the saturation point, charging the sediment with gas. The observed subsurface stratigraphic relations, geochemical characteristics, and measured geochemical properties of peaty mud all point to gas venting as the cause of the small surface craters in Norton Sound. Increased organic content in sediment normally increases water content and compressibility while decreasing shear strength and density (Whelan and others, 1976). This effect can be demonstrated in peaty mud of Norton Sound because the normal downward increase in shear strength and decrease in water content do not occur in peat zones (Clukey and others, 1978). These characteristics, together with the high compressibillity of peaty mud, increase the chance of gas venting.

Two basic mechanisms for gas venting can be proposed. The first is that continuous piping or local degassing may maintain craters as continually active gas vents on the seafloor. The second and favored hypothesis proposes that gas is intermittently vented, particularly under severe storm conditions. In the first case, generally continuous bubbling should be apparent but has never been observed on any seismic and "bubble detector" profiles. Also, with more or less continuous degassing, the entire sediment section should generally be underconsolidated, and it is not (Clukey and others, 1978). Instead, sediment typically is overconsolidated, as might be expected from intermittent rapid sediment degassing, collapse, and densification. Continual degassing should allow the continuous reworking of sediment to form a crater with a deep funnel-shaped cross section; like those observed at the active seep site in Norton Sound (Nelson and others, 1978). Continuous sediment disruption by bubbling should result in elliptical crater shapes (King, Mclean and others) elongated parallel to the strong east to west directed storm-tide currents of Norton Sound (Cacchione and Drake). Round shapes, however, prevail in Norton Sound. Also, continual venting over the large area of Norton Sound should enrich surface sediment and near-bottom water in methane, but methane is not enriched (see surface samples in Fig. 5; Cline, 1976).

In contrast to the aforementioned hypothesis, the extremely low content of gas in overlying Holocene marine sediment compared to that in the Pleistocene mud (Fig. 5) suggests that gas diffusion to the surface is slow, even though the sediment is only a few tens of centimeters thick. This contrast indicates that gas generated in peaty mud will build up with time and be trapped relatively close to the surface, particularly throughout northern Norton Sound where pre-transgressive peaty mud is only thinly buried by Holocene mud. When this gas-enriched, compressible sediment comes under increased stress from rapidly fluctuating storm wave pressures, it is likely that gas venting, sediment collapse, and surface crater formation will occur.

The presence of the craters and high quantities of methane trapped beneath marine mud in Norton Sound suggest that gas venting is episodic rather than by slow diffuson to the surface; diffusion may take place in the noncohesive sediment of Chirikov Basin. Episodic gas venting on this extremely shallow shelf is most likely associated with the storms of this regon. Significant sea-level set-up is common in Norton Sound (Fathauer, 1975), and the movement of immense amounts of water into the region should affect bottom-sediment pore pressures. The associated storm waves can cause rapid fluctuation in wave loading and affect the seafloor stability. Storm waves also resuspend sediment and may cause sediment unloading over extensive areas (Nelson and Creager, 1977).

The absence of acoustic anomalies and craters in the Yukon prodelta area suggests that gas saturation is at a delicate equilibrium state in subsurface sediment in the crater area. Greater sediment loading and thickness of the Holocene delta wedge over the Pleistocene sediment in the prodelta area may prevent subsurface dissolved gas from reaching bubble phase or venting to the surface, whereas storm wave loading over thin Holocene sediment in the crater area may trigger gas releases from Pleistocene sediment.

GEOLOGIC SIGNIFICANCE

Characteristics of craters or pockmarks in the northern Bering Sea agree with basic observations of these features on other shelves (King and MacLean, 1970; Offshore Engineer, 1977; Platt, 1977; Josenhaus and others, 1978). The Bering Sea craters are found in the finest textured surface sediment in the region which indicates that a sealing surface unit with fine-grained texture is required to facilitate crater formation. The Bering shelf has the greatest number of craters per unit area and smallest craters described to date compared to other cratered shelves (Offshore Engineer, 1977). Since Holocene sediment of the Bering shelf is the thinnest of any crater area observed at present, observations there correlate with other findings that the thicker the surface unit is, the larger and fewer are the craters (Josenhaus and others, 1978). On the Scotian and North Sea continental shelves, crater formation is thought to be inactive because crater patterns and lineation appear to be related to deeper structure and because numerous buried relict pockmarks are found. In contrast, the Bering shelf is an example of an active system with no apparent correlation to subsurface structure, only to lithology and present-day biogenic methane formation.

Widespread deposition of organic-rich paralic sediment during the Pleistocene history of regression, emergence, and transgression over epicontinental shelf areas suggests that this dynamic process of gas cratering should be a worldwide phenomenon, particularly where thin deposits of Holocene mud may form a seal over gas-generating paralic sediment. Ancient analogs, perhaps indicated by vertical escape structures and filled craters, should be searched for in the extensive stratigraphic record of past epicontinental sea deposits.

ACKNOWLEDGMENTS

We thank Keith Kvenvolden and John Rapp for providing additional geochemical analyses and helpful discussion of chemical analytical results. We greatly appreciate the help of Steven Robinson for carbon-14 dating of freshwater peat samples and Dave Winter for mass spectrometer analysis. We also thank Per Stokke for sharing his thoughts and some unpublished data on cratering in other parts of the world, Mark Holmes for his help in interpreting seismic records, and Ian Kaplan for informative discussions on marine gas. Dwight Sangrey and Edward Clukey provided beneficial discussion on geotechnical characteristics of gas-charged sediment. Mathew Larsen assisted with preparaton of figures. We commend the officers, crew, and scientific staff of R/V SEA SOUNDER for excellent cooperation and assistance in collection of data at sea.

The cruises were supported jointly by the U.S. Geological Survey and by the Bureau of Land Management through interagency agreement with the National Oceanic and Atmospheric Administration, under which a multiyear program responding to needs of petroleum development of the Alaska continental shelf is managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office.

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Sample	Depth (cm)	CH_4 (μmol/g dry sediment)	$CH_4/C_2H_6+C_3H_8$	$CH_4/\Sigma\ CH_4 - C_4H_{10}$	$\delta^{13}C_{PDB}$ (a) (parts per thousand)
121 VIBR	10-20	0.67	49	0.974	n.d. (b)
	60-70	5.91	256	0.995	n.d. (b)
	170-180	201.97	6536	0.999	-72.16‰
125 VIBR	72-80	38.07	3626	0.999	n.d. (b)
	148-150	149.91	n.d.	n.d.	-68.94‰
131 VIBR	70-75	4.19	873	0.998	n.d. (b)
	160-165	173.31	7669	0.999	-75.01‰

(a) measured relative to PDB standard (Craig, 1953)

(b) n.d. = not determined. Insufficient gas available for isotopic measurement.

Table D-1. Hydrocarbon gas content and carbon isotope ratios of vibracore samples taken in the gas crater area of north-central Norton Sound.

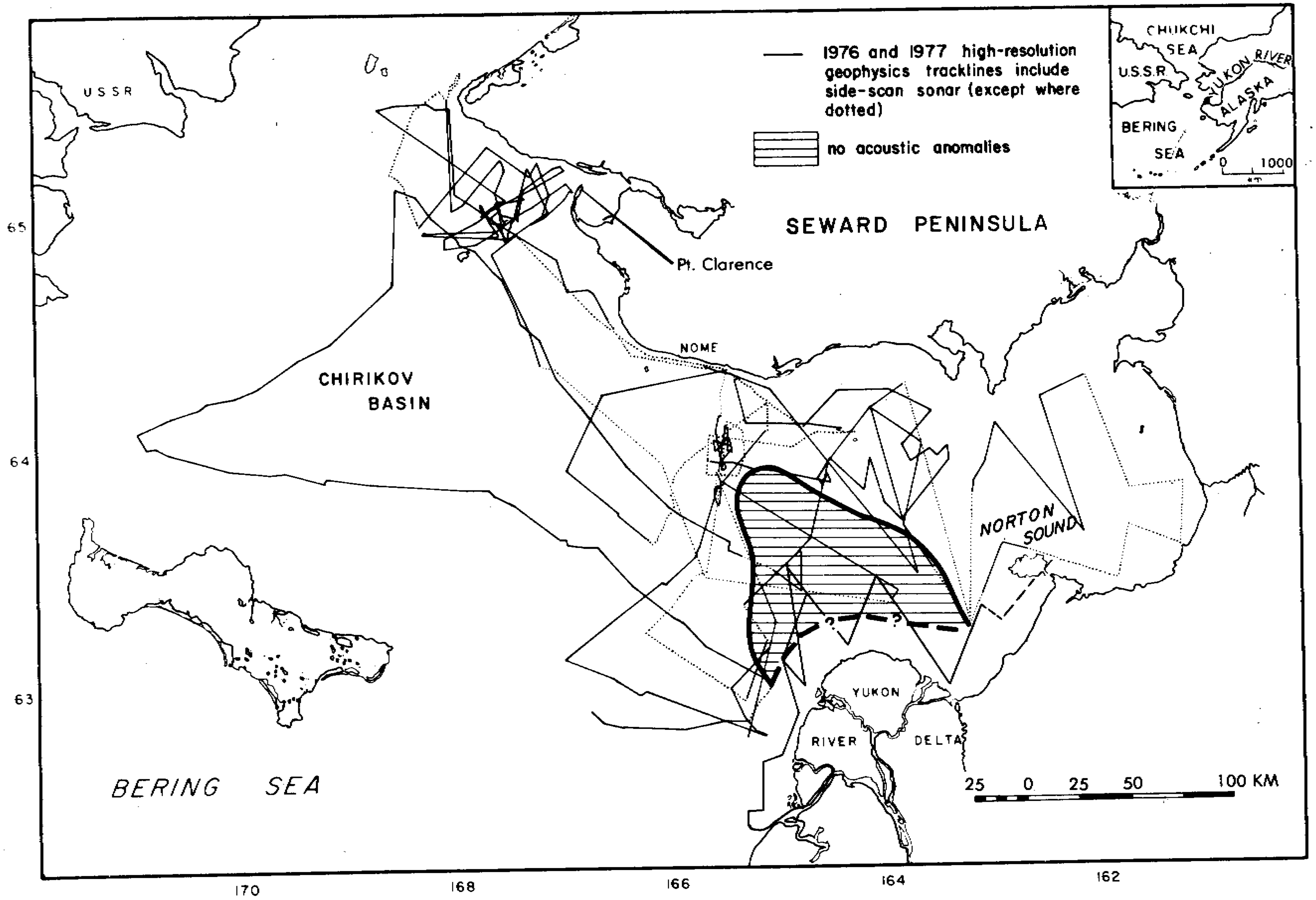

Figure D-1 Index map showing 1976 and 1977 high-resolution seismic profile tracklines and the area without acoustic anomalies.

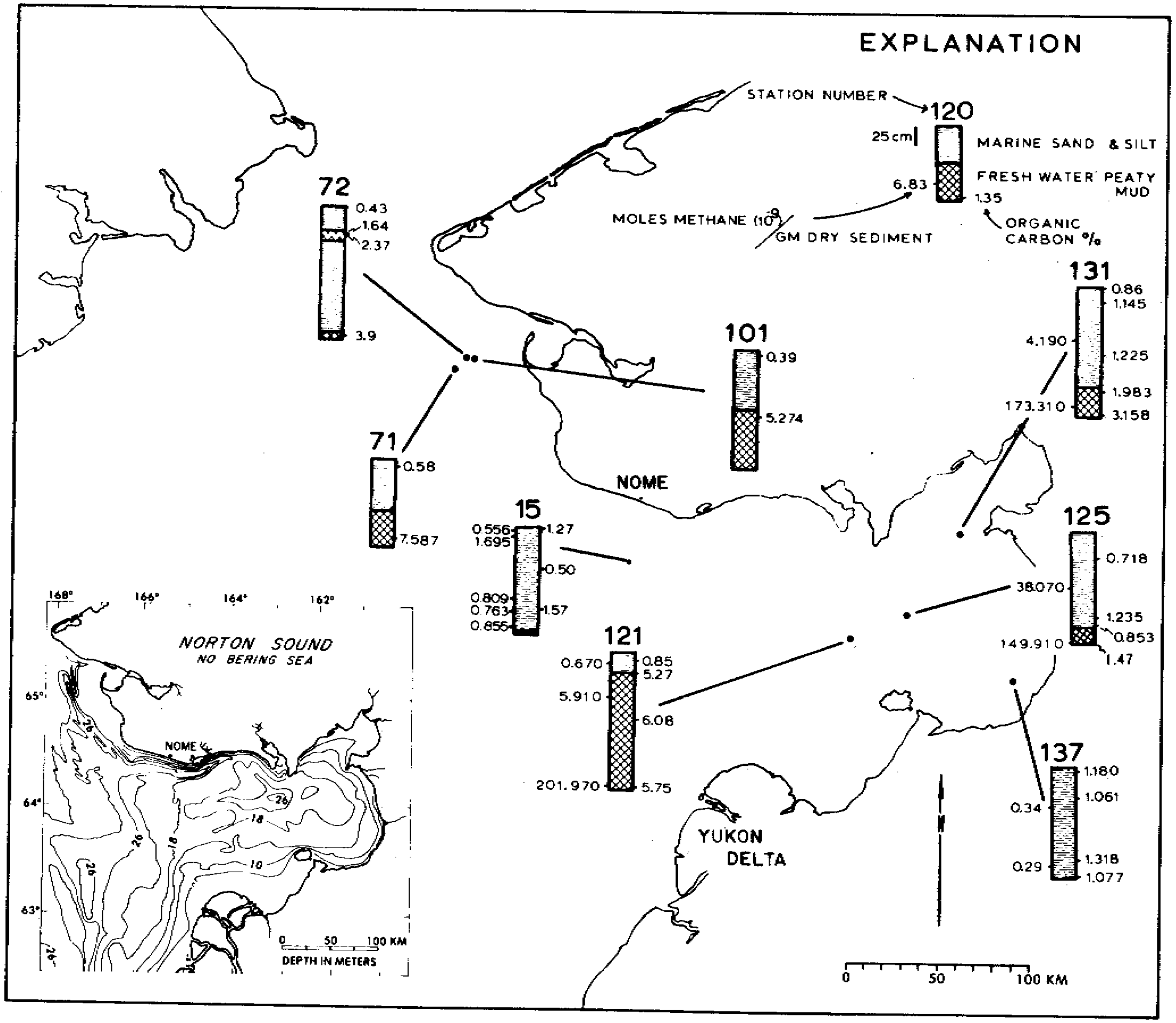

Figure D-2 Presently known locations of freshwater peaty mud in northeastern Bering Sea and comparison of organic carbon content and methane content with normal marine sediment overlying these pre-transgressive deposits.

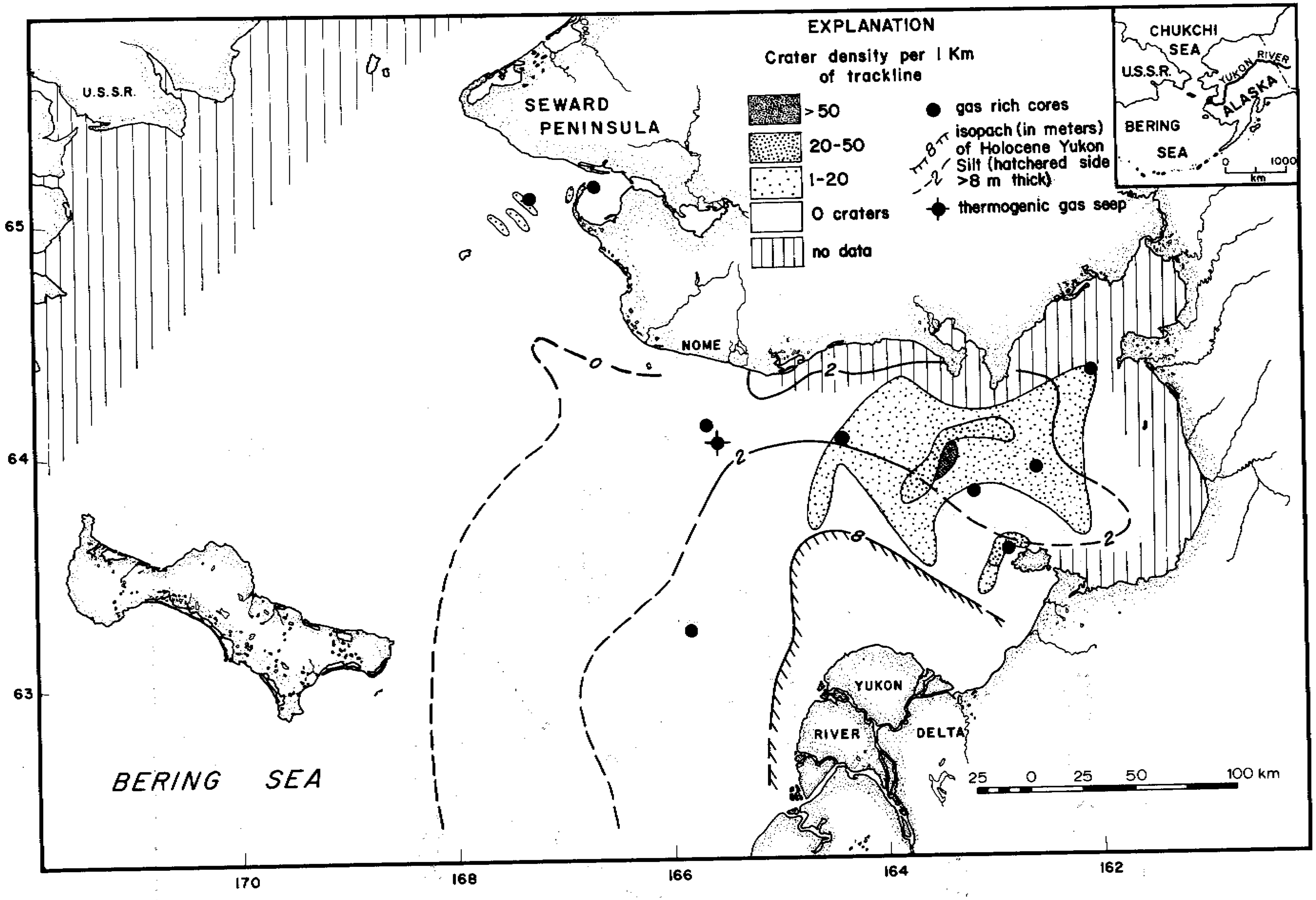

Figure D-3 Distribution and density of craters on the seafloor of Norton Sound. Circles show locations of Figure 2 cores 121, 125, and 131 that contain gas-rich sediment.

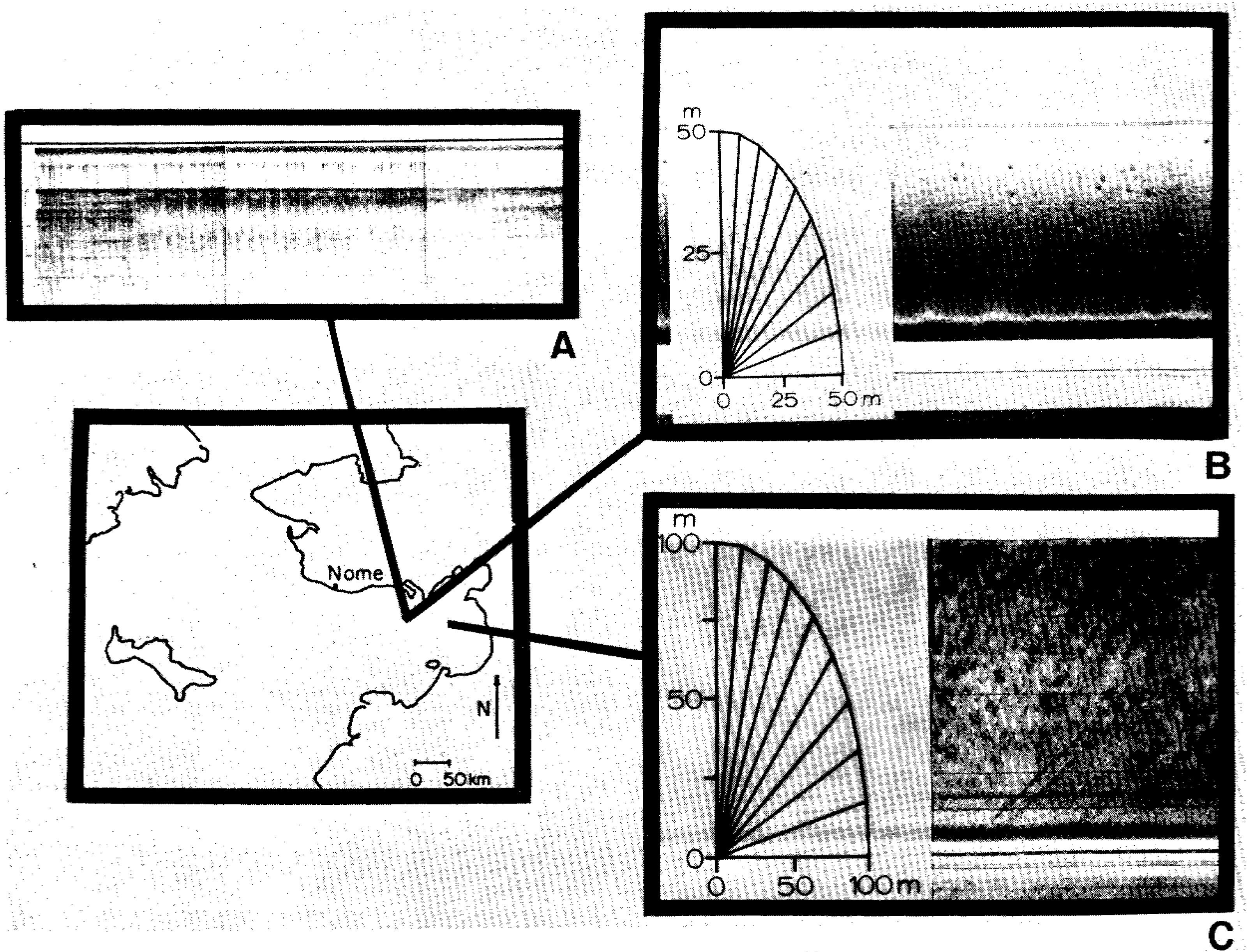

Figure D-4 A - Characteristic acoustic anomaly on Uniboom profile.
B - characteristic craters on sonograph associated with acoustic anomalies, as shown in "A".
C - craters formed within an ice gouge.

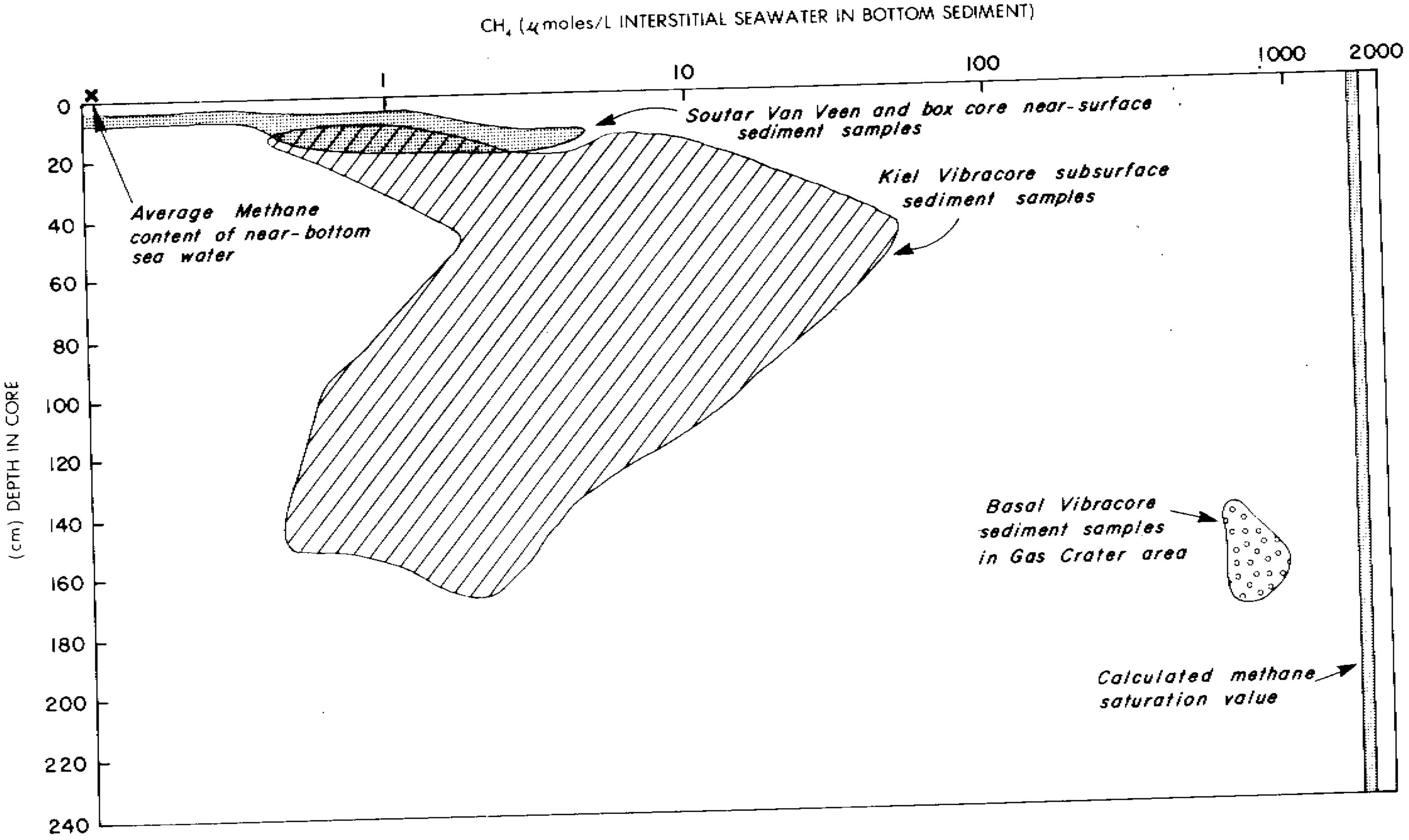

Figure D-5 Characteristic CH_4 content of sediment samples in Norton Basin. Average methane content in near-bottom water from Cline, 1976; calculation of saturation after Yamamoto et al., 1976.

VI. RESULTS

E. GEOLOGIC IMPLICATIONS AND POTENTIAL HAZARDS OF SCOUR DEPRESSIONS ON BERING SHELF, ALASKA

Matthew C. Larsen, Hans Nelson, and Devin R. Thor

Introduction

Broad (50-150 m) shallow (less than 1 m deep) depressions have been observed on sonographs from western Norton Sound. The large depressions described in this paper may result from active sediment scour by strong near-bottom currents, and appear to be the first reported natural occurrence of features generated by Seaflume experiments in similar marine muds (Young and Southard, 1978). These features have much greater diameter, more irregular shape, and flatter bottoms than the small, (3-10 m) more conical craters observed in eastern Norton Sound (Nelson, Thor, and Sandstrom, 1978). The small conical craters are associated with seismic acoustic anomalies and high biogenic methane concentrations. They are caused by gas venting at the sea floor (King and McLean, 1970; Garrison, 1974; Nelson, Thor and Sandstrom, 1978).

Current scour of large depressions and association with intense ice gouging (Thor and others, 1978) may be a hazard to the development of petroleum facilities (Palmer, 1969; Posey, 1971; Demars and others, 1977; Herbich, 1977) in the Norton Sound area. Such potential geologic hazards are of concern because Norton Sound is favored for future resource development (Nelson, Kvenvolden, and Clukey, 1978).

Substrate reconnaissance employing high-resolution profiling, side-scan sonar reflection, bottom photography, underwater television, sediment-grain-size analysis, and examination of current dynamics has been undertaken to determine if large depressions represent areas of intense scour by currents. This paper describes depressions and their correlation with occurrence of strong currents, ice gouge furrows, major topographic shoals, and very fine sand to coarse silt substrate.

Methods

A total of 4400 km of trackline of E.G. & G. side scan sonar was collected at a 100 m sweep during the 1976, 1977, and 1978 field seasons in Norton Sound. High resolution profiling records were collected simultaneously (Thor and others, 1978). Occurrence, extent, and morphology of probable scour depressions were mapped from the sonographs (Fig. 1).

One hundred and fifty sediment samples from Norton Sound were analyzed using rapid settling tubes for the 2 mm to 0.063 mm size fraction and a hydrophotometer for the 0.044 mm to 0.004 mm range (Jordan and others, 1971; Nelson, T.A., 1976). Coarse fractions, greater than 2 mm, were dry-sieved and weighed.

Current observations (within 1 to 5 m of the bottom) were compiled from previous studies in Norton Sound (Goodman and others, 1942; Fleming and Heggarty, 1966; Husby, 1969, 1971; McManus and Smyth, 1970; McManus and others, 1974; Coachman, Aagaard and Trip, 1976; Nelson and Creager, 1977; Cacchione and Drake, 1978a) and from our own measurements at 50 current meter stations in this area in 1976 and 1977 (Fig. 1 A). Since the measurements compiled are temporally unrelated, results for current speeds are fairly uniform, but current-direction data are conflicting. A map showing mean current speeds greater than 20 cm/sec was compiled for Norton Sound (Fig. 2); these data are not presented for Chirikov Basin, where no scour features have been found.

At each of 30 stations in Norton Sound, approximately 30 minutes of underwater television scanning was videotaped and 20 bottom photographs taken with a 70 mm format black and white still camera. Large-scale features such as scour depressions could not be seen on videotape or photographs owing to the limited field of view (40 cm diameter). In addition, turbidity in the water column was a particular problem in the south-central part of Norton Sound in areas near the Yukon Delta. The technique of scanning the substrate with underwater television proved to be effective in examining small-scale bottom features such as animal burrows, sediment characteristics, and ripple bedforms. A compass with a vane marked out in centimeters was suspended in the field of view of the TV camera. Using this as a measuring device, it was possible to determine ripple wavelength and height.

Morphology of Depressions

Zones of depressions occur in two principal areas of Norton Sound. The most extensive area is west of the Yukon prodelta, where ice gouging is commonly associated with shallow depressions (Thor and others, 1978). The second zone is 50 km southeast of Nome on the western flank of a broad shallow trough where water depth is greater than 20 m (Fig. 1). Isolated scour also occurs 10 km west of Stuart Island where sedimentary structures suggest frequent strong currents (Nelson and Creager, 1977).

Scour features range from individual, more or less elliptical depressions, 10 to 30 m in diameter, to large areas of scour with irregular margins, 80 to 150 m in diameter (Fig. 3). Most depressions observed appear to have very sharp margins with a broad flat bottom between steep walls. Some locations of observed scour are so extensive that only one margin is visible as a long sinuous scarp.

Sonographs over areas with depressions southeast of Nome are of sufficient quality that relief can be measured on the horizon line of the sonograph (Fig. 4). Scour in this location is 60 to 80 cm deep. Since side-scan reflectors at this location are of the same order of magnitude as scour features at other observed locations, 60 to 80 cm may be a common scour depth of these depressions in Norton Sound.

Current Regimes and Bottom Character

Regional current direction in the northeastern Bering Sea is to the north at a mean velocity of 20 to 25 cm/sec (Coachman and others, 1976). Current speed slows down as water moves through Norton Sound in a counterclockwise gyre. Tidal movement of water in Norton Sound is east-west (Cacchione and Drake 1978a). The highest non-storm velocities, 30 cm/sec, have been measured during spring tidal cycles (Cacchione and Drake, 1978a) in 80 days of continuous measurement taken within 1 m of the bottom by the GEOPROBE instrument (Cacchione and Drake, 1978b) (see Fig. 2 for location). The maximum current speed measured was 70 cm/sec, recorded during an autumn storm of 2 to 3 days duration (Cacchione and Drake, 1978a). Storm-wave components contributed a major part of maximum current speeds observed at this time.

Normal bottom-current speeds under non-storm conditions are between 5 and 10 cm/sec in eastern Norton Sound. Current speeds increase toward the center of the sound and are greatest at the west end. Bottom-current speeds in scour areas on the Yukon prodelta and in the trough area southeast of Nome (Fig. 2) range from 10 to 35 cm/sec during non-storm conditions. The mean bottom-current speed in both scour areas is about 20 cm/sec (Fig. 2).

Well-developed ripples occur in both major scour areas. Ripples in scour areas on the prodelta and south of Nome are asymmetric; wavelength is 10 to 15 cm, height, 3 to 5 cm. Photographs in non-scour areas reveal only a flat fine-grained substrate with no visible bedforms.

Sediment grain size in Norton Sound ranges from very fine sand to fine silt (Fig. 5). The mean size over the central area containing most depressions is relatively homogeneous and ranges from very fine sand to coarse silt. Sediment in the southwestern area of depressions in Norton Sound is finer grained and is derived entirely from the Yukon River (McManus and others, 1974, 1977). Prodelta sediment is 25 to 50 percent sand, 40 to 70 percent silt, and less than 20 percent clay (Clukey and others, 1978); mean grain size is 0.044 mm (4.5 phi). Sediment in the trough southeast of Nome is typified by coarser grain size. Sediment from Seward Peninsula sources is 65 to 78 percent sand, 20 to 30 percent silt, and less than 8 percent clay. Mean grain size, 0.058 mm (4.2 phi), is slightly coarser than for southwestern prodelta sediment. Sediment near the delta shoreline and in Chirikov Basin, gravel to fine sand, is much coarser grained than that found in scour areas of Norton Sound. Fine silt of easternmost Norton Sound contains no areas of scour depressions.

Depressions in northern Norton Sound are on a slope at the edge of a shallow east-west-trending trough (Fig. 1). Ebbing tidal currents may be concentrated on the western face of the trough, owing to east-west motion of tidal-water masses; strong currents generated by receding water of storm-surge set up in Norton Sound (Fathauer, 1975; Nelson and

Creager, 1977) may focus on the northwestern face of the trough. On both of these topographic slopes, small-scale ripple forms indicate stronger current speeds compared to areas of Norton Sound where ripples are absent.

Sediment liquefaction and failure may occur on slopes such as these and consequent development of scarps may trigger flow separation and formation of depressions. One scarp has been observed in association with a depression in this area (see Fig. 3A); no other features related to sediment failure such as downslope bulges are apparent. The depressions here have a steep vertical face around their entire margins.

Depressions on the west edge of the Yukon prodelta are on a gradual slope of less than 0.5° (Fig. 1). Although sediment failure may occur in this area, the predominance of ice gouging makes it difficult to judge the role of sediment failure in forming or initiating depressions; most depressions appear as completely enclosed features and are associated with outgrowths of original ice gouge furrows (Fig. 3).

The west-facing slope of the prodelta can focus wave energy and projects into Sphanberg Strait. Here it is exposed to north-trending currents that are intensified on the right side of the strait, apparently because of the Coriolis Force (Coachman, Aagaard, and Trip, 1976). These intensified currents have sheared against the western part of the prodelta, limiting progradation; a steeper offshore gradient has developed there than on other parts of the prodelta.

Ice gouges commonly expand into large shallow depressions in the western area of the Yukon prodelta, where strong bottom-current shear occurs. More than half of the depressions observed in sonographs taken in Norton Sound are associated with ice gouging. Gouge-furrow width ranges from 5 to 60 m; gouge width of 15 to 25 m predominates (Thor and others, 1978). Gouge depth to 1 m has been observed but 0.25-0.50 m is the average. Most gouging in the northern Bering Sea occurs in water depths of 10-20 m. The highest concentration of ice-gouge furrows is north and west of the Yukon delta, where there are 5.5 per km of trackline. Northwestern Norton Sound has a lower concentration of gouge furrows, 0.5 per km of trackline.

Genesis of depressions

Depressions are associated with a substrate of specific grain size, strong bottom current regimes, local morphologic obstructions, and topographic shoals. Flume experiments in fine sand and silt have shown that currents flowing over an obstruction will erode material immediately behind the obstruction (Southard and Dingler, 1971; Southard, 1977; Young and Southard, 1978). As with development of bedforms in fine sand, disruption of a flat sandy-silt bottom by gouging apparently provides a similar mechanism for initiating downstream scour. Once the irregularities in the substrate and the current speeds of storm conditions develop, flow may separate over the disruption; the resulting eddy can erode sediment to a certain depth and distance downstream (Young and Southard, 1978). Small-scale ripples are the only bedforms that have been observed to form in the grain size ranges (3.5-5 phi, 0.088-0.031 mm) that are present in much of Norton Sound (Harms and others, 1975; Middleton and Southard, 1977). The large scour depressions we observe may be a characteristic erosional bedform response developed during storms when strong current and wave energy is focused on silt-covered slopes with local topographic obstructions.

In Chirikov Basin, where generally stronger current regimes and coarser grain size exist (0.50 mm to 0.088 mm, 1 to 3.5 phi), the bedform response on the sea floor is characterized by fields of large-scale sand waves and sand lineations (Nelson, 1977a; Nelson and others, 1977; Field and others, 1977). The only similar scour described for sandy areas is in the form of regularly-shaped comet marks scoured downstream from solitary boulders that disrupt current flow (Werner and Newton, 1975).

Depressions in Norton Sound all occur in areas covered by Holocene silt (McManus and others, 1974, 1977), but the grain size, 0.044 mm to 0.063 mm (4.0 to 4.5 phi), is slightly coarser in depression areas than in the central or eastern regions of Norton Sound where grain size ranges from 0.044 mm to 0.031 mm (4.5 to 5 phi) (Fig. 5). This again shows that areas containing depressions are associated with locations of strongest current regime in Norton Sound (Fig. 2). It also points out that potentially more cohesive, finer grained silt in eastern Norton Sound is not associated with scour depressions.

Evidence at the GEOPROBE site, just west of the northern set of depressions in similar silt-size sediment (Fig. 2), shows that critical shear velocities are seldom exceeded under the normal current regime of the region (Cacchione and Drake, 1978a). During storms, current velocities are doubled and large amounts of suspended sediment are detected by the GEOPROBE transmissometer and nephelometer. Since the GEOPROBE site is apparently representative of the general oceanographic conditions in western Norton Sound, we infer that storm conditions provide an adequate mechanism for intense scour of Yukon silt deposits and formation of large-scale scour depressions.

The GEOPROBE site differs from areas of scour in regional topography and incidence of ice gouging. It is located in a broad flat area of the Norton Sound floor where no shoals or troughs constrict movements of bottom currents. Occurrence of ice-gouge furrows in this area is low to moderate (Thor and others, 1978), thereby reducing the possibility of scour initiation by localized obstruction.

The broad, flat-bottomed steep-walled nature of scour depressions suggests a temporary base-level control to erosion. In north-central Norton Sound, erosion occurs through a thin (0.2-1 m) coarse marine silt apparently down to underlying more cohesive Pleistocene fresh-water peaty mud that may provide a flat-floor resistant to erosion (Nelson and Creager, 1977; Clukey and others, 1978). In prodelta scour areas, this Pleistocene mud is buried by as much as 8 to 10 m of Holocene silt (Nelson and Creager, 1977) containing intercalated storm-sand layers that thicken toward the shore of the modern Yukon subdelta (Nelson, 1977b). In a scour depression, upper sand layers may be completely eroded to an underlying depositional surface of more cohesive silt that could form a temporary base level, and the depth of this base level could determine the flat-floored depth of scour in these depressions.

Potential Geologic Hazards in Scour Areas

Synergistic effects of strong bottom currents from storms and ice gouging that trigger scouring of large depressions in Yukon silt suggest that a potential geologic hazard may exist for offshore development of pipelines and gravity structures in Norton Sound. Current scour is a known problem along routes of subsea pipelines because it can expose and leave lengths of pipeline unsupported (Demars and others, 1977). Extensive undermining of pipelines poses serious risks of stress and structural damage.

Gravity structures are used in shallow-water areas of well-consolidated undersea sediments such as occur in Norton Sound and the North Sea (Gerwick, 1976). Gravity structures are stable by virtue of their large mass and broad base (approximately 20 m in diameter), which gives them a low center of gravity. Problems in gravity-structure stability arise from differential settling of sediment at the base that can be initiated by compaction of poorly consolidated substrate material, or loss of substrate support by current scour (Wilson and Able, 1973; Palmer, 1976).

Two types of current-scour, initiated by an artificial obstruction on the sea floor, have been documented by Posey (1971) to occur around the base of a drilling platform offshore of Padre Island, Texas. One type, called the "bridge pier" type, is a cone-shaped hole localized in the sea bed around individual piers of the structure. The second type, more extensive, is similar in dimension to Norton Sound scour depressions; it appears as a broad (50 m) shallow (2-3 m) depression eroding in a matter of minutes to hours under the entire platform base.

Because disruption of natural flow of storm-derived currents over Yukon sediment seems to set off widespread intense scour, it is apparent that, in the areas of scour depressions delineated to this time (Fig. 2), any artificial structure on the sea floor may trigger the same type of large-scale scour around the disrupting structure (Palmer, 1970; Posey, 1971).

Acknowledgments

Discussions with John Southard and David Cacchione greatly aided our interpretaton of scour features. David Cacchione and David Drake very generously provided information on current measurements from Norton Sound. We thank Ron Williams for assistance with analyzing sonographs, Lee Bailey for help with drafting, and Helen Ogle for typing the manuscript. Paul Carlson, Harry Cook, and David Rubin provided beneficial comments.

The cruises were supported jointly by the U.S. Geological Survey and the Bureau of Land Management through interagency agreement with the National Oceanic and Atmospheric Administration, under which a multiyear program responding to needs of petroleum development of the Alaska continental shelf is managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office. Any use of trade names or trademarks in this publication is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

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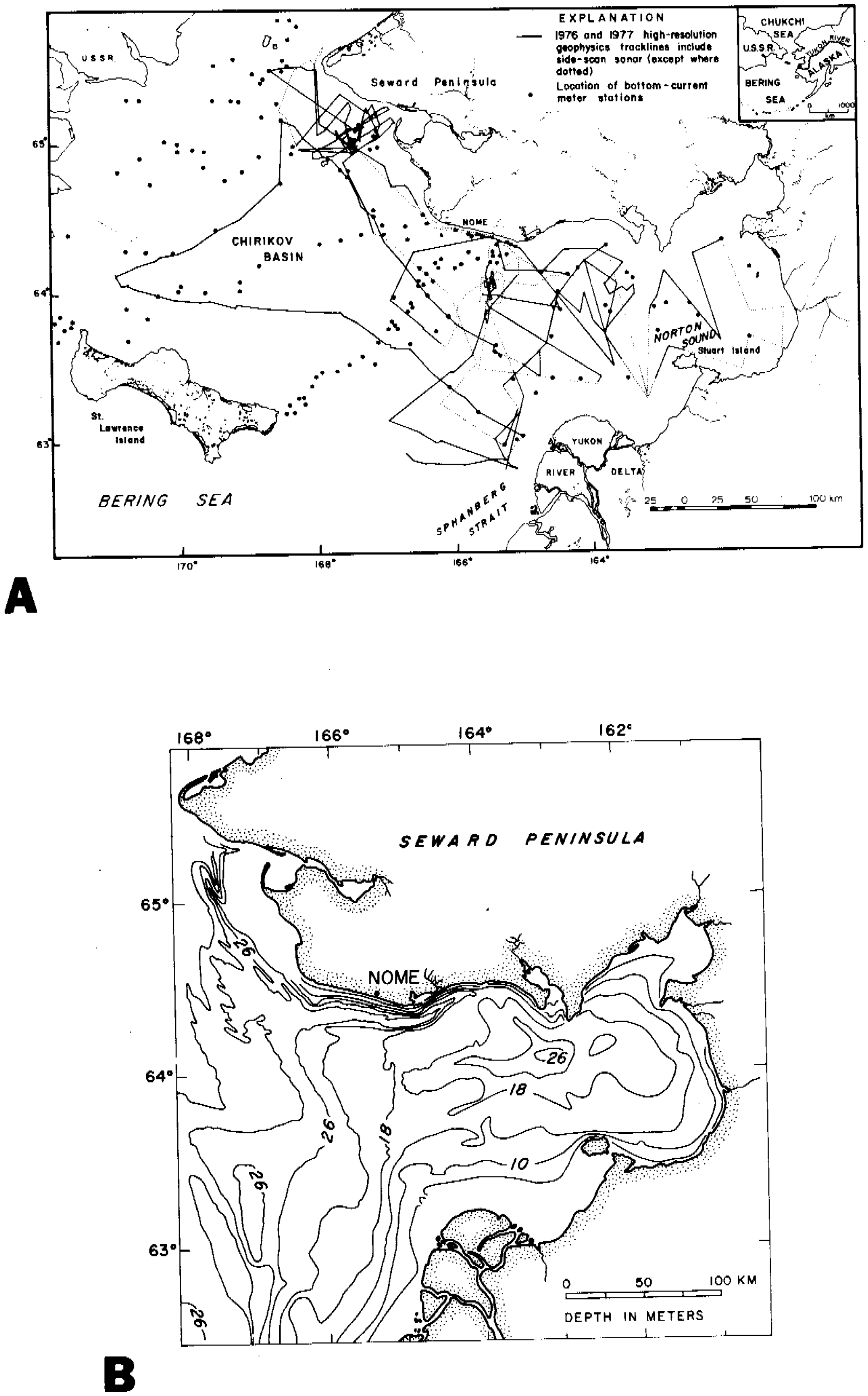

Figure E-1 A. Location of high-resolution geophysical and side-scan sonar tracklines.
B. Northern Bering Sea bathymetry in 4 m contour intervals

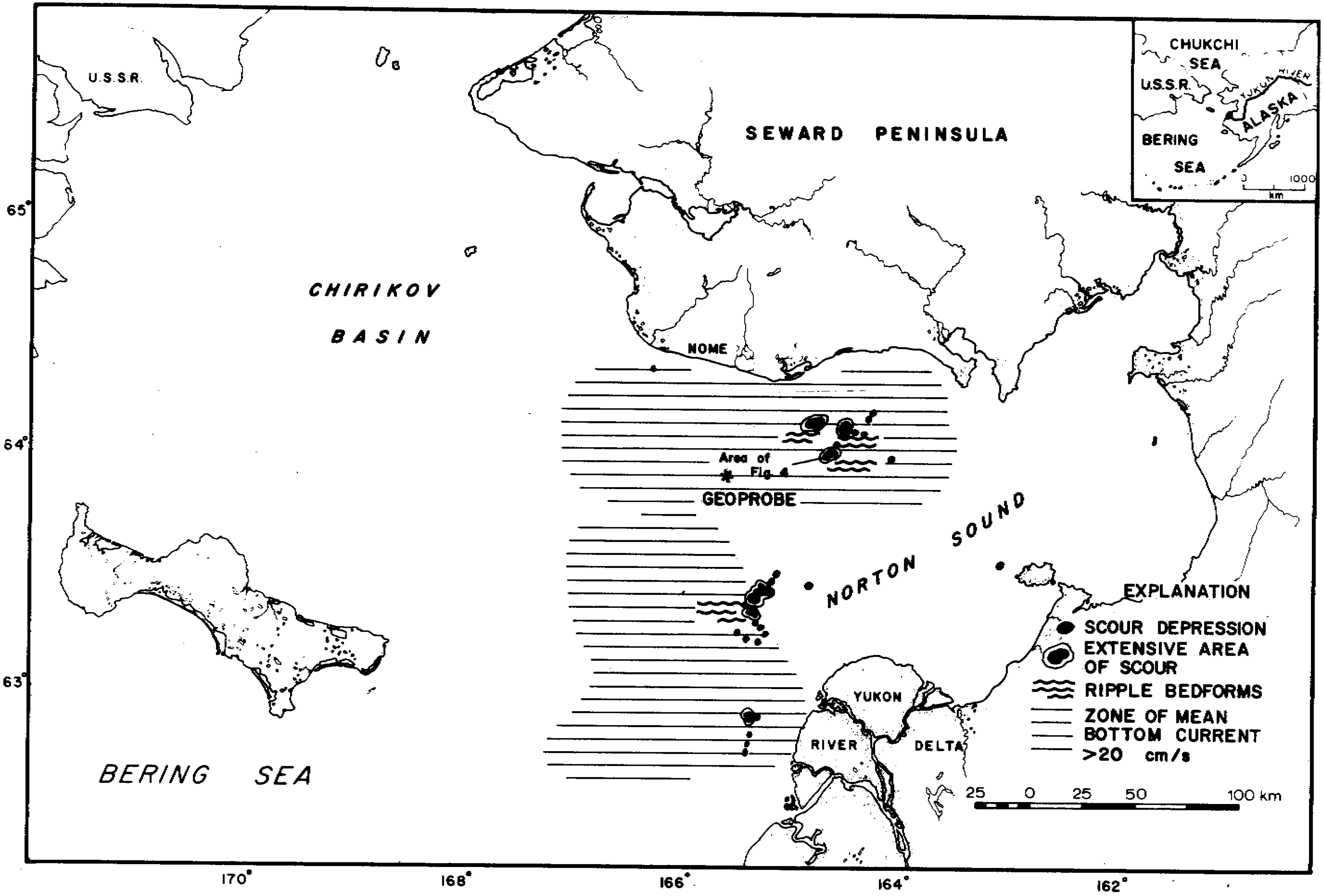

Figure E-2 Location of scour depressions, extensive scour and ripple zones, and strongest bottom currents in Norton Sound. Geoprobe instrument measured current velocities.

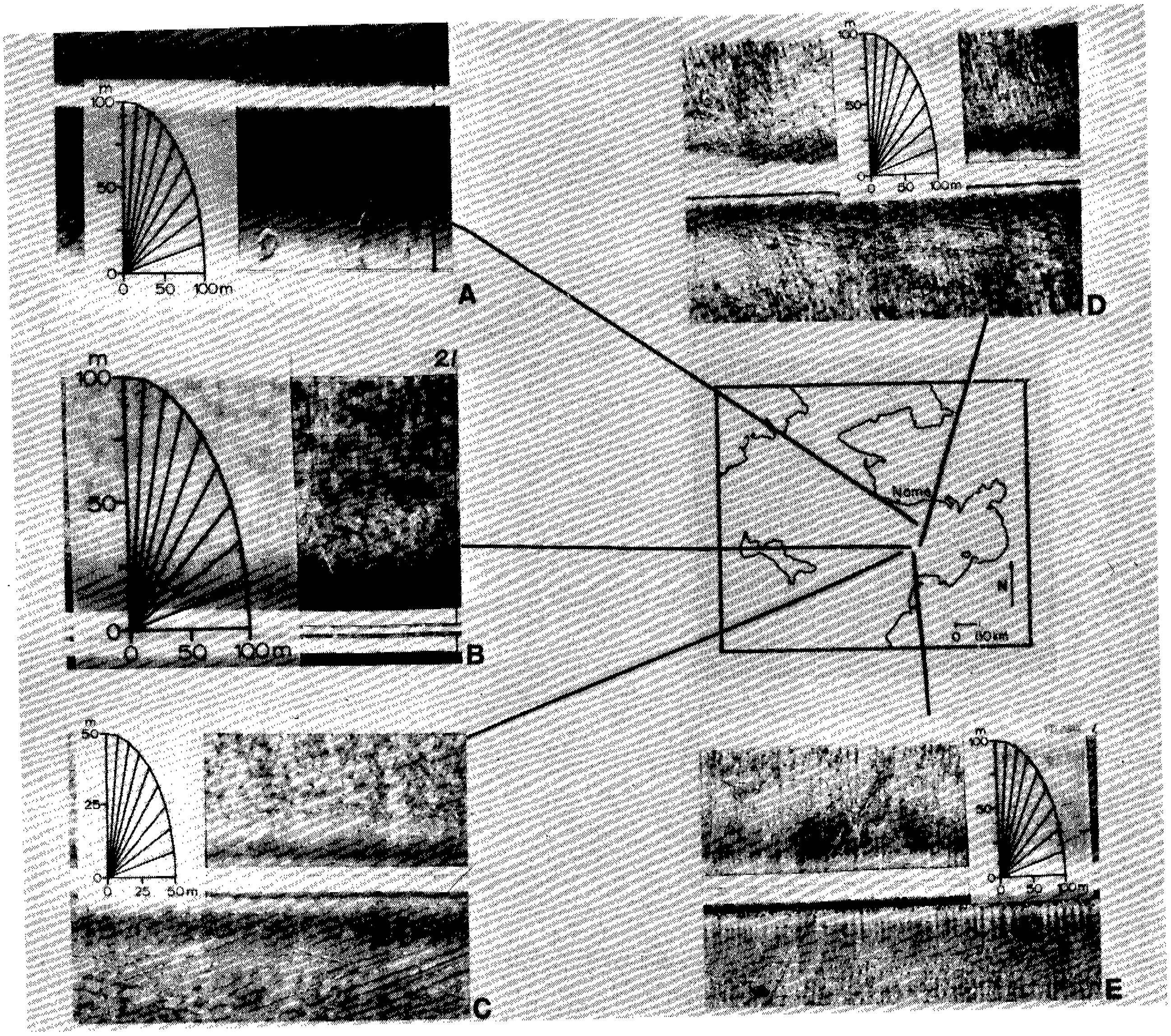

Figure E-3 Side-scan sonograph examples of scour features. A and B are examples of individual depressions. C, D, and E show large scour zones.

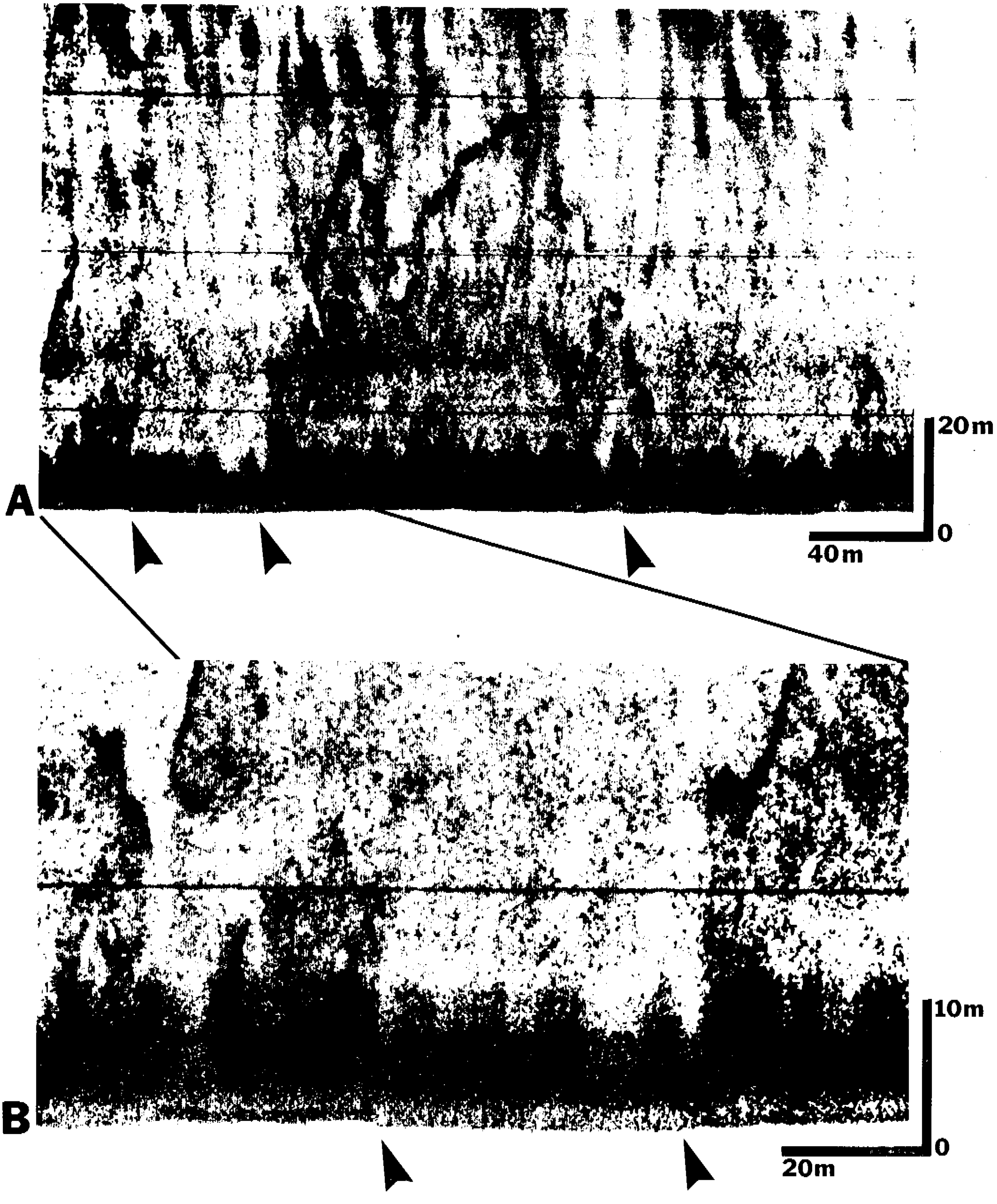

Figure E-4 Example of large scour zone (location keyed on Fig. 2). B is an expanded version of A. Arrows point to scarps defining scour margins crossed by sonograph horizon line.

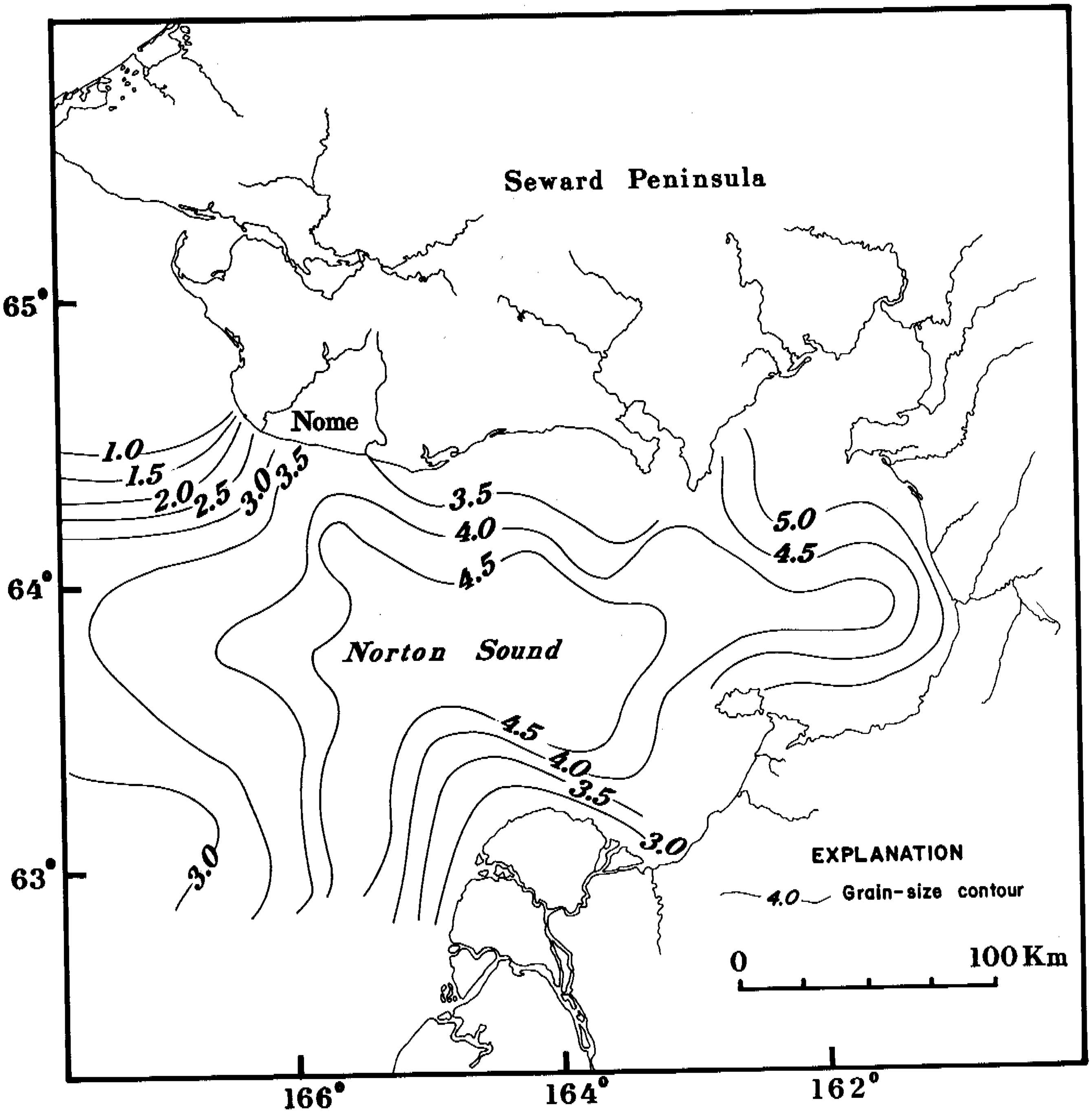

Figure E-5 Contour map of sediment-grain-size distribution in mean phi in Norton Sound. Values represent first-moment calculation at each station. Sediment samples were taken on a 5 to 10 km grid spacing.

IX. NEEDS FOR FURTHER STUDY AND WORK IN PROGRESS

Projected studies include the use of an in situ flume to investigate the interaction between bottom currents and sediment. Quantitative data obtained from this type of investigation is crucial to a further understanding of erosion and depostion hazards. More detailed information can be collected with the use of in situ diver-operated sampling devices. Discreet sampling of geotechnical, geochemical, and sedimentological properties of the seafloor on targets such as ice-gouges, scour depressions, and biogenic gas-craters is an important aspect of hazards study that should be attempted.

A safer and more effective method of discreet seafloor sampling could be achieved with the use of a submersible. SCUBA diving reconnaissance attempted in 1978 proved to be hazardous due to conditions of high turbidity and high current speeds. A submersible would enable greater manueverability, longer bottom time and safer conditions for the sampler/observer.

The R/V KARLUK cruise, K1-78-BS, obtained new data in Norton Sound. With a draft of only one meter, the R/V KARLUK was able to sample areas that are too shallow for our large research vessels. In the area of the Yukon Delta, 420 km of side-scan sonar, 480 km of 7 & 200 kHz and 400 km of Uniboom were run. A total of 22 vibracores and 6 grab samples were collected on three separate traverses offshore of the delta. These data will be analysed and integrated into the Final Report at the end of 1979.

Data currently being analysed include sediment grain size, organic carbon percents, radiocarbon dates, paleontology and geotechnical properties. UTM projection base maps will be used to show the following data:

1. Geologic map showing physiographic zones and distribution of surface sediment type (gravel, sand, silt, and clay).

2. Isopach of Holocene sediment and areas of filled channels indicating areas of potentially thixotropic sediment.

3. Maps of relative sediment stability: gas craters, thermogenic gas seeps, areas of gas-charged sediment (thermogenic and biogenic), and discussions on geochemistry of gas-charged sediment.

4. Maps of intense bottom activity: scour depressions, mobile bedforms, ice gouging, and storm sand layers.

5. Map showing surface and subsurface faulting.

6. Generalized hazards maps combining all data.

NOAA is planning the emplacement of year long current meters in the northern Bering Sea starting in the 1979 field season. Data collected from these meters will be integrated into our own data files.

ANNUAL REPORT

Contract #: 03-5-022-55
Research Unit #: 483
Reporting Period: 1 April 1978 -
31 March 1979
Number of Pages: 50

SEISMOTECTONIC STUDIES OF NORTHERN AND WESTERN ALASKA

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Prepared for the

National Oceanic and Atmospheric Administration

Under Contract No. 03-5-022-55

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I. SUMMARY: OBJECTIVES, CONCLUSIONS AND IMPLICATIONS FOR OIL AND GAS DEVELOPMENTS

The objectives under the present study are to evaluate the extent of seismic hazards posed by earthquakes in northern and western Alaska. The consideration of all available seismic data for the Arctic region shows that the earthquakes do not distribute randomly in space but tend to concentrate along zones which were reactivated in the geologic past.

The modern seismicity of the Canadian coast and its continuation through Barter Island in northeast Alaska and then along the thrust zone of the Brooks Range, has been interpreted as an active regional intraplate tectonic zone. The reactivation of this zone continues to the present. In view of these observations, it is premature to assign an upper bound for the magnitude of future earthquakes along this zone from a data base of ten years or so. However, the trends in the available data appear to be sufficient in attributing the areas lying north of the thrust zone of the Brooks Range, including the Colville Geosyncline and Alaskan Beaufort Sea to the west of 147°W as being predominantly aseismic.

The dense clustering of earthquakes around the Kobuk trench and Porcupine fault indicates that these two structures are active. Thus, linear structures, like pipelines, used for transportation of oil and gas through the eastern part of Brooks Range and Chandalar and Yukon River basins should take into account the possibility of ground dislocations, perhaps by a significant amount over a period of time, at points of mapped fault crossings.

In the western part of Alaska, around the Seward Peninsula, analysis of the data gathered to date indicates a higher level of seismicity than was recognized prior to this study. This phenomenon appears to be common to both offshore and onshore areas. A number of distinct seismic trends could be identified which closely follow the mapped traces of geologic structures. Most of these structures are faults.

The investigation of icequakes has continued. Despite unusually warmer weather conditions during 1978, which resulted in a thin sheet of sea ice formations, one swarm of icequakes was successfully recorded during February of 1978 by the 3-component station at Kotzebue. The analysis of these data is in progress.

II. INTRODUCTION

A. General Nature and Scope of Study

This report describes seismicity studies in the northern and western parts of Alaska. The outline of the study area is shown by heavy lines in Figure 1. The locations of the epicenters of earthquakes shown this figure were compiled by Meyers (1976) from the Alaskan earthquake catalog of the United States Geological Survey. The data represent the time period from 1786 to 1974.

The spatial distribution of earthquakes in Figure 1 shows that the active central Alaska seismic zone extends up to about 66°N. However, an isolated zone of seismic activity is seen to occur around Barter Island in the Beaufort Sea.

In the western part of Alaska, particularly west of 154°W, the earthquakes are sparsely distributed with some concentration northwest of a point lying near 66°N and 156°W. Further west, around Seward Peninsula, all earthquakes in the Meyer catalog of magnitude equal to and greater than 4.0 are shown in Figure 2. It is seen in this figure that during the past 30 years, a number of earthquakes of magnitude greater than 5.0 occurred in this area, which indicates that this part of Alaska is moderately active. The rest of the study area shown in Figure 1 may be classified as an area of low seismicity. However, it was the intent of the present study to more closely define the characteristics of the seismicity of northern and western Alaska by the operation of carefully spaced seismographic networks.

B. Scientific Objectives

The specific objectives of the seismological studies for the study areas are the following:

(i) To determine the spatial and temporal characteristics of the seismicity, and its relationship to mapped tectonic features.

(ii) To determine the predominant failure mechanisms associated with the earthquakes located along or near the known geological features or trends.

(iii) To determine magnitudes, and if possible, recurrence rates of strong earthquakes in the respective areas for use in projections as to possible activity in the future.

(iv) To determine the characteristics of velocity spectra and seismic energy attenuation as functions of epicentral distance.

(v) To synthesize results of studies under (i)-(iv) in order to integrate the seismotectonic settings of the study areas with the overall tectonic framework of Alaska.

C. Relevance to Problems of Petroleum Development

It has been well established that hydrocarbons in commercial quantities occur in onshore and offshore areas of the Beaufort Sea. Large scale exploration programs for hydrocarbon concentrations, and their eventual development in areas adjoining the proven reserves, are a certainty in the near future. Consequently, the evaluation of the level of seismicity for these areas is a logical undertaking to assist in the planning and design of future construction projects.

Similar development, planning, and construction in the potentially oil-rich areas of the western Alaskan continental shelf is not as far advanced as that along the northern coast of the state. Results obtained thus far in this part of the state, however, indicate that the level of seismicity is much higher than previously thought. To establish this finding within desirable bounds of precision will require a data base which can only be obtained by the operation of a localized, high-resolution seismographic network for a reasonable length of time.

III. CURRENT STATE OF KNOWLEDGE

A. Northern Alaska

As mentioned earlier, it appears from past data that seismic activity along the Beaufort Sea Coast (west of 140°W) tend to concentrate in and around Barter Island. Also, this active zone appeared to be isolated from the rest of the central Alaskan active zones. However, results obtained since the inception of the present study have shown (Gedney, et al., 1977; Biswas, et al., 1977; Biswas and Gedney, 1978) that this zone is actually on a northward extension of the central Alaskan zone of shallow seismicity. Earthquakes in the latter zone, as shown by Bhattacharya and Biswas (1979), are a direct consequence of lithospheric plate subduction. This phenomenon results in normal and strike-slip faulting (Estes, et al., 1978; Bhattacharya and Biswas, 1979; Huang, 1979) at earthquake foci in the depth interval of 0-60 km, and underthrusting at greater depth. It is difficult, however, to invoke this phenomenon as being the immediate cause of earthquakes in northeast and western Alaska, both areas being more than 400 km distant from the Alaskan subduction zone. It thus appears that a more indirect association must be at work relating the activity of the three seismic regions which are generally contiguous in extent and contemporaneous in time.

The largest earthquake reliably recorded in northeast Alaska during the past decade had a magnitude (M_L) of 5.3 and was located about 30 km north of Barter Island on the Beaufort Sea shelf. Since the emplacement of the local seismographic network, however, we have found that a great many more earthquakes over a wider magnitude range occur here than earlier data have revealed. During about a two and a half year recording period (January 1976 through August 1978), locatable events ranged approximately from 1.0 to 4.0 in magnitude, and many others occurred which were non-locatable due to equipment outages or low magnitude.

B. Western Alaska

The largest earthquake to have been instrumentally documented in western Alaska occurred about 30 km inland from the northern coast of

Norton Sound in 1950, and was of magnitude 6.5. Since then, recording at stations remote from the area has failed to reveal any further significant seismic activity. This is shown in Figure 2. However, the present study with the localized network demonstrates clearly that the area is still active, and points out a north-south distribution of epicenters passing through the area of the 1950 earthquake. In addition, earthquakes located during a two-year period (1977-78) spread widely throughout the entire area, including both Norton and Kotzebue Sounds. Most significantly, there are a number of instances where earthquake clusters are found to lie along, or parallel to mapped faults or linear structural trends. Earthquakes recorded during 1978 ranged in magnitude from 1.0 to 4.5.

IV. STUDY AREA, SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Although the study area as shown in Figure 1 is relatively large, the seismographic coverage used, particularly for the section east of 155°W, may be considered satisfactory. The locations of the stations in this part of Alaska are shown by hollow triangles in Figure 3 and their system gains (peak at period 0.2 sec) are given in Table 1. Also, in the same figure, the layout for a temporary network comprising five stations around Prudhoe Bay (Camden Basin) is shown by hollow circles. The data from this array will be recorded locally at Prudhoe Bay, and these will be analyzed primarily to obtain attenuation factors of seismic waves through the propagation medium.

The seismic attenuation properties of ground motions as a function of epicentral distance are important parameters needed for design engineering information. Because of the station layout (located mostly in metamorphic terrane) around Barter Island, the attenuation characteristics of sedimentary sections (features of immediate interest for OCSEAP studies) could not be provided from the available data. However, it is anticipated that land-based measurements of attenuation values to be obtained by the temporary network will provide some measures of this important seismic parameter.

The operation of the four-station array around Barter Island was discontinued in August, 1978, partly due to the high cost of data telemetry. However, the operation of the Fort Yukon array has been continued with partial support (yearly field service of stations) from OCSEAP. Earthquakes located by this array are helping to refine the seismotectonic model of northern Alaska and will be utilized for the attenuation studies around Camden Bay mentioned earlier.

The location of the seismographic stations around Norton and Kotzebue Sounds are shown in Figure 4 and their system gains (peak at period 0.2 sec) are given in Table 2. With the exception of one station at Kotzebue which is three-component, the rest of the stations of this array are single-component (vertical) stations. In addition to these, a new one-component (vertical) station has been installed at Pt. Barrow during the early part of March, 1979 in cooperation with NOAA. The data from this station is telemetered to the Geophysical Institute at Fairbanks via a satellite circuit leased by the Palmer Alaska Tsunami Warning Center of NOAA. The primary objective for the operation of this station is to resolve the questions of possible low level seismic activity in the western part of the Beaufort Sea and Colville geosyncline, and in adjoining areas of Chukchi Sea.

From August 1978 (stations serviced) to the present, the signal-to-noise levels of the seismic signals of this network have been improved greatly, and the station outages could be reduced considerably compared to 1977. However, one of the stations of the network at Granite Mountain (GMA), operated by the Palmer Observatory of NOAA, had to be closed around April 1978 due to the closure of the U.S. Air Force facilities at this site. Through a mutual agreement, the NOAA observatory has installed a one-component (vertical) station at our site at Anvil Mountain (ANV) in the Nome area. This has allowed us to move and install a new station at Candle (CDL) as a partial substitution for the station at Granite Mountain (GMA). It should be mentioned that GMA was the only station which provided seismographic coverage on the eastern side of the study area.

It can be seen in Figures 3 and 4 that the seismographic coverage of the study area consists of land-based stations. Aside from the obvious impracticality of employing ocean-bottom seismometers due to high cost, there are other reasons for utilizing land-based seismographic networks in what is largely meant to be an assessment of offshore seismic hazards.

Crustal earthquakes commonly migrate with time along a fault or fault system. This means that if a given section of an active fault yields (resulting in an earthquake), then at a later time a somewhat distant point of the same fault may yield to accumulated stresses. This points to the necessity of providing seismographic coverage over a relatively larger area. It may be noted, as discussed in later sections, that the study area is predominantly characterized by crustal earthquakes.

In addition to the factors mentioned above, local ground failures along active faults and their trends, although they may appear as a localized phenomenon, are intimately related to the regional seismotectonic setting. Thus, for appropriate assessment of seismic hazards for an area, it is imperative to integrate the area into the regional tectonic picture. In view of this, the stations of the networks were distributed on a near-regional scale, providing the capability to locate earthquakes of magnitude as low as 1.0 occurring within the area of interest.

Details of the stations, the equipment used at the field and recording sites, and the mode of data telemetry to the Geophysical Institute at Fairbanks are discussed in detail elsewhere (Biswas et al., 1977) and will not be repeated here. However, it should be mentioned that to avoid the ever-increasing cost (usually 90 percent of the allocated budget) of leasing microwave circuits for data telemetry, arrangements are in the final stages to begin recording data for the western network at Nome on the Seward Peninsula.

V. RESULTS

A. Northern Alaska

The earthquake data compiled for this study consists of all locatable earthquakes which occurred north of 66°N latitude in Alaska during the ten-year period from January 1968 to December 1978. The data collected prior to 1968 were found incomplete and poorly representative for this part of Alaska, due to a lack of seismographic coverage. Consequently, these data were excluded for this study.

Data from two principal sources, namely, the northern and central Alaska seismographic networks of the Geophysical Institute, and the regional seismographic network of Canada were used in the compilation mentioned above. For the periods from 1968 to 1973 (both years inclusive), the best available data are those collected by the Canadian network. This information has been compiled from eight Canadian annual catalogs (Stevens et al., 1976; Horner et al., 1974, 1975, and 1976; Bashman et al., 1977a; Wetmiller, 1976 and 1977). Locations are numerical solutions computed by a least-squares method utilizing a one-layer crustal model 36 km in thickness, and hypocentral depths were constrained to mid-layer (18 km). In some cases, the Canadians supplemented their network data with central Alaskan data in the location process.

A majority of the earthquakes listed in Canadian catalogs for northern Alaska fall in the magnitude range from 3.0 to 4.0. A general estimate of errors in location of the epicenters is on the order of ± 100 km (Bashman, et al., 1977b). It was also noted that the standard deviations (σ) of the travel time residuals generally run greater than 1.0 sec (Biswas and Gedney, 1978). These factors indicate the detection threshold and location precision for earthquakes located in northeast Alaska by the Canadian network.

During 1974 and 1975, routine data reduction procedures utilizing the basic central Alaskan network located a number of earthquakes on the southern edge of the study area. None were located north of 67°N. This, plus the factors mentioned above, indicate the limitations of locating earthquakes in northeast Alaska by the central Alaskan network or Canadian network or a combination of both. These limitations are due to the inherent network configuration and minimum station distances ($\approx$ 200 km) from the source area.

Since the installation of the Barter Island and Fort Yukon arrays in late 1975, many earthquakes have been located in northeast Alaska. The preliminary location details of these earthquakes were given by Biswas et al. (1977) and Biswas and Gedney (1978). Data for all earthquakes having σ greater than 1.5 sec and located north of 66°N latitude during 1974 and 1975 by the central Alaskan network, and by the Barter Island and Fort Yukon arrays from January 1976 to December 1977, were rescaled and relocated to prepare a final list, particularly for the northeast area. This list is given in Table 3. In this table, the earthquakes located by the Barter Island network during 1978 prior to the closure of this network and nine earthquakes located during 1974 and 1975 by the Canadian network are also included.

All solutions in Table 3 are based on a weighted least squares minimization technique. The details of the computer program are given by Lee and Lahr (1975); the P-wave velocity structure used in the location process is given elsewhere (Biswas et al., 1977). The symbols NO, GAP, DMIN, RMS and ERH refer, respectively, to the number of station readings used to locate each earthquake, largest azimuthal difference between stations with respect to the epicenter, distance of the epicenter from the nearest station, the root mean square of travel time residuals (σ), and the standard error in epicenter location.

In the initial computer runs, all focal parameters were allowed to vary. The results indicated that focal depths ranged between the surface and about 20 km for 90 percent or more of the events. In subsequent computer runs, focal depths were thus constrained to 10 km to eliminate one degree of freedom in the location problem.

A plot of the epicenters of earthquakes compiled for the ten-year period, including those given in Table 3, is shown in Figure 5. In this plot, the earthquakes were not sorted according to magnitude. However, it should be noted that their magnitudes range from about 0.5 to 5.3, with the strongest one (5.3) being located about 30 km offshore of Barter Island in 1968. A significant number of events have magnitudes between 4.0 to 5.0. Since the complete list of earthquakes shown in Figure 5 is relatively long, it is not included in this report. But the list is to be copied on magnetic tape in OCSEAP compatible format for submission to the Data Center soon. The tectonic implications of the seismicity patterns as seen in Figure 5 are discussed in later sections.

B. Western Alaska

This study area is relatively large and the seismographic coverage attained so far for this section of Alaska is not satisfactory. This limitation being understood, the location of all earthquakes in this area during 1978 has been maintained up to date. Compared with 1977, more events could be recorded and located during 1978. The location details of the locatable earthquakes occurring during 1978 are given in Table 4. The symbols used for the heading of each column represent the same quantities as in Table 3.

As was done for the northeast sector, the scaled data were initially processed for free solutions (all focal parameters allowed to vary). The results showed that hypocentral depths generally ranged between the surface and 20 km, which implies that the seismicity of the area is predominantly characterized by crustal earthquakes. Thus, in subsequent computer runs, we constrained the focal depths here, also, to 10 km. The velocity structure used was also the same as that used for the northeast Alaska. The resulting plot of epicenters is shown in Figure 6. In this plot, the 1978 data were supplemented with those of the previous year (1977). In Table 6, it can be seen that the values of σ are generally less than 1.0 sec. However, despite fixing the focal depths to 10 km, a number of earthquakes show significant uncertainties in locations. It is anticipated that the errors associated with the locations of these events can be reduced by rescaling the raw data as has been done for the northeast Alaska. This will be taken up in the near future for submissions to the OCSEAP Data Center.

VI. DISCUSSION

A. Northern Alaska

(i) Spatial Characteristics of Seismicity

To relate the epicentral locations of earthquakes determined in this study to known tectonic elements, all earthquakes shown in Figure 5 are plotted on an overlay of structural trends (Figure 3, Grantz et al., 1976) in northern Alaska. These are shown in Figure 7. The offshore traces of these structures were mapped by the above authors using marine geophysical methods.

Figure 3 of Grantz et al., was enlarged photographically by a factor of about 10, and the structural traces were digitized at close intervals. These data were then converted to the same projection and linear scale as was used to plot the epicenters shown in Figure 7. This figure should not be used to correlate individual earthquakes with particular structures, since all locatable earthquakes occurring during a ten-year period (1968-1978), regardless of the order of error in their epicentral locations, have been retained in this figure. However, on a regional scale it illustrates the relationships between the general trends of seismicity and structures.

It can be seen (Figure 7) that the earthquakes are not distributed randomly in space, but tend to align approximately in a northeast-southwest direction. Further south of 66°N (not shown in Figure 7), this epicentral trend merges smoothly to that of the highly to moderately active zones of central Alaska. Scattered activity extends generally westward, except for a distinct linear cluster which trends NNW-SSE immediately to the west of Kobuk trench. Although available structural maps (geological) do not show any tectonic feature having the same trend on or around this cluster, the seismic data appear to indicate an active fault. Results of detailed study of this feature will be reported elsewhere.

From Cape Lisburne to about 148°W, the available data indicate that the northern limit of Alaskan seismicity is approximately marked by the thrust zone of Brooks Range. Further east of 148°W, this boundary turns to the northeast, and is marked by the interface between Romanzoff Mountain and Camden Basin.

In the offshore area, the active zone extends to about 20-30 km north of Barter Island. It should be noted that the epicentral concentration in this area is that resulting from a magnitude 5.3 earthquake in 1968 and its aftershocks. This cluster aligns parallel to the axes of anticlines and synclines in a northeast-southwest direction. An attempt to study the focal mechanism of this earthquake from short-period data of the World Wide Standard Seismographic Network (WWSSN) was unsuccessful. However, it is important to find the nature of the stress field in order to be able to relate the seismicity to regional tectonics. It is planned to use long period data to resolve this problem. Until then, the apparent causal relationship between folded structures and earthquakes must remain a matter of conjecture.

Along the Romanzoff Mountains, the epicenters scatter considerably with some lying on structural traces. The overall distribution is so diffused that it is not possible with the available data to identify which fault or faults are active at present. Further south, however, the epicentral concentration increases notably, particularly along the Kobuk trench and Porcupine fault, which appears to indicate that these two structures are quite active at present. Studies of focal mechanisms along this cluster are in progress.

(ii) Relationships Between Seismicity and Regional Tectonics

In order to integrate the observed seismicity of northern Alaska to the regional tectonic framework, a simultaneous consideration of all known tectonic features of the Arctic region is imperative. This is beyond the scope of this report. However, we will refer to some specific features of the Arctic region.

The composite of seismicity and tectonic features prepared by Basham et al. (1977) for northern Canada is shown in Figure 8. In this figure, the approximate direction of principal stresses derived by Hasegawa (1977), Leblame and Wetmiller (1974a) and Sykes and Sbar (1974) are also shown. The trends of seismicity in Siberian Arctic and around Greenland is shown in Figure 9. The epicentral plot of this figure was compiled by Tarr (1970) from data gathered by U.S. Geological Survey (PDE) from 1961 to 1969. A comparison between this figure and Figure 7 and 8 shows that the epicentral distribution of Figure 9 represents partially the nature of the seismicity in northern Alaska and northern Canada. However, it illustrates well the trends of the Nansen Ridge (also called Gakkel Ridge) and North Atlantic Ridges of the polar region, besides others on the south.

On a global scale, earthquakes tend to concentrate along accreting or converging plate boundaries (Le Pichon, et al., 1973) due to the relative motions between the plates. In addition to these, within a number of continental blocks (for example, northern and western Alaska, northern Canada, to name a few), frequently earthquakes of all magnitudes (large and small) are located in areas remote from the nearest plate boundaries. Sykes (1978) studied on a worldwide scale the relationships between these intraplate earthquakes and preexisting zones of weakness, namely, faults, organic belts and alkaline volcanism in the context of plate tectonics. One of his observations of special significance for the present study is that intraplate seismicity tends to concentrate either near the ends of major oceanic transform faults along pre-existing zones of deformation or along faults of old fold belts within the continents. He also observed that the pre-existing faults generally trend either parallel or transverse to modern continental margins.

In the Arctic region, from seismicity studies (Heezen and Ewing, 1961; Sykes, 1965, 1967; Tarr, 1970) the Nansen Ridge has been identified as the modern accreting plate boundary. Its inland expression through the eastern part of Siberia as inferred by others (Sykes, 1965; Le Pichon, et al., 1973) is shown by broken line A B C in Figure 9. This trend, though, may not have any immediate relevance due to its remoteness with respect to the study area, it is shown in Figure 9 for the sake of completeness.

In the north, near the northeast corner of Greenland, the Nansen Ridge joins the North Atlantic Ridge by an offset section, labelled DE in Figure 9. This well-defined ridge system marks the boundary between the well known Eurasian plate on the west and the American plate on the east.

Along the offset section DE, the current directions of principal stresses are not known, due to a lack of focal mechanism studies. However, if we extend DE along its trend in the southwest direction, it approximately follows the 1000-2000 m isobath of the Canadian shelf and intersects the continental margin near 70°N and 140°W. From this point, two well defined seismic zones extend inland. Both of these zones trend transversely to the continental margin. One follows the highly faulted zone along Peel River (Figure 8) in Yukon Territory of Canada and the other along Romanzoff Mountains (Figure 7) in northeast Alaska. Further south, this latter zone turns westward and follows the thrust zone of Brooks Range, approximately, paralleling NE continental margin of northern Alaska.

The trend of the seismicity along the Canadian Arctic coast (Figure 8) closely follows the southwest extension of DE (Figure 9). Although the level of seismicity along this trend is not uniform (note the sparseness of earthquakes on the immediate north of Prince Patrick uplift), it is difficult to construe that the very presence of modern seismic activity over such a long trend is due to yielding of unhealed faults, primarily, under stress fields of localized origin and extent as implied by Hasegawa (1977). It rather appears to represent continued reactivation of a zone of regional significance. This is particularly evident when the north Alaskan seismic trends are viewed along with those of northern coast of Canada. Also, this trend of seismicity mostly parallels the continental margins, a common feature noted by Sykes (1978) for a number of other intraplate zones.

The model (Figure 10) of Herron et al. (1974) for the evolution of the Arctic region requires right lateral strike-slip motion over an extended zone along the Prince Patrick Uplift-Richardson Mountain area dating from 81 m.y. to 63 m.y. age for convergence along the Alpha Cordillera. This zone closely follows the current seismic zone. Combining this observation with those of Sykes (1978) as mentioned earlier, lends credence to the above inference. That is, there exists a major tectonic boundary along the Arctic coast of Canada, and the northeastern expression of this zone may be linked to the offset section DE (Figure 9) between North Atlantic and Nansen Ridges. The westward continuation of the inferred zone may be linked to the thrust zone of Brooks Range which passed through extensive compressional deformations (Taillure, 1973; Pittman and Talwani, 1972) in the geologic past.

The directions of principal stresses in Sverdrup Basin (Figure 9) as derived by Hasegawa (1977) result in right-lateral motions on a northeast-southwest oriented steeply dipping planes. He also found appreciable deep-slip motions along the same fault zone. In any case, these results should not be considered as supporting evidence for those inferred by Herron, et al. (1974). This is because the model of the latter authors corresponds to a geologic epoch when convergence along the Alpha-Mendeleyev Ridge was shown to be a dominant tectonic process as opposed to the spreading at present.

To the west along the McKenzie Valley, two available solutions of principal stress directions are those given by Sykes and Sbar (1974) and Lablanc and Wetmiller (1974a) as mentioned earlier. The solution of the former authors shows compression oriented in the northwest-southeast direction while the latter authors show tension in that direction. It is anticipated that the solution for the earthquake of magnitude 5.3 around Barter Island will resolve the discrepancies noted above. Also, in the absence of focal mechanism studies, the orientation of the stress field along the thrust belt of Brooks Range remains an unresolved problem at this stage.

B. Western Alaska

In order to relate observed trends in seismicity to tectonic features, the epicenters of all earthquakes shown in Figure 6 are plotted on an overlay of known structural traces in Figure 11. For the offshore areas in Norton and Kotzebue Sounds, the structures mapped by Johnson and Holmes (1977) and Grantz and Eittreim (1979), respectively, were digitized at close intervals. Similarly, for the Seward Peninsula, the structural traces compiled by Hudson (1977) were digitized. These data were then converted to the same projection and linear scale as was used to plot the epicenters in Figure 11.

Despite considerable scatter in the distribution of earthquakes as seen in Figure 11, a number of distinct trends could be discerned. The inland trace of Kaltag fault, a major tectonic element of the area, appears to traverse through the clusters labelled A. Offshore in Norton Sound, the earthquakes align along a trend (BB) which appears to be 10-20 km off (in northwest direction) the inferred trace of Kaltag fault. However, along the trend BB, a number of faults have been mapped by Johnson and Holmes (1977) from marine geophysical data.

The seismic trend CC in Norton Sound appears to follow closely a series of mapped faults and ridge axes identified by Johnson and Holmes (1977). These authors also mapped a number of offshore faults trending east-west from Port Clarence where earthquakes also tend to cluster (DD) in the same direction.

In Kotzebue Sound, it is interesting to note that the results of marine geophysical surveys (Grantz and Eittreim, 1979) do not show any faults. On the other hand, three trends (EE, FF, GG) emerge from the earthquake data. The difference between the marine data and earthquake data need to be resolved from further studies.

Inland in Seward Peninsula, the clustering of earthquakes and mapped fault traces is quite significant. For instance, the cluster HH follows closely a well defined fault system, and traverses the epicenter of the 1950 (M_L = 6.5) earthquake. Also, this zone is characterized by extensive felsic intrusive activity in the geologic past. According to the observations of Sykes (1978) for the trends of intraplate seismicity as referenced earlier, the zone HH with its transverse trend with respect to the continental margin and associated volcanics lead us to interpret it as an onshore expression of a major weak zone. The reactivation of this zone continues to the present as indicated by the modern seismicity.

About 100-150 km to the west of the trend HH, a second onshore trend (II) in seismicity is seen to follow closely the mapped en echelon type of fault system. Similar clustering of earthquakes and fault traces appear on the immediate east and northeast of Port Clarence. The implications of these onshore trends of modern activity from the offshore areas of Norton Sound remained unresolved from the vailable data.

VII. CONCLUSION

A. Northern Alaska

(i) The available seismic data in conjunction with Sykes' (1978) observations regarding the intraplate activities in other parts of the world lend support to the postulation of a major tectonic zone along the Arctic coast of Canada. Its northeast continuation can be tentatively linked to the offset section between the Nansen and North Atlantic Ridges. The westward continuation of this zone can be linked to the thrust zone of Brooks Range.

(ii) The modern orientation of the stress field, particularly around Sverdrup Basin in northern Canada, results in ground failures along northeast-southwest oriented planes. This feature closely follows the direction of the tectonic zone inferred above.

(iii) In the absence of focal mechanism solutions, the true orientation of the stress field in northeast Alaska and along the Brooks Range remains a matter of conjecture. However, if the current tectonics of the Arctic Coast of Alaska are predominantly controlled by the spreading along the Nansen Ridge, it would orient the principal stresses (compression) in the northwest-southeast and north-south directions along Romanzoff Mountain in northeast Alaska, and along a large part of Brooks Range, respectively. This would also demand a zone of transition where the predominantly strike-slip and normal faulting motions of the Canadian coast would change to thrust type of motions along the Alaskan coast.

(iv) Although the reactivated intraplate zones of weakness are seismically less active than plate boundaries, there is no known physical basis to justify that the magnitude of the largest expected earthquake along major intraplate zones is limited by the strongest earthquake instrumentally located during the past few decades. For instance, Biswas and Gedney (1978) proposed from the local trend in seismicity an upper magnitude bound of about 6.0 for the Beaufort Sea coast of northeast Alaska from ten years' of past data. From the present regional considerations, the size of the strongest expected earthquake in this area may be considered as an open question.

(v) From the available data, it may be concluded that the areas from the Brooks Range further north along the Beaufort Sea coast in Alaska are predominantly aseismic, excepting the coastal area east of about 147°W.

B. Western Alaska

(i) In this part of Alaska, analysis of data gathered from the local seismographic network indicates a higher level of seismicity than was recognized prior to this study. The area may be classified as moderately active.

(ii) Within the last 27 years, the largest earthquake instrumentally recorded in the study area was of magnitude 6.5; it was located about 30 km inland from the northern boundary of Norton Sound. This was followed by earthquakes of magnitudes 6.0 (1964), 6.0 and 5.8 (1965), and 5.2 (1966), located about 60 km, 40 km and 15 km inland from Port Clrence, Norton Bay and Hotham Inlet (Kotzebue Sound), respectively. Since the areas around the epicenters of these earthquakes are thinly populated, their seismic impact passed largely undocumented.

(iii) The local network recorded a large number of earthquakes in the magnitude range of $1.0 \leq M_L \leq 4.5$ during a period of slightly more than 12 months (1978). The epicenters of these earthquakes are found to be distributed on and around the offshore and onshore traces of mapped faults. An epicentral concentration is found to extend in the north-south direction along a fault system about 150 km east of Cape Nome. A diffused distribution of epicenters are seen in Norton and Kotzebue Sounds with some scatter around the 1966 earthquake to the immediate west of Hotham Inlet.

(iv) No attempt has been made at this stage of our study to interpret the tectonic significance and the associated seismic hazards posed by the features mentioned above. However, it should be pointed out that, compared to the areal extent of the study area, the seismographic coverage attained to date is insufficient to delineate the details of the features mentioned above.

VIII. SUMMARY: FOURTH QUARTER OPERATIONS

A. Task Objectives

(i) To install 5-station short-period one-component (vertical) seismographic network around Prudhoe Bay for attenuation studies.

(ii) To install recording system at Nome for recording data from the western Alaska seismographic network.

(iii) To continue scaling and processing of daily recorded data.

B. Field and Laboratory Activities

(i) The seismometers and associated electronics for the Prudhoe Bay network were tested and assembled for deployment to the field sites.

(ii) For recording data of the above network at Prudhoe Bay on magnetic tape, the recorder, time code generator and WWV radio receiver were tested and assembled for shipment to the recording site.

(iii) Identical recording equipment for recording data at Nome for the western network have been assembled. The installation of this system at Nome has been delayed due to shortage of personnel. However, it is planned to install and start recording at Nome during May 1979.

(iv) One swarm of icequake has been recorded during February 1979. The scaling of data for these events including earthquakes are progressing smoothly.

C. Results

None.

D. Preliminary Interpretation

None.

E. Problem Encountered

None.

F. Estimate of Funds Expended

$120,000.

ACKNOWLEDGEMENTS

We thank Drs. G. Weller and J. Kravitz of the Arctic Project Office (OCSEAP) for their continuous support and encouragement during the study period. We also express appreciation to Mr. T. R. Flesher of OCSEAP for logistic support in time. We are indebted to R. Siegrist and R. Foster for the maintenance of the seismographic networks. We are grateful to Mr. R. Eppley and other members of the Alaska Tsunami Warning Center for making available the seismic records gathered by the center. We are also grateful to Drs. W. H. K. Lee and J. C. Lahr of the U.S. Geological Survey, for providing a copy of their computer program for the location of earthquakes, and for participating in helpful discussion for its adoption on the University of Alaska computer.

This research was supported by the NOAA Contract No. 03-5-022-55, Task #12, and by the State of Alaska.

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TABLE 1

Station	System Magnification (0.2 sec)
BI1	1.9×10^6
BI2	2.0×10^6
BI3	2.0×10^6
BI4	1.5×10^6
FY1	2.2×10^6
FY2	2.0×10^6
FY3	1.2×10^6
FY4	8.6×10^5
FY5	9.2×10^5 (T = 0.33 sec)
FYU	6.0×10^6

TABLE 2

Station	System Magnification (0.2 sec)
TNA	2.4×10^5
ANV	2.6×10^6
UNL (= NRA)	2.7×10^6
CDL	3.3×10^6
DMA	1.3×10^6
KTA (Z)	1.1×10^6
KTA (N-S)	3.4×10^5
KTA (E-W)	2.4×10^5

TABLE 3

Date	Origin	Lat(N)	Long(W)	Depth	Mag	NoGapDmin	RMS	ERH
740321	1141 37.0	66 10.9	144 47.4	18.0	3.4	14	1.2	
740331	0507 44.2	68 51.0	143 42.0	18.0	2.4	3	1.6	
740515	1617 21.0	66 23.4	142 24.6	18.0	0.0	7	1.0	
740521	0137 45.0	70 25.2	143 10.8	18.0	3.2	2	0.0	
740609	9 5 29.19	66-21.73	147-35.28	10.00*	1.67	4 261107.3	0.55	
740614	1555 9.30	66-32.23	145-16.45	10.00*	1.22	4 181 3.7	0.24	
740616	658 38.49	66-56.64	149- 2.44	10.00*	2.32	5 250172.7	0.45	190.7
740629	714 58.81	66-12.41	147-33.81	10.00*	1.72	4 187111.7	0.83	
740720	0422 55.0	69 53.4	145 27.6	18.0	0.0	7	0.7	
740825	841 2.31	66- 7.46	148-18.46	10.00*	2.30	4 191146.6	0.75	
740901	1844 14.43	67-15.82	149-18.24	10.00*	3.52	5 238194.6	0.37	20.8
741022	424 16.97	68-16.09	145- 1.33	10.00*	3.83	5 321190.0	0.44	142.2
741031	546 16.05	67-17.99	149-12.62	10.00*	2.47	4 240192.5	0.60	
741120	158 53.99	66- 5.36	148-54.21	10.00*	3.75	8 163141.5	6.29	1.9
741204	1254 23.42	67- 2.46	149- 0.62	10.00*	2.75	4 278233.7	0.05	
741224	158 0.59	66-12.06	146-32.60	10.00*	1.80	4 217 71.4	0.43	
741226	533 9.73	67-17.72	146-25.03	10.00*	2.30	4 315 96.5	0.71	
750104	444 26.41	66- 4.63	147- 9.83	10.00*	2.40	5 210102.4	0.77	33.3
750109	2313 24.61	66- 5.46	147-16.75	10.00*	2.08	4 228106.1	0.66	
750111	1554 14.87	66- 8.57	147-25.72	10.00*	2.31	4 235108.9	0.69	
750129	1116 40.43	66- 3.95	144- 8.48	10.00*	1.93	4 273 74.2	1.39	
750211	1824 55.52	66-46.57	148-28.44	10.00*	2.78	4 237145.1	0.52	
750211	2250 54.48	66-25.82	144-59.75	10.00*	2.66	4 241 18.4	1.04	
750212	1515 4.67	67-14.73	146-13.56	10.00*	2.05	4 314 87.4	0.26	
750219	1417 7.56	66- 1.39	148- 6.81	10.00*	1.96	4 181120.3	0.66	
750228	1541 11.60	66-21.00	145-24.02	10.00*	1.31	4 186 25.2	0.63	
750309	355 56.51	66-39.23	145-42.75	10.00*	2.68	4 215 23.5	1.02	
750323	1451 21.95	66-15.29	147-45.57	10.00*	1.84	4 250118.2	0.35	
750329	1439 21.3	69 37.8	142 51.0	18.0	3.6	4	1.5	
750329	1439 25.64	69-37.53	142-44.35	10.00*	3.82	4 354356.7	0.07	
750329	1546 34.1	69 42.6	142 39.6	18.0	3.3	4	0.8	
750329	1546 46.41	69- 7.17	143-55.94	10.008*	3.72	5 320290.0	0.15	60.2
750330	1133 34.2	69 36.0	143 13.8	18.0	3.9	3	0.9	
750331	1253 03.0	69 58.8	142 32.4	18.0	3.8	15	0.6	
750503	1048 34.98	69- 2.00	145-51.32	10.00*	2.59	4 323276.5	0.31	
750528	228 37.43	66-46.93	148-29.13	10.00*	2.03	4 208145.7	0.70	
750630	037 46.07	66- 5.62	147-15.95	10.00*	1.68	4 237105.4	0.61	
750808	1144 39.0	68 57.6	145 09.0	18.0	4.5	18	1.2	
751201	1533 49.47	66- 7.91	142-44.68	10.00*	3.19	6 273121.7	0.23	15.0
751201	2148 42.55	66-24.70	148-48.09	10.00*	2.9	5 256171.6	0.67	120.0
751231	1721 48.74	66-22.27	147-19.81	10.00*	2.60	5 198 95.9	0.98	152.2
760110	1310 33.08	66-31.25	146-22.25	10.00*	2.62	4 203 51.0	0.35	
760115	712 26.29	66-47.82	145-51.91	10.00*	1.36	4 236 38.0	0.47	
760118	452 39.75	68-24.76	149-24.61	10.00*	3.66	4 284272.6	0.98	
760118	1521 40.51	67- 9.24	149- 8.95	10.00*	2.15	5 232183.7	0.96	64.5
760120	276 44.38	66-53.94	149- 2.38	10.00*	3.02	6 217172.2	0.65	40.0
760121	738 11.89	66- 1.14	148- 8.09	10.00*	2.15	5 181120.1	0.30	6.0
760131	855 16.81	66-56.39	147-17.90	10.00*	3.02	6 224100.0	0.36	14.5
760207	2329 4.48	66- 3.08	147-50.58	10.00*	2.32	4 281120.5	0.09	
760210	1614 22.62	67-21.03	145-56.05	10.00*	2.83	3 292 92.7	0.61	
760212	2335 15.49	66-56.30	147-36.45	10.00*	3.09	4 221112.4	0.99	
760213	2026 33.05	66-34.45	148-23.98	10.00*	2.53	4 194140.5	0.60	
760214	556 33.14	66-43.46	145- 2.73	10.00*	1.45	3 354 19.5	0.90	
760214	1319 41.04	67-27.83	147-53.34	10.00*	2.76	4 275153.2	0.49	
760214	2357 5.84	67-54.74	146-15.35	10.00*	3.35	4 303156.5	0.57	
760216	17 3 1.01	67- 3.91	147-26.06	10.00*	2.05	4 232111.7	0.57	
760217	2317 26.49	66- 2.70	148-31.00	10.00*	2.26	5 188129.0	0.33	6.7
760219	456 9.47	67- 2.50	142-27.21	10.00*	4.39	6 227320.5	0.70	44.8
760308	721 48.31	67- 7.09	144-39.71	10.00*	2.99	3 268 76.6	0.18	
760309	148 7.81	67-18.28	149-14.54	10.00*	2.83	5 240194.0	0.27	90.2
760309	1154 52.83	67-11.04	146-55.03	10.00*	2.53	5 246101.0	0.48	139.6
760317	2337 3.29	66- 7.04	144-31.25	10.00*	3.80	5 225 59.3	0.28	19.4
760403	6 6 12.23	66-30.71	147-17.54	10.00*	2.00	6 186 91.9	0.79	19.6
760405	22 1 53.24	69- 5.56	147-13.60	10.00*	2.05	4 182 79.1	0.74	
760407	2232 24.36	69-37.87	145- 3.76	10.00*	1.64	3 168 27.4	0.00	
760412	723 59.61	69-42.56	145-48.31	10.00*	0.69	4 264 10.1	0.15	
760412	2159 27.03	69- 8.45	147-35.31	10.00*	2.26	4 250 85.7	1.30	
760413	745 15.49	66-15.43	147- 4.49	10.00*	2.23	4 184 89.3	0.43	
760424	2142 20.47	69-29.50	143-38.44	10.00*	1.51	5 197 26.1	0.08	35.4
760425	639 12.58	65-42.23	148-31.96	10.00*	1.82	3 195164.2	0.07	
760426	1255 46.95	66-15.90	149- 7.95	10.00*	2.43	4 211163.6	0.82	
760427	2221 19.05	66-30.87	148-59.60	10.00*	2.84	5 213169.1	0.42	0.2
760429	2079 27.44	66-20.07	144-42.78	10.00*	3.51	5 238350.7	0.07	6.5
760430	622 35.47	68-54.76	145-20.79	10.00*	2.75	5 130 82.2	0.81	14.4
760503	1445 4.32	69- 4.10	144-47.59	10.00*	1.55	4 270 60.2	1.05	
760505	023 12.00	66-53.51	136-27.08	10.00*	4.09	5 283389.5	0.40	48.8
760505	222 47.29	66-54.89	136-29.22	10.00*	4.19	5 268388.1	0.17	10.5
760506	274 41.76	68-40.10	144-18.63	10.00*	3.16	4 160102.5	0.51	
760507	539 19.55	66-25.49	146-57.32	10.00*	3.07	4 176 78.3	1.05	
760508	610 33.83	67-17.26	147-54.30	10.00*	3.00	5 171142.1	0.01	0.2
760509	1249 30.25	66-34.06	146-52.64	10.00*	1.70	3 263 73.0	0.54	
760513	1832 50.09	69-36.40	143-42.23	10.00*	0.94	4 204 26.1	0.02	
760515	2 6 4.88	69-27.84	146-30.89	10.00*	2.15	3 326 30.2	0.05	
760518	12 3 39.57	69- 1.69	144-57.50	10.00*	1.65	6 276 66.5	0.92	5.0
760519	1624 36.17	69-29.54	143-46.57	10.00*	0.85	6 196 25.5	0.09	15.0
760519	1638 8.55	69-27.41	143-48.08	10.00*	0.71	5 205 26.6	0.15	22.4
760519	1831 10.81	69-24.49	144-50.50	10.00*	0.83	4 220 27.1	0.94	
760521	23 5 13.91	69-15.08	144- 6.77	10.00*	1.64	3 245 38.8	0.00	
760527	743 6.72	67- 8.05	144-14.18	10.00*	2.75	5 200 76.9	0.94	16.9
760527	2151 36.86	69- 8.83	144-21.28	10.00*	1.50	4 307 49.0	1.17	
760530	7 4 3.97	69-34.42	144- 8.67	10.00*	0.44	3 182 8.9	0.60	
760530	16 1 55.31	69-37.65	143-29.29	10.00*	0.87	4 218 23.1	0.02	
760601	15 8 55.56	69-15.61	144- 7.72	10.00*	1.45	4 288 37.6	0.70	
760602	1551 21.51	67-21.36	144-21.79	10.00*	2.01	4 190 95.9	0.27	
760602	2123 0.65	67-20.06	144-28.74	10.00*	2.78	3 200 91.8	0.27	
760608	1936 32.38	66-20.60	149-10.94	10.00*	2.85	5 216172.2	0.75	18.8
760613	23 0 23.53	66- 1.58	146-43.13	10.00*	3.54	6 158 89.9	1.19	26.9

TABLE 3 (Cont'd)

Date	Origin	Lat(N)	Long(W)	Depth	Mag	No	Gap	Dmin	RMS	ERH
760616	1727 25.11	66-26.11	148-43.68	10.00*	2.85	4	290	172.8	0.87	
760621	837 35.81	69-42.65	142-42.05	10.00*	2.53	4	234	23.7	0.02	
760623	1156 0.38	69-42.48	142-45.39	10.00*	2.75	4	232	22.5	0.04	
760623	16 2 35.65	66-54.89	136-29.73	10.00*	3.32	5	282	387.8	0.16	10.6
760624	1243 39.57	66-35.35	146- 3.94	10.00*	3.65	4	182	37.1	0.17	
760624	1318 28.21	66-22.64	146-20.50	10.00*	3.05	6	163	53.7	0.36	9.2
760628	212 41.77	66- 2.33	147-58.20	10.00*	3.26	6	154	136.2	0.54	6.8
760702	013 5.21	67- 8.17	143-18.17	10.00*	1.98	4	156	2.8	0.34	
760722	1940 6.21	67-22.26	143-39.39	10.00*	2.20	4	190	31.2	0.16	
760728	7 4 41.68	69-35.30	144-22.36	10.00*	1.54	3	297	0.2	0.26	
760728	856 9.49	69-34.89	144-13.09	10.00*	1.72	4	182	6.0	0.18	
760802	720 3.44	68-20.47	147-51.23	10.00*	2.87	4	238	120.6	0.00	
760809	1646 23.08	69-46.54	144-11.75	10.00*	1.81	3	190	22.1	0.00	
760811	1632 35.70	69-45.32	144-11.35	10.00*	1.25	4	186	20.1	0.06	
760819	1130 44.87	68-43.01	147-16.01	10.00*	3.73	9	206	90.8	0.50	4.9
760823	9 9 4.46	66-25.84	147-24.63	10.00*	2.84	7	136	77.9	0.33	3.0
760826	313 48.89	69-43.72	143-44.87	10.00*	1.47	5	128	28.9	1.30	7.3
760829	1916 4.88	68-10.85	143-10.75	10.00*	2.35	6	178	104.3	0.87	15.1
760906	236 20.12	69-47.88	145-46.85	10.00*	1.54	4	281	19.9	0.87	
760916	2123 15.97	66-54.56	143-42.30	10.00*	3.32	4	202	32.9	0.03	
760917	1040 7.09	69-34.96	142-18.86	10.00*	2.22	4	295	26.7	0.45	
760923	2245 30.58	68-10.80	145-50.13	10.00*	2.70	7	154	7.0	0.48	4.5
760930	1977 45.60	69-10.72	143-54.48	10.00*	2.45	5	132	49.0	0.31	1.9
761004	4 1 26.51	67-47.53	145-26.23	10.00*	3.65	4	143	40.9	0.25	
761021	1529 4.14	69-13.72	143-49.41	10.00*	1.77	5	253	45.4	0.26	49.2
761022	1613 37.48	68-17.03	144-32.34	10.00*	2.22	6	132	116.2	0.86	13.2
761030	14 2 50.73	69-35.34	145-11.51	10.00*	1.82	4	183	27.6	0.14	
761030	1530 7.83	69- 8.14	144-11.81	10.00*	1.76	3	261	50.8	0.01	
761105	9 4 51.51	69-16.04	145-26.68	10.00*	2.08	4	262	43.5	0.37	
761125	2244 43.90	68-37.69	148- 4.33	10.00*	2.78	5	231	141.0	0.11	5.8
761206	1357 17.12	66-32.82	148-36.57	10.00*	3.48	5	223	91.6	0.79	5.2
761207	17 8 11.25	69-30.65	145- 9.02	10.00*	2.05	4	122	31.5	0.33	
761222	1950 10.41	67-12.38	145- 0.61	10.00*	2.70	5	182	58.7	0.18	4.0
761223	1216 24.53	68-55.16	146-14.38	10.00*	2.50	6	180	79.8	0.60	13.3
761226	256 25.46	66-52.56	143-13.44	10.00*	2.27	5	258	95.2	0.33	21.1
761227	0 0 56.79	66-25.22	147-18.99	10.00*	2.71	5	191	94.2	0.52	72.5
761228	643 26.96	69-40.58	144-33.38	10.00*	1.21	4	241	12.3	0.05	
761230	18 6 36.67	68-55.59	146-25.21	10.00*	2.61	6	187	80.5	0.83	12.0
770103	430 28.62	66-56.79	145-49.04	10.00*	1.85	3	166	49.6	0.01	
770103	431 39.58	66-56.83	145-48.70	10.00*	2.08	3	166	49.6	0.00	
770103	1077 49.65	69-19.90	142-53.27	10.00*	2.48	7	207	21.5	0.41	5.4
770109	1141 6.22	66-29.29	144-39.03	10.00*	2.35	5	287	27.3	4.11	16.2
770110	1917 20.20	68-55.42	145-47.28	10.00*	2.37	6	171	78.2	0.74	12.8
770110	20 8 10.98	69- 9.81	143-34.80	10.00*	2.82	5	227	56.5	1.24	126.6
770111	957 14.67	66-21.41	144-53.34	10.00*	3.41	5	242	27.9	0.49	25.8
770115	1419 38.90	69-34.74	144-20.70	10.00*	2.53	4	193	1.3	0.38	
770119	839 15.30	69- 9.10	143-48.02	10.00*	2.00	5	176	52.5	0.36	3.3
770127	1278 41.57	69-30.66	144-41.00	10.00*	1.02	3	196	14.8	0.00	
770203	220 30.97	69-10.90	143- 6.72	10.00*	2.51	3	208	67.0	0.00	
770208	724 11.70	69-11.43	144-54.70	10.00*	2.40	4	170	49.0	0.65	
770210	7 8 11.10	69-59.46	144-44.06	10.00*	2.08	4	295	47.2	0.09	
770217	2053 43.17	66-47.18	148-33.68	10.00*	2.81	6	242	56.4	0.12	2.7
770311	3 6 36.20	67-11.05	145-36.51	10.00*	3.50	5	171	257.9	0.31	22.0
770313	556 13.91	69-13.94	145- 4.79	10.00*	2.54	5	156	48.4	0.77	14.0
770326	2028 0.82	69-18.88	144-29.77	10.00*	1.88	3	190	30.7	0.00	
770406	250 59.59	68- 1.98	147-27.43	10.00*	2.53	5	230	74.6	0.44	2.8
770422	1747 57.13	67-55.32	148-16.52	10.00*	3.39	5	185	79.0	0.75	6.5
770424	245 26.16	66-37.81	148- 1.83	10.00*	2.80	5	236	67.7	0.20	6.0
770424	7 2 18.03	66-43.14	145-11.69	10.00*	2.42	6	169	17.1	0.19	7.6
770430	130 3.87	66-20.65	137-20.08	10.00*	3.57	6	308	352.4	0.49	67.1
770501	178 10.92	66-42.10	145-33.42	10.00*	2.22	6	205	20.9	0.58	42.7
770507	4 8 40.49	67-47.32	148-34.05	10.00*	2.07	6	274	60.9	0.71	1.9
770512	14 8 6.39	67-26.14	150- 1.94	10.00*		4	314	49.2	0.23	
770515	1624 12.25	67- 1.48	146-54.79	10.00*	2.35	5	162	13.8	0.35	3.0
770518	1 0 19.33	68-46.14	142-17.18	10.00*	2.46	4	309	155.8	0.22	
770604	1956 11.37	66-25.65	147-16.01	10.00*	2.36	6	134	77.4	0.67	9.5
770605	10 1 27.36	67-26.66	149-36.51	10.00*	1.79	4	298	33.7	0.58	
770607	1343 59.97	67- 0.41	146-58.16	10.00*	1.96	5	166	14.1	0.12	1.1
770607	1573 27.12	66-26.78	152-36.31	10.00*	2.95	6	191	64.0	0.29	10.7
770618	1117 47.71	66-35.46	147-21.69	10.00*	1.86	6	225	59.9	0.76	4.9
770624	17 4 53.80	67-18.30	142-49.21	10.00*	2.05	4	308	25.7	0.55	
770625	1221 4.26	67-22.99	142-55.04	10.00*	1.93	5	261	30.3	0.90	63.6
770625	2232 14.99	67-39.67	147- 4.13	10.00*	2.48	6	165	43.1	0.37	4.3
770701	2017 55.21	67-20.56	149-18.36	10.00*	1.26	3	324	16.6	0.00	
770703	1742 23.23	66-15.80	136-38.15	10.00*	3.75	4	332	444.6	0.45	
770707	754 36.98	66-24.51	148-48.50	10.00*	2.14	8	128	95.9	0.40	1.7
770709	359 16.89	66-34.31	147-24.01	10.00*	2.52	4	228	62.3	0.16	
770709	1975 39.34	66- 8.33	148-43.08	10.00*	2.76	8	119	126.2	0.41	3.7
770712	318 10.24	66- 9.93	149-26.48	10.00*	2.92	6	211	124.4	0.80	17.1
770712	325 9.73	66-10.17	149-30.39	10.00*	2.37	6	144	124.5	0.60	7.4
770712	1522 53.64	66-33.38	147- 9.00	10.00*	2.09	4	225	62.8	0.20	
770713	432 26.46	67-24.77	149-54.57	10.00*	2.70	5	261	43.5	0.18	7.8
770729	727 55.07	68- 8.13	145-19.64	10.00*	2.37	7	117	15.3	0.77	8.9
770729	1538 32.55	67- 6.26	145-56.29	10.00*	2.74	6	119	40.8	0.40	2.6
770729	1553 16.25	67- 6.30	145-57.98	10.00*	1.50	6	120	40.4	0.25	2.4
770802	16 2 44.39	67-58.91	144-21.51	10.00*	2.83	8	135	58.5	0.17	1.4
770804	1150 34.56	66- 1.68	148-25.55	10.00*	2.69	8	108	125.6	0.69	5.9
770806	053 29.05	69-20.05	142-25.75	10.00*	2.94	6	247	30.0	0.22	20.7
770807	12 2 29.19	66-16.98	149-49.64	10.00*	2.34	5	282	149.0	0.78	66.0
770825	1851 37.29	67- 1.21	146-31.61	10.00*	2.41	8	82	27.9	0.38	2.3
770825	2233 1.16	67-15.30	147-45.58	10.00*	1.78	3	207	31.7	0.01	
770826	1072 49.75	66-31.04	148-10.25	10.00*	2.12	5	157	81.6	0.14	3.0

TABLE 3 (Cont'd)

Date	Origin	Lat(N)	Long(W)	Depth	Mag	NoGapDmin	RMS	ERH
770828	638 25.39	66-32.52	146-59.82	10.00*	2.07	5 118 64.6	0.70	96.3
770829	11 8 49.37	68-33.90	145-32.23	10.00*	2.57	7 157 47.2	0.75	8.3
770831	230 25.93	66- 5.73	149-36.55	10.00*	2.16	4 272141.2	0.65	
770903	319 1.83	66-53.36	139-33.91	10.00*	3.23	5 287252.8	0.46	78.5
770906	1149 33.93	67-20.71	144-52.13	10.00*	2.16	4 212 58.9	0.33	
770910	1729 52.27	67-22.20	145-59.94	10.00*	1.96	6 94 13.1	0.25	2.2
770913	1345 31.20	67-15.24	145-50.38	10.00*	1.52	4 202 57.2	5.66	
770916	16 3 19.12	69-22.06	144-41.83	10.00*	2.38	5 141 27.6	0.69	0.4
770916	2119 1.73	68-35.45	147-34.58	10.00*	2.88	7 207 92.0	0.44	7.8
770919	839 40.24	66- 7.91	149-40.10	10.00*	2.40	4 274141.9	0.63	
770919	9 0 21.27	66-57.95	144-31.25	10.00*	2.06	6 144 54.5	0.67	7.9
770919	2035 40.89	67-24.65	142-55.51	10.00*	2.25	5 259 32.9	0.64	27.0
771005	323 57.40	66-52.81	145-14.00	10.00*	1.53	4 147 35.0	0.91	
771007	639 34.50	67-32.90	149-42.31	10.00*	2.72	6 276 44.4	0.89	43.9
771007	2045 42.56	66-19.82	147-17.79	10.00*	2.28	4 172 88.4	0.03	
771008	2250 54.74	66-55.67	147-37.65	10.00*	3.52	4 192 30.9	0.18	
771009	1115 43.94	66- 1.15	148-15.56	10.00*	2.42	9 95121.9	0.82	6.3
771013	22 2 38.71	67-48.91	148-45.96	10.00*	3.27	4 236206.9	0.85	
771025	1928 46.69	69-17.71	142-58.75	10.00*	2.25	5 197 25.2	4.18	
771030	2058 9.03	68- 6.38	152-22.65	10.00*	3.22	4 298352.6	0.34	
771031	312 14.32	67-32.63	147- 6.85	10.00*	2.37	5 216 39.8	0.67	0.1
771102	455 56.42	66-29.83	147-21.23	10.00*	2.60	8 95 70.2	0.89	6.3
771104	2370 15.35	67-24.42	155-29.58	10.00*	3.24	7 220169.4	0.70	11.3
771105	040 42.64	66-19.43	150-14.19	10.00*	2.50	6 238118.8	0.52	19.9
771106	2049 38.03	67-58.47	144-20.88	10.00*	2.90	6 135 59.2	0.21	2.2
771106	2145 48.75	67-59.63	144-20.96	10.00*	2.87	5 136 99.2	0.19	1.4
771109	712 51.53	66-30.74	149- 7.32	10.00*	2.23	6 188164.8	0.87	3.4
771109	729 46.53	66-25.05	148-57.02	10.00*	2.82	10 100 94.6	0.69	3.8
771115	141 45.74	66-40.57	147-11.79	10.00*	2.37	4 128 88.0	0.33	
771116	1445 30.72	68- 6.06	145-20.32	10.00*	3.23	7 250 15.6	0.39	7.2
771117	554 37.60	66- 5.19	150-49.42	10.00*	3.12	8 123105.2	0.53	4.7
771122	712 44.89	69-16.38	146-14.19	10.00*	2.28	5 172 41.4	0.04	0.0
771203	1734 41.97	66-31.94	147-34.19	10.00*	2.19	4 154102.4	0.37	
771205	1858 22.55	66-42.40	147- 1.57	10.00*	2.15	4 194 81.1	0.75	
771210	2318 2.67	69- 4.13	147-44.18	10.00*	2.79	5 173103.8	0.33	22.6
771213	859 14.72	69-38.47	144-51.08	10.00*		3 167 40.6	0.00	
771215	254 29.99	66- 2.89	149-41.59	10.00*	2.81	6 163159.3	0.25	3.8
771217	719 19.86	67-21.61	146-22.83	10.00*	2.40	4 126 41.7	0.64	
771217	719 59.52	66-53.40	147- 2.67	10.00*	2.69	3 182 25.8	0.00	
771218	715 9.33	66- 5.59	146-33.27	10.00*	2.46	5 149 79.4	0.41	30.8
771226	1313 35.29	69-34.24	146-17.33	10.00*	1.91	4 326 16.5	0.60	
771226	1643 9.78	66-20.03	149- 2.20	10.00*	2.14	5 237168.2	0.78	8.4
771227	13 7 32.32	66- 7.45	146-41.62	10.00*	2.35	5 141 82.1	0.41	7.2
771231	826 20.34	66-42.55	148-12.31	10.00*	2.34	3 235 70.6	0.09	
780103	1027 49.72	69-20.00	142-54.08	10.00*	2.52	6 206 21.2	0.41	6.9
780106	2159 42.36	68- 6.09	145-23.42	10.00*	3.16	4 322170.7	0.05	
780111	2014 15.33	67-20.94	141- 7.83	10.00*	2.86	3 261199.1	0.48	
780111	2033 27.01	67-30.91	159-48.10	10.00*	3.72	8 303465.3	5.90	195.5
780121	2249 45.04	66-20.19	154-57.90	10.00*		9 280283.1	2.81	121.8
780125	970 21.91	69-18.55	142-50.02	10.00*	3.50	9 212 24.3	0.44	4.8
780125	1014 12.87	69-18.88	142-53.02	10.00*	1.93	4 295 23.3	0.76	
780208	139 58.53	68-53.17	146-19.73	10.00*	2.54	5 160 84.1	0.09	2.5
780214	2224 30.16	69- 4.19	139-52.50	10.00*	2.99	5 270132.4	3.29	150.8
780222	1940 2.24	68-38.52	143-34.80	10.00*	2.39	4 306101.0	1.57	
780224	1713 58.24	68-46.32	143-27.34	10.00*	2.86	7 184 85.7	3.75	58.5
780224	1714 49.33	68- 9.72	135-23.69	10.00*	3.79	5 316341.7	2.94	969.9
780226	011 3.41	67-21.92	159-39.98	10.00*	3.95	9 306460.8	6.46	457.8
780301	1158 15.14	66-20.25	156- 2.14	10.00*	4.19	11 287327.3	7.68	233.8
780312	1846 39.55	69-16.23	143-42.70	10.00*	2.04	4 249 40.2	0.24	
780317	314 40.59	67- 2.65	139-10.94	10.00*	3.33	6 286271.4	0.85	75.2
780325	524 32.23	66-33.24	147- 9.53	10.00*	3.49	10 122 85.5	2.75	17.4
780326	4 6 19.24	68-23.04	146-13.22	10.00*	3.22	9 142138.9	7.58	48.8
780329	1950 42.64	68-51.36	145-13.01	10.00*	2.22	5 148 88.1	0.20	1.7
780406	036 55.18	68-48.48	144-26.78	10.00*	3.21	9 151 86.9	0.83	3.4
780406	454 57.10	66-46.62	136- 6.06	10.00*	3.86	7 282419.2	0.34	45.7
780413	1539 34.74	69- 9.16	143-32.15	10.00*	2.13	6 166 46.7	4.48	63.5
780415	879 36.36	66-32.48	135-56.02	10.00*	3.80	8 283412.3	0.44	21.3
780421	846 25.15	69-15.46	144-57.13	10.00*	1.87	5 125 43.2	0.77	5.2
780421	854 45.17	69- 5.79	145- 2.17	10.00*	1.99	4 271 60.7	0.60	
780422	1716 21.28	68-52.60	146-22.48	10.00*	2.18	5 162 85.5	0.31	9.2
780429	1479 11.11	69-31.12	144-33.92	10.00*	1.78	4 193 10.7	0.40	
780430	934 56.87	67-42.61	143-25.64	10.00*	2.39	7 168 63.9	1.11	23.7
780430	1012 37.74	69- 9.68	144-41.17	10.00*	1.72	4 139 49.0	0.18	
780430	1240 42.36	69-35.80	144-33.75	10.00*	1.86	3 184 7.5	0.14	
780502	15 1 59.70	69-33.69	144- 3.52	10.00*	1.56	3 180 12.5	0.02	
780507	827 11.75	69-30.18	144-25.48	10.00*	1.76	3 195 9.6	0.00	
780512	1927 42.91	69- 9.36	144-48.44	10.00*	1.98	4 136 51.0	0.26	
780512	1939 13.76	69- 8.90	144-48.86	10.00*	1.88	4 137 51.9	0.23	
780519	1051 41.76	69-22.77	145-21.76	10.00*	1.48	3 242 34.2	0.09	
780522	2073 43.86	69-10.11	144-59.77	10.00*	2.51	5 131 52.7	0.77	59.0
780609	12 5 29.10	69-14.13	146- 8.93	10.00*	3.11	10 165 44.5	0.66	3.7
780621	1353 3.41	69-28.93	143-54.19	10.00*	2.65	7 166 21.7	0.95	26.0
780624	1220 37.71	68-49.01	144-10.54	10.00*	3.03	8 160 86.2	0.94	11.6
780701	1357 4.94	68-49.12	144-25.96	10.00*	3.15	9 129 91.0	0.91	5.0
780703	1218 4.43	69-53.12	145-53.24	10.00*	2.10	4 252 29.2	0.03	
780703	21 8 18.41	68- 9.09	159-56.93	10.00*	4.06	12 302475.3	5.77	203.9
780705	12 3 58.79	69-22.23	144-14.36	10.00*	2.77	7 130 52.3	2.72	16.5

TABLE 4

DATE	ORIGIN	LAT (N)	LONG (W)	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH
790101	518 28.62	66-19.89	163-35.41	10.00*	1.94	4	129	41.9	3.62	
790101	533 49.02	66-22.06	163-54.13	10.00*	1.53	4	149	28.5	3.39	
790101	540 50.94	67-27.55	166-45.80	10.00*	2.02	4	302	161.2	1.59	
790102	1 8 55.03	66-24.99	163-53.45	10.00*	1.72	4	161	30.5	3.36	
790102	1958 38.73	65-50.07	164-36.57	10.00*	1.90	4	204	145.1	1.03	
790106	1935 41.10	65-16.38	165-22.30	10.00*	3.20	4	144	79.5	7.97	
790106	2040 25.18	65-14.60	166-57.05	10.00*	2.09	3	267	106.8	1.46	
790106	22 7 37.13	64-14.24	163-32.66	10.00*	2.04	3	198	95.1	0.01	
790108	13 0 41.26	64-35.24	158-34.42	10.00*	2.65	3	284	122.1	0.00	
790109	1748 2.54	66-22.06	157-23.04	10.00*	2.38	5	178	170.2	0.75	16.4
790111	155 5.94	66-50.87	163-43.92	10.00*	1.81	3	239	49.1	0.01	
790112	510 39.63	65-15.56	164-21.40	10.00*	1.75	3	231	91.6	0.06	
780112	1139 22.54	65-16.11	164-23.63	10.00*	2.30	3	233	91.5	0.08	
780112	1150 49.57	65- 1.08	164- 5.18	10.00*	1.84	4	148	79.6	0.99	
790114	445 18.99	65-12.09	161-48.62	10.00*	2.11	4	110	37.0	0.14	
780115	719 2.37	64-20.79	165-22.30	10.00*	0.96	3	302	23.8	1.90	
780117	2344 40.71	66-50.89	163-44.19	10.00*	1.39	3	239	49.3	0.01	
790119	620 13.21	61-22.38	168-38.11	10.00*	3.19	3	315	275.7	2.25	
780119	2027 36.20	64-14.35	161-49.96	10.00*	0.68	3	161	75.0	0.00	
780121	2249 34.74	66-14.55	157-28.51	10.00*	3.73	6	170	172.1	0.31	4.0
790122	1646 30.27	66-34.13	162- 7.62	10.00*	2.44	4	196	38.6	0.17	
780123	726 36.15	64-31.02	164-54.82	10.00*	3.10	4	174	22.4	0.06	
780123	1358 58.24	63-56.41	164-16.12	10.00*	2.08	3	231	87.3	0.01	
780125	527 30.35	64-43.59	165-58.71	10.00*	1.43	4	258	34.6	0.38	
780128	1941 26.30	63-22.64	165-49.33	10.00*	2.87	6	201	133.7	0.30	4.1
780130	032 55.49	65-57.94	165- 2.75	10.00*	1.49	3	283	45.4	0.39	
790130	421 10.81	64-34.08	165-31.29	10.00*	1.84	4	266	7.3	1.55	
780131	0 1 37.60	65-34.51	162-45.89	10.00*	1.33	4	124	72.8	0.40	
790131	337 51.58	65-15.99	164- 4.64	10.00*	2.20	4	136	99.8	0.70	
780131	1423 19.18	65-22.27	164-20.67	10.00*	1.11	4	147	102.6	0.12	
780131	1649 48.14	65-22.46	165- 9.59	10.00*	1.93	3	189	91.3	0.09	
780131	17 0 21.78	66-13.39	162-51.70	10.00*	1.31	3	138	71.6	0.00	
780201	230 51.96	64-57.52	162-31.82	10.00*	2.48	5	111	80.3	0.20	3.7
790201	2239 49.81	64-21.13	162-41.68	10.00*	1.25	3	164	118.1	0.00	
790202	522 19.60	65- 4.83	157-54.20	10.00*	1.92	3	163	160.1	0.00	
780204	232 12.91	64-31.04	163-40.77	10.00*	2.06	4	159	81.4	0.25	
780204	1832 27.01	66-58.15	162-53.36	10.00*	1.12	3	271	17.4	0.71	
780207	2147 31.06	66-38.40	161-14.63	10.00*	1.85	3	248	65.1	0.26	
780208	1439 23.25	64-38.51	162-53.31	10.00*	1.65	3	140	117.5	0.00	
780209	1810 13.46	63-23.15	162-58.31	10.00*	2.39	3	253	134.4	0.17	
780209	22 5 12.96	65- 8.67	162-17.87	10.00*	1.07	4	97	59.0	0.38	
780210	1428 36.71	64-16.59	162-41.98	10.00*	2.70	4	172	114.9	0.96	
790215	1718 44.76	63-34.69	165-32.00	10.00*	1.77	3	287	250.7	0.10	
780215	1740 4.27	66-27.96	163-56.89	10.00*	1.33	3	177	30.8	0.02	
780216	750 44.23	64-59.44	170-36.39	10.00*	2.92	4	319	253.5	0.96	
780219	1340 55.83	64-36.64	172-41.10	10.00*	3.20	4	331	350.3	1.60	
780224	1750 37.12	65-34.11	163-19.52	10.00*	1.65	3	228	98.2	0.39	
790225	1511 6.06	65-37.19	165-47.69	10.00*	1.49	4	226	96.5	0.19	
790226	2159 42.58	65-52.19	166-31.59	10.00*	2.52	5	258	103.3	1.08	46.3
790228	851 31.40	65-55.23	156-19.94	10.00*	3.60	3	186	121.6	0.00	
780228	1623 8.24	64-52.75	174- 9.14	10.00*	3.56	4	331	420.5	1.45	
790228	1628 37.31	64-48.54	165-46.39	10.00*	2.31	4	234	33.8	0.56	
780303	8 7 6.73	64- 6.69	169-43.75	10.00*	4.20	6	186	59.3	1.76	102.1
790303	1156 38.86	60-52.58	165-43.79	10.00*	2.89	4	324	411.0	2.59	
790304	557 4.46	65- 9.37	165-13.95	10.00*	1.19	4	189	66.8	0.39	
780305	1449 22.91	66- 3.82	172-29.45	10.00*	2.72	3	329	360.1	0.75	
780306	1411 7.91	64-51.05	169-27.49	10.00*	2.27	4	213	138.0	0.06	
780307	511 43.05	66-22.44	163-34.51	10.00*	1.01	3	138	43.0	0.00	
790308	1327 58.90	66-51.57	163-16.66	10.00*	1.20	3	228	29.2	0.01	
790308	1424 25.34	66-42.03	162- 0.15	10.00*	1.10	4	223	32.0	0.61	
790310	720 30.19	65-38.09	166-27.01	10.00*	2.73	6	188	115.7	0.47	7.5
780310	1527 23.54	65-41.00	166-57.53	10.00*	1.67	5	199	131.1	2.37	18.6
790310	1530 58.89	65-48.45	168-53.22	10.00*	2.09	4	297	205.3	1.81	
790310	1532 22.50	65-37.09	166-31.59	10.00*	1.75	3	254	119.5	1.17	
780310	2159 35.89	65-40.31	163- 9.37	10.00*	1.12	3	210	94.7	0.00	
790311	1437 22.98	66-51.53	161- 5.51	10.00*	1.62	3	272	66.6	0.95	
790315	751 37.85	63-56.00	163-11.72	10.00*	2.90	4	211	126.7	0.31	
790317	21 3 55.91	65- 9.28	166-42.56	10.00*	1.49	3	262	91.8	0.23	
790318	1335 57.42	64-44.90	165-35.68	10.00*	1.70	5	223	23.6	1.24	60.9
790318	1554 11.15	66-33.73	164- 5.34	10.00*	0.59	3	208	33.9	0.36	
790319	540 19.98	65-56.18	167-13.99	10.00*	2.07	4	273	129.6	1.27	
790319	1925 18.78	65- 5.35	164- 2.16	10.00*	1.88	5	124	96.6	0.86	13.4
790319	2122 26.13	65- 3.44	164- 2.48	10.00*	1.70	4	122	84.0	0.76	
790320	410 13.62	66-42.08	157-35.11	10.00*	2.90	4	243	188.3	0.03	
790320	14 3 57.16	65- 0.81	164- 1.94	10.00*	1.87	5	120	91.2	1.05	33.2
790320	1743 17.10	64-44.41	173- 4.10	10.00*	2.90	4	331	367.8	1.90	

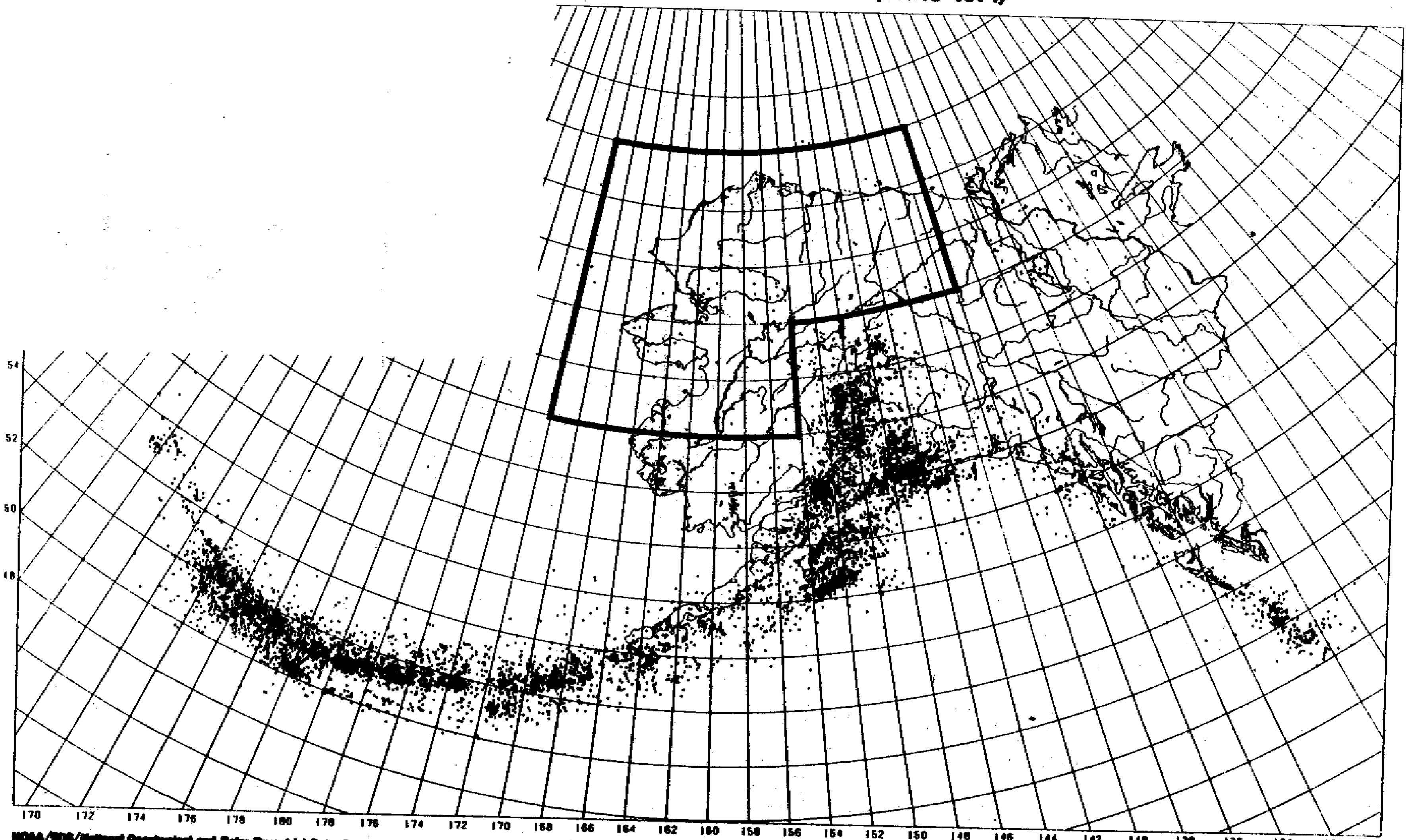
TABLE 4 (Cont'd)

Date	Origin	Lat(N)	Long(W)	Depth	Mag	NoGapDmin	RMS	ERH
780320	2139 3.44	66-21.72	162-12.82	10.00*	1.91	5 174 58.0	1.67	9.5
780323	124 39.13	65-14.13	169-12.37	10.00*	2.30	4 219182.3	0.98	
780327	254 5.81	65-23.30	166-27.14	10.00*	3.16	5 175105.5	0.95	21.9
780327	2246 8.91	64-47.94	164-18.73	10.00*	1.35	3 123 57.1	0.00	
780329	2352 49.70	64-34.14	163-29.60	10.00*	1.56	3 152 89.9	0.00	
780330	127 5.07	65- 0.94	157-40.21	10.00*	2.13	4 143185.4	0.46	
780330	10 9 37.81	64-58.23	164-14.30	10.00*	2.17	4 125 70.6	0.60	
780331	650 13.97	64-32.53	162-44.50	10.00*	3.14	4 147125.9	0.91	
780331	657 52.58	65- 6.10	164-56.28	10.00*	1.53	3 170 63.8	0.13	
780401	2136 45.31	65- 3.84	163-51.27	10.00*	4.11	6 103 91.4	1.83	7.7
780401	2141 52.14	64-51.84	164-34.83	10.00*	2.33	4 133 50.7	0.89	
780401	2151 15.69	65- 4.38	164-48.38	10.00*	1.44	3 178 63.2	0.00	
780401	2224 6.25	65- 2.58	164-10.34	10.00*	2.34	4 127 78.4	0.33	
780402	2020 39.95	64-38.12	166-11.36	10.00*	1.88	4 276 40.1	0.92	
780406	1927 32.27	64-43.10	166- 2.23	10.00*	2.24	4 263 36.5	1.32	
780407	1756 47.01	65-16.52	162-15.17	10.00*	1.99	4 157155.5	0.17	
780408	2012 37.30	64-44.03	162-32.75	10.00*	1.49	4 134136.0	0.45	
780408	2319 54.07	64-44.42	162-31.69	10.00*	1.46	4 135135.8	0.33	
780410	339 51.42	64-30.62	164-19.44	10.00*	2.11	4 166 50.6	1.67	
780413	1956 21.30	65-55.64	164-25.09	10.00*	2.13	3 158 43.3	0.00	
780414	1243 43.98	64-44.46	164-58.83	10.00*	0.91	3 162 27.4	0.00	
780414	19 4 22.38	64-44.13	166- 3.96	10.00*	2.12	3 262 38.6	1.14	
780418	314 44.78	65- 6.75	164-42.46	10.00*	1.63	3 179 69.2	0.01	
780418	1137 33.95	67-13.07	160-46.93	10.00*	2.24	4 229 89.4	0.48	
780419	1648 43.23	64-23.72	167-18.29	10.00*	2.50	4 164 94.8	0.83	
780420	1835 16.70	66-22.99	163-56.83	10.00*	1.96	4 155 27.0	1.90	
780422	953 58.90	64-50.07	162-23.05	10.00*	1.82	4 142138.5	0.48	
780426	232 17.98	64-44.86	165-40.70	10.00*	1.60	3 232 25.6	0.01	
780426	441 54.49	64-55.47	164- 8.50	10.00*	1.66	4 118 71.3	0.60	
780430	211 38.35	61-51.93	169- 0.54	10.00*	3.00	3 277217.3	0.65	
780504	710 19.78	64-30.56	163-15.57	10.00*	1.38	4 156101.6	1.65	
780505	2256 35.28	65-17.24	166-16.40	10.00*	1.51	3 243 91.7	0.07	
780507	2148 59.45	65-47.24	166- 2.26	10.00*	1.96	3 242 90.2	0.59	
780511	737 43.32	64-33.70	162-49.74	10.00*	1.29	3 146121.7	0.00	
780513	231 49.75	64-59.79	162-19.27	10.00*	2.35	4 148150.9	0.08	
780514	2345 2.93	62-36.91	169-30.77	10.00*	3.55	5 265129.8	1.62	85.9
780518	938 19.09	65-28.23	164-10.76	10.00*	1.71	3 184 95.2	0.01	
780518	1336 26.28	65-44.25	165-45.43	10.00*	1.90	3 229 85.2	0.90	
780520	1254 26.71	64-31.26	162-50.15	10.00*	1.87	4 150121.9	0.04	
780520	1345 33.86	64-30.38	162-50.84	10.00*	2.69	4 152121.4	0.01	
780523	1428 36.74	65-18.83	164-24.51	10.00*	1.63	3 183 95.6	0.00	
780528	1741 39.46	65-13.90	165-59.73	10.00*	2.60	4 231 80.5	0.66	
780529	1441 54.69	66-47.12	163-46.31	10.00*	2.72	4 229 51.7	0.93	
780530	2342 17.61	64-56.43	162-14.37	10.00*	2.52	4 149143.5	0.84	
780531	1151 22.64	65- 5.69	162-42.41	10.00*	2.25	4 141139.9	0.37	
780601	1759 58.68	65- 1.92	164-14.47	10.00*	1.61	3 131 75.2	0.00	
780602	725 37.20	65-20.40	162-36.11	10.00*	1.63	3 187139.6	0.00	
780605	1017 18.77	63-29.40	162- 0.45	10.00*	2.67	4 247 86.4	0.19	
780610	953 4.27	65-20.40	162-48.45	10.00*	1.83	3 182133.9	0.01	
780610	1753 10.14	65-22.96	164-15.72	10.00*	2.50	4 144104.4	0.56	
780612	1522 54.79	64-44.32	166- 2.05	10.00*	2.50	3 260 37.5	0.89	
780612	1612 11.00	65-32.13	164-40.06	10.00*	2.14	3 167 97.0	0.00	
780612	2021 8.82	64-50.30	161-34.36	10.00*	2.70	3 194117.2	0.00	
780613	2020 53.45	64-52.16	162-38.36	10.00*	2.02	3 165134.8	0.00	
780614	819 49.67	65- 1.78	164- 7.95	10.00*	2.70	3 133 78.7	0.00	
780619	513 29.51	64-41.29	166-16.87	10.00*	2.85	4 276 45.9	3.72	
780630	341 37.19	65-23.13	163- 2.43	10.00*	2.10	3 223123.7	0.05	
780630	1413 37.61	65-24.97	162-58.66	10.00*	2.06	3 224122.5	0.00	
780703	19 1 6.70	63-49.17	163- 3.69	10.00*	2.97	3 260125.4	0.94	
780705	1129 20.78	66-15.79	162-20.06	10.00*	1.51	3 173 67.4	0.00	
780710	1026 16.60	64-53.08	162-39.76	10.00*	2.43	3 195151.6	0.23	
780716	1050 8.97	66-22.84	163- 9.72	10.00*	2.12	3 131 58.5	0.00	
780718	521 29.48	64-42.74	164-22.95	10.00*	2.71	3 242178.6	0.22	
780722	1935 51.93	66-26.93	162- 4.35	10.00*	1.33	3 193 51.5	0.00	
780802	15 9 15.11	65-12.70	162-47.55	10.00*	2.17	3 237142.0	0.07	
780803	920 36.55	63-42.27	169-39.56	10.00*	2.99	3 203 40.6	0.01	
780815	1839 18.93	65-24.86	162-57.78	10.00*	1.75	3 224122.9	0.02	
780817	1729 16.63	66-45.46	163-32.67	10.00*	1.17	3 214 42.5	0.01	
780818	1741 57.26	65-23.17	162-35.02	10.00*	2.37	3 190136.2	0.01	
780827	2316 52.79	65-30.90	165- 7.38	10.00*	1.97	3 191 93.1	0.02	
780918	218 3.30	64- 8.31	165-14.59	10.00*	2.90	3 256 47.4	1.09	

TABLE 4 (Cont'd)

Date	Origin	Lat(N)	Long(W)	Depth	Mag	NoGapDmin	RMS	ERH
791007	1520 26.41	64-45.19	162-58.18	10.00*	3.12	6 130116.5	2.98	36.1
791018	1429 28.89	65-17.18	166-35.28	10.00*	2.40	3 255 99.4	0.00	
791019	1712 7.24	66-21.83	162-14.16	10.00*	1.40	3 154 38.2	0.00	
791021	22 6 31.02	65-34.17	167-22.64	10.00*	3.00	5 164 2.9	0.10	1.9
791023	320 53.72	66-28.86	162- 8.08	10.00*	3.43	7 133 46.2	2.17	16.6
791025	1239 14.62	63-39.39	164- 8.40	10.00*	1.82	3 248117.2	0.00	
791025	15 7 35.08	65-23.06	162-46.97	10.00*	2.18	3 290 96.4	0.11	
791026	419 5.52	64-56.04	162-18.85	10.00*	1.33	4 133135.1	0.63	
791027	546 30.31	66-24.99	162-25.25	10.00*	1.29	3 144 48.1	0.00	
791028	844 49.40	64-52.45	162- 5.84	10.00*	2.55	6 140129.0	1.99	14.1
791108	245 15.32	65-14.61	167-16.42	10.00*	1.51	3 218 36.3	0.01	
791121	8 2 12.89	65-31.08	167-24.83	10.00*	2.92	5 209 5.0	3.88	231.2
791122	5 0 48.99	65-43.61	165-41.88	10.00*	1.98	5 142 82.3	1.07	15.9
791122	1749 44.57	65-19.17	161-54.39	10.00*	1.94	6 152 89.3	0.78	11.9
791123	1043 24.97	65- 7.78	164-23.85	10.00*	1.41	4 167 78.6	1.35	
791124	028 48.70	63-31.73	155-38.02	10.00*	2.90	5 321252.7	2.09	545.0
791124	851 23.61	63-40.26	155-41.11	10.00*	3.00	5 318247.3	1.44	141.7
791127	1153 36.96	65- 2.04	163-35.30	10.00*	3.40	6 106 99.8	1.01	1.4
791203	048 36.77	66-21.24	157-28.40	10.00*	2.08	4 199173.9	0.91	
791204	552 9.08	64-53.13	162-24.38	10.00*	1.92	5 129138.5	1.11	18.4
791204	1056 21.60	60-41.69	163- 1.67	10.00*	4.20	7 279447.3	8.18	241.8
791205	1448 45.54	65-26.06	166-11.34	10.00*	1.96	5 125 59.5	9.39	405.6
791206	833 55.42	64-45.74	165-11.73	10.00*	1.80	3 190 24.1	0.00	
791206	12 9 26.58	66- 7.97	164- 1.61	10.00*	1.28	3 221 30.0	0.01	
791210	2321 35.06	65- 5.38	167-37.12	10.00*	2.17	5 250 53.3	1.85	371.5
791211	1136 28.12	65-44.56	166-56.88	10.00*	1.31	5 189 30.2	1.92	156.8
791212	14 7 59.85	63-19.57	166-34.43	10.00*	3.93	6 273149.7	0.47	23.7
791212	1512 23.93	65-39.46	161-27.00	10.00*	0.78	4 247 51.8	6.95	
791212	2239 18.48	66-50.63	161-36.15	10.00*	1.46	5 270 44.2	3.71	19.4
791214	1926 34.34	66-42.07	162-28.60	10.00*	0.77	4 170 18.4	1.27	
791218	210 49.05	65-54.83	162- 1.38	10.00*	2.69	5 127 27.8	0.26	3.0
791220	19 4 42.14	64-33.70	167-32.35	10.00*	2.23	3 272103.9	1.08	
791220	21 3 49.26	66-19.66	164-48.27	10.00*	0.57	3 319 12.8	0.23	
791224	7 2 0.26	66-38.06	157-23.81	10.00*	2.41	4 218177.8	0.81	
791224	1313 5.54	63-40.65	157-37.09	10.00*	4.50	21 138152.7	0.72	3.5
791225	155 56.40	66- 8.62	157-26.55	10.00*	2.41	4 184170.5	0.01	

EARTHQUAKES IN AND NEAR ALASKA (THRU 1974)



NOAA/EDS/National Geophysical and Solar-Terrestrial Data Center

Figure 1

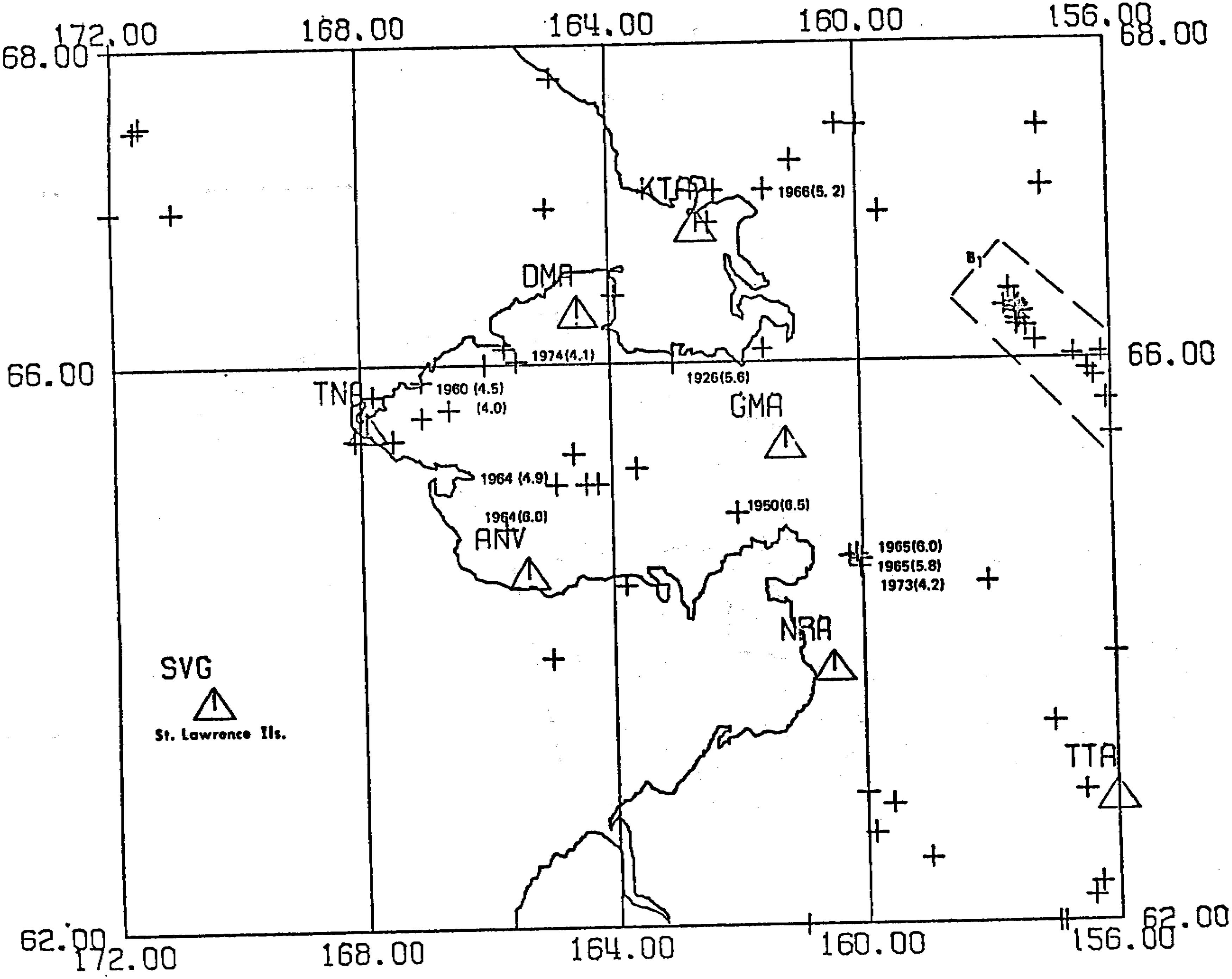

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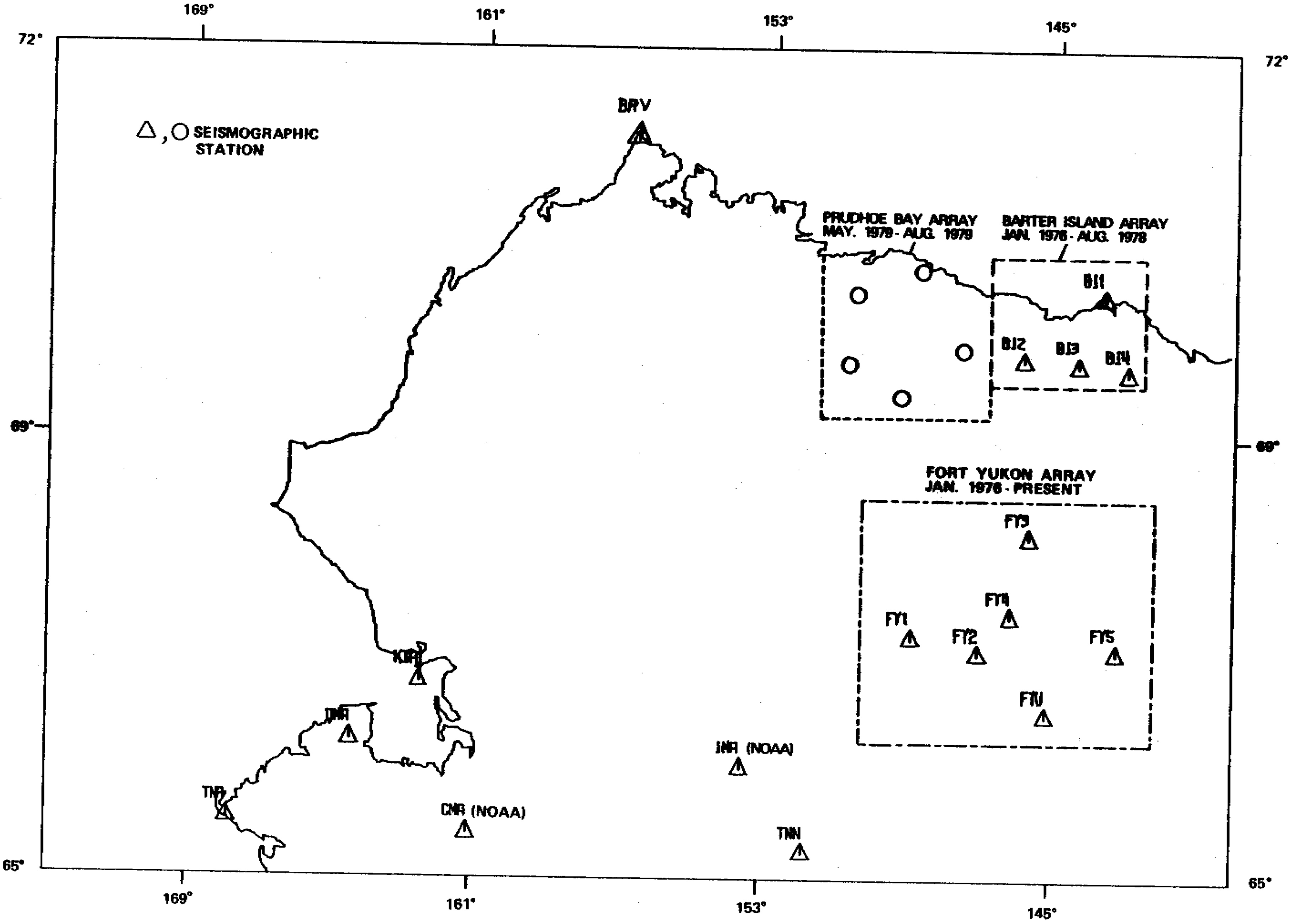
Figure 2

169°
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△, ○ SEISMOGRAPHIC STATION
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PRUDHOE BAY ARRAY
MAY. 1979 - AUG. 1979
BARTER ISLAND ARRAY
JAN. 1976 - AUG. 1978
BI1
BI2
BI3
BI4
FORT YUKON ARRAY
JAN. 1976 - PRESENT
FY3
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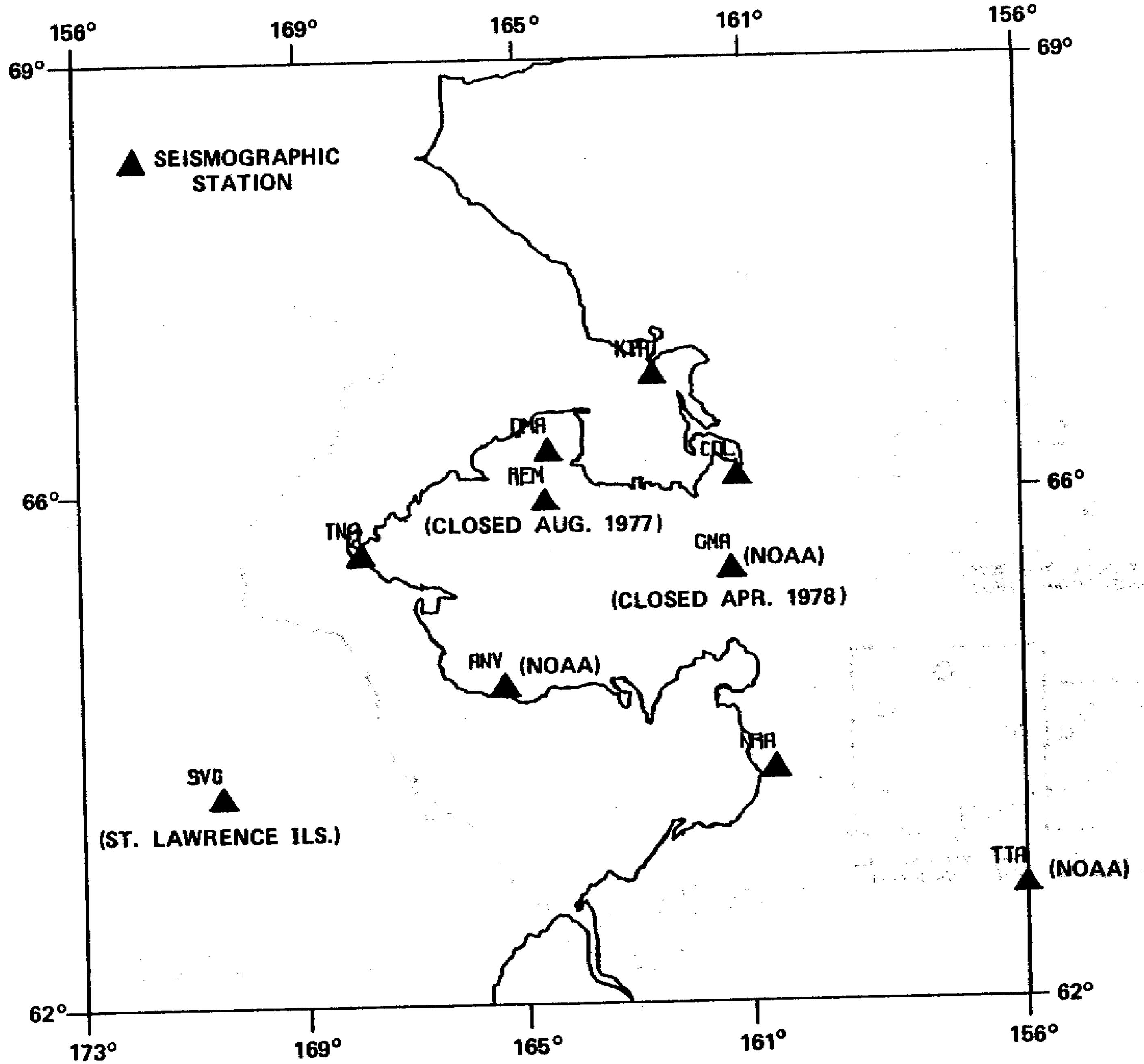
Figure 3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(CLOSED AUG. 1977)
TNA
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(CLOSED APR. 1978)
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(ST. LAWRENCE ILS.)
TTA (NOAA)
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Figure 4

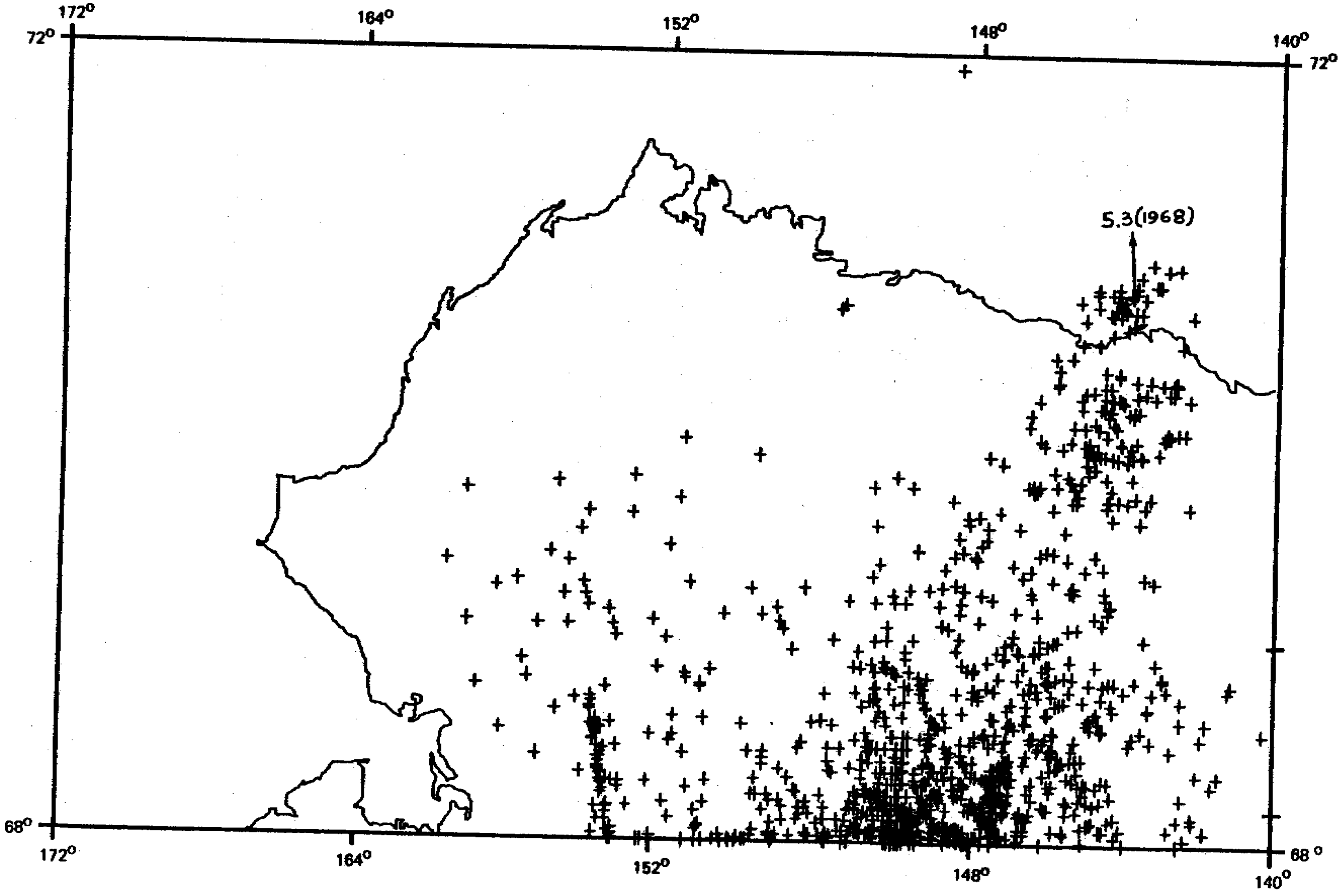


Figure 5

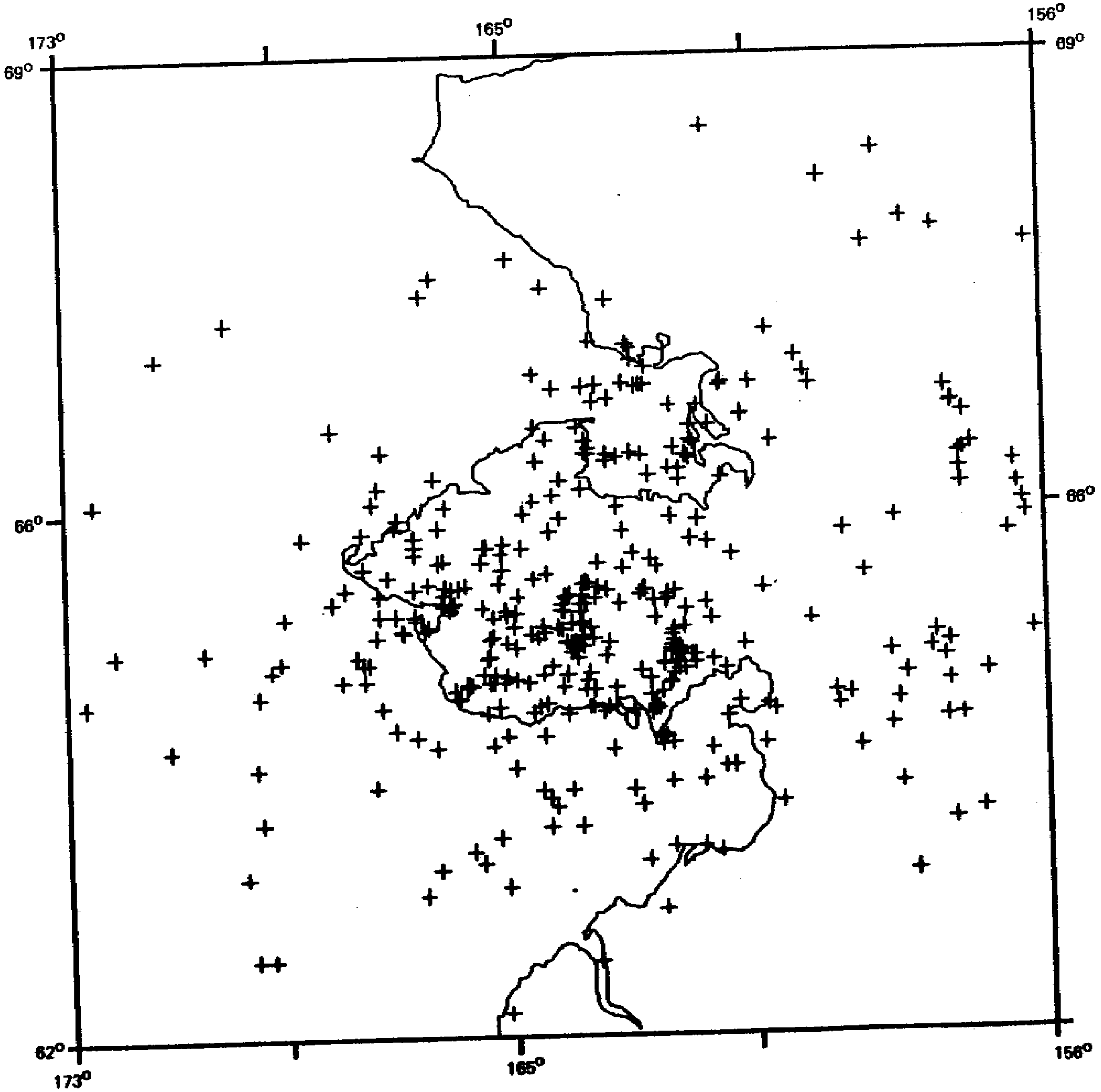
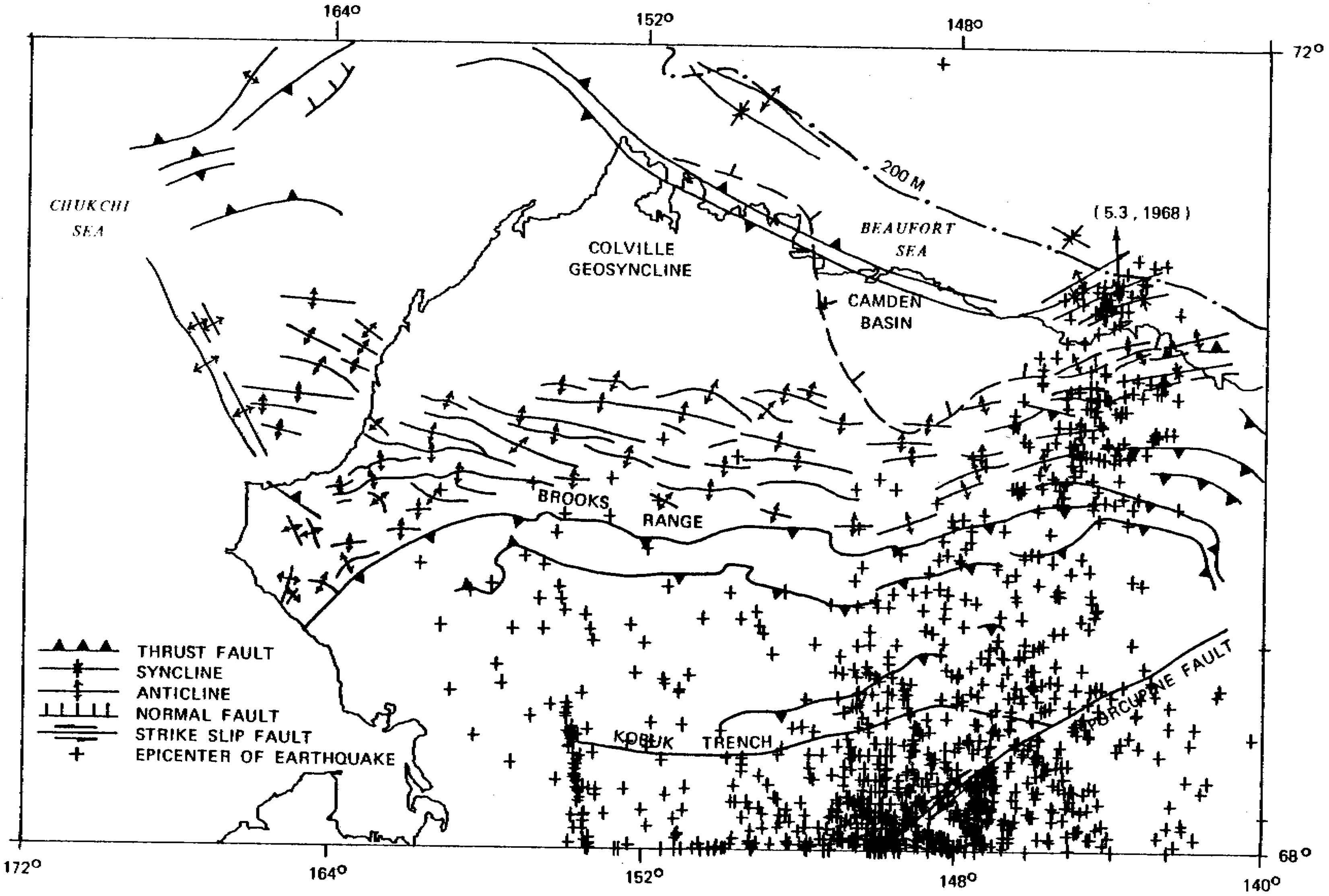


Figure 6


164°
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CHUKCHI SEA
COLVILLE GEOSYNCLINE
200 M
BEAUFORT SEA
(5.3, 1968)
CAMDEN BASIN
BROOKS RANGE
KOBUK TRENCH
PORCUPINE FAULT
THRUST FAULT
SYNCLINE
ANTICLINE
NORMAL FAULT
STRIKE SLIP FAULT
EPICENTER OF EARTHQUAKE
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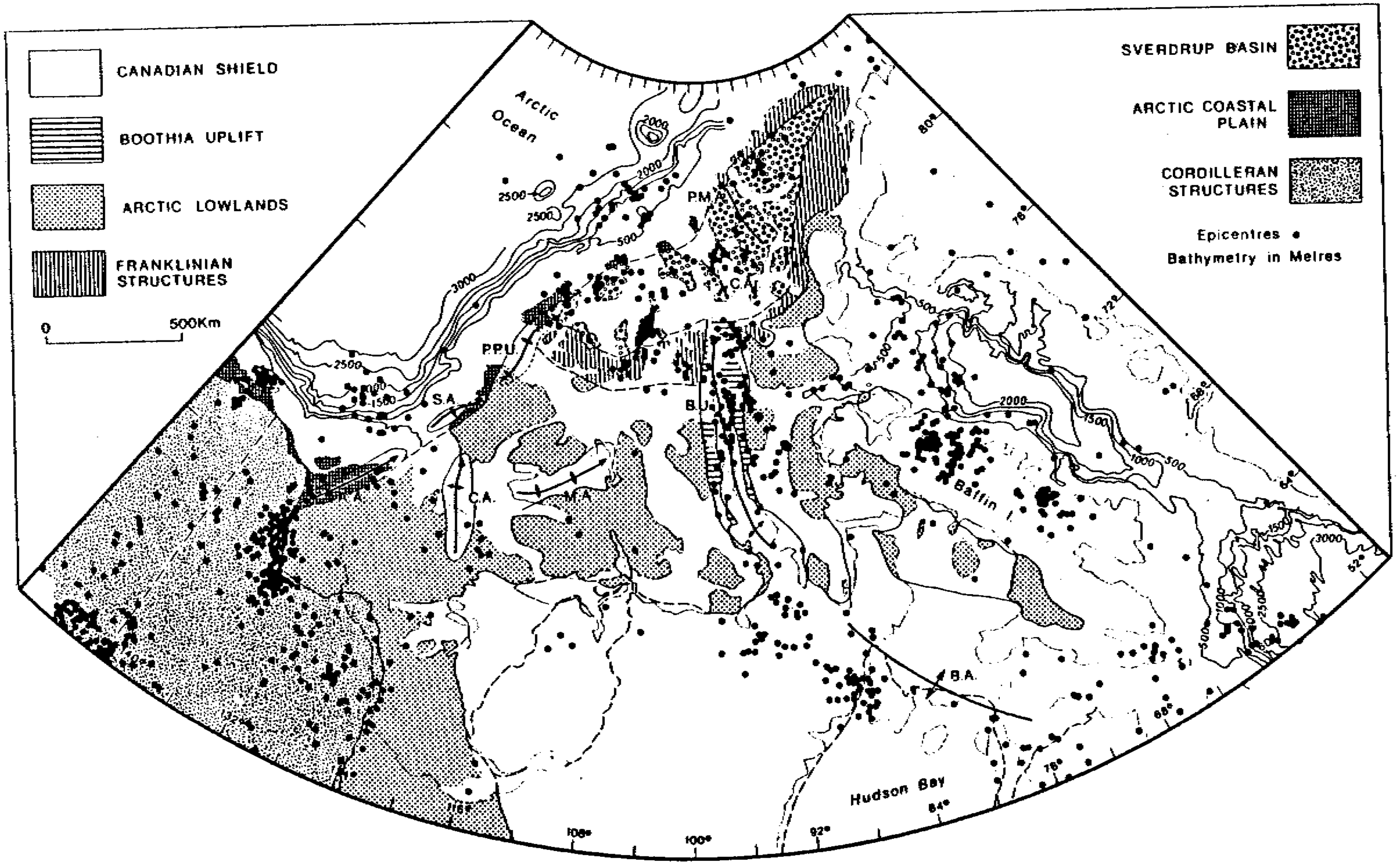
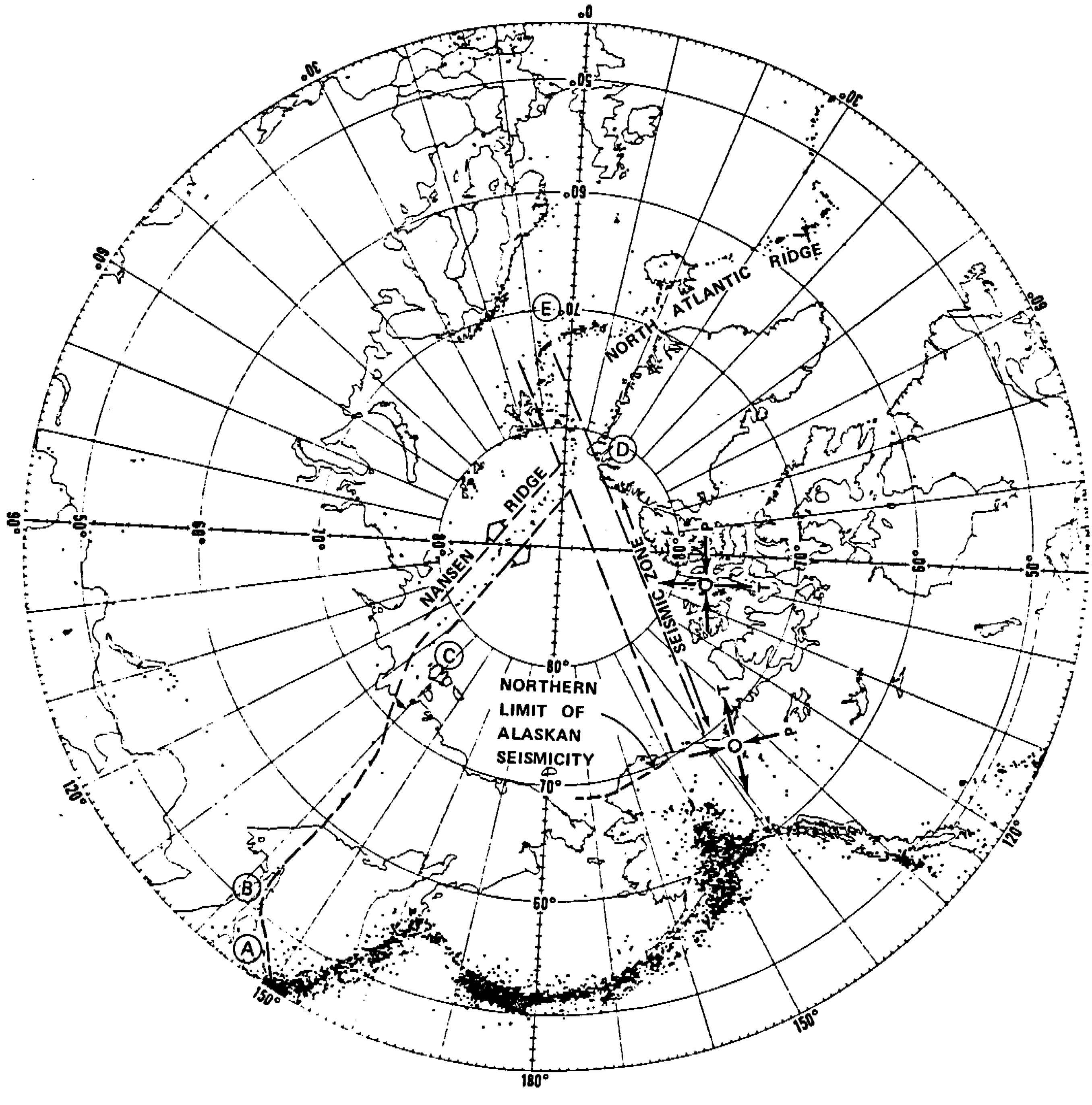
Figure 7



General geological provinces in northern Canada and seismicity for the period 1962–1974. *P.M.A.*: Princess Margaret Arch. *C.Ar.*: Cornwall Arch. *B.U.*: Boothia Uplift. *P.P.U.*: Prince Patrick Uplift. *S.A.*: Storkerson Arch. *C.A.*: Coppermine Arch. *M.A.*: Minto Arch. *B.A.*: Bell Arch.

Figure 8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NORTH ATLANTIC RIDGE
NANSEN RIDGE
SEISMIC ZONE
NORTHERN LIMIT OF ALASKAN SEISMICITY
A
B
C
D
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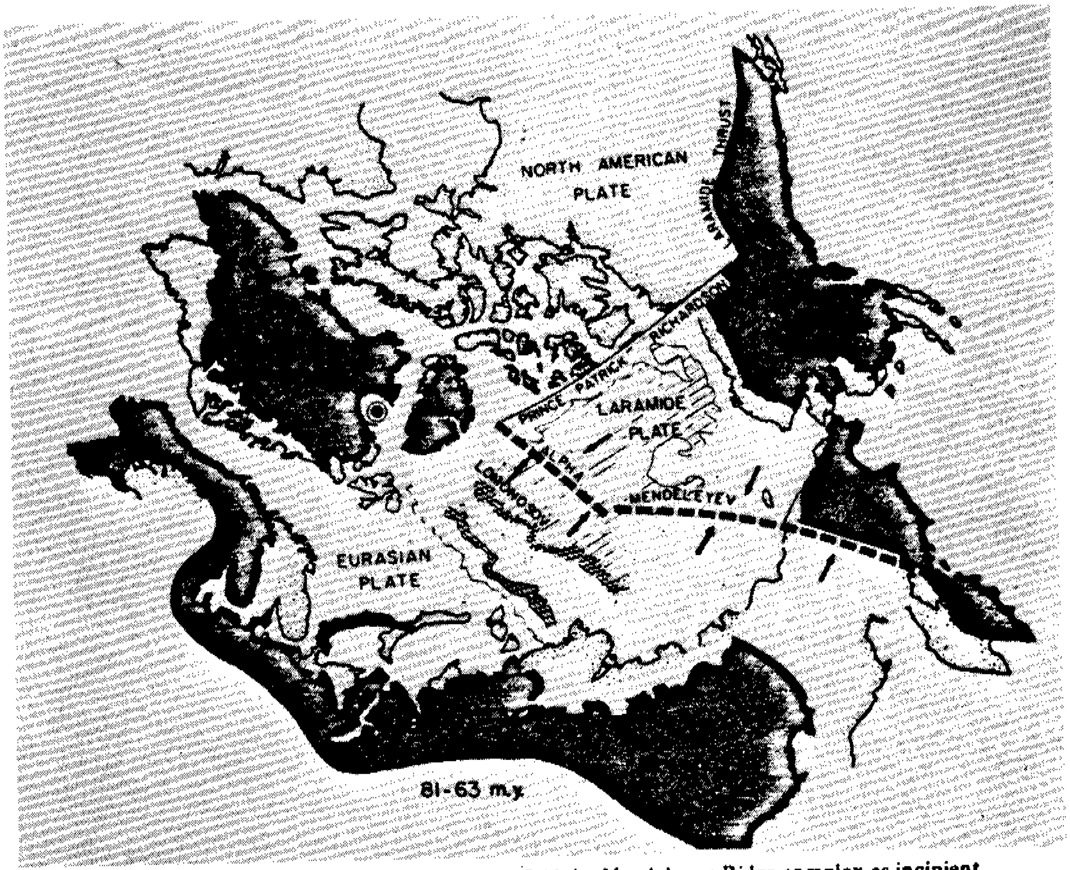
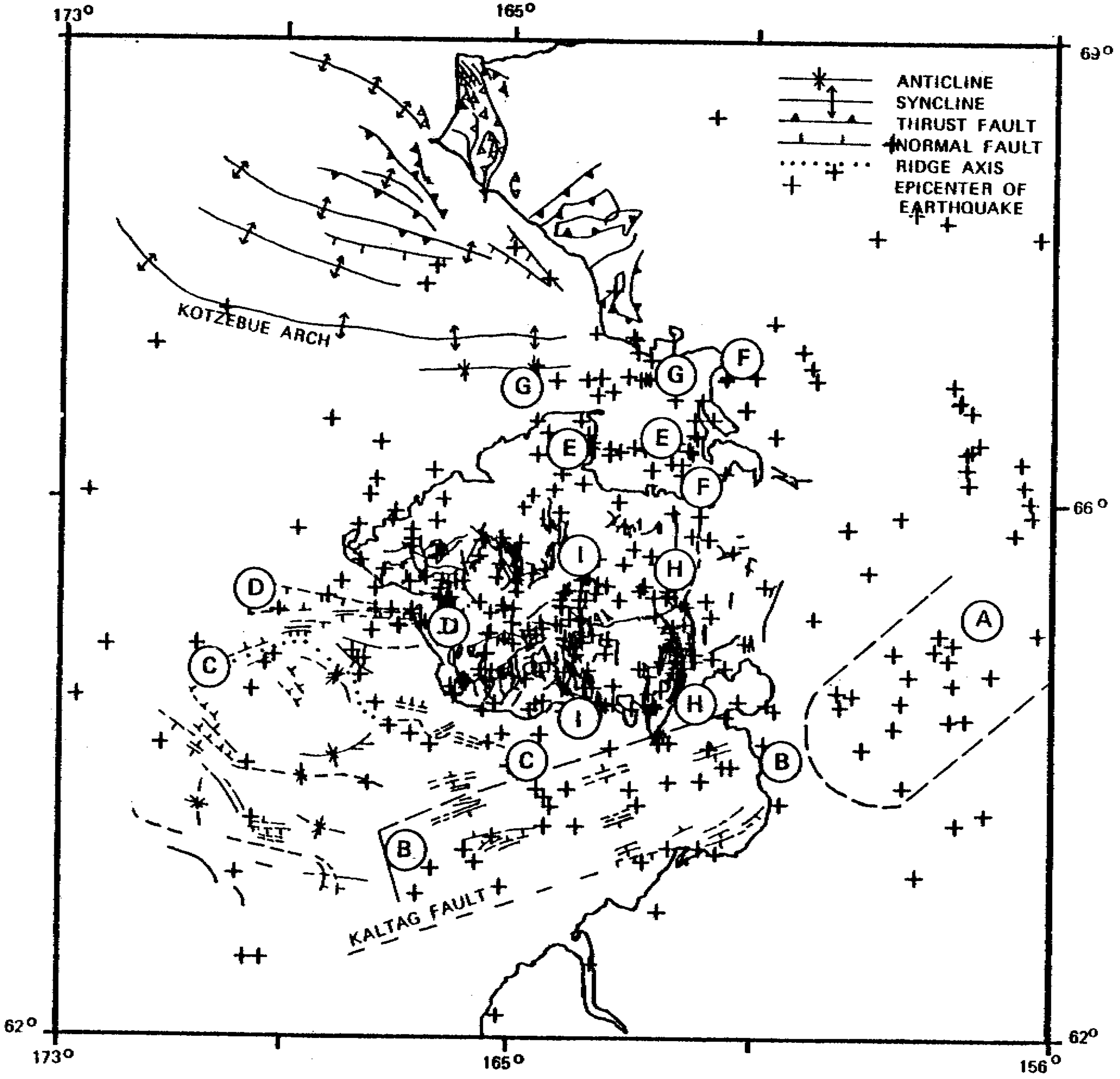
Figure 9



Schematic model for evolution of Alpha-Mendeleyev Ridge complex as incipient subduction zone-island arc, produced by initial rotation of Eurasia away from North America. Pole of opening of North Atlantic relative to North America determined by Pitman and Talwani (1972) for period between 81 and 63 m.y. ago (Laramide time) shown by bull's-eye on northernmost Greenland. Solid black = position of Greenland and Eurasia relative to North America at 81 m.y.; stipple = position at 63 m.y. We have also suggested relative motion within what is now North American continent, along line of Laramide thrust, and have further assumed that "Laramide" plate included Chukotskiy and Koryak-Kamchatka as well as most of what is now Amerasian Basin. Boundary between North American and Laramide plates is continued north of Laramide thrusts into Arctic via Richardson Mountains and Prince Patrick uplift, which we have interpreted as strike-slip fault zones, analogous to San Andreas. Alpha Cordillera-Mendeleyev Ridge form compressive plate boundary between Eurasian and Laramide plates. Hachures = areas underlain by oceanic crust in Arctic; cross hatching = position of Lomonosov Ridge at 81 and 63 m.y.

Figure 10


173°
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ANTICLINE
SYNCLINE
THRUST FAULT
NORMAL FAULT
RIDGE AXIS
EPICENTER OF EARTHQUAKE
KOTZEBUE ARCH
KALTAG FAULT
A
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Figure 11

ANNUAL REPORT

Contract #03-5-022-56
Research Unit #530
Reporting Period 4/1/78-3/31/79
Task Order #34

THE ENVIRONMENTAL GEOLOGY AND GEOMORPHOLOGY OF THE BARRIER ISLAND - LAGOON SYSTEM ALONG THE BEAUFORT SEA COASTAL PLAIN

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March 31, 1979

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I. Summary of Objectives

The scientific objectives relate to areas of unknown data and parameters which are needed to make an environmental assessment of the Beaufort Sea Continental Shelf. The products: reports, maps, and tables, provide information about the scientific objectives and can be drawn on as needed to aid decision-making prior and during leasing and developemnt. Information about the natural processes, in and around the lease area, indicates the stability of the area and predicts the influence of development.

The most important landforming process in the area is loss of ground ice. The natural stability of the landforms is directly related to the rates at which ground ice is lost. Developmental planning must take these rates into consideration to minimize environmental impact. Planning must also be site-specific because the rates of natural changes greatly range in value from one portion of the area to another. The objectives address this range in values.

II. Introduction

A. General Nature and Scope of Study

The purpose of this investigation is to provide quantitative and qualitative data for assessing the environmental impact of development within the lease area. The existing, naturally occurring geomorphic processes are herein identified, and where possible, the dynamics of these processes are quantified.

All the major landforms of the area, including barrier islands, lagoons, streams, lakes, and deltas, are shaped or influenced by the loss of ground ice. Hence, there is an important interrelationship between the major landforms; a landform changes at the expense of another, or it evolves into another landform.

This study provides an understanding of natural geomorphic conditions which exist in the area. This understanding can be used to determine the impact that man-related activities may have on the environment.

B. Specific Objectives

1. To determine the origin and stability of the barrier island - lagoon system.
2. To identify the natural geomorphic processes involved in creating and maintaining the natural physical environment.
3. To determine the rates of natural change in features due to natural processes.

4. To provide baseline information that can be used to predict and assess environmental impact in an unbiased manner.

5. To provide geomorphic information that can be used to establish guidelines for land use and resource management.

6. To compile information that can be used to construct a model which can be manipulated to indicate long and short term changes either naturally or as the result of development.

C. Relevance to Problems of Petroleum Development

The information gathered by this study is directly applicable to such development problems as:

a. siting of drill pads
b. sources of gravel
c. location of landfills
d. transportation routes
e. engineering aspects of stability
f. stream channel dynamics
g. shoreline changes

The natural stability of geomorphic features should be known before long life structures are built. Sources of nearby materials should be identified so that energy resources can be conserved. Waste materials must be placed in secure locations. Transportation routes must be planned so that they are economical, conserve energy resources, and minimize environmental impact.

III. Current State of Knowledge

Previous research shows that the Arctic coastal plain is the common source of materials that make up the gravel and tundra islands along the Beaufort Sea coast. Previous research also shows that the lagoons are created by enlargement of coastal plain lakes. Since the lakes on the coastal plain are important to barrier island - lagoon development, the rates of natural change and the processes involved have been closely studied.

Streams that enter lagoon systems along the Beaufort Sea are important to the geomorphology and the ecology of these ecosystems and have been studied by examining the channels and the deltas at their mouths. Deltas are very delicate landforms that respond easily to natural processes and record the intensity and magnitude of these processes in the morphology.

Shorelines along the Beaufort Sea are retreating horizontally. There is a corresponding vertical drop in the land surface with this horizontal retreat, however, the absolute rates of vertical change are still unknown. Information has been collected about relative rates in vertical change.

IV. Study Area

The area of investigation includes the barrier islands and lagoons of the Beaufort Sea Offshore Lease Area and the adjacent coastal plain. The adjacent coastal plain must be considered in this study because it is the source of materials in the barrier island - lagoon system, and it will also suffer the impact of development. The landforms of the area have a strong interrelationship because they all suffer the effects of the loss of ground ice. The actual study area stretches from the Colville River eastward to the Canning River.

V. Sources, Methods and Rationale of Data Collection

There are two basic aspects behind the rationale of this study: (1) expand information learned in the Simpson Lagoon area to the rest of the lease area, and (2) fill in existing information gaps about geomorphic processes and the rates of natural change. Information from field observations and remote sensing data were combined to produce the final products. The following is a list of the basic methodology followed during the study:

1. Interpretations of aerial photographs, radar imagery, and Landsat imagery.
2. Ground reconnaissance on foot and boat.
3. Low altitude aerial reconnaissance.
4. Literature evaluation and inspection of weather records.
5. Exchange of data with Dr. A. S. Naidu and other principal investigators.
6. Quantitative and qualitative analysis of the deltas in the area.
7. Comparison of sequential data.
8. Compilation of a landforms map of the region.
9. Analysis of the geomorphic setting of the lease area.
10. Compilation of shoreline erosion maps for islands, important lakes, and the coast, outside the Simpson Lagoon area.
11. Evaluation of remote sensing techniques best suited for various aspects of the project.
12. Analysis of the future results of natural processes.
13. Compilation of information about changes in the Sagavanirktok River.

The natural changes in the barrier island - lagoon system and the coastal plain were determined using aerial photographs and Landsat imagery. Field studies of geomorphic processes and the interpretation of remote sensing data provided information concerning the origin and stability of the barrier island - lagoon system and the importance of the adjacent coastal plain.

VI. Results

A. Terrain and Landform Map

The terrain and landform map of the Beechey Point Quadrangle (Figure 1) differentiates 10 units based on lake density and orientation, and wetness/dryness. Complete unit descriptions and their significances are in progress and will appear in future reports. Landforms shown in Figure 1 are active river floodplains, abandoned river floodplains, bedrock, deltas, and pingos.

B. Delta Morphology

Figures 2, 3, and 4, show the channel networks for the Colville, Kuparuk, and Sagavanirktok river deltas, respectively. These networks are based on channels shown as double lines on 1:63,360 U. S. Geological Survey topographic maps. Several other channels were added from 1972 U-2 photography.

Smart and Moruzzi (1972) present a technique for describing delta networks based on vertices and links. Vertices are points where channels bifurcate, merge, or empty into the ocean, and are designated forks, junctions, and outlets, respectively. Links are channel segments that connect two successive vertices and are designated by the upstream and downstream vertices; for example, a link connecting a fork vertice to a downstream junction vertice is an FJ link. The numbers of the various vertices and links were determined from Figures 2, 3, and 4, and mapping photography (Table 1).

Table 1 - The numbers of vertices and links of the Colville, Kuparuk, and Sagavanirktok Deltas.

River Delta	Vertices				Links						
	Nv	Nf	Nj	No	Nl	FF	FJ	JF	JJ	FO	JO
Colville	223	111	84	28	302	65	138	42	29	14	14
Kuparuk	77	37	29	11	103	21	44	14	13	9	2
Sagavanirktok	591	294	272	25	857	154	418	136	125	15	10

The delta channel networks of Figures 2, 3, and 4, begin where a single channel or braided network begins to fan. The Colville delta fans from a single channel whereas the Kuparuk and Sagavanirktok deltas fan from braided channels. Table 2 shows the ratios of the longest chords down and across the delta networks.

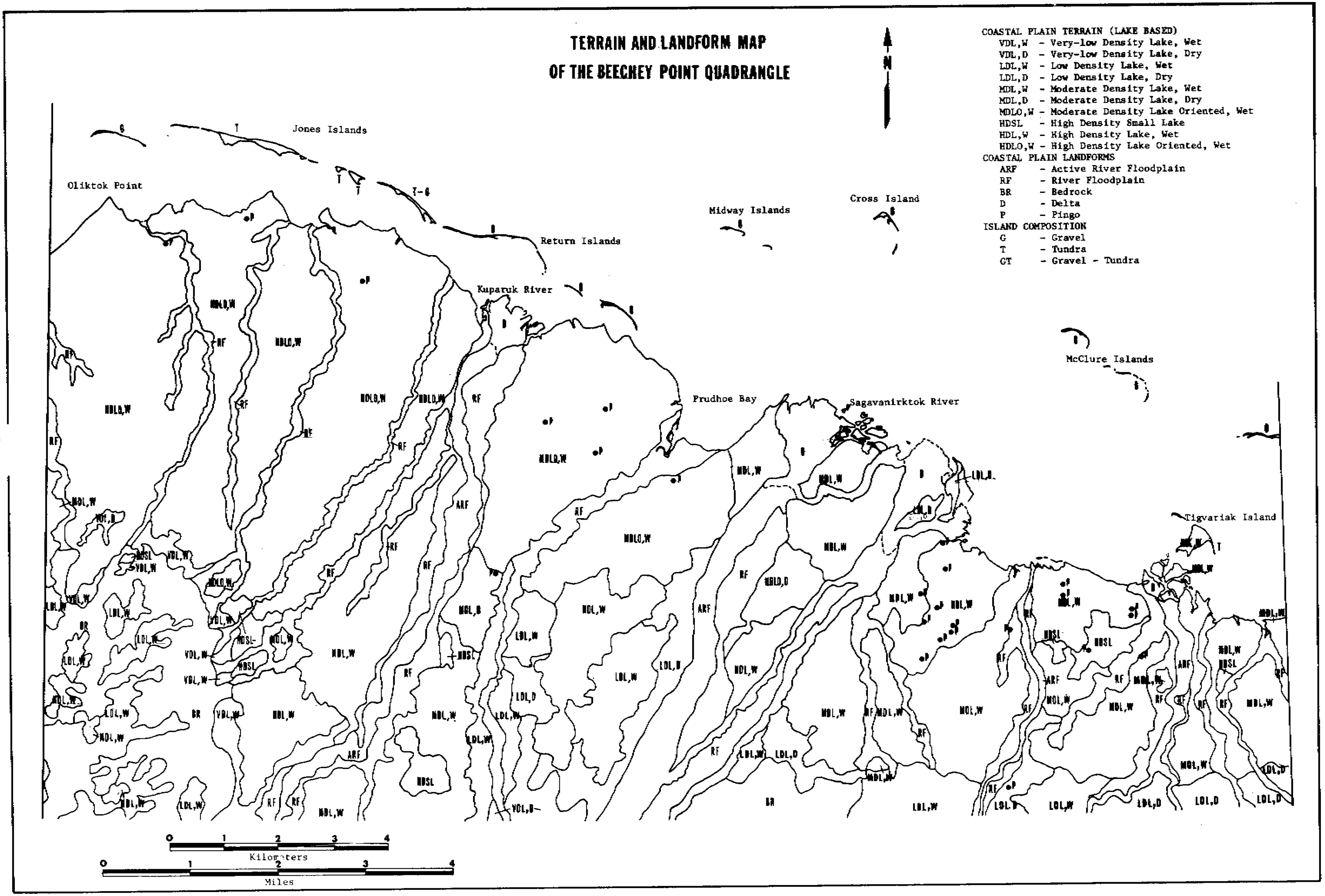


Figure 1 - Terrain and landform map of the Beechey Point Quadrangle.

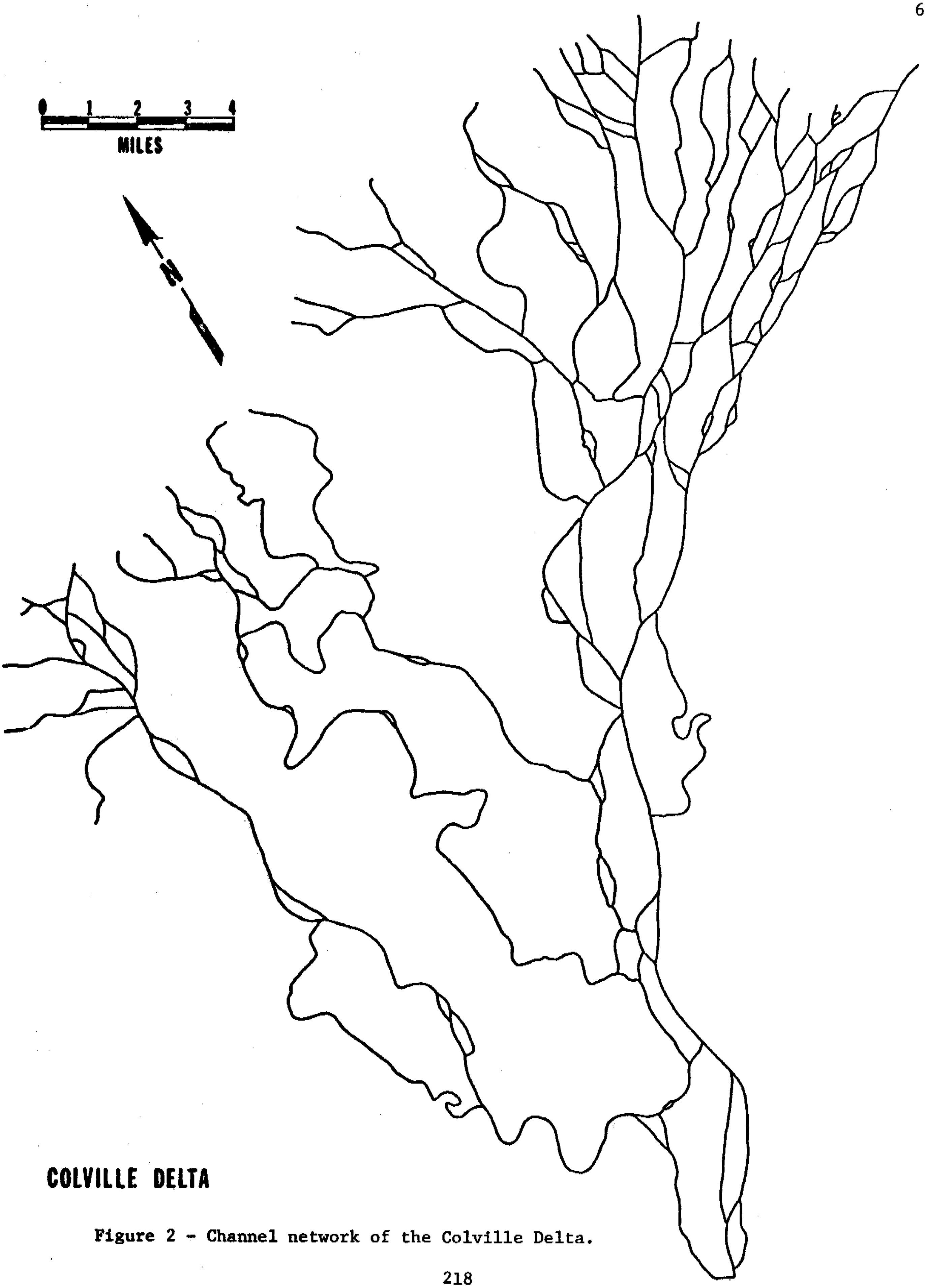
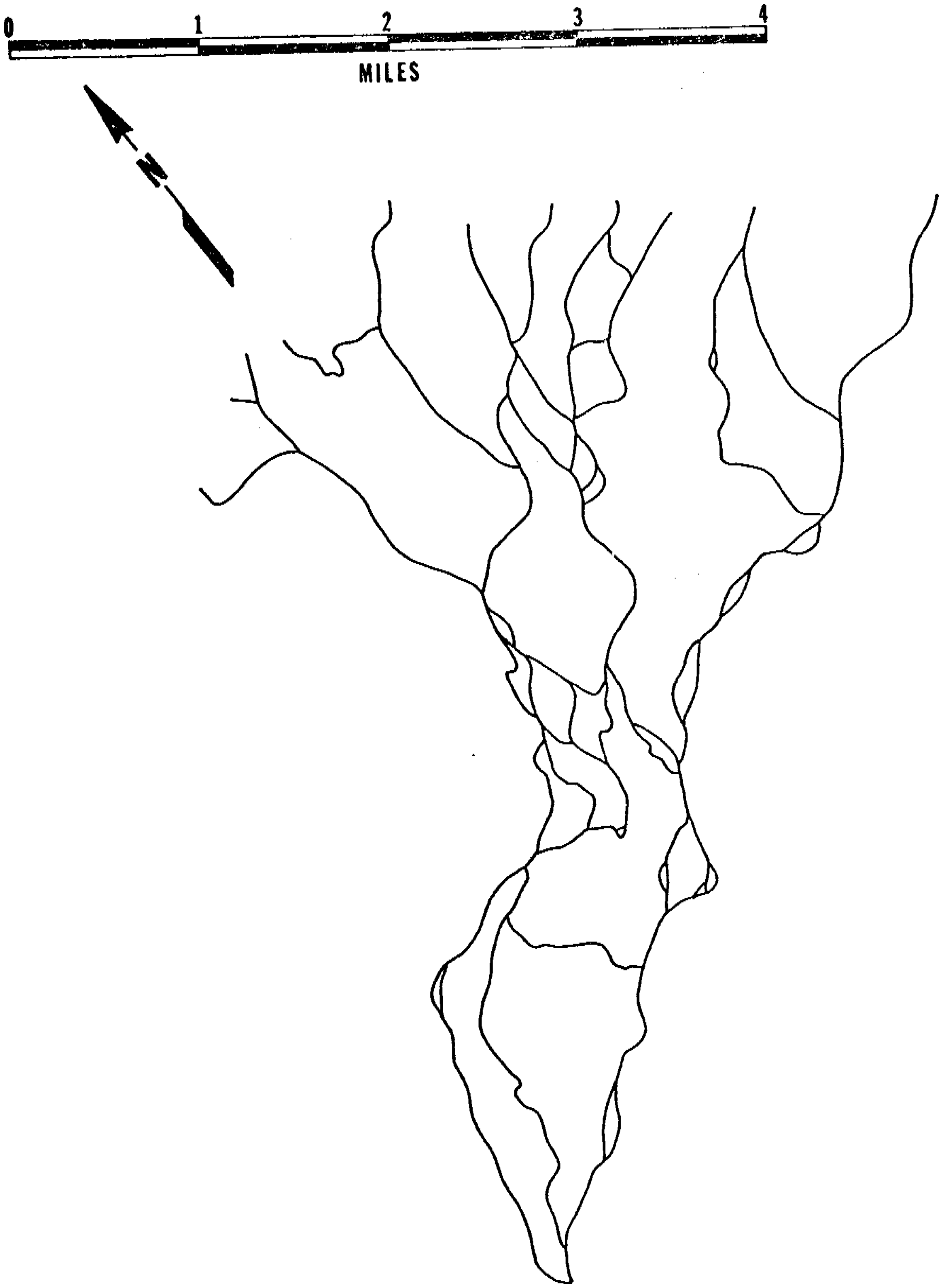


Figure 2 - Channel network of the Colville Delta.



KUPARUK DELTA

Figure 3 - Channel network of the Kuparuk Delta.

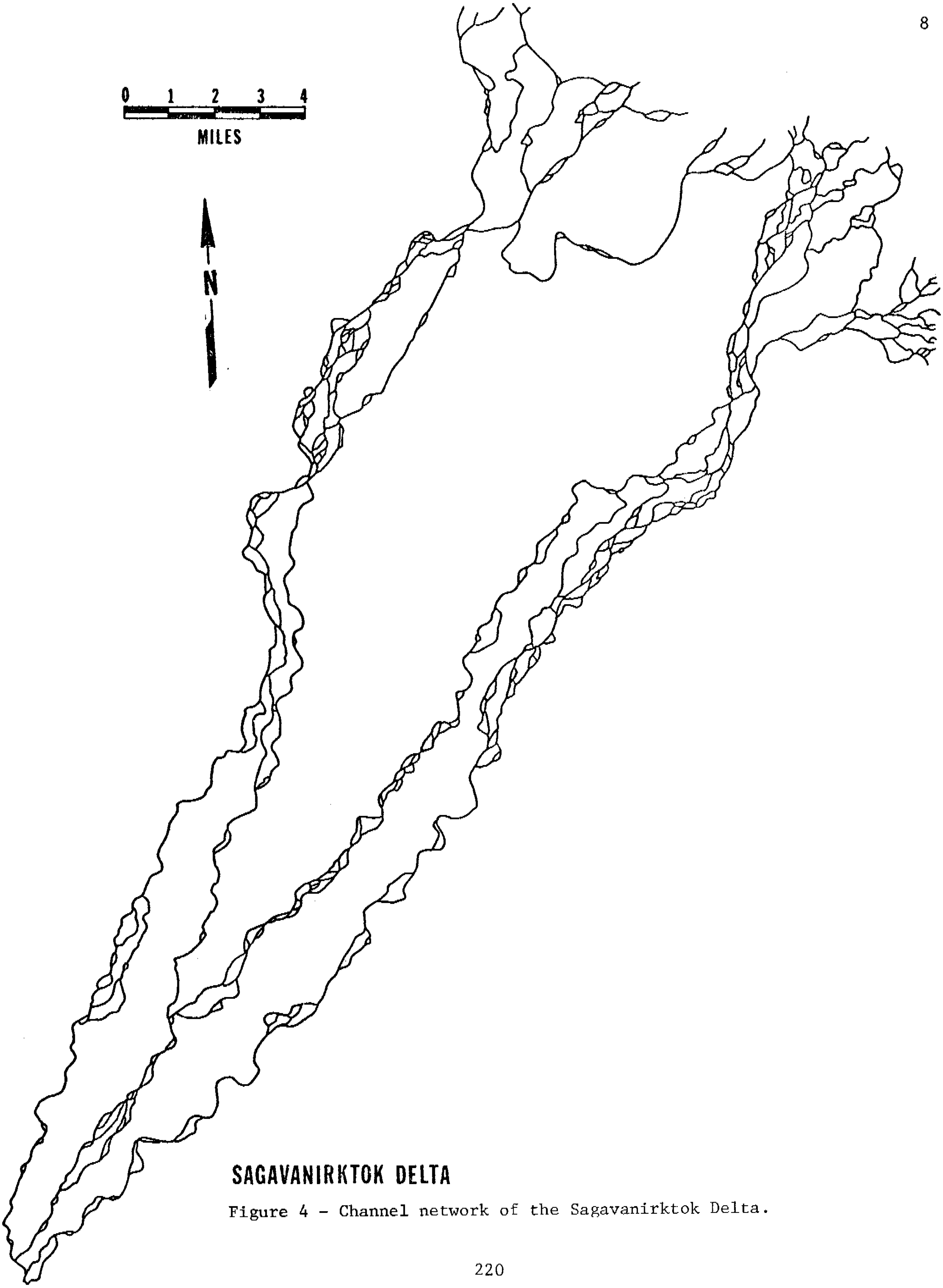


Figure 4 - Channel network of the Sagavanirktok Delta.

Table 2 - Length/width relationships of the Colville, Kuparuk, and Sagavanirktok Deltas.

Delta	Length		Width		L/W
	Miles	Kilo.	Miles	Kilo.	
Colville	25.4	40.9	22.6	36.4	1.1
Kuparuk	5.8	9.3	4.2	6.8	1.3
Sagavanirktok	31.8	51.2	13.0	20.9	2.4

The Colville and Kuparuk delta networks are lobate and constructive; the Sagavanirktok delta is elongate and constructive. Smart and Moruzzi (1972) call the ratio of the number of junctions to the number of forks in a delta network, the recombination factor. This ratio may range from zero for a network with no junctions to one for a braided stream. The recombination factor values for the Colville, Kuparuk, and Sagavanirktok deltas are as follows:

Colville - 84/111 = 0.76

Kuparuk - 29/37 = 0.78

Sagavanirktok -272/294 = 0.92

The recombination factor values confirm the similarity of the Colville and Kuparuk delta networks. The recombination factor value of the Sagavanirktok delta network shows braided stream characteristics. This network, therefore, should be regarded as two adjacent deltas. Further study of the Sagavanirktok delta in this regard is in progress.

C. Tundra Erosion Rates

1. Introduction

Erosion rates of tundra areas bordering the Sagavanirktok River, large inland lakes, and the Beaufort Sea were determined in the vicinities of Prudhoe Bay, Camden Bay, and Flaxman Island. The erosion rates were determined by comparing lateral distances on 1955 U.S.G.S. vertical mapping photography enlarged to 1:17,800, with distances on 1972 U-2 vertical photography enlarged to 1:33,330 and to 1:40,420. Distances were measured from a point, which was identifiable on photographs from both years, to the tundra edge.

The primary purpose of erosion rate measurements is to determine the stability of the Arctic Coastal Plain. Knowledge of variations of erosion rates and the reasons for these variations will aid in planning future development on the coastal plain. Measurements of the tundra erosion rate along the western bank of the Sagavanirktok River near Prudhoe Bay are useful for planning ongoing development in this area.

Cannon, et al. (1978) suggest that morphological changes in the Beaufort Sea coastline, including development of some barrier islands is, in part, from coalescence of inland lakes. Determination of erosion rates of lake shorelines, therefore, is necessary to assess the contribution of lake coalescence to shoreline morphological changes.

A mean erosion rate value will eventually be determined for the entire Beaufort Sea coastline based on the areas described here and on other areas presently under study. This mean erosion rate is useful in nutrient dynamic studies since organic material introduced into the Beaufort Sea by coastal erosion is an integral part of the offshore food chain.

2. Erosion Rates In the Prudhoe Bay Area

Figure 5 and Table 3 show the tundra erosion rates in the vicinity of Prudhoe Bay and the mouth of the Sagavanirktok River. Nineteen measurements show a mean erosion rate of 1.9 meters per year along the Prudhoe Bay shoreline. The erosion rates became progressively larger east to west along the shoreline. This suggests that erosion here is largely a function of exposure to the dominant southwesterly wind and wave impact.

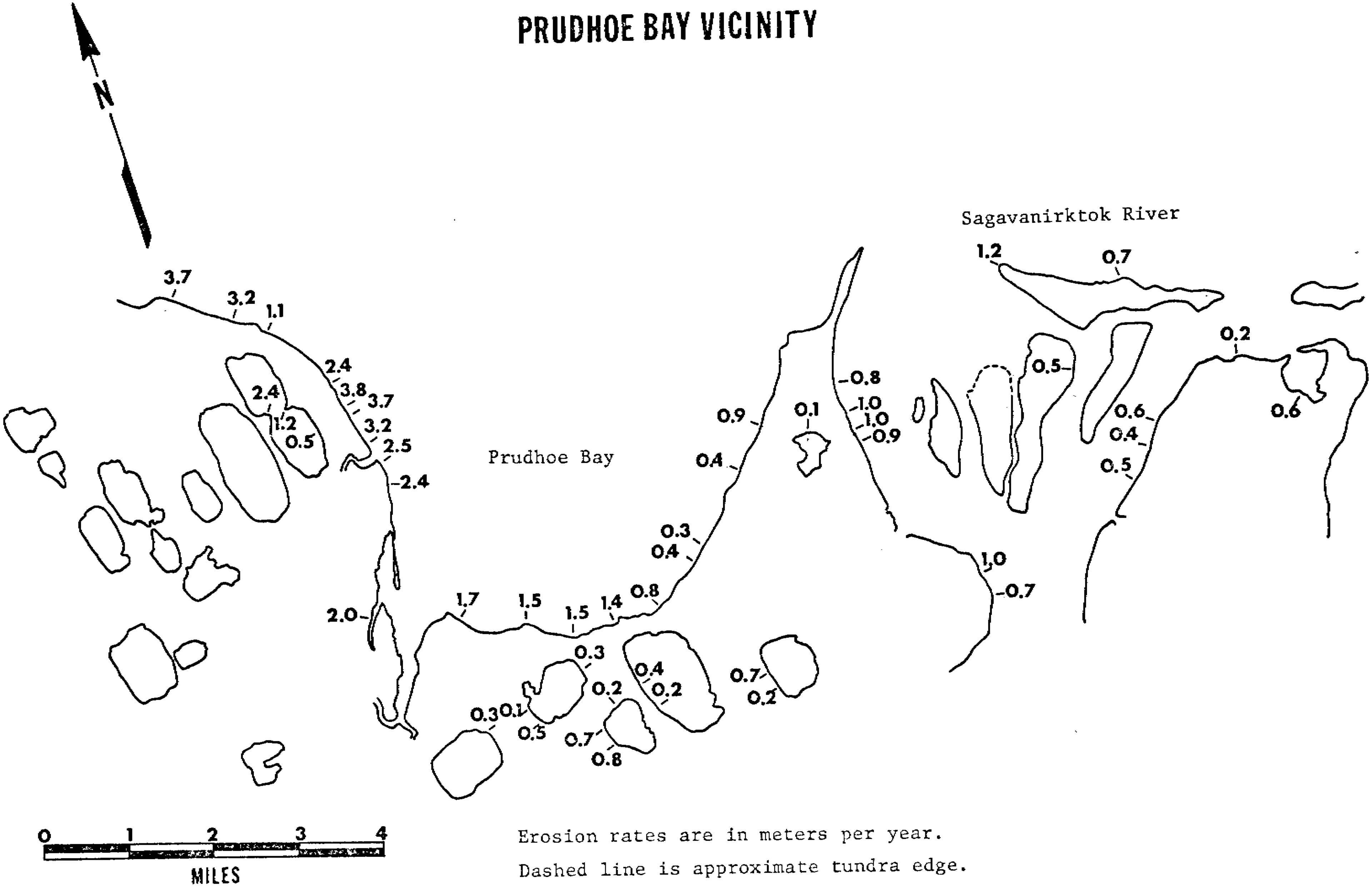
The eastern, northwestern-facing shoreline is protected from the dominant wind and wave impact and has a mean erosion rate of 0.6 meter per year. The north-facing shore is slightly more open to the dominant wind and wave impact and has a mean erosion rate of 1.5 meters per year. The western, northeast-facing shoreline is completely open to the dominant wind and wave impact and has a mean erosion rate of 2.8 meters per year.

The indentation of Prudhoe Bay on the Arctic Coastal Plain corresponds to the boundaries of the abandoned Putuligayuk River floodplain (Figure 1). The indentation represents either preferential erosion of these floodplain deposits or inundation of the river mouth subsequent to a decrease in discharge from inland stream piracy by the Sagavanirktok River. It, perhaps, represents an interaction of both.

Erosion rates tend to be low along lake shorelines in the vicinity of Prudhoe Bay. Thirteen measurements show a mean erosion rate of 0.4 meter per year along lake shorelines. Most of these measurements are from western, northeast-facing shorelines because these land-water boundaries are sharp on the photography. The mean erosion rate of these western shorelines is 0.5, and excludes a high value obtained on a promontory in one of the lakes. The mean erosion rate of the eastern shorelines is 0.4 meter per year and also excludes a high value obtained on a promontory. The mean erosion rate of northern shorelines is 0.2 meter per year. No measurements were taken of southern shorelines.

Fourteen measurements show a mean erosion rate of 0.7 meter in the vicinity of the Sagavanirktok River mouth. The mean erosion rate of eastern-facing river banks is 0.8 meter per year and the mean erosion rate of western-facing banks is 0.5 meter. Measurements of north-facing shorelines show a mean erosion rate of 0.7 meter per

TUNDRA EROSION RATES, PRUDHOE BAY VICINITY



Erosion rates are in meters per year.

Dashed line is approximate tundra edge.

Figure 5 - Tundra erosion rates in the vicinity of Prudhoe Bay.

year in this area.

Table 3 - Erosion rates in the vicinity of Prudhoe Bay.

Area	No. Meas.	Mean
Total Prudhoe Bay Shoreline	19	1.9
East-facing shoreline (Prudhoe Bay)	10	2.8
West-facing shoreline (Prudhoe Bay)	5	0.6
North-facing shoreline (Prudhoe Bay)	4	1.5
Total Inland Lake Shoreline	13	0.4
East-facing shoreline (inland lakes)	8	0.5
West-facing shoreline (inland lakes)	3	0.4
South-facing shoreline (inland lakes)	2	0.2
Total Sagavanirktok River Bank	14	0.7
East-facing Sagavanirktok River bank	7	0.8
West-facing Sagavanirktok River bank	3	0.5
North-facing Sagavanirktok River bank	4	0.7

Figure 6 is a map showing the approximate morphology of Prudhoe Bay after successive periods of time. This map is based on the mean erosion rates of the Prudhoe Bay shoreline and the east-facing bank of the Sagavanirktok River.

3. Erosion Rates In the Camden Bay Area

Figure 7 shows tundra erosion rates in the vicinity of Camden Bay. Nine measurements show a mean erosion rate of 1.9 meters per year. The number of measurements here is limited because inland talik lakes that serve as reference points are few in number. There seems to be no regularity in the erosion rates in this area; rates vary between 0.1 meter and 4.0 meters per year.

4. Erosion Rates In the Flaxman Island - Brownlow Point Area

Figure 8 and Table 4 show tundra erosion rates in the vicinity of Flaxman Island and Brownlow Point. Thirty-six island and coastal plain measurements show a mean erosion rate of 0.9 meter per year.

Six of the measurements show a mean erosion rate of 1.4 meters per year on Flaxman Island. Based on two measurements, the seaward side of the island erodes at a rate of 2.1 meters per year. The remaining four measurements on the south side of the island show a mean erosion rate of 1.1 meters per year.

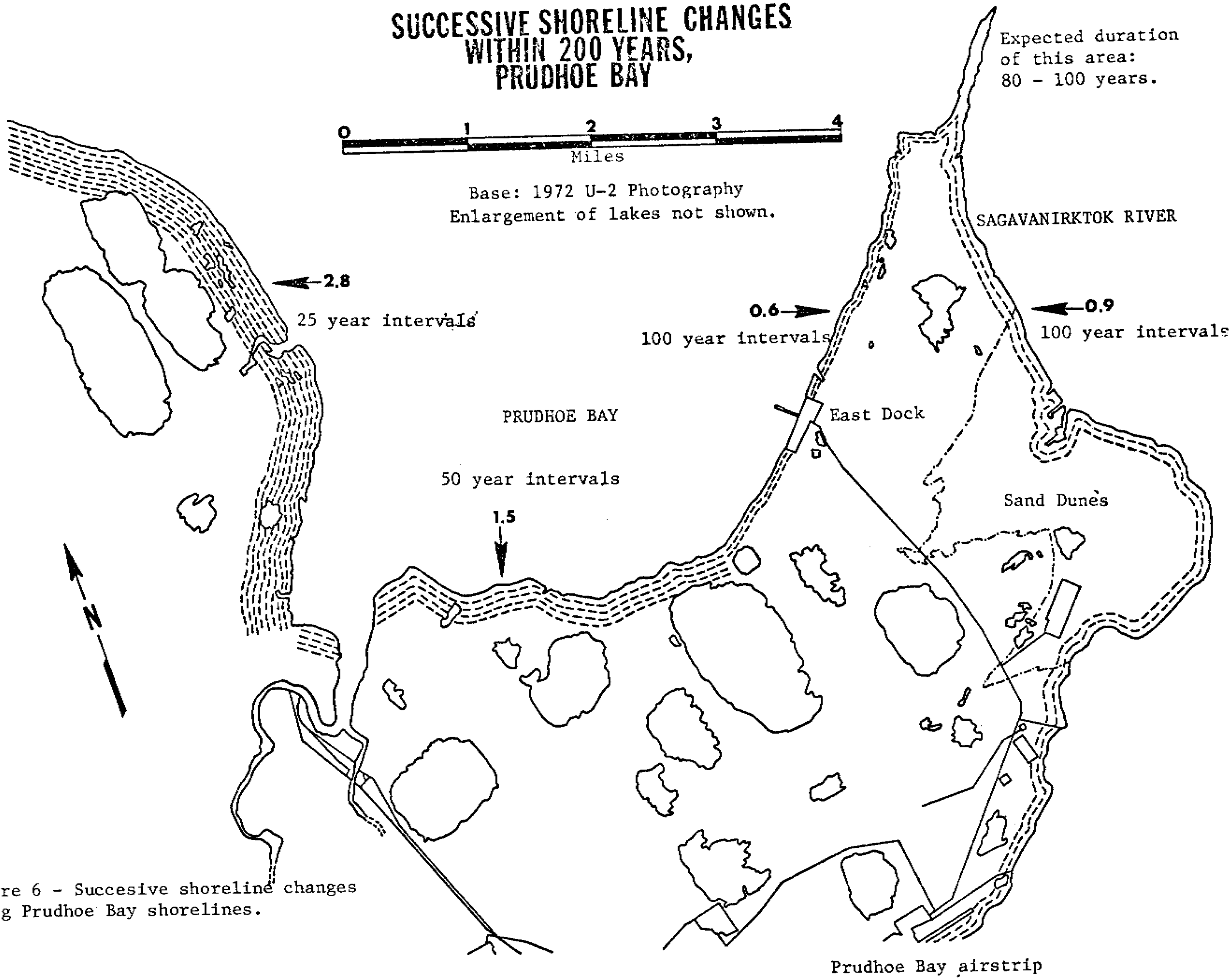
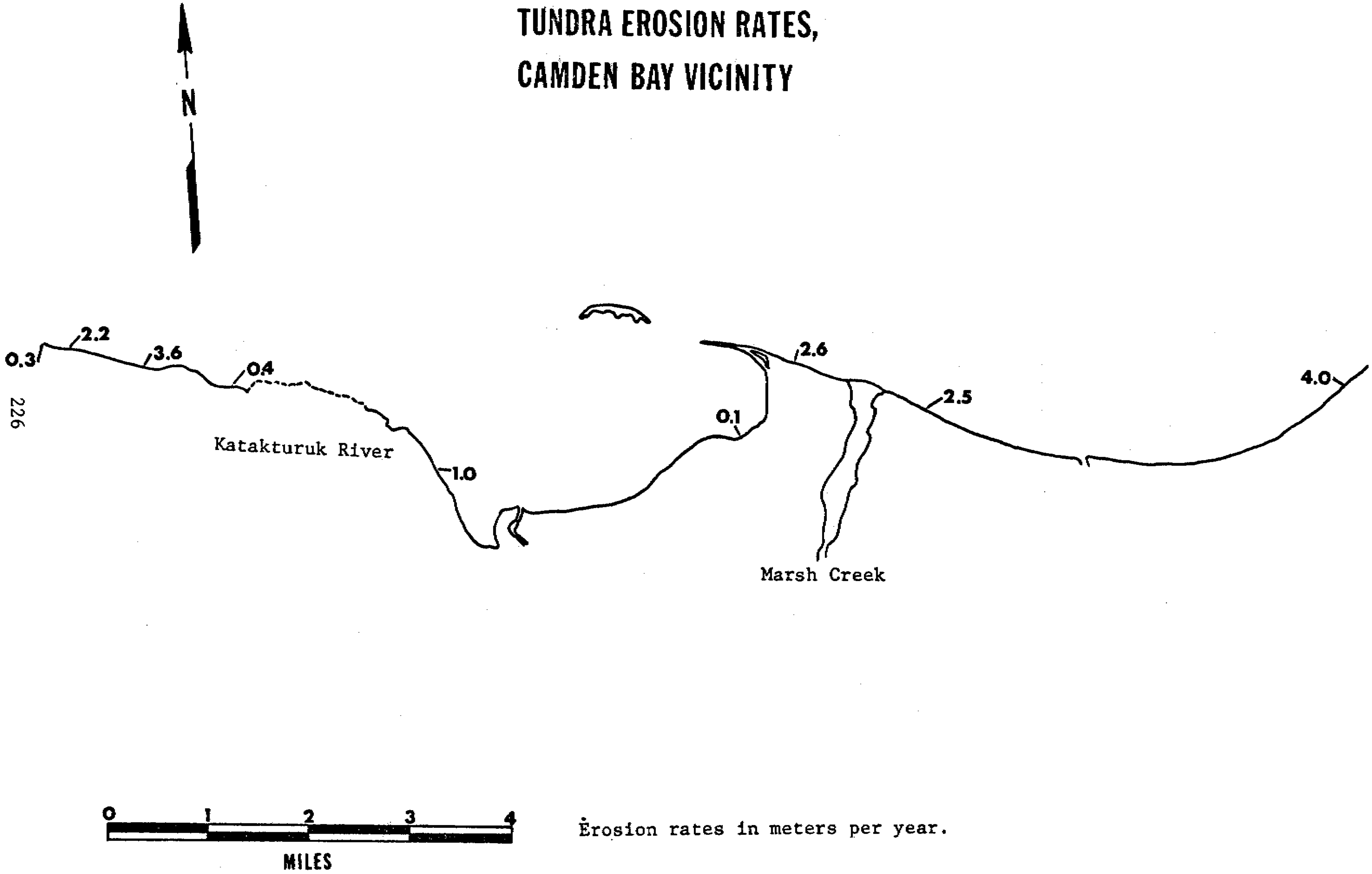
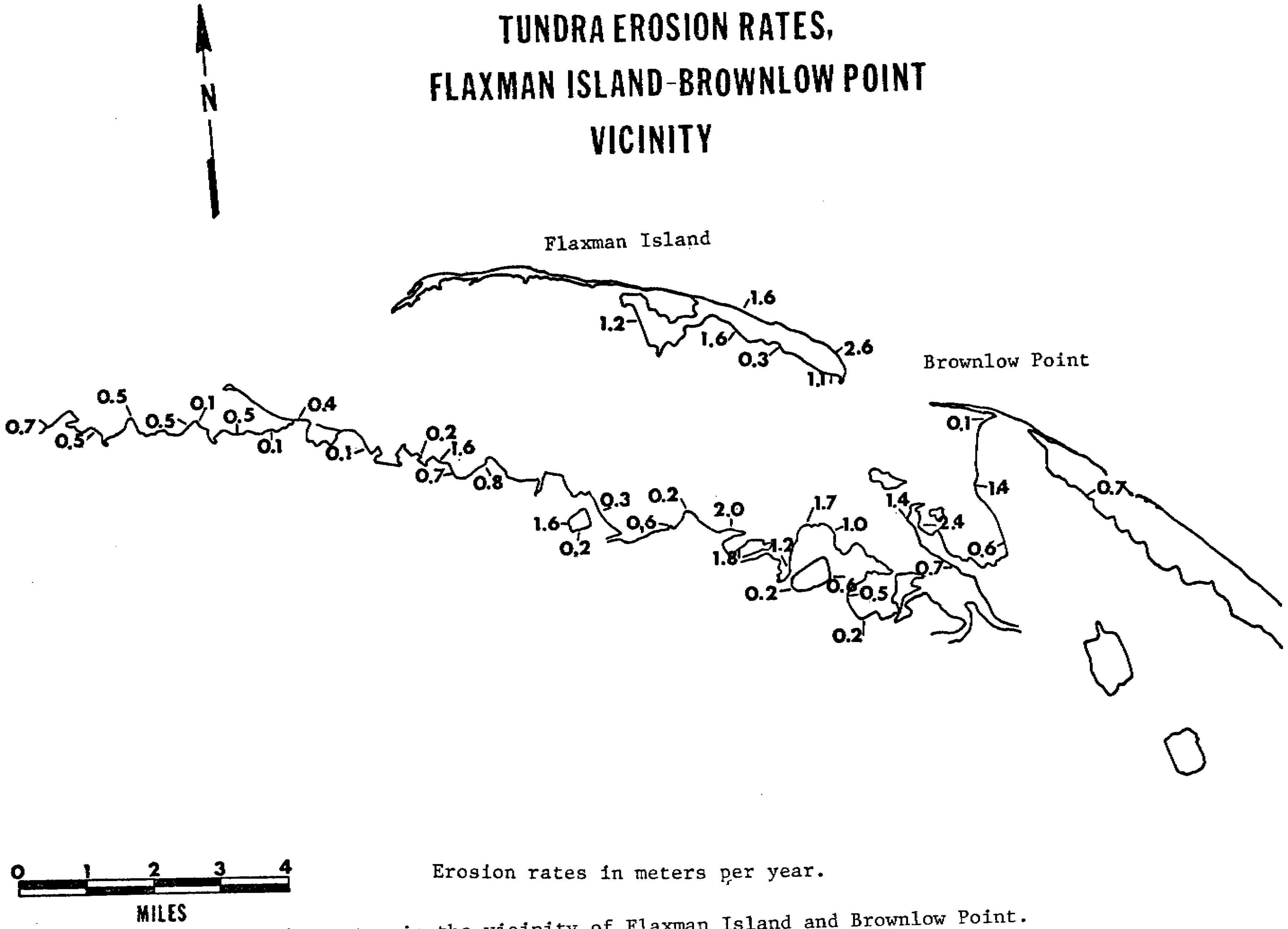


Figure 6 - Succesive shoreline changes along Prudhoe Bay shorelines.



Erosion rates in meters per year.

Figure 7 - Tundra erosion rates in the vicinity of Camden Bay.



Erosion rates in meters per year.

Figure 8 - Tundra erosion rates in the vicinity of Flaxman Island and Brownlow Point.

Thirty measurements along the coastal plain show a mean erosion rate of 0.8 meters per year. There seems to be no regularity in the distribution of these thirty erosion rates; rates vary between 0.1 and 2.4 meters per year.

Table 4 - Erosion rates in the vicinity of Flaxman Island and Brownlow Point.

Area	No. Meas.	Mean
Total Flaxman Island Shoreline	6	1.4
Seaward shoreline (Flaxman Island)	2	2.1
Lagoon shoreline (Flaxman Island)	4	1.1
Coastal Plain Shoreline	30	0.8
Total Inland Lake Shoreline	3	0.3
Total Shoreline (coastal plain and island)	36	0.9

Three measurements show a mean erosion rate of 0.3 meter per year along inland lake shorelines. This rate approximates the mean erosion rate of 0.4 meter per year for lake shorelines in the vicinity of Prudhoe Bay. These relatively low means may be common to all coastal plain talik lakes but need further substantiation. Erosion of lake shorelines toward the Beaufort Sea coast, to effect changes in the coastal morphology, is three to four times less rapid than the opposite relationship.

D. Lake Orientation and Morphology

The lengths and orientations of 512 lakes in the Prudhoe Bay area were measured on 1:63,360 U. S. Geological Survey topographic maps of Beechey Point: B-5, B-4, B-3, and A-3. The average orientation of the long axes (major axes) of the lakes is 350° azimuth and approximately represents most of the lakes on the coastal plain west of the Sagavanirktok River (Figures 9 and 10).

Two factors have been suggested for the orientation of the lakes: (1) the lakes are formed perpendicular to the prevailing wind direction by wind-induced currents, and (2) the lakes are aligned along jointing which has propagated through the frozen materials of the coastal plain and caused preferential melting of ground ice.

There are two published sources of prevailing wind data for locations on the Arctic Coastal Plain. One is the <u>Climatic Atlas of the United States</u> published by the U. S. Department of Commerce. The second is the <u>Climatic Atlas of the Outer Continental Shelf Waters and Coastal Regions of Alaska, Volume III, Chukchi-Beaufort Sea</u>, by the U. S. Department of Commerce and the U. S. Department of the Interior. Oliktok is the closest point of data for the area. Wind data from Oliktok

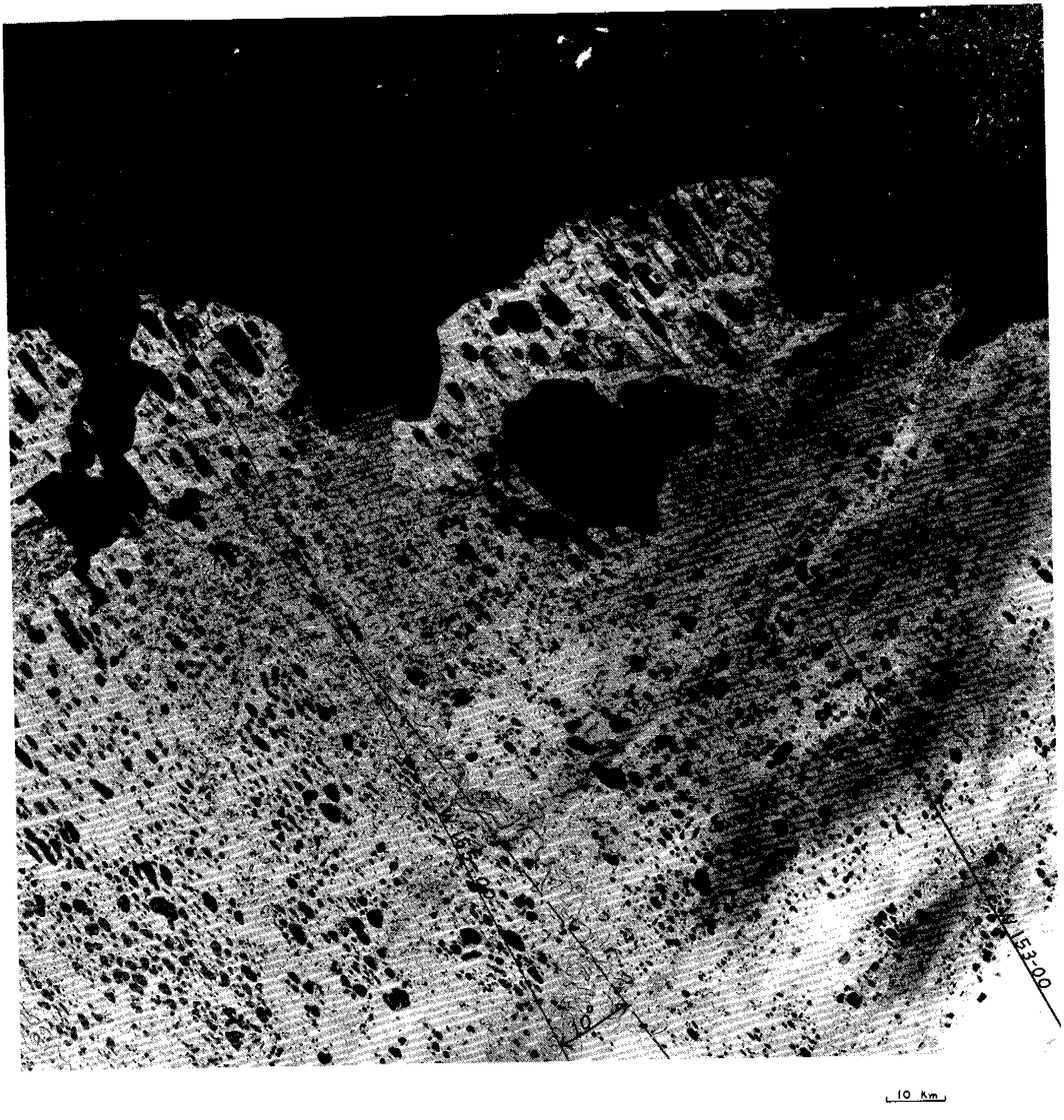


Figure 9. This is a band 7 Landsat scene of a part of the Arctic coastal plain showing Teshekpuk Lake and many other lakes. This scene was acquired 07 September, 1978. The dashed line which has an azimuth direction of 350°, approximates the average orientation of the lakes.

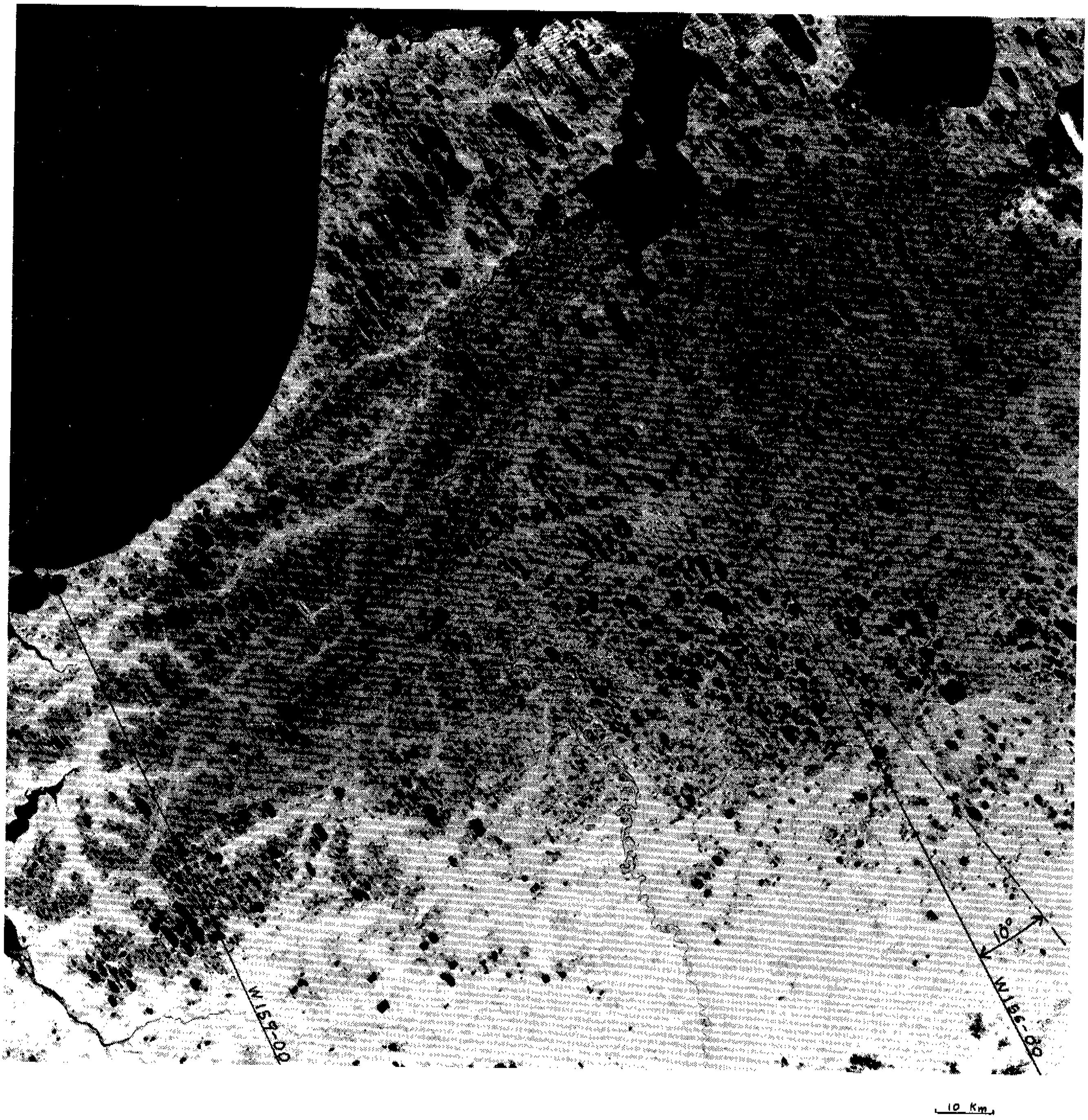


Figure 10. This is a band 7 Landsat image of the Arctic coastal plain south of Barrow. This scene was acquired on 17 July, 1978. The dashed line has an azimuth direction of 350°. This direction approximates the average orientation of the lakes. Note the square and rectangular lakes in the foothills at the bottom of the scene.

indicate that the prevailing winds are from azimuth directions between 060° and 070° during the ice free time of the year. These azimuths are not perpendicular to the orientations of the lakes. A better indication of the prevailing wind direction during the ice free time of the year is the orientation of sand dunes in the Beechey Point, B-3, quadrangle. The orientation of sand dunes here indicates a prevailing wind from azimuth 070°. This is also not perpendicular to the orientation of the lakes. Data from other points on the coastal plain indicate that nowhere are the lakes oriented perpendicular to the prevailing wind direction.

The long axes of the coastal plain lakes, however, are similarly aligned with the dominant jointing in the foothills of the Brooks Range. The jointing in the foothills is expressed in the preferential orientation of stream valleys and the shapes of lakes. The lakes in the foothills are square or rectangular in shape and a pair of the straight sides lines up with the orientation of the joint influenced stream valleys (Figure 10).

E. Remote Sensing Studies

Aerial photography taken over a span of 25 years has been used extensively to determine the rates of shoreline changes. The entire study area, however, has not been covered with such photography; this has restricted measurements to areas where good photography exists. Aerial photography is the only available remote sensing technique with resolution adequate for these measurements.

Data available from other types of remote sensing techniques are better suited to regional applications. The all weather, all winter capabilities of radar imagery makes it an excellent source for neoteric information and ice related data. The radar imagery in general is good for enhancing minor relief and showing cultural features (Figure 11).

The multispectral data from the Landsat satellite is useful but suffers from poor spatial resolution. During half of the year in the Arctic four bands of data are available from the Landsat system. Band four shows the visible green (wavelength 0.5 to 0.6 micrometers) of the electromagnetic spectrum. Band four is best suited for turbid water studies (Figure 12). Band five shows the visible red (wavelength 0.6 to 0.7 micrometers). Band five shows best bare soils and rocks but is well suited for turbid water studies and vegetation studies (Figure 13). Band six shows the solar IR (near IR) in a narrow band (wavelength 0.7 to 0.8 micrometers). Band six can be best used for land-water contacts and some vegetation work (Figure 14). Band seven shows the solar IR in a wide band (wavelength 0.8 to 1.1 micrometers). Band seven is not affected by clouds and haze as much as the other bands. It gives a sharp view of land-water contacts and the best stream information (Figure 15).

During the early winter and early spring some data can be obtained from the Arctic areas on band seven. This low-sun angle, winter time imagery enhances minor topography very well (Figure 16). It was this low-sun angle imagery which indicated that the Colville River once joined with a stream system farther to the east. In Figure 16 the

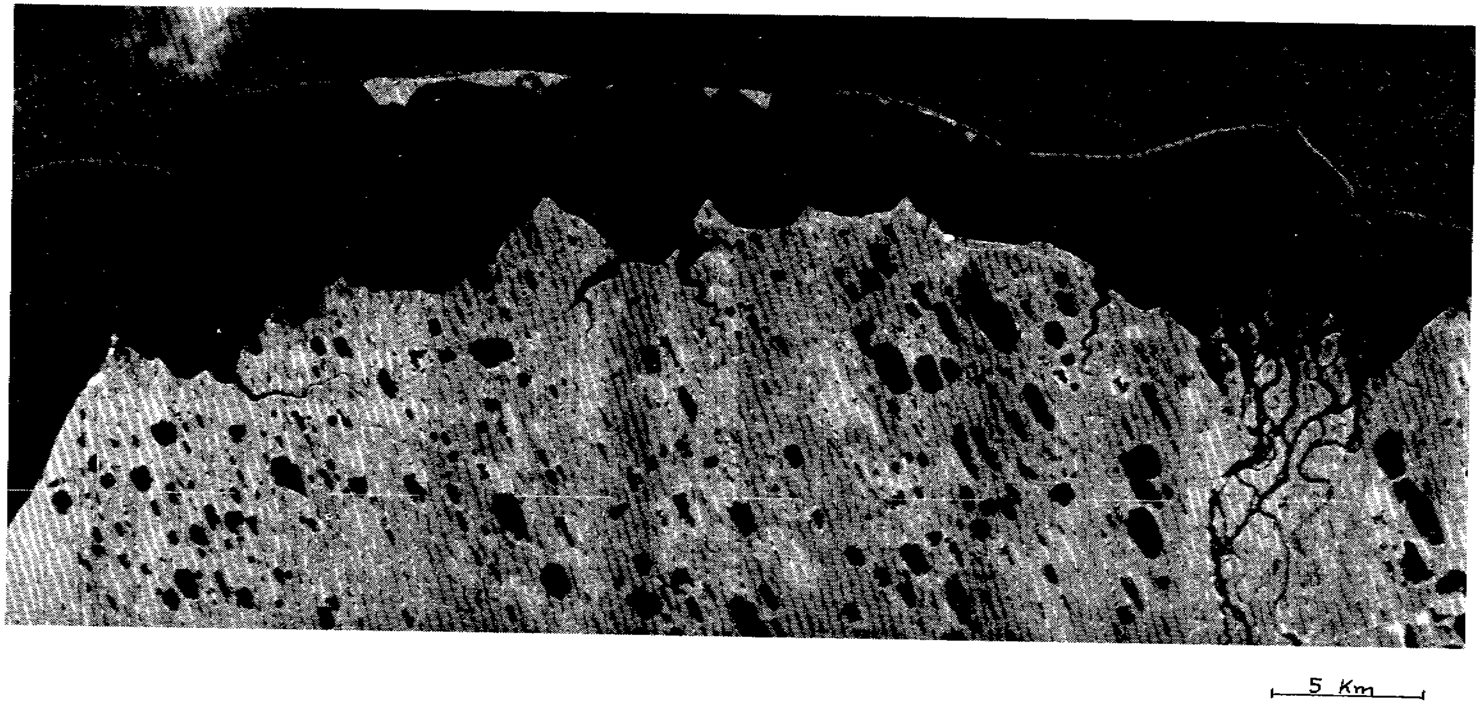


Figure 11. Real aperture x-band, radar imagery of Simpson Lagoon. This imagery was acquired through solid cloud cover during August, 1976. The shape of the coastline shows very well and the higher bluffs show up as bright lines. Cultural features, even minor roads, show up well.

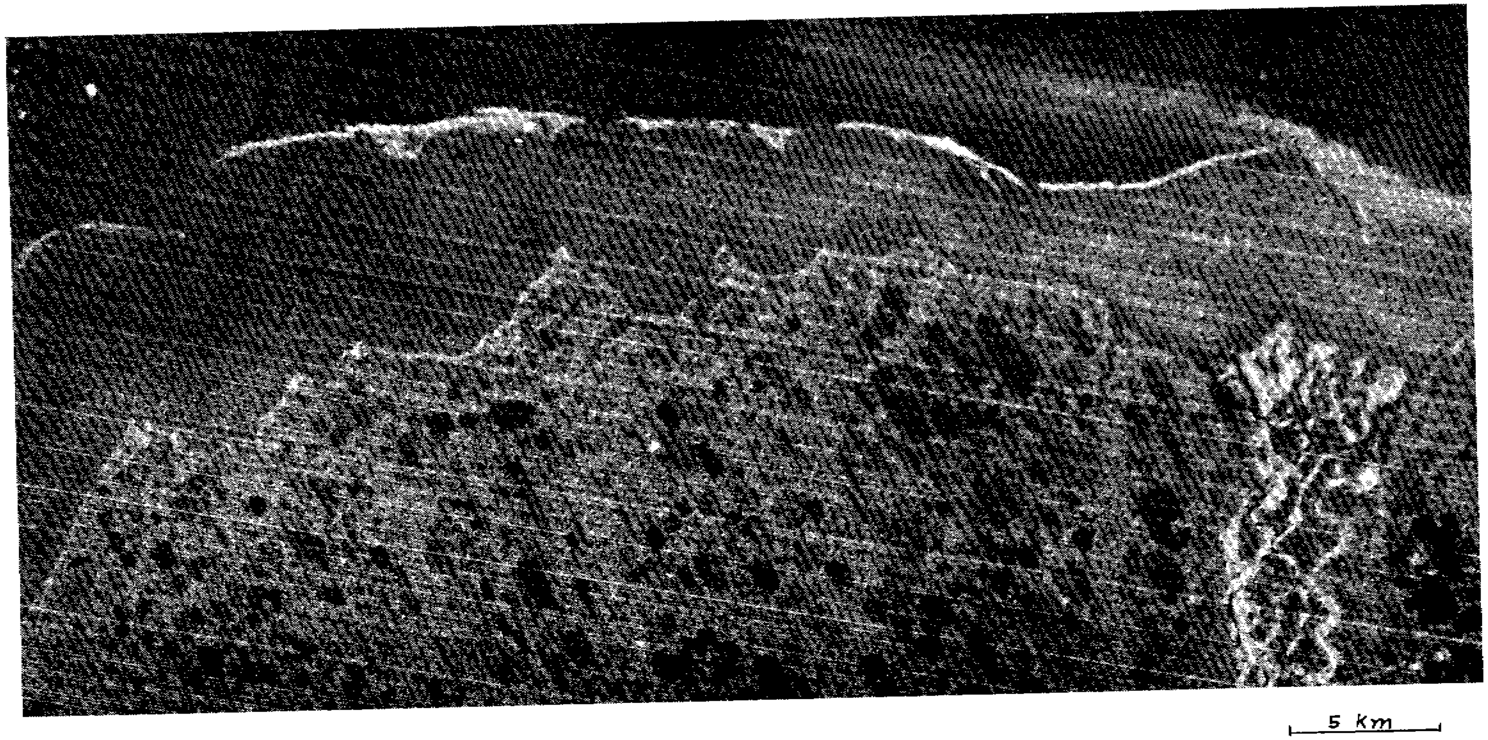


Figure 12. Band 4 Landsat imagery of the same part of Simpson Lagoon shown in Figure 11. This imagery taken in the visible green is best suited for studies of turbid water. This imagery was acquired 25 July, 1977.

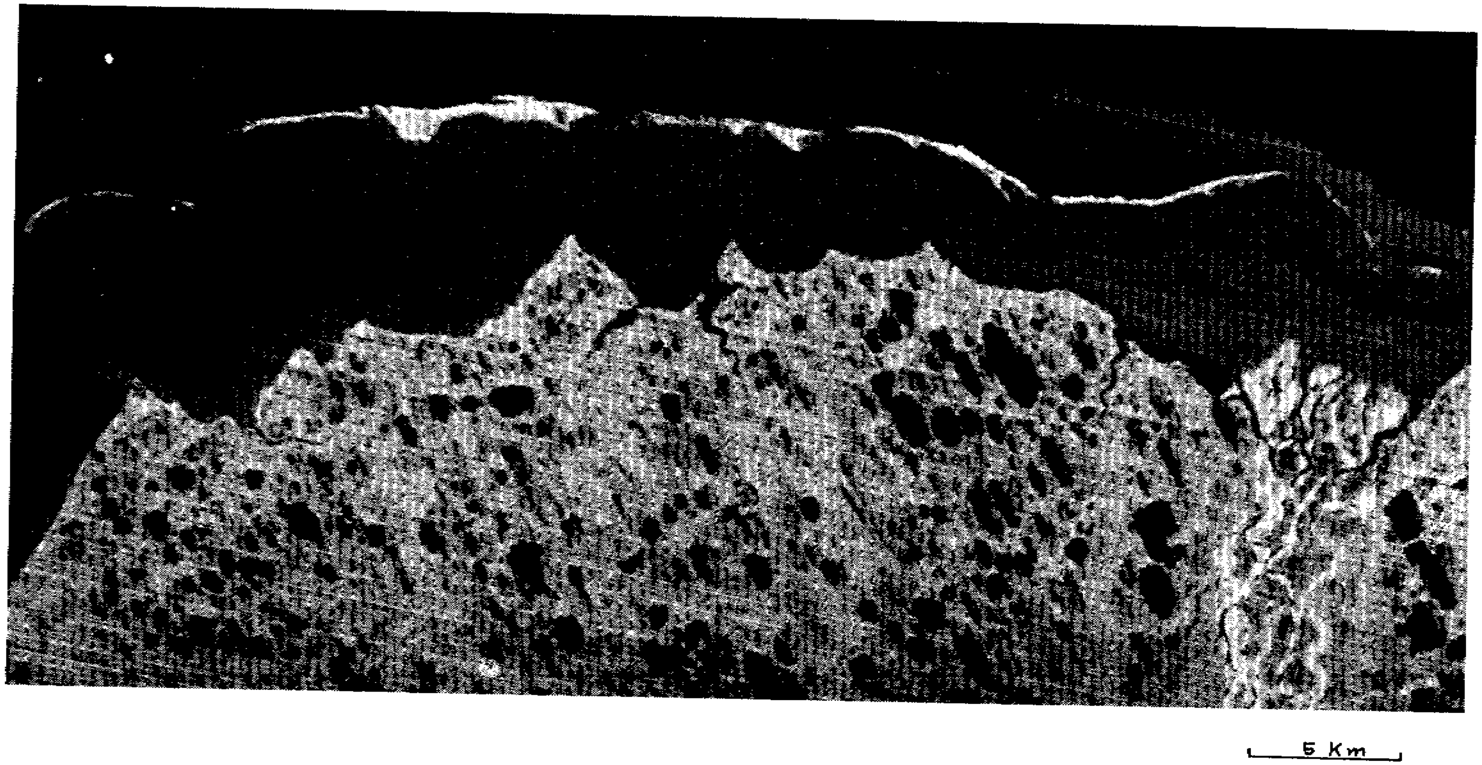


Figure 13. Band 5 Landsat imagery of Simpson Lagoon, taken on 25 July, 1977. Band 5 shows the visible red part of the spectrum and is perhaps the most useful single Landsat band. Band 5 shows water quality, bare rock material, vegetation, and cultural features.

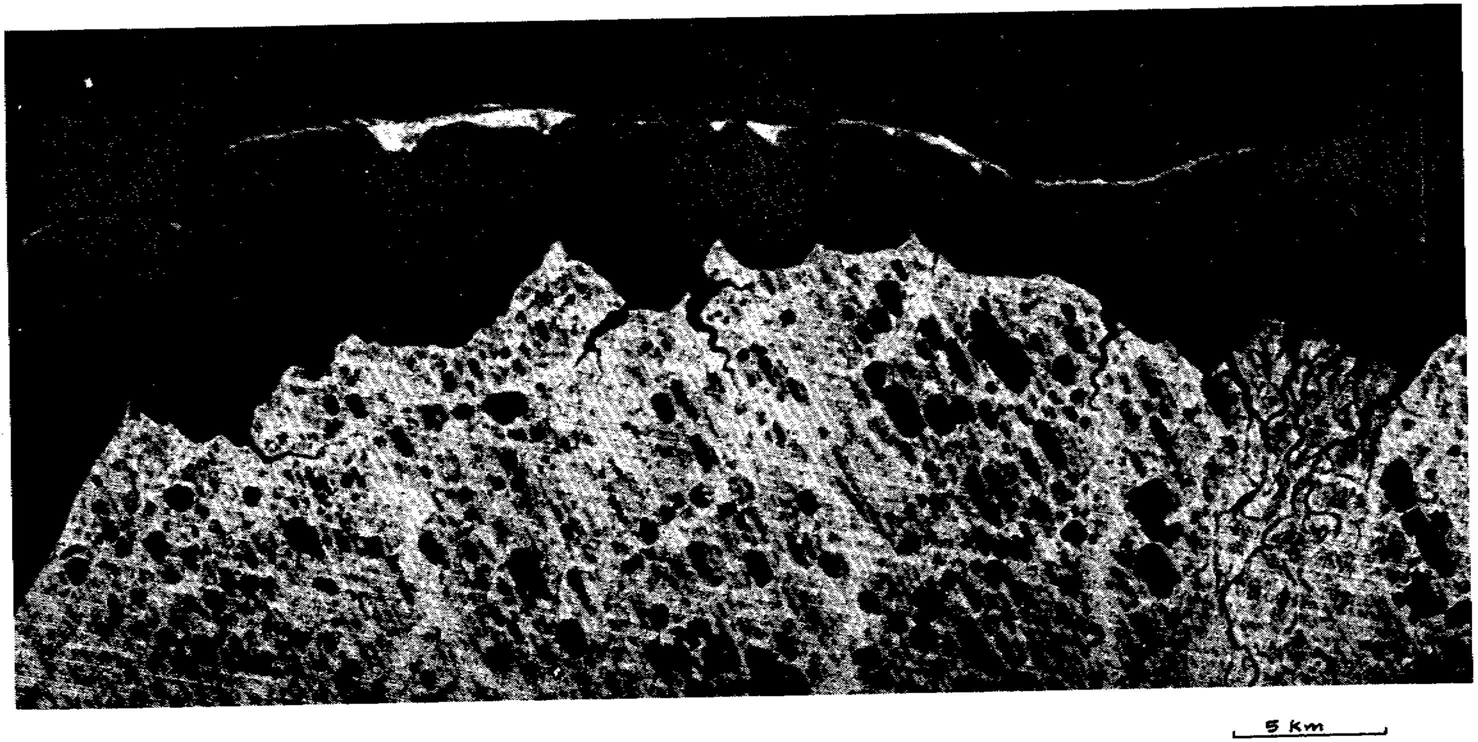


Figure 14. Band 6 Landsat imagery of Simpson Lagoon, taken on 25 July, 1977. Band 6 shows a small part of the Solar IR (near IR). Band 6 is useful for rock and vegetation studies.

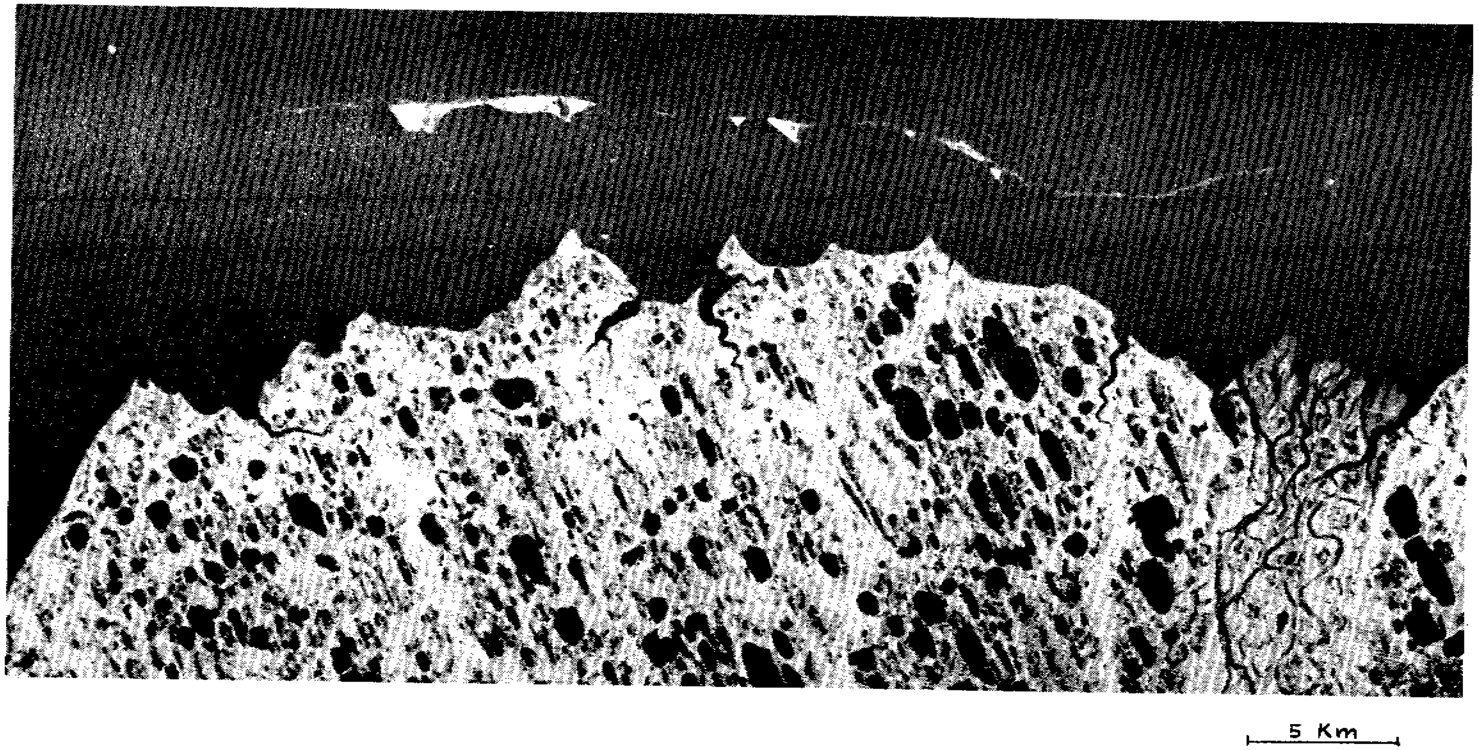


Figure 15. Band 7 Landsat imagery of Simpson Lagoon, taken on 25 July, 1977. Band 7 shows a larger part of the Solar IR (near IR) than band 6. Band 7 is less affected by haze and clouds than the other bands. It shows land-water contacts very well.

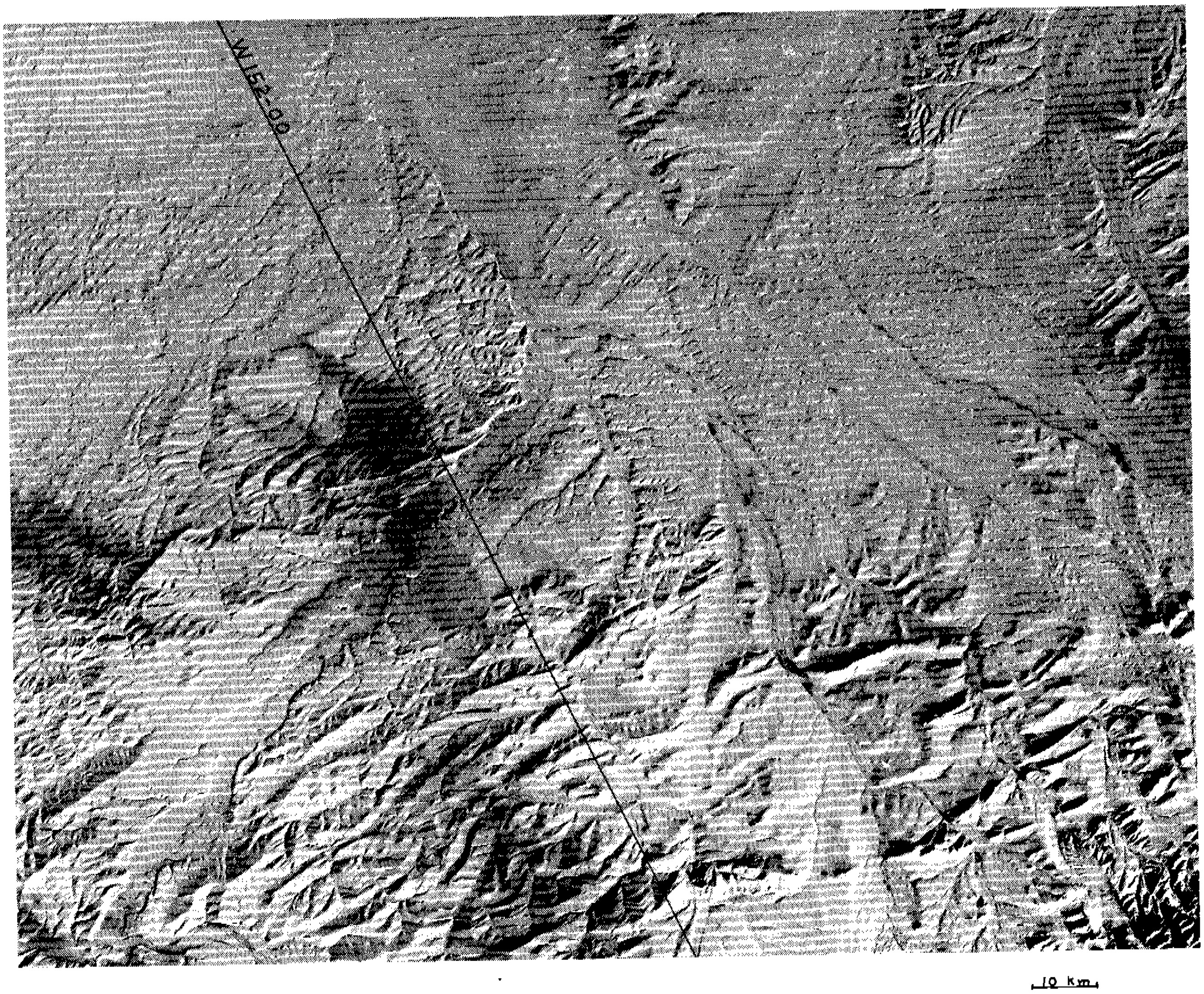


Figure 16. This is a band 7 Landsat image taken 27 February, 1978. The area shown is around Umiat, Alaska, which is just left of the center of the scene. The Colville River runs in the large flat floored valley that starts in the lower left corner of the scene. Near the center the Colville River turns north and flows in a direction of 350° azimuth. The Colville River at one time flowed down the now abandoned channel which can be seen just to the right of the center of the upper portion of the scene. The sun's elevation, at the time this scene was taken, was eleven degrees above the horizon. These low sun-angle scenes enhance the minor topography very well.

breached area where the Colville River was pirated to the north is easily seen. The wind gap, or the abandoned stream channel left by the piracy, also shows up well continuing eastward.

The valley of the Putuligayuk River appears too large for the stream on Landsat imagery, bands six and seven, of the Prudhoe Bay area (Figure 17). Field observations confirmed that the Putuligayuk River is a misfit stream; the size of the original channel and the volume of gravels can not be accounted for by the present stream. From Landsat imagery a series of figures were drawn showing possible past changes in the streams systems in the area (Figures 18, 19, 20, and 21). It appears from this study that Prudhoe Bay was once the extension of a larger stream system.

VII. Discussion

The major landforming process in the study area is removal of ground ice by melting. This process for the creation of landforms is unique on this planet.

Since the coastal plain slopes toward the coastline, the bluffs along the beach should become higher as the coastline retreats. However, the bluffs appear to have maintained a low height of 1-3 meters. If coastline retreat had started just at the islands, the coastal bluffs should be over 10 meters in height. From this, it appears that vertical subsidence of the surface due to loss of ground ice is occurring along with the horizontal retreat of the coastline. In any consideration, it would be illogical to assume that loss of ground ice would only be at the coastline in an horizontal direction.

The coastline along the lease area shows a range of morphologies. Typically, there is about a 2 meter bluff along the back of a narrow beach. However, in some areas the tundra surface slopes to the back of the beach with no break or bluff. In these areas the beach consists of a berm of sand and gravel on top of tundra. The tundra continues out from under the beach berm and under the water of the adjacent lagoon. This bluffless shoreline attests to the vertical subsidence of the coastal plain.

The shorelines of the lakes show the same range of morphologies as the coastline. Some lakes have bluffs at the shoreline while others have no bluffs and the tundra slopes to the edge of the water and continues below the lake surface. In general, large lakes have bluffs and small lakes are bluffless.

The streams show this same bluff phenomenon. In small stream channels tundra often slopes down the banks and under the stream, and in larger stream channels, intransit gravels may be seen on top of tundra. The largest streams have bluffs or a bluff only on one side of the channel.

Stream channels are not being created or rapidly enlarged by mechanical erosion of bank and bed materials, but rather by loss of ground ice. This explains why some streams show very intense meandering without any meandering scars, point bars, chutes, or chute cutoffs. Meandering in streams, where mechanical erosion is the major process, always shows scars of erosion and features of deposition.

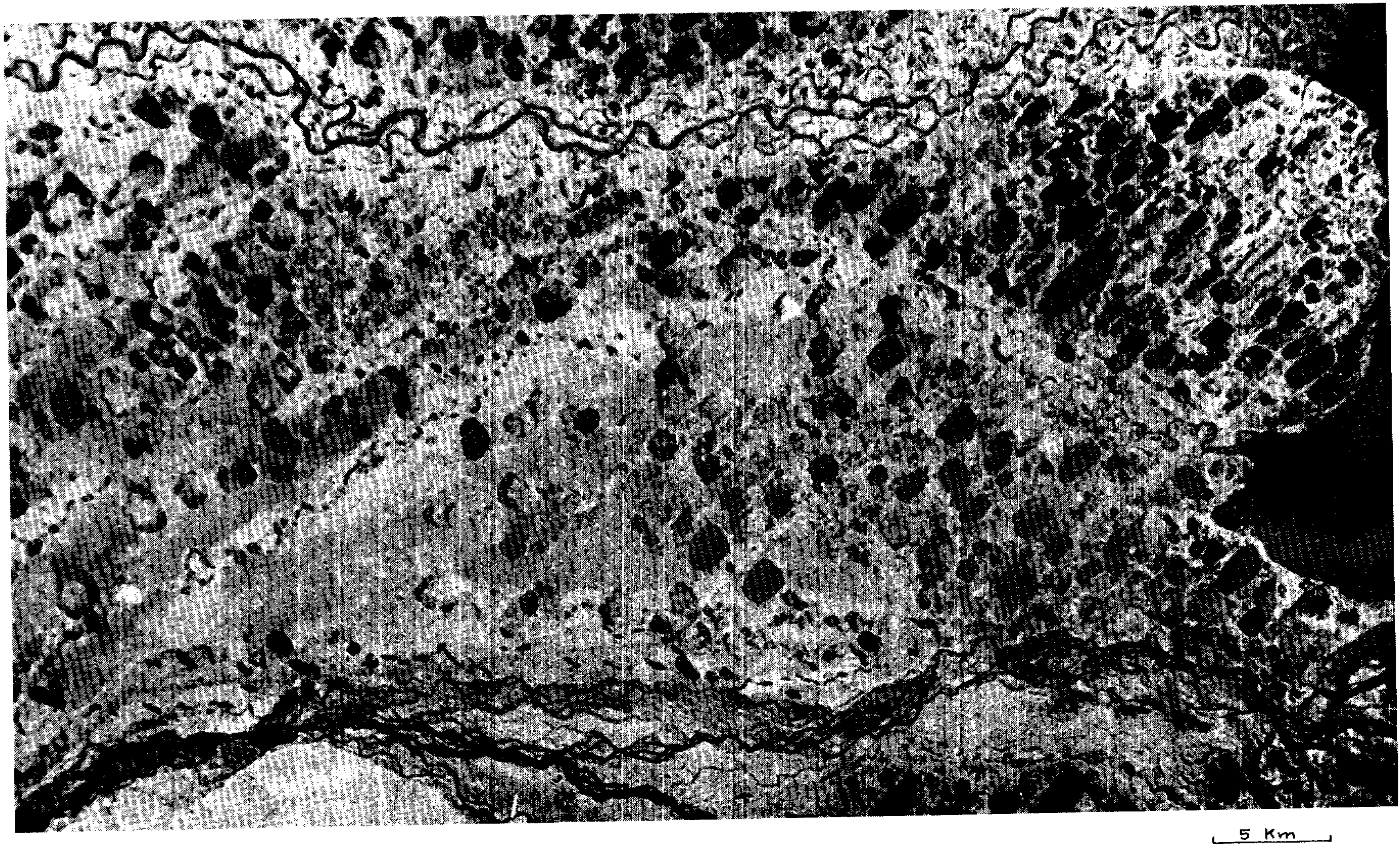


Figure 17. This is a band 6 Landsat image of the Putuligayuk River taken on 25 July, 1977. The Putuligayuk River runs from the lower left corner of the scene, where it starts at the Sagavanirktok River, to the southwest corner of Prudhoe Bay, on the right side of the scene. It appears that the present Putuligrauk River was once the major channel of the Sagavanirktok River. The Kuparuk River runs along the top of the scene.

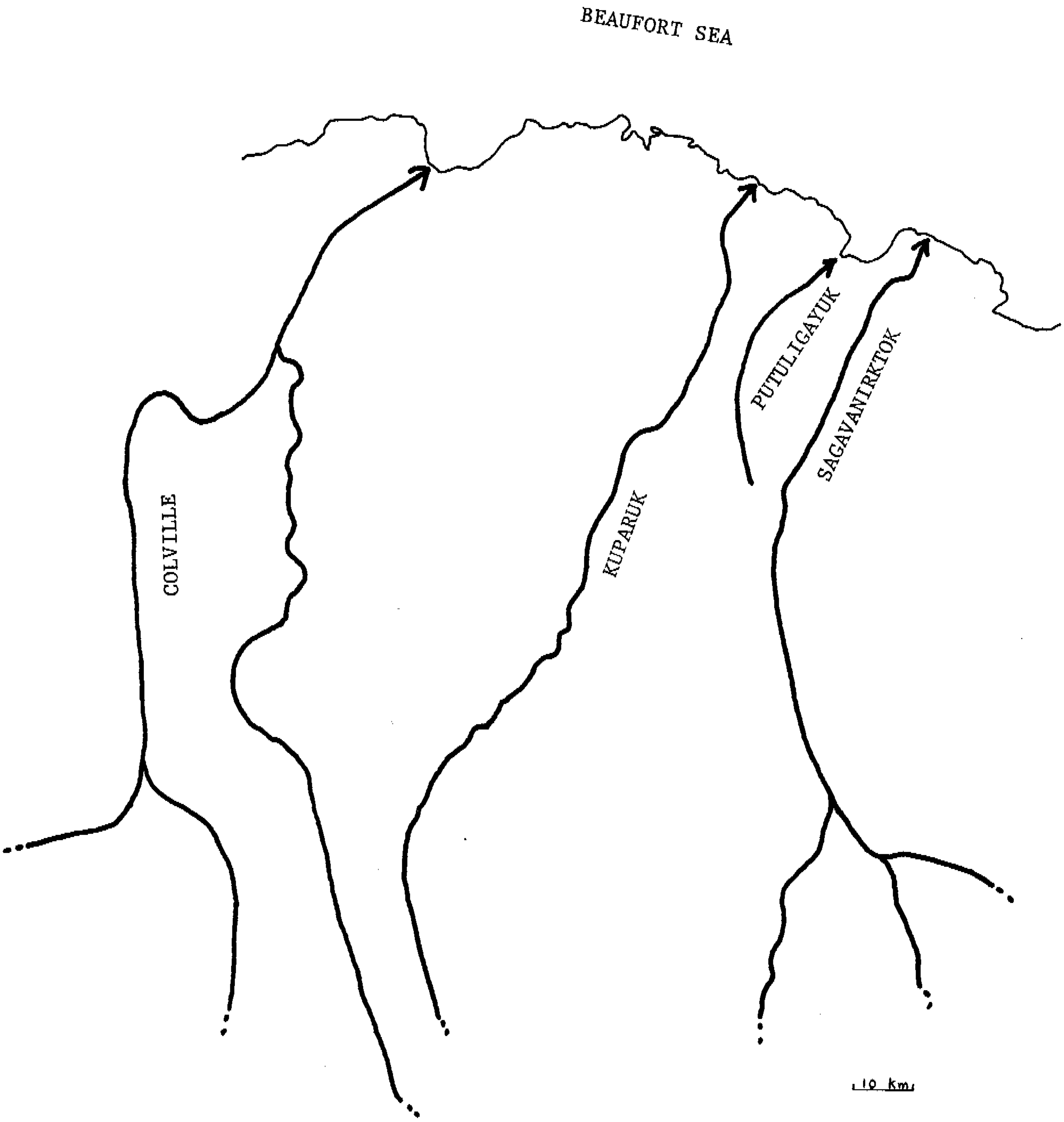


Figure 18. This is a schematic drawing of the Colville, Kuparuk, Putuligayuk, and Sagavanirktok Rivers. It shows how the four rivers presently flow separately into the Beaufort Sea. The next three figures attempt to reconstruct the past drainage routes of these four rivers in progressively older steps.

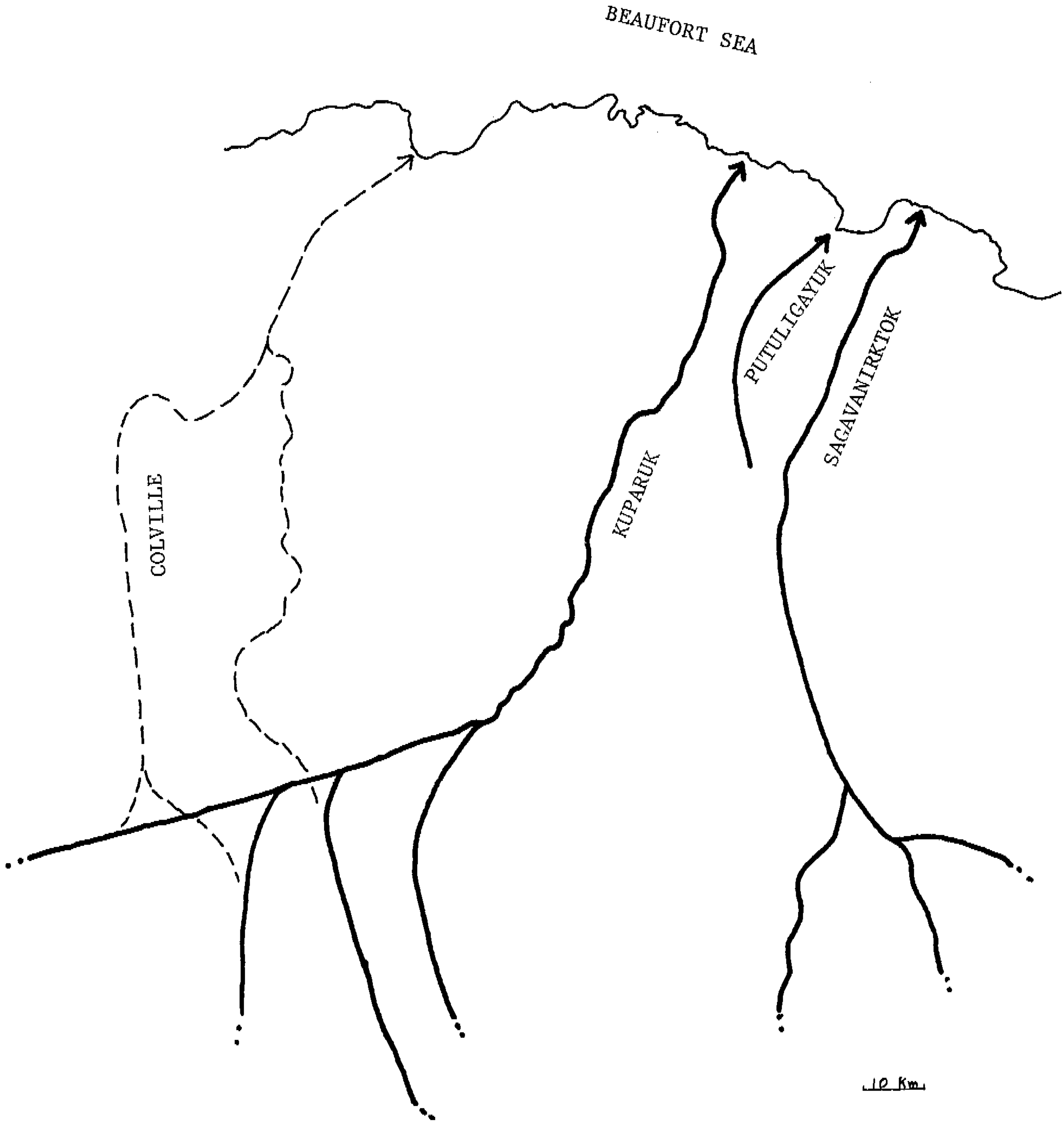


Figure 19. This shows the four rivers at time, present - time X_1. The Colville River joins the Kuparuk before entering the Beaufort Sea. How long ago this situation existed is unknown.

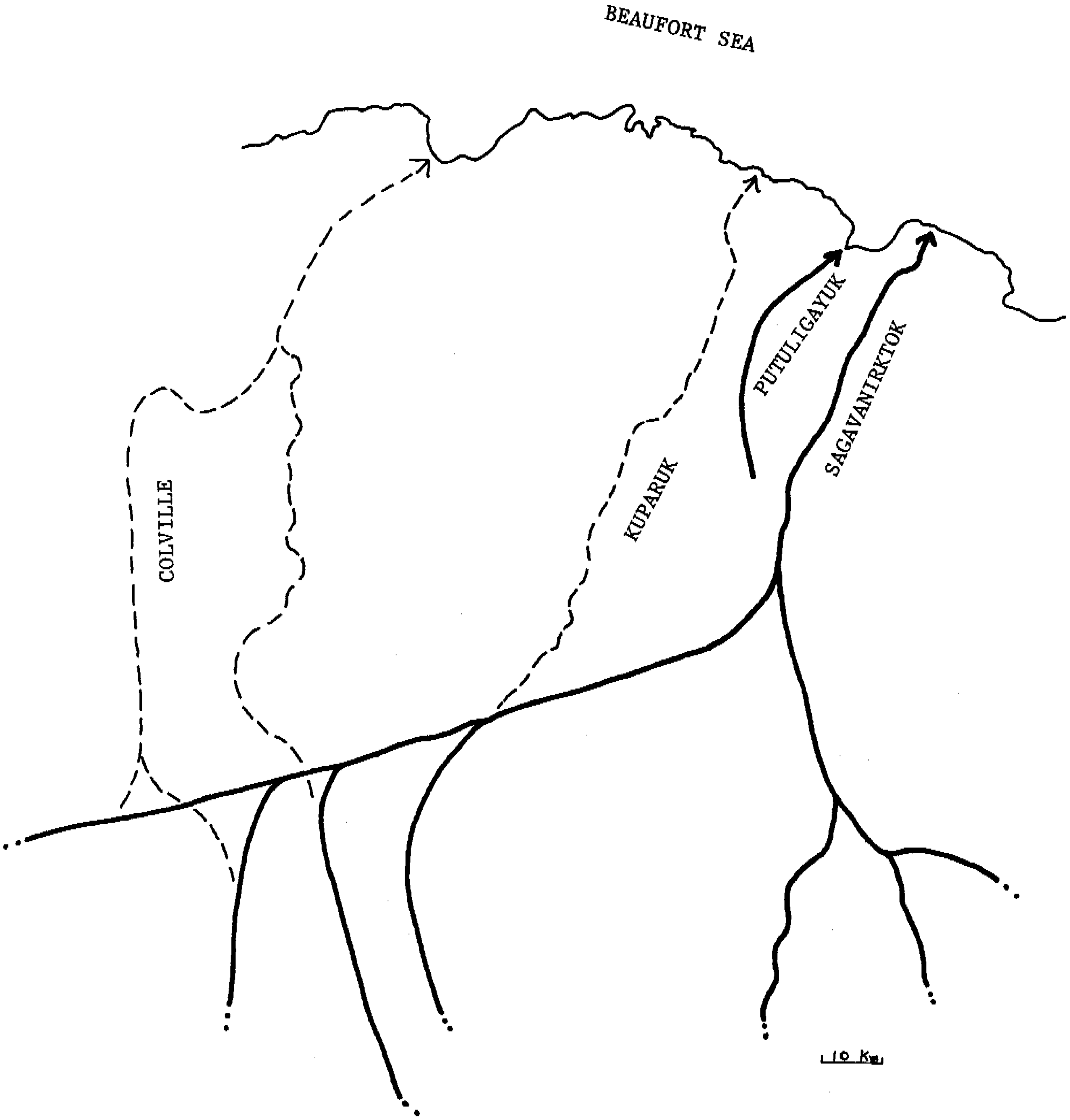


Figure 20. This shows the four rivers at time, present - time $X_1 + X_2$. The Colville and Kuparuk Rivers join the Sagavanirktok River before flowing into the Beaufort Sea.

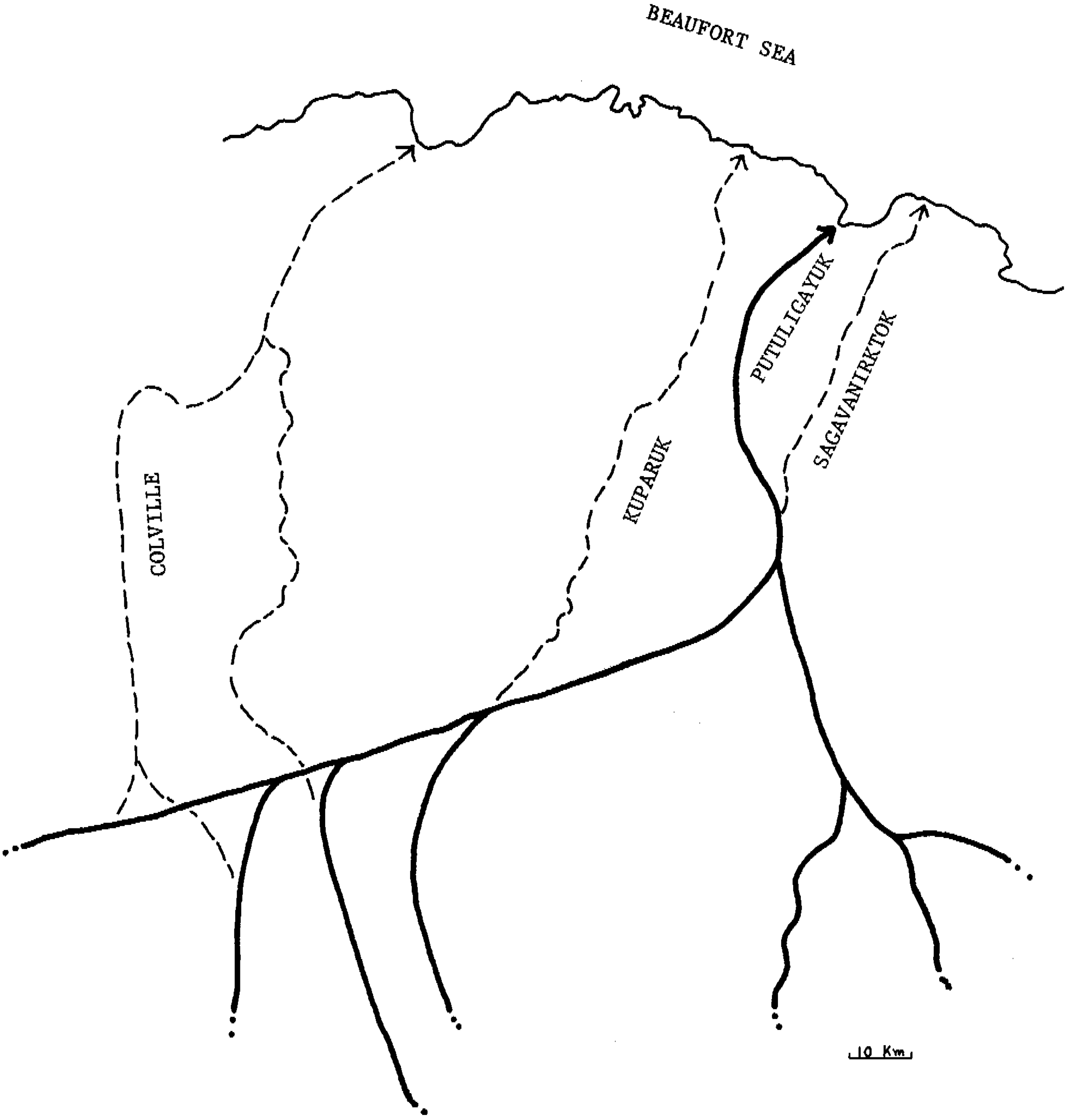


Figure 21. This shows the four rivers at time, present - time $X_1 + X_2 + X_3$. The Colville, Kuparuk, and Sagavanirktok Rivers all join and flow into the Beaufort Sea via the Putuligayuk River. This can account for the misfit of the Putuligayuk River to its valley and perhaps the origin of Prudhoe Bay.

Stream channels begin during breakup with water flowing overland in vast sheets. Channels begin by the melting of near surface ground ice. As channel flow increases, the melting of ground ice increases and the tundra mat subsides. Thus, the original material which is removed to make the channels, is ground ice and not soil or rock materials.

As the channels are deepened by the melting of ground ice, the tundra mat is stretched until it breaks, at which time blocks of tundra mat and underlying peat are dropped into the stream and transported. This rupture of the tundra mat produces a bluff in which the rock materials of the coastal plain are exposed. With availability of rock materials, the stream begins to carry sand and gravel.

The conclusion drawn from the bluff to bluffless shoreline range, is that the rates of vertical subsidence vary between areas. A bluff forms where the rate of horizontal retreat is significantly greater than the rate of vertical subsidence. There is no bluff where the rate of vertical change keeps pace with the horizontal component of change.

VIII. Conclusions

The coastline, lagoons, islands, lakes, and streams are the major landforms of the Beaufort Sea coastal plain. These landforms are created by the loss of ground ice and are modified by other processes. The major geomorphic process on the coastal plain is the loss of ground ice.

Although not extensive on the coastal plain, the deltas are perhaps the most important landforms in the ecosystem. The deltas are the sources of detritus which is picked up and transported throughout the barrier island - lagoon system for most of the ice-free season.

In order to save extensive discussion, the more pertinent points of this study are summarized in two tables (Tables 5 and 6).

Table 5 - Summary of information gathered from the area of the Beaufort Sea lease.

1. Some of the islands consist of ice-cored tundra with non-ice-cored gravel spits on the ends of the islands.
2. Some of the islands consist of elongate gravel bars that are non-ice-cored or that have ice at depth.
3. Most islands are umbrella shaped, due to recurved spits on the ends.
4. The islands are composed mainly of gravel.
5. Non-ice-cored islands consist of gravel and some sand.
6. Ice-cored tundra-covered islands consist of sand, angular gravels, cobbles, and angular boulders.

7. Materials of all islands are identical with materials on coastal plain.

8. Tundra on islands is identical to tundra on coastal plain.

9. Lakes on tundra islands are identical to lakes on the coastal plain.

10. Sometimes tundra-covered islands are connected to the tundra on the coastal plain with a strip of continuous tundra.

11. The tundra cover on the islands is continually being lost.

12. Tundra is not being generated on the gravel islands.

13. The shorelines of the tundra-covered islands are presently retreating.

14. The shoreline of the coastal plain is presently retreating in the same manner as the shorelines of the tundra-covered islands.

15. The islands are at different distances from the coastal plain.

16. The lagoons between the islands and the coastal plain are shallow, 2-6 meters.

17. Some of the boulders found on the islands and the coastal plain exhibit indisputable glacial striae.

18. River water that flows over near-shore ice at breakup transports only very fine material.

19. Water on the lagoon side of the islands freezes over first.

20. Pack ice normally does not enter the lagoons and the pack ice which does enter the lagoons is of such shallow draft and small size it could not raft any significant amounts of rock material or individual rock masses of any large dimensions.

21. No rock materials were observed being added to the islands by ice rafting.

22. In the fall during freezeup ice shove sometimes reworks the beach materials.

23. Most ice shove occurs after freezeup when the gravels of the islands are frozen.

24. Ice shove was not observed to contribute any significant materials to the islands.

25. Due to the presence of the pack ice, the fetch on the open Beaufort Sea is limited.

26. Longshore currents generated by winds in the area do not transport gravel across the lagoons or the lagoon entrances to the islands.

27. The major geomorphic changes are due to loss of ground ice.

28. Stream valleys form by the loss of ground ice. Mechanical erosion of stream valleys is minor.

29. Lakes form due to the loss of ground ice.

30. The shorelines of the lakes are presently retreating.

Table 6 - A Summary of the Steps in the Evolution of the Beaufort Sea Coastal Plain.

Part A: Barrier Island - Lagoon System

1. Coastal area lowers due to loss of ground ice.

2. Lakes form on the coastal plain due to loss of ground ice.

3. Lakes continue to increase in size due to loss of ground ice, and eventually coalesce.

4. Coastal shoreline retreats due to loss of ground ice.

5. Coalescing lakes are breached by the retreating shoreline.

6. Sea water fills coalesced lakes and an embayment is created bounded by tundra-covered arms or promontories.

7. Portions of the tundra-covered promontories become detached from the coastal plain due to continued loss of ground ice.

8. The detached portions of the tundra-covered promontories thus become tundra-covered islands.

9. The tundra-covered islands are reworked by erosion and gravel spits form on the ends of the islands.

10. The tundra-cover is stripped off some islands and the ground ice retreats leaving gravel islands.

11. Gravel islands are reworked into shoestring islands.

12. Further loss of ground ice causes island remnants to subside.

13. Wave action distributes gravel over the shallow sea floor.

14. Island remnants subside below wave base and are left as slight rises on the sea floor.

Part B: The Streams

1. At breakup the coastal plain is flooded over completely frozen near-surface materials.

2. Water flows toward the coast running from flooded lake to flooded lake.
3. Streams begin as channels between lakes. The channels are formed by the melting of ground ice with the energy from the running water.
4. Stream systems at first stage are a series of channel tied lakes.
5. Stream channels are deepened by melting of ground ice.
6. The tied lakes are drained as the channels between them deepen.
7. Stream systems at second stage consist of tundra floored channels which interconnect drained lake basins.
8. Tributaries form and grow in the same manner as the major branch develops.
9. Sediments from the drained lake basins are picked up and transported by the stream systems.
10. The channels continue to deepen by loss of ground ice and the tundra mat is broken, exposing the sands and gravels of the coastal plain.
11. As materials are exposed, the stream begins to transport them.
12. When the volume of transported materials reaches a critical amount, the construction of a delta begins at the stream's mouth.

Part C: The Lakes

1. Depressions and irregularities form in the coastal plain due to loss of ground ice.
2. Lakes begin as small rectangular or square shaped basins, floored with tundra mat.
3. The length of the rectangles or one parallel set of sides on the squares develop in the same direction as the dominant jointing runs in the foothills of the Brooks Range.
4. The lakes continue to increase in size as ground ice melts and the tundra mat is broken.
5. The lakes lengthen preferentially in the direction of the dominant jointing and begin to become elliptical.
6. The lakes increase in size, in some cases coalescing with adjacent lakes, and the materials of the coastal plain are reworked in a minor manner by wave action.
7. Irregularities in the materials of the coastal plain and wave action modify the shapes of the lakes in a small way. Increased loss of ground ice along the joints in the frozen coastal plain materials accounts for the orientation and location of the lakes. Most lakes are located along a line which runs through other lakes.

IX. Needs for Further Study

It appears that the deltas are the most important landform in the ecosystem of the coastal plain and the lease area. The deltas are perhaps more important than the islands or lagoons. Detritus and fine grain materials are reworked from the deltas throughout the ice-free season. It might be that materials are reworked from the prodelta throughout the winter. This is not known. The most important need for further study is a very close investigation of the deltas along the coastal plain. This would necessitate a detailed study of the stream systems which bring the materials to the deltas.

X. Summary of January - March Quarter

There were no field activities during this quarter. This quarter was spent compiling and summarizing the previous year's data for the annual report.

XI. Auxilliary Material

A. References Used

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DATA MANAGEMENT

DATA MANAGEMENT

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ANNUAL REPORT

Contract # 03-5-022-55
Research Unit #267
Reporting Period:
April 1, 1978 to
March 31, 1979
Number of pages: 40

OPERATION OF AN ALASKAN FACILITY FOR APPLICATIONS OF REMOTE-SENSING DATA TO OCS STUDIES

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Geophysical Institute
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April 1, 1979

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OPERATION OF AN ALASKAN FACILITY FOR APPLICATIONS OF REMOTE-SENSING DATA TO OCS STUDIES

1978/79 Annual Report

Principal Investigator: Albert E. Belon
Affiliation: Geophysical Institute, University of Alaska
Contract: NOAA # 03-5-022-55
Research Unit: # 267
Reporting Period: April 1, 1978 - March 31, 1979

I - SUMMARY OF OBJECTIVES

The primary objective of the project is to assemble available remote-sensing data of the Alaskan outer continental shelf and to assist OCS investigators in the analysis and interpretation of these data to provide a comprehensive assessment of the development and decay of fast ice, coastal geomorphology and ecology, sediment plumes and offshore suspended sediment patterns along the Alaskan coast from Yakutat to Demarcation Bay.

Four complementary approaches are used to achieve this objective. They are: 1) the operation of a remote-sensing data library which acquires, catalogs and disseminates satellite and aircraft remote-sensing data; 2) the operation and maintenance of remote-sensing data processing facilities; 3) the development of photographic and computer techniques for processing remote sensing data; and 4) consultation and assistance to OCS investigators in data processing and interpretation.

Thus, the project has primarily a support role for other OCS projects, and in itself does not usually generate disciplinary conclusions and implications with respect to OCS oil and gas development. Such results will be generated by the various disciplinary OCS projects, most of which are users of remote-sensing data and services provided by our project. At this time at least two dozen OCS projects are utilizing remote-sensing data routinely, six of them (RU #88, 205, 248, 530, 265, and 289) almost exclusively. In addition, the availability of near-real-time remote-sensing data (NOAA and DMSP satellites) and delayed repetitive data (Landsat and aircraft) provides a continuous monitoring of environmental conditions along the Alaskan continental shelf for research and logistic support of the OCSEAP Program.

II - INTRODUCTION

A. General Nature and Scope of Study

The outer continental shelf of Alaska is so vast and so varied that conventional techniques, by themselves, are unlikely to provide the detailed and comprehensive assessment of its environmental characteristics which is required before the development of its resources is allowed to proceed during the next few years. The utilization of remote-sensing techniques, in conjunction with conventional techniques, provides a solution to this dilemma for many disciplinary investigations. Basically the approach involves the combined analysis of ground-based (or sea-based), aircraft and satellite data by a technique known as multistage sampling. In this technique, detailed data acquired over relatively small areas by ground surveys or sea cruises are correlated with aerial and space photographs of the same areas. Then the satellite data, which extend over a much larger area and provide repetitive coverage, are used to extrapolate and update the results of the three-way correlations to the entire satellite photograph. Thus, maximum advantage is taken of the synoptic and repetitive view of the satellite to minimize the coverage and frequency of data which have to be obtained by conventional means.

B. Specific Objectives

The principal objective of the project is to make remote-sensing data, processing facilities and interpretation techniques available to the OCS investigators so that the promising applications and cost effectiveness of remote-sensing techniques can be incorporated in their disciplinary investigations. The specific objectives of the project are: 1) the acquisition, cataloging and dissemination of existing remote-sensing data obtained by aircraft and satellites over the Alaskan outer continental shelf, 2) the operation and maintenance of University of Alaska facilities for the photographic, optical and digital processing of remote-sensing data, 3) the development of photographic, optical and computer techniques for processing remote-sensing data for OCS purposes and 4) the active interaction of the project with OCS users of remote-sensing data, including consultation and assistance in disciplinary applications, data processing and data interpretation.

C. Relevance to Problems of Petroleum Development

The acquisition of remote-sensing data, especially satellite data, has proved to be a cost-effective method of monitoring the environment on a synoptic scale. Meteorological satellites have been used for over a decade to study weather patterns and as an aid to weather forecasting. The earth resources satellite program, initiated in 1972, offers a similar promise to provide, at a higher ground resolution, synoptic information and eventually forecasts of environmental conditions which are vital to petroleum development on the continental shelf. For instance the morphology and dynamics of sea-ice which are relevant to navigation and construction of offshore structures, the patterns of sediment transport and sea-surface circulation which will aid to forecast trajectories of potential oil spills and impact on fisheries, the nature of ecosystems in the near-shore regions which can be changed by human activity, are among the critical development-related environmental parameters which can be studied, in conjunction with appropriate field measurements, and eventually routinely monitored by remote-sensing.

III - CURRENT STATE OF KNOWLEDGE

The utilization of remote-sensing techniques in environmental surveys and resource inventories has made great strides during the last few years with the development of advanced instruments carried by aircraft and satellites. The early meteorological satellites had a ground resolution of a few miles and a broad-band spectral response which made them well-suited to meteorological studies and forecasting but inadequate for environmental surveys. The ground resolution of the sensors has been gradually much improved over the years and thermal sensors were added for cloud and sea temperature measurements, but generally the relatively low ground and spectral resolution of the meteorological satellites is a limitation for environmental surveys.

The initiation of a series of Earth Resources Technology Satellites (now renamed Landsat) in July 1972 was intended to fill the need for synoptic and repetitive surveys of environmental conditions on the land and the near-shore sea. With a ground resolution of about 80 meters and sensitivity in four visible spectral bands, Landsat-1 and 2, have fulfilled that promise beyond all expectations. Landsat 3 was launched on March 5, 1978 and is acquiring MSS data in all four spectral bands as well as RBV data which provides higher ground resolution (40 meters) than either of the first two satellites. Unfortunately the thermal spectral band on Landsat 3 never worked properly and very little useful data was acquired from it.

The development of techniques for analyzing and interpreting Landsat have proceeded at an even more rapid pace than the satellite hardware. While in 1972 much of the Landsat data interpretation was done by visual photointerpretation, the last four years have seen major developments in photographic, optical and, in particular, digital techniques for processing and interpreting the Landsat data. Some of these techniques, applicable to OCS studies, will be discussed in section V and VI of this report.

Through the impetus provided by the national commitment to satellite observations of the earth, the aircraft remote-sensing program has also made great strides in the last few years. While in the early 1960's airborne platforms were mostly used for aerial photography, the late 1960's saw the development of advanced multispectral scanners, thermal scanners, side-looking radars and microwave radiometers, partly for the testing of future satellite hardware and partly because the airborne observations serve for middle-altitude observations between ground and satellite measurements as part of the multistage sampling technique. Two philosophies are apparent in the airborne remote-sensing program: the first, exemplified by the NASA program as well as several universities and industrial agencies, involves relatively large aircraft and sophisticated instrumentation which produce vast quantities of data usually applied to intensive, non-repetitive surveys of relatively small areas. The second approach uses airborne remote-sensing in a truly supporting role for ground-based or satellite measurements. The aircraft are smaller and the instrumentation usually consists of proven, simpler instruments such as aerial cameras, single-band thermal scanners, and single wavelength side-looking radars which usually generate data only in photographic format. The costs of data acquisition and data processing, while they are not small, are sufficiently low that the approach is often used for repetitive surveys of relatively large areas. In our opinion the second approach fulfills best the needs of the NOAA/OCSEAP program and we have been working very closely with the NOAA Arctic Project Office toward the implementation of such a remote-sensing program.

IV - STUDY AREA

The study area for the project includes the entire continental shelf of Alaska, except for the southeastern Alaska panhandle. This area includes the Beaufort, Chukchi and Bering Seas and the Gulf of Alaska shelves and coastal zone. Temporal coverage is year-round, although the data coverage from November 1 to February 15 is limited owing to the very low solar illumination prevailing at high latitudes during winter.

V - SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

A remote-sensing data library and processing facility was established in 1972 on the Fairbanks campus of the University of Alaska as a result of a NASA-funded program entitled "An interdisciplinary feasibility study of the applications of ERTS-1 data to a survey of the Alaskan environment". This experimental program, which covered ten environmental disciplines and involved eight research institutes and academic departments of the University, terminated in 1974, but the facility which it established proved to be so useful to the statewide university and government agencies that it has continued to operate on a minimal basis with partial funding from a NASA grant and a USGS/EROS contract. In view of the large potential demand of the OCS program on these facilities, a proposal was submitted to NOAA in March 1975 for partial funding of the facility for OCS purposes. This proposal resulted in a contract from NOAA on June 12, 1975, and the work performed since that time is the basis for the present report.

As a result of the NASA-funded program, the remote-sensing data library had total cloud-free and repetitive coverage of Alaska by the ERTS - now renamed Landsat - satellite from the date of launch (July 29, 1972) to May 1974 (about 30,000 data products), 60 rolls of imagery acquired by NASA aircraft (NP3 and U-2) some of which includes coverage of the Beaufort Sea, Cook Inlet and Prince William Sound, and substantial facilities for photographic, optical and digital processing of these data. Through a NOAA-funded pilot project, which studied applications of NOAA satellite data in meteorology, hydrology, and oceanography, the remote-sensing data library also had nearly complete coverage of Alaska by the NOAA satellites since February 1974.

A. Remote-Sensing Data Acquired for the OCS Program

1) Landsat data

At the initiation of the project we performed searches of the EROS Data Center (EDC) data bank for Landsat and aircraft remote-sensing data obtained over the four areas of interest to the OCSEAP program. From the several thousand scenes so identified, we selected the scenes which we did not have in our files and which had satisfactory quality and 30% or less cloud cover. As a result of this search 566 Landsat scenes (2830 data products) were ordered from the EROS Data Center in the following data formats:

-70mm positive transparencies of multispectral scanner (MSS) spectral bands 4, 5 and 7
-70mm negative transparencies of MSS spectral band 5
-9-1/2 inch print of MSS spectral band 6

During the first three years of the project, 2,273 additional cloud free scenes were acquired by the satellite and purchased from EDC.

After March 31, 1977, the EDC price for Landsat products having increased by an average of 166%, we reduced our routine purchase of selected Landsat scenes to two formats:

-70mm positive transparency of MSS, spectral band 5
-9 1/2 inch print of MSS, spectral band 7

Other formats are ordered on a case-by-case basis and at the request of individual OCS investigators. During the past year, 533 scenes were added to our files.

2) NOAA satellite data

With the termination of a NOAA pilot project, sponsored by NOAA/NESS, in October 1975, our acquisition of NOAA satellite scenes stopped after having accumulated 1320 images since February 1974. Following an interim arrangement with the National Weather Service, which turned out to be inconvenient for both parties, funding was provided by OCSEAP, starting on 1 February 1976, to purchase NOAA satellite imagery directly from the NOAA/NESS Satellite Data Acquisition Facility at Fairbanks. Under this purchase order we are receiving two NOAA scenes daily from the Bering Sea pass of the satellite (covering the Beaufort, Chukchi and Bering Seas) and one scene daily from the interior Alaska pass (covering the Gulf of Alaska) in both the visible and infrared spectral bands (6 images daily except in winter) for a total of 972 images received during the reporting period.

In addition we have made arrangements with the NOAA/NESS facility to save digital tapes of the thermal infrared data, upon request and for the cost of tape replacement, for scenes which are especially cloud-free or of high interest to OCS investigators. These tapes allow the precise mapping of sea-surface temperatures at locations and at times of special interest to OCS investigators.

3) USGS/OCS aircraft remote-sensing data

In November 1975, we started receiving the remote-sensing data acquired by USGS aircraft, under a NOAA/OCS contract, along the Alaskan arctic coast since July 1975.

These data consist of six 250 ft. rolls of black and white aerial photography and 42 strips of side-looking radar imagery. This program terminated in December 1975.

4) NASA aircraft remote-sensing data

Over the last few years the NASA Earth Resources Aircraft Program has flown several missions over preselected test sites within Alaska. The program is directed primarily at testing a variety of remote-sensing instruments and techniques and to support NASA-sponsored investigations. However, black and white and color-infrared aerial photography were obtained on most missions and in particular during the May 1967, July 1972, June 1974, and October 1976 missions which include flights over portions of the Alaskan coast and coastal waters. We have acquired copies of these data from NASA.

The U-2 imagery of the Beaufort Sea obtained in June 1974 is of particular interest to OCS investigators because it was obtained during the sea-ice break-up period, it covers a large area (20x20 mi.) in a single frame with good ground resolution (10 ft.), and nearly concurrent Landsat data are available. Similarly, the U-2 imagery of the northern Gulf of Alaska and Prince Williams Sound, acquired in October 1976, is of excellent quality.

During June 1977 the U-2 aircraft once again acquired photography over Alaska. New flight lines, mostly in the Prudhoe Bay area, using a 6" and 12" focal length lens were flown and copies of the data are included in our files.

This year several state and federal agencies combined efforts to obtain high altitude aerial photographic coverage of the whole State of Alaska. This imagery will be acquired by NASA over a three-year period which commenced in summer 1978. Approximately fifty percent of the state was satisfactorily covered in the first year's effort. Two cameras are being used with focal length lenses of 6" and 12" resulting in black and white coverage at 1:120K scale and color infrared coverage at 1:60,000 scale. Coastal areas covered this year include Point Hope to Cape Espenberg, most all of Kodiak Island and most of the coastal areas from Seldovia to Glacier Bay. Although copies of this imagery are not yet in our files, we do have the indices and are able to obtain the imagery for investigators.

Currently a C-131 aircraft from Nasa Lewis Research Center in Cleveland, Ohio is in Alaska and has made several SLAR flights in the Beaufort and Bering Seas with an X-Band radar. Copies of these data will be made and archived in our data library.

5) NOS aircraft remote-sensing data

In spring 1976 we learned that the National Ocean Survey's (NOS) Buffalo aircraft was scheduled to obtain aerial photographic coverage of Shelikof Strait during summer 1976. Knowing that this area is frequently covered by clouds, we requested NOS to acquire aerial photography of other areas of the Alaskan coastal zone on a non-interference basis with their primary mission. NOS agreed to do so for the cost of the raw film. As a result 1316 frames of color aerial photography were acquired, covering the entire coast from the Yukon delta to Cape Lisburne and several isolated areas in the Gulf of Alaska.

During July 1977 the NOS aircraft flew additional flight lines on the Chukchi and Beaufort coasts extending our coverage eastward to the mouth of the Kogu River, in Harrison Bay. This medium scale photography is of excellent quality and has been used heavily by OCS investigators.

6) Army aircraft remote-sensing data

With the termination of the USGS/OCS remote-sensing data acquisition program in December 1975, an important need developed for all-weather remote-sensing coverage of the Beaufort and Chukchi coasts during critical periods (end of winter and end of summer). We worked closely with the OCSEAP Arctic Project Office and with a major user (Dr. Cannon, RU #99) in investigating various options culminating in a contractual arrangement with the U. S. Army remote-sensing group at Ft. Huachuca, Arizona.

Under this contract an Army Mohawk aircraft equipped with an all-weather side-looking radar (SLAR) flew two missions in Alaska in May and August 1976 resulting in complete SLAR coverage (51 flights) of the Beaufort and Chukchi shelves during the critical periods. These data have been heavily used, particularly by OCSEAP RU #88 (Weeks) and RU #99 (Cannon). An April 1977 SLAR mission was flown which resulted in spring sea-ice coverage of the Chukchi and Beaufort coastlines as far east as Camden Bay.

During this reporting period arrangements were made by NOAA/BLM and USA/CRREL to obtain SLAR missions along the Beaufort coast on a regular basis. The imagery is obtained by an Army Mohawk OV-1B and to-date data has been received on a monthly basis since December 1978. The film is copied in the Geophysical Institute photo lab, transparencies made as well as several copies of prints for distribution. The original imagery is then returned to the Army and a copy is retained in our file.

7) Near-real-time satellite imagery

Near-real-time satellite imagery is now available to OCS investigators through the Remote-Sensing Library. Air Force weather satellite imagery (DMSP) is received at Elmendorf Air Force Base near Anchorage and shipped daily to the Geophysical Institute. Also, Landsat quick-look data from selected scenes is received from Canadian sources two or three days after acquisition. These new data products are made possible through a State-funded project to evaluate the utility of near-real-time satellite imagery to Alaskan problems. OCS has made extensive use of these data, primarily to determine sea-ice conditions.

8) Preparation and distribution of remote-sensing data catalogs

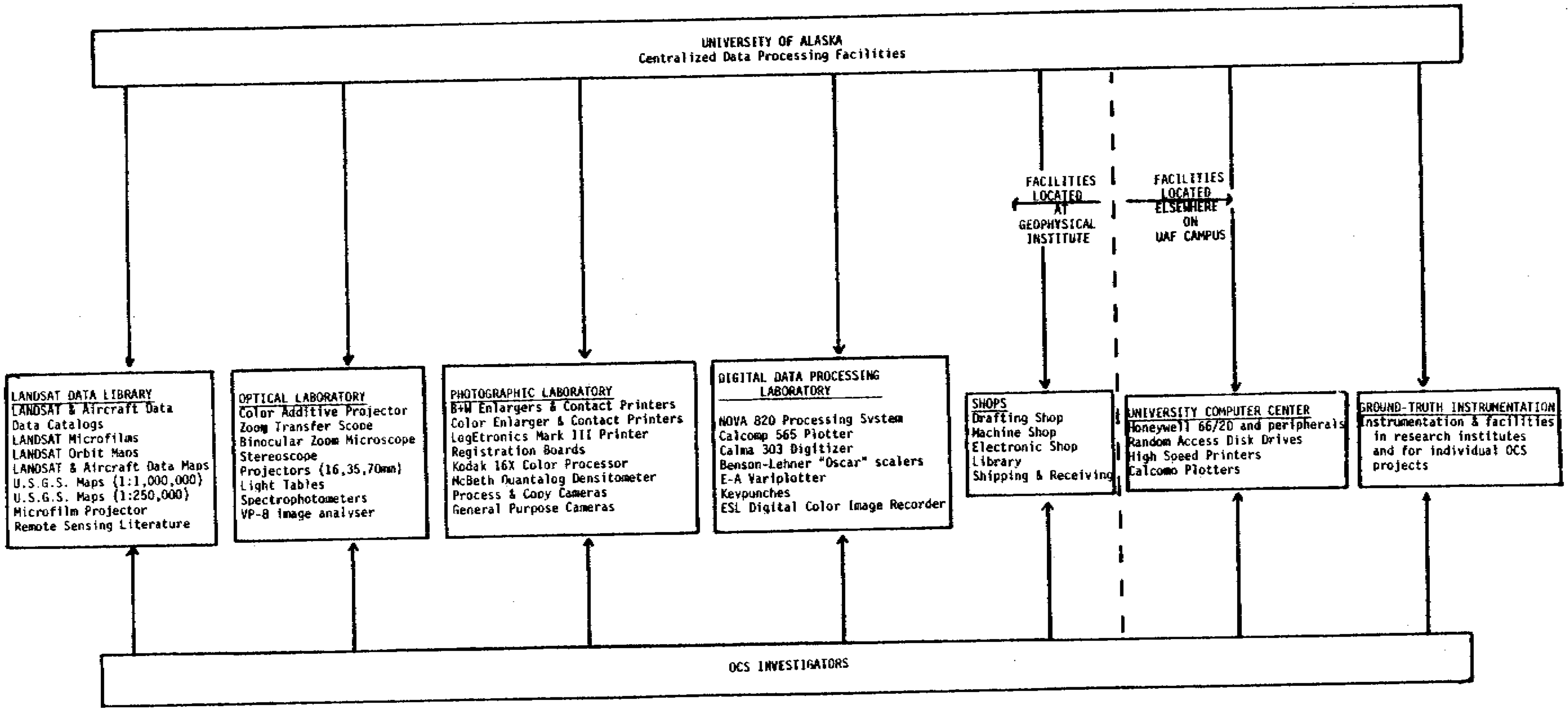
All the remote-sensing data available in our files for the Alaskan continental shelf have been indexed and plotted on maps. Catalogs summarizing the availability of these data and providing instructions for selecting and ordering data have been prepared and distributed to all OCS investigators as appendices to the series of Arctic Project Bulletins (Nos. 6, 9, 10, 12, 14, 17, and 22). In addition we have developed a file of catalogs and photo indices of aerial photography obtained by federal, state and industrial agencies in Alaska, and we attempt to stay informed on plans for future aircraft photographic missions.

B. Remote-Sensing Data Processing Facilities and Techniques

The facilities and equipment commonly used for remote-sensing data processing are listed in Figure 1. Most of this equipment is not devoted exclusively to remote-sensing data processing but arrangements have been made to support the needs of the OCS investigators on a time-share and work-order basis, and to take into account the needs of the OCS program in any planned modifications or expansions.

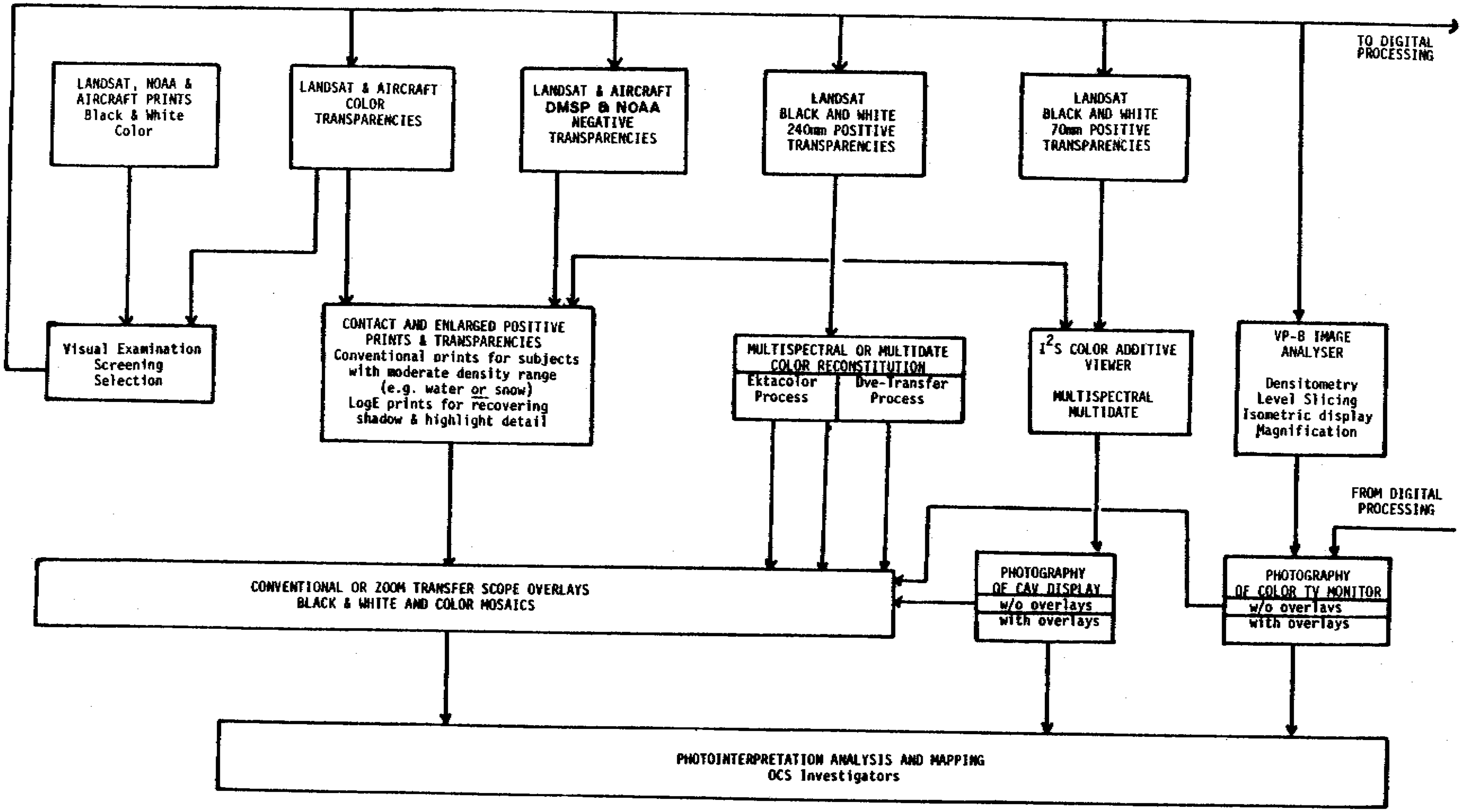
The optical and photographic processing techniques developed for the remote-sensing program are described in the flow diagram of Figure 2.

Photographic processing probably needs no further explanation. The full range photographic laboratory of the Geophysical Institute is well adapted to the generation of custom, as distinct from production run, photographic products. However, the available equipment limits photographic enlargements to 16x20" maximum size from 8x10" originals. Electronically dodged prints or transparencies are produced by contact printing only.



Centralized Data Processing Facilities

Figure 1



Optical and Photographic Processing

Figure 2

Optical processing revolves around the use of specialized equipment such as the multiformat photo-interpretation station, the zoom transfer scope, the color additive viewer and the VP-8 image analyzer in addition to conventional light tables, stereoscopes and a binocular zoom magnifier.

Multiformat Photo Interpretation Station - Analysis of aerial imagery in roll form is a cumbersome task and is likely to damage the original material even with careful handling if one uses ordinary reel holders and a light table. With stereo coverage, it is impossible to achieve stereo viewing with the frames appearing on the roll format unless one uses the photo interpretation machine. It can accommodate either 5-inch or 9-inch film formats and the film transport adjusts to permit stereo viewing with varying amounts of forward lap between frames. The viewing turret includes zoom binoculars with up to 5X magnification.

Zoom Transfer Scope - The time-consuming process of transferring information from images to maps is made considerably easier by the use of the zoom transfer scope. This table-top instrument allows the operator to view simultaneously both an image and a map of the same area. Simple controls allow the matching of differences in scales (up to 14X) and provide other optical corrections so that the image and the map appear superimposed. In particular a unique one-directional stretch capability (up to 2X) allows the matching of computer print-out "images" to a map or photograph.

Color Additive Viewer/projector/tracer - This instrument is primarily intended for the false-color recomposition of Landsat images from 70mm black and white transparencies and tracing information contained on these images at scales of 1:1,000,000 and 1:500,000. However it has proved to be very useful also for superimposing and color-coding Landsat images acquired on different dates and looking for change or movement and for viewing any other enlarged image on 70mm film format.

VP-8 Image Analysis System - The VP-8 image analysis system provides an electronic means of quantizing information contained in a photograph when the sought information can be expressed in terms of density ranges. It consists of:

- a light table having uniform brightness and a working surface of 15x22 inches
- a vidicon camera which transforms the photographic (transmittance) data to electrical signals
- an electronic image analyser which quantizes and formats the vidicon signals
- a CRT oscilloscope
- a color television monitor as an output device

The capabilities of the VP-8 image analysis system include:

- density level slicing. This feature allows lines of uniform density on the input image to be displayed as contours. These contours form the boundaries of density bands which are displayed as up to 8 color bands on the color television monitor. The base density levels and the density range of the bands are individually as well as collectively variable. An example and illustration of the density slicing technique applied to coastal sedimentation studies was provided in the OCSEAP Arctic Project Bulletin No. 7, Appendix C, "Environmental Assessment of Resource Development in the Alaskan Coastal Zone based on Landsat Imagery" by A. E. Belon, et al, University of Alaska.

- single scan line display. Any single horizontal scan line of the vidicon camera can be selected for display on the CRT oscilloscope by positioning a horizontal cross-hair on the image. This display of a single scan line is effectively a microdensitometer trace.

- digital read-out of point densities, selected by adjustable cursors or of total area of the image having a given (color-coded) density range. For instance the VP-8 image analysis system is well adapted to the area measurement of sea-ice, newly refrozen ice, and open water in any area of the Beaufort Sea imaged by Landsat.

- 3-D display. This mode of operation allows a three-dimensional presentation where the X and Y coordinates of the original image are displayed in isometric projection and intensity information is shown as a vertical deflection. Subtle features of the image which are often lost on level-sliced displays, become obvious in 3-D displays.

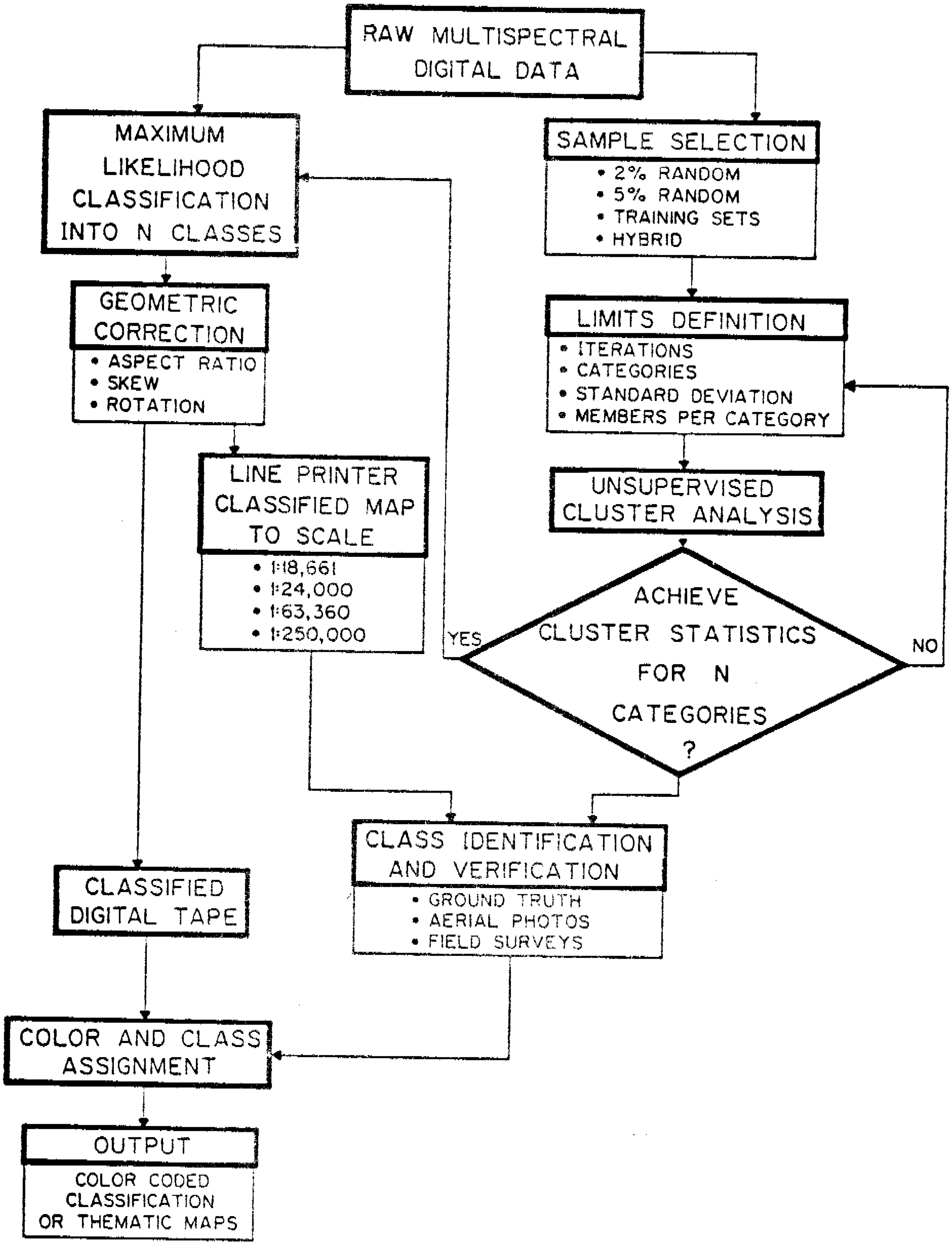
- 5X magnification. This feature allows the expansion of a small part of the image on the 3-D display to full screen size.

The digital data processing equipment available to the OCS investigators include the main University computer, a Honeywell model 66/20 with 1 M bytes of core memory, which has a remote time-share terminal at the Geophysical Institute, a NOVA 820 data preprocessing computer as well as conventional line printers, plotters and digitizers. Most remote-sensing imagery in digital format is reformatted, classified or otherwise processed on offline computing systems. An overall flow diagram of digital processing of Landsat imagery is illustrated in figure 3 and discussed later in this report. Once the digital data have been processed, they are displayed on line printer maps or the digital image film recorder.

Digital Color Image Recorder - It often is necessary to reconstitute an image from the processed digital data in order to convey information in the most suitable form to the human mind. Also, if one deals with multi-spectral data it is impossible to convey the density of information required without the use of color. A digital image recorder with the capability of reconstituting color products was procured and installed in 1976 using State of Alaska funds appropriated to the University of Alaska Geophysical Institute. Basically it is a rotating-drum film recorder which produces four simultaneous standard images on film up to 8x10" in size. Density resolution is 255 levels of gray, and spatial resolution is 500 lines per inch. Recording rate is 1.5 lines per second. Any combination of the four negatives so produced can be registered and printed with suitable filters to produce a reconstituted color negative which can be processed and enlarged photographically.

Remote-Sensing Data Interpretation Techniques - The basic techniques for remote-sensing data reduction and interpretation are described in flow diagram format in figure 2 (optical and photographic data processing) and figure 3 (digital data processing). The techniques for visual photointerpretation, as applied to sea-ice mapping; for density slicing, as applied to sea-surface suspended sediment mapping and transport; and for digital data processing, as applied to ecosystem thematic mapping, are described in the OCSEAP Arctic Project Bulletin No. 7, in particular its Appendix C "Environmental Assessment of Resource Development in the Alaskan Coastal Zone based on Landsat Imagery" by A. E. Belon, J. M. Miller and W. J. Stringer.

Variations of these techniques offer considerable promise of effective applications to OCS studies, but are too numerous and varied to be discussed in detail here. Usually they are developed in cooperation with individual OCS investigators for application to a specific project. Therefore we refer to the reports of other OCS investigators for detailed descriptions of applications of remote-sensing data to disciplinary studies.



FLOW CHART FOR GENERATING ECOSYSTEM MAPS

Figure 3 Digital Processing of Landsat Imagery

Flow chart of the unsupervised classification algorithms used for generating ecosystem maps of the Alaskan coastal zone from Landsat digital imagery.

C. Consultation and Assistance to OCS Investigators

This activity may be subdivided into two parts: general assistance to all OCS investigators provided through the Arctic Project Bulletins, program planning and negotiations and meetings/workshops; and individual assistance through consultation, training sessions on the use of remote-sensing data and equipment, and cooperative data analyses.

1. General Assistance

In order to familiarize OCS investigators with the available remote-sensing data, processing equipment, and interpretation techniques, we prepared seven substantial reports which were included as appendices to the OCSEAP Arctic Project Bulletins Nos. 6, 7, 9, 10, 12, 14, 17 and 22 and distributed to all OCS investigators active in studies of the Beaufort, Chukchi and Bering Seas and the Gulf of Alaska.

The appendix to Arctic Project Bulletin No. 6 described the operation of the remote-sensing data library, provided catalogs of Landsat and aircraft data available in our files and provided instructions to OCS investigators on the selection and ordering of these data.

The appendix to Arctic Project Bulletin No. 7 described the facilities and techniques available for analyzing remote-sensing data and included a scientific report in which these facilities and techniques were used to analyse and interpret remote-sensing data in three representative investigations of the Alaskan continental shelf: sea-surface circulation and sediment transport in the Alaskan coastal waters, studies of sea-ice morphology and dynamics in the near-shore Beaufort Sea, and mapping of terrestrial ecosystems along the Alaskan coastal zone.

The appendix to Arctic Project Bulletin No. 9 provided a cumulative catalog of all available OCS remote-sensing data including Landsat and NOAA satellite data, USGS/OCS aircraft data and NASA aircraft data.

Arctic Project Bulletin No. 10 provided a catalog of the SLAR (Side-looking radar) imagery obtained by the Army Mohawk remote-sensing aircraft in May 1976.

The Appendix to Arctic Project Bulletin No. 12 provided an updated catalog of satellite and aircraft remote-sensing data acquired since the issuance of the cumulative catalog of Bulletin No. 9.

Arctic Project Bulletin No. 14 provided a catalog of the SLAR imagery obtained in May 1977 by the Army-Mohawk aircraft.

Arctic Project Special Bulletin No. 17 provided an updated catalog of satellite and aircraft remote sensing data acquired through the spring and summer field season of 1977.

Arctic Project Special Bulletin No. 22 provided an updated catalog of Landsat and NOAA imagery acquired through the spring and summer field season of 1978.

Although the existing remote-sensing data base is very useful in supporting OCS disciplinary projects, there is also a vital need for an airborne remote-sensing data acquisition program dedicated to OCS purposes. To this end we have worked very closely with the NOAA Arctic Project Office in attempting to implement such a program. We participated in several meetings at the Geophysical Institute and one at Barrow in an attempt to set the USGS/OCS airborne remote-sensing data acquisition program on the right course, and took over responsibility for cataloguing, reproducing and disseminating these data. When this program failed and was terminated in January 1976, we studied alternatives and recommended several options to NOAA, one of which was a contractual arrangement with the U. S. Army remote-sensing squadron at Ft. Huachuca, Arizona. This recommendation was implemented, and two missions of the Army Mohawk remote-sensing aircraft were conducted in May and August 1976, resulting in high quality SLAR imagery of the Beaufort, Chukchi and Gulf of Alaska shelves at critical period. Another mission was conducted in April 1977. In parallel with these activities we have negotiated with NASA for the acquisition of high altitude (U-2, 65,000 ft.) aerial photography of the entire Alaskan coastal zone. This program was approved by NASA at no cost (so far) to NOAA/OCSEAP. The first attempt to acquire the requested data, in June 1975, failed because of prevailing heavy cloud cover during the 3 weeks the U-2 aircraft was in Alaska. A second attempt, unfortunately delayed until October 1976, was partially successful and acquired high quality aerial photography of the Gulf of Alaska and Prince Williams Sound. Due to excessive cloud cover very little usable U-2 imagery was acquired from the June 1977 mission; however, two flight lines in the Prudhoe Bay area were of good quality. We also participated in successful negotiations with the National Ocean Survey for acquisition of color aerial photography of the Bering and Chukchi Sea coasts during a previously scheduled mission of their Buffalo aircraft to Alaska in summer 1976.

Excellent medium altitude photography was acquired from the Yukon delta to Cape Lisburne, as well as isolated areas of the Gulf of Alaska coast. In summer 1977 NOS again flew several flight lines, extending from Cape Sabine on the Chukchi Sea coast to Cape Halkett on the Beaufort Sea. This imagery is of excellent quality and is archived here for OCS investigators' use.

While the OCSEAP Arctic Project Office and our project have been fairly successful in negotiating remote-sensing data acquisition by other agencies on an irregular basis, such arrangements are not wholly satisfactory on a long-term basis because the type and format of the data vary from one mission to another and the frequency of data acquisition is insufficient to provide timely observations and good statistical information on coastal zone conditions and processes. For this reason we worked with the Arctic Project Office on a plan which would utilize a Naval Arctic Research Laboratory (NARL) C-117 aircraft, remote-sensing equipment available from several sources, and local processing of the data to provide more frequent and more relevant data on a consistent format.

OCSEAP agreed with this plan and contracted with NARL for the airborne data acquisition program and with our project (RU 267) for the processing of the data. The Cold Regions Research Laboratories (CRREL) provided a Motorola side-looking radar and a laser profilometer, as well as a qualified engineer, to NARL, and we located and secured four aerial cameras for installation in the aircraft which was subsequently modified and committed to a remote-sensing program by NARL. Our project also acquired wide-film processing and printing equipment and constructed a photographic laboratory for processing of the data acquired by the NARL aircraft. Unfortunately, the NARL data acquisition program failed after acquiring very little SLAR data, and it was terminated by OCSEAP in the spring of 1978.

The most recent attempt to acquire SLAR data on regular basis is based on a contract, through CRREL, to the local (Ft. Wainwright) Army Mohawk squadron which obtained well-equipped, new model, remote-sensing Mohawk aircraft in early 1978. A trial mission was flown at our request in September 1978 as a training army mission. The resultant SLAR data of the Beaufort Sea coast proved to be of sufficiently good quality that formal arrangements were made for identical flight lines to be flown on a monthly basis during winter 1978/79. Good quality SLAR data have been received for December 1978, January, February and March 1979. They provide for the first time excellent coverage of Beaufort sea-ice morphology and dynamics during the important mid-winter period when other remote-sensing data are not available owing to the absence of daylight.

2. Individual Assistance

Individual assistance to OCS investigators involves consultations on the applicability of remote-sensing data to specific studies, data selection and ordering, preparation and supervision of work orders for custom photographic products and data processing, training in the use of remote-sensing data processing equipment and techniques, development of data analysis plans and sometimes participation in or performance of data analysis and interpretation.

This individual assistance has stabilized over the past year as requests become more site specific and detailed in nature. 65 OCS investigators utilized our facilities during the past year, most of them for several hours, and some of them repeatedly. In addition, numerous contacts occurred by mail or telephone correspondence. Therefore, it is not possible to describe in detail these individual activities but their scope is illustrated by listing the user projects: RU's numbers 6, 59, 69, 87, 88, 172, 194, 196, 205, 248, 250, 251, 258, 261, 265, 289, 290, 356, 467, 481, 483, 526 529, 530, 537. Of these about twelve are using remote sensing data routinely and six of them (RU no. 205, 530, 248, 88, 265, 289) almost exclusively. The principal applications are sea-ice morphology and dynamics, coastal geomorphology and geologic hazards, sea-surface circulation and sedimentation, sea-mammals habitat and herd habitat mapping. A partial list of users and their needs is included as Appendix A of this report.

VI - RESULTS

The results of the project so far can be separated into two categories: the operational results (establishment of a remote-sensing data facility) and the research results (disciplinary applications of remote-sensing data to OCS studies).

A. Establishment of a Remote-sensing Facility for OCS Studies

The principal result of the project, as specified in the work statement of the contract, is that there now exists at the University of Alaska an operational facility for applications of remote-sensing data to OCS studies. This facility and its functions have been described in detail in the previous section of the report. Briefly it consists of:

1) A remote-sensing data library which routinely acquires catalogs and disseminates information on Landsat and NOAA satellite imagery and aircraft imagery of the Alaskan continental shelf.

2) A remote-sensing data processing laboratory which provides specialized instrumentation for the photographic reproduction and optical or digital analysis of remote-sensing data of various types and formats.

3) A team of specialists that generates and develops techniques of remote-sensing data analysis and interpretation which appear to be particularly well-suited for OCS studies.

4) A staff that is continually available to OCS investigators for consultation and assistance in searching for, processing and interpreting remote-sensing data for their disciplinary investigations.

As a result of the establishment of the remote-sensing facility established by our project, about twelve OCS projects are routinely using remote-sensing data, six of them almost exclusively, and many more OCS investigators are occasional users of remote-sensing data.

B. Disciplinary Results of the Applications of Remote-Sensing Data to OCS Studies

In general, the results of applications of remote-sensing data to OCS studies will be contained in the annual reports of the individual projects and need not be repeated here. However as part of our function to develop techniques of remote-sensing data analysis and interpretation, we did prepare a scientific report entitled "Environmental Assessment of Resource Development in the Alaskan Coastal Zone based on Landsat Imagery" which illustrates the applications of Landsat data to three important aspects of the OCSEAP program: studies of sea-surface circulation and sediment transport in Alaskan coastal waters, studies of sea-ice morphology and dynamics in the near-shore Beaufort Sea, and mapping of terrestrial ecosystems in the Alaskan coastal zone. This report was presented at the NASA Earth Resources Symposium, Houston, Texas, June 1975 where it was acclaimed as one of the best presentations. It was also distributed to OCS investigators as part of Arctic Project Bulletin No. 7 and is now out of print due to heavy demand in spite of the fact that 250 copies were made.

A report (see Appendix B) produced by RU's 267 and 258, was released in September by the OCSEAP Arctic Project Office. The report incorporates part of the RU 267 annual report for 1977 and an article by RU's 267 and 258 in Arctic Project Bulletin No. 20 to illustrate, by means of historical Landsat imagery and sea ice morphology maps, the seasonal sequence of sea ice and sea-surface conditions from fall freeze-up to summer breakup in the 1979 Beaufort lease sale area.

C. Results of Beaufort Lease Area Investigations

With the proposed Beaufort Sea lease sale approaching, emphasis of OCSEAP efforts has shifted from broad synoptic studies to more site specific investigations. To support ongoing research, in addition to acquiring general coastal coverage, we have initiated a search for more detailed data in and adjacent to the lease area. This section illustrates with images and maps, information that has been identified by disciplinary investigators. Our intent is to show graphically some of the processes that are occurring and relate them to the area proposed for leasing.

1) Beaufort Coast Mosaic

As a result of a Landsat data search, a series of six scenes were identified which provide the best available coverage of the Beaufort coast from Point Barrow to Demarcation Bay during the short open-water season. Sections of these images were custom enlarged to a scale of 1:250,000 for study by RU's 529-Naidu, 537-Schell and 530-Cannon. One set of these prints was mosaiced together and is reproduced here (Figure 4). The imagery shows sediment transport and circulation patterns along the coast, recorded by reflected light from the visible red (0.6 - 0.7 micron) portion of the spectrum. The mosaic contains portions of Landsat scenes:

2910-20203-5	20 July 77
2915-20483-5	25 July 77
5828-19272-5	25 July 77
5830-19384-5	27 July 77
2921-21274-5	31 July 77
2954-21033-5	2 Sept 77

As is usually the case, most of the surface sediment originates at river mouths and is transported westward along the shore within the bays and the lagoons-barrier islands systems. However, there are numerous eddies throughout. In particular, the effect of the ARCO causeway on the local circulation is well portrayed.

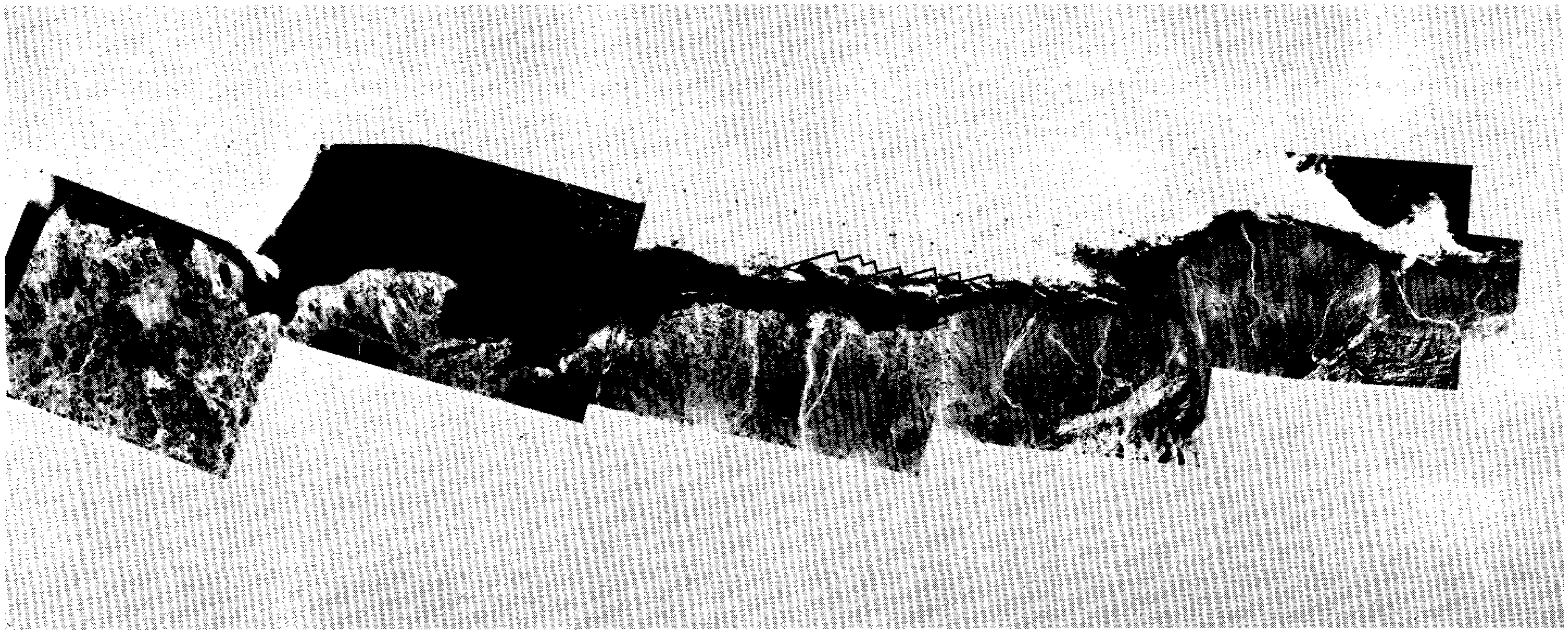


Figure 4. Beaufort Sea Coast

A mosaic of Landsat scenes, originally constructed at a scale of 1:250,000, shows the Beaufort Sea coast from Point Barrow to Demarcation Bay during the open water season of 1977.

RU 267 Belon

2) Spring Flooding

Rivers abutting the Beaufort lease area are known to annually flood as melt water from the Brooks Range flows downstream onto the still frozen coastal plain. At the river mouth, a pulse of melt water flows out over the top of the shorefast ice. On 8 June 1978, fresh water from the Kupuruk River reached a tide gauge in the Egg Island channel of Simpson Lagoon (Brian Matthews-RU 526). A sharp drop in salinity occurred at 3:30 A.M. AST followed by an increase in sea level starting at 6:00 A.M. Figure 5 is an enlargement of NOAA image 8407, which recorded the areal extent of the overflow several hours later. Notice similar flooding (arrows) associated with the Colville, Sagavanirktok, Kadleroshilik and Shaviovik Rivers. A Landsat scene (Fig. 6) provides a higher resolution look at the flood occurring that day to the west on the Colville River. Landsat recorded a similar event during 1976, which better shows its relationship to the lease area (Figure 7). More detailed information on the 1978 flood is available from Matthews - RU 526.

3) Sediment Transport and Sea-Surface Circulation

We have undertaken a data search for imagery of the Beaufort Lease area during the open water season. Approximately 60 Landsat images have been identified and are filed by season, from 1972 to 1978. Of these, twelve scenes provide good details of suspended-sediment patterns and sea-surface circulation. We are presently examining these images with RU 529-Naidu, to further analyze the data. Presented here are four selected scenes that show the range of conditions observed during the summer of 1977.

Before the ice has broken up and melted (July 13th), sediments are already visible in Prudhoe Bay and can be seen in transport westward through Simpson Lagoon (Figure 8).

On July 25th an unusually clear image was acquired (Figure 9). Here, suspended sediments which appear to be coming from the Sagavanirktok River are being transported westward through Prudhoe Bay toward Simpson Lagoon. The ARCO causeway is clearly visible on the west side of the bay. This image suggests that the causeway may influence circulation into the lagoon. Special computer enhancement is being performed on this scene for more detailed study.

On August 14th (Figure 10) sediments fill the western half of Simpson Lagoon and extend seaward. Notice the structure in the sediment pattern along the coast and on Teshekpuk Lake.

Figure 5. NOAA Image 8407, acquired on 8 June 1978, shows the spring overflow of river melt water (arrows) onto the sea ice on the Beaufort coast. This scene was acquired a few hours after a sharp drop in salinity was recorded at a station near the mouth of the Kuparuk River.

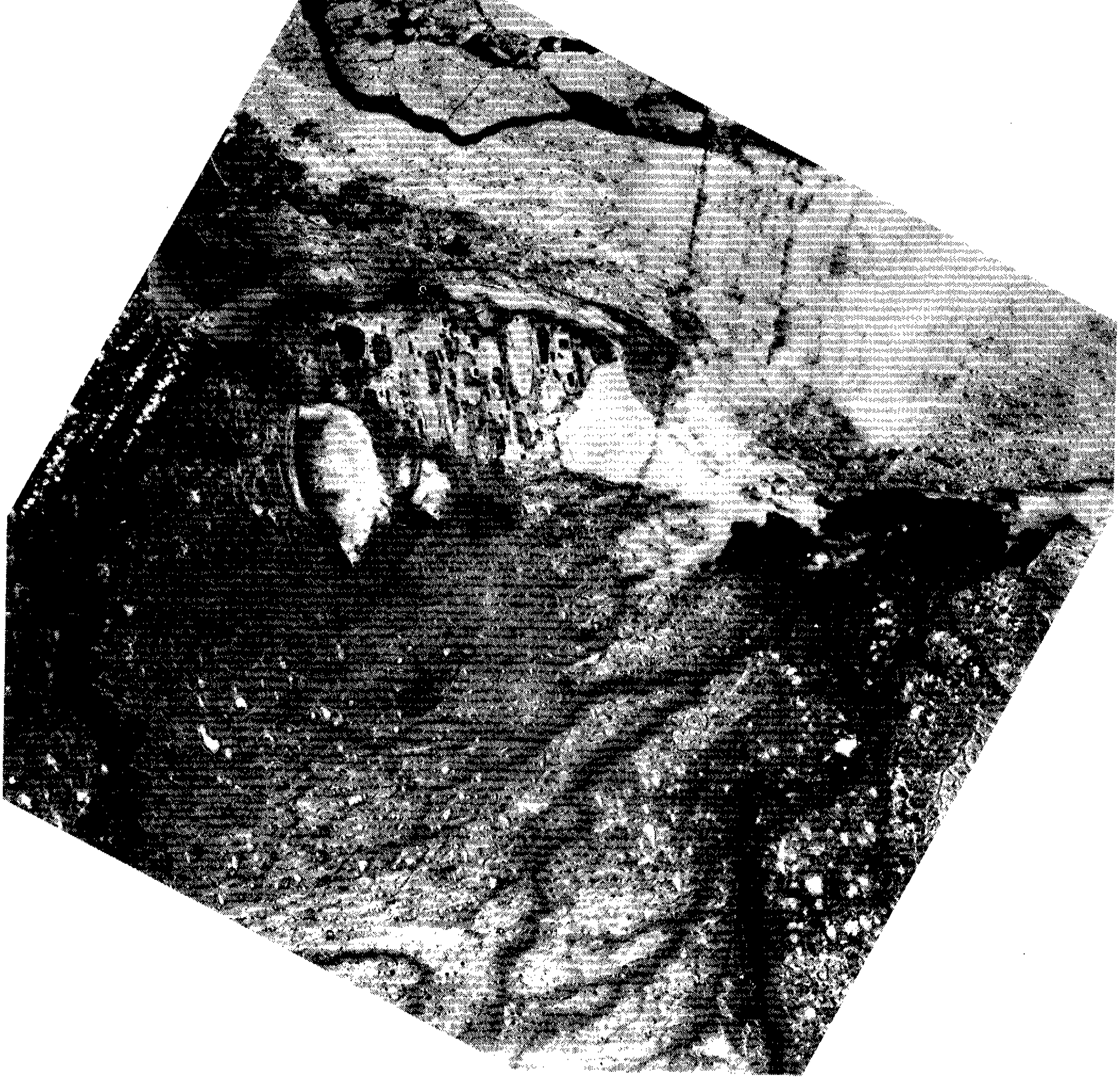


Figure 6. Landsat scene 30095-21281, 8 June 1978 showing spring overflow in progress on the Colville River.

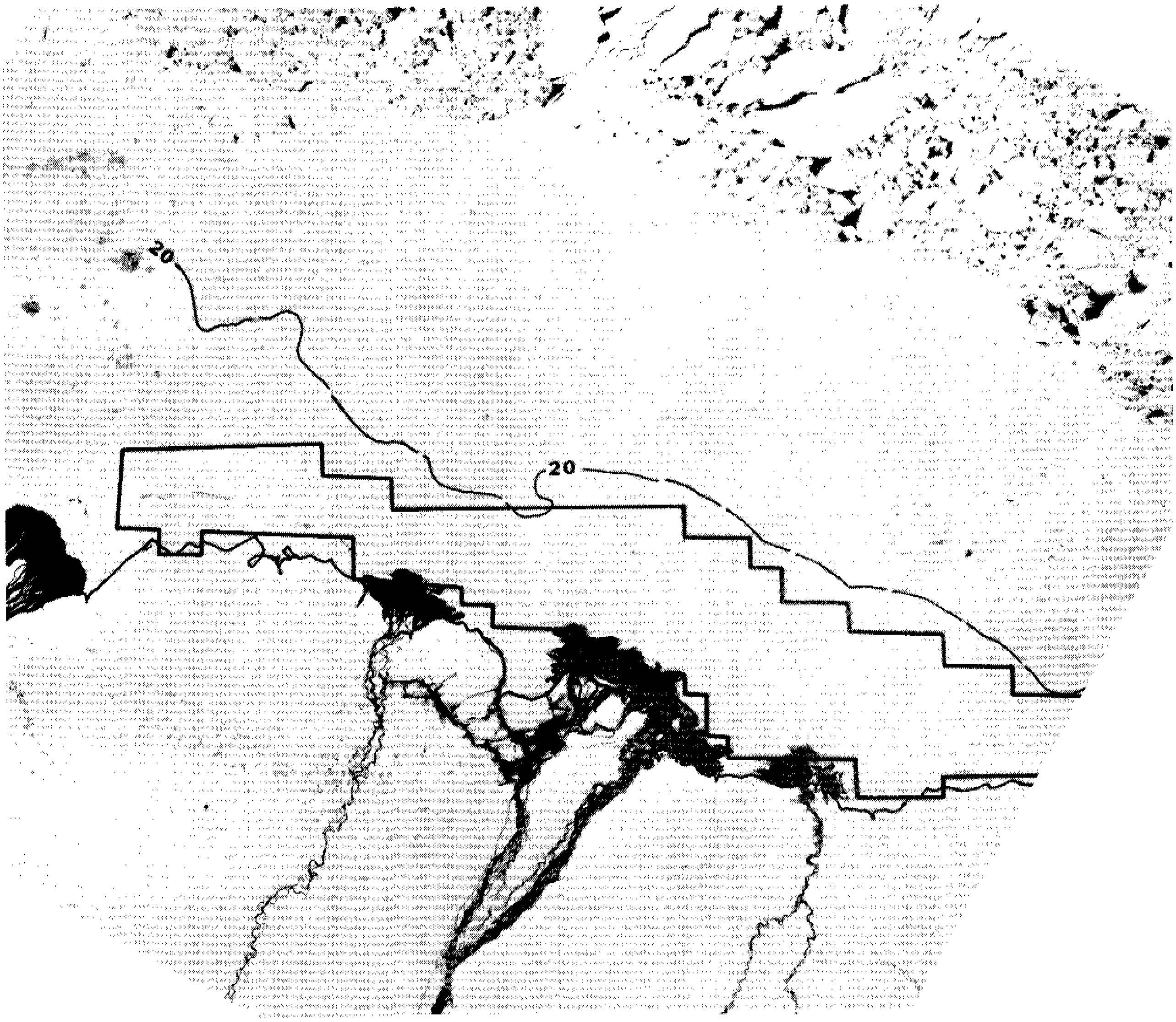


Figure 7. Landsat scene 2501-21051, 6 June 1976, shows spring overflow in the Beaufort lease area as it occurred that year.

RU 267 Belon

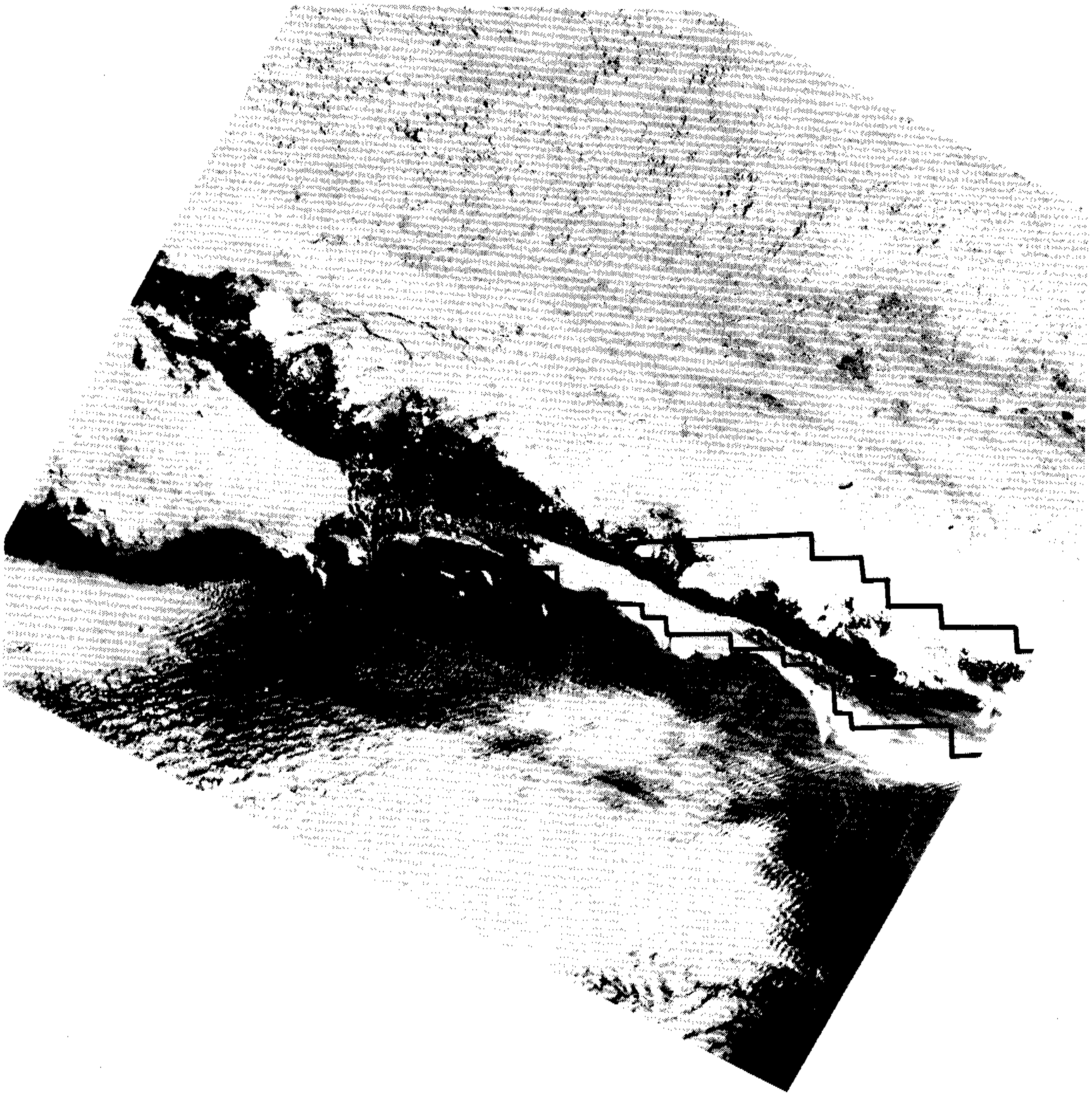


Figure 8. Sediment transport is seen occurring before the ice has cleared Prudhoe Bay, on 13 July 1977. Landsat scene 5816-20024-5.

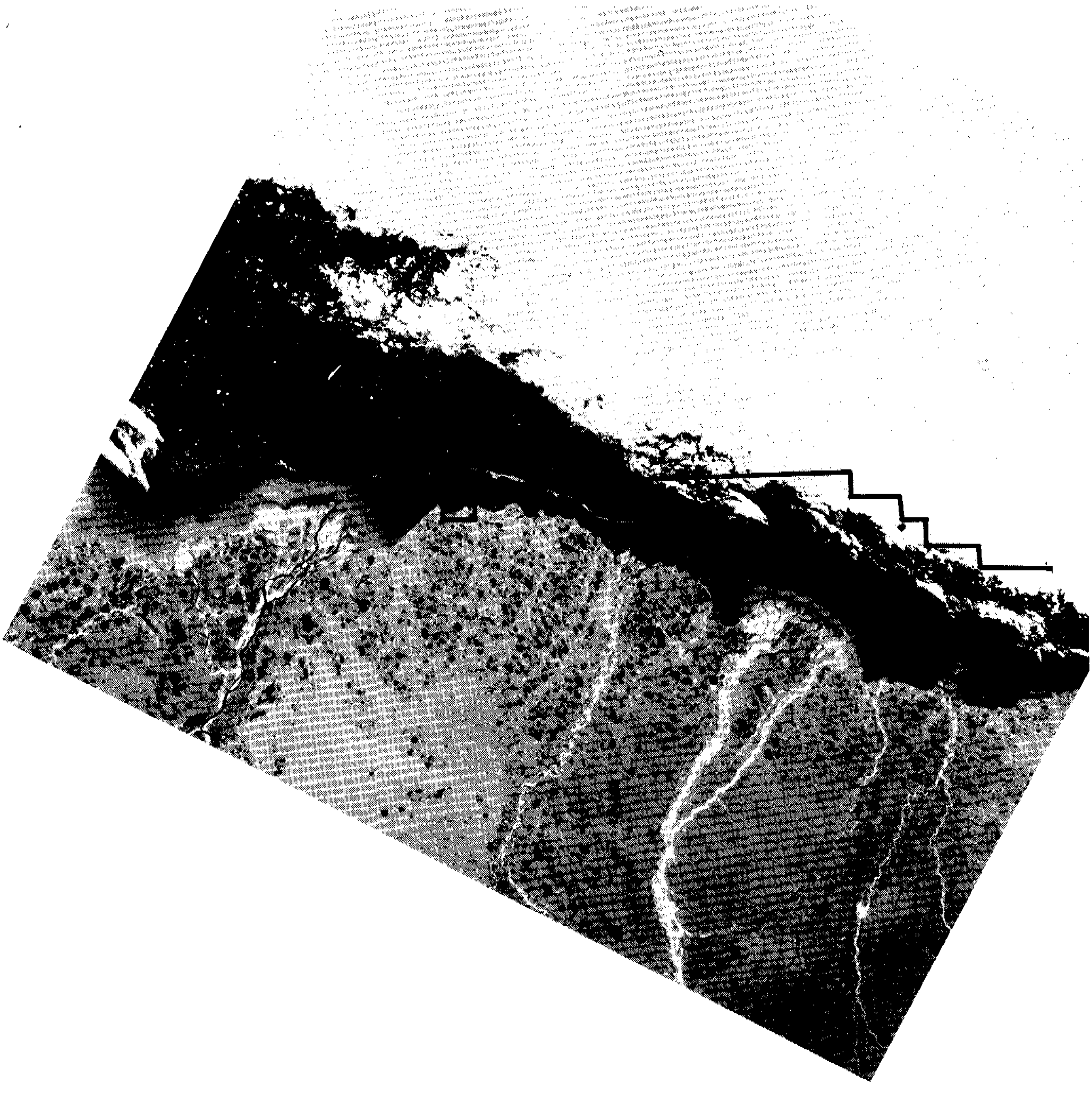


Figure 9. An unusually clear image of sediment being transported from the Sagavanirktok River westward. The ARCO causeway is visible on the west side of Prudhoe Bay. Landsat scene 2915-20483-5.

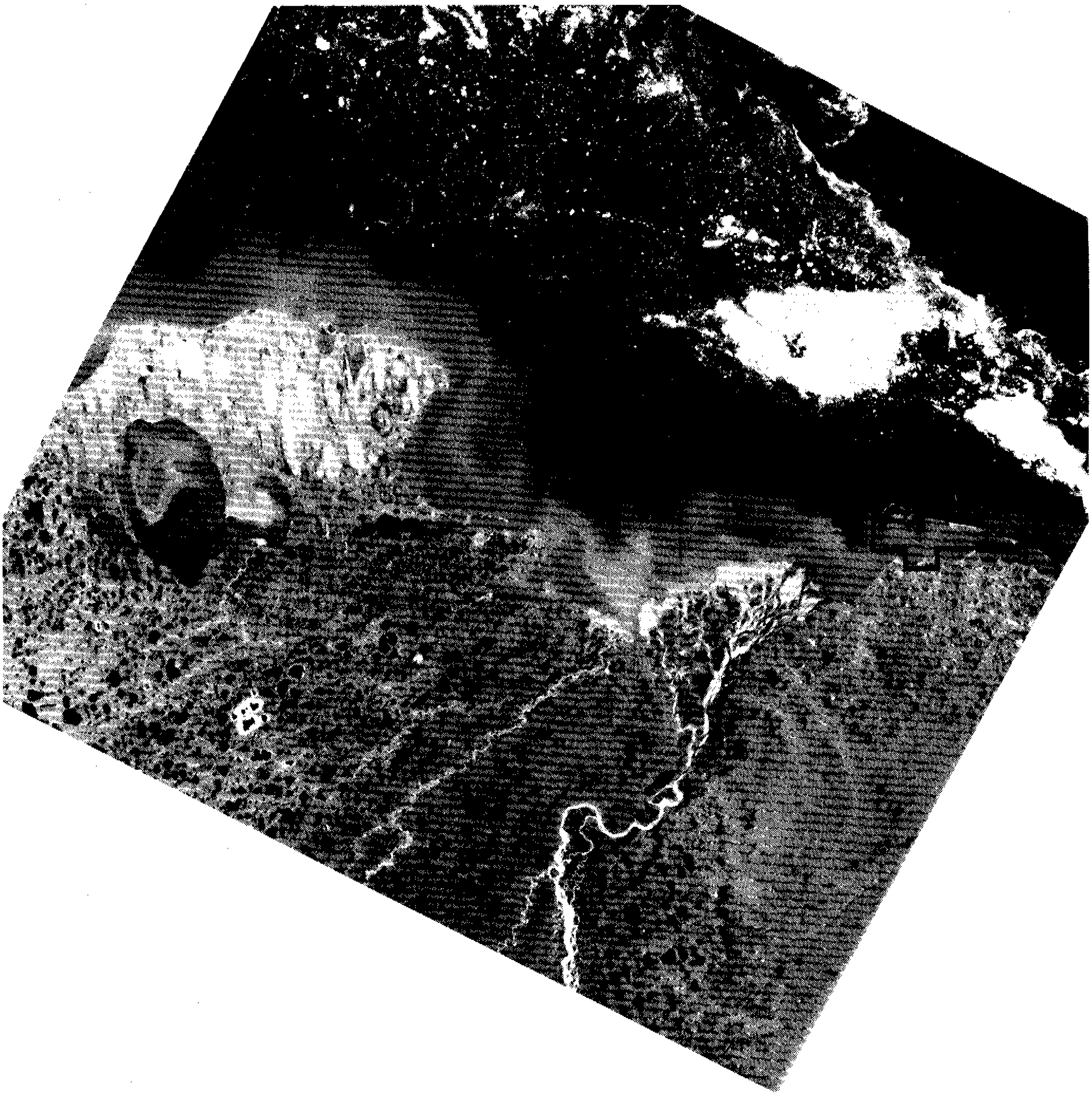


Figure 10. West edge of the lease area and mouth of the Colville River on 14 August 1977. Note sediment structure along shore and in Teshekpuk Lake. Landsat scene 2935-20585-5.

Finally, on October 3rd, a much different condition is seen (Figure 11). The sediments form a broad, diffuse band, extending up to 15 miles offshore. The distribution of materials appears quite uniform on both sides of the barrier islands.

Knowledge of sediment distribution and transport is important for assessing impact of causeways, gravel islands or other structures planned in the lease area. Work will continue with Dr. Naidu - RU 529 to better document the range and variation of this phenomenon for the entire 7 years of available data.

4) Sea-Ice Stability

Knowledge about the stability of sea ice in the Beaufort Lease area is very important in order to plan or evaluate developmental activities. Landsat imagery has been used to systematically map sea ice conditions from 1973 to 1977 in the Beaufort (Stringer - RU 257).

Quick-look Landsat data, obtained by a project funded by the Alaska State Legislature, shows that recent activity has occurred in the ice, closer to shore than previously observed. Figure 12 is a Landsat image acquired on March 18, 1979. It shows a zone of shearing and ice failure near the Maguire Islands, well inside the 20-meter isobath. This information is mapped in Figure 13, in comparison to the previously observed spring ice edge.

It is noteworthy that this Quick-look Landsat image was obtained and analyzed within 3 days of acquisition by the satellite. Through normal channels there is a six-week or greater delay before data is available for analysis. In this case, the timely acquisition and interpretation of the Landsat image permitted us to warn agencies working on the ice that hazardous conditions existed in that area.

As was previously mentioned, repetitive SLAR missions have been flown along the Beaufort coast this winter. Figure 14 contains segments from this imagery from four different flights. They show a progression of ice events in the Prudhoe Bay area. The data was X band (3.5 cm wavelength) radar imagery which was originally recorded at a scale of approximately 1:250,000. On November 28th (Figure 14a) the ice appears smooth near shore with areas of increasing surface roughness (bright returns) further seaward. The upper left corner of the image shows the shear zone, with open water and floating ice seaward of the ice edge. By

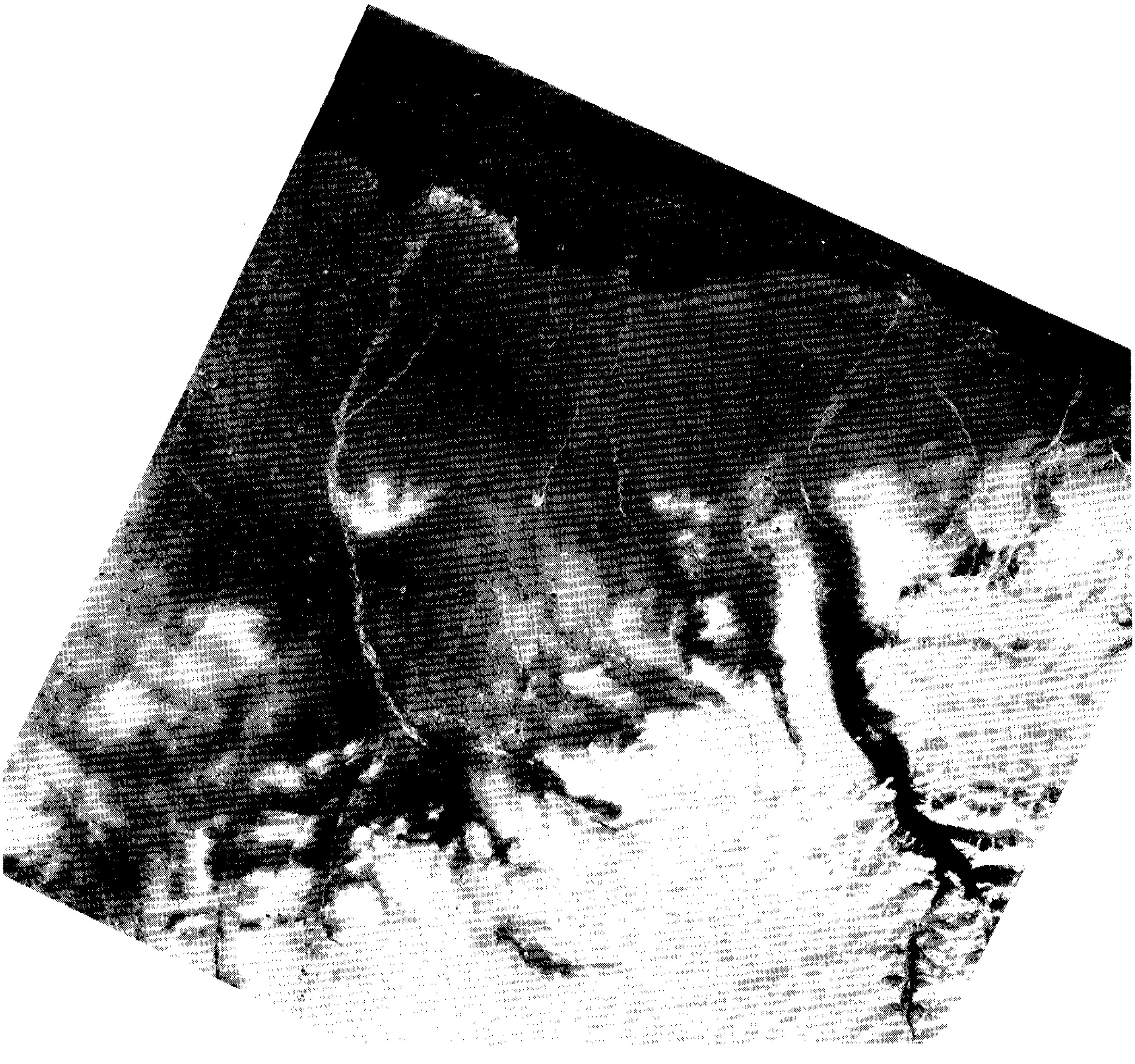


Figure 11. Prudhoe Bay and the east Beaufort lease area on 3 October 1977. A diffuse band of sediment extends beyond the barrier islands. Landsat scene 2985-20333-5.

RU 267 Belon

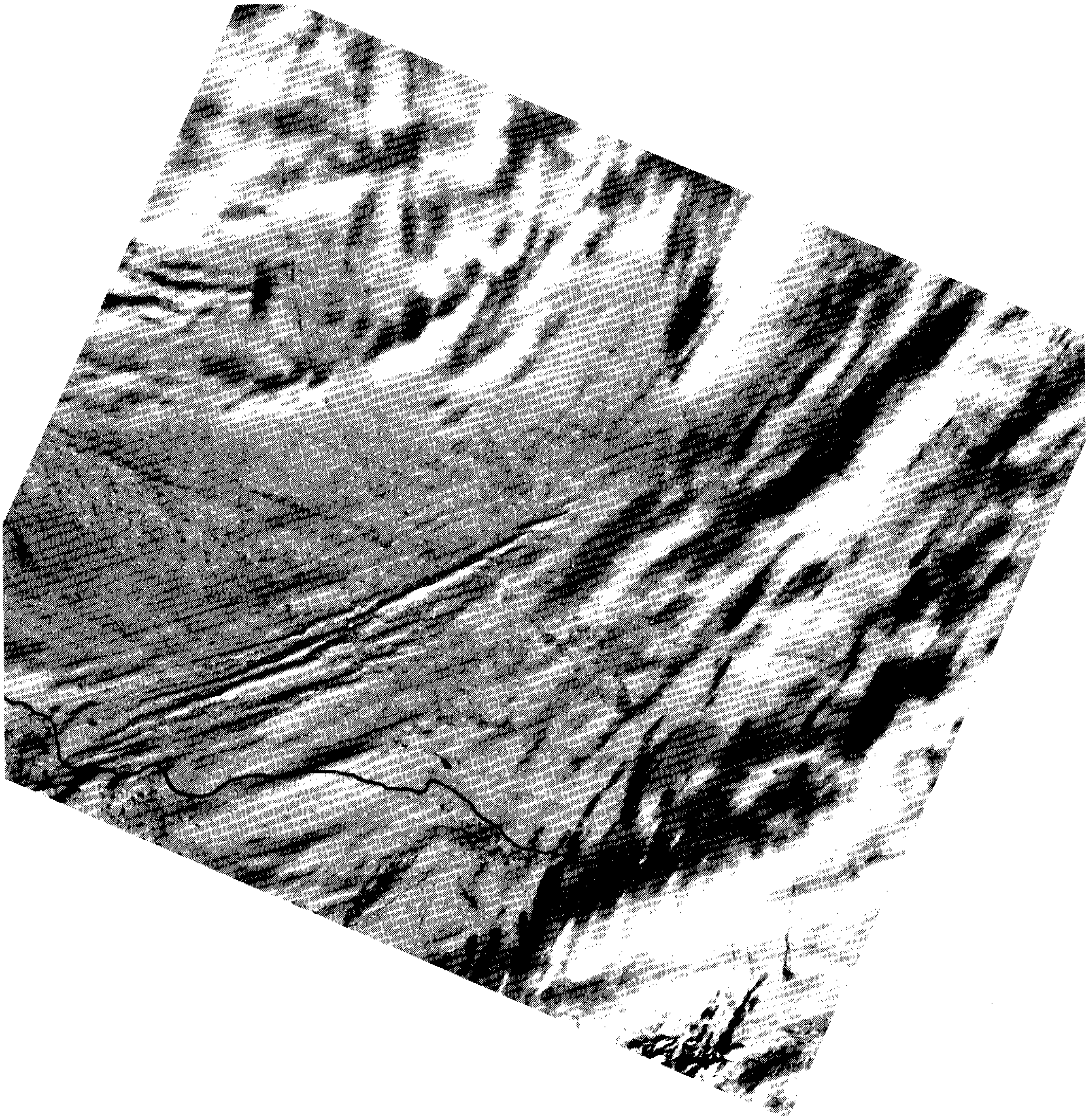
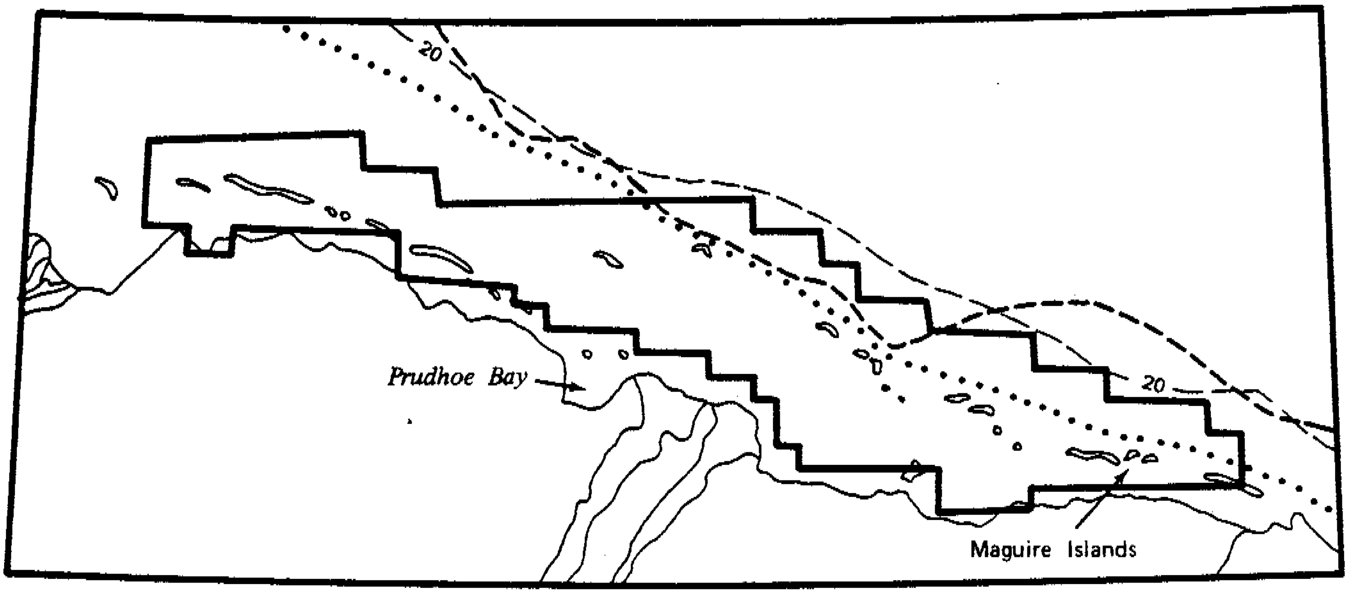


Figure 12. Quick-look Landsat image of sea ice conditions on 18 March 1979. Features interpreted from this image indicate failures in the landfast ice more shoreward than previously observed. Landsat scene 30378-21001-7.

RU 267 Belon



Prepared by W. J. Stringer, 3/21/79
Northern Remote Sensing Laboratory

Figure 13. Edge of deformation of landfast ice (dotted line), as mapped from Quick-look Landsat imagery acquired on 19 March 1979. The heavy dashed line is the most shoreward edge of the contiguous ice sheet observed previously by Stringer (RU 257). The 20-meter isobath (light dashed line) is shown for reference.

FIGURE 14A 28 NOVEMBER 1978

FIGURE 14B 3 JANUARY 1979

FIGURE 14C 21 FEBRUARY 1979

FIGURE 14D 9 MARCH 1979

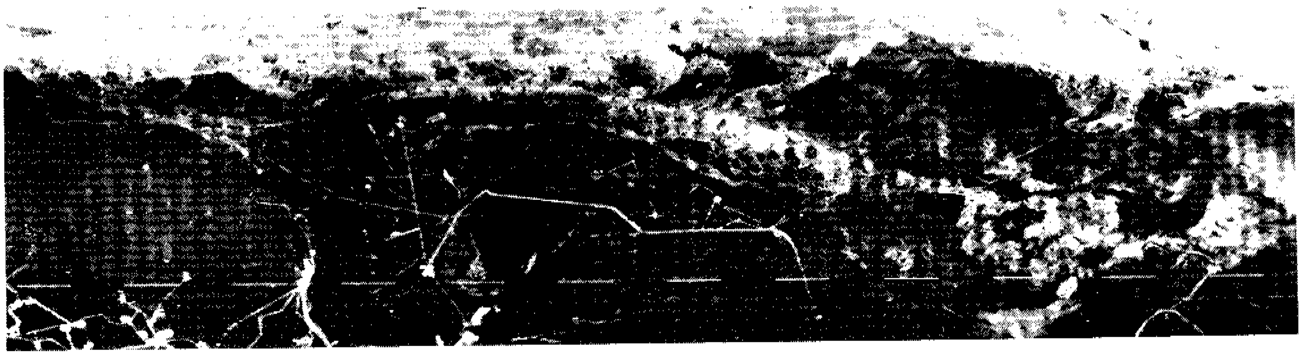


FIGURE 14. SIDE LOOKING AIRBORNE RADAR OF THE PRUDHOE BAY AREA ACQUIRED DURING THE WINTER OF 1978-1979. RU 267 BELON

January 3rd (Figure 14b), the open water area has frozen and the ice edge is out of the image. Other ice features seen in November can be recognized here, and on the February 21st and March 9th images as well, indicating little or no movement of the shorefast ice in this area during this period.

Manmade features are well documented by SLAR. In January (Figure 14b) an ice road extends into Prudhoe Bay to the Exxon ice island (circular feature). A second road goes on out to Argo Island (faintly visible) 9 miles offshore. Along the coast to the east is yet another road. By mid-February (Figure 14c) a large maze of roads and trails is evident. An area of high returns can be seen on Reindeer Island, 10 miles north of Prudhoe Bay, indicating substantial human activity there. At the east, near the edge of the image, a new feature appears on Tigvariak Island. The March flight (Figure 14d) covers an area further to the south than previously imaged. In addition to ice features, the main network of roads in the Prudhoe Bay oil field is clearly displayed. SLAR, due to its all-weather characteristics, is an important source of information for sea ice conditions as well as monitoring activities in the Beaufort lease area.

VII & VIII - DISCUSSION AND CONCLUSIONS

The principal objective of the contract, as specified in its work statement, has been achieved: a facility for applications of remote-sensing data to outer continental shelf studies has been established at the University of Alaska and is now fully operational.

The remote-sensing data library has acquired all available cloud-free remote-sensing imagery of the Alaskan continental shelf, catalogued it and provided information on its availability to all OCS investigators through the series of Arctic Project Bulletins.

Existing instrumentation for analyzing remote-sensing data has been consolidated into a data processing laboratory and techniques for its use have been developed with particular emphasis on the needs of the OCSEAP program. New instrumentation is being acquired and new analytical techniques are continually being developed from this contract and other funding sources.

The staff of the project is interacting with a number of OCS investigators, providing consultation and assistance in all aspects of remote-sensing applications from data searches and ordering to advanced analyses of the data in photographic and digital format. We have also worked very closely with the OCSEAP Arctic Project Office in designing an interim remote-sensing data acquisition program using contract and aircraft missions by other agencies.

At this time about twelve OCS projects are using remote-sensing data and processing facilities routinely, some of them almost exclusively of other research activities, and many more OCS investigators are occasional users of remote-sensing data. As the focus of OCSEAP changes from synoptic studies to the leasing process, requests have become more detailed and site specific. Studies of processes and potential impacts on individual areas rely heavily on historical remote sensing data and detailed interpretations on a case by case basis. It is important to collect and archive available coverage as well as assist in the acquisition of more detailed imagery of key areas.

It is clear from the foregoing discussions and from consultations with OCS investigators, regarding their study plans for the next year, that there will be a continuing need for the research support that our project provides. We intend to submit a continuation proposal to NOAA for this purpose.

IX - SUMMARY OF FOURTH QUARTER OPERATIONS

This quarterly report covers the period January 1 to March 31, 1979.

A. Laboratory Activities During the Reporting Period

1. Operation of the remote-sensing data library

We continue to search continuously for new Landsat imagery of the Alaskan coastal zone entered into the EROS Data Center (EDC) data base. During this reporting period 121 new scenes have been received at a total cost of $2580. We also searched the files retroactively for higher-resolution RBV imagery and many of these scenes were added to our files of early spring through late fall 1978 acquisitions.

We continued to receive three daily scenes from NOAA satellite for a total of 268 scenes at a cost of $2,281.40. Again, owing to the low solar illumination during January and February, images in the visible spectral band were not acquired by the satellite for the first six weeks, but the thermal IR images which depend on emitted, rather than reflected radiation, were received throughout the reporting period.

Under a State-funded project we are receiving Air Force weather satellite imagery (DMSP) on a daily near-real-time basis. During this reporting period 90 scenes were received in a variety of data products.

Side-looking Airborne Radar (SLAR) imagery of the Beaufort coastline from Oliktok Point to Brownlow Point was obtained on January 3, February 21 and March 9, 1979 and copies are available in our files.

Imagery from the statewide high-altitude aerial photography program (see section V.A.4) has just arrived at the remote sensing library. We are currently inventorying and indexing the coverage, which will be available for investigators soon.

2. Operation of data processing facilities

During this quarter, we have made a variety of photographically enhanced custom products for several investigators. Imagery of the Beaufort coast during the summer often contains an extreme brightness range caused by the presence of highly reflective ice cover next to a relatively dark water mass. Standard data products, printed for average brightness values, frequently fail to provide the detail required, particularly in water-sediment features. By custom printing for special contrast control, we have been able to produce the needed information to facilitate these investigations.

3. Development of data analysis and interpretation techniques

As a result of our data search for the open water season, one particularly clear Landsat image of the Prudhoe Bay, Simpson Lagoon area was identified (see Figure 9, this report). It shows sediments from the Sagavanirktok River being carried westward to the lagoon around the ARCO causeway. At the request of RU-529 (Naidu), we are performing a computer enhancement of the image for more detailed analysis. The final product will be enhanced and density-sliced images produced on our color film recorder.

4. Consultation and assistance to OCS investigators

Sixteen OCS investigators requested our assistance in searching for, obtaining or analysing remote-sensing data. Some visitors to our facility are not formal OCSEAP investigators but their activities are OCSEAP-related and they are mentioned here. Users (OCS and non-OCS) this quarter included:

John Hall, RU 481, telephoned a request for a specific Landsat transparency of Hinchinbrook Island for use in a publication. A 70 mm transparency was ordered and sent to him.

Seelye Martin, RU 87, asked for a detailed map of Landsat orbit tracks to correlate his spring cruise in the Bering Sea to possible Landsat acquisition on the same dates.

Curt Wallace (Shapiro RU 265) looked through all of the NOAA data on file to compare visible ice conditions and other data received on this project.

John Smith, a student working with Peter Mikkelson, looked through imagery of the Copper River Delta and used the Zoom Transfer Scope to transfer information from the imagery to his maps.

Juergen Kienle, RU 251, requested enhanced images, both NOAA and DMSP, of a volcanic eruption of Westdahl on Unimak Island. Several enhancements were made and assistance given in interpreting these images.

Brendan Kelly, (Burns RU 248) asked for current imagery of the Gulf of Anadyr to aid in navigation on a planned cruise in the Bering Sea. We obtained NOAA and DMSP imagery for the day prior to his departure and also sent additional images for pick-up at a later date.

Stu Rawlinson (Cannon RU 530) ordered and received a considerable number of Landsat and aerial images to aid in a shoreline study of the Beaufort coast. He also borrowed imagery from the Remote-sensing Library to map river deltas along the coast.

Jeff Brotnov, OSI-Seattle, who is involved in wetland mapping of the North Slope asked for any literature we might have concerning this area. We referred him to Jack Mellor who has done similar work on the North Slope and also gave him a tour of our facility to acquaint him with equipment and imagery available here.

David Dirkins, Yellowknife, N.W.T., asked for any catalogs available listing Landsat imagery of the Beaufort Sea. He is interested in mapping offshore ice beyond the 30-meter distance. We suggested that he talk with Dr. Stringer (RU 257) who has done similar work in the Beaufort and sent him a catalog of remote-sensing data. He plans to visit the facility in the future and utilize the imagery as an aid in scene selection.

Thomas Rothe, U.S.F.& W. S., looked through NOAA data for information on a severe storm in the Yukon Delta area. He also ordered all available U-2 photography of Prudhoe Bay.

Rich Kornbrath, USGS Conservation Division, is involved with evaluation of geologic and geophysical data of the Beaufort lease tracts for oil and gas development and the geologic hazards which might be encountered. For this reason he spent a day in our facility discussing ways Landsat might be useful in this evaluation and browing through file copies of imagery of the lease area. While here we also introduced him to personnel working with the OCSEA Program to compare notes on work being undertaken.

Terry Ralston, Exxon-Houston, submitted an order for Landsat imagery of the Beaufort Sea area. He receives our catalogs of remote-sensing imagery and used these for his scene selection.

Bruce LaRose, Office of Pipeline Coordinator, requested aerial photography of the Prudhoe Bay area which we ordered and sent to him.

Claus Naske, RU 261, ordered several images for inclusion as illustrations in a book he is writing.

Austin Kovacs, RU 88, looked through the SLAR imagery obtained this season and was given a set of prints for his files. He also made arrangements to receive quick-look data while in the field.

Arne Hanson (NARL) spent several days looking through Landsat, NOAA and DMSP imagery available in our files.

Fred Sorenson, U.S.F.& W.S., asked for our help in selecting one NOAA or DMSP image a week to send him showing ice conditions at that time. This is in connection with his study tracking polar bears in Beaufort Sea.

Jerry Kreitner, State Division of Mineral and Energy Management contacted our office and requested information concerning sea-ice activity northeast of Prudhoe Bay. New leads, forming in the area of a joint State/USGS drilling and seismic project, are causing concern about the safety of the operations. Quick-look Landsat imagery was acquired and a map of current ice conditions was sent to DMEM (see Figures 12 & 13, this report).

B. Estimates of Funds Expended

Expenditures of the project were $7,340 in January, $2,817 in February, and an estimated $8,000 in March. There was also an outstanding, but unpaid, obligation of $13,006 for purchases of remote-sensing data from NOAA/NESS and the EROS Data Center. Thus total expenditures of the project for the reporting period are estimated to be about $31,163.

APPENDIX A

FIRST TO THIRD QUARTER USER ACTIVITY

APPENDIX A

FIRST TO THIRD QUARTER USER ACTIVITY

In addition to those users mentioned in our summary of fourth-quarter operations, the following persons utilized our facilities during the previous nine months of the 1978/79 reporting period, either as OCSEAP investigators or in OCSEAP-related activities:

Don Schell (RU 537) discussed methods of data analysis with our applications specialist. He is interested in salinity and nutrient distribution on the Beaufort coast between Pt. Barrow and Prudhoe Bay. Landsat imagery was ordered for visual photo interpretation on an experimental basis.

Kristina Ahlnas (Royer, RU 289) continues to look through daily NOAA and DMSP imagery and orders enhanced products of certain scenes.

Brian Matthews (RU 526) asked for any satellite imagery that would verify data he had which showed a marked drop in salinity in the Simpson Lagoon on June 8, 1978. Enlargements of NOAA imagery for several days preceding that date were made for him in order to document gradual melting and run-off leading to freshwater flooding of the shorefast ice.

Dick Hoopes (National Weather Service) visited the library to become familiar with data available here and asked for copies of any NOAA or DMSP imagery which would be useful for their daily ice forecasts.

Mitchell Taylor (University of Minnesota) called to ask for imagery for a polar bear study he is involved in. We told him that we had already conducted a search for imagery and had furnished NOAA imagery to one of his co-workers, Fred Sorenson. Mr. Taylor was not aware of this and thought that it would be adequate. Recently Mr. Sorenson again contacted us and would now like a search done for Landsat imagery to give more detail on ice conditions for a given date and site in the Chukchi Sea.

Gary Wohl (Oceanographic Services Inc.) telephoned to ask for a data search for Landsat imagery in an area in the Bering Sea to aid in his study of sea ice. A complete listing was sent to him and he asked that we order the scenes for him. Since it was an extremely large order it has been only partially filled at this time.

Jerry Kreitner (Office of the Pipeline Coordinator) asked for recent aerial photographs of Prudhoe Bay to aid in an environmental impact statement being prepared for a gas conditioning plant. Photos from a 1977 NASA U-2 mission were plotted on a map and sent to him.

Louis Barton (Alaska Department of Fish & Game, Anchorage) asked that we send him sample prints of NOS aerial photography to see if it would be useful in his study of herring along the coast of the Seward Peninsula. Representative copies of CIR and natural color were sent to him and he later returned them with the intention of personally browsing through the photography on file here in the near future.

Kris Tommos (RU 290) asked for a data search in the Bristol Bay area to help correlate marine sediment data to surface circulation. Several Landsat images were ordered for her.

Jack Mellor (BLM) used our light table to view aircraft imagery of the northern sea coast.

Ron Metzner (RU 248/249, 250)viewed all the SLAR imagery we have of the Beaufort Sea area.

Jim Scudd (USGS) ordered NOS aerial photography of proposed drilling sites in the Barrow, Cape Simpson area.

As a special service to Dr. Frank Fay (RU 194), we received daily NOAA images of the Bering Sea and forwarded them to him for pickup at Savoonga. These current NOAA images aided him in determining where the RV Surveyor should proceed and thereby eliminated a considerable amount of wasted time searching for the edge of the pack ice.

Niren Biswas (RU 483) looked at NOAA and Landsat imagery which might be useful in the evaluation of ice-quake activity in the Norton and Kotzebue Sound areas. A standing order for Landsat imagery for the area for a specific time period was placed for him.

Peter Reinhardt and Miles Hayes (RU 59) called from the University of South Carolina and asked for appropriate summer and winter Landsat imagery of Kodiak Island. A selection was made and enlargements ordered for them.

George Divoky (RU 196, Pt. Reyes Observatory) visited our facility while in Fairbanks for an OCSEAP meeting and spent several hours browsing through the last year's NOAA and Landsat imagery and ordered several prints.

Joe Truett (RU 467, LGL Ltd.) looked at the recent Landsat imagery of Simpson Lagoon to update his record of good imagery for that area.

Stu Rawlinson (Cannon, RU 530) asked for assistance in locating historical air photos of the Beaufort coast. Microfiche of USGS mapping photo indices were studied and an order placed for contact prints and enlargements of these photos.

Seelye Martin (RU 87, University of Washington) called and asked that orbital maps of Landsat coverage for Spring 1978 and 1979 be sent to him. These were sent to him by return mail and also were included in the catalogs of remote-sensing data distributed during this reporting period.

Jay Brueggeman (Braham, RU 69) requested a data search for Landsat imagery of the Norton Sound-Bering Sea area. A list of scenes and their geographic coordinates, cloud cover and dates of acquisition was sent to him along with zerox copies of the scenes.

Peter Craig (RU 467, LGL Ltd.) browsed through available Landsat images from 1977 and 1978 and ordered several of his study area in Simpson Lagoon.

Erk Reimnitz (RU 205, USGS, Menlo Park) looked through the recent imagery of the Beaufort Sea and was interested in the latest ice conditions. Copies of that day's DMSP imagery were given to him and prints made from imagery received after his departure were sent to him.

Dr. Naidu (RU 529) browsed through Landsat images of Simpson Lagoon and ordered copies of several scenes. He also checked on dates of satellite coverage for that area so that he could coordinate field sampling with satellite passes. We are now looking for the imagery for those dates. Thus far, two scenes have been entered into the data base and should be available for his use very shortly.

David Mason (RU 356) browsed through our library and ordered several images which he picked up on his return from doing field work.

Brendan Kelly (Shapiro RU 250) looked through NOAA imagery to correlate ice data already compiled to the satellite imagery.

Harold Mortensen (Seattle Fisheries) looked through all the available Landsat data for Iliamna and ordered several images.

Craig Wiese (Sea Grant Office) ordered several Landsat images and U-2 aerial photographs of the Cordova area.

Faye Alexiev (Research Design, Anchorage) ordered U-2 aerial photography of the offshore islands in the Beaufort Sea to use in her study for the North Slope Borough.

Fred Sorenson (U.S.F. & W.S.) asked for our assistance in choosing NOAA satellite data from June 1977 through July 1978. Mr. Sorenson is involved in a project that is tracking a radio-collared polar bear in its trek across the Chukchi Sea. He knows the geographic location of the bear for given dates but needed the satellite data to give him information on ice conditions which may have influenced the bear's activities. A search was made and order placed for available NOAA imagery for him.

David Lapp and George Comfort (Arctic Canada Ltd.) came in to look for historical ice data for the Prudhoe to Demarcation Point area. Catalogs listing available data in our library were given to them and the imagery was made available for their use.

Wilford Weeks (RU 88) visited to check on the latest imagery available for his study area.

Dr. Naidu (RU 529) looked at and ordered some Landsat imagery showing sediment and circulation patterns in the Beaufort Sea.

Max Puhl (Polar Research Institute) called to ask about the availability of NOAA imagery and how much imagery we had on hand.

John Burns (RU 248) spent a day looking at both Landsat and NOAA imagery and ordered copies of each.

Teri McClung (Shapiro, RU 250) used our equipment and light tables in her work for Shapiro.

Steve Barrett (Stringer, RU 258) searched through the files for sea-ice imagery.

Mike McGuire (Cities Service Oil Company, Tulsa) visited our facility and looked at imagery available. He expressed surprise at finding such a complete compilation of remote-sensing data for the State.

David Yesner (University of Maine) asked for flight line maps of the Port Heiden area.

John Hall (RU 481, U.S.F. & W.S., Sacramento) ordered U-2 and Landsat imagery of the Prince Williams Sound area.

Jim Lockings (graduate student working for Peter Mikkelson) used the Zoom Transfer Scope to transfer information from current photos to maps in their study of the Copper River Delta.

Bob Gleason (SOHIO, Anchorage) called to ask for imagery of the Prudhoe Bay area which shows smoke plumes. He is conducting a study of the changes which might occur if more power were generated in the Prudhoe area.

G. Carleton Ray (John Hopkins University) looked at latest NOAA imagery.

Peter Connors (RU 172, Bodega Marine Lab.) used the Zoom Transfer Scope to transfer information from NOS aerial photographs to maps. He used photos he had purchased as well as transparencies from our files.

Jan Cannon (RU 530) periodically checks through the latest imagery and orders those scenes useful to his OCS investigation.

Juergen Kienle (RU 251) looked at and ordered NOAA imagery of a volcanic eruption on Kamchatka Peninsula.

Christopher Ruby and Peter Reinhardt (Hayes, RU 59) of the University of South Carolina, spent several days in our facility looking through Landsat, NOAA and NOS imagery and placed several orders for data of their study areas.

Gene Ruff (Carey, RU 6) checked the latest NOAA imagery to determine ice conditions before going into the field to pursue their studies in the Beaufort Sea.

APPENDIX B

ICE CONDITIONS IN THE BEAUFORT LEASE AREA

ICE CONDITIONS IN THE BEAUFORT LEASE AREA

The following report is reprinted, with some additions and a reorganization of the sequence of illustrations, from the 1 June 1978 Arctic Project Bulletin No. 20, Outer Continental Shelf Environmental Assessment Program. It is a joint effort between RU 267 (Belon) and RU 257 (Stringer) to illustrate with satellite imagery and interpretive maps, the sequence of seasonal changes of ice conditions in the 1979 Beaufort Sea Lease Area.

The OCS Environmental Assessment Program supports the operation of an "Alaskan Facility for Application of Remote-Sensing data to studies of the Outer Continental Shelf". This project (RU 267-Belon) is primarily a service function for other OCS projects and has three primary activities:

1) operation of a remote-sensing data library

2) operation and maintenance of remote-sensing data processing facilities

3) assistance to OCS investigators in data selection, processing and interpretation

To perform these tasks, RU 267 routinely collects and archives remote-sensing data of the Alaskan coastal areas; compiles and distributes data catalogs to OCS investigators; performs data searches and obtains data products on a case-by-case basis; operates and maintains analysis equipment and provides assistance to investigators in the application of remote sensing to individual projects. These activities have been described in detail in Arctic Project Bulletins No. 6, 7, 9, 10, 12, 14, 17 and 20, as well as in the quarterly and annual reports of RU 267.

Another OCSEAP project, RU 267 (Stringer), has used Landsat imagery to map near-shore sea-ice conditions in the Beaufort, Chukchi and Bering Seas. Sea-ice maps have been prepared for these areas, covering the last five ice seasons. In turn, these maps have been used to identify the basic, often repetitive, elements of sea-ice morphology and dynamics, and the associated geophysical hazards, in the Alaskan coastal zone.

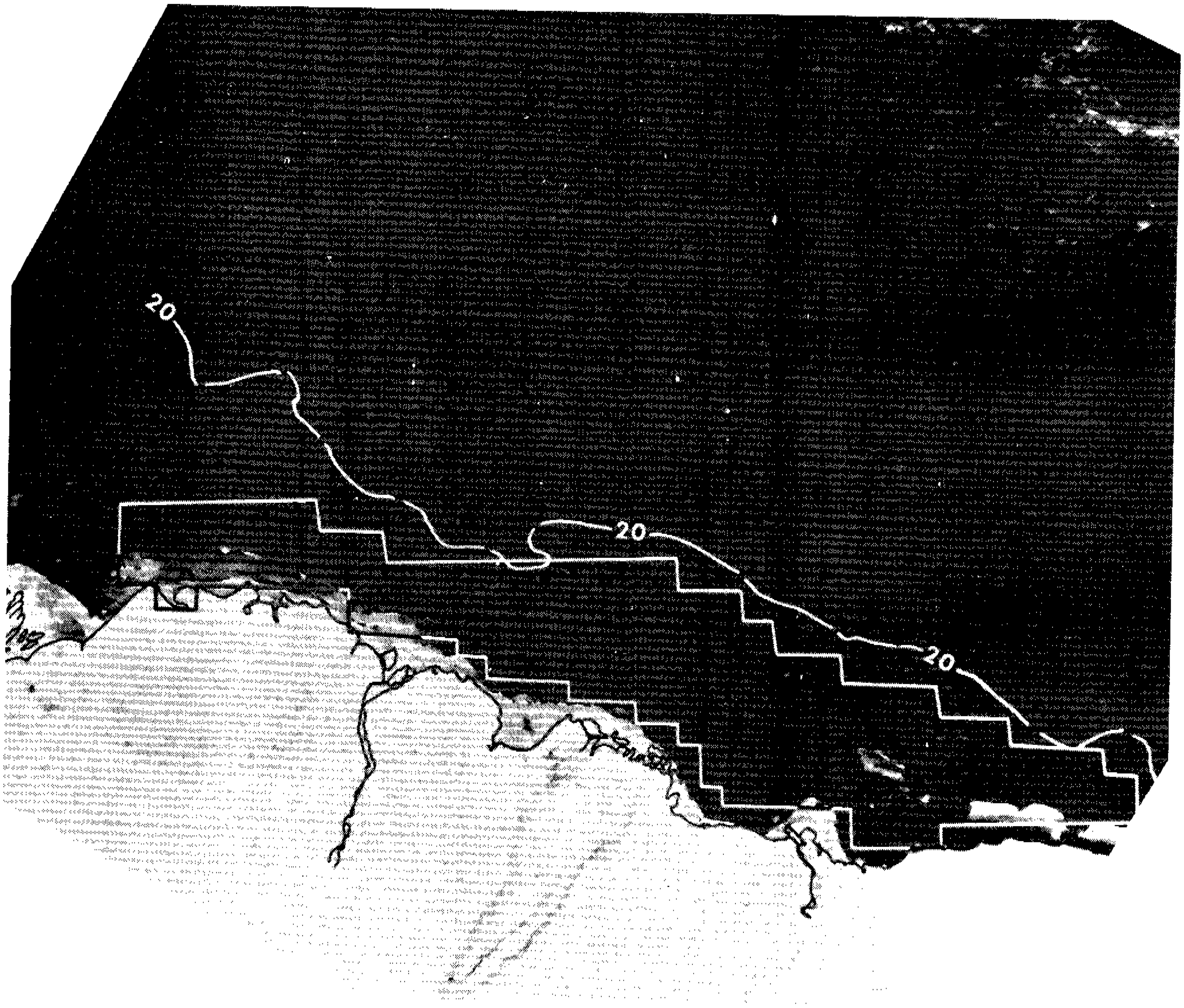
Both research units (257 and 267) have combined efforts to prepare the following report on ice and other conditions in the area of the Beaufort Sea proposed for leasing in December, 1979. The proposed lease area, and the twenty-meter isobath have been delineated on the Landsat images shown. Additionally, on those Landsat scenes where the coastline is obscured, it has been highlighted.

Landsat scenes have been chosen to illustrate the variety of conditions typical of an average year. The scenes are displayed here in seasonal order starting with early stages of freeze-up and ending with a late summer scene showing sediment plumes and drift ice.

In addition to the Landsat scenes displayed, portions of maps prepared by RU 257 have been chosen to illustrate various aspects of statistical ice morphology related to the conditions seen on the Landsat examples.

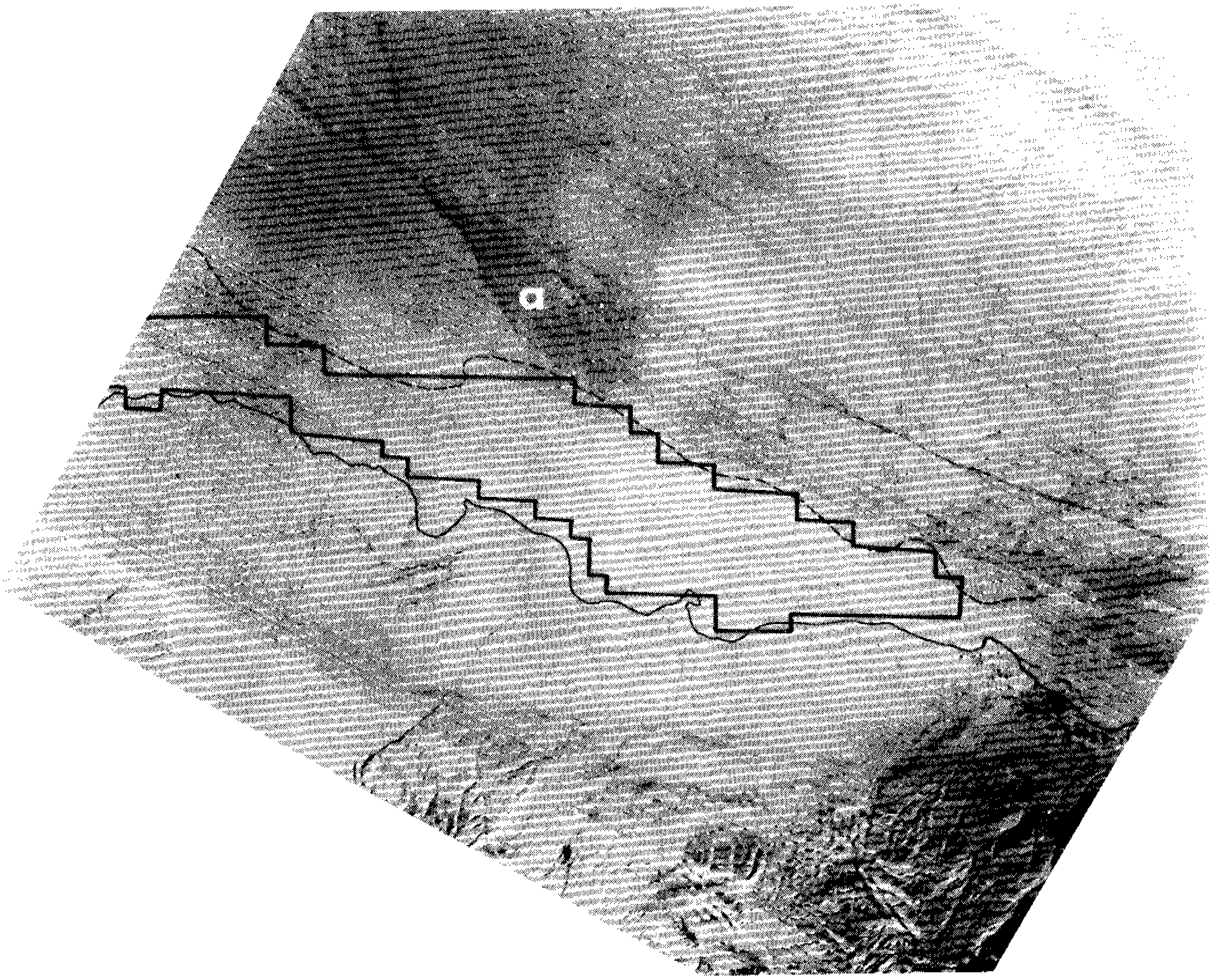
FALL ICE FORMATION

Beaufort Sea Lease Area



Landsat Scene 1073-21223

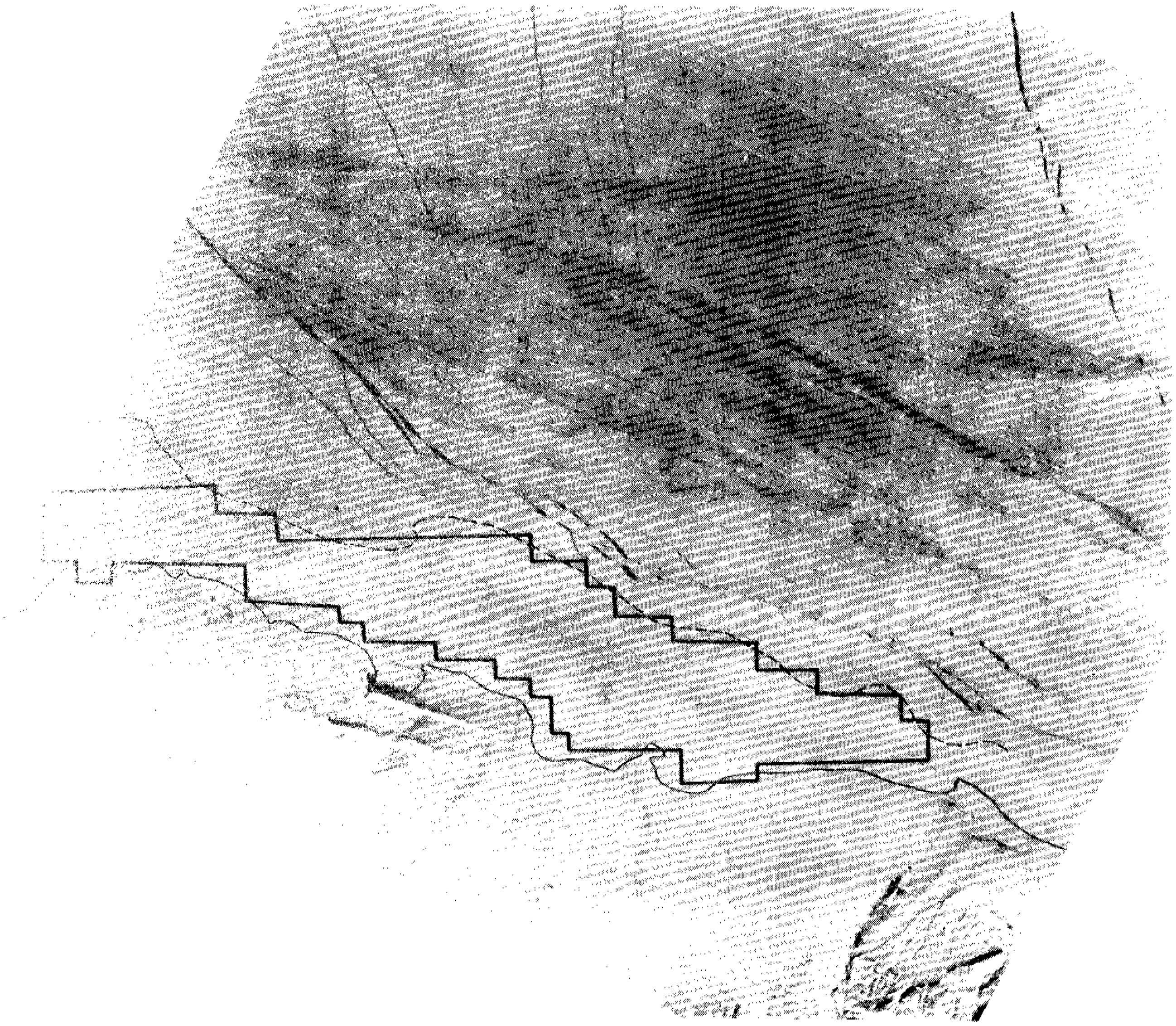
This image was obtained during the early stages of Beaufort Sea freeze-up on October 4, 1972. The spectral range of this Landsat band 4 image is particularly sensitive to thin ice cover. Most of the ice seen on this image is considerably thinner than 30 centimeters. Relatively thick ice has formed in the nearshore areas, especially within the barrier-island lagoons and in Prudhoe Bay.



Beaufort Lease Area - Midwinter 1976

Landsat Scene 2392-21023 18 February 1976 This mid-winter Landsat scene shows contiguous ice extending great distances from shore. No flaw lead is visible. Near the 20-meter isobath (dashed line) along the seaward boundary of the proposed lease area large ridge systems can be seen. Condensation trails from water vapor sources in the Prudhoe Bay vicinity indicate onshore winds which could be partly responsible for the absence of open lead systems. Almost every year during the winter and early spring this phenomenon occurs in the Beaufort Sea and persists for several weeks. The dark patch (a), representative of thin ice to the west of the main ridge systems, indicates that in the recent past the ice had been moving leaving this area uncovered. It is likely that some of the ridges apparent on the scene were created at that time.

Scale 1:1 Million



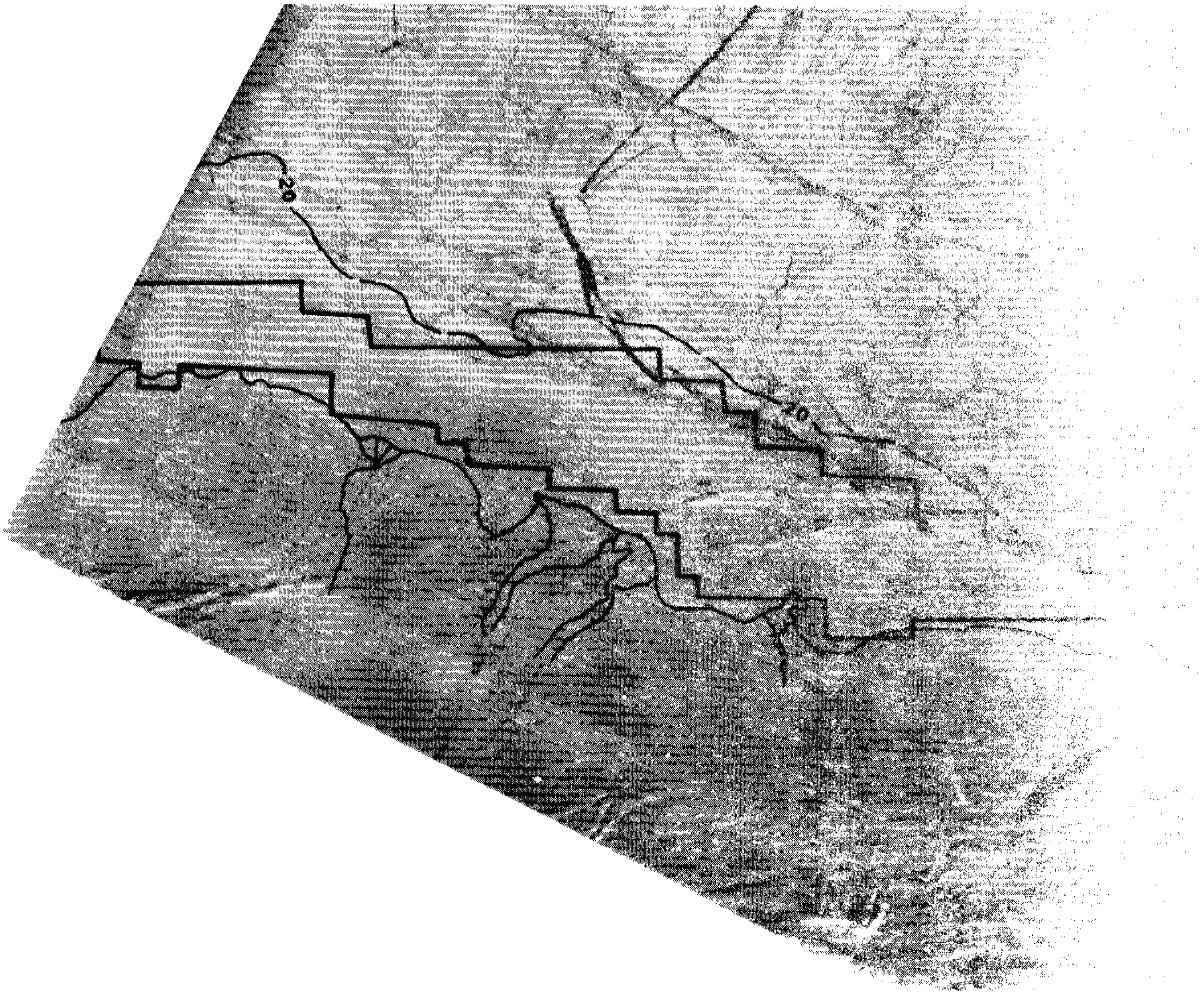
Beaufort Lease Area - Midwinter 1977

Landsat Scene 2752-20505 12 February 77 In contrast to the Midwinter 1976 scene, this midwinter Landsat image shows an active shear zone a few kilometers seaward of the 20-meter isobath (dashed line). Cracks appearing to result from shear stress can be seen extending shoreward of the major fracture system. It is interesting to observe from the water vapor condensation trails that Prudhoe Bay surface winds are eastward trending while winds aloft (∿70 meters) are bearing approximately 45° to the right, giving them a heading of nearly southeast. Clearly the surface winds at that time would not tend to hold the ice into shore as indicated for the Midwinter 1976 scene.

Scale 1:1 Million

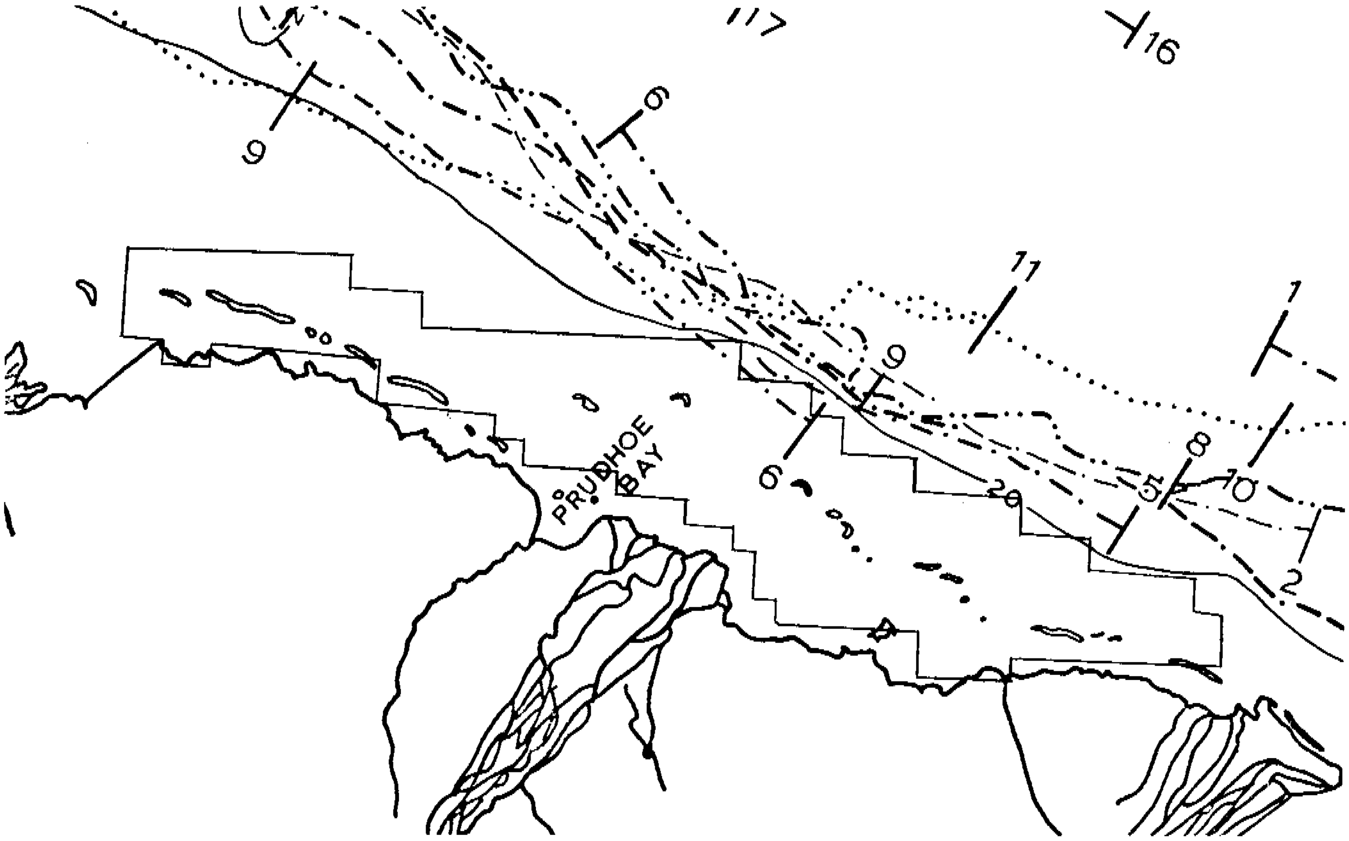
LATE-WINTER OPEN LEADS

Beaufort Sea Lease [illegible]



Landsat Scene 1234-21175

This Landsat scene shows the proposed lease sale area on March 14, 1973, [illegible] a large portion of the Beaufort Sea nearshore ice has moved toward the east [illegible] 2½ kilometers and is in the process of freezing over. Following this dislocation [illegible] of pack ice remained stationary and fast with respect to shore for over six [illegible] be noted that this lead has propagated through the northern portion of the [illegible] area well inshore (up to 10 kilometers) from the 20-meter isobath.

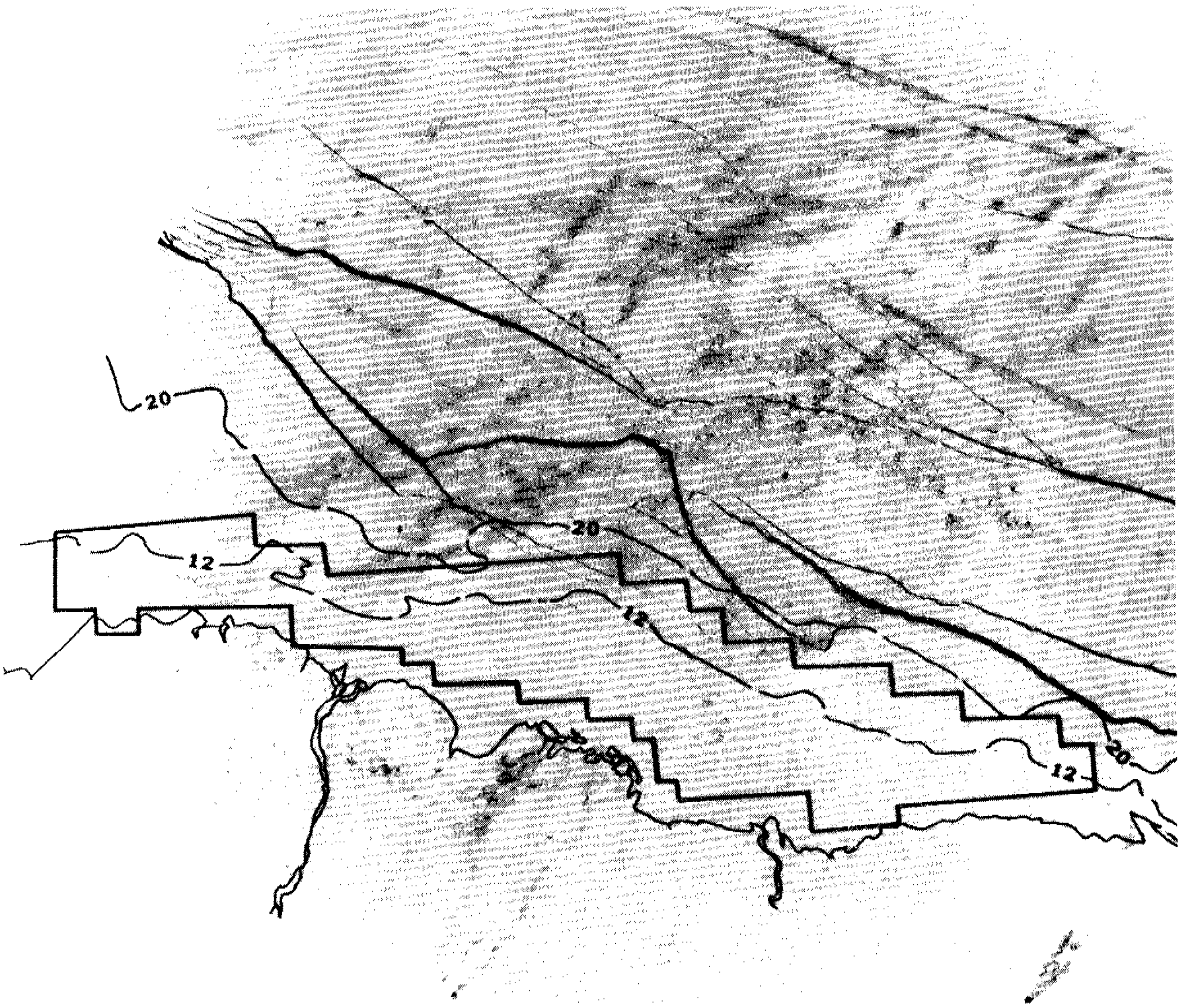


Beaufort Sea Late-Winter Ice Edge Map

This is a portion of a map showing edges of fast ice (flow leads) observed between 1973 and 1977. This portion of the map shows the area of the proposed lease sale. It can be seen that the 1973 event was the most shoreward location of ice edge observed. Hence the lease area appears to be relatively free from lead formation during this period based on five years' statistics.

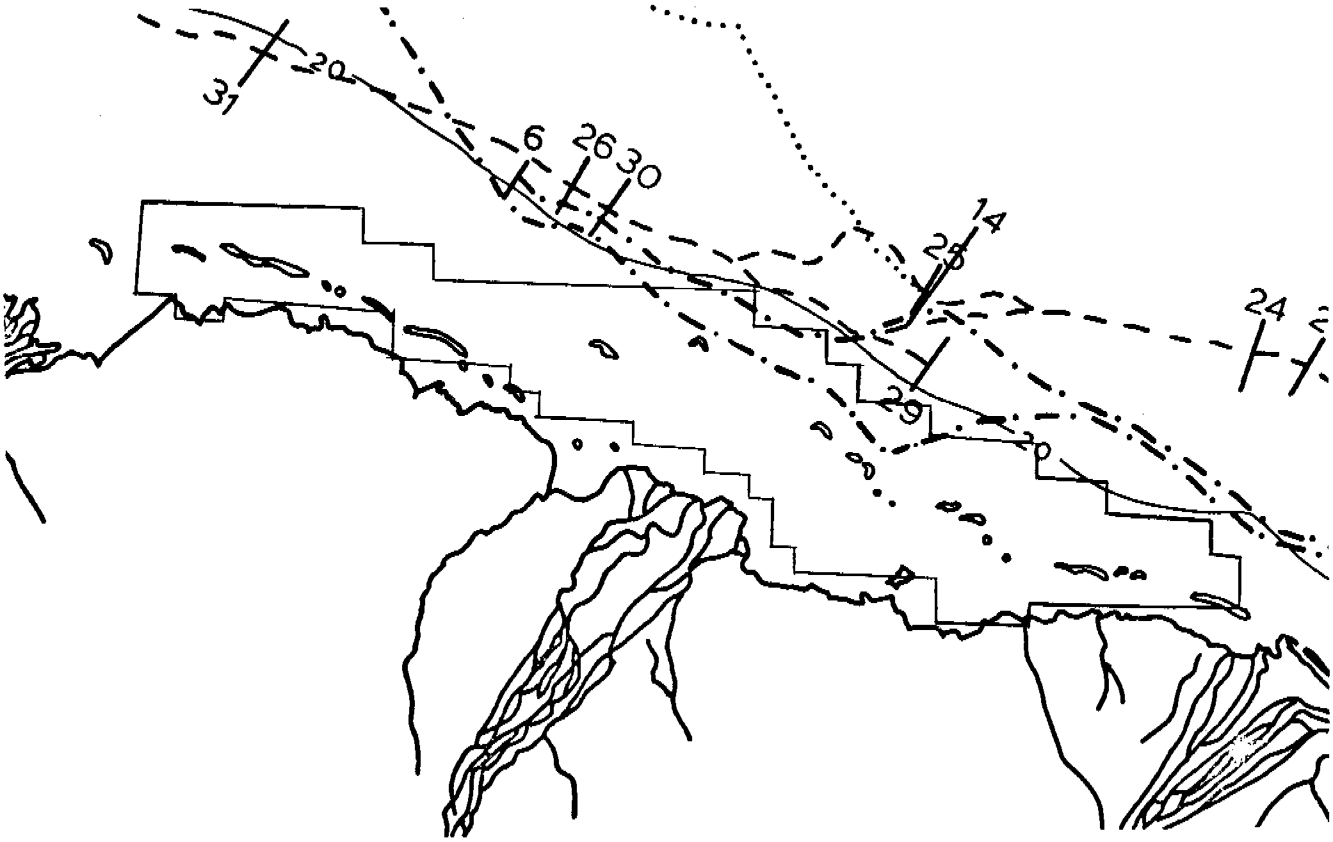
EARLY-SPRING OPEN LEADS

Beaufort Sea Lease Area



Landsat Scene 2-806-20482

This Landsat scene shows sea ice conditions in the proposed lease area on April 7, 1977. The 12- and 20-meter isobaths have been superimposed on this image along with an outline of the tracts proposed for the December 1979 lease sale. A fresh set of leads can be seen across this entire image, and while most of this lead system is seaward of the 20-meter isobath, several leads can be seen in the region between the 12- and 20-meter isobaths in the area between Midway and Stockton islands. This image illustrates that the 20-meter isobath does not represent an absolute barrier to dynamic ice events during the ice season.

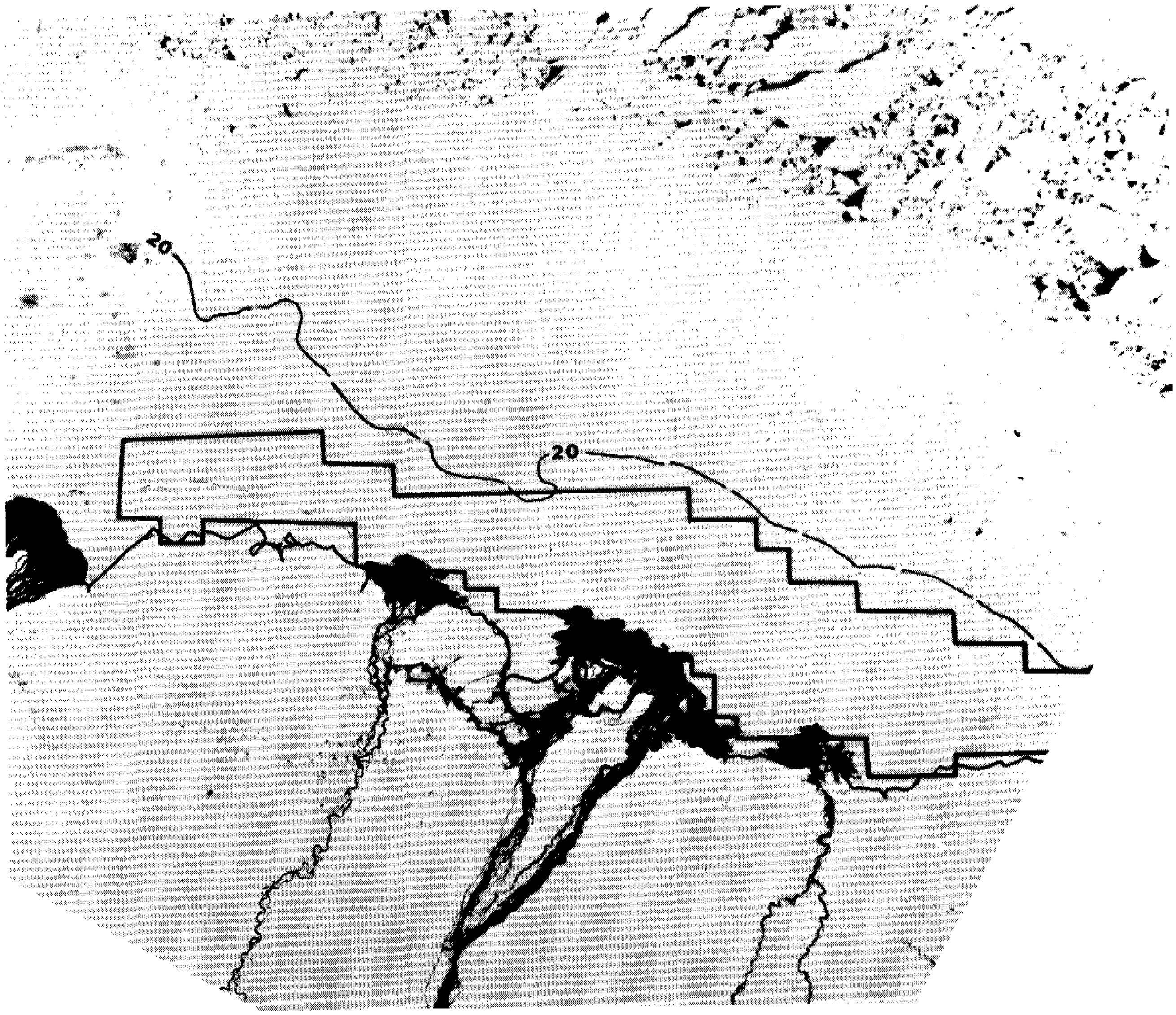


Beaufort Sea Early-Spring Ice Edge Map

Shown here is a portion of a map of edges of contiguous ice observed between 1973 and 1977 for the entire Beaufort Sea. The portions chosen for display includes the proposed lease tracts. In addition, the 12- and 20-meter isobaths have been illustrated. This map shows that statistically, the area between the 12- and 20-meter isobaths located between Cross and Stockton islands has been the site of lead-forming events for several years. This result illustrates that the 20-meter isobath cannot be taken as the absolute shoreward limit of shear zone activity in this area.

SPRINGTIME OVERFLOW

Beaufort Sea Lease Area

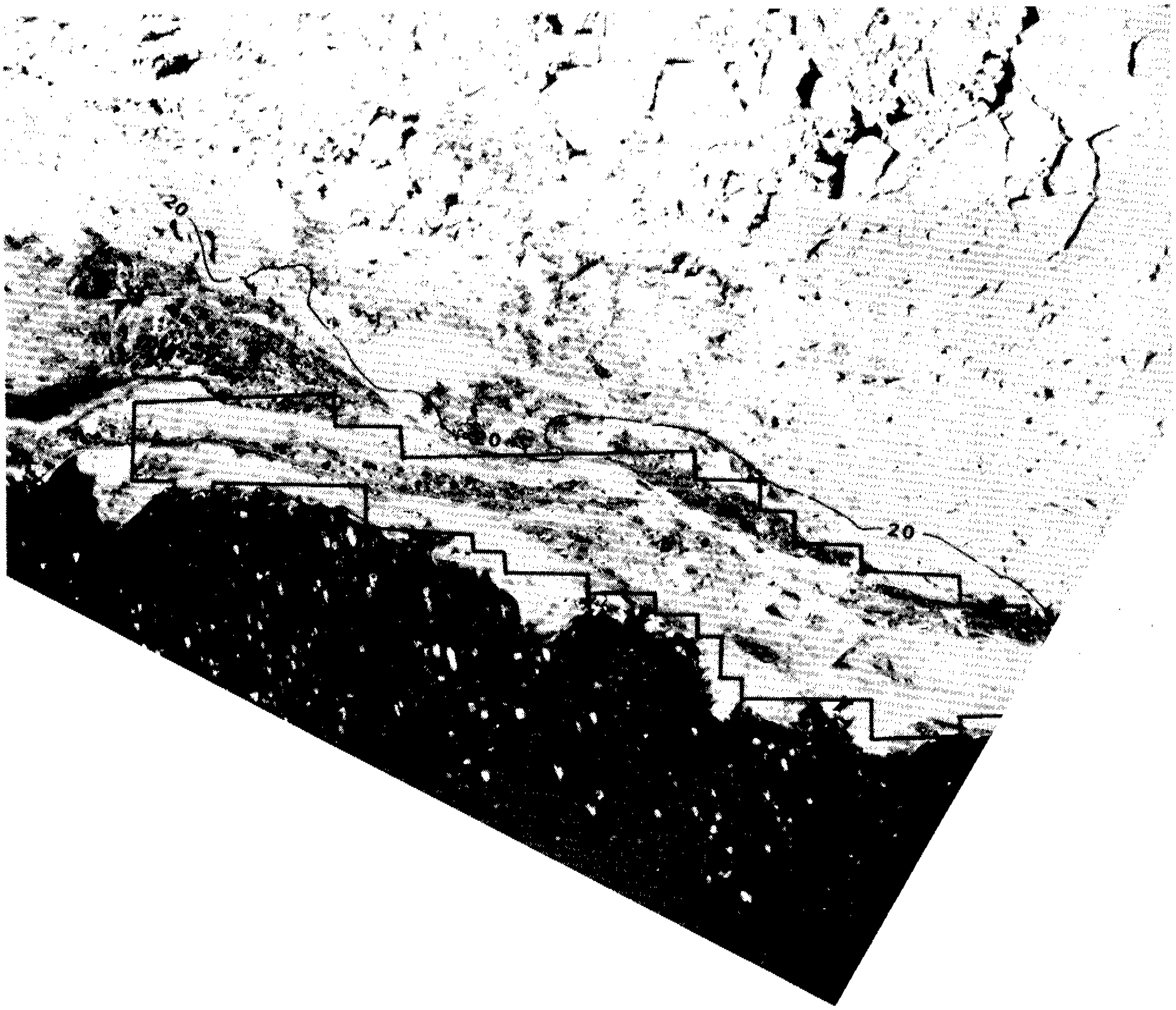


Landsat Scene 2501-21051

This scene obtained on June 6, 1976, shows the annual flooding of nearshore ice by the coastal rivers well under way. Typically of high sun-angle images, individual ice features are difficult to distinguish. However, the barrier islands forming the seaward boundary of Simpson Lagoon can clearly be seen in the western portion of the proposed lease sale area. During this springtime flooding the coastal rivers are estimated to conduct as much as 80% of their annual flow and an even greater portion of their annual sediment load. Not all dark features on this image are associated with river overflow; the pipeline haul road and road network in the Prudhoe Bay area can also clearly be seen. In addition to these dust plumes extending from river sandbars and the drilling-pad/road network can also be distinguished.

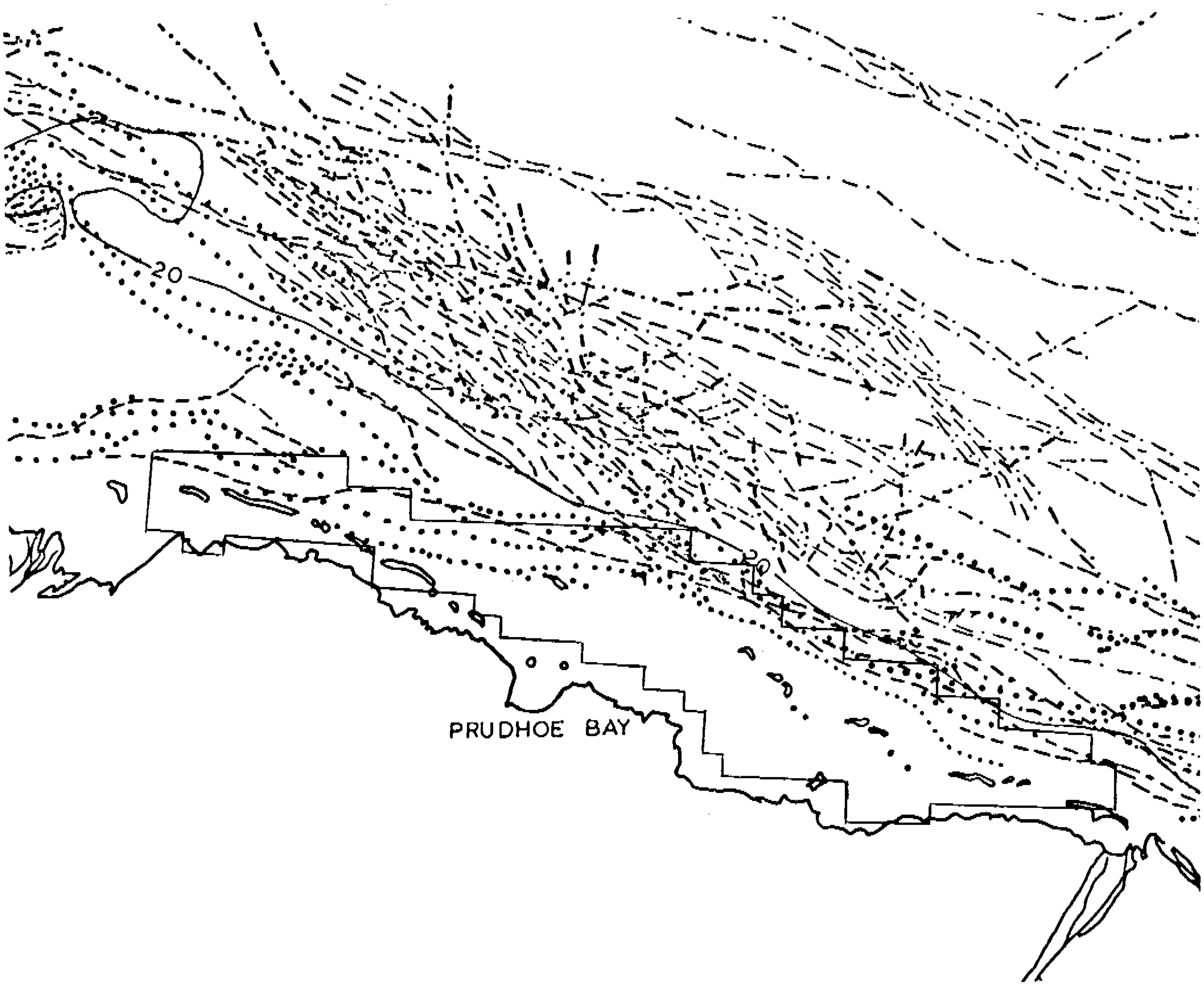
RIDGE SYSTEMS

Beaufort Sea Lease Area



Landsat Scene 1703-21151

This Landsat scene shows ice conditions in the proposed lease area on June 26, 1974. A number of sinuous ice features can be distinguished roughly following the 20-meter isobath. Many of these were confirmed to be ridge systems or hummock fields during an aerial reconnaissance performed very near this date. It is noteworthy that the best formed of these features are found well within the 20-meter isobath and in the eastern sector of the proposed lease area, well within the lease area.

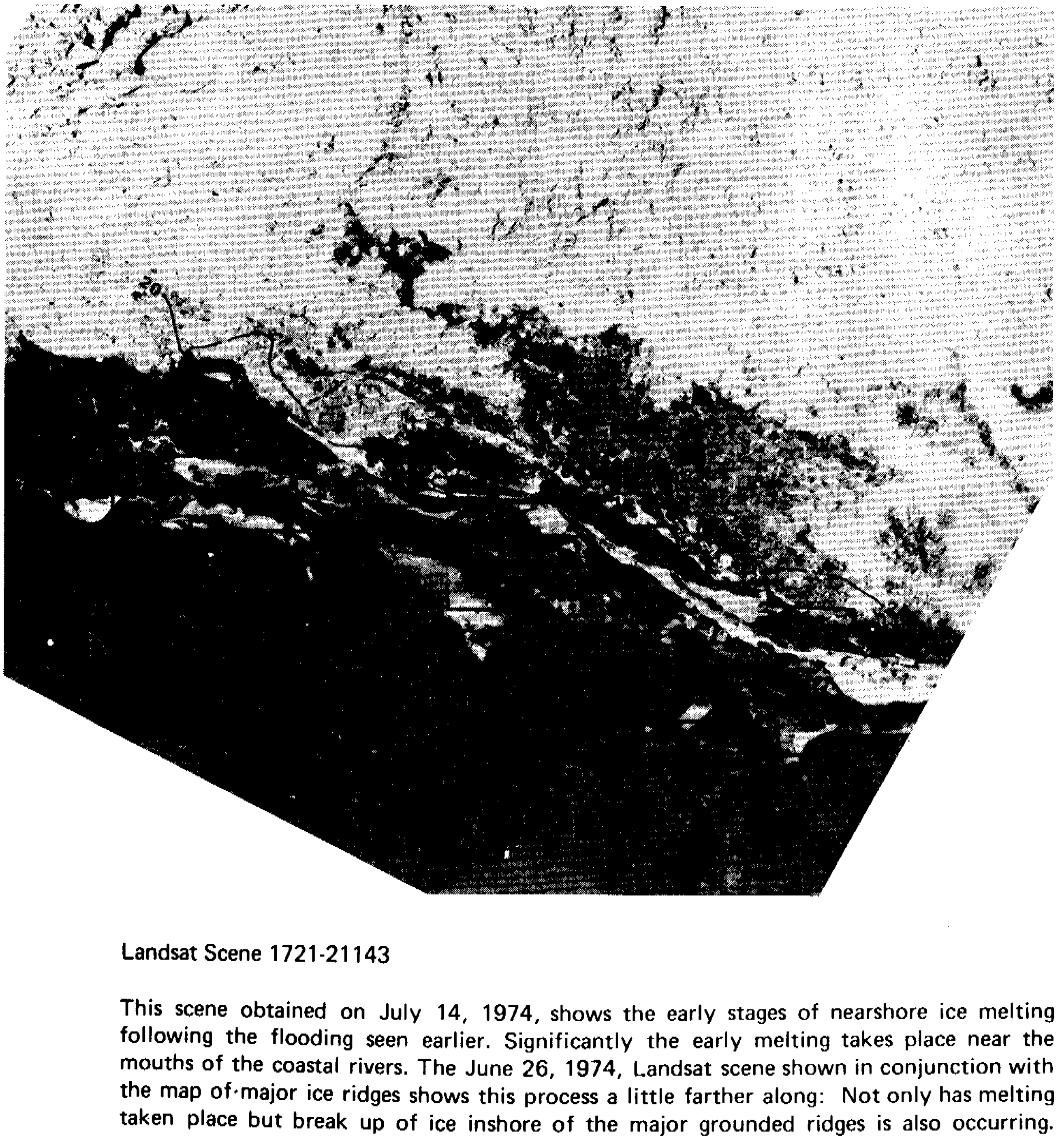


Beaufort Sea Ridge System Map

Shown here is a portion of a map of all major ridges observed in the Beaufort Sea between 1973 and 1977. It can be seen that in the eastern sector of the proposed lease area many ridges are roughly coincident with the 20-meter isobath and many are well inshore of that isobath and well within the tracts proposed for leasing. In the western sector, however, the principal trend of major ridges bridges the indentation in the 20-meter isobath, leaving a relative minimum of major ridges within the proposed lease area. Thus the trend observed on the 1974 Landsat image is borne out by compiled statistics.

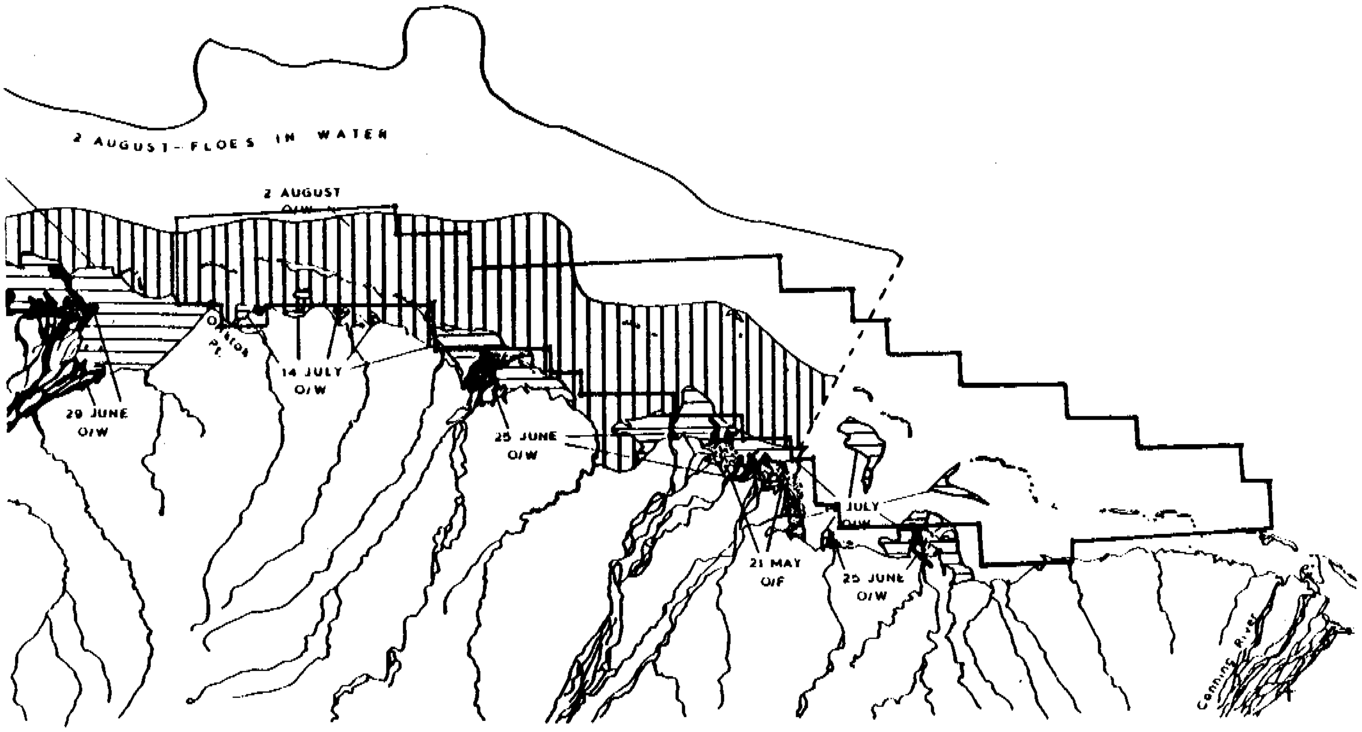
EARLY OPEN WATER

Beaufort Sea Lease Area



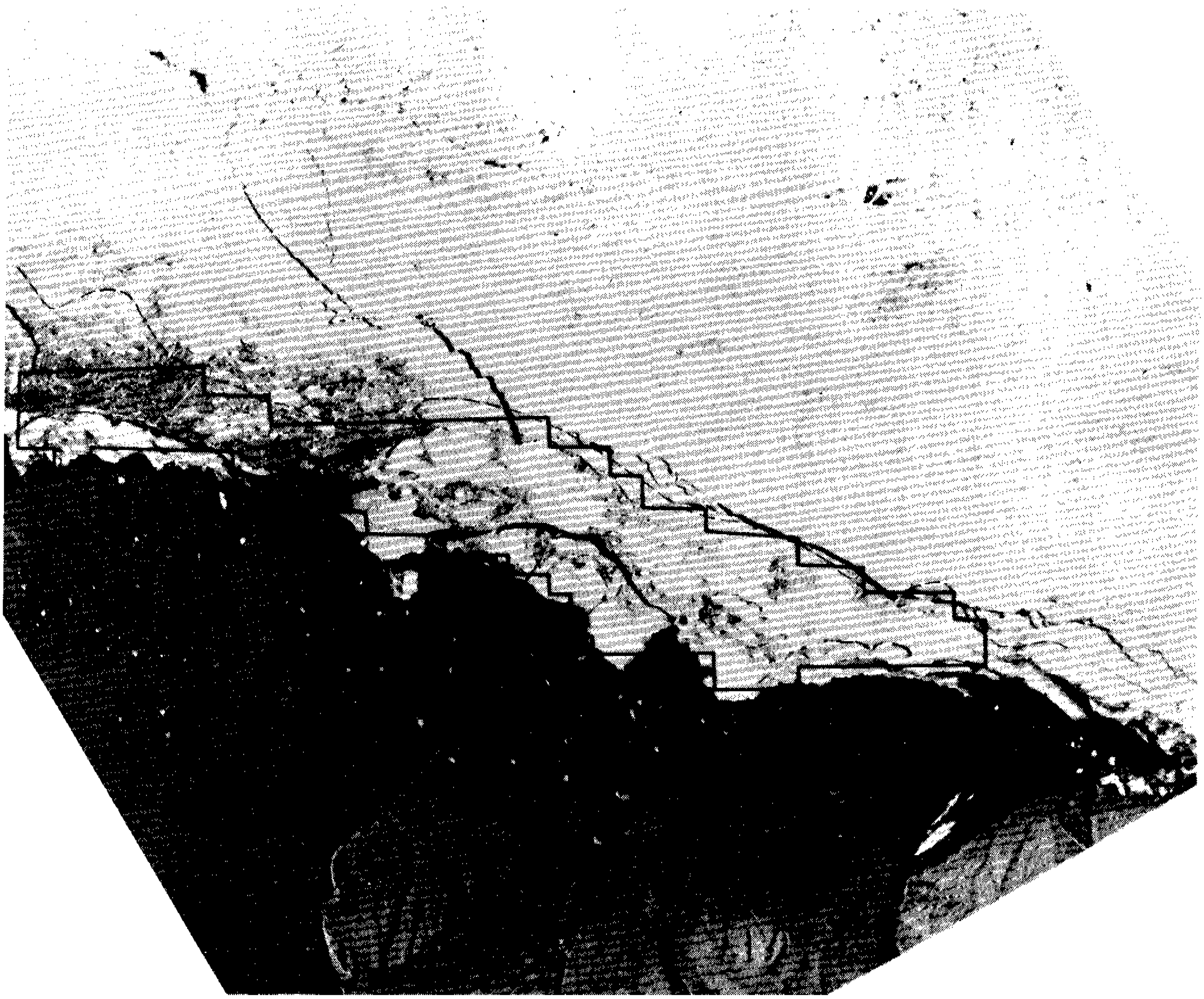
Landsat Scene 1721-21143

This scene obtained on July 14, 1974, shows the early stages of nearshore ice melting following the flooding seen earlier. Significantly the early melting takes place near the mouths of the coastal rivers. The June 26, 1974, Landsat scene shown in conjunction with the map of major ice ridges shows this process a little farther along: Not only has melting taken place but break up of ice inshore of the major grounded ridges is also occurring.



Beaufort Sea 1974 Open-Water Map

Shown here is a portion of a map showing successive stages of open water in the Beaufort Sea following the initial flooding in early June. Comparing this map with the corresponding open-water image obtained on July 14, 1974, shows the rapidity with which the ice breaks up. On July 14, there was open water only in the vicinity of river mouths. By August 2, open water existed nearly 50 kilometers off shore.



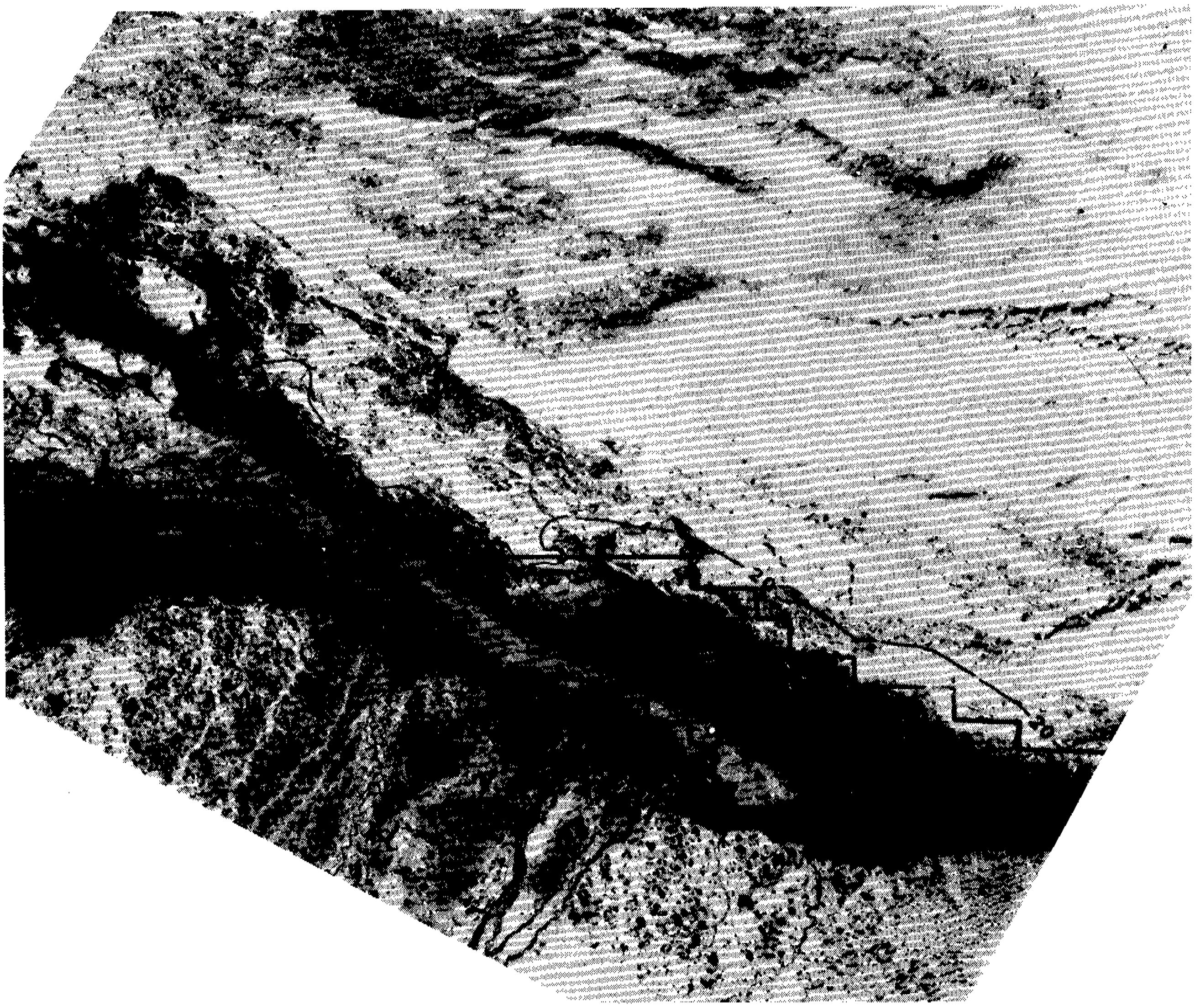
Beaufort Lease Area - Early Summer 1977

Landsat Scene 2898-05155 8 July 1977 This early summer Landsat scene shows breakup ice conditions along the Beaufort Coast. A variety of processes are at work within the lease area: Far offshore along the seaward boundary of the lease area a large lead system has opened up shifting the pack ice almost due east by a kilometer. Clearly the ice seaward of this lead is not well-grounded at this time. It is interesting to note that this lead system nearly coincides with the 20-meter isobath (dashed line). Inside the barrier islands, overflow waters from coastal rivers have helped melt the ice adjacent to shore. Further offshore but still within the lagoons, the ice sheet is breaking into fragments free to float around the lagoons. This phenomenon indicates two interesting pieces of information: 1) The ice within the lagoons was not piled during the winter sufficiently to cause anchoring and 2) The draft of the ice sheet in the areas breaking off is now less than the water depth which, in turn when compared with bathymetric charts indicates the state of decay of the fast ice.

Scale 1:1 Million

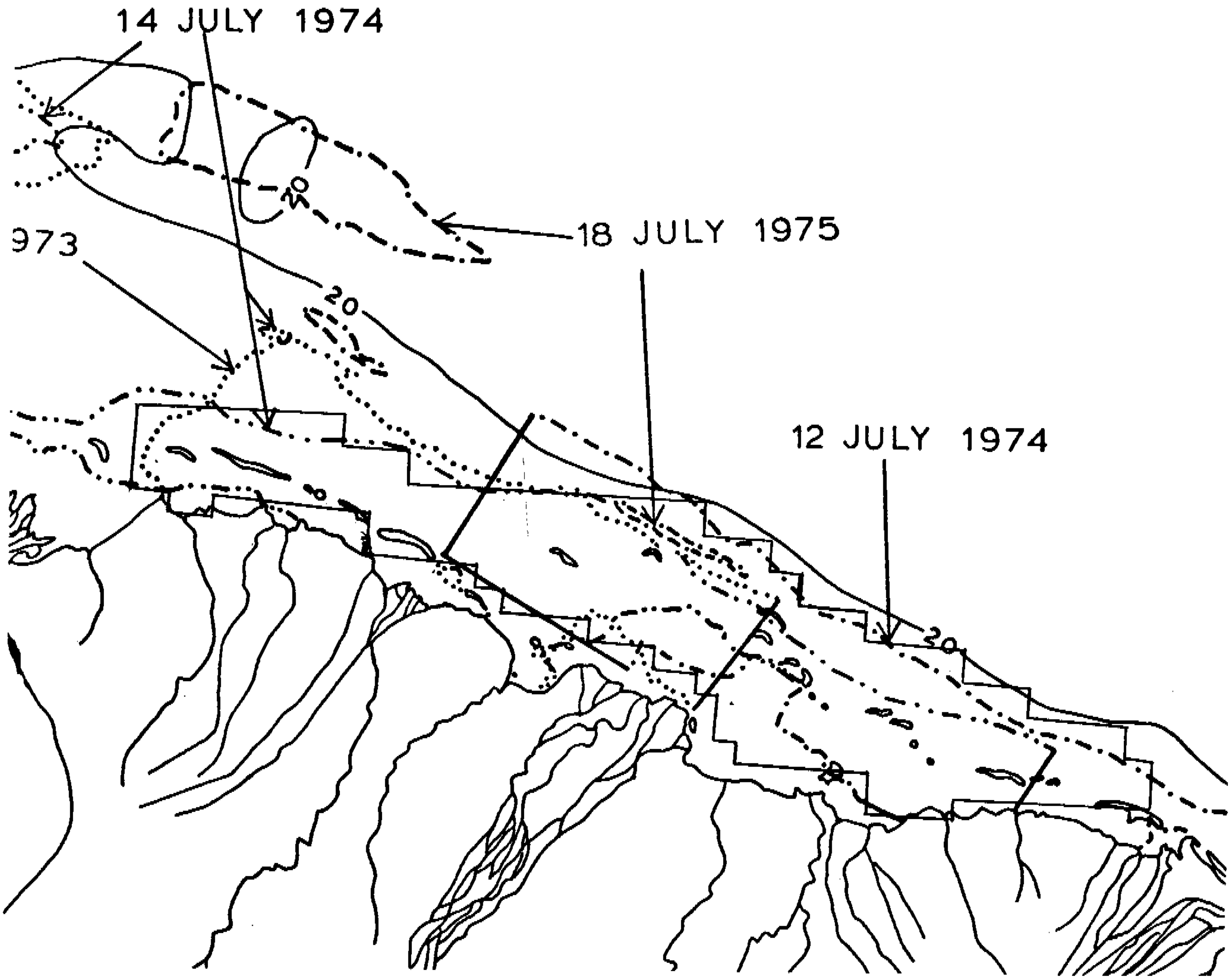
STATIONARY SUMMER ICE

Beaufort Sea Lease Area



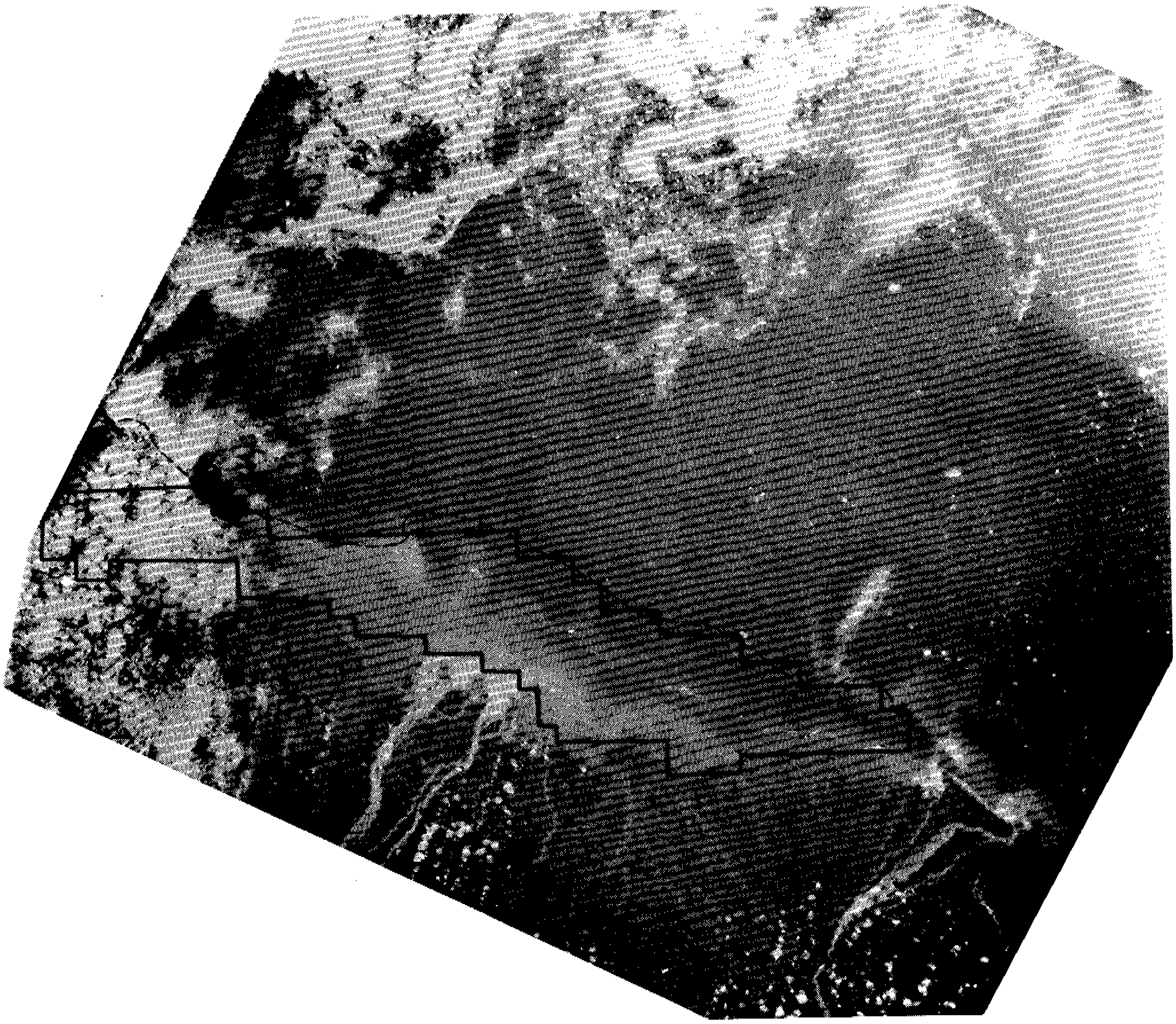
Landsat Scene 2177-21110

This scene, obtained on July 18, 1975, shows the ice in the proposed lease area in an advanced stage of break-up. In the area generally off shore from the barrier islands but well within the 20-meter isobath can be seen an extensive area of isolated ice. This is not an unusual phenomena in the Beaufort Sea. The ice is often temporarily held in place by remnants of ridges and other features (sometimes called Stamukhi) grounded on shoals. Farther off shore, just inside the lease area other grounded features can be seen lying roughly parallel to the 20-meter isobath. Many of these features are grounded portions of major ridge systems. In many cases, after the ridges themselves break up, significant segments of these ridges are driven shoreward by winds or internal pressure within the adjacent pack ice. This particular year, 1975, was unusual in that this condition persisted nearly the entire summer. One large system of grounded ridges (referred to as a "floeberg") seen seaward of the western portion of the lease area and also seaward of the 20-meter isobath remained grounded throughout the summer of 1975 and the following winter.



Beaufort Sea Stationary Ice

Seen here is a portion of a map prepared to show "stationary ice" in the Beaufort Sea. Because of mid-summer cloudiness, this is a difficult phenomena to document. However, between 1973 and 1975 several cases showing "stationary" ice have been documented in the proposed lease area. Upon cursory examination it might appear that a large portion of the ice seen on Landsat scene 2177-21110 might be stationary. However, careful comparison of ice seen on successive Landsat images shows that most of this ice is actually mobile and only a small portion is actually "stationary." Identification of stationary ice in summer helps identify ice features which may have either been formed as well-grounded features the previous winter or driven aground during summer.



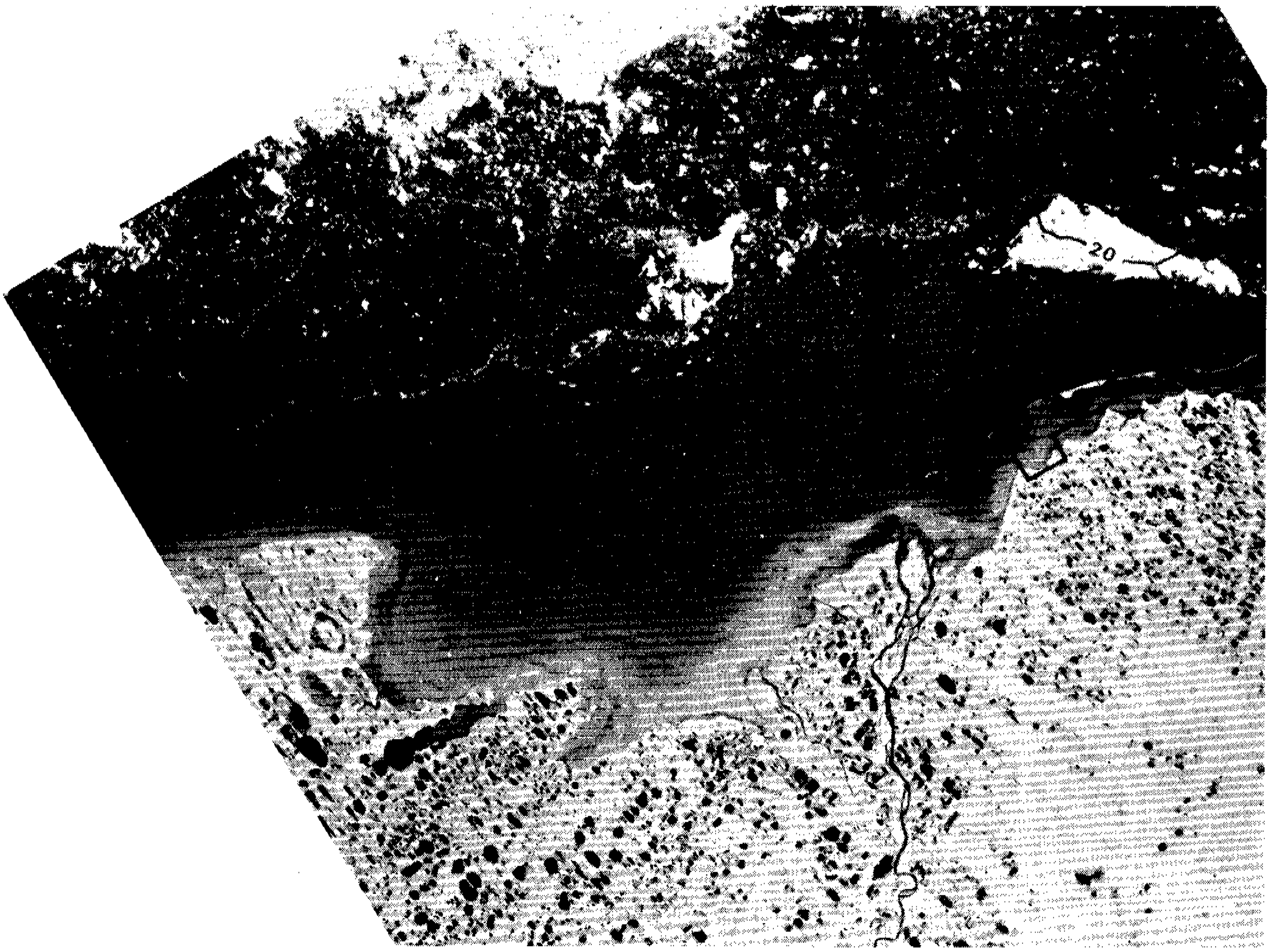
Beaufort Lease Area - Summer 1973

Landsat Scene 1396-21162 23 August 1973 This mid-summer scene shows sediment plumes from coastal rivers within the boundary of the proposed lease area. These sediment plumes should be useful for tracing nutrient transport resulting from erosion of nutrient-bearing soils along rivers and the coast. Farther offshore a few pieces of drift ice can be seen near the boundaries of the proposed lease area. Other mid-summer Landsat scenes show drift ice grounding within these boundaries.

Scale 1:1 Million

SUMMER DRIFT ICE AND SEDIMENTS

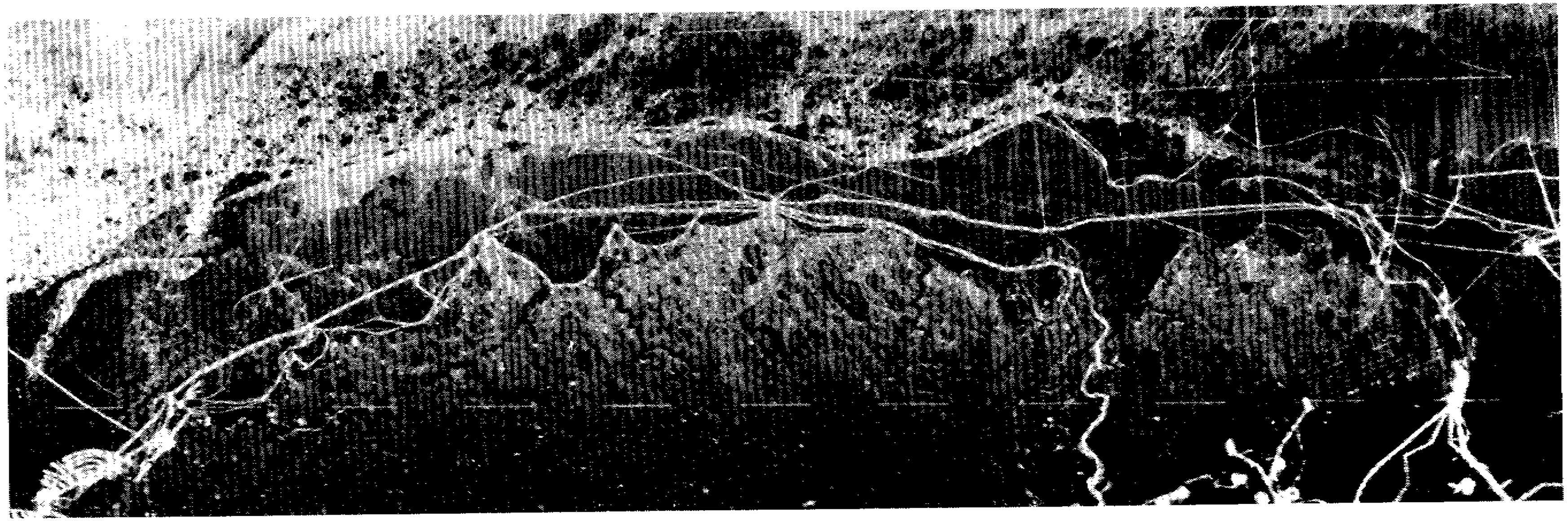
Beaufort Sea Lease Area



Landsat Scene 1777-21240

This Landsat scene shows the western portion of the proposed lease area on September 8, 1974. At this time the wind was out of the east, southeast at average speeds between 15 and 20 knots. This condition had persisted for the four previous days and continued yet another day after September 8. During these six days, the three-hour average winds were as great as 35 knots and the wind direction remained constant. Great quantities of suspended sediment can be seen drifting along the coast, driven by these winds. Assuming an average speed of 20 knots over the 144-hour period yields a reach of 2880 nautical miles. Even a 1% drag coefficient for pollutants floating on the surface of the water would be sufficient to cause transport a distance twice the width of this Landsat scene.

Seaward of the lease area, two large accumulations of ice can be seen. These temporarily stationary piles of ice occur as a result of large draft ice features grounding on shoals and other pack ice members being held against the grounded ice by the wind. Streamlines of drift ice can be seen trailing down wind from these stationary piles of ice.



Side Looking Airborne Radar

This Radar image was acquired in April 1977 over the Prudhoe Bay-Simpson Lagoon area. SLAR is particularly sensitive to surface roughness and the availability of reflecting surfaces for the 3.5 cm radar signal. Consequently ice roughness is well mapped, although the return signal tends to saturate in areas of increased roughness thereby limiting the dynamic range of the recorded information. For instance, man-made features such as ice roads give a saturated return signal while the berm on the roadside is less than a meter high. On the other hand, the texture of ice piled around smooth pans is well portrayed. This information would be extremely useful when planning field work on the ice. Note the Union Oil's Ice Island and surrounding snow fences in the extreme lower left corner of the image, Prudhoe Bay oil field facilities on the right and numerous roads and trails on the near shore ice.

ANNUAL REPORT

Contract 03-5-022-56
Research Unit #350
Reporting Period 4/1/78-3/31/79
Number of Pages - 37

ALASKAN OCS PROGRAM COORDINATION

Donald H. Rosenberg
OCS Coordination Office
University of Alaska

March 31, 1979

I. Summary of Objectives

This project provides for coordination of all NOAA/OCS Task Orders within the University of Alaska. It provides for a coordination and related support staff and services necessary to conduct the scientific program of OCS. This is accomplished by being a focal point for all contract, data management, and logistics coordination.

II. Introduction

Not applicable

III. Current State of Knowledge

Not applicable

IV. Study Area

Not applicable

V. Sources, Methods, Rationale of Data Collection

Not applicable

VI. Results

A. Scientific and Contract Monitoring

During the reporting period this office has exercised monitoring authority over the Task Orders listed in Table 1. As noted on this table, certain tasks have been completed during the reporting period and final reports have been submitted.

The monitoring effort of this office is limited to the following: the evaluation of the scientific effort relative to the work statements to insure contractual compliance, the coordination of proposal submission, logistic requirements, and data submission. In the last case, Data Management Plans are formulated and submitted through this office, as are the resulting Data Submission Schedules and formatted, taped data. All reports are also submitted through this office.

In the past year, the proposals tabulated in Table II were submitted to NOAA for OCS work.

Contact with the Juneau, Arctic Project and Boulder OCS offices was maintained to insure that progress in the scientific programs pursued by University of Alaska principal investigators is consistent with NOAA/OCS program needs and that any problems that arise are solved in a timely manner.

The staff of this office and their duties relative to OCS are outlined in Table III.

B. Data Management

Data Management Plans were formulated and kept up-to-date by this office as needed.

Formats for submitting data on magnetic tape have been received for all data which will be so submitted. One problems continues to trouble me; this is the continuous need to revise existing formats. When dealing with a large number of formats as this office does, it is easy to miss corrections, especially for a rarely used format. <u>May I request that when a change occurs a completely new format be sent, not just the corrected record type</u>.

C. Data Submissions

During the past year contract 03-5-022-56 investigators have submitted through this office batches of data which were checked for format, keypunched, transferred to tape and submitted to NOAA/OCS. See Table IV for a listing of these data submissions.

We have also furnished, through this office, a keypunching and data transmittal service for investigators as designated by the Project Offices, on a limited basis. We have in the past year processed data for Dr. P. Connors at the request of the Arctic Project Office.

D. Travel Coordination

Funds were provided through this Task Order to allow for travel of management, staff and principal investigators under this contract to meetings requested by NOAA/OCS. These funds were used to attend synthesis and coordination meetings as well as meetings requested by the Project Offices between principal investigators and their Trackers.

E. Logistics Coordination

Coordination of logistics requirements in the pursuit of tasks assigned to this contract was carried out through this office in the past year. We attempt to act as a pipeline for changes requested in project instructions as well as in the submission of Chief Scientists Reports and ROSCOP II forms where appropriate.

VII. Discussion

Not applicable

VIII. Conclusions

Not applicable

IX. Needs for Further Study

Not applicable

X. Summary of Fourth Quarter Operations

A. Ship or Laboratory Activities

Not applicable

B. Results

See results section above and Tables

C. Problems Encountered

The only major problem encountered centers on the Voucher Specimen Policy. In various aspects this problem has been with us since the beginning of the OCS projects.

Recent advances have been made. The problem now centers around whether it is necessary for task orders which have been completed to post facto comply with the policy, and if so, how this will be handled, particularly in reference to time and money.

As is apparent from recent correspondence, the University is continuing to work toward a mutually agreeable solution.

Table I

University of Alaska OCS Projects

Contract 03-5-022-56

Task Order	R.U.#	Project Title	Principal Investigator
1*	427	Bering Sea Ice-Edge Ecosystem Studies	Vera Alexander R. T. Cooney
2	350	Alaskan OCS Program Coordination	Donald H. Rosenberg
3*	290	Grain Size Analysis of Sediment from Alaskan Continental Shelves	Charles M. Hoskin
5	275	Hydrocarbons: Natural Distribution and Dynamics on the Alaskan Outer Continental Shelf	David G. Shaw
7	278	Microbial Release of Soluable Trace Metals from Oil-Impacted Sediments	Robert J. Barsdate
8	194	Morbidity and Mortality of Marine Mammals	Francis H. Fay
12	162	Natural Distribution of Trace Heavy Metals and Environmental Background in Three Alaskan Shelf Areas	David C. Burrell
15	5/303/281	The Distribution, Abundance, Diversity and Productivity of Benthic Organisms in the Bering Sea	Howard M. Feder
19	289	Mesoscale Currents and Water Masses in the Gulf of Alaska	Thomas C. Royer
23	351	Logistic & R/V Acona	Dolly Dieter
24		Administrative Support NODC/EDS	David M. Hickok
27*	441	Avian Community Ecology at Two Sites on Espenberg Peninsula	P. G. Mickelson
32	537	Nutrient Dynamics and Primary Production in Alaska Beaufort Sea Coastal Waters	D. M. Schell
33	529	Sediment Characteristics, Stability, and Origin of the Barrier Island-Lagoon Complex, North Arctic Alaska	A. S. Naidu

Task Order	R.U.#	Project Title	Principal Investigator
34	530	The Environmental Geology and Geomorphology of the Barrier Island-Lagoon System Along the Beaufort Sea Coastal Plain from Prudhoe Bay to the Corville River	P. Jan Cannon

* Final reports for these projects have been submitted and the Task Order work completed.

TABLE II

Proposals Submitted to NOAA/OCS for Contract 03-5-022-56
4/1/78 - 3/31/79

Submission Date	Proposal No.	Title	Principal Investigator	Cost Proposal
3/30/78	78-17	Nutrient Dynamics and Primacy Production in Alaska Beaufort Sea Coastal Waters	Schell/Matthews	$37,166
4/4/78	78-18	Some Effects of Petroleum on Arctic Marine Organisms	Shaw	74,905
6/4/78	79-1	Alaska OCS Program Coordination	Rosenberg	90,079
6/14/78	79-2	Marine Logistics Support	Dieter	18,000
6/27/78	79-3	Nutrient Dynamics and Trophic System Energetics in Nearshore Beaufort Sea Waters	Schell	56,691
6/27/78	79-4	Sources, Transport Pathways, Depositional Sites and Dynamics of Sediments in the Lagoon and Adjacent Shallow Marine Region Northern Arctic Alaska	Naidu	64,370
6/27/78	79-5	The Environmental Geology and Geomorphology of the Barrier Island-Lagoon System Along the Beaufort Sea Coastal Plain	Cannon	36,622
6/28/78	79-6	Morbidity and Mortality of Marine Mammals	Fay	50,198
6/30/78	79-7	Hydrocarbons: Natural Distribution and Dynamics on the Alaskan Outer Continental Shelf	Shaw	39,992
6/30/78	79-8	Circulation and Water Masses in the Gulf of Alaska	Royer	105,334
11/8/78	79-8	Modification	Royer	101,948
12/12/78	79-8	Modified and Amended	Royer	101,948

Submission Date	Proposal No.	Title	Principal Investigator	Cost Proposal
7/5/78	79-9	Distribution, Abundance, Community Structure and Trophic Relationships of the Nearshore Benthos of the Kodiak Shelf, Cook Inlet and NEGOA	Feder	$162,158
9/30/78	79-9	Modification	Feder	162,158
12/1/78	79-9	Second Modification	Feder	162,158
7/11/78	79-10	Administration and Technical Support for the OCSEAP Data Processing Center and the NODC/OCSEAP Representative	Hickok	83,000
1/10/79		Supplemental Request		10,300
10/18/78	79-11	Work Statement Modification	Fay	11,302
10/20/78	79-12	Nutrient Dynamics and Trophic System in Nearshore Beaufort Sea Waters	Schell	30,537

TABLE III

University of Alaska OCS Project

Management Staff

Position	Percent Effort	Name
Coordinator[1]	Approximately 12%	Donald H. Rosenberg
Data Manager[1]	50%	Raymond S. Hadley
Keypunch operator[1]	100%	Monique Schamell
Typist[2]	Approximately 30%	Helen Greschke

Note: [1] Funded directly from project

[2] Funded from overhead

TABLE IV

Submitted Data Batches

File I.D.	File Type	Cruise/Field Operation	Submission Date
Task Order 1			
UH1H	029	Helicopter 03/31/77-04/04/77	12/19/78
SU77B	024	Surveyor 06/28/77-04/07/77	12/04/78
NUT004	029	Discoverer 05/22/77-06/09/77	05/09/78
NUT005	029	Surveyor 03/18/77-04/04/77	05/09/78
NUT006	029	Surveyor 04/17/77-05/01/77	05/09/78
Task Order 3			
780414	073	Field Season Data 1977	05/09/78
Task Order 5			
SHAW01	044	Aluminiak 08/14/77-08/25/77	12/04/78
SHAW02	044	Discoverer 03/25/76-03/27/76 05/22/77-06/06/77	03/29/79
SHAW03	044	06/77-11/77	03/29/79
SHAW04	044	Surveyor and Acona 05/05/77-11/15/77	03/29/79
Task Order 8			
BFAY04	027	End of 77 Season 07/10/77-12/01/77 All of 78 Season 03/11/78-08/29/78	01/17/79
BFAY03	027	Alaska Penn 6/77 St. Lawrence Island 7/77	06/28/78
Task Order 15			
FN002	032	Miller Freeman 3/76-6/76	06/28/78

File I.D.	File Type	Cruise/Field Operation	Submission Date
FN003	032	Miller Freeman 10/17/76-10/29/76	06/28/78
MW002	032	Moana Wave 03/30/76-04/15/76	06/28/78
Task Order 19			
CM0023 & CM0025	015	Montaque Strait 11/12/77-05/01/78	11/07/78
CM0016 CM0017 CM0018 CM0019	015	Hinchenbrook Entrance 11/14/77-05/01/78	11/07/78
CM011 CM012 CM013 CM014 CM015	015	GAS9B 04/20/76-07/24/76	08/02/78
IMS814	022	Resubmission Surveyor 814 10/30/75-11/13/75	07/24/78
MU6IMS	22	Moana Wave 09/13/76-09/19/76	07/24/78
IMS260	22	Acona 04/21/78-05/08/78	07/24/78
CM001 CM002 CM003 CM004 CM005	015	Resubmission 07/22/76-11/02/76	06/28/78
256IMS	022	Acona 02/16/78-02/25/78	05/09/78
CM0025 CM0026	015	Gulf of Alaska 07/02/74-10/08/74	01/25/79
253IMS	022	Acona 11/01/77-11/17/77	11/08/78

File I.D.	File Type	Cruise/Field Operation	Submission Date
Task Order 20			
DIS761	032	Discoverer 03/17/76-03/26/76	09/28/78
Task Order 27			
MICLSN	034	Season 76 07/10/76-09/04/76	01/17/79
PETE M		Season 77 07/27/77-09/10/77	
LARK03	035	Additional 76 Season 06/04/76-09/15/76	01/17/79
LARK02	035	1976 Field Season 06/04/76-09/15/76	06/28/78
LARK	035	1977 Field Season 05/19/77-09/20/77	05/09/78
ESPNBG	034	Cape Espenberg 06/22/76-09/12/76 05/22/77-09/24/77	03/29/79
Task Order 33			
780518	073	Simpson Lagoon 8/77	06/28/78

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1979

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 2

PRINCIPAL INVESTIGATOR: Mr. Donald H. Rosenberg

No environmental data are to be taken by this task order as indicated in the Data Management Plan. A schedule of submission is therefore not applicable[1]

NOTE: [1] Data Management Plan has been approved and made contractual.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1979

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 5 R.U. NUMBER: 275/276/294

PRINCIPAL INVESTIGATOR: Dr. D. G. Shaw

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]		
	From	To	Batch 1	2	3
Silas Bent Leg I #811	8/31/75	9/14/75	None	submitted	submitted
Discoverer Leg III #810	9/12/75	10/3/75	None	None	submitted
Discoverer Leg IV #812	10/3/75	10/16/75	Submitted	None	submitted
Surveyor #814	10/28/75	11/17/75	None	submitted	None
North Pacific	4/25/75	8/7/75	submitted	None	None
Contract 03-5-022-34	Last	Year	submitted	submitted	submitted
Moana Wave MW 001	2/21/76	3/5/76	None	submitted	submitted
Miller Freeman	5/17/76	6/4/76	submitted	None	None
Glacier	8/18/76	9/3/76	None	submitted	None
Discoverer	9/10/76	9/24/76	None	submitted	submitted
Moana Wave	10/7/76	10/16/76	None	submitted	submitted
Acona	6/25/76	7/2/76	submitted	submitted	submitted
Discoverer	5/20/77	6/11/77	submitted	None	None
Acona	6/22/77	6/27/77	submitted		
Surveyor	11/03/77	11/17/77	submitted	None	None
Discoverer	5/4/78	5/17/78	3/31/79	None	None

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]		
	From	To	Batch 1	2	3
Discoverer	8/29	9/2/78	3/31/79	3/31/79	None
Alumiak	8/3	9/2/78	3/31/79	None	None

Note: [1] Data Management plan has been approved and made contractual.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1979

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 8 R.U. NUMBER: 194

PRINCIPAL INVESTIGATOR: Dr. F. H. Fay

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 1			
Data as yet to be submitted:						
Tugidak Is.	July 1977		Submitted			
Surveyor Leg 4	4/16 - 4/20/78		"			
Surveyor Leg 7	6/19 - 7/9/78		"			
Tugidak Is.	May - June 1978		"			
Alaska Peninsula	May 1978		"			
Priblofs	7/1 - 7/31/78		"			
Alaska Peninsula	7/7 - 7/19/78		"			
Lower Cook Inlet	8/14 - 8/18/78		"			

Note: [1] Data Management Plan has been approved by M. Pelto; we await approval by the Contract Officer. Specimen data will be reported separately in tabular format.

Information on histology of animals reported by others has been submitted, and those collected by P.I. are currently being assembled by the P.I.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1979

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 12 R.U. NUMBER: 162/163/288/293/312

PRINCIPAL INVESTIGATOR: Dr. D. C. Burrell

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches are identified as foot notes. Only data due are listed.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates		
	From	To	Batch 1	2	3
Acona	6/21	6/26/77		6/30/79*	
Discoverer	5/25	6/5/77		6/30/79*	6/30/79*
Acona 246	7/25	7/30/77	6/30/79*		
Volna	7/77	8/77	6/30/79*		
Surveyor	3/31	4/27/77			6/30/79*
Surveyor	11/3	11/17/77		6/30/79	6/30/79*
Acona 254	11/20	12/4/77		6/30/79*	
Acona 260	4/22	4/26/78		6/30/79*	
Discoverer	5/4	5/17/78	6/30/79*	6/30/79*	
Acona 262	7/10	7/11/78	6/30/79	6/30/79	
Discoverer	8/29	9/2/78	6/30/79	6/30/79	
Acona 270	10/78	10/78		6/30/79*	

Data Batch 1	Trace elements in water column
Data Batch 2	Trace elements in sediment or sediment extracts
Data Batch 3	Trace elements in biota

* Data appear in quarterly and annual reports, but still to be submitted on tape.

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University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1979

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 15/20[2] R.U. NUMBER: 5/303/281

PRINCIPAL INVESTIGATOR: Dr. H. M. Feder

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 1	2	3	4[3]
			032	032	032	023
LCI						
Surveyor	77/11/4 -	77/11/16	None	3/1/79*	None	6/30/79
Surveyor	78/3/27 -	78/4/2	None	3/1/79*	None	6/30/79
Surveyor	78/8/13 -	78/8/22	None	3/1/79*	None	6/30/79
Miller Freeman	78/5/8 -	78/5/16	None	3/1/79*	None	6/30/79
Miller Freeman	78/6/6 -	78/6/16	None	3/1/79*	None	6/30/79
Miller Freeman	78/7/12 -	78/7/22	None	3/1/79*	None	6/30/79
Kodiak						
Yankee Clipper/Commando	78/4/8 -	78/4/21	None	3/1/79*	None	4/30/79
Yankee Clipper/Commando	78/5/1 -	78/5/22	None	3/1/79*	None	4/30/79
Yankee Clipper/Commando	78/6/8 -	78/6/21	None	3/1/79*	None	4/30/79
Yankee Clipper/Commando	78/7/9 -	78/7/21	None	3/1/79*	None	4/30/79
Yankee Clipper/Commando	78/8/8 -	78/8/23	None	3/1/79*	None	4/30/79
Yankee Clipper/Commando	78/11/4 -	78/11/17	None	3/1/79*	None	4/30/79
Miller Freeman	78/6/19 -	78/7/9	None	3/1/79*	3/1/79	4/30/79
Miller Freeman	78/3/21 -	78/3/24	None	3/1/79*	None	4/30/79
Scuba	78/5/4 -	78/10/30	None	None	None	4/30/79

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 1	2	3	4[3]
			032	032	032	023
Scuba	78/5/4	78/5/19	None	None	None	4/30/79
Negoa						
Searcher	78/7/27	78/8/8	None	6/30/79	None	Limited data 8/1/79
Commando	79/3/5	79/3/19	None	12/31/79	None	12/31/79

Note: (1) Data Management Plan and Data Format have been approved and are considered contractual.

(2) Only data which have not been submitted are listed.

(3) Data batch 4 is feeding data, the proper format for submission is 023.

Data batch 1 = Grab data, File Type 032

2 = Trawl data, File Type 032

3 = Pipe dredge data, File Type 032

* Data awaits return of keypuncher from annual leave.

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University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1979

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 19 R.U. NUMBER: 289

PRINCIPAL INVESTIGATOR: Dr. T. C. Royer

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]		
	From	To	Batch 1	2	3
Acona #193	7/1/74	7/9/74	submitted	None	None
Acona #200	10/8/74	10/14/74	submitted	None	None
Acona #202	11/18/74	11/20/74	submitted	None	None
Acona #205	2/12/75	2/14/75	submitted	None	None
Acona #207	3/21/75	3/27/75	submitted	None	None
Acona #212	6/3/75	6/13/75	submitted		
Oceangrapher #805	2/1/75	2/13/75	submitted	None	None
Silas Bent #811	8/31/75	9/28/75	Submitted		
Discoverer #812	10/3/75	10/16/75	(a)		
Surveyor #814	10/28/75	11/17/75	submitted		
Discoverer #816	11/23/75	12/2/75	(b)	None	None
Station 60	7/2/74	10/08/74	None	Submitted	None
Station 64	4/28/75	5/20/75	None	(c)	None
Station 9A	-	-	-	Lost	
Station 9B	4/20	7/24/76	-	submitted	submitted
Moana Wave MW 001	2/21/76	3/5/76	submitted		
Moana Wave MW 003/004	4/20/76	5/21/76	submitted		
Moana Wave MW005	7/22/76	8/1/76	submitted		
Moana Wave 006	9/13	9/19/76	submitted		

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]		
	From	To	Batch 1	2	3
Surveyor SU 003	9/7/76	9/17/76	submitted		
Surveyor	9/20/76	10/2/76	submitted		
Miller Freeman	11/1/76	11/19/76	submitted		
Moana Wave	10/7/76	11/16/76	submitted		
Miller Freeman	3/9/77	4/2/77	submitted		
Station 9C	7/22/76	11/2/76	submitted		
Acona 248	8/11/77	8/14/77	submitted		
Discoverer	11/8/77	11/16/77	submitted		
Acona 253	11/10/77	11/17/77	submitted		
Hinchinbrook	11/10/77	9/19/78	None	Submitted	Submitted
Montegue	11/10/77	9/19/78	None	Submitted	Submitted
Station 9D	11/3/76	3/29/77	None	Submitted	Submitted
Acona 256	2/16/78	2/25/78	submitted		
Acona 260	4/22/78	5/8/78	submitted		
Acona 264	7/31	8/12/78	1/15/79		
Acona 266	9/17	9/30/78	1/15/79		
Hinchinbrook	9/19/78	2/15/79	None	6/30/79	lost
Monteque	9/19/78	2/13/79	None	6/30/79	6/30/79
Acona 271	2/12/79	2/17/79	6/30/79		
Surveyor	2/8/79	2/21/79	6/30/79		
Monteque	2/13/79	Current			

Note: [1] Data Management Plan and Data Formats have been approved and are considered contractual.

(a) Parent tapes were coded in PODAS format, tapes were submitted to F. Cava as requested.

(b) Data useless due to malfunction of shipboard data logger.

(c) In edit process. Development of computer editing program has held up data.

Data Batch 1 = STD/CTD
2 = Current meter
3 = Pressure guage

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1979

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 23 R.U. NUMBER: 351

PRINCIPAL INVESTIGATOR: Ms. E. R. Dieter

No environmental data are to be taken by this task order as indicated in the Data Management Plan. A schedule of submission is therefore not applicable[1].

NOTE: [1] Data Management Plan has been approved and made contractual.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1979

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 24 R.U. NUMBER:

PRINCIPAL INVESTIGATOR: Mr. David M. Hickok

No environmental data are to be taken by this task order as indicated in the Data Management Plan. A schedule of submission is therefore not applicable[1].

NOTE: [1] Data Management Plan has been approved and made contractual.

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University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1979

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 32 R.U. NUMBER: 537

PRINCIPAL INVESTIGATOR: Dr. D. M. Schell

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]		
	From	To	Batch 1		
Dease Sampling Trip 1	3/31/77		6/30/78*		
Elson Lagoon Sampling Trip 1	5/23/77		6/30/78*		
Simpson Lagoon Sampling Trip	4/78 -	8/78	3/31/79*		
Simpson Lagoon Stefausson Sound	11/78		9/30/79		
Smith Bay Dease Inlet, Elson Lagoon	11/78		9/30/79		

* In Keypunching, to be submitted in the next quarter.

OCS COORDINATION OFFICE

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ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1979

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 33 R.U. NUMBER: 529

PRINCIPAL INVESTIGATOR: Dr. H. S. Naidu

Submission dates are estimated only and will be updated, if necessary, each quarter. Data batches refer to data as identified in the data management plan.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 1	2	3	4
Archived Samples			None	7/30/79	submitted	10/30/78*
Simpson Lagoon	8/77		submitted	6/30/79	Submitted	10/30/78*
Barrier Islands	8/77		None	6/30/79	None	None
Glacier	8/77	9/6/77	10/30/78*	None	submitted	10/30/78*
Summer '78 Field Season			None	None	6/30/79	None

* Data awaits coding and keypunching, will be submitted next quarter.

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[1] Data Management Plan has been submitted to the Arctic Project Office. We await approval.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1979

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 34 R.U. NUMBER: 530

PRINCIPAL INVESTIGATOR: Dr. P. Jan Cannon

No environmental data are to be taken by this task order as indicated in the Data Management Plan. A schedule of submission is therefore not applicable[1].

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[1] Data Management Plan has been submitted to the Arctic Project Office. We await approval.

ANNUAL REPORT

Contract #03-5-022-56
Research Unit #351
Task Order 23
Reporting Period 4/1/78 - 3/31/79
Number of Pages - 3

R/V ACONA AND MARINE LOGISTICS SUPPORT

Ms. E. R. Dieter
Institute of Marine Science
University of Alaska
Fairbanks, Alaska 99701

March 31, 1979

I. Summary of Objectives

This project provides logistics and vessel time support for portions of the NOAA program. Provided is technician support for all of the seagoing projects funded through the University of Alaska contract. Required ship time for the R/V Acona is also funded and monitored through this project.

II. Introduction

Not applicable.

III. Current State of Knowledge

Not applicable.

IV. Study Area

Not applicable.

V. Sources, Methods, and Rationale of Data Collection

Not applicable.

VI. Results

A. A limited amount of marine technician support is funded under this project to support University of Alaska's OCS cruises, and support non-University OCS investigators in the use of the R/V Acona. The technician is shared between the Seward Station and IMS, Fairbanks. At the Seward Station he is responsible for maintenance, storage and transfer of equipment used on OCS cruises as well as direct technical support at sea, primarily aboard the R/V Acona, while at IMS, Fairbanks, he provides internal data processing support to OCS projects and participates in numerous cruises as a general technician for OCS both on the Acona and NOS vessels.

B. Logistics Travel

Research and vessel support travel has been provided in this project for the transportation of support personnel handling logistics.

C. R/V Acona

During the reporting period the R/V Acona has sailed in support of NOAA/OCS cruises as follows:

4/22 - 4/25/78	Gulf of Alaska	Royer/Burrell
4/27 - 5/8/78	Gulf of Alaska	Royer/Burrell
7/31 - 8/12/78	Gulf of Alaska	Royer
9/17 - 9/30/78	Gulf of Alaska	Royer
2/12 - 2/17/79	Gulf of Alaska	Royer

VII. Discussion

Not applicable.

VIII. Conclusions

Not applicable

IX. Needs for Further Study

Not applicable.

X. Summary of Fourth Quarter Operations

A. Ship of Laboratory Activities

The R/V Acona sailed between 2/12 - 2/17/79, during the last quarter in support of OCS.

B. Results

None

C. Problems

None

ANNUAL REPORT

1 April 1978 - 31 March 1979

RU 362

OCSEAP DATA BASE MANAGEMENT SUPPORT

John J. Audet

NODC OCSEAP Data Coordinator

31 March 1978

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DATA PROCESSING

The majority of digital data sets received this past year have been biological which is similar to last year's trend. The number of biological data sets received increased from 274 last year to 414 with the total for all data received increasing from 396 to 522 (Table 1.).

Table 1.

Data, Data Reports and ROSCOPs Received
for April 1978 through March 1979

	Apr-Jun 78	Jul-Sep 78	Oct-Dec 78	Jan-Mar 79*	Total	Total Last Year
A. Digital Data						
Biological	218	28	108	60	414	274
Physical	52	35	9	1	97	78
Chemical	3	1	0	2	6	21
Geological	0	1	0	0	1	2
Non-OCSEAP Format+	1	2	1	0	4	11
TOTALS	274	67	118	63	522	396
B. Seismic and Epicenter Data	2	2	0	0	4	8
C. Data Reports	30	18	15	5	68	136
D. ROSCOPs	46	60	99	33	238	184

*Through March 15.
+Non-OCSEAP refers to digital data sets received in non-OCSEAP formats and includes surface pressure, microbiological and certain fish specimen data.

Developments in data checking over the past year have resulted in more intensive and comprehensive reviews of the data including specific data ranges, acceptable format and taxonomic codes and reported precisions, all of which result in a much greater number of errors and problems to be resolved before final processing is completed. This checking effort is now being supplemented by RUs 370/497 and RU 527 for pre-checking selected biological file types.

Improvements in data checking have provided investigators and Project Office personnel with substantial information for evaluating the contractual digitized versions of their data results. In most cases, the Data Center must rely on the responsiveness and interest of the investigators to assure an accurate final processed version of their data for inclusion in the OCSEAP data base. This interest is increasing as more detailed digital data reviews are developed.

Check runs have been distributed over the past year to 46 different investigators for 25 different file types. A total of 1016 data sets have been checked this past year including many that had been checked in prior years before the more comprehensive checking programs were developed.

NODC has kept pace with data submissions by completing processing of 518 data sets since last March (Table 2.), an increase of nearly 100 data sets over last year's effort. The totals for this year include the processing of data for master tapes and therefore include some data that were considered final processed earlier but had not been subjected to the more intensive checking.

Table 2.

Comparison of Digital Data Final Processed during the Past Three Years

	Total	Apr-Jun	Jul-Sep	Oct-Dec	Jan-Mar*
1978-79	518	168	50	64	236
1977-78	434	215	41	81	97
1976-77	91	10	24	20	37

*Through March 15 of each year.

The status of all data received to date is summarized for each major discipline in Table 3. Over 65 percent of all data are final processed with only 9 percent currently undergoing processing. The status by individual file types is listed in Appendix A.

Table 3.

Status of Data Sets by Discipline through March 15, 1979

	Received	Final Processed	In Hold	In Processing
Biological	1157	736	331	90
Physical	305	243	41	21
Chemical	38	1	20	17
Geological	7	3	3	1
TOTALS	1507	983 (65%)	395 (26%)	129 (9%)

The number of data sets 'in hold' is beginning to be reduced as a result of Project Office follow-up memos concerning required actions by investigators on data initially discussed in memos accompanying their check run results. The number is further expected to be reduced as taxonomic code problems are resolved for many of the biological data sets through the help of Mike Crane's Anchorage facility working with NODC personnel.

As the final step in final processing, originator tapes are returned to investigators; a total of 102 magnetic tapes were returned this year to 16 different investigators or their data processors.

The number of master or archive tapes now totals 12 files containing OCSEAP data compared to 3 last year. Supplementing prior master files for 015 (Current Meters), 029 (Primary Productivity), and 043 (Hydrocarbons), are the following:

017 - Pressure Gauges
021 - Trace Metals
022 - STD/CTD (data are assembled on several tapes--data checking completed on an individual basis)
024 - Zooplankton (converted to file type 124)
028 - Phytoplankton
032 - Benthic Organisms (additional check by Crane underway)
056 - Lagrangian Currents
063 - Marine Invertebrate Pathology
101 - Wind Data

All biological file types have had taxonomic codes converted to the NODC taxonomic codes during this process. A total of 1400 data sets are contained on 18 NODC master files; approximately 50% consist of OCSEAP data sets.

A summary of the data distribution by lease area for data received to date is included in Appendix B. The revised Part II of the Data Catalog, which should be published within the next two months, will provide more detail concerning data for each lease area.

In other data processing actions the following items are noted:

- A coding form was developed for investigators to submit hydrocarbon data (File Type 044).
- NODC personnel participated with Program and Project Office personnel and investigators in the development of inputs for new marine bird formats - Marine Bird Specimen (031) and Marine Bird Colony (135).
- A memo was distributed on September 14, 1978 to Program and Project personnel detailing the steps necessary for pre-processing the designated file types to be completed by Crane and Petersen

prior to NODC final processing. These steps are now being carried out (with minor modifications) for File Types 023, 025, 031 and 032 (Crane) and 033, 034, 038 and 135 (Petersen).

- Efforts are underway to develop several plot products and possibly format output listings to supplement the data checking results and provide investigators with additional information for a review of their digital data submissions. Annotated station location plots are planned for the first plot product to accompany the check results.

FORMAT DEVELOPMENT

Format updates and modifications, identified as 'FACT' sheets, were distributed in the past year to OCSEAP data management personnel and PIs as follows:

Distribution Date	Formats Modified	Number of Codes Modified
3/16/78	025, 030, 033	11
6/ 1/78	024, 032, 038	4
9/12/78	023, 024, 029, 038	9
11/ 8/78	013, 023, 024, 025, 044, 063	8
3/13/79	013, 021, 023, 028, 037, 044, 057, 063, 124	11

Distribution of complete formats and codes (DDF versions) were forwarded to all FY78/79 investigators on May 8 for Juneau Project Office PIs and on November 22 for Arctic Project Office PIs. This amounted to a total of 220 copies of formats including OCSEAP management copies.

The final draft version of File Type 135 was received from the Program Office in May 1978 and the automated version distributed with other OCSEAP formats to data management personnel (but not PIs) on January 10, 1979. The final DDF version of the new Marine Bird Specimen (File Type 031) was distributed to OCSEAP personnel and PIs on November 20, 1978 following the final review of the June 28 version by Program and Project Office personnel and marine bird investigators.

All OCSEAP formats and codes were entered on an automated system (WYLBUR) for more efficient management and retrieval. Distribution of Part III of the Data Catalog, which included OCSEAP formats and codes, a parameter index and an inventory of codes for each format, was completed in January 1979. Distribution was limited to OCSEAP management personnel to allow for a final review which was requested to be completed within a month of distribution. An updated version of all OCSEAP formats and codes (and all other project formats) has been completed within the past month. As few modifications have been received from OCSEAP, the formats are now considered available for distribution to investigators; this action will be completed within the next month.

Modifications to seven biological formats to accommodate the NODC 12-digit taxonomic codes and distribution of both the DDF and the automated versions with these changes was completed.

A revision of the zooplankton format (024) was completed and all data received to date converted to the new format (File Type 124).

A list of all formats used by OCSEAP investigators and their current date are listed in Appendix C.

DATA REQUESTS

A total of 106 requests for data, data products and OCSEAP data reports have been received by NODC and NGSDC this past year. Only requests that have been coordinated through the NODC OCSEAP Data Coordinator are included in this total. Routine requests for data formats, data tracking system products and copies of the Data Catalog and NODC Taxonomic Codes also are excluded from this total and are discussed elsewhere in this report.

As expected, the majority of requests for OCSEAP data continue to be from OCSEAP offices and PIs. The number of requests in these categories has nearly doubled from last year as shown in Table 4. Examples of the more relevant requests received during the year are listed in Table 5.

Table 4.

Summary of Data Requests (April 78-March 79)

Requestor	Data Type	Apr-Jun 78	Jul-Sep 78	Oct-Dec 78	Jan-Mar 78	Total	Total Last Year
BLM	OCSEAP	0	0	0	0	0	5
	Archives	0	0	0	0	0	0
OCSEAP Offices	OCSEAP	16	6	6	7	35	16
	Archives	1	1	1	2	5	1
OCSEAP PIs	OCSEAP	5	6	11	5	27	16
	Archives	2	1	3	5	11	5
Non-OCSEAP Requestors	OCSEAP	3	4	5	1	13	11
	Archives	NA	NA	NA	NA	NA	NA
Special MGMT Requests	NA	5	2	5	3	15	--
TOTALS		32	20	31	23	106	54

Table 5.

Examples of Data Requests Completed in the Last Year

Date Completed	Requestor	Description
4/78	Arneson, ADF&G (RU 003)	Plots of selected bird species distribution on UTM map projection in Lower Cook.
4/78	Cava, JPO	List of all OCSEAP data reports received to date by NODC.
4/78	Robertson, Corps of Engineers	Inventory of OCSEAP offshore data for NEGOA, Lower Cook and Kodiak areas.
5/78	Nat'l Park Service, Fairbanks	Inventory of offshore environmental data for Glacier Bay area.
6/78	SAI, Boulder (RU 468)	Data synthesis product applications - • Location of walrus hauling-out areas • Seasonal presence of Mallard and Pintail ducks and shearwaters • Seasonal distribution of selected ground fish and benthic species with catches exceeding 100 and 1000 lbs/hour, respectively. • Dynamic height contour plots • Primary productivity contour plots.
6/78	Harrison, U. Alaska (RU 468)	Annotated bottom temperature plots for Chukchi Sea.
6/78	Vigdorchick, INSTAAR (RU 516)	Magnetic tape of grain size data for Bering Sea surveys.
8/78	Pease, PMEL (RU 541)	Magnetic tape copies of selected IMS CTD surveys for NEGOA.
8/78	Lowry, ADF&G	Formatted listing of RU 5/502 benthic data for Bering/Chukchi Seas for selected species.
8/78	Thibodeaux, L.S.U.	STD/CTD data listing for Beaufort Sea stations.
8/78	NMFS, Kodiak	Current meter data for summer months in St. George area of Bering Sea.
9/78	Pelto, JPO	Listing and magnetic tape of all Nansen/STD data for area east of NEGOA.

Date Completed	Requestor	Description
10/78	Carey, Oregon St. (RU 006)	Tape copies of Beaufort Sea OCSEAP data for CTDs, zooplankton, phytoplankton, primary productivity, ice drift and benthic data for all lease areas.
11/78	Hall, USFWS (RU 481)	Formatted listing of OCSEAP mammal sighting data for the Gulf of Alaska.
11/78	SAI, Boulder (RU 468)	OCSEAP lease area maps and earthquake seismic charts.
12/78	Lowry, ADF&G	Bottom temperatures within 3 days/5 miles of selected trawl locations in the Bering and Chukchi Seas (200 sta.).
12/78	Ingraham, NMFS	Tape copy of selected OCSEAP STD/CTD data (29 cruises).
12/78	Tobias, ADF&G	Temperature and salinity data for Hotham Inlet, Alaska.
12/78	Ludwig, PMEL	Formatted listing of selected OCSEAP CTD data sets.
12/78	Wakefield, House Approp. Sub-Comm.	OCSEAP catalogs and data management information.
12/78	Wormuth, Texas A&M	Listing of selected OCSEAP zooplankton collected by RU 425.
12/78	Crane, Anchorage (RU 497)	Tape copy of RU 417 intertidal data to review for taxonomic code problems.
1/79	SAI, Boulder (RU 468)	Walrus behavior summary plots for Bering and Chukchi Seas.
1/79	Petersen, U. of RI (RU 527)	Copy of land mass file on magnetic tape with coastline and map plotting subroutines.
2/79	Royer, IMS (RU 289)	Tape copy and listing of USCG station data for Gulf of Alaska - continuing request.
2/79	Farentinos, Program Office	Walrus behavior plots incorporating data from both mammal sighting formats.
2/79	Wesnousky, Lamont-Doherty	Hypocenter data listings for selected lease areas.
3/79	SAI, Boulder (RU 468)	Dynamic height contour plots and temperature/salinity/density profiles for Hinchinbrook Entrance

Although no BLM requests for OCSEAP data have been directed to the Data Centers the past year, Mike Crane has been working with BLM-Anchorage personnel throughout the year in developing prey-predator matrices for selected OCSEAP data and answering other questions concerning OCSEAP data and inventories.

The category 'special management requests' has been added to the summary table to differentiate these requests from routine management activities and data product requests. These requests, which include specific ROSCOP or DDF inventories, special summaries of data sets, DTS information, or other management services, were included in past years under OCSEAP Office data requests.

In other request activities, both NODC and NGSDC have completed OCSEAP data request forms which are now distributed with copies of catalogs and completed data product requests.

DATA PRODUCT DEVELOPMENT

The major new product development efforts for the past year concerned products to support the OCSEAP annual technical summary report and data synthesis activities for Science Applications, Inc. Existing NODC programs were adapted to OCSEAP data for such products as seasonal location and abundance of specific marine mammal and bird species, seasonal distributions of fish and benthos, graphic summaries of mammals by behavior groups, ice and water movement plots, hydrocarbon and primary productivity contour charts and bottom temperature summaries. Standard products such as dynamic height anomaly contours, current vectors, rotary plots, and temperature/salinity profiles also were provided.

As biological data began to be received in the new NODC taxonomic codes, existing programs required modification to retrieve data in either Alaskan or NODC codes and to convert the codes to the same species names for requested summaries or plot products.

The improved land mass file received through NGSDC was adapted to NODC's computer system and is now being used in all products for OCSEAP management and investigator requests.

Work is currently underway to adopt portions of the SAI biostatistics computer package to OCSEAP file types. Initial efforts using file type 032 (benthic organisms) will include graphic presentations such as dendrograms, kite diagrams and other statistical plots.

Forms for requesting OCSEAP data and for evaluating OCSEAP products received from the Data Center have been developed and distributed to OCSEAP data management personnel and now accompany all completed data requests.

DATA INVENTORIES AND CATALOGS

Distribution of 300 copies of Part I (revised) and Part II of the OCSEAP Data Catalog was completed during August and September 1978. Distribution included OCSEAP, NOAA and BLM personnel, OCSEAP investigators, User panel members and all individuals or institutions requesting copies. Information was included for each digital data set received through May 1978 by NODC, NGSDC and NIH. With Program Office assistance, broad environmental regions were established to incorporate nearly all OCSEAP-related observations in one of the nine lease areas.

A computerized mailing list was developed by the Technical Records Branch at NODC to accommodate future OCSEAP mailings. Updates and deletions will be completed as this information is received from the Program and Project Offices through data tracking updates or other information sources.

As all copies of Part II have been distributed, it has been decided to update and print approximately 400 copies of a second revised Part II rather than reprint the June 1978 version. A new version of Part I which involves relatively expensive computer plotting and additional editing and labor costs will be published and distributed later in 1979 at which time a third version of Part II also will be completed. The revision of Part I may include seasonal plots.

Distribution and other activities concerning Part II of the Catalog - Data Formats, has been discussed previously under Format Development.

Initial efforts are underway to identify specific graphic products that can be readily provided or derived from current OCSEAP file types (Part IV, of the Catalog), providing data have been submitted in the proper format and supported by adequate documentation. A draft version of this part of the Catalog is planned for June.

An inventory has been completed for all parameters submitted to date for some of the master file types. This information, when completed for all master tapes, together with similar planned data submission inventories for FY79/80 data, will be used to support Project Office evaluations of PI contract compliance and format usage of 'core' parameters for future format modifications.

Twenty copies of the OCSEAP Data Tracking System, sorted by either RU, Discipline or Project Office, and a similar number of File Type Summaries have been distributed each quarter to OCSEAP and BLM personnel. Updates and changes to the tracking system over the past year amounted to over 1500 new data records and nearly 10,000 individual parameter modifications.

TAXONOMIC CODE DEVELOPMENTS

A revised, updated version of the NODC taxonomic code was distributed to OCSEAP management and investigators in June 1978; approximately 75 copies were sent to OCSEAP personnel.

Three major problems concerning taxonomic codes occurred during the past year. The use of codes for species groups, previously indicated as acceptable codes by the Program, were determined at the Asilomar data management meeting to be not relevant for the OCSEAP data base. The codes were to be specified as internal codes, not to be maintained by the Data Center and not to be used in the future by investigators. Information concerning species groups could however, continue to be included in text records but would not be considered as retrievable data. A memo to this effect was distributed by the NODC OCSEAP Data Coordinator to OCSEAP management on September 29, 1978 requesting that any further action be taken by the Program and Project Offices.

The second problem concerned the submission by some investigators of taxonomic codes developed prior to the official distribution of the Alaskan code file in early 1976. Although many of these 'pre-Alaska' codes have been verified as identical to Alaskan codes, some codes may identify different species entirely. Corrections must be completed on a data set by data set basis; Mike Crane's Anchorage facility will be assisting in this effort by checking certain file types and interfacing with investigators known to be using this earlier unofficial list of codes.

Finally, it became necessary to modify all biological data formats to accommodate the NODC 12-byte taxonomic code. These changes have been completed and distributed to all OCSEAP personnel via 'FACT' sheets and the automated versions of each format.

Mike Crane's office is maintaining an up-to-date file of both Alaskan and NODC codes as supplied by NODC to assist in checking and preliminary processing of selected OCSEAP data files and to provide species information such as summaries and prey-predator lists to investigators and BLM personnel.

Summary of Fourth Quarter (January - March 1979)

Data Base Management Activities
(through March 20, 1979)

DIGITAL DATA

A total of 71 data sets were received this quarter (43 in January, 19 in February and 9 in March), 235 data sets were final processed and check run results were sent to investigators for 231 data sets.

DATA REPORTS

Only five data reports were entered as received in the tracking system this quarter, all in January. These reports concerned fish, sea ice, geology and geophysics. A total of 331 reports have been entered in the tracking system to date.

ROSCOPs

Forty-three ROSCOPs were received this quarter (13 in January, 27 in February and 3 in March) for a total of 669 ROSCOPs to date. ROSCOPs were received this quarter from USGS, NMFS, ADF&G, University of Alaska, University of California and Dames and Moore.

DATA REQUESTS

Data requests received and/or completed this quarter included the following:

- Summary plots of walrus behavior groups for SAI and the Program Office.
- Temperature, salinity and density plots, listings and tape copies for Tom Royer (IMS), Nelle Terpening (ADF&G), Lloyd Lowry (ADF&G), and Ed Sobey (SAI).
- Tape copies of selected OCSEAP biological data sets for Mike Crane.
- Tape copy of the new land mass file and associated plot subroutines for Hal Petersen (URI).
- Formatted output listings of mammal sightings for Don Calkins (ADF&G).
- USCG and other archival ocean station data for Mauri Pelto and Tom Royer.

- Magnetic tape copy of hypocenter data for Steve Wesnousky (Lamont-Doherty).
- Contour plots of dynamic height anomalies for Ed Sobey.

FORMAT DEVELOPMENT

A final draft version of Part II, the automated version of OCSEAP-related formats, codes and cross-reference information was distributed to OCSEAP management personnel for their review prior to distribution to individual investigators.

A 'FACT' sheet of all DDF versions of format modifications, code updates and revised layouts was distributed to OCSEAP management and investigators on March 20, 1979.

DATA PROCESSING

Master tape documentation was completed and sent to investigators and OCSEAP management for File Types 021 - Trace Metals and 032 - Benthic Organisms.

Thirty-three originator tapes were returned to investigators this quarter.

A summary of all data sets 'in hold' and an indication of where the action is required was distributed to OCSEAP management on February 2, 1979.

A further improvement of the check programs was completed by Chris Noe which summarizes the precisions reported for each parameter and checks for specific allowable codes rather than a range of codes.

DATA PRODUCTS

The recent mammal behavior group plot represented the first OCSEAP product to incorporate data from more than one PI and from more than one file type (026/027). Similar products are anticipated for products other than walrus groups.

Some progress has been made to develop dendrogram plots for sample benthic organism data (File Type 032), adapting an SAI (La Jolla) biostatistics package received several months ago.

A product evaluation form has been completed and is now enclosed (with a return envelope) with each completed request along with a blank OCSEAP data request form.

TAXONOMIC CODES

A copy of the 'pre-Alaska' codes was received from Dames and Moore personnel through Mike Crane's assistance to help NODC evaluate the differences between these 'unofficial' codes and the Alaskan codes distributed by NODC in early 1976.

Additions and changes to the taxonomic codes were forwarded to Mike Crane to maintain an updated file at the Anchorage facility.

DATA CATALOGS AND INVENTORIES

Work is progressing to complete a revision of Part II which is anticipated for distribution by May 1979. New files from NGSDC--Grain Size (073) and Epicenter Data (401)--and from NIH--Microbiology (402)--are being incorporated in this catalog.

ADMINISTRATIVE

The FY80 planning meeting was held in Boulder and inputs to the information management cluster were discussed.

A list of RU 362 achievements and a tentative FY80 budget were provided to Toni Johnson during her visit to NODC in March.

Hal Petersen and two of his staff visited NODC in March and discussed NODC's data processing and data tracking activities.

ADMINISTRATIVE

The anticipated EDIS replacement of the IBM computer system with a new UNIVAC system has been delayed, the result of which has been little impact on OCSEAP data management functions with the exception of loss of personnel at times for mini-computer and UNIVAC training purposes.

The new mini-computer at NODC is operational and has been utilized a number of times for resolving tape reading problems and for obtaining rapid answers to other data processing problems.

A list of the major meetings and briefings for RU362 is included in this report as Appendix D. An updated milestone chart is attached as Appendix E.

PROBLEMS

To effectively manage the data format and code modifications, control of requested input parameters and related format structure must become more of a Data Center responsibility. There has been a continuing increase and need for standard output products such as formatted listings, graphics and statistical packages. In addition, the multi-project use of many of the current formats further demonstrates the need for central control by Data Center personnel. The scientific expertise of various Project personnel and investigators obviously will be needed to help support this activity at the Data Center level but this approach appears to be necessary to fulfill the variety of Project and Program product needs.

The timely response to many OCSEAP data requests is still often the result of time spent by Data Center personnel to identify data sets that contain the necessary parameters to provide the requested product. Generation of new software for some of the more specialized products and computer system 'down-time' also may delay completion of requests. These factors often prevent a realistic estimate of a completion date. It is anticipated that a package of 'shelf item' products to be described in Part IV of the Catalog will help reduce this problem by indicating those products that can be prepared within a reasonable length of time (where data are adequate and of sufficient quality to provide the required products).

Procedures recently outlined by the Juneau Project Office for requesting data and data products of the Data Centers (the Cava memo of February 8, 1979) may cause serious delays in responding to urgent requests and in some cases may imply that a product is forthcoming before the Data Center is even involved where further investigation shows that such a product is not feasible or will require time or manpower that are not justified by the request or cannot meet the requestor's deadline.

In terms of taxonomic codes, all users of the pre-Alaska codes must be identified and editing of their data submissions completed separately to certify that all species are properly coded. This action and some instruction to investigators concerning species group codes must be completed by the Project or Program Offices if the Data Center is to improve the quality of the data base and the retrieval of taxonomic data.

GOALS (Next Quarter)

- Complete and distribute a revised Part II of the Data Catalog.
- Distribute the automated version of formats and codes (as included in Part III of the Catalog) to all current OCSEAP investigators.
- Complete a first draft of Part IV of the Data Catalog which will provide sample graphics and plot products for each file type used by OCSEAP investigators.
- Complete additional parameter inventory summaries based on master tape efforts for those file types used by OCSEAP.
- Distribute quarterly 'FACT' sheets to provide all OCSEAP personnel with up-to-date DDF versions of formats, codes and layouts.
- Supplement and update the Anchorage facility's master or crunch tapes and provide selected plot tapes for reproducing multiple plot products at different scales and on different materials (such as Mylar) as requested by OCSEAP offices and BLM.
- Continue to provide investigators and OCSEAP offices with updates and additions to the NODC taxonomic code file.

APPENDIX A.

OCSEAP File Type Status - March 15, 1979

File Type	Rc'd to Date	Final Processed	Data in Hold	Date In Processing
013	6	1	5	0
015	105	60	31	14
017	19	16	0	3
021	11	0	11[1]	0
022	87	76	10	1
023	183	146	30	7
024	49	33	1	15
025	41	7	34[2]	0
026	34	34	0	0
027	211	141	70[3]	0
028	58	57	0	1
029	162	155	0	7
030	26	14	11	1
032	32	27	3	2
033	203	59	89[4]	55
034	8	6	0	2
035	58	3	55[5]	0
037	8	8	0	0
040	33	0	33[6]	0
043	11	1	9[7]	1
044	1	0	0	1
056	87	85	0	2
057	44	44	0	0
061	15	0	0	15[8]
063	1	1	0	0
072	1	0	1	0
073	6	3	2	1
101	7	6	0	1
TOTALS	1507	983 (65%)	395 (26%)	129 (8%)

NOTES

[1] Waiting for final review of check run results by PI.

[2] Waiting for additions from PI and updates from Crane.

[3] Waiting for response to check run results from PIs.

[4] Received annotated corrections from PI for 77 data sets 2/78-edit underway.

[5] Waiting for decision for conversion to File Type 135.

[6] Waiting for final updates from PI/Crane.

[7] Waiting for final review of check run results by PI.

[8] Waiting for DIP modification by NODC (for variable parameters).

APPENDIX B.

Data Distribution by Lease Area (through March 15, 1979)

File Type	Total Data Sets	Lease Area Codes 1	2	3	4	5	6	7	8	9
013	6	0	0	1	5	0	4	0	0	0
015	105	26	0	15	14	1	10	0	4	3
017	19	8	0	0	7	0	4	0	0	1
021	11	5	3	5	2	0	3	0	2	0
022	87	40	19	34	26	5	22	8	14	4
023	183	27	11	50	49	2	29	28	37	1
024	49	13	24	13	10	2	9	2	1	1
025	41	10	4	10	2	6	1	11	0	3
036	34	0	0	0	11	4	15	18	4	6
027	211	56	16	62	29	1	21	11	36	6
028	58	10	5	10	10	3	5	0	8	0
029	162	19	10	18	13	4	7	0	33	0
030	26	3	10	5	2	8	1	1	4	3
032	32	9	3	10	2	9	4	1	0	1
033	203	59	31	78	35	77	22	15	27	25
034	8	0	0	0	2	2	0	2	0	2
035	58	3	0	0	46	0	0	6	0	3
037	8	1	0	7	1	0	1	0	3	0
040	33	6	20	6	1	0	12	0	8	0
043	11	5	5	5	2	0	2	1	2	1
044	1	0	0	0	0	1	0	0	0	0
056	87	8	0	3	7	38	3	0	0	8
057	44	0	0	0	6	0	33	10	16	2
061	15	7	4	6	7	1	5	1	2	1
063	1	0	0	0	0	0	0	1	0	1
072	1	1	0	0	0	0	0	0	0	0
073	7	3	0	0	2	1	2	1	0	1
101	7	3	0	0	0	4	0	0	0	0

Lease Area Codes

1 - NEGOA
2 - Lower Cook
3 - Kodiak
4 - St. George
5 - Beaufort
6 - Bristol
7 - Norton
8 - Aleutians
9 - Chukchi

NOTE: Many data sets have stations in more than one lease area.

APPENDIX C.

Current Formats for OCSEAP Investigators

File Type	Name	Most Recent Update (automated version)
013	Fish Pathology	3/ 5/79
015	Current Meters	1/10/79+
017	Pressure Gauges	7/ 1/76
021	Trace Metals	3/ 5/79
022	STD/CTD	9/16/76
023	Fish Resource Assessment I	3/ 5/79
024	Zooplankton I	10/ 6/78
025	Marine Mammal Specimen	9/11/78
026	Marine Mammal Sighting II	1/19/77
027	Marine Mammal Sighting I	5/24/77
028	Phytoplankton	12/ 8/78
029	Primary Productivity	7/ 7/78
030	Intertidal Data	3/13/78
031	Marine Bird Specimen	6/15/78
032	Benthic Organisms	2/11/77
033	Marine Bird Census (Ship/Aircraft)	1/18/78
034	Marine Bird Census (Land)	6/29/77
035	Marine Bird Colony I	(not included)
036	Marine Birds - Ship Followers	2/20/76
037	Marine Birds - Feeding Flock	1/11/77
038	Migratory Bird Sea Watch	7/ 7/78
040	Marine Bird Habitat	1/21/77
043	Hydrocarbon I	11/ 9/77
044	Hydrocarbon II	3/ 5/79
056	Lagrangian Currents	1/ 5/77
057	Herring Spawning	12/ 8/78
061	Trace Elements	9/ 9/77
063	Marine Invertebrate Pathology	3/ 5/79
072	Beach Profiles	3/10/77
073	Grain Size Analysis	2/ 7/77
101	Wind Data	8/23/76
123	Fish Resource Assessment II	12/12/78*
124	Zooplankton II	11/ 6/78
135	Marine Bird Colony II	2/ 1/78*

+Incorrectly dated 2/20/76 on distribution copy.
*Temporarily removed from file for revisions.

APPENDIX D.

Major OCSEAP Meetings Involving RU 362
(April 1, 1978 to March 31, 1979)

4/78	BLM-Anchorage personnel Arbegast and Morris and John Murphy of the Program Office met at NODC to discuss data management, processing and the data retrieval capabilities for RU 362.
4/78	Joe Dygas (BLM-Anchorage) briefed by NGSDC personnel on NOS files and other data holdings.
6/78	Toni Johnson briefed by NODC personnel on data processing, data requests, taxonomic codes and other OCSEAP activities.
6/78	Audet attended meeting with Micah Krichevsky, Ron Atlas and Lois Killewich at NIH to discuss microbiology data base and its management.
7/78	OCSEAP Data Management Meeting at Asilomar - EDIS attendees included Picciolo, Noe, Loughridge, Audet, Crane, Falk and Ross.
8/78	Boulder mini-data management meeting - Elaine Collins, Mike Crane and Jim Audet met with Program and Project Office personnel to discuss details for data processing priorities, revision of work statements and other Data Center activities - Carol Potter and Peter Sloss attended some of the sessions for NGSDC.
8/78	Mike Crane met with NODC personnel in Washington to resolve problems concerning Arctic PIs, data checking procedures, parameter inventories, and FY79 work statement revisions.
10/78	Kent Hughes and Jim Audet met with Program Office personnel in Boulder to discuss NODC's future role in project data management.
10/78	Fischer and Audet represented EDIS at the Physical Oceanography and Meteorology Workshop at Orcas Island, Washington.
2/79	FY80 Objectives meeting held in Boulder - EDIS representatives Audet, Crane and Sloss attended to discuss RU370/497 and RU 362 objectives. Inputs to a proposed 'Information Management Cluster' also were discussed.
2/79	Hal Petersen (URI) met with NODC personnel to discuss key entry systems, mini-computer and remote terminal applications for OCSEAP use.
3/79	Toni Johnson visited NODC to discuss various aspects of data management and objectives and achievements of RU362.

3/79 Hal Petersen visited NODC with other URI staff to discuss aspects of data processing and data products.

---- A number of meetings were held throughout the year with NODC individuals and groups during Wayne Fischer's periodic visits to NODC.

MILESTONE CHART

APPENDIX E.

0 - Planned Completion Date

X - Actual Completion Date

RU # 362 PI: John J. Audet

Major Milestones: Reporting, data management and other significant contractual requirements; periods of field work; workshops; etc.

	1978			1979											
MAJOR MILESTONES	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Data Catalog (I) - Plots by lease area													0		
Data Catalog (II) - Data listed by PI								0					0		
Data Catalog (III) - Format Descriptions				X					0					0	
Data Catalog (IV) - Typical Data Products									0(Draft)						0
Data Tracking System/File Type Summary			X			X			0			0			0
Telephone Lists/'Wallchart' Product			X						0						0
Format 'FACT' Sheets		X				X		0			0			0	
Master Tape Preparation	(As scheduled)														
Parameter Inventory - Master Tapes					X(Selected files)				0						0(Updated)
Attendance at Workshops and data management meetings		X			X			(as scheduled)							

ANNUAL REPORT

RU Contract No.
497 - - - - - - -
370 03-5-022-56

Reporting Period 1 April 78
31 March 79

10 Pages

OCSEAP Alaskan Data Processing Facility

Michael L. Crane

David M. Hickok
David M. Hickok

31 March 1979

I. Introduction

The Outer Continental Shelf Environmental Assessment Program (OCSEAP) has a special responsibility to project and future users to make available the fundamental environmental data collected during the lifetime of the program. To meet this need, the OCSEA Program established a digital data base at the NOAA Environmental Data and Information Service (EDIS). The arrangement with EDIS encompasses data base service, data management support and technical data processing.

In order to implement the data management responsibility, OCSEAP has contracted the University of Alaska, AEIDC and the EDIS to jointly provide professional data management assistance. In partial fulfillment of these commitments, the AEIDC and the EDIS Alaskan Liaison Officer have established a facility providing project management support, digital data base support, and originator support. This report summarizes the major accomplishments of the facility from 1 April 1978 to 31 March 1979.

II. Significant Accomplishments:

The most important activities have been programming development, data control, creation and maintenance of automated files, and data management support. Significant accomplishments during the reporting period are listed below. Details are contained in the monthly reports and special reports on data management.

Significant Accomplishments

1. Created the initial keyentry of the OCSEAP digital codes.
2. Checked, corrected and returned File Type 025 data to originators and data base.
3. Developed taxonomic checking programs for all biological data.
4. Developed special printing programs to display the data records and taxonomic names for biological data.
5. Developed and maintained the "Parameter Checklist."
6. Developed and operated the Predator/Prey Display program for marine mammal specimen data.
7. Developed special parameter inventory programs for management review of digital data.
8. Developed taxonomic code conversion programs to convert the Alaskan Code to the NODC Code.
9. Assisted in the development of telecommunication access between Anchorage and Juneau.

10. Tested batch communications between Anchorage and NODC in Washington, D.C.

11. Edited, controlled and forwarded File Type 033 and 038 data to Dr. H. Petersen, RU 527 from the USF&WS, RU337 and from LGL, RU467.

12. Forwarded new data entries for the Data Tracking System to each project data manager.

13. Drafted data management reports on data problems and position papers on data management.

Data Processing Summary

The productivity in data control has increased because computer programs and effective management procedures were developed and implemented. The analysis of the processing activity will be partitioned into "sponsored" processing and "required" processing. The data types identified in the proposal (work statement) are "sponsored" data types. Additional data types processed that are not specifically identified in the proposal are characterized as "required."

The checking activity is identified as a subset of the "sponsored" processing. The "required" processing activity is cross-referenced to OCSEAP requests where appropriate. The term "required" was chosen because these activities although not proposed are necessary to meet the data management objectives of the OCSEA Program. Tables 1, 2 and 3 indicate the status of data processing.

TABLE 1

Data Processing Activity, Total

Activity	Data Sets Sponsored	Data Sets Required	Total
Received	128	174	302
Controlled (Processed)	64	128	192
Forwarded	93	139	232

TABLE 2

Sponsored Processing

RU	Name	File Type	# Received	# Controlled	# Forwarded
005	Feder	032	7	-	-
006	Carey	032	9	-	-
229	Pitcher	025	21	17	12
230	Burns	025	42	23	23
230	Burns	026	1	1	1
243	Calkins	025	17	13	6
281	Feder	032	10	-	-
417	Lees	023	12	-	-
467	Truett (LGL)	023	1	1	-
485	Hartt	023	4	-	-
502	Feder	032	1	-	-
517	Feder	032	4	-	-

TABLE 3

Required Processing

RU	Name	File Type	# Received	# Controlled	# Forwarded
003	Arneson	040	33	-	-
196	Divoky	033	81	81	81
341	Gill	038	13	13	13
359	Horner	024	1	1	1
359	Horner	028	1	1	1
359	Horner	029	1	1	1
337	Lensink	033	27	27	27
417	Lees	030	12	12	12
467	Truett(LGL)	038	1	1	1
467	Truett(LGL)	033	6	6	6

In summary, the professional and efficient operation of the Anchorage data processing activities have accomplished much more than was proposed which has resulted in direct savings to the OCSEA Program. Often, these significant contributions are not recognized by the OCSEAP. With adequate resources and assistance from management, each category of data processing can be expanded to match the demand for services.

Table 4 indicates the data sets "in hold" by RU, name, file type, and number of data sets. These data sets can be processed only with assistance by OCSEAP and the investigators, and by providing the resources to execute the processing functions.

TABLE 4

Data Sets in Hold

RU	NAME	FILE TYPE	# OF DATA SETS
003	Arneson	040	33
005	Feder	032	7
006	Carey	032	9
196	Divoky	033	1
229	Pitcher	025	21
230	Burns	025	19
243	Calkins	025	17
281	Feder	032	10
337	Lensink	033	1
417	Lees	030	13
417	Lees	023	10
467	Truett	023	1
485	Hartt	023	4
502	Feder	032	1
517	Feder	032	5

OCSEAP REQUEST SUMMARY:

Although precise records of requests were only started in October 1978, Table 5 is indicative of the requests for the entire reporting period. Table 5 was compiled from similar ones in monthly reports.

TABLE 5

OCSEAP REQUESTS

October

Requester	Status	Description
T. Johnson	Completed	Review and draft letter assessing data submission for RU467
R. Swope	Completed	Send a list of marine mammal specimen numbers to Dr. F. Fay RU194
F. Cava	In Hold	Contact Mr. Lees RU417/27 about corrections to check runs
R. Combellick	Completed	Send two blank tapes to C. Ruby RU192
P. Becker	Completed	Send a list of taxonomic codes to Mr. Lees RU417
J. Roberts (RU289)	In Hold	Pressure data at Middleton Island from Nov. 1976 to March 1977
K. Frost (RU230)	Completed	Send a Predator/Prey list, copy of Program listings, and tax code conversions of Arctic mammals.

January

Cava	Completed	Update "Parameter Checklist" and retrieve a new printed version.
Johnson	Completed	Check diskette of 033 data from G. Divoky (Leo Karl), RU 196.
Johnson	Completed	Check, convert tax codes, print data listing with tax code name for R. Horner RU 359. The data types are 024 and 028 to be used as documentation for voucher specimen archive.
Gill/Cava	Completed	Convert tax codes to NODC code, create a 9-track tape, mail to Dr. Petersen RU 527.
Arneson/Swope	In Progress	Control the data entries, tax codes, and record types entries.

TABLE 5 (Continued)

Requester	Status	Description
Audet	Completed	Print a new version of "Parameter Checklist"
Walter(PMEL)	Completed	Mailed a copy of meteorological logs from offshore platforms operated by the oil industry in Lower Cook Inlet and Harrison Bay, Ak.
Butcher	On loan	Gave our copy of the NODC taxonomic codes to Ms. Butcher for her BLM assignment.
February		
Cava	Completed	Print prey records for FT023, RU485 for M. Butcher.
Cava	Completed	Run parameter checklist (sample).
Johnson	Completed	Run predator/prey program for FT025, RU 229 and RU 243.
Frost	Completed	Return cards of 1978 specimens.
Audet	Completed	Send ROSCOP pads to USF&WS.
Divoky	Completed	Send diskettes containing taxonomic codes for birds.
Hadley	Completed	Send tape and listing of taxonomic code file.
Falk	Completed	Send sample output from FT032 check programs.
Walter	Completed	Send copy of oil rig met data from Lower Cook Inlet.

MILESTONE CHART/PROGRAMMING STATUS

The production of new computer programs is generally ahead of schedule. In addition, new programs not identified in the proposal have also been created or planned. All of these programs meet the data management objectives of the OCSEA Program. Some of the new programs were designed to assist OCSEAP in managing digital data. Table 6 notes the status of each check program.

TABLE 6

DATA CHECK PROGRAMS

			File Type			
			025	023	032	031
+	START	Begin program	X	X	X	X
+	IDXXX	NODC checks	X	X	X	X
	TXxxx	Tax code check	X	X	X	X
	TXExxx	Print error tax code	X	X	X	X
	PCxxx	Predator/Prey	X	?	NA	X
	TFILExxx	List with tax names	X	X	X	X
	PFILE	List of file	X[1]	X	X	X
+	SQxxx	Sequence check	X	X	?	X
	BLxxx	Embedded blank	X[2]	X	X	X
	RAxxx	Range check	X[2]	X	X	X
	RLxxx	Relational check	X[2]	—	—	—
	SDxxx	Select on code	X	X	X	X
	CDxxx	Code check	X	X	X	X
	EXxxx	Parameter inventory	X	X	X	X
	TXxxx	Correct tax codes	X	X	X	X
	SLxxx	Select on range	X	—	—	—
	RXxxx	Format convert	NA	—	NA	NA
	MXMNxxx	Maximum/Minimum	—	—	X	X
	SUMxxx	Summary of Contract	—	—	—	—

+ data set dependent

[1] PFILE1 for 025

[2] In RL025A

The new programs not identified in the proposal are divided into two categories. The first category is Utility Programs and the second is Management Support Programs. The two categories are summarized in tables 7 and 8.

TABLE 7

UTILITY PROGRAMS

A) Printing Programs

1. PFILE - Prints the address (diskette) and data record
2. RTPRINT - Prints one type of record with diskette address
3. SEARCH (Modified) - Prints the records which pass a search criteria
4. PLWDE - Prints data records on special computer paper and print size
5. PLONG - Prints data records on 8-1/2 X 11 paper
6. LIST-CAT - Prints the contents of the label tracks of IBM diskettes.

* HDPRINT - Formatted outputs of headings program

B) Editing Programs

1. EDIT - Invokes the Wang Editor functions
2. REFORMAT - Places the taxonomic abbreviation next to tax code

* REFORM - Changes format of specific records

C) Taxonomic Code Programs

1. TC-ANY - Checks tax code for one record type only
2. TC-TWO - Checks tax code for two record types only
3. TX-ANY - Converts tax code from Alaskan code to NODC code
4. TXE-NEW - Prints records with tax code errors
5. TFILE - Prints a data file and the taxonomic name for biological records

* TX-SPL - Illegal code conversion program - uses special IBM table to test and convert illegal tax codes.

D) Tax Code Master File Programs

1. TC-TAX - Converts IBM diskettes to Wang diskettes of the tax code file
2. TAXDISK - Modifies and prints the data file "TAX#S" used to identify each tax code diskette
3. PAKTAX - Prints the Wang diskettes of the master tax code file

* TAXTEST - Checks for duplicate tax codes in master file on IBM diskettes

E) Structural and Code Check Programs

1. FINDFILE - Searches for different file idents on IBM diskette
2. RTCHECK (RTSPLCK) - Both programs range check the record type field
3. CDFILE - Captures the digital codes for each file type

TABLE 8

MANAGEMENT SUPPORT PROGRAMS

1. START - parameter checklist begin program
2. PCHECK - Prints the Parameter Checklist at 6 lines/inch
3. PLONG - Prints the formatted output of the Parameter Checklist at 8 lines/inch
4. APCHECK - Builds the array for the key file table.
5. RUCHECK - Prints and verifies the RU table entries.

The programs which are marked by an asterisk (*) will be developed to augment the productivity in data control.

PROBLEMS:

1. A recent meeting in Juneau, Alaska with Jawed Hameedi, Laurie Jarvella and Suzy Swanner underscored the need to review the current data formats.

2. Unauthorized taxonomic codes have been used by OCSEAP investigators. OCSEAP management must identify who has received and is using the unauthorized codes and have NODC assign proper codes as required. A new conversion table may be required along with a new taxonomic code conversion computer program. This additional work will delay processing of data sets in "hold." Potentially, the scale of this problem exceeds all other data management problems for FY 79/80.

Plans:

The Anchorage Data Processing Facility has a reduced staff (one programmer). The creation of a new position will allow replacement of a data control clerk. The plans for the remainder of FY79 are completion of check programs, and maintain internal master files. No data control activities will be initiated until new employees are trained in the operation of check programs and are trained in data control procedures.

TRACKING SYSTEM INPUT REPORT

RU	NAME	FILE TYPE	FILE IDENT	DATE RECEIVED YY MM DD	DATE CONTROLLED YY MM DD	PLATFORM	SURVEY START YY MM DD	SURVEY END YY MM DD	UNIQUE
003	ARNESON	040	FG7601	79/01/03		A/C	75/10/13	75/10/27	2563 & 2729
003	ARNESON	040	FG7702	79/02/27		A/C	76/10/13	76/10/16	1572 & 2738
003	ARNESON	040	FG7605	79/01/03		A/C	76/05/03	76/05/07	1576 & 2730
003	ARNESON	040	FG7607	79/01/03		A/C	76/06/21	76/06/25	1578 & 2731
003	ARNESON	040	FG7604	79/01/03		A/C	76/05/01	76/05/09	1575 & 2607
003	ARNESON	040	FG7701	79/02/27		A/C	76/09/20	76/10/02	2569 & 2737
003	ARNESON	040	FG7612	79/01/03		A/C	76/04/01	76/04/01	2565 & 2398
003	ARNESON	040	FG7613	79/01/03		A/C	76/10/05	76/10/05	2566 & 2734
003	ARNESON	040	FG7614	79/01/03		A/C	76/06/24	76/06/24	2567 & 2735
003	ARNESON	040	FG7615	79/01/03		A/C	76/09/30	76/09/30	2568 & 2736
003	ARNESON	040	FG7606	79/01/03		A/C	76/05/17	76/05/20	1577 & 2610
003	ARNESON	040	FG7603	79/01/03		A/C	76/02/22	76/03/24	1574 & 2608
003	ARNESON	040	FG7608	79/01/03		A/C	76/07/24	76/07/25	1579 & 2609
003	ARNESON	040	FG7610	79/01/03		A/C	76/06/16	76/06/17	1581 & 2612
003	ARNESON	040	FG7609	79/01/03		A/C	76/07/30	76/08/01	1580 & 2732
003	ARNESON	040	FG7611	79/01/03		A/C	76/03/05	76/03/06	2564 & 2733
003	ARNESON	040	FG7703	79/02/27		A/C	77/02/28	77/03/04	3820 & 4955
003	ARNESON	040	FG7704	79/02/27		A/C	77/03/04	77/03/04	4525 & 4956
003	ARNESON	040	FG7705	79/02/27		A/C	77/03/16	77/03/16	3821 & 4957
003	ARNESON	040	FG7706	79/02/27		A/C	77/05/06	77/05/07	3881 & 4958
003	ARNESON	040	FG7708	79/02/27		A/C	77/05/13	77/05/13	3883 & 4960
003	ARNESON	040	FG7707	79/02/27		A/C	77/05/10	77/05/12	3882 & 4959
003	ARNESON	040	FG7709	79/02/27		AVON RAFT	77/06/18	77/07/14	4293 & 4961
003	ARNESON	040	FG7803	79/01/03		AIRCRAFT	78/03/03	78/03/03	5291 & 5636
003	ARNESON	040	FG7602	79/01/03		AIRCRAFT	76/02/09	76/02/18	1573 & 2611
003	ARNESON	040	FG7801	79/02/27		AIRCRAFT	77/11/22	77/11/22	4738 & 5207
003	ARNESON	040	FG7802	79/02/27		AIRCRAFT	78/01/12	78/01/12	4965 & 5208
003	ARNESON	040	FG7804	78/10/24	78/12/18	AIRCRAFT	78/04/28	78/04/28	5970
003	ARNESON	040	FG7805	78/10/24	78/12/18	AIRCRAFT	78/05/01	78/05/01	5971
003	ARNESON	040	FG7806	78/10/24	78/12/18	AIRCRAFT	78/05/04	78/05/04	5972
003	ARNESON	040	FG7807	78/10/24	78/12/18	AIRCRAFT	78/05/11	78/05/11	5973
003	ARNESON	040	FG7808	78/10/24	78/12/18	AVONE	78/05/16	78/06/07	6732
003	ARNESON	040	FG7809	78/10/24	78/12/18	FIXED	78/06/16	78/08/13	6731
005	FEDER	032	TR3268	78/10/24		MILLER FREEMAN	76/03/23	76/06/04	6005
005	FEDER	032	TR0504	78/12/13		DISCOVERER	75/05/15	75/06/19	4497
005	FEDER	032	TR0599	78/12/13		M FREEMAN	75/08/16	75/10/20	4498
005	FEDER	032	TR2111	78/12/13		M FREEMAN	76/03/23	76/06/00	4662

TRACKING SYSTEM INPUT REPORT

RU	NAME	FILE TYPE	FILE IDENT	DATE RECEIVED YY MM DD	DATE CONTROLLED YY MM DD	PLATFORM	SURVEY START YY MM DD	SURVEY END YY MM DD	UNIQUE
005	FEDER	032	TR3269	78/12/13		M FREEMAN	76/03/00	76/06/00	6006
005	FEDER	032	TR3270	78/12/13		M FREEMAN	76/10/17	76/10/29	6007
005	FEDER	032	TR3271	78/12/13		MOANA WAVE	76/03/30	76/04/15	6008 & 5835
006	CAREY	032	BR5PI5	78/11/10		RV ALUMIAK	76/08/19	76/09/03	IN HOLD REPLA
006	CAREY	032	TR0888	78/11/30		HELICOPTER	76/05/17	76/06/02	0677
006	CAREY	032	TR0889	78/11/30		GLACIER	76/08/30	76/09/03	1027
006	CAREY	032	TR1311	78/11/30		HELICOPTER	76/11/02	76/11/10	2907
006	CAREY	032	TR1312	78/11/30		ALUMIAK	76/08/19	76/09/07	1028
006	CAREY	032	TR0522	78/12/13		HELICOPTER	75/10/26	75/10/30	0786
006	CAREY	032	TR0523	78/12/13		HELICOPTER	76/03/12	76/03/19	0787
006	CAREY	032	TR0524	78/12/13		GLACIER	71/08/19	71/09/14	3043
006	CAREY	032	TR0525	78/12/13		GLACIER	72/08/04	72/08/22	3044
196	DIVOKY	033	1SR678	79/01/27	79/01/29	SURVEYOR	78/00/00	78/00/00	
229	PITCHER	025	W75PWS	77/09/07	78/10/09	SHIP	75/10/01	75/12/31	2174
229	PITCHER	025	376KEN	77/09/07	78/10/09	BIG VALLEY	76/03/17	76/03/22	1468 & 2176
229	PITCHER	025	276KOD	77/09/07	78/10/09	RESOLUTION	76/02/03	76/02/13	1467 & 2175
229	PITCHER	025	676YAK	77/09/07	78/10/09	SURVEYOR	76/05/25	76/06/03	1470 & 3209
229	PITCHER	025	576MID	77/09/07	78/10/09	SURVEYOR	76/05/25	76/06/03	3034 & 3208
229	PITCHER	025	576KAY	77/09/07	78/10/09	SURVEYOR	76/05/25	76/06/03	3035 & 3207
229	PITCHER	025	576ICY	77/09/07	78/10/09	SURVEYOR	76/05/25	76/06/03	3036 & 3212
229	PITCHER	025	776TUG	77/09/07	78/10/09	ON FOOT	76/07/08	76/07/12	1939 & 2178
229	PITCHER	025	476KOD	77/09/07	78/10/09	RESOLUTION	76/04/12	76/04/24	3033 & 3215
229	PITCHER	025	076KOD	77/09/07	78/10/09	SURVEYOR	76/10/05	76/10/14	2588 & 3213
229	PITCHER	025	W76KOD	77/09/07	78/10/09	RESOLUTION	76/11/04	76/11/10	2589 & 3214
229	PITCHER	025	476KEN	77/09/07	78/10/09	RESOLUTION	76/04/12	76/04/12	1469 & 2177
229	PITCHER	025	W77ICY	78/03/23	79/01/25	SURVEYOR	77/10/25	77/11/02	4757
229	PITCHER	025	377KEN	78/03/23	79/01/25	PANDALUS	77/03/20	77/03/26	3816
229	PITCHER	025	477KOD	78/03/23	79/01/25	RESOLUTION	77/04/27	77/05/04	3891
229	PITCHER	025	577KOD	78/03/23	79/01/25	RESOLUTION	77/05/20	77/05/27	4013
229	PITCHER	025	778KOD	78/10/03		PANDALUS	78/07/29	78/07/31	6155
229	PITCHER	025	878KOD	78/10/03		SU IIB	78/08/27	78/09/09	6807
229	PITCHER	025	678GOA	78/10/03		SU IIIA	78/06/21	78/07/02	6805
229	PITCHER	025	478LCI	78/10/03		SURV	78/04/07	78/04/11	5389
229	PITCHER	025	478TUG	78/10/03		ON FOOT	78/05/07	78/09/05	6806
230	BURNS	025	N77PRU	78/11/06		AIRCRAFT	77/11/06	77/11/10	5713 P
230	BURNS	025	877GLA	78/11/06		SHIP	77/07/31	77/09/06	5712 P
230	BURNS	025	477SUV	78/11/06		ON FOOT	77/03/15	77/05/03	3893 R&P&S

TRACKING SYSTEM INPUT REPORT

RU	NAME	FILE	FILE	DATE	DATE	PLATFORM	SURVEY	SURVEY	UNIQUE	
		TYPE	IDENT	RECEIVED	CONTROLLED		START	END		
				YY MM DD	YY MM DD		YY MM DD	YY MM DD		
230	BURNS	025	677SAV	78/11/06		ON FOOT	77/06/19	77/06/24	4079	S&P
230	BURNS	025	677GAM	78/11/06		ON FOOT	77/05/20	77/06/15	4080	S&P
230	BURNS	025	577DIS	78/04/28		ON FOOT	77/05/20	77/06/11	4075	S&P&R
230	BURNS	025	677SHI	78/11/06		ON FOOT	77/06/13	77/07/11	4082	S
230	BURNS	025	677WAL	78/11/06		ON FOOT	77/05/28	77/07/02	4340	S
230	BURNS	025	177NOM	78/04/28		ON FOOT	77/01/25	77/01/29	5700	P
230	BURNS	025	377NOM	78/11/06		AIRCRAFT	77/03/07	77/03/24	3892	P
230	BURNS	025	677NOM	78/11/06		ON FOOT	77/05/29	77/06/27	4077	P
230	BURNS	025	677DIO	78/11/06		ON FOOT	77/05/20	77/06/24	4081	P
230	BURNS	025	577PTH	78/04/28		ON FOOT	77/04/15	77/06/01	4076	P
230	BURNS	025	277BAR	78/04/28		ON FOOT	77/02/11	77/02/16	5707	P
230	BURNS	025	477BAR	78/11/06		ON FOOT	77/04/04	77/04/14	3894	P
230	BURNS	025	N77BAR	78/11/06		HELICOPTER	77/11/14	77/11/17	5710	
230	BURNS	025	577WAI	78/11/06						
230	BURNS	025	577BAR	78/11/06						
230	BURNS	025	N77SHI	78/11/06		ON FOOT	77/10/14	77/11/05	5704	
243	CALKINS	025	W75LIO	77/09/07	78/10/09	MONTAGUE	75/10/28	75/11/04	1582	& 3216
243	CALKINS	025	276LIO	77/09/07	78/10/09	RESOLUTION	76/02/03	76/02/13	1583	& 3217
243	CALKINS	025	376LIO	77/09/07	78/10/09	BIG VALLEY	76/03/17	76/03/22	1584	& 3218
243	CALKINS	025	476LIO	77/09/07	78/10/09	RESOLUTION	76/04/12	76/04/24	1585	& 3219
243	CALKINS	025	576LIO	77/09/07	78/10/09	SURVEYOR IVA	76/05/25	76/06/03	1586	& 3220
243	CALKINS	025	W76LIO	77/09/07	78/10/09	SURVEYOR	76/10/05	76/10/14	2591	& 3221
243	CALKINS	025	277LIO	78/03/23	79/01/25	YANKEE CLIPPER	77/02/10	77/02/18	3817	
243	CALKINS	025	377LIO	78/03/23	79/01/25	PANDALUS	77/03/22	77/03/26	3818	
243	CALKINS	025	477LIO	78/03/23	79/01/25	RESOLUTION	77/04/28	77/05/21	3896	
243	CALKINS	025	577LIO	78/03/23	79/01/25	RESOLUTION	77/05/21	77/05/27	4027	
243	CALKINS	025	W77LIO	78/03/23	79/01/25	SURVEYOR	77/10/25	77/11/02	4758	
243	CALKINS	025	N77LIO	78/03/23	79/01/25	RESOLUTION	77/11/13	77/11/19	4911	
243	CALKINS	025	C77LIO	78/03/23	79/01/25	ON FOOT	77/03/15	77/06/01		
243	CALKINS	025	478LIO	78/10/03		SURVEYOR	78/04/12	78/04/19	5894	
243	CALKINS	025	678LIO	78/10/03		SU IIIA	78/06/21	78/06/27	6808	
243	CALKINS	025	778LIO	78/10/03		PANDALUS	78/07/27	78/08/01	6156	
243	CALKINS	025	878LIO	78/10/03		SU IIB	78/08/27	78/09/05	6813	
281	FEDER	032	TR0440	78/12/13		DISCOVERER	75/10/08	75/10/16	2220	
281	FEDER	032	TR0461	78/12/13		N. PACIFIC	75/04/25	75/08/07	0875	
281	FEDER	032	TR0465	78/12/13		ACONA193	74/07/01	74/07/11	0878	
281	FEDER	032	TR0466	78/12/13		ACONA10/74	74/10/08	74/10/14	3178	

TRACKING SYSTEM INPUT REPORT

RU	NAME	FILE TYPE	FILE IDENT	DATE RECEIVED YY MM DD	DATE CONTROLLED YY MM DD	PLATFORM	SURVEY START YY MM DD	SURVEY END YY MM DD	UNIQUE
281	FEDER	032	TR0467	78/12/13		ACONA 11/74	74/11/18	74/11/21	3179
281	FEDER	032	TR0468	78/12/13		OCEANOG.	75/02/19	75/02/28	3180
281	FEDER	032	TR0469	78/12/13		CROMWELL	75/05/06	75/05/16	3181
281	FEDER	032	TR0505	78/12/13		MOANA WAVE	76/03/30	76/04/15	1527
281	FEDER	032	TR1336	78/12/13		SILAS BENT	75/08/31	75/09/14	1146 & 3971
281	FEDER	032	TR1337	78/12/13		SILAS BENT	75/08/31	75/09/14	3972 & 0271
337	LENSINK	033	FW5038	78/09/08	78/09/15	ALEUTIAN TERN	75/04/16	75/09/07	4094 J&J
417	LEES	030	TR1551	78/12/20		HUMDINGER	75/07/30	75/09/12	2571 & 4248
417	LEES	030	TR1552	78/12/20		HUMDINGER	76/05/03	76/05/08	2572 & 4249
417	LEES	030	TR1553	78/12/20		HUMDINGER	76/06/30	76/07/11	3023 & 4250
417	LEES	030	TR1554	78/12/20		HUMDINGER	76/08/30	76/08/31	3024 & 4251
417	LEES	023	OKENA1	77/05/06		HUMDINGER	75/07/30	75/09/12	4146 & 4252
417	LEES	023	OKENA2	77/05/06		HUMDINGER	76/05/03	76/05/08	4147 & 4253
417	LEES	023	OKENA3	77/05/06		HUMDINGER	76/07/01	76/07/11	3993 & 4254
417	LEES	023	OKENA4	77/05/06		HUMDINGER	76/08/30	76/08/31	4149 & 4255
417	LEES	030	TR2938	78/12/20		HUMDINGER	76/05/12	76/08/24	2976
417	LEES	030	TR2937	78/12/20		HUMDINGER	76/04/20	76/04/29	5128
417	LEES	023	NGULF1	78/11/10	78/11/13		75/07/23	75/07/28	
417	LEES	023	NGULF2	78/11/10	78/11/13		75/09/11	75/09/17	
417	LEES	023	NGULF3	78/11/10	78/11/13		75/11/23	75/11/30	
417	LEES	023	NGULF4	78/11/10	78/11/13		76/03/13	76/06/22	
417	LEES	030	NGULF1	78/11/10			75/07/23	75/07/28	J&J
417	LEES	030	NGULF2	78/11/10			75/09/14	75/09/17	J&J
417	LEES	030	NGULF3	78/11/10			75/11/23	75/11/30	J&J
417	LEES	030	NGULF4	78/11/10			76/30/14	76/03/20	J&J
417	LEES	030	NGULF5	78/11/10			76/06/22	76/06/26	J&J
417	LEES	023	LCOOK2	79/02/14			77/03/04	77/03/13	
417	LEES	023	LCOOK3	79/02/14			77/04/06	77/05/13	
417	LEES	030	LCOOK2	79/02/14			77/03/04	77/03/13	
417	LEES	030	LCOOK3	79/02/14			77/04/06	77/05/13	
467	TRUETT	023	FYKE	78/09/12	78/09/15	ZODIAC	77/06/01	77/09/25	
485	HARTT	023	TR1331	78/09/18		COMMANDO 1	76/05/21	76/06/03	3973 & 0593
485	HARTT	023	TR1332	78/09/18		DUTCH GIRL 2	76/06/16	76/06/30	3974 & 0592
485	HARTT	023	TR1333	78/09/18		COMMANDO 3	76/07/14	76/08/07	3975 & 0595
485	HARTT	023	TR1334	78/09/18		COMMANDO 4	76/08/25	76/09/16	3976 & 0596
502	FEDER	032	TR2836	78/12/13					
517	FEDER	032	TR2107	78/12/13		BIG VALLEY	76/06/17	76/06/23	4658

TRACKING SYSTEM INPUT REPORT

RU	NAME	FILE TYPE	FILE IDENT	DATE RECEIVED YY MM DD	DATE CONTROLLED YY MM DD	PLATFORM	SURVEY START YY MM DD	SURVEY END YY MM DD	UNIQUE
517	FEDER	032	TR2108	78/12/13		BIG VALLEY	76/07/18	76/07/28	4659
517	FEDER	032	TR2109	78/12/13		BIG VALLEY	76/08/19	76/08/29	4660
517	FEDER	032	TR2110	78/12/13		BIG VALLEY	77/03/03	77/03/18	4661

ANNUAL REPORT
April - December 1978
January - March 1979
Research Unit 516
Contract 03-7022-35127

ENVIRONMENTAL DATA MANAGEMENT SYSTEM AND COMPLEX OF COMPUTERIZED SYNTHESIS MAPS FOR BEAUFORT SEA

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Prepared for:
U.S. Department of Commerce
National Oceanic and Atmospheric Administration

I

TASK OBJECTIVES

During April-December 1978, the final report on the submarine permafrost study in Beaufort and Chukchi Seas was completed. Two volumes of the "Data Management System for Submarine Permafrost Predictions in the Beaufort and Chuckchi Seas" (485 pages) and the "State of the Computerized Environmental Maps of the Alaskan Continental Shelf" (32 maps, including the maps showing the areas suitable for submarine permafrost development) were sent to the OCS Project Office and BLM by January 1, 1979. The main objectives were the following:

The first principal objective was to develop a computerized system to aid in the prediction of the distribution and characteristics of offshore permafrost. Development of this system involved (1) the gathering and study of all source data about direct and indirect indicators of permafrost in the given area (depth, temperature and salinity of water, topography, bottom deposits, ice, etc.) and (2) the generation of source and derived maps and construction of a candidate area map for submarine permafrost in the Beaufort and Chukchi seas.

The decisive factor in this work was the close relationship with the NOAA Environmental Data and Information Service, especially the National Geophysical and Solar-Terrestrial Data Center (NGSDC) in Boulder, that also operates World Data Centers-A for Solid Earth Geophysics and for Solar-Terrestrial Physics. We also used data from World Data Center-A, Oceanography, in Washington, D.C., and Glaciology in Boulder (INSTAAR). A description of the system and results is given in the Part I of the Final Report. The base map for computerized mapping was received from "Science Application, Inc." The environmental maps of the Alaskan shelf were included in the "Atlas" as the Attachment to Part I.

The second objective was to undertake a comprehensive review and analysis of past and current Soviet literature on subsea permafrost and related natural processes. The data and concept analysis, on subsea permafrost of the Eurasiatic part of the Arctic in its relationship with the Arctic development in Pleistocene, is given in the Part II of the Report as a monograph with bibliography related to the problem.

The work was done by M. Vigdorchik (Principal Investigator), B. Skholler (Computer Programmer), and by J. Adams (Senior Graphic Artist) during the period of October 1976-September 1978. The cost was $100,000.

SUMMARY OF RESULTS INCLUDED IN THE FINAL REPORT

1. An evaluation of existing environmental data on submarine permafrost of the Alaskan Shelf has been made. The reliability of the data and the gaps have been defined.
2. The paleoenvironmental aspects of the submarine permafrost of the Beaufort and Chukchi seas have been discussed. According to the specifics of the origin and development of the permafrost the Beaufort Sea shelf has been divided into three parts: a) the shelf area suitable for submarine relic permafrost (western part); b) the area with low suitability for relic permafrost (central part); c) the area without relic permafrost (eastern part). The estimations of thickness and specifics of submarine permafrost in each area have also been made.
3. A computer system has been developed for the evaluation of all existing environmental data on recent subsea permafrost development. Thirty computerized maps of different oceanographic, geologic,

glaciologic, and other parameters, have been generated: source data maps, derived maps (three generations), and a composite map specifying the candidate area for submarine permafrost development. To develop the system a composite mapping algorithm for submarine permafrost prediction has been made.

4. The system has been checked in the Beaufort Sea areas with known permafrost. A comparison with Canadian data on submarine permafrost has shown positive results and high correlation.
5. The system can be readily up-dated according to new data and in this way the results can be enhanced.
6. The shelf maps showing suitability for submarine permafrost have been compared with the BLM Lease nomination map. The extension of the suitable areas for permafrost at each nomination site has also been calculated.
7. The same work was done for the Chukchi Sea. It was found that there is a limited distribution of areas suitable for ice-bonded submarine permafrost. The areas were to the northwest from the Barrow Canyon and at some sites along the coastal line.

II

During the report period we have begun to work on the use of the computer techniques for managing large amounts of sea ice data as a sea-ice subblock of the environmental block of the system. Together with Dr. B. Stringer, the structuring and preparation of the data for input into the computer was in progress. Amount of money spent: $30,000.

Annual Report

Contract Number 03-7-022-35139
Research Unit Number: 527
Reporting Period: 1/1/79-3/31/79

OCSEAP Data Processing Services

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1 April 1979

Background

One of the major aspects of the OCSEAP Program is the receipt of quality-controlled data by the Project Offices, and subsequent use of this data in Quarterly, Annual, and Final Reports by investigators, by the Program in Synthesis Reports, and by the Bureau of Land Management in formulating Environmental Impact Statements. As the Program evolved, the need arose for a variety of data processing services which would ensure the efficient execution of such activities. Many of these services were provided within the original framework of the Program, but many required additional, dedicated support. This Research Unit (RU) began such activities in March 1977, with primary emphasis on ensuring that bird census data were received in the desired fashion, and more recently that analysis products be generated as needed. Past Quarterly and Annual Reports by this RU detail the background and evclution of each situation. This report summarizes progress made in several areas during the last quarter in particular, and during the last year in general.

Summary of Results

1. Validation of File Type 033 Data:

A summary of activities with respect to this type of data is shown in the Field Operation Status Report given in Appendix I. The following commentary references that report.

New Tapes:

One tape containing data for one field operation coded in National Oceanic Data Center (NODC) format was received on 6 February 1979. The field operation, 1SR678, brings to four the total number of data sets received from RU 196. The validation products CODEPULL and LOGLIST were mailed to this RU on 12 February 1979. This operation was originally entered via use of a Sol 20 microcomputer, and these validation products served as a check on the entry procedures used by the RU.

Total Receipts:

The one operation referenced above brings to 137 the total number of data sets received for File Type 033 data. They include 81 in the U.S. Fish and Wildlife Service (FWS) version

(80 from RU 337, 1 from RU 083) and 56 in the NODC version (12 from RU 108, 8 from RU 239, 12 from RU 337, 6 from RU 467, 4 from RU 196, and 14 from RU 083). Of the total, 26 were received during the past contract year, all in NODC format.

Current Processing:

CODEPULL and LOGLIST validation products were sent to RU 196 for the one operation received during this quarter, and for the eight other outstanding operations received from RU 083 during the previous quarter. The yearly total consists of such products for 34 operations (26 operations received during the past year plus 8 others from RU 239 received at the end of the previous contract year). These mailings complete such products for all 137 operations received to date.

A total of 10 of the 137 sets of validation products are outstanding. These include 6 from RU 467 and 4 from RU 196. Of the 127 sets returned, 8 have been returned to RU 083 for further error resolution. The remaining 119 have passed the validation tests, but two, from RU 083, while they pass the validation tests, are known to require changes to environmental data. The other 117 have been sent to the contributing RU's and to NODC, 107 during the past year, including the following 33 during this past quarter:

FW5003 FW5006 FW5029 FW5025 FW5031 FW6002

FW6004 FW6005 FW6007 FW6008 FW6010 FW6011

FW6013 FW6014 FW6016 FW6018 FW6019 FW6027

FW6050 FW6051 FW6052 FW6064 FW6077 FW6078

FW6083 FW6092 FW6094 FW6095 UCI501 UCI601

UCI602 UCI703 UCI704

The 117 operations completed and mailed to both the contributing RU and NODC contain 81 which required conversion from FWS to the NODC version of the 033 format. The final 9 of these conversions were carried out during this past quarter (all 81 during the past year):

FW6013 FW6018 FW6027 FW6050 FW6051

FW6064 FW6083 FW6094 FW6095

Thus, the following operations remain outstanding at this time:

RU 083:

UCI701 UCI702 UCI702L UCI801 UIC802

UCI803 UCI804 UCI805 UCI806 UCI808

RU 196:

1SR377 1SR477 1DI577 1SR678

RU 467:

AERSR1 AERSR2 AERSR3 AERSR4 AERSR5 AERSR6

After data are submitted to NODC, that agency also runs validation check programs on the data. While many of the checks are the same as those carried out by this RU (see Appendix II for a current listing of 033 processing), a check for allowable taxonomic codes is presently carried out only by NODC. Exceptions to the allowable codes found by NODC are transmitted to this RU for resolution. Such edit products have been received for all 117 operations sent to date, and resolutions are being found for all exceptions. These are being relayed to NODC for update of the operations, and will also be used to update copies of the data held at RU 527.

2. Validation of File Type 038 Data:

During the past year, work was begun on a validation procedure for File Type 038 data in a manner analogous to that employed for File Type 033 data. As with the 033 data, this data has been recorded in two versions of the format, an FWS and an NODC version. Two tapes of data recorded in FWS version, a total of 13 field operations, have been received from RU 341, and one tape, containing data for one field operation coded in the NODC version was received from RU 467. CODEPULL and LOGLIST validation products were adapted to these versions, and products for the following 14 operations mailed during the past quarter:

To RU 467:

77PGI3

To RU 341:

FW6020 FW6022 FW6023 FW6024 FW6054 FW6056

FW6059 FW6061 FW6063 FW6073 FW6076 FW6091

FW6099

None have yet been returned. After they are returned, editing and conversion (except for 77PGI3, which is already in NODC format) will be carried out.

3. File Type 033 Data Base Formation and Analysis Products:

Beginning during the third quarter of this past year, work was begun on the design and production use of four analysis products from File Type 033 data. Carried out in conjunction with RU 083, this work has lead to the products described in detail in Appendix III.

Generation of the products was preceded by conversion of the data from the NODC format into the data base format of the MARMAP Information System (the MIS is used for the validation aspects of this RU's activities as well). Following such conversion, data required for a given analysis are retrieved for that purpose.

Data for the following 63 field operations have been converted during this year:

RU 083:

UCI501 UCI601 UCI602 UCI701 UCI702 UCI703

UCI704

RU 337:

FW5003 FW5006 FW5009 FW5011 FW5012 FW5013
FW5014 FW5016 FW5018 FW5024 FW5025 FW5027
FW5029 FW5030 FW5031 FW5034 FW6001 FW6002
FW6004 FW6005 FW6007 FW6008 FW6010 FW6011
FW6013 FW6014 FW6016 FW6018 FW6019 FW6025
FW6026 FW6027 FW6028 FW6029 FW6050 FW6051
FW6052 FW6064 FW6077 FW6068 FW6083 FW6092
FW6094 FW6095 FW7026 FW7027 FW7028 FW7031
FW7032 FW7033 FW7034 FW7035 FW7036 FW7042
FW7045 FW7046

Based on data from RU 083 in this data base, a total of 18 File Type 033 Data Summary Tables, 135 Digital Density Plots, 107 Statistical Analysis runs (three analyses per run), 23 Star Diagrams, and several sample Contour Plots have been generated for a variety of bird species, geographical area, and time period groupings. Also, several sample runs have been made for RU 337 data as well.

It should be noted that through generation of these products, the interrelationships and significance of several of the parameters characteristic of this file type were realized. In some instances, certain critical parameters such as distance to shelf break were absent from the data base. However, the data were obtained from charts, etc., and were used to update the data base prior to final production runs of the products. Based on this knowledge, the following parameters should be considered as "required" in future field efforts of this type:

Bottom depth
Distance to shore
Sea surface temperature
Distance to shelf break
Surface salinity
Direction of flight

It is fully expected that, as analysis of the data continues, additional parameters will be added to this list as new interrelationships are found.

4. Interactive Data Entry and Analysis (IDEA) Network:

Also begun during the last half of this year was the establishment of an Interactive Data Entry and Analysis (IDEA) distributed processing network for OCSEAP data. The network is composed of Texas Instruments Model 771 intelligent terminals at investigator sites, plus a Model 774 host system at RU 527. In this network, investigators enter field data at the 771 terminals, using quality control data entry programs prepared for them by RU 527. These programs carry out all validation steps carried out by CODEPULL and LOGLIST, but as the data are entered, not at a later date. After entry, the data are either sent to the host site by telephone as a remote job entry (RJE) submission or by mail (floppy disks), where they are copied to tape for submission to NODC, and also converted into the MIS data base format for use in analysis products. The individual investigator can then retrieve selected portions of the data base for use in analysis at his site, using either the PROCEDURES or BASIC languages available on the 771, using resources available through a local host computer system, or RU 527 can generate such analyses and deliver them to the investigator either via an RJE submission to the investigator's terminal or via the mail, depending upon urgency of the need and associated costs.

Data entry and validation programs are currently planned for File Types 031, 033, 034, and 135 data. To date, 771 terminals have been installed and user training initiated at RU 083 and RU 196/172, and programming for File Type 033 has been delivered to these sites.

Financial Report

The Financial Report given in Figure 1 summarizes expenses during the past quarter in terms of salaries (and indirect costs), computer expenses, supplies, travel, equipment rental, equipment purchase, and other.

Figure 1

OCSEAP Data Processing Services

Financial Report

Period Covered: 1/1/79 - 3/31/79

Salaries	$12,702.21
Indirect Costs (55% of salaries)	6,986.22
Sub-total	$19,688.43
Supplies	64.87
Travel	1,851.45
Equipment rental	1,334.46
Equipment	20,228.00
Computer	5,211.47
Repairs	150.00
Other (Xeroxing, postage, etc.)	423.99
Total	$48,952.67

Activity/ Milestone Chart

The Activity/Milestone Chart given in Figure 2 shows actual and planned completion dates for past, present, and future activities.

Figure 2

Activity/Milestone Chart

RU #: 527 PI: Harcld Petersen Jr. -- University of Rhode Island

	1978										1979											
Major Milestones	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Choice of validation criteria for type 038 data		X																				
Procedures for validation of FWS type 038 data operational											X											
Procedures for validation of 033 data operational	X																					
Procedures for conversion of 033 data operational							X															
Completion date for editing 033 data										X												
Completion date for conversion of 033 data													X									
Feasibility study for distributed data entry and processing completed							X															

(continued)

Activity/Milestone Chart

	1978										1979											
Major Milestones	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Establishment of distributed data entry and processing node at RU 527														O								
Establishment of distributed data entry sites at RU 083 and RU's 196/172													X									
Establishment of distributed data entry sites at RU 337 and RU 237															O							
Preparation of File Type 033 data entry/validation program for IDEA System													X									
Preparation of File Types 031, 034, and 135 data entry/validation programs for IDEA System																	O					
Establishment of format for four Program-authorized 033 data analysis products for RU 083							X															

(continued)

Activity/Milestone Chart

	1978										1979											
Major Milestones	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Delivery of first of four 033 analysis products to RU 083 and JPO									X													
Delivery of evaluation samples of remaining 033 analysis products to RU 083 and JPO											X											
Delivery of production runs of 033 analysis products to RU 083 for use in Annual Report												X										
Quarterly Reports		X			X			X			X			X			O			O		
Annual Report		X												X								
Final Report																					O	

Past Contract
<-- Period --><--------- Present Contract Period -------->

O = Planned Completion Date
X = Actual Completion Date
FWS = Fish and Wildlife Service
NODC = National Oceanic Data Center

Appendix I

Field Operation Status Report

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                         *** FIELD OPERATION STATUS REPORT ***

                                  AS OF 03/31/79

        THE DATA PROJECTS GROUP                  OCSEAP - GULF OF ALASKA PROJECT


COLUMN HEADING DEFINITIONS:

TAPE NUMBER -          IDENTIFYING NUMBER ASSIGNED TO THE TAPE AS IT IS RECEIVED BY RU 527.

RESEARCH UNIT -        RESEARCH UNIT NUMBER OF THE PRINCIPAL INVESTIGATOR.

DATE RECEIVED -        DATE THE TAPE WAS RECEIVED BY RU 527.

FILE FORMAT -          FORMAT IN WHICH THE DATA ON THE TAPE HAVE BEEN CODED.

FIELD OPER. -          NAME ASSIGNED TO THE FIELD OPERATION BY THE PRINCIPAL INVESTIGATOR.
                       "FW" FIELD OPS. FROM DR. CALVIN LENSINK; "UCI" FIELD OPS. FROM DR. GEORGE HUNT;
                       "W" FIELD OPS. FROM DR. JOHN WIENS; "UC" FIELD OPS. FROM DR. JUAN GUZMAN;
                       "SR" & "DI" FIELD OPS. FROM DR. GEORGE DIVOKY; "AERSR" FIELD OPS. FROM JOE TRUETT.

CODEPULL MAILED -      DATE THE OUTPUT FROM THE QUALITY CONTROL PROGRAM "CODEPULL" WAS
                       MAILED TO THE PRINCIPAL INVESTIGATOR FOR CORRECTIONS.

LOGLIST MAILED -       DATE THE OUTPUT FROM THE QUALITY CONTROL PROGRAM "LOGLIST" WAS
                       MAILED TO THE PRINCIPAL INVESTIGATOR FOR CORRECTIONS.

CODEPULL RETURNED -    DATE THE CORRECTED OUTPUT FROM "CODEPULL" WAS RECEIVED BY RU 527.

LOGLIST RETURNED -     DATE THE CORRECTED OUTPUT FROM "LOGLIST" WAS RECEIVED BY RU 527.

EDITLOG COMPLETE -     DATE THE CORRECTIONS WERE MADE TO THE FIELD OP. AT RU 527, THROUGH THE USE
                       OF AN INTERACTIVE PROGRAM "EDITLOG".

FINAL CHECK -          DATE THE FIELD OP. WAS READY FOR CONVERSION OR TRANSFORMATION.
                       OCCASIONALLY ADDITIONAL PROBLEMS ARISE WHEN "CODEPULL" AND "LOGLIST"
                       ARE RERUN AFTER EDITING. IF THESE CANNOT BE RESOLVED OVER THE TELE-
                       PHONE THE LISTINGS ARE SENT BACK TO THE PI FOR FURTHER CORRECTIONS.
                       THIS FIELD IS NOT FILLED IN UNTIL ALL CORRECTIONS HAVE BEEN MADE.

CONVERT TO NODC -      DATE THE FIELD OP. WAS CONVERTED FROM FWS FORMAT TO NODC FORMAT. AN "NA"
                       (NOT APPLICABLE) IS ENTERED HERE FOR FIELD OPS. RECEIVED IN NODC FORMAT.

MAIL TO NODC -         DATE THE FIELD OP. IN FINAL FORM WAS SUBMITTED TO NODC.

ENDNOTES -             REFERENCE NUMBER TO ADDITIONAL COMMENTS FOLLOWING THE TABLE.
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*** FIELD OPERATION STATUS REPORT ***

AS OF 03/31/79

THE DATA PROJECTS GROUP   OCSEAP - GULF OF ALASKA PROJECT

TAPE NUMBER	RESEARCH UNIT	DATE RECEIVED	FILE FORMAT	FIELD OPER.	CODEPULL MAILED	LOGLIST MAILED	CODEPULL RETURNED	LOGLIST RETURNED	EDITLOG COMPLETE	FINAL CHECK	CONVERT TO NODC	MAIL TO NODC	END NOTES
ALASKA1	337	03/12/77	FWS	FW5004	07/12/77	08/16/77	08/29/77	10/06/77	02/15/78	02/15/78	10/06/78	10/31/78	1A,8
ALASKA2	337	03/12/77	FWS	FW5009	07/12/77	08/16/77	10/06/77	10/06/77	01/26/78	01/30/78	09/05/78	09/18/78	1A,8
				FW5013	07/12/77	08/16/77	08/29/77	10/06/77	01/24/78	01/26/78	10/17/78	11/10/78	1A,8
				FW5018	07/12/77	08/16/77	08/29/77	10/06/77	01/30/78	02/01/78	09/02/78	10/31/78	1A,8
				FW5023	SV/MI/FR	08/16/77	08/29/77	10/06/77	02/06/78	02/14/78	11/01/78	11/10/78	1A,8
				FW5024	07/12/77	08/16/77	08/29/77	10/06/77	02/14/78	02/15/78	11/01/78	11/10/78	1A,8
				FW5030	07/12/77	08/16/77	08/29/77	10/06/77	12/01/77	12/05/77	08/30/78	09/18/78	6,8
				FW5032	07/12/77	08/16/77	08/29/77	10/06/77	12/01/77	12/05/77	08/30/78	09/18/78	6,8
ALASKA3	337	05/27/77	FWS	FW5008	07/14/77	08/16/77	09/06/77	09/06/77	12/09/77	12/09/77	09/07/78	09/18/78	8
				FW5016	07/14/77	08/16/77	09/06/77	09/06/77	07/25/78	07/28/78	11/15/78	11/30/78	1A,8
				FW5021	07/14/77	08/16/77	09/06/77	09/06/77	07/26/78	07/28/78	11/02/78	11/10/78	1B,8
				FW5026	07/14/77	08/16/77	09/06/77	09/06/77	01/31/78	02/01/78	11/17/78	11/30/78	8
				FW5027	07/14/77	08/16/77	09/06/77	09/06/77	02/03/78	02/06/78	09/05/78	09/18/78	8
				FW5033	07/14/77	08/16/77	09/06/77	09/06/77	07/28/78	07/31/78	11/15/78	11/30/78	1B,8
				FW5035	07/14/77	08/16/77	09/06/77	09/06/77	01/30/78	02/01/78	11/15/78	11/30/78	8
				FW6008	12/12/77	12/12/77	01/10/78	01/10/78	08/02/78	08/08/78	12/22/78	01/12/79	1B,8
				FW6027	07/14/77	08/16/77	09/06/77	09/06/77	10/24/78	10/26/78	01/02/79	01/12/79	1C,8
				FW6050	07/14/77	08/16/77	09/06/77	09/06/77	10/02/78	10/06/78	01/02/79	01/16/79	1C,8
				FW6051	07/14/77	08/16/77	09/06/77	09/06/77	10/24/78	10/27/78	01/02/79	01/16/79	1C,8
				FW6074	07/14/77	08/16/77	09/06/77	09/06/77	08/08/78	09/08/78	11/29/78	12/15/78	1B,8
				FW6083	07/14/77	08/16/77	09/06/77	09/06/77	07/21/78	07/24/78	01/02/79	01/16/79	1B,8
ALASKA4	337	06/24/77	FWS	FW5011	08/16/77	08/16/77	11/01/77	11/01/77	10/24/78	10/27/78	11/09/78	11/30/78	1C,8
				FW5012	08/16/77	08/16/77	11/01/77	11/01/77	10/17/78	10/17/78	11/16/78	11/30/78	1C,8
				FW5020	08/16/77	08/16/77	11/01/77	11/01/77	10/31/78	11/02/78	11/09/78	11/30/78	1C,8
				FW5031	08/16/77	08/16/77	11/01/77	11/01/77	10/24/78	10/26/78	12/21/78	01/09/79	1C,8
				FW5034	08/16/77	08/16/77	11/01/77	11/01/77	04/17/78	04/19/78	09/03/78	10/31/78	8
				FW6015	08/16/77	08/16/77	11/01/77	11/01/77	04/05/78	04/18/78	09/06/78	09/18/78	8
				FW6018	08/16/77	08/16/77	11/01/77	11/01/77	10/24/78	10/26/78	01/02/79	01/12/79	1C,8
				FW6019	08/16/77	08/16/77	11/01/77	11/01/77	12/01/78	12/14/78	12/22/78	01/12/79	1C,8
				FW6067	08/16/77	08/16/77	11/01/77	11/01/77	10/24/78	10/26/78	11/29/78	12/15/78	1C,8
				FW6068	08/16/77	08/16/77	11/01/77	11/01/77	10/24/78	10/26/78	11/29/78	12/15/78	1C,8
				FW6088	09/29/77	09/29/77	10/20/77	10/20/77	10/24/78	10/26/78	11/02/78	11/10/78	1C,8
				FW6089	08/16/77	08/16/77	11/01/77	11/01/77	07/21/78	07/24/78	11/29/78	12/15/78	1B,8
				FW6094	08/16/77	08/16/77	11/01/77	11/01/77	10/19/78	10/20/78	01/02/79	01/16/79	1C,8
ALASKA5	337	07/01/77	FWS	FW5015	09/29/77	09/29/77	10/20/77	10/20/77	08/08/78	08/09/78	11/15/78	11/30/78	1B,8

*** FIELD OPERATION STATUS REPORT ***

AS OF 03/31/79

THE DATA PROJECTS GROUP   OCSEAP - GULF OF ALASKA PROJECT

TAPE NUMBER	RESEARCH UNIT	DATE RECEIVED	FILE FORMAT	FIELD OPER.	CODEPULL MAILED	LOGLIST MAILED	CODEPULL RETURNED	LOGLIST RETURNED	EDITLOG COMPLETE	FINAL CHECK	CONVERT TO NODC	MAIL TO NODC	END NOTES
ALASKA5	337	07/01/77	FWS	FW5025	09/29/77	09/29/77	10/20/77	10/20/77	07/24/78	07/26/78	12/21/78	01/09/79	1E,8
				FW6001	09/29/77	09/29/77	10/20/77	10/20/77	04/20/78	04/28/78	09/06/78	09/18/78	8
				FW6002	09/29/77	09/29/77	10/20/77	10/20/77	07/24/78	07/26/78	12/21/78	01/09/79	1E,8
				FW6007	09/29/77	09/29/77	10/20/77	10/20/77	07/24/78	07/27/78	12/22/78	01/12/79	1E,8
				FW6009	09/29/77	09/29/77	10/20/77	10/20/77	08/03/78	08/08/78	11/29/78	12/15/78	1E,8
				FW6021	10/28/77	10/28/77	11/30/77	11/30/77	07/25/78	07/26/78	12/01/78	12/15/78	1E,8
				FW6026	09/29/77	09/29/77	10/20/77	10/20/77	04/26/78	04/28/78	10/12/78	10/31/78	8
				FW6029	09/29/77	09/29/77	10/20/77	10/20/77	04/26/78	05/08/78	10/12/78	10/31/78	8
				FW6057	09/29/77	09/29/77	10/20/77	10/20/77	08/04/78	08/07/78	12/01/78	12/15/78	1E,8
				FW6064	09/29/77	09/29/77	10/20/77	10/20/77	07/21/78	07/27/78	01/03/79	01/16/79	1E,8
				FW6066	09/29/77	09/29/77	10/20/77	10/20/77	02/22/78	02/24/78	11/02/78	11/10/78	8
				FW6070	09/29/77	09/29/77	10/20/77	10/20/77	08/03/78	08/07/78	11/29/78	12/15/78	1E,8
				FW6095	09/29/77	09/29/77	10/20/77	10/20/77	08/08/78	08/09/78	01/02/79	01/16/79	1E,8
ALASKA6	337	07/07/77	FWS	FW5014	10/21/77	10/21/77	11/14/77	11/14/77	02/17/78	02/22/78	09/05/78	09/18/78	8
				FW5022	10/21/77	10/21/77	11/14/77	11/14/77	11/09/78	11/10/78	11/10/78	11/30/78	1F,8
				FW5029	10/21/77	10/21/77	11/14/77	11/14/77	12/14/78	12/14/78	12/21/78	01/09/79	1F,8
				FW5036	10/21/77	10/21/77	11/14/77	11/14/77	06/05/78	06/07/78	11/09/78	11/30/78	8
				FW5037	10/21/77	10/21/77	11/14/77	11/14/77	06/05/78	06/07/78	11/10/78	11/30/78	8
				FW6004	10/21/77	10/21/77	11/14/77	11/14/77	12/15/78	12/18/78	12/21/78	01/09/79	1F,8
				FW6005	10/21/77	10/21/77	11/14/77	11/14/77	12/08/78	12/14/78	12/21/78	01/09/79	1F,8
				FW6010	10/21/77	10/21/77	11/14/77	11/14/77	12/08/78	12/14/78	12/21/78	01/09/79	1F,8
				FW6011	10/21/77	10/21/77	11/14/77	11/14/77	12/08/78	12/14/78	12/22/78	01/12/79	1F,8
				FW6012	10/21/77	10/21/77	11/14/77	11/14/77	11/09/78	11/10/78	11/29/78	12/15/78	1F,8
				FW6016	10/21/77	10/21/77	11/14/77	11/14/77	12/14/78	12/14/78	12/22/78	01/12/79	1F,8
				FW6028	10/21/77	10/21/77	11/14/77	11/14/77	06/07/78	06/08/78	10/11/78	10/31/78	8
				FW6052	10/21/77	10/21/77	11/14/77	11/14/77	12/18/78	12/21/78	12/22/78	01/16/79	1F,8
				FW6077	10/21/77	10/21/77	11/14/77	11/14/77	12/15/78	12/18/78	12/22/78	01/16/79	1F,8
				FW6078	10/21/77	10/21/77	11/14/77	11/14/77	12/14/78	12/14/78	12/22/78	01/16/79	1F,8
				FW6084	10/21/77	10/21/77	11/14/77	11/14/77	11/03/78	11/08/78	11/29/78	12/15/78	1F,8
				FW6085	10/21/77	10/21/77	11/14/77	11/14/77	10/24/78	10/26/78	11/02/78	11/10/78	1F,8
				FW6092	10/21/77	10/21/77	11/14/77	11/14/77	12/14/78	12/19/78	12/22/78	01/16/79	1F,8
				FW7026	10/21/77	10/21/77	11/14/77	11/14/77	10/24/78	10/25/78	10/26/78	10/31/78	1F,8
				FW7027	10/21/77	10/21/77	11/14/77	11/14/77	06/26/78	06/27/78	09/06/78	10/31/78	8
ALASKA7	083	07/07/77	FWS	UCI601	10/07/77	10/07/77	05/26/78	05/26/78	08/25/78	08/25/78	08/28/78	02/08/79	1G
ALASKA8	337	07/28/77	FWS	FW5038	10/28/77	10/28/77	11/30/77	11/30/77	11/21/78	11/22/78	11/22/78	11/30/78	1F,8
				FW6013	10/28/77	10/28/77	11/30/77	11/30/77	12/21/78	12/22/78	01/05/79	01/12/79	1F,8
				FW6025	10/28/77	10/28/77	11/30/77	11/30/77	06/15/78	06/19/78	10/11/78	10/31/78	8
				FW6082	10/28/77	10/28/77	11/30/77	11/30/77	11/16/78	11/20/78	11/29/78	12/15/78	1F,8

*** FIELD OPERATION STATUS REPORT ***

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TAPE NUMBER	RESEARCH UNIT	DATE RECEIVED	FILE FORMAT	FIELD OPER.	CODEPULL MAILED	LOGLIST MAILED	CODEPULL RETURNED	LOGLIST RETURNED	EDITLOG COMPLETE	FINAL CHECK	CONVERT TO NODC	MAIL TO NODC	END NOTES
ALASKA8	337	07/28/77	FWS	FW6087	10/28/77	10/28/77	11/30/77	11/30/77	11/09/78	11/10/78	11/29/78	12/15/78	1F,8
ALASKA9	337	08/03/77	FWS	FW5003	10/28/77	10/28/77	11/30/77	11/30/77	10/02/78	10/17/78	12/21/78	01/09/79	2,1H,8
				FW5006	10/28/77	10/28/77	11/30/77	11/30/77	10/02/78	10/13/78	12/21/78	01/09/79	2,1H,8
				FW5010	10/28/77	10/28/77	11/30/77	11/30/77	10/02/78	10/13/78	11/03/78	11/10/78	2,1H,8
				FW6006	10/28/77	10/28/77	11/30/77	11/30/77	10/02/78	10/13/78	11/29/78	12/15/78	2,1H,8
				FW6014	10/28/77	10/28/77	11/30/77	11/30/77	10/02/78	10/03/78	12/22/78	01/12/79	2,1H,8
ALASKA10	337	09/06/77	NODC	FW7032	10/07/77	10/07/77	11/03/77	11/03/77	11/22/77	11/30/77	/NA/	12/12/77	
				FW7033	10/07/77	10/07/77	11/03/77	11/03/77	11/22/77	11/30/77	/NA/	12/12/77	
ALASKA11	337	11/16/77	NODC	FW7034	11/30/77	11/30/77	01/04/78	01/04/78	01/09/78	01/10/78	/NA/	02/28/78	
				FW7035	11/30/77	11/30/77	01/04/78	01/04/78	01/06/78	01/17/78	/NA/	02/28/78	
				FW7042	11/30/77	11/30/77	01/04/78	01/04/78	01/09/78	01/16/78	/NA/	02/28/78	
				FW7046	11/30/77	11/30/77	01/04/78	01/04/78	01/09/78	01/16/78	/NA/	02/28/78	
ALASKA12	337	01/10/78	NODC	FW7028	01/18/78	01/18/78	01/30/78	01/30/78	01/31/78	02/01/78	/NA/	02/28/78	
				FW7031	01/18/78	01/18/78	01/30/78	01/30/78	02/01/78	02/02/78	/NA/	02/28/78	
				FW7036	01/18/78	01/18/78	01/30/78	01/30/78	01/31/78	02/01/78	/NA/	02/28/78	
				FW7045	01/18/78	01/18/78	01/30/78	01/30/78	02/01/78	02/01/78	/NA/	02/28/78	
ALASKA13	337	01/10/78	FWS	FW6086	01/18/78	01/18/78	01/30/78	01/30/78	07/25/78	07/26/78	10/26/78	11/10/78	1B,8
				FW6186	01/18/78	01/18/78	01/30/78	01/30/78	02/17/78	02/17/78	11/01/78	11/10/78	5,8
ALASKA14	083	04/10/78	NODC	UCI602	04/14/78	04/14/78	04/25/78	04/25/78	06/02/78	06/06/78	/NA/	02/08/79	
ALASKA15	083	06/13/78	NODC	UCI501	07/07/78	07/07/78	07/27/78	07/27/78	08/25/78	08/28/78	/NA/	02/08/79	7
				UCI701	07/07/78	07/07/78	07/27/78	07/27/78	09/05/78	09/05/78	/NA/		10
				UCI702	07/07/78	07/07/78	07/27/78	07/27/78	09/05/78	09/05/78	/NA/		10
				UCI703	07/07/78	07/07/78	07/27/78	07/27/78	08/25/78	08/28/78	/NA/	02/08/79	
				UCI704	07/07/78	07/07/78	07/27/78	07/27/78	08/25/78	08/28/78	/NA/	02/08/79	
ALASKA16	337	09/05/78	NODC	FW6093	09/08/78	09/08/78	09/18/78	09/18/78	10/23/78	10/25/78	/NA/	10/31/78	
				FW7029	09/08/78	09/08/78	09/18/78	09/18/78	10/23/78	10/25/78	/NA/	10/31/78	

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TAPE NUMBER	RESEARCH UNIT	DATE RECEIVED	FILE FORMAT	FIELD OPER.	CODEPULL MAILED	LOGLIST MAILED	CODEPULL RETURNED	LOGLIST RETURNED	EDITLOG COMPLETE	FINAL CHECK	CONVERT TO NODC	MAIL TO NODC	END NOTES
ALASKA17	467	10/23/78	NODC	AERSR1	10/30/78	10/30/78					/NA/		9
				AERSR2	10/30/78	10/30/78					/NA/		9
				AERSR3	10/30/78	10/30/78					/NA/		9
				AERSR4	10/30/78	10/30/78					/NA/		9
				AERSR5	10/30/78	10/30/78					/NA/		9
				AERSR6	10/30/78	10/30/78					/NA/		9
ALASKA18	083	12/15/78	NODC	UCI702	01/18/79	01/18/79	02/02/79	02/02/79	16/02/79		/NA/		11, 1J
				UCI801	01/18/79	01/18/79	02/02/79	02/02/79	23/02/79		/NA/		1J
				UCI802	01/18/79	01/18/79	02/02/79	02/02/79	23/02/79		/NA/		1J
				UCI803	01/18/79	01/18/79	02/02/79	02/02/79	23/02/79		/NA/		1J
				UCI804	01/18/79	01/18/79	02/02/79	02/02/79	23/02/79		/NA/		1J
				UCI805	01/18/79	01/18/79	02/02/79	02/02/79	16/02/79		/NA/		1J
				UCI806	01/18/79	01/18/79	02/02/79	02/02/79	16/02/79		/NA/		1J
				UCI808	01/18/79	01/18/79	02/02/79	02/02/79	16/02/79		/NA/		1J
OREGON1	108	05/25/77	NODC	W05220	10/26/77	10/26/77	01/03/78	01/03/78	05/05/78	05/17/78	/NA/	05/24/78	3B
				W05221	10/26/77	10/26/77	01/03/78	01/03/78	05/05/78	05/17/78	/NA/	05/24/78	3B
				W05310	10/26/77	10/26/77	01/03/78	01/03/78	05/08/78	05/17/78	/NA/	05/24/78	3B
				W05311	10/26/77	10/26/77	01/03/78	01/03/78	05/09/78	05/17/78	/NA/	05/24/78	
				W05325	10/26/77	10/26/77	01/03/78	01/03/78	05/10/78	05/17/78	/NA/	05/24/78	3B
				W06211	10/26/77	10/26/77	01/03/78	01/03/78	05/10/78	05/17/78	/NA/	05/24/78	3A
				W06221	10/26/77	10/26/77	01/03/78	01/03/78	05/12/78	05/17/78	/NA/	05/24/78	3A,3B
				W16140	10/26/77	10/26/77	01/03/78	01/03/78	05/12/78	05/17/78	/NA/	05/24/78	3B
				W16150	10/26/77	10/26/77	01/03/78	01/03/78	05/02/78	05/17/78	/NA/	05/24/78	3B
				W16161	10/26/77	10/26/77	01/03/78	01/03/78	05/12/78	05/17/78	/NA/	05/24/78	3A,3B
				W26140	10/26/77	10/26/77	01/03/78	01/03/78	05/05/78	05/17/78	/NA/	05/24/78	3B
				W36070	10/26/77	10/26/77	01/03/78	01/03/78	05/04/78	05/17/78	/NA/	05/24/78	3B
CANADA1	239	03/30/78	NODC	01UC75	04/17/78	04/17/78	05/08/78	05/08/78	05/11/78	05/15/78	/NA/	06/12/78	4
				02UC75	04/17/78	04/17/78	05/08/78	05/08/78	05/12/78	05/15/78	/NA/	06/12/78	4
				03UC75	04/17/78	04/17/78	05/08/78	05/08/78	05/15/78	05/16/78	/NA/	06/12/78	4
				01UC76	04/17/78	04/17/78	05/08/78	05/08/78	06/09/78	06/09/78	/NA/	06/12/78	4,1D
				02UC76	04/17/78	04/17/78	05/08/78	05/08/78	06/09/78	06/09/78	/NA/	06/12/78	4,1D
				03UC76	04/17/78	04/17/78	05/08/78	05/08/78	05/15/78	05/16/78	/NA/	06/12/78	4
				04UC76	04/17/78	04/17/78	05/08/78	05/08/78	06/09/78	06/09/78	/NA/	06/12/78	4,1D
				05UC76	04/17/78	04/17/78	05/08/78	05/08/78	06/09/78	06/09/78	/NA/	06/12/78	4,1D
CALIF 1	196	07/18/78	NODC	1SR377	08/31/78	08/31/78					/NA/		
				1SR477	08/31/78	08/31/78					/NA/		

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THE DATA PROJECTS GROUP OCSEAP - GULF OF ALASKA PROJECT

TAPE NUMBER	RESEARCH UNIT	DATE RECEIVED	FILE FORMAT	FIELD OPER.	CODEPULL MAILED	LOGLIST MAILED	CODEPULL RETURNED	LOGLIST RETURNED	EDITLOG COMPLETE	FINAL CHECK	CONVERT TO NODC	MAIL TO NODC	END NOTES
CALIF 1	196	07/18/78	NODC	1DI577	08/31/78	08/31/78					/NA/		
CALIF 2	196	02/06/79	NODC	1SR678	02/12/79	02/12/79					/NA/		

*** FIELD OPERATION STATUS REPORT ***

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THE DATA PROJECTS GROUP   OCSEAP - GULF OF ALASKA PROJECT

ENDNOTES:

1. A. LOGLIST AND CODEPULL SENT BACK TO PI FOR ADDITIONAL CORRECTIONS (12/12/77), RETURNED TO RU 527 (01/10/78).
   B. LOGLIST AND CODEPULL SENT BACK TO PI FOR ADDITIONAL CORRECTIONS (03/16/78), RETURNED TO RU 527 (06/26/78).
   C. LOGLIST AND CODEPULL SENT BACK TO PI FOR ADDITIONAL CORRECTIONS (04/26/78), RETURNED TO RU 527 (07/05/78).
   D. LOGLIST AND CODEPULL SENT BACK TO PI FOR ADDITIONAL CORRECTIONS (05/18/78), RETURNED TO RU 527 (06/08/78).
   E. LOGLIST AND CODEPULL SENT BACK TO PI FOR ADDITIONAL CORRECTIONS (06/06/78), RETURNED TO RU 527 (06/26/78).
   F. LOGLIST AND CODEPULL SENT BACK TO PI FOR ADDITIONAL CORRECTIONS (06/27/78), RETURNED TO RU 527 (07/13/78).
   G. LOGLIST AND CODEPULL SENT BACK TO PI FOR ADDITIONAL CORRECTIONS (07/07/78), RETURNED TO RU 527 (07/27/78).
   H. LOGLIST AND CODEPULL SENT BACK TO PI FOR ADDITIONAL CORRECTIONS (07/21/78), RETURNED TO RU 527 (07/28/78).
   J. LOGLIST AND CODEPULL SENT BACK TO PI FOR ADDITIONAL CORRECTIONS (03/02/79).

2. TAPE WAS UNREADABLE, SENT BACK TO PI TO BE RE-GENERATED (08/31/77), RETURNED TO RU 527 (10/21/77).

3. A. UNAUTHORIZED LIGHT LEVEL AND WEATHER CODES USED BY PI, THESE WILL NOT BE INCLUDED IN SUBMISSION TO NODC.
   B. UNAUTHORIZED DISTANCE TO BIRDS ENTRY REPLACED BY OUTSIDE ZONE CODE FOR SUBMISSION TO NODC.

4. TAPE RETURNED TO PI BECAUSE SEVEN OF THE EIGHT EXPECTED FIELD OPS. COULD NOT BE FOUND (01/03/78).
   NEW TAPE WITH EIGHT FIELD OPS. RECEIVED (03/30/78).

5. FIELD OP. FW6186 IS A CONTINUATION OF FIELD OP. FW6086 BECAUSE FW6086 NEEDED MORE THAN 999 STATIONS.

6. ONE OF FIRST FIELD OPS. CONVERTED (02/28/78). FWS AND NODC FORMATS SENT TO PI FOR REVIEW.
   RETURNED TO RU527 FOR REVISIONS TO CONVERSION (07/07/78).

7. DATA FOR THIS FIELD OP. REPLACES THAT ORIGINALLY CODED IN FWS FORMAT AND RECEIVED ON TAPE ALASKA 7.

8. ADDITIONAL PROGRAM WAS REQUIRED TO CORRECT TRANSECT TYPE AND WIDTH FOR RU337.

9. TAPE HAD ONLY 2 OF 6 SPECIFIED FIELD OPS. RETURNED (10/12/78). NEW TAPE RECEIVED (10/23/78).

10. PROBLEMS WITH CODING OF ENVIRONMENT RECORDS DETECTED BY RU083 AFTER USUAL DATA VALIDATION
    COMPLETED. FURTHER CORRECTION NEEDED.

11. ADDITIONAL DATA FOR FIELD OP. UCI702 WHICH WAS ORIGINALLY RECEIVED ON TAPE ALASKA 15.

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                  *** FIELD OPERATION STATUS REPORT ***

                            AS OF 03/31/79

  THE DATA PROJECTS GROUP                OCSEAP - GULF OF ALASKA PROJECT



 SUMMARY:

      TOTAL FIELD OPS.
        RECEIVED BY RU 527       137

      CODEPULLS MAILED
        TO INVESTIGATOR          137

      LOGLISTS MAILED
        TO INVESTIGATOR          137

      CODEPULLS RETURNED
        TO RU 527                127

      LOGLISTS RETURNED
        TO RU 527                127

      TOTAL FIELD OPS. BEING
        EDITED AT RU 527           8

      FIELD OPS. WHICH PASSED
        FINAL CHECK              119

      FIELD OPS. CONVERTED
        TO NODC                   81

      FIELD OPS. MAILED
        TO NODC                  117
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Appendix II

File Type 033 Data Validation Procedures

OCSEAP DATA VALIDATION PROCEDURES
For File Type 033
(Release 6: December 31, 1978)

In order to provide data validation for the File Type 033 data from the OCSEAP Project, four areas need consideration. These include card type validation, data range and relational parameter checking, and format, code, or unit conversion. Since this is a multi-card type file, the card type designation must first be verified (an incorrect value would lead to the improper interpretation of remaining fields on that card), along with the occurrence and sequencing of card types. Second, codes used in each code field (ex. - a two digit weather code) must be compared against all valid codes for that field for verification. Next, range checks must be carried out on all appropriate fields (ex. - sea surface temperature should be between certain upper and lower limits), and relational checks on interrelated fields (ex. - wet bulb temperature readings should be less than or equal to corresponding dry bulb temperature readings). Lastly, if the data are not coded in NODC format, the necessary format changes must be carried out.

Card type designation and sequencing, and valid code field contents are checked in a program called CODEPULL. First the card type is verified. This must be between one and five, and certain other fields are also checked for further verification (ex. - a type five card must have a taxonomic code and a sequence number). Extra cards and missing cards are detected with the sequencing routine. This checks that the cards are in order, that each station has a unique one card followed by a unique two card, and that there are no duplicated or skipped sequence numbers. Then the appropriate code tables are called, and each code of each code field is compared with the appropriate table containing all valid codes for that field.

The output from CODEPULL is a listing of the file in order by station number. Any errors detected are flagged by a brief descriptive message, including a record count for ease in correcting, and, in the case of a bad code, a string of asterisks under the field. Following the file listing is a summary of all the codes used for each code field and their definitions. For a bad code, the record in which it appeared replaces the definition. Figure 1 is a list of the code groups checked and Figure 2 is a portion of a CODEPULL listing.

Data range and relatonal checking are done in a program called LOGLIST. This verifies the data coded as raw numbers, rather than as codes. The contents of the data fields are first checked for numerics, signs, and leading zeros and then compared to upper and lower limits appropriate to each field. In some cases the value of one field is dependent on the value of another field and these relational checks are also made.

LOGLIST prints a columnar listing for each card type. The columns are identified by a three character field code defined prior to the data listing. The record number is listed on the left and any errors detected are flagged in the diagnostics section on the right. A totally blank field is indicated by a row of dots and embedded blanks by an asterisk. Figure 3 is a list of the limit and relational checks made and Figure 4 is a portion of a LOGLIST listing.

These outputs are sent to the Principal Investigator for correcting. He checks the diagnostic messages and the data and marks any necessary corrections directly on the listing. These are returned to us and the updates made to the file with an interactive program called EDITLOG. Then CODEPULL and LOGLIST are rerun for final verification.

Finally the data are converted to NODC format (if they were coded in another format) and submitted to NODC. Format conversion is done with a program called CONVPROG. Many different operations are carried out at this point. For example, data fields are moved from one place to another on a given card, or onto a different card; units are converted and rounded or truncated, or converted to codes; and codes are converted to those equivalent codes acceptable to NODC. Figure 5 is a list of the conversion routines carried out. Data collected in NODC format is also run through the conversion program. This is necessary in order to standardize certain fields since coding varies between investigators, and includes providing leading zeros or blanks, and checking for signs. Figure 6 is a list of transformation routines required.

All of these programs form part of the MARMAP Information System. Their operation is directed by a Master System Table (MST). The MST has an entry for each field of each card type in a file. This contains all the information needed for processing, including field code, data type, position, upper limit, lower limit, relational checking and conversion routines. The programs therefore are data independent and readily adaptable to any file type.

NOTE: An * denotes a change in this entry since the previous report.

FIGURE 1: CODE GROUPS VALIDATED

Code Field	FWS Columns	NODC Columns
CARD TYPE 1		
Platform Type	67-68	69
Ship Activity	70	71
Sampling Technique	69	70
Collection Code	-	72
Zone Scheme	-	73
Angle of View	-	74
Observation Conditions	-	75
Speed Type	60	-
O.B.S. Region	28-30	-
Observer Location	74	-
CARD TYPE 2		
Wind Direction	-	45-46
Swell Direction	-	50-51
Sea State	-	49
Weather	16-17	55-56
Cloud Type	-	57
Cloud Amount	-	58
Water Color	-	59
Visibility	18	61
Sun Direction	-	62
Glare Intensity	61	63
Glare Area	62	64
Moon Phase	-	68
Tide Height	-	69
Debris	-	80
Observation Conditions	19	-
Turbidity	-	63
CARD TYPE 3		
Ice Cover	16,23,35	16,22,51
Ice Pattern/Description	17,24	32
Ice Type	18,25	17,23
Ice Form	19,26,34	18,24,50
Ice Relief	20,27	19,25
Ice Thickness	21,28	20,26
Ice Melting Stage	22,29	21,27
Open Water Type	30	28
Ice Direction	31,36	29,33
Distance	32,37	30,34
Lead/Polyna Width	33,39,40	31,43,44
Ship in Lead/Polyna Location	38	42
Collection Code	41,42,43	35,36,37
Mammal Trace	44,45	38,39
Pond Size	-	49
Ice Pattern	-	40,41

Code Field	FWS Columns	NODC Columns
CARD TYPE 4		
No Code Groups Appear Here.		
CARD TYPE 5		
Age Class	50	32
Sex	51	33
Color Phase	52	34
Plumage	53	35
Molt	54	36
Counting Method	-	42
Reliability	-	43
Distance Measurement Type	-	44
Association Type	55-56	50
Behavior	46-47	56-57
Special Marks	62	58
Bird Condition	63	59
Food Source Association	-	60
Debris	74	71
Oil	-	72
Habitat	-	76,77
Substrate Type	-	81
Cover Code	-	82
Outside Zone	-	83
Text Flag	77	-

NOTE: An * denotes a change to this entry since the previous report.

FIGURE 2: SAMPLE CODEPULL LISTING

CODEPULL consists of two major sections. The first lists the data, sorted by station, card type, and sequence number, flagging any errors detected. The second sums the records by card type; then lists all the codes used in the file with their definitions.

Figure 2A is a page from the first section showing how the file is listed. The dashed lines divide the stations which are listed in order by card type and sequence number. The incorrect records are flagged and numbered, first by record#, which gives the location in the entire file; and second by card type#, which gives the location relative to other records of the same type. This second number corresponds to the record number on LOGLIST. The following errors have been flagged:

Bad Card Type -->
The card type is not between 1 and 5.

Missing 2 Card -->
No environment data was entered for this station.

Bad Code -->
The code entered in the field delimited by an asterisk is invalid.

Needs Seq No. -->
The 5 card is missing a sequence number.

Suspicious seq# -->
The sequence number 002 has been skipped, this also flags duplicate sequence numbers.

Figure 2B is a portion of the second section. This first gives a summary of the number of each type of record found in the file, then a list of the codes used and their definitions. For an invalid code the definition is replaced by the record number in which it appeared, as can be seen for the Visibility Code on card type 2.

```
*** CODEPULL - FOR CRUISE FW9001 - FORMAT  FWS

------------------------------------------------------------------------------------------------------------------------------
                               033FW90010017015838014824OW09122021800                05+100150       1351 10
                               033FW9001001702037 29015 2 6  43                 97730 143
RECORD #    3
TYPE 0 #    1  BAD CARD TYPE -->
                               033FW9001001706NOFU8803020201            30020        6                          004
                               033FW9001001705GWGU8810080103          3000020                                   001
                               033FW9001001705GWGU8810080103           102040                                   002
                               033FW9001001705BLKI8810080301            50020                                   003
------------------------------------------------------------------------------------------------------------------------------
                               033FW900100178158460148270W09122 21800                15+1001501159   1333 10
RECORD #    8
TYPE 2 #    1  MISSING 2 CARD -->
                               033FW9001001785UNGU8810080100            22030                                   001
                               033FW9001001785GWGU8810080103            40010                                   002
                               033FW9001001785UNMU8810100300            11020                                   003
                               033FW9001001785UNMU8810100300            22030                                   004
                               033FW9001001785NOFU8803020201            20010        6                          005
RECORD #   13
TYPE 5 #    9  BAD CODE -->    033FW9001001705NOFU8803020201            11020        X                          006
                                                                                     *
                               033FW9001001785NOFU8803020201            12030        6                          007
                               033FW9001001785NOFU8803020201            10010        2                          008
------------------------------------------------------------------------------------------------------------------------------
                               033FW000100270158420148220W09122021900                5+100150        1351 10
RECORD #   17
TYPE 2 #    2  BAD CODE -->    033FW3001002702O3A. 060 8 0 2  40                98130 150
                                                *

RECORD #   18
TYPE 5 #   12  NEEDS SEQ NO. -->
                               033FW9001002705NOFU8803020201            72040        6
                               033FW9001002705NOFU8803020201           100020        6                          001
RECORD #   20
TYPE 5 #   14  SUSPICIOUS SEQ# -->
                               033FW9001002705NOFU8803020201            30020        2                          003
                               033FW9001002705NOFU8803020201            22040        2                          004
                               033FW9001002705GWGU8810080103          1620020                                   005
                               033FW9001002705GWGU8810080103           532040                                   006
                               033FW9001002705GWGU8810080103          1770020      N                            007
                               033FW9001002705GWGE8810080100000 1       10020                                   008
------------------------------------------------------------------------------------------------------------------------------
                               033FW000100271158200146270W09224 21900                15+1001501090   1333 10
                               033FW9001002712037 30018 3 6  30                 9810-2516
                               033FW9001002715GWGU8810080103            20010                                   001
                               033FW9001002715GWGU8810080103            31020                                   002
                               033FW9001002715GWGU8810080103            22030                                   003
                               033FW9001002715UNLG8810080100000 3       22030                                   004
                               033FW9001002715NOFU8803020201            11020        6                          005
------------------------------------------------------------------------------------------------------------------------------
```

FIGURE 2A

```
                              ***** SUMMARY *****

                               FOR CRUISE FW9001


                              661 TOTAL RECORDS

                              113 TYPE 1 RECORDS
                              112 TYPE 2 RECORDS
                                0 TYPE 3 RECORDS
                                2 TYPE 4 RECORDS
                              433 TYPE 5 RECORDS

                                1 RECORDS WITH AN
                                  INVALID TYPE




RECORD TYPE     1



         CODE FIELD: O.B.S. REGION - FWS(1:28-30)

                CODES              COMMENT
                 091             NORTHWEST GULF OF ALASKA (NWGOA)
                 092             NORTHEAST GULF OF ALASKA (NEGOA)


         CODE FIELD: SPEED TYPE - FWS(1:60)

                CODES              COMMENT
                 BLANK                -
                 1               SPEED MADE GOOD


         CODE FIELD: PLATFORM TYPE - FWS(1:67-68)

                CODES              COMMENT
                 13              MOANA WAVE


         CODE FIELD: SAMPLING TECHNIQUE - NODC(1:70) - FWS(1:69)

                CODES              COMMENT
                 5               COUNT FROM SHIP TO HORIZON WITH ZONE
                 3               COUNT FROM SHIP TO FIXED DISTANCE WITH ZONE
```

FIGURE 2B

```
*** CODEFULL - FOR CRUISE FW9001 - FORMAT  FWS

    CODE FIELD: SHIP ACTIVITY - FWS(1:70)

              CODES                   COMMENT
                1                   STATIONARY/LAYING TO
                3                   STEAMING


    CODE FIELD: OBSERVER LOCATION - FWS(1:74)

              CODES                   COMMENT
               BLANK                     -


RECORD TYPE     2




    CODE FIELD: WEATHER - NODC(2:55-56) - FWS(2:16-17)

              CODES                   COMMENT
               03                   CLOUDS GENERALLY FORMING OR DEVELOPING
               75                   CONTINUOUS FALL OF SNOW FLAKES, HEAVY
               00                   CLOUD DEVELOPMENT NOT OBSERVED OR NOT OBSERVABLE
               71                   CONTINUOUS FALL OF SNOW FLAKES, SLIGHT
               43                   FOG OR ICE FOG, SKY INVISIBLE, THINNING DURING LAST HOUR
               68                   RAIN OR DRIZZLE AND SNOW, SLIGHT
               69                   RAIN OR DRIZZLE AND SNOW, MODERATE OR HEAVY


    CODE FIELD: VISIBILITY - NODC(2:61) - FWS(2:18)

              CODES                   COMMENT
                7                   10-20 KM
                A           *** 000017
                8                   20-50 KM
                3                   500-1000 METRES
                6                   4-10 KM
                4                   1-2 KM
                5                   2-4 KM
               BLANK                     -


    CODE FIELD: OBSERVATION CONDITIONS - FWS(2:19)

              CODES                   COMMENT
               BLANK                     -


    CODE FIELD: GLARE INTENSITY - NODC(2:63) - FWS(2:61)

              CODES                   COMMENT
               BLANK                     -
```

FIGURE 3: LIMITS AND RELATIONAL CHECKS

Field	Format	Ranges		Relations
ALL CARD TYPES				
File Type		-		Must be 033
File ID		-		Must match that of first record on file
Unused Columns		-		Must be blank
CARD TYPE 1				
Start/End Latitude	F	33-73	degrees	-
		0-599	minutes/tenths	
	N	33-73	degrees	-
		0-59	minutes	
		0-59	seconds	
		N	hemisphere	
Start/End Longitude	F	118-180	degrees	-
		0-599	minutes/tenths	
		W	hemisphere	
	N	118-180	degrees	-
		0-59	minutes	
		0-59	seconds	
		W	hemisphere	
Date		1-31	days	-
		1-12	months	
Time		0-23	hours	-
		1-59	minutes	
* Elapsed Time		0-30	minutes	Must not be omitted
Ships Heading	F	0-359	degrees	-
	N	0-35	degrees/tens	
* Ships Speed	F	0-15	knots	When platform is ship
		> 5	knots	When transect type is 71
	N	0-15	knots	For ship surveys
		60-100	knots	For aircraft surveys
				Must not be omitted

Field	Format	Ranges	Relations
CARD TYPE 2			
Wind Direction	F	0-360 degrees	(NODC uses a code)
Wind Speed		0-50 knots	-
* Swell Height	F N	0-25 feet 0-76 meters/tenths	-
* Sea Surface Temp		-3°C to +20°C	Check signs & numerics
* Wet/Dry Bulb Temperature		-20°C to +30°C	Wet bulb <= Dry bulb Check signs & numerics
Barometric Pressure		.9600-1.0400 bars	-
Barometric Trend		+, -, 0, or blank	Must be blank when Baro Pressure is blank
Salinity		20 o/oo to 34 o/oo	-
Thermocline Depth		0-100 meters	-
CARD TYPE 3			
Excess Sediment	F	-	Must be blank
Ice Algae	F	-	Must be blank
Other Features	F	-	Must be blank
Time of Ice Conditions	N	-	Must increase for subsequent ice cards in one station

CARD TYPE 4

No processing required

Field	Format	Ranges	Relations
CARD TYPE 5			
Taxonomic Code		88-92 class	Trailing blanks must be paired Species needed if subspecies coded
Direction of Flight	F N	1-12 o'clock 0-35 degrees/tens	-
Begin/End Zone	F	0-30 0-60	When transect 71 or 78 When transect 70 or 77 (unless BZN coded 97-99) Begin must be < End zone
Number of Individuals		-	Must be numeric Must not be omitted

NOTES:

In the format field, F=FWS, N=NODC, and Blank=Both formats.
An * denotes a change to this entry since the previous report.

FIGURE 4: SAMPLE LOGLIST LISTING

LOGLIST lists the data for each card type individually in columnar form. Fields in each record are keyed by acronym codes, which are defined on a header page.

Figure 4A shows the header page, with acronym definitions, and a page from the listing of type 1 cards. Blank data fields are depicted by a series of dots as in the LTD and LNG fields, while leading or embedded blanks appear as asterisks as in the DAT and ELT fields. The following errors have been flagged:

* FID = FW0001 *
  The ID does not match that of the rest of the file.

* HOR Field Outside *
  The hour subfield of time is not between 00 and 23.

* LAT Field Missing *
* LON Field Missing *
  The start latitude and longitude have been omitted.

Figure 4B shows the header page and a partial listing of type 2 cards. Here the following errors have been flagged:

* BMT Bad Trend *
  The barometric trend is not +, -, or 0.

* WSP Not Match WDR *
  Wind direction is not valid for a wind speed of 00.

```
*** LOGCOL - FOR CRUISE FW9001   - CARD TYPE 1 - FORMAT FWS

        ACRONYM DEFINITIONS

  FID   FIELD OPERATION
  STA   STATION
   SLD   START LATITUDE DEGREES
  LAT   START LATITUDE
   SLM   START LATITUDE MINUTES
   SGD   START LONGITUDE DEGREES
  LON   START LONGITUDE
   SGM   START LONGITUDE MINUTES
  OBR   O.B.S. REGION
   DAY   DAY (SUBFIELD OF DAT)
  DAT   DATE - DDMM
   MON   MONTH (SUBFIELD OF DAT)
   HOR   HOUR (SUBFIELD OF TIM)
  TIM   TIME - HHMM
   MIN   MINUTES  (SUBFIELD OF TIM)
   ELD   END LATITUDE DEGREES
  LTD   END LATITUDE
   ELM   END LATITUDE MINUTES
   EGD   END LONGITUDE DEGREES
  LNG   END LONGITUDE
   EGM   END LONGITUDE MINUTES
  ELT   ELAPSED TIME
  TZS   TIME ZONE SIGN
  TZN   TIME ZONE NUMBER
  SPD   SPEED MADE GOOD
  SPT   SPEED TYPE

        ACRONYM DEFINITIONS

  HED   COURSE MADE GOOD
  HGT   HEIGHT OF OBS. EYES (ABOVE SEA)
  PLT   PLATFORM TYPE
  SMP   SAMPLING TECHNIQUE
  ACT   SHIP ACTIVITY
  PHO   PHOTOS TAKEN
  OBN   O.B.S. NUMBER
  LOC   LOCATION ON SHIP
  FIL   CC 75-80 FLAG IF NON-BLANK

        SPECIAL CHARACTERS

   -    INDICATES A CODE FIELD
   *    INDICATES A BLANK CHARACTER IN A FIELD
   .    INDICATES A TOTALLY BLANK FIELD
   /    FIELD IS LISTED IN THE DIAGNOSTICS IF NON-BLANK
        (DATA WOULD OTHERWISE NOT FIT ON ONE LINE)
```

FIGURE 4A

```
*** LOGCOL - FOR CRUISE FW9001   - CARD TYPE 1 - FORMAT FWS

      F S   L     L       O   D    T    L     L       E  T T  S    S H   H   P  S A P O  L F
      I T   A     O       R   A    I    T     N       L  Z Z  P    P E   G   L  M C H B  O I
      D A   T     N       R   T    M    D     G       T  S N  D    T D   T   T  P T O N  C L        DIAGNOSTICS
      /                   -                                        -         -  - -      - /

 1:   00170 58380 148240W 091 2202 1800 ..... ....... 05 + 10 0150 . ... ... 13 5 1 . 10 .
 2:   00178 58460 148270W 091 22*2 1800 ..... ....... 15 + 10 0150 1 159 ... 13 3 3 . 10 .
 3:   00270 58420 148220W 091 2202 1900 ..... ....... *5 + 10 0150 . ... ... 13 5 1 . 10 .       * FID =FW0001     *
 4:   00271 58200 146270W 092 24*2 1900 ..... ....... 15 + 10 0150 1 090 ... 13 3 3 . 10 .       * FID =FW0001     *
 5:   00370 58390 148240W 091 2202 2100 ..... ....... *5 + 10 0150 . ... ... 13 5 1 . 10 .
 6:   00371 58180 146040W 092 24*2 2000 ..... ....... 15 + 10 0150 1 090 ... 13 3 3 . 10 .
 7:   00470 58290 147500W 091 2202 2200 ..... ....... *5 + 10 0150 . ... ... 13 5 1 . 10 .
 8:   00471 58190 145530W 092 24*2 2100 ..... ....... 15 + 10 0150 1 090 ... 13 3 3 . 10 .
 9:   00570 58360 148500W 091 2202 2300 ..... ....... *5 + 10 0150 . ... ... 13 5 1 . 10 .
10:   00571 58200 145410W 092 24*2 2403 ..... ....... 15 + 10 0150 1 095 ... 13 3 3 . 10 .       * HOR FIELD OUTSIDE *
11:   00670 58440 148010W 091 2302 0000 ..... ....... *5 + 10 0150 . ... ... 13 5 1 . 10 .
12:   00571 58210 145210W 092 2502 0000 ..... ....... 15 + 10 0150 1 100 ... 13 3 3 . 10 .
13:   00770 58440 147300W 091 2302 0100 ..... ....... *5 + 10 0150 . ... ... 13 5 1 . 10 .
14:   00771 58190 145070W 092 2502 0140 ..... ....... 15 + 10 0150 1 100 ... 13 3 3 . 10 .
15:   00870 58260 147410W 091 2302 0200 ..... ....... *5 + 10 0150 . ... ... 13 5 1 . 10 .
16:   00871 58200 144560W 092 2502 0300 ..... ....... 15 + 10 0150 1 095 ... 13 3 3 . 10 .
17:   00970 58430 148120W 091 2302 2315 ..... ....... *5 + 10 0150 . ... ... 13 5 1 . 10 .
18:   00971 58230 141430W 092 2502 1910 ..... ....... 15 + 09 0150 1 037 ... 13 3 3 . 10 .
19:   01070 58400 148180W 091 2402 0010 ..... ....... *5 + 10 0150 . ... ... 13 5 1 . 10 .
20:   01071 ..... ....... 092 2502 2215 ..... ....... 15 + 09 0150 1 034 ... 13 3 3 . 10 .       * LAT FIELD MISSING *
                                                                                               * LON FIELD MISSING *
21:   01170 58380 148160W 091 2402 0130 ..... ....... *5 + 10 0150 . ... ... 13 5 1 . 10 .
22:   01171 58460 141140W 092 2602 0140 ..... ....... 15 + 09 0150 1 090 ... 13 3 3 . 10 .
23:   01270 59210 146320W 092 2402 1800 ..... ....... *5 + 10 0150 . ... ... 13 5 1 . 10 .
24:   01271 59330 139440W 092 26*2 2200 ..... ....... 15 + 09 0150 1 270 ... 13 3 3 . 10 .
```

```
*** LOGCOL - FOR CRUISE FW9001   - CARD TYPE 2 - FORMAT FWS

          ACRONYM DEFINITIONS                               SPECIAL CHARACTERS

     FLD    FIELD OPERATION                          -    INDICATES A CODE FIELD
     STA    STATION                                  *    INDICATES A BLANK CHARACTER IN A FIELD
     WEA    WEATHER                                  .    INDICATES A TOTALLY BLANK FIELD
     VIS    VISIBILITY                               /    FIELD IS LISTED IN THE DIAGNOSTICS IF NON-BLANK
     OBC    OBSERVATION CONDITIONS                        (DATA WOULD OTHERWISE NOT FIT ON ONE LINE)
     WDR    WIND DIRECTION
     WSP    WIND SPEED
     SEA    SEA STATE
     SWL    SWELL HEIGHT
     SFT    SURFACE TEMPERATURE
     SFT    TEMPERATURE (XBT)
     WBT    WET BULB TEMPERATURE
     DBT    DRY BULB TEMPERATURE
     BMP    BAROMETRIC PRESSURE
     BMT    BAROMETRIC TREND
     BDP    DEPTH TO BOTTOM
     SAL    SURFACE SALINITY
     TMD    DEPTH OF THERMOCLINE
     GLI    GLARE INTENSITY
     GLA    GLARE AREA
     TUR    TURBIDITY
     FIL    CC 64-80 FLAG IF NON-BLANK
```

FIGURE 4B

```
*** LOGCOL - FOR CRUISE FW9001   - CARD TYPE 2 - FORMAT FWS

    F S     W  V O W   W  S  S  S    S    W    D    B     B B    S   T   G G T F
    I T     E  I B D   S  E  W  F    E    B    B    M     M D    A   M   L L U I
    D A     A  S C R   P  A  L  T    T    T    T    P     T P    L   D   I A R L                             DIAGNOSTICS
    /       -  - -                                                       - - - /

 1:   00170 03 7 . 290 15 *2 *6 **43 .... .... .... *9773 0 *143 ... ... . . .
 2:   00270 03 A . 060 *8 *0 *2 **40 .... .... .... *9813 0 *150 ... ... . . .
 3:   00271 03 7 . 300 18 *3 *6 **30 .... .... .... *9810 - 2516 ... ... . . .
 4:   00370 03 8 . 325 *8 *0 *0 **40 .... .... .... *9813 0 *200 ... ... . . .
 5:   00371 75 7 . 230 20 *2 *6 **10 .... .... .... *9813 Q 2607 ... ... . . .                             * BMT BAD TREND     *
 6:   00470 03 8 . 045 *6 *0 *2 **40 .... .... .... *9810 0 *142 ... ... . . .
 7:   00471 03 7 . 140 25 *2 *6 **30 .... .... .... *9823 + 2416 ... ... . . .
 8:   00570 03 8 . 270 10 *0 *1 **40 .... .... .... *9810 0 *139 ... ... . . .
 9:   00571 03 7 . 160 19 *1 *5 **29 .... .... .... *9860 + 2315 ... ... . . .
10:   00670 03 8 . 290 *8 *0 *2 **42 .... .... .... *9806 0 *149 ... ... . . .
11:   00671 03 8 . 180 20 *1 *3 **31 .... .... .... *9876 + 2416 ... ... . . .
12:   00770 03 8 . 270 *8 *0 *0 **42 .... .... .... *9800 - *142 ... ... . . .
13:   00771 03 8 . 180 19 *1 *4 **29 .... .... .... *9880 + 2375 ... ... . . .
14:   00870 03 8 . 290 *7 *0 *4 **42 .... .... .... *9786 - *140 ... ... . . .
15:   00871 00 7 . 180 00 *1 *3 **29 .... .... .... *9903 + 2164 ... ... . . .                             * WSP NOT MATCH WDR *
16:   00970 03 8 . 310 18 .. .. **43 .... .... .... *9806 0 *151 ... ... . . .
17:   00971 75 3 . 090 18 *1 *3 **39 .... .... .... 10006 0 2003 ... ... . . .
18:   01070 03 8 . 290 18 *2 10 **42 .... .... .... *9806 + *152 ... ... . . .
19:   01071 03 6 . 090 36 *3 20 **19 .... .... .... 10016 + 1830 ... ... . . .
20:   01170 03 8 . 255 20 *2 *7 **42 .... .... .... *9806 0 .... ... ... . . .
21:   01171 03 7 . 090 25 *2 12 **44 .... .... .... 10056 + *103 ... ... . . .
22:   01270 03 7 . 250 20 *3 *6 **32 .... .... .... *9813 0 2516 ... ... . . .
23:   01271 00 8 . 110 *4 *0 *0 **34 .... .... .... 10133 + **10 ... ... . . .
24:   01370 03 7 . 160 24 *2 *5 **30 .... .... .... *9853 + 2340 ... ... . . .
25:   01371 00 8 . 130 *5 *0 *0 **39 .... .... .... 10133 + **51 ... ... . . .
```

FIGURE 5: FWS - NODC CONVERSION ROUTINES

Field	FWS Cols	NODC Cols	Special Processing
CARD TYPE 1			
File type	1-3	1-3	-
File ID	4-9	4-9	-
Station Number	10-14	11-15	-
Record Type	15	10	-
Start Latitude	16-20	16-22	Degrees, minutes and tenths convert to degrees, minutes, seconds. Add hemisphere "N".
Start Longitude	21-27	23-30	Degrees, minutes, tenths convert to degs, mins, secs.
OBS Region	28-30	-	No NODC counterpart.
Date	31-34	31-36	Add year and convert from day and month to YYMMDD.
Time	35-38	37-40	-
End Latitude	39-43	41-47	Same as Start Lat above.
End Longitude	44-50	48-55	Same as Start Long above.
Elapsed Time	51-52	56-57	-
Time Zone Sign	53	58	-
Time Zone Number	54-55	59-60	-
Ships Speed	56-59	61-65	Round tenths to whole knots.
Speed Type	60	-	No NODC counterpart.
Course Heading	61-63	64-65	Round whole degrees to tens of degrees.
Height of Eyes	64-66	66-68	Convert feet to meters (multiply by 0.3048, round).
Platform Type	67-68	69	Convert FWS to NODC code.
Sampling Technique	69	70	-
Ship Activity	70	71	convert FWS to NODC code.
Photos Taken	71	-	No NODC counterpart.
OBS Number	72-73	-	No NODC counterpart.
OBS Location	74	-	No NODC counterpart.
Observation Cond	-	75	Move from col 19 of FWS card type 2.
Distance	-	76-79	No FWS counterpart.
Watch Type	-	80	No FWS counterpart.
Transect Width	-	83	No FWS counterpart.
(Blanks)	75-80	-	-

Field	FWS Cols	NODC Cols	Special Processing
CARD TYPE 2			
File type	1-3	1-3	-
File ID	4-9	4-9	-
Station Number	10-14	11-15	-
Record Type	15	10	-
Weather	16-17	55-56	-
Cloud Type	-	57	No FWS counterpart.
Cloud Amount	-	58	No FWS counterpart.
Water Color	-	59-60	No FWS counterpart.
Visibility	18	61	-
Observation Cond	19	-	Move to col 75 of NODC card type 1.
Wind Direction	20-22	45-46	Convert FWS degrees to NODC code (divide by 10, truncate, and add 1).
Wind Speed	23-24	47-48	-
Wave Ht/Sea State	25-26	49	Convert feet to NODC code.
Swell Direction	-	50-51	No FWS counterpart.
Swell Height	27-28	52-54	Convert feet to tenths of meters (multiply by 3.048 then round).
Sea Surface Temp	29-32	23-26	Move sign adjacent to first significant digit (remove embedded zeros or blanks).
XBT Temp	33-36	-	No NODC counterpart.
Wet Bulb Temp	37-40	34-37	Same as Sea Surf Temp above.
Dry Bulb Temp	41-44	30-33	Same as Sea Surf Temp above.
Relative Humidity	-	38-39	No FWS counterpart.
Barometric Pressure	45-49	40-43	Truncate left digit.
Barometric Trend	50	44	-
Bottom Depth	51-54	16-19	Convert fathoms to meters (multiply by 1.829, round).
Surface Salinity	55-57	27-29	-
Thermocline Depth	58-60	20-22	-
Sun Direction	-	62	No FWS counterpart.
Glare Intensity	61	63	-
Glare Area	62	64	-
Turbidity Code	63	-	No NODC counterpart.

Field	FWS Cols	NODC Cols	Special Processing
Light Level	-	65-67	No FWS counterpart.
Moon Phase	-	68	No FWS counterpart.
Tide Height	-	69	No FWS counterpart.
Tide Rise/Fall	-	70	No FWS counterpart.
Distance to Shore	-	71-74	No FWS counterpart.
Distance to Shelf	-	75-77	No FWS counterpart.
SECCHI Depth	-	78-79	No FWS counterpart.
Debris Code	-	80	No FWS counterpart.
(Blanks)	64-80	81-83	-

CARD TYPE 3

File type	1-3	1-3	-
File ID	4-9	4-9	-
Station Number	10-14	11-15	-
Record Type	15	10	-
Ice In Transect			
Cover	16	16	-
Pattern	17	40	Code groups not convertible.
Type	18	17	-
Form	19	18	-
Relief	20	19	-
Thick	21	20	-
Melt	22	21	-
Ice Outside Transect			
Cover	23	22	-
Pattern	24	41	Code groups not convertible.
Type	25	23	-
Form	26	24	-
Relief	27	25	-
Thick	28	26	-
Melt	29	27	-
Open Water			
Type	30	28	-
Direction	31	29	-
Distance	32	30	-
Lead/Polyna Wd	33	31	-
Visible Ice			
Form	34	50	-
Covar	35	51	-
Description	-	32	No FWS counterpart.
Direction	36	33	Code groups not convertible.
Distance	37	34	Code groups not convertible.

Field	FWS Cols	NODC Cols	Special Processing
Ship in Lead/Polyna			
Location	38	42	-
Width	39	43	-
Distance	40	44	-
Miscellaneous			
Arctic Cod	41	35	Convert FWS to NODC code.
Excess Sediment	42	36	Code groups not convertible.
Ice Algae	43	37	Code groups not convertible.
Mammal Trace	44	38	-
Other Features	45	39	Code groups not convertible.
Ice Not Coverable	46	-	No NODC counterpart.
Time of Ice Cond	-	45-46	No FWS counterpart.
Water/Land Percent	-	47-48	No FWS counterpart.
Pond Size	-	49	No FWS counterpart.
(Blanks)	47-80	52-77	-
Sequence Number	-	78-80	No FWS counterpart.
(Blanks)	-	81-83	-

CARD TYPE 4

File type	1-3	1-3	-
File ID	4-9	4-9	-
Station Number	10-14	11-15	-
Record Type	15	10	-
Text	16-77	16-77	-
Sequence Number	78-80	78-80	-
(Blanks)	-	81-83	-

CARD TYPE 5

File type	1-3	1-3	-
File ID	4-9	4-9	-
Station Number	10-14	11-15	-
Record Type	15	10	-
Species Name	16-19	-	No NODC counterpart.
Taxonomic Code	20-31	18-29	Blank out trailing zero doublets.
Species Group	32-33	30-31	-
No of Individuals	34-38	37-41	-

Field	FWS Cols	NODC Cols	Special Processing
Counting Method	-	42	No FWS counterpart.
Reliability	-	43	No FWS counterpart.
Dist Measure Type	-	44	No FWS counterpart.
Distance to Birds	-	45-47	No FWS counterpart.
Begin/Outside Zone	39-40	83	Convert to Outside Zone only when coded 97-99.
End Zone	41-42	-	No NODC counterpart.
Time into Transect	43-45	16-27	Round minutes and tenths to whole minutes.
Behavior	46-47	56-57	-
Flight Direction	48-49	48-49	Convert from clock position relative to ship to compass direction in tens of degrees (multiply by 30, add rounded heading from card type 1).
Age	50	32	-
Sex	51	33	-
Color	52	34	-
Plumage	53	35	-
Molt	54	36	-
Association Type	55-56	50	Convert FWS to NODC code.
Multi-Species Link	57-59	51-53	-
No of Species	60-61	54-55	-
Special Marks	62	58	-
Bird Condition	63	59	-
Food Source	-	60	No FWS counterpart.
Tax Code for Food	64-73	61-70	-
Debris	74	71	-
Oil	-	72	No FWS counterpart.
Dist from Breed Colony	-	73-75	No FWS counterpart.
Habitat	-	76-77	No FWS counterpart.
OBS Observer No	75-76	-	No NODC counterpart.
Text Flag Code	77	-	No NODC counterpart.
Sequence Number	78-80	78-80	-
Substrata	-	81	No FWS counterpart.
Cover	-	82	No FWS counterpart.

The following fields will have Leading Zeros or Leading Blanks inserted as necessary.

Leading Zeros

Station Number
Start Latitude
Start Longitude
End Latitude
End Longitude
Date and Time
Course Heading
Multi-Species Link
Flight Direction
Sequence Number

Leading Blanks

Ships Speed
Height of Eyes
Wind Speed
Sea Surface Temp
Wet Bulb Temp
Dry Bulb Temp
Bottom Depth
No of Individuals

NOTE: An * denotes a change to this entry since the previous report.

FIGURE 6: NODC TRANSFORMATION ROUTINES

Field	Card:Cols	Processing
Sea Surface Temp	2:23-26	Move sign adjacent to first significant digit (remove embedded zeros or blanks).
Dry Bulb Temperature	2:30-33	Same as Sea Surf Temp above.
Wet Bulb Temperature	2:34-37	Same as Sea Surf Temp above.
Flight Direction	5:48-49	Compass reading of 36 replaced by 00 degrees.
Taxonomic Code	5:18-29	Blank out trailing zero doublets.

The following fields will have Leading Zeros or Leading Blanks inserted as necessary.

Leading Zeros	Leading Blanks
Station Number	Ships Speed
Start Latitude	Height of Eyes
Start Longitude	Wind Speed
End Latitude	Sea Surface Temp
End Longitude	Wet Bulb Temp
Date and Time	Dry Bulb Temp
Course Heading	Bottom Depth
Multi-Species Link	No of Individuals
Flight Direction	Transect Width
Sequence Number	

NOTE: An * denotes a change to this entry since the previous report.

Appendix III

File Type 033 Data Analysis Products

OCSEAP
Bird Census Analysis Products
(Release 1.0; 1 February 1979)

Background

A series of four products have been identified by OCSEAP for use in the analysis of bird census data. Developed through the auspices of the Juneau Project Office, Dr. George Hunt (RU083), and the Data Projects Group (RU527), these products are based on data acquired in File Type 033, and are stored, retrieved, and portrayed through use of the MARMAP Information System.

The four products are entitled Digital Density Plot, Contour Plot, Star Diagram, and Statistical Analyses. This report describes the products, associated Data Summary Table, and includes sample output from each.

File Type 033 Data Summary Table

The Data Summary Table serves as a reference point for use with the four analysis products. Shown in Figure 1, it lists a variety of raw data parameters for each transect. In addition, two parameters listed are derived from other raw data in the file. These parameters are the transect length (in meters) and the area surveyed (in square kilometers). Also listed is a block reference number defined in the Digital Density Plot description.

Digital Density Plot

This analysis produces a digital plot of bird densities, using a high speed printer, as shown in Figure 2. The area portrayed corresponds to the geographical area in which the data were collected, separated into ten minute by ten minute blocks. A reference number for each block is included in the File Type 033 Data Summary Table. A Block Identification Number display, Figure 3, is similar in appearance to the plot, but contains block reference numbers instead of bird densities. This master reference is used to relate a block number on the plot with transect data in the table.

Three values are obtained for each block. They are the largest number of birds per square kilometer on any transect, the mean number of birds per square kilometer for all transects, and the smallest number of birds per square kilometer seen on any transect. The values are printed in a position on the plot which corresponds to the particular block. The mean value is printed in the middle, with the largest and smallest density values printed above and below the mean, respectively. To assist in interpreting the plot, a mylar overlay is available, which shows land masses and bottom depth contour lines in the area being studied.

Densities can be calculated with respect to any time of day, behavior, season, month, subset of species, or combination of these or other parameters. Also, the user may specify that only a certain portion of the total area surveyed be displayed.

Figure 1

File Type 033 Data Summary Table

SEE LAST PAGE FOR NECESSARY KEYS

OCSEAP - FILE TYPE 033 DATA SUMMARY

DATA PROJECTS GROUP
PASTORE LABORATORY
UNIVERSITY OF RHODE ISLAND

UCI701

7 JULY 1977 - 11 JULY 1977

10' X 10' BLOCK NUMBER AND POSITION (DEG & MIN) BLK	LATITUDE	LONGITUDE	FIELD OPER.	DATE DD MM YY	TIME HHMM	TRAN. LENG. (M)	AREA SURV. (KM2)	ENVIRONMENTAL CONDITIONS STMP	SAL	BDEP	DNSH	OSD	OBSERVATIONS NAME	NUMBER SEEN	BC	DC
129	58 04 N	170 34 W	UCI701	10 07 77	0650	4015	1.20	86	324	79	54	102	HORNED PUFFIN	2	32	
													MURRE SP.	1	20	15
													MURRE SP.	3	20	15
													MURRE SP.	4	20	00
													MURRE SP.	4	20	18
													MURRE SP.	20	20	18
													NORTHERN FULMAR	1	20	09
													NORTHERN FULMAR (DARK)	2	32	
													NORTHERN FULMAR (LIGHT)	1	20	09
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													TUFTED PUFFIN	1	32	
													TUFTED PUFFIN	1	32	
129	58 04 N	170 38 W	UCI701	10 07 77	0640	4015	1.20	86	324	80	54	104	BLACK-LEGGED KITTIWAKE	1	20	18
													MURRE SP.	1	01	
													MURRE SP.	1	20	
													MURRE SP.	2	20	18
													MURRE SP.	3	20	09
													MURRE SP.	3	20	15
													MURRE SP.	4	20	15
													MURRE SP.	5	20	18
													NORTHERN FULMAR (DARK)	1	32	
													NORTHERN FULMAR (DARK)	3	20	
													NORTHERN FULMAR (LIGHT)	1	20	18
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	2	20	
													SOOTY SHEARWATER	1	20	
													SOOTY SHEARWATER	3	20	18
130	58 01 N	170 26 W	UCI701	10 07 77	1720	3706	1.11	83	321	75	49	100	MURRE SP.	1	20	18
													MURRE SP.	5	20	18
													MURRE SP.	13	20	18
													NORTHERN FULMAR (DARK)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	

OCSEAP - FILE TYPE 033 DATA SUMMARY

DATA PROJECTS GROUP
PASTORE LABORATORY
UNIVERSITY OF RHODE ISLAND

UCI701

7 JULY 1977 - 11 JULY 1977

10' X 10' BLOCK NUMBER AND POSITION (DEG & MIN)			FIELD	DATE	TIME	TRAN. LENG.	AREA SURV.	ENVIRONMENTAL CONDITIONS					OBSERVATIONS			
BLK	LATITUDE	LONGITUDE	OPER.	DD MM YY	HHMM	(NM)	(KM2)	STMP	SAL	BDEP	DNSH	DSB	NAME	NUMBER SEEN	BC	OC
													TUFTED PUFFIN	1	20	18
130	58 03 N	170 26 W	UCI701	10 07 77	1710	4015	1.20	83	321	75	51	103	HORNED PUFFIN	2	32	
													MURRE SP.	1	20	00
													MURRE SP.	1	32	
													MURRE SP.	2	20	18
													MURRE SP.	3	20	18
													MURRE SP.	3	32	
													MURRE SP.	4	20	18
													NORTHERN FULMAR (DARK)	2	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													SOOTY SHEARWATER	1	20	18
													SOOTY SHEARWATER	1	32	
													TUFTED PUFFIN	2	32	
130	58 05 N	170 26 W	UCI701	10 07 77	1700	3706	1.11	83	321	75	53	105	ALCIDAE	5	20	18
													MURRE SP.	1	20	00
													NORTHERN FULMAR (DARK)	1	32	
													NORTHERN FULMAR (DARK)	1	32	
													NORTHERN FULMAR (LIGHT)	1	20	
													NORTHERN FULMAR (LIGHT)	1	32	
													SHEARWATER (PUFFINUS)	1	32	
													SHEARWATER (PUFFINUS)	2	20	18
130	58 07 N	170 25 W	UCI701	10 07 77	1650	3706	1.11	88	318	76	55	106	BLACK-LEGGED KITTIWAKE	2	20	00
													COMMON MURRE	2	20	18
													MURRE SP.	1	20	00
													MURRE SP.	4	20	18
													NORTHERN FULMAR (DARK)	1	20	00
													NORTHERN FULMAR (LIGHT)	1	20	00
													NORTHERN FULMAR (LIGHT)	1	20	00
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													SOOTY SHEARWATER	5	20	15

OCSEAP - FILE TYPE 033 DATA SUMMARY

DATA PROJECTS GROUP
PASTORE LABORATORY
UNIVERSITY OF RHODE ISLAND

UC1701

7 JULY 1977 - 11 JULY 1977

10' X 10' BLOCK NUMBER AND POSITION (DEG & MIN) BLK	LATITUDE	LONGITUDE	FIELD OPER.	DATE DD MM YY	TIME HHMM	TRAN. LENG. (M)	AREA SURV. (KM2)	ENVIRONMENTAL CONDITIONS STMP	SAL	BDEP	ONSH	OSB	OBSERVATIONS NAME	NUMBER SEEN	BC	DC
													THICK-BILLED MURRE	4	20	18
130	58 09 N	170 26 W	UC1701	10 07 77	1640	4015	1.20	88	318	75	57	108	HORNED PUFFIN	2	32	
													NORTHERN FULMAR (DARK)	1	20	
													NORTHERN FULMAR (DARK)	3	32	
													NORTHERN FULMAR (LIGHT)	1	20	00
													NORTHERN FULMAR (LIGHT)	1	32	
138	58 00 N	169 04 W	UC1701	11 07 77	0200	4324	1.30	90	319	71	58	105	BLACK-LEGGED KITTIWAKE	1	32	
													BLACK-LEGGED KITTIWAKE	1	32	
													BLACK-LEGGED KITTIWAKE	2	01	
													BLACK-LEGGED KITTIWAKE	5	32	
													MURRE SP.	1	32	
													MURRE SP.	2	20	09
138	58 01 N	169 01 W	UC1701	11 07 77	0210	4324	1.30	90	319	71	60	106	BLACK-LEGGED KITTIWAKE	1	20	15
													BLACK-LEGGED KITTIWAKE	2	32	
													BLACK-LEGGED KITTIWAKE	2	32	
													MURRE SP.	1	20	05
													MURRE SP.	1	20	09
													MURRE SP.	1	20	09
													MURRE SP.	1	20	09
													NORTHERN FULMAR	1	20	18
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													RUDDY TURNSTONE	1	20	15
139	58 03 N	168 58 W	UC1701	11 07 77	0220	4324	1.30	90	319	71	62	108	BLACK-LEGGED KITTIWAKE	1	32	
													BLACK-LEGGED KITTIWAKE	1	32	
													BLACK-LEGGED KITTIWAKE	3	32	
													MURRE SP.	1	20	05
													NORTHERN FULMAR (LIGHT)	1	32	
139	58 04 N	168 55 W	UC1701	11 07 77	0230	4015	1.20	89	319	71	65	110	BLACK-LEGGED KITTIWAKE	1	20	27
													BLACK-LEGGED KITTIWAKE	1	32	
													BLACK-LEGGED KITTIWAKE	2	32	
													BLACK-LEGGED KITTIWAKE	3	32	

OCSEAP - FILE TYPE 033 DATA SUMMARY

DATA PROJECTS GROUP
PASTORE LABORATORY
UNIVERSITY OF RHODE ISLAND

UCI701

7 JULY 1977 - 11 JULY 1977

10' X 10' BLOCK NUMBER AND POSITION (DEG & MIN)			FIELD	DATE	TIME	TRAN. LENG.	AREA SURV.	ENVIRONMENTAL CONDITIONS					OBSERVATIONS			
BLK	LATITUDE	LONGITUDE	OPER.	DD MM YY	HHMM	(M)	(KM2)	STMP	SAL	BDEP	DNSH	DSB	NAME	NUMBER SEEN	BC	DC
139	58 06 N	168 52 W	UCI701	11 07 77	0240	4015	1.20	89	319	70	67	112	BLACK-LEGGED KITTIWAKE	1	32	
													MURRE SP.	1	01	
													MURRE SP.	1	20	05
													MURRE SP.	1	20	22
													MURRE SP.	1	32	
													MURRE SP.	2	20	09
													NORTHERN FULMAR (LIGHT)	1	32	
140	58 01 N	168 45 W	UCI701	11 07 77	0340	4015	1.20	90	314	70	64	105	BLACK-LEGGED KITTIWAKE	6	20	18
													BLACK-LEGGED KITTIWAKE	10	32	
													BLACK-LEGGED KITTIWAKE	51	20	18
140	58 03 N	168 45 W	UCI701	11 07 77	0330	4015	1.20	90	314	70	66	107	BLACK-LEGGED KITTIWAKE	1	32	
													BLACK-LEGGED KITTIWAKE	1	99	
													BLACK-LEGGED KITTIWAKE	3	32	
													BLACK-LEGGED KITTIWAKE	9	32	
													JAEGER (JPO)	1	32	
													JAEGER (JPO)	1	99	
													NORTHERN FULMAR	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													SOOTY SHEARWATER	1	20	09
140	58 05 N	168 45 W	UCI701	11 07 77	0320	3706	1.11	88	314	70	68	109	BLACK-LEGGED KITTIWAKE	1	99	
													JAEGER (JPO)	1	20	05
													JAEGER (JPO)	2	99	
													NORTHERN FULMAR	1	32	
140	58 07 N	168 45 W	UCI701	11 07 77	0310	3706	1.11	88	314	70	69	110	BLACK-LEGGED KITTIWAKE	22	32	
													NORTHERN FULMAR (DARK)	1	20	18
140	58 09 N	168 46 W	UCI701	11 07 77	0300	4015	1.20	88	314	69	71	116	BLACK-LEGGED KITTIWAKE	1	32	
													BLACK-LEGGED KITTIWAKE	2	32	
													BLACK-LEGGED KITTIWAKE	3	20	05
													JAEGER (JPO)	1	20	18
													MURRE SP.	1	20	05
													NORTHERN FULMAR	1	32	
													NORTHERN FULMAR (DARK)	1	32	
													NORTHERN FULMAR (LIGHT)	1	20	09

OCSEAP - FILE TYPE 033 DATA SUMMARY

DATA PROJECTS GROUP
PASTORE LABORATORY
UNIVERSITY OF RHODE ISLAND

UCI701

7 JULY 1977 - 11 JULY 1977

10' X 10' BLOCK NUMBER AND POSITION (DEG & MIN) BLK	LATITUDE	LONGITUDE	FIELD OPER.	DATE DD MM YY	TIME HHMM	TRAN. LENG. (M)	AREA SURV. (KM2)	ENVIRONMENTAL CONDITIONS STMP	SAL	BDEP	DNSH	DSB	OBSERVATIONS NAME	NUMBER SEEN	BC	DC
													NORTHERN FULMAR (LIGHT)	1	20	09
143	58 07 N	168 19 W	UCI701	11 07 77	0250	4015	1.20	89	319	69	69	114	BLACK-LEGGED KITTIWAKE	2	32	
													BLACK-LEGGED KITTIWAKE	3	32	
													BLACK-LEGGED KITTIWAKE	6	20	09
													BLACK-LEGGED KITTIWAKE	25	32	
													MURRE SP.	1	20	09
													MURRE SP.	1	32	
													NORTHERN FULMAR	1	32	
													RUDDY TURNSTONE	1	20	09
													RUDDY TURNSTONE	1	32	
145	57 59 N	171 50 W	UCI701	10 07 77	0230	4324	1.30	89	326	102	68	83	BLACK-LEGGED KITTIWAKE	1	20	22
													BLACK-LEGGED KITTIWAKE	1	32	
													BLACK-LEGGED KITTIWAKE	2	20	30
													BLACK-LEGGED KITTIWAKE	3	20	
													BLACK-LEGGED KITTIWAKE	4	20	30
													COMMON MURRE	1	20	27
													HORNED PUFFIN	1	20	15
													NORTHERN FULMAR (DARK)	1	20	00
													NORTHERN FULMAR (DARK)	1	32	
													NORTHERN FULMAR (DARK)	2	20	
													NORTHERN FULMAR (DARK)	2	20	
													NORTHERN FULMAR (DARK)	2	32	
													NORTHERN FULMAR (DARK)	2	32	
													NORTHERN FULMAR (LIGHT)	1	20	
													NORTHERN FULMAR (LIGHT)	1	20	
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													SOOTY SHEARWATER	1	20	00
													SOOTY SHEARWATER	7	20	27
146	57 54 N	171 42 W	UCI701	10 07 77	0200	4015	1.20	89	326	102	61	81	BLACK-LEGGED KITTIWAKE	1	20	30
													BLACK-LEGGED KITTIWAKE	2	01	
													NORTHERN FULMAR	3	32	
													NORTHERN FULMAR (DARK)	1	01	
													NORTHERN FULMAR (DARK)	1	01	
													NORTHERN FULMAR (DARK)	1	20	27

OCSEAP - FILE TYPE 033 DATA SUMMARY

DATA PROJECTS GROUP
PASTORE LABORATORY
UNIVERSITY OF RHODE ISLAND

UCI701

7 JULY 1977 - 11 JULY 1977

10' X 10' BLOCK NUMBER AND POSITION (DEG & MIN)			FIELD	DATE	TIME	TRAN. LENG.	AREA SURV.	ENVIRONMENTAL CONDITIONS					OBSERVATIONS			
BLK	LATITUDE	LONGITUDE	OPER.	DD MM YY	HHMM	(M)	(KM2)	STMP	SAL	BDEP	DNSH	DSB	NAME	NUMBER SEEN	BC	DC
													NORTHERN FULMAR (DARK)	1	32	
													NORTHERN FULMAR (DARK)	2	99	
													NORTHERN FULMAR (DARK)	3	20	30
													NORTHERN FULMAR (LIGHT)	1	20	27
													NORTHERN FULMAR (LIGHT)	1	20	30
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	3	20	30
													NORTHERN FULMAR (LIGHT)	3	99	
													NORTHERN FULMAR (LIGHT)	4	32	
146	57 56 N	171 44 W	UCI701	10 07 77	0210	4015	1.20	89	326	102	64	82	BLACK-LEGGED KITTIWAKE	2	20	30
													JAEGER (JPO)	1	20	27
													NORTHERN FULMAR	1	32	
													NORTHERN FULMAR	3	32	
													NORTHERN FULMAR (DARK)	1	20	22
													NORTHERN FULMAR (DARK)	1	20	27
													NORTHERN FULMAR (DARK)	4	01	
													SHORT-TAIL SHEARWATER	1	20	22
													SHORT-TAIL SHEARWATER	1	20	27
													THICK-BILLED MURRE	1	20	22
													TUFTED PUFFIN	1	20	09
													TUFTED PUFFIN	1	32	
													TUFTED PUFFIN	1	32	
146	57 57 N	171 47 W	UCI701	10 07 77	0220	4015	1.20	89	326	102	66	82	BLACK-LEGGED KITTIWAKE	1	20	15
													BLACK-LEGGED KITTIWAKE	1	20	30
													BLACK-LEGGED KITTIWAKE	2	32	
													BLACK-LEGGED KITTIWAKE	6	01	
													JAEGER (JPO)	1	20	22
													JAEGER (JPO)	2	20	18
													NORTHERN FULMAR (DARK)	1	01	
													NORTHERN FULMAR (DARK)	1	20	00
													NORTHERN FULMAR (DARK)	1	32	
													NORTHERN FULMAR (DARK)	2	20	30
													NORTHERN FULMAR (DARK)	3	32	
													NORTHERN FULMAR (LIGHT)	1	20	
													NORTHERN FULMAR (LIGHT)	1	20	27
													NORTHERN FULMAR (LIGHT)	1	20	30

OCSEAP - FILE TYPE 033 DATA SUMMARY

DATA PROJECTS GROUP
PASTORE LABORATORY
UNIVERSITY OF RHODE ISLAND

UC1701

7 JULY 1977 - 11 JULY 1977

10' X 10' BLOCK NUMBER AND POSITION (DEG & MIN) BLK	LATITUDE	LONGITUDE	FIELD OPER.	DATE DD MM YY	TIME HHMM	TRAN. LENG. (M)	AREA SURV. (KM2)	ENVIRONMENTAL CONDITIONS STMP	SAL	BDEP	DNSH	DSB	OBSERVATIONS NAME	NUMBER SEEN	OC	OC
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													SOOTY SHEARWATER	1	20	30
													THICK-BILLED MURRE	1	32	
147	57 51 N	171 36 W	UC1701	10 07 77	0140	4015	1.20	89	325	101	57	80	HORNED PUFFIN	1	32	
													JAEGER (JPO)	1	20	09
													NORTHERN FULMAR	1	20	
													NORTHERN FULMAR	3	20	00
													NORTHERN FULMAR (DARK)	1	32	
													NORTHERN FULMAR (DARK)	2	32	
													NORTHERN FULMAR (DARK)	3	32	
													NORTHERN FULMAR (DARK)	4	32	
													NORTHERN FULMAR (DARK)	4	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	1	32	
													NORTHERN FULMAR (LIGHT)	3	32	
													SOOTY SHEARWATER	2	20	
													TUFTED PUFFIN	2	31	
													TUFTED PUFFIN	2	31	
147	57 52 N	171 39 W	UC1701	10 07 77	0150	4015	1.20	89	325	101	59	80	BLACK-LEGGED KITTIWAKE	1	20	15
													BLACK-LEGGED KITTIWAKE	1	32	
													BLACK-LEGGED KITTIWAKE	1	32	
													JAEGER (JPO)	1	32	
													MURRE SP.	1	20	
													MURRE SP.	2	32	
													NORTHERN FULMAR (DARK)	2	20	27
													NORTHERN FULMAR (DARK)	2	32	
													NORTHERN FULMAR (DARK)	3	20	30
													NORTHERN FULMAR (LIGHT)	1	20	18
													NORTHERN FULMAR (LIGHT)	1	20	30
													NORTHERN FULMAR (LIGHT)	2	01	
													NORTHERN FULMAR (LIGHT)	2	20	30
													SOOTY SHEARWATER	1	20	15
													SOOTY SHEARWATER	2	20	27

KEY FOR ABBREVIATED COLUMN HEADINGS

HEADING	DEFINITION
BLK-LAT-LON	BLOCK NUMBER CORRESPONDING TO BLOCK IDENTIFICATION NUMBER ON ASSOCIATED MAP. EACH NUMBER REPRESENTS A UNIQUE 10' X 10' BLOCK OF AREA. FOR EXAMPLE, THE BLOCK INDICATED BY LATITUDE 57 00 N AND LONGITUDE 169 30 W WILL ENCOMPASS ALL SIGHTINGS WITHIN THE BOUNDARIES OF LATITUDES 57 00 00 N AND 57 09 59 N AND LONGITUDES 169 30 00 W AND 169 39 59 W. A BLOCK NUMBER OF ZERO INDICATES THAT THE AREA IN WHICH THE TRANSECT TOOK PLACE WAS NOT WITHIN THE SPECIFIED BOUNDS. AN ASTERISK NEXT TO THE BLOCK NUMBER INDICATES THAT THE TRANSECT WILL NOT BE USED IN THE CALCULATION OF DENSITIES.
FIELD OPER.	FIELD OPERATION DURING WHICH SIGHTING WAS MADE
DATE	DATE (DD MM YY)
TIME	START TIME OF TRANSECT IN HOURS AND MINUTES
TRAN. LENG. (M)	TRANSECT LENGTH IN METERS
AREA SURV. (KM2)	AREA SURVEYED IN SQUARE KILOMETERS
STMP	SURFACE TEMPERATURE IN TENTHS OF DEGREES CELSIUS
SAL	SURFACE SALINITY IN TENTHS OF PARTS PER THOUSAND
BDEP	BOTTOM DEPTH IN WHOLE METERS
DNSH	DISTANCE TO NEAREST SHORE IN WHOLE NAUTICAL MILES
DSB	DISTANCE TO SHELF BREAK IN WHOLE NAUTICAL MILES
NAME	COMMON NAME OF THE BIRD SIGHTED. IF THE COMMON NAME IS NOT KNOWN, THE SCIENTIFIC NAME WILL BE PRINTED. IF THESE ARE NOT AVAILABLE, THE TWELVE DIGIT TAXONOMIC CODE WILL BE PRINTED.
NUMBER SEEN	NUMBER OF BIRDS ACTUALLY SIGHTED. AN ASTERISK INDICATES THAT THE VALUE WILL NOT BE USED IN THE CALCULATION OF DENSITIES.
BC	BEHAVIOR CODE
DC	DIRECTION OF FLIGHT IN TENS OF DEGREES FROM DUE NORTH IN A CLOCKWISE FASHION

Figure 2

Digital Density Plot

OCSEAP - MAXIMUM, MEAN, AND MINIMUM BIRDS/KM2 FOR ALL TRANSECTS WITHIN EACH 10' X 10' BLOCK

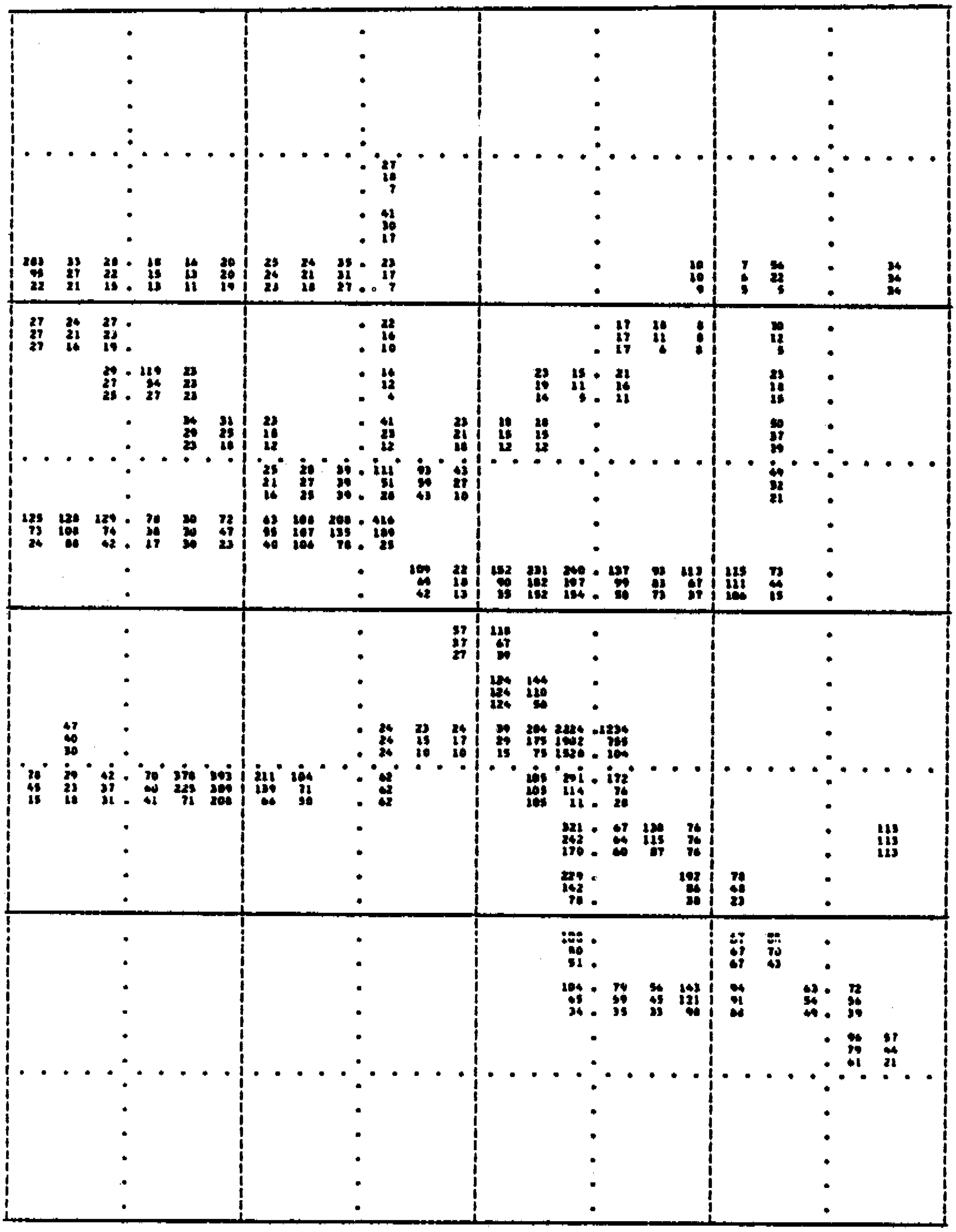
DATA PROJECTS GROUP
PASTORE LABORATORY
UNIVERSITY OF RHODE ISLAND

MC1701 - ALL SPECIES

7 JULY 1977 - 11 JULY 1977

59 N - 172 W

59 N - 168 W



55 N - 172 W

55 N - 168 W

EACH BLOCK CONTAINS THREE VALUES. THE TOP VALUE IS THE MAXIMUM NUMBER OF BIRDS/KM2 FOR ALL TRANSECTS IN THAT BLOCK. THE MIDDLE VALUE IS THE MEAN NUMBER OF BIRDS/KM2 FOR ALL TRANSECTS IN THAT BLOCK. THE BOTTOM VALUE IS THE MINIMUM NUMBER OF BIRDS/KM2 FOR ALL TRANSECTS IN THAT BLOCK. ASTERISKS INDICATE THAT THE NUMBER TO BE PRINTED WAS GREATER THAN 9999. PLUS SIGNS INDICATE THAT, WHILE SIGHTINGS WERE REPORTED IN THAT BLOCK, NO TRANSECT IN THAT BLOCK CONTAINED ALL OF THE DATA REQUIRED FOR THE CALCULATION OF BIRDS/KM2 VALUES.

Figure 3

Block Identification Numbers

OCSEAP - MAXIMUM, MEAN, AND MINIMUM BIRDS/KM2 FOR
ALL TRANSECTS WITHIN EACH 10' X 10' BLOCK

DATA PROJECTS GROUP
PASTORE LABORATORY
UNIVERSITY OF RHODE ISLAND

BLOCK IDENTIFICATION NUMBERS

TOTAL MAP BOUNDARIES - LATITUDES 55 N TO 59 N, LONGITUDES 160 W TO 172 W

59 N - 172 W

59 N - 160 W

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144
145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168
169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192
193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216
217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264
265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288
289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312
313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336
337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360
361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384
385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408
409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432
433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456
457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480
481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504
505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528
529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552
553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576

55 N - 172 W

55 N - 160 W

Contour Plot

Surfaces of constant bird abundance (numbers of individuals) are plotted in this horizontal contour product shown in Figure 4. Abundance data for all sightings at a given point are first summed (i.e. more than one transect could have been made at the same location), and, together with location, are used as input to a horizontal contour analysis program written by Calcomp, Inc. A grid pattern (latitude, longitude) covering the area studied is established, and input location and abundance data are used to determine an abundance at the location corresponding to each grid intersection. From this regular array, contours of constant abundance are determined and drawn.

The user has the option of specifying many of the parameters used in the calculation. These include the upper and lower location bounds, the number of grid subdivisions, the number of nearest neighbor values used in the calculation of abundance at each grid point, the order of the function used to estimate abundance at each grid point, the levels at which contour lines are to be drawn, and the size of the resultant plot. The choice of parameters depends upon the amount and geographical distribution of sightings data. In the example (Figure 4), a twenty by twenty grid, twelve nearest neighbors, third order fit, auto-determination of plot boundaries, and contour lines from zero to nine hundred in increments of one hundred were specified.

Any subset of abundance data may be chosen. Selection may be made, as in the Digital Density Plot, on the basis of species, time, behavior, temperature, or any other observed parameter or combination thereof.

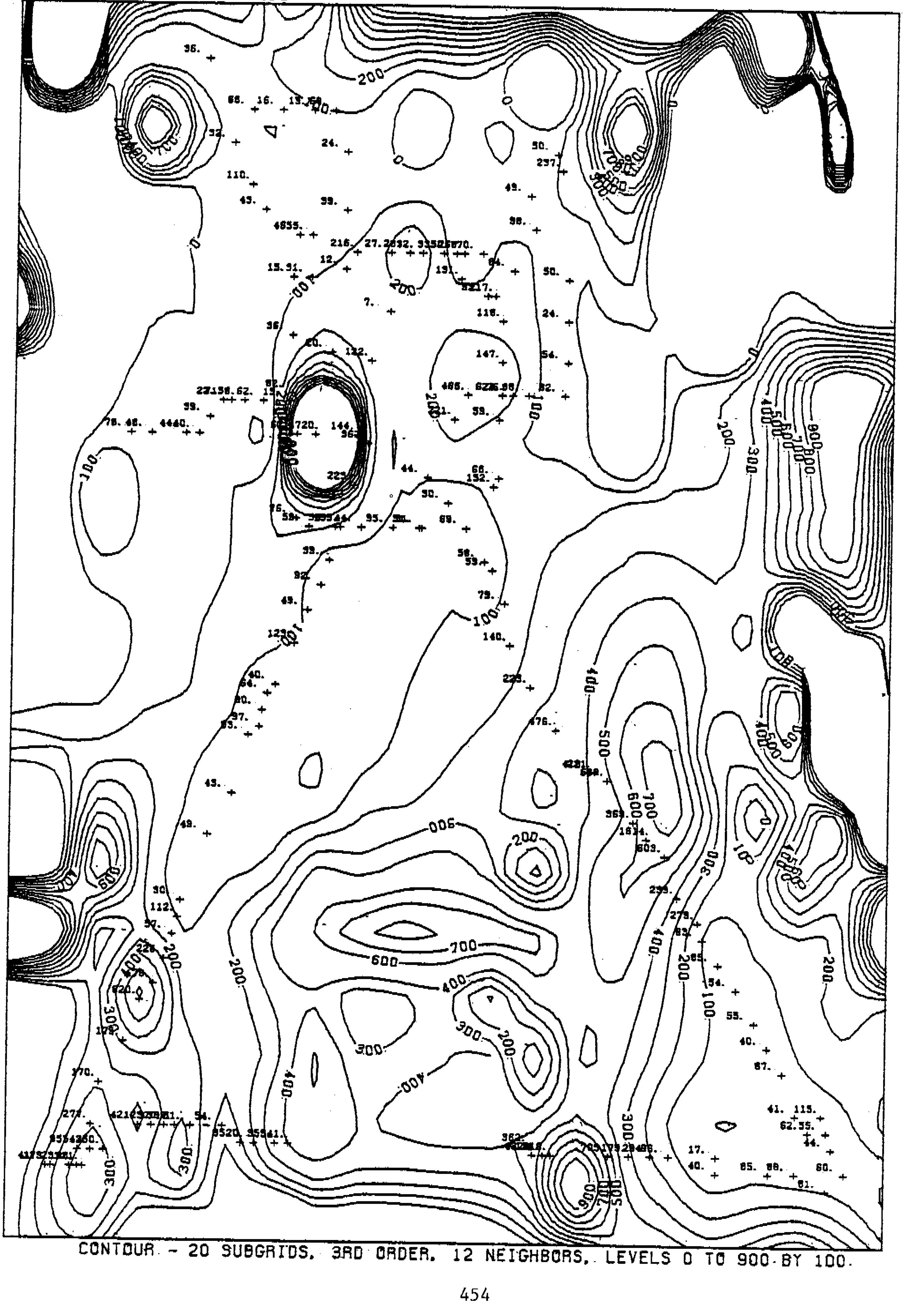
Star Diagram

This analysis produces a map showing bird flight patterns, as shown in Figure 5. The survey area represented is divided into twenty minute by twenty minute blocks. Within each block, abundance data are summed as a function of flight direction in thirty degree intervals. A vector, whose length is proportional to the number of individuals flying in a given direction, is then drawn. A star pattern results when all vectors within a block are drawn from a common origin. The number of individuals represented is recorded just following each vector arrowhead.

Drawn on a twelve inch drum plotter, a convenient map size shows two degrees latitude and any number of degrees longitude. For cases where the area of interest covers more than two degrees latitude, several two degree-wide maps are drawn, and can be aligned to show the total area. The map in Figure 5 covers an area of four degrees latitude by five degrees longitude and is drawn in a Miller projection.

As with other products in this series, the user may select abundance and flight direction data based on a series of criteria which include, for example, species, time, distance from shore, etc., or any combination of parameters.

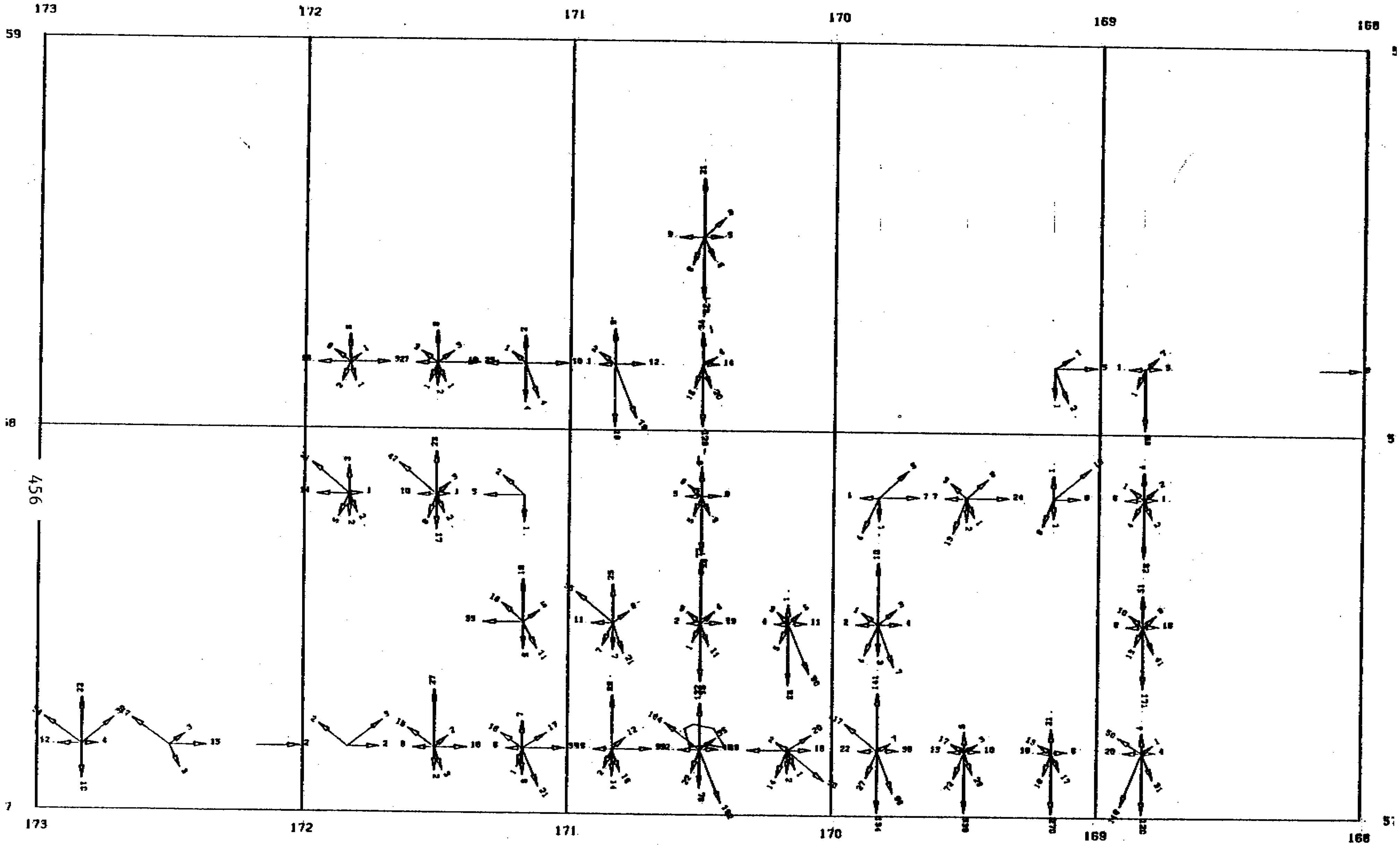
Figure 4 Contour Plot



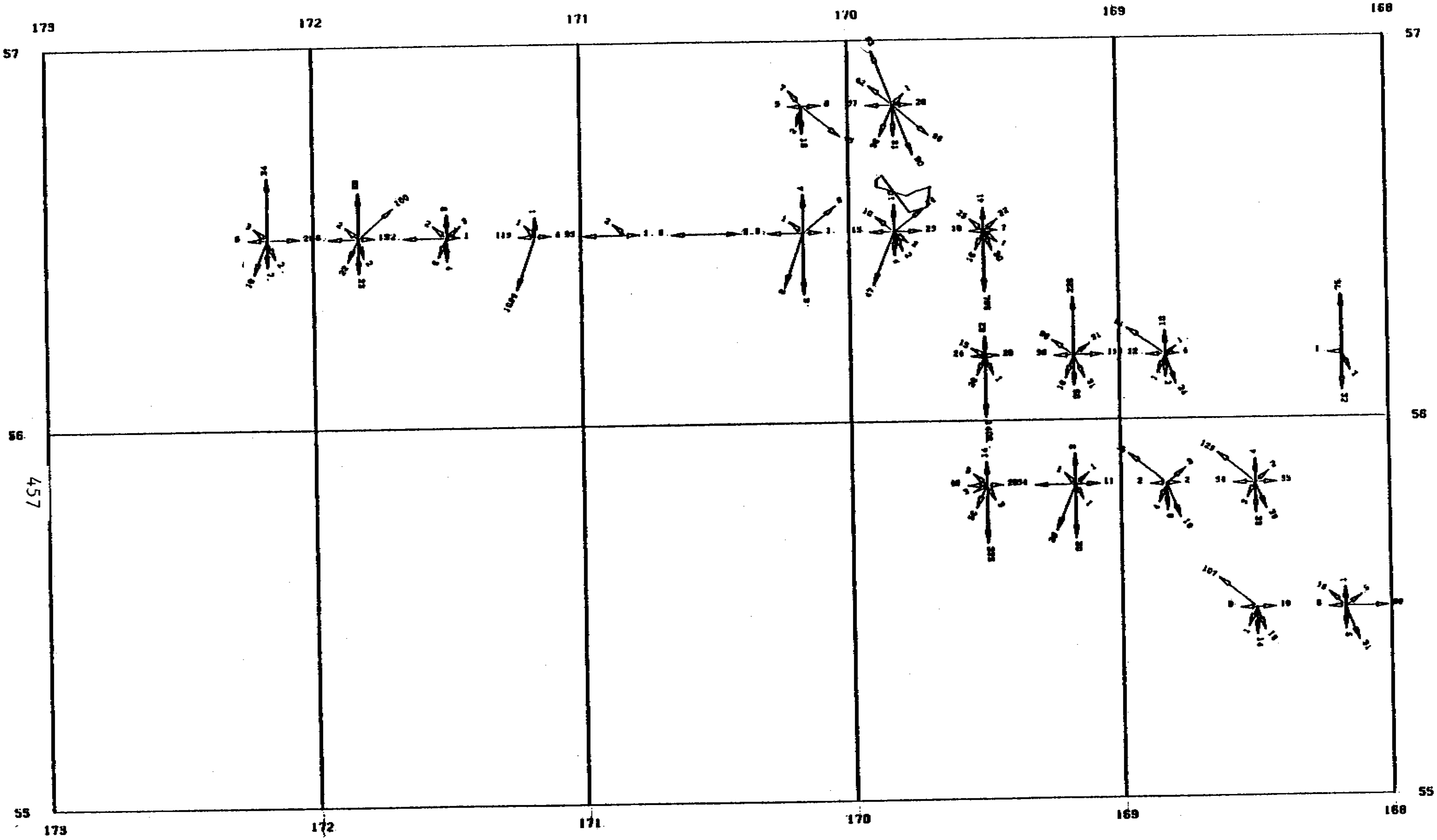
CONTOUR - 20 SUBGRIDS, 3RD ORDER, 12 NEIGHBORS, LEVELS 0 TO 900 BY 100.

Figure 5

Star Diagram



UCI701 STAR DIAGRAM (TOP)



UC1701 STAR DIAGRAM (BOTTOM)

Statistical Analyses

In this product, the interdependence of bird density and physical parameter data (selected according to user criteria) is evaluated through use of selected programs from the Statistical Package for the Social Sciences. Individual sighting data are used vis a vis data summed by region. Three analyses are performed: stepwise multiple regression, factor analysis, and canonical correlation. Sample results are shown in Figure 6.

The stepwise multiple regression routine is used to examine variations in the number of birds per square kilometer (the dependent variable) as a function of variations in sea surface temperature, surface salinity, distance to shelf break, distance to nearest shore, and bottom depth (the independent variables). A linear regression formula is calculated along with a number of other statistics including a table showing which independent variable(s) is (are) the best predictor(s) of the dependent variable.

The factor analysis subroutine attempts to reduce the number of variables required for study by examining the intercorrelations of all variables and indicating a small number of variables which account for most of the variance in all of the variables. The major difference between stepwise multiple regression and factor analysis is that factor analysis does not distinguish between dependent variables and independent variables. Factor analysis does not explain dependent variable variance in terms of independent variable variance. It maximizes the explained variance of all variables available to it.

Canonical correlation analysis takes as input two sets of variables and attempts to account for a maximum amount of relationship between them. This is done by deriving a linear combination from each of the sets of variables in such a way that the correlation between the two linear combinations is maximized. In this case, one set consists of the set of dependent variables (the density per square kilometer) while the other set is comprised of the independent variables as listed in the discussion of the stepwise multiple regression subroutine.

Figure 6

Statistical Analyses

```
STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES SPSSH - RELEASE 6.02

          SPACE ALLOCATION FOR THIS RUN..

              TOTAL AMOUNT REQUESTED                              81920 BYTES


              DEFAULT TRANSPACE ALLOCATION                        10240 BYTES


                 MAX NO OF TRANSFORMATIONS PERMITTED         102
                 MAX NO OF RECODE VALUES                     408
                 MAX NO OF ARITHM.OR LOG.OPERATIONS          816

              RESULTING WORKSPACE ALLOCATION                      71680 BYTES

                    RUN NAME        DENSITY STATISTICS - UCI701 - ALL SPECIES
                    FILE NAME       BIRDSKM2
                    DATA LIST       FIXED BKM2 29-35 STMP 36-39 SAL 41-43 BDEP 45-48
                                    DNSH 50-53 DSB 55-57

THE DATA LIST PROVIDES FOR   6 VARIABLES AND  1 RECORDS ('CARDS') PER CASE. A MAXIMUM OF    57 COLUMNS ARE USED ON A RECORD.

DUMP OF THE CONSTRUCTED FORMAT STATEMENT..
        (28X,F7.0,F4.0,1X,F3.0,1X,F4.0,1X,F4.0,1X,F3.0)

                    INPUT MEDIUM    DISK
                    N OF CASES      UNKNOWN
                    MISSING VALUES  BKM2 STMP SAL BDEP DNSH DSB(-1)
                    VAR LABELS      BKM2 NUMBER OF BIRDS PER SQUARE KILOMETER/
                                    STMP SURFACE TEMPERATURE-TENTHS OF DEGREES C/
                                    SAL SURF SALINITY-TENTHS OF PARTS PER 1000/
                                    BDEP BOTTOM DEPTH IN WHOLE METERS/
                                    DNSH DISTANCE TO NEAREST SHORE-WHOLE NAUT MI/
                                    DSB DISTANCE TO SHELF BREAK-WHOLE NAUT MI/
                    REGRESSION      VARIABLES=BKM2 STMP SAL BDEP DNSH DSB/
                                    REGRESSION=BKM2 WITH STMP SAL BDEP DNSH DSB(1) RESID=0/
                    OPTIONS         2
                    STATISTICS      ALL

 ***** REGRESSION PROBLEM REQUIRES    1248 BYTES WORKSPACE, NOT INCLUDING RESIDUALS *****


                    READ INPUT DATA

AFTER READING    346 CASES FROM SUBFILE BIRDSKM2, END OF FILE WAS ENCOUNTERED ON LOGICAL UNIT # 8
```

```
DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE   BIRDSKM2

VARIABLE            MEAN      STANDARD DEV      CASES

BKM2             90.1121          212.6409        330
STMP             83.8684           10.7593        342
SAL             322.7105            2.9879        342
BDEP            317.7601          635.9427        346
DNSH             37.8435           22.7532        345
DSB              57.5660           41.0020        212





DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE   BIRDSKM2

CORRELATION COEFFICIENTS

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

LOWER TRIANGLE:  CORRELATION COEFFICIENTS
UPPER TRIANGLE:  N OF CASES FOR CORRELATION


                BKM2       STMP        SAL       BDEP       DNSH        DSB

BKM2            330.       326.       326.       330.       329.       196.
STMP        -0.33806       342.       342.       342.       341.       212.
SAL         -0.04003    0.11457       342.       342.       341.       212.
BDEP        -0.05240    0.20940    0.59709       346.       345.       212.
DNSH        -0.29771    0.56311    0.23986    0.27408       345.       212.
DSB         -0.52491    0.07163   -0.64513   -0.55056    0.11347       212.
```

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DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE    BIRDSKM2

* * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * *   VARIABLE LIST  1
DEPENDENT VARIABLE..     BKM2       NUMBER OF BIRDS PER SQUARE KILOMETER                                          REGRESSION LIST  1

VARIABLE(S) ENTERED ON STEP NUMBER  1..     DSB        DISTANCE TO SHELF BREAK-WHOLE NAUT MI


MULTIPLE R            0.52491                        ANALYSIS OF VARIANCE     DF       SUM OF SQUARES        MEAN SQUARE            F
R SQUARE              0.27553                        REGRESSION               1.       2429356.95543       2429356.95543         73.78056
ADJUSTED R SQUARE     0.27179                        RESIDUAL               194.       6387796.74076         32926.78732
STANDARD ERROR      181.45740


----------------- VARIABLES IN THE EQUATION ------------------           ------------ VARIABLES NOT IN THE EQUATION -------------

VARIABLE               B          BETA      STD ERROR B         F          VARIABLE      BETA IN      PARTIAL    TOLERANCE          F

DSB               -2.72222    -0.52491        0.31692        73.781        STMP         -0.30201     -0.35391     0.99487         27.635
(CONSTANT)       246.81947                                                  SAL          -0.64861     -0.58224     0.58381         98.985
                                                                            BDEP         -0.48990     -0.48047     0.69688         57.928
                                                                            DNSH         -0.24126     -0.28162     0.98713         16.625


* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

VARIABLE(S) ENTERED ON STEP NUMBER  2..     SAL        SURF SALINITY-TENTHS OF PARTS PER 1000


MULTIPLE R            0.72189                        ANALYSIS OF VARIANCE     DF       SUM OF SQUARES        MEAN SQUARE            F
R SQUARE              0.52113                        REGRESSION               2.       4594862.79383       2297431.39691        105.01509
ADJUSTED R SQUARE     0.51617                        RESIDUAL               193.       4222290.90236         21877.15493
STANDARD ERROR      147.90928


----------------- VARIABLES IN THE EQUATION ------------------           ------------ VARIABLES NOT IN THE EQUATION -------------

VARIABLE               B          BETA      STD ERROR B         F          VARIABLE      BETA IN      PARTIAL    TOLERANCE          F

DSB               -4.89227    -0.94334        0.33809       209.384        STMP         -0.20637     -0.29076     0.95059         17.731
SAL              -46.15919    -0.64861        4.63953        98.985        BDEP         -0.30923     -0.34517     0.59665         25.969
(CONSTANT)     15267.79751                                                  DNSH         -0.04284     -0.05603     0.81925          0.605
```

```
DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE    BIRDSKM2

* * * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * *   VARIABLE LIST  1
                                                                                                                    REGRESSION LIST  1

DEPENDENT VARIABLE..    BKM2       NUMBER OF BIRDS PER SQUARE KILOMETER

VARIABLE(S) ENTERED ON STEP NUMBER  3..    BDEP       BOTTOM DEPTH IN WHOLE METERS


MULTIPLE R           0.76038                  ANALYSIS OF VARIANCE      DF      SUM OF SQUARES       MEAN SQUARE           F
R SQUARE             0.57818                  REGRESSION                3.      5097903.49787      1699301.16596        87.72355
ADJUSTED R SQUARE    0.57159                  RESIDUAL                192.      3719250.19832        19371.09478
STANDARD ERROR     139.18008


----------------- VARIABLES IN THE EQUATION -----------------          ------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE              B           BETA      STD ERROR B        F          VARIABLE        BETA IN      PARTIAL    TOLERANCE          F

DSB               -5.34652     -1.03093       0.33039       261.867       STMP           -0.15624     -0.22758     0.89494        10.433
SAL              -37.04071     -0.52048       4.71819        61.632       DNSH            0.03861      0.05140     0.74754         0.506
BDEP              -0.10340     -0.30923       0.02029        25.969
(CONSTANT)     12384.17194


* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

VARIABLE(S) ENTERED ON STEP NUMBER  4..    STMP       SURFACE TEMPERATURE-TENTHS OF DEGREES C


MULTIPLE R           0.77461                  ANALYSIS OF VARIANCE      DF      SUM OF SQUARES       MEAN SQUARE           F
R SQUARE             0.60003                  REGRESSION                4.      5290533.55460      1322633.38865        71.63317
ADJUSTED R SQUARE    0.59165                  RESIDUAL                191.      3526620.14159        18463.97980
STANDARD ERROR     135.88223


----------------- VARIABLES IN THE EQUATION -----------------          ------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE              B           BETA      STD ERROR B        F          VARIABLE        BETA IN      PARTIAL    TOLERANCE          F

DSB               -5.07442     -0.97846       0.33338       231.677       DNSH            0.16362      0.19424     0.56372         7.450
SAL              -35.38553     -0.49722       4.63481        58.289
BDEP              -0.08744     -0.26151       0.02042        18.344
STMP              -3.08790     -0.15624       0.95601        10.433
(CONSTANT)     12088.27312
```

```
DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE    BIRDSKM2

* * * * * * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * *   VARIABLE LIST  1
                                                                                                                          REGRESSION LIST  1
DEPENDENT VARIABLE..    BKM2       NUMBER OF BIRDS PER SQUARE KILOMETER

VARIABLE(S) ENTERED ON STEP NUMBER  5..    DNSH       DISTANCE TO NEAREST SHORE-WHOLE NAUT MI


MULTIPLE R          0.78429                        ANALYSIS OF VARIANCE      DF       SUM OF SQUARES        MEAN SQUARE             F
R SQUARE            0.61512                        REGRESSION                 5.      5423594.28389      1084718.85678        60.73169
ADJUSTED R SQUARE   0.60499                        RESIDUAL                 190.      3393559.41230        17860.83901
STANDARD ERROR    133.64445


----------------- VARIABLES IN THE EQUATION ------------------          ------------ VARIABLES NOT IN THE EQUATION -------------

VARIABLE                B          BETA      STD ERROR B        F          VARIABLE      BETA IN     PARTIAL   TOLERANCE           F

DSB              -5.41843     -1.04480        0.35128       237.921
SAL             -39.17153     -0.55042        4.76485        67.584
BDEP             -0.09883     -0.29558        0.02051        23.224
STMP             -4.55343     -0.23040        1.08278        17.685
DNSH              1.52909      0.16362        0.56022         7.450
(CONSTANT)    13398.52211


MAXIMUM STEP REACHED




DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE    BIRDSKM2

* * * * * * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * *   VARIABLE LIST  1
                                                                                                                          REGRESSION LIST  1
DEPENDENT VARIABLE..    BKM2       NUMBER OF BIRDS PER SQUARE KILOMETER

                                                                 SUMMARY TABLE

VARIABLE                                                   MULTIPLE R  R SQUARE  RSQ CHANGE   SIMPLE R              B                 BETA

DSB       DISTANCE TO SHELF BREAK-WHOLE NAUT MI             0.52491    0.27553    0.27553    -0.52491           -5.41843           -1.04480
SAL       SURF SALINITY-TENTHS OF PARTS PER 1000            0.72189    0.52113    0.24560    -0.04003          -39.17153           -0.55042
BDEP      BOTTOM DEPTH IN WHOLE METERS                      0.76038    0.57818    0.05705    -0.05240           -0.09883           -0.29558
STMP      SURFACE TEMPERATURE-TENTHS OF DEGREES C           0.77461    0.60003    0.02185    -0.33806           -4.55343           -0.23040
DNSH      DISTANCE TO NEAREST SHORE-WHOLE NAUT MI           0.78429    0.61512    0.01509    -0.29771            1.52909            0.16362
(CONSTANT)                                                                                                    13398.52211


DENSITY STATISTICS - UCI701 - ALL SPECIES


***** REGRESSION PROBLEM REQUIRES    2352 BYTES WORKSPACE INCLUDING RESIDUALS *****
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DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE    BIRDSKM2

* * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * * * * * * * * * * * *

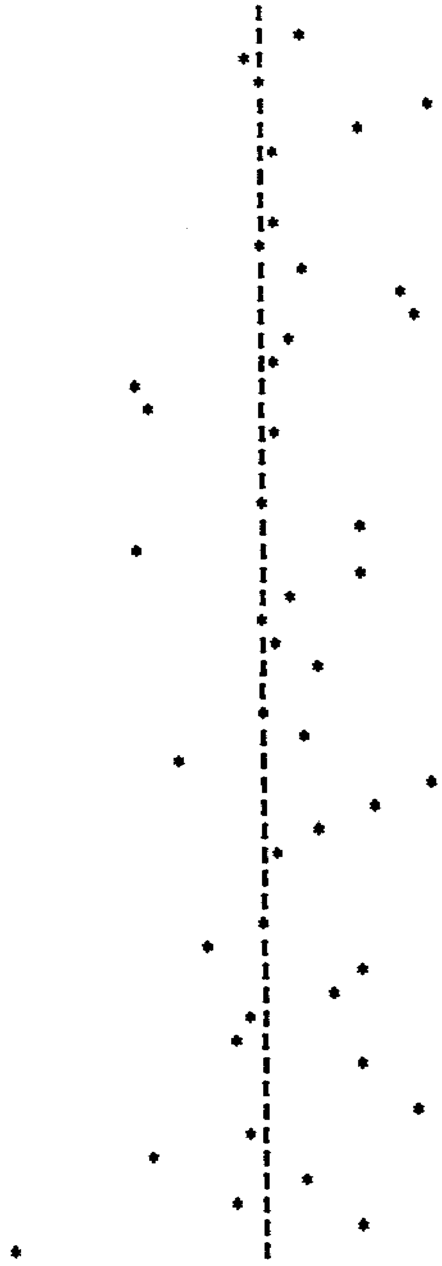
DEPENDENT VARIABLE:   BKM2        FROM    VARIABLE LIST  1
                                         REGRESSION LIST  1

            OBSERVED         PREDICTED                                    PLOT OF STANDARDIZED RESIDUAL
SEQNUM        BKM2              BKM2          RESIDUAL             -2.0      -1.0      0.0        1.0       2.0

     1      MISSING**        -104.4747        MISSING**                                  I
     2      MISSING**        -78.62524        MISSING**                                  I
     3      MISSING**         164.1298        MISSING**                                  I
     4      MISSING**         187.9656        MISSING**                                  I
     5      MISSING**         233.4986        MISSING**                                  I
     6      MISSING**         187.9656        MISSING**                                  I
     7      MISSING**         158.9462        MISSING**                                  I
     8      MISSING**         208.6105        MISSING**                                  I
     9      MISSING**         172.5960        MISSING**                                  I
    10      MISSING**        -92.14255        MISSING**                                  I
    11      MISSING**         147.1793        MISSING**                                  I
    12      MISSING**         183.9331        MISSING**                                  I
    13      MISSING**         190.8806        MISSING**                                  I
    14      MISSING**         166.2951        MISSING**                                  I
    15      MISSING**         213.7837        MISSING**                                  I
    16      MISSING**         227.6787        MISSING**                                  I
    17      4.000000         -26.08493         30.08493                                  I*
    18      5.000000         -4.407610         9.407613                                  *
    19      5.000000          204.4118        -199.4118                         *        I
    20      5.000000          155.0241        -150.0241                           *      I
    21      5.000000          220.1701        -215.1701                        *         I
    22      5.000000         -17.09163         22.09164                                  I*
    23      6.000000         -6.103772         12.10378                                  I*
    24      6.000000         -57.42195         63.42195                                  I  *
    25      7.000000         -.4900329         7.490041                                  *
    26      7.000000          35.82999        -28.82997                                 *I
    27      7.000000         -13.78362         20.78362                                  I*
    28      8.000000         -70.42139         78.42139                                  I   *
    29      9.000000          5.731330         3.268682                                  *
    30      9.000000         -46.37752         55.37753                                  I  *
    31      10.00000          7.288644         2.711360                                  *
    32      10.00000          3.371079         6.628932                                  *
    33      10.00000          171.1689        -161.1689                          *       I
    34      10.00000         -26.85149         36.85149                                  I *
    35      10.00000         -55.06169         65.06171                                  I  *
    36      10.00000          174.3720        -164.3720                          *       I
    37      10.00000         MISSING**        MISSING**                                  I
    38      10.00000         MISSING**        MISSING**                                  I
    39      10.00000         MISSING**        MISSING**                                  I
    40      11.00000         -152.8457         163.8458                                  I        *
    41      11.00000          181.3195        -170.3195                          *       I       *
    42      11.00000         -11.29414         22.29413                                  I*
    43      11.00000         -14.03347         25.03346                                  I*
    44      11.00000         MISSING**        MISSING**                                  I
    45      12.00000         -48.77850         60.77850                                  I   *
```

DENSITY STATISTICS - UC1701 - ALL SPECIES

```
 46      12.00000        MISSING**       MISSING**
 47      12.00000      -49.89636        61.89636
 48      12.00000       31.83252       -19.83250
 49      12.00000       20.86568       -8.865668
 50      13.00000     -239.8423        252.8425
 51      13.00000     -132.1019        145.1021
 52      13.00000       -9.952540       22.95255
 53      13.00000        MISSING**       MISSING**
 54      13.00000        MISSING**       MISSING**
 55      14.00000      -10.52757        24.52757
 56      14.00000       16.84309        -2.843096
 57      14.00000      -57.67503        71.67505
 58      15.00000     -201.5120        216.5120
 59      15.00000     -220.7265        235.7267
 60      15.00000      -18.40508        33.40508
 61      15.00000       -3.801786       18.80179
 62      15.00000      196.0769       -181.8769
 63      15.00000      189.0982       -174.0982
 64      15.00000       -9.279847       24.27985
 65      15.00000        MISSING**       MISSING**
 66      15.00000        MISSING**       MISSING**
 67      15.00000       13.18289         1.817111
 68      16.00000     -140.5786        156.5787
 69      16.00000      203.0836       -187.0836
 70      16.00000     -133.1812        149.1814
 71      16.00000      -24.39240        40.39241
 72      16.00000        6.734532        9.265476
 73      16.00000       -1.044157       17.04414
 74      16.00000      -60.03529        76.03529
 75      16.00000        MISSING**       MISSING**
 76      17.00000       24.16196        -7.161963
 77      17.00000      -49.53455        66.53455
 78      17.00000      149.5784       -132.5784
 79      18.00000     -232.9937        250.9938
 80      18.00000     -161.2328        179.2329
 81      18.00000      -58.04555        76.04555
 82      18.00000        .8465954       17.15341
 83      18.00000        MISSING**       MISSING**
 84      18.00000        MISSING**       MISSING**
 85      18.00000       12.38906         5.610940
 86      18.00000      112.9915        -94.99152
 87      19.00000     -138.9844        157.9846
 88      19.00000      -90.71959       109.7196
 89      19.00000       48.93330       -29.93330
 90      19.00000       62.03159       -43.03159
 91      20.00000     -137.7985        157.7986
 92      20.00000        MISSING**       MISSING**
 93      21.00000     -213.1395        234.1397
 94      21.00000       43.50983       -22.50983
 95      21.00000      200.5225       -179.5225
 96      21.00000      -32.64900        53.64900
 97      21.00000       64.38231       -43.38229
 98      21.00000     -124.2414        145.2416
 99      21.00000      412.9661       -391.9663
```



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DENSITY STATISTICS - UCI701 - ALL SPECIES
   100      22.00000           16.69524       5.304755                                    *
   101      22.00000          -126.5645       148.5647                                    I      *
   102      22.00000          -27.80270       49.80272                                    I *
   103      22.00000           7.565694       14.43431                                    I*
   104      22.00000           MISSING**       MISSING**                                  I
   105      23.00000           27.60034      -4.600342                                    *
   106      23.00000          -124.1055       147.1057                                    I      *
   107      23.00000          -128.7533       151.7533                                    I      *
   108      23.00000          -40.99982       63.99983                                    I  *
   109      23.00000          -132.3502       155.3502                                    I      *
   110      23.00000          -50.07961       73.07962                                    I  *
   111      23.00000         -.1128323E-01    23.01128                                    I*
   112      23.00000           52.82266      -29.82265                                   *I
   113      23.00000          -55.00996       78.00996                                    I   *
   114      23.00000           MISSING**       MISSING**                                  I
   115      23.00000           MISSING**       MISSING**                                  I
   116      23.00000           MISSING**       MISSING**                                  I
   117      23.00000           MISSING**       MISSING**                                  I
   118      23.00000           112.2936      -89.29359                                *   I
   119      23.00000           179.3736      -156.3736                             *      I
   120      24.00000          -136.9334       160.9334                                    I       *
   121      24.00000          -130.1231       154.1232                                    I      *
   122      24.00000           167.9204      -143.9204                             *      I
   123      24.00000           MISSING**       MISSING**                                  I
   124      24.00000           MISSING**       MISSING**                                  I
   125      25.00000          -135.7007       160.7009                                    I       *
   126      25.00000          -140.2170       165.2172                                    I       *
   127      25.00000          -85.99908       110.9991                                    I    *
   128      25.00000           MISSING**       MISSING**                                  I
   129      25.00000           MISSING**       MISSING**                                  I
   130      25.00000           54.87688      -29.87686                                   *I
   131      25.00000           MISSING**       MISSING**                                  I
   132      25.00000           MISSING**       MISSING**                                  I
   133      26.00000           9.469615       16.53040                                    I*
   134      27.00000           14.50207       12.49793                                    I*
   135      27.00000          -173.4999       200.5000                                    I        *
   136      27.00000          -132.4834       159.4834                                    I       *
   137      27.00000          -93.77777       120.7778                                    I     *
   138      27.00000          -45.43399       72.43399                                    I  *
   139      27.00000          -7.030916       34.03091                                    I *
   140      27.00000           MISSING**       MISSING**                                  I
   141      27.00000           MISSING**       MISSING**                                  I
   142      28.00000          -200.1804       228.1806                                    I          *
   143      28.00000          -51.55034       79.55035                                    I   *
   144      28.00000           MISSING**       MISSING**                                  I
   145      28.00000           MISSING**       MISSING**                                  I
   146      28.00000           MISSING**       MISSING**                                  I
   147      28.00000           MISSING**       MISSING**                                  I
   148      28.00000           MISSING**       MISSING**                                  I
   149      28.00000           MISSING**       MISSING**                                  I
   150      29.00000          -74.53198       103.5320                                    I    *
   151      29.00000           32.25186      -3.251859                                    *
   152      29.00000           74.14590      -45.14590                                  * I
   153      30.00000           164.2331      -134.2331                              *     I
```
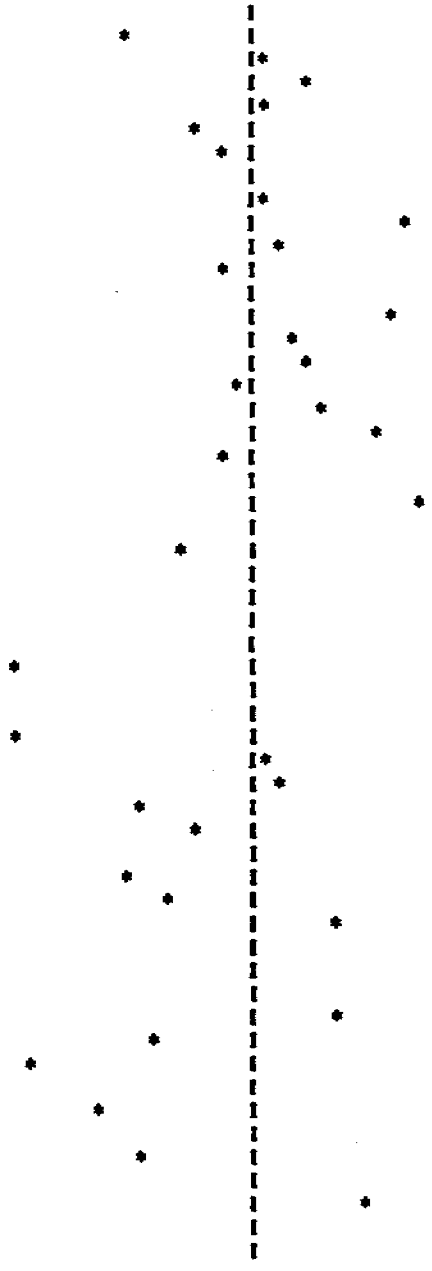

DENSITY STATISTICS - UC1701 - ALL SPECIES

```
 154      30.00000          MISSING**     MISSING**
 155      30.00000        216.2176      -186.2176
 156      31.00000        18.77737       12.22263
 157      31.00000       -52.55087       83.55087
 158      31.00000        5.613432       25.38657
 159      31.00000        120.6479      -89.64795
 160      32.00000        72.62740      -40.62740
 161      32.00000          MISSING**     MISSING**
 162      33.00000        7.109352       25.89064
 163      33.00000       -197.3201       230.3201
 164      33.00000       -5.489330       38.48933
 165      33.00000        77.58894      -44.58894
 166      33.00000          MISSING**     MISSING**
 167      33.00000       -179.1257       212.1259
 168      34.00000       -21.46346       55.46346
 169      34.00000       -52.05060       86.05061
 170      34.00000        51.18520      -17.18520
 171      34.00000       -82.92677       116.9268
 172      35.00000       -162.5643       197.5643
 173      35.00000        83.36543      -48.36543
 174      35.00000          MISSING**     MISSING**
 175      35.00000       -219.6130       254.6131
 176      37.00000          MISSING**     MISSING**
 177      38.00000        147.3676      -109.3676
 178      39.00000          MISSING**     MISSING**
 179      39.00000          MISSING**     MISSING**
 180      39.00000          MISSING**     MISSING**
 181      39.00000          MISSING**     MISSING**
 182      39.00000        391.8127      -352.8127
 183      40.00000          MISSING**     MISSING**
 184      40.00000          MISSING**     MISSING**
 185      40.00000        398.4778      -358.4780
 186      41.00000        30.05943       10.94057
 187      41.00000        7.806608       33.19339
 188      41.00000        210.4822      -169.4822
 189      42.00000        133.4590      -91.45900
 190      42.00000          MISSING**     MISSING**
 191      42.00000        227.6883      -185.6883
 192      42.00000        167.0591      -125.0591
 193      43.00000       -77.59015       120.5902
 194      43.00000          MISSING**     MISSING**
 195      43.00000          MISSING**     MISSING**
 196      43.00000          MISSING**     MISSING**
 197      43.00000       -91.18913       134.1891
 198      43.00000        190.6057      -147.6057
 199      43.00000        388.6560      -345.6560
 200      44.00000          MISSING**     MISSING**
 201      45.00000        288.6812      -243.6814
 202      46.00000          MISSING**     MISSING**
 203      47.00000        207.3574      -160.3574
 204      47.00000          MISSING**     MISSING**
 205      47.00000       -130.2198       177.2200
 206      48.00000          MISSING**     MISSING**
 207      48.00000          MISSING**     MISSING**
```



```
DENSITY STATISTICS - UC1701 - ALL SPECIES
   208      49.00000          75.32753      -26.32753                                   *I
   209      49.00000          92.57436      -43.57436                                  * I
   210      49.00000          256.9497      -207.9458                          *         I
   211      49.00000          303.6765      -254.6767                        *           I
   212      50.00000          92.31514      -42.31514                                  * I
   213      50.00000           MISSING**      MISSING**                                  I
   214      50.00000           MISSING**      MISSING**                                  I
   215      50.00000          333.1328      -283.1328                       *            I
   216      51.00000           MISSING**      MISSING**                                  I
   217      51.00000         -73.61899       124.6190                                    I    *
   218      52.00000          137.8486      -85.84860                                *   I
   219      53.00000         -178.4953       231.4953                                    I         *
   220      54.00000         -215.7237       269.7236                                    I           *
   221      54.00000          303.9790      -249.9793                        *           I
   222      55.00000          160.6330      -105.6330                               *    I
   223      56.00000          210.8623      -154.8623                             *      I
   224      56.00000           MISSING**      MISSING**                                  I
   225      56.00000         -90.25029       146.2503                                    I     *
   226      56.00000          408.0884      -352.0884                   *                I
   227      57.00000           MISSING**      MISSING**                                  I
   228      57.00000           MISSING**      MISSING**                                  I
   229      57.00000          406.5593      -349.5593                    *               I
   230      58.00000           MISSING**      MISSING**                                  I
   231      60.00000           MISSING**      MISSING**                                  I
   232      60.00000           MISSING**      MISSING**                                  I
   233      60.00000         -161.9608       221.9608                                    I        *
   234      61.00000          404.6873      -343.6873                    *               I
   235      62.00000           MISSING**      MISSING**                                  I
   236      62.00000           MISSING**      MISSING**                                  I
   237      63.00000           MISSING**      MISSING**                                  I
   238      63.00000           MISSING**      MISSING**                                  I
   239      63.00000         -221.1420       284.1421                                    I           *
   240      63.00000          305.7463      -242.7466                         *          I
   241      65.00000          358.8489      -293.8491                      *             I
   242      66.00000           MISSING**      MISSING**                                  I
   243      67.00000           MISSING**      MISSING**                                  I
   244      67.00000          275.7507      -208.7508                          *         I
   245      70.00000          163.3331      -93.33310                                *   I
   246      70.00000          273.0964      -203.0966                          *         I
   247      70.00000           MISSING**      MISSING**                                  I
   248      71.00000           MISSING**      MISSING**                                  I
   249      72.00000           MISSING**      MISSING**                                  I
   250      72.00000          121.6749      -49.67493                                  * I
   251      72.00000          265.6240      -193.6241                           *        I
   252      73.00000           MISSING**      MISSING**                                  I
   253      73.00000           MISSING**      MISSING**                                  I
   254      73.00000         -169.7394       242.7395                                    I         *
   255      75.00000           MISSING**      MISSING**                                  I
   256      76.00000          364.7791      -288.7791                      *             I
   257      78.00000           MISSING**      MISSING**                                  I
   258      78.00000           MISSING**      MISSING**                                  I
   259      78.00000          54.59555       23.40445                                    I*
   260      78.00000          323.7598      -245.7600                        *           I
   261      78.00000          195.1289      -117.1289                              *     I
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DENSITY STATISTICS - UC1701 - ALL SPECIES
  262      79.00000       -221.1420      300.1421
  263      83.00000        MISSING**      MISSING**
  264      83.00000       373.4341      -290.4343
  265      84.00000       374.6799      -290.6802
  266      87.00000       414.6011      -327.6011
  267      88.00000       136.6057      -48.60568
  268      88.00000       381.9644      -293.9646
  269      88.00000       54.70021       33.29977
  270      92.00000        MISSING**      MISSING**
  271      92.00000       139.8444      -47.84439
  272      93.00000        MISSING**      MISSING**
  273      93.00000        MISSING**      MISSING**
  274      94.00000      -7.082971       101.0830
  275      96.00000       397.7397      -301.7397
  276      98.00000      -101.0871       199.0872
  277      102.0000        MISSING**      MISSING**
  278      103.0000        MISSING**      MISSING**
  279      104.0000        MISSING**      MISSING**
  280      104.0000        MISSING**      MISSING**
  281      104.0000       321.3994      -217.3997
  282      104.0000      -215.7237       319.7236
  283      105.0000        MISSING**      MISSING**
  284      105.0000        MISSING**      MISSING**
  285      106.0000        MISSING**      MISSING**
  286      106.0000        MISSING**      MISSING**
  287      108.0000        MISSING**      MISSING**
  288      108.0000       258.2700      -150.2701
  289      109.0000        MISSING**      MISSING**
  290      111.0000        MISSING**      MISSING**
  291      113.0000        MISSING**      MISSING**
  292      113.0000        MISSING**      MISSING**
  293      115.0000        MISSING**      MISSING**
  294      117.0000        MISSING**      MISSING**
  295      118.0000        MISSING**      MISSING**
  296      118.0000        MISSING**      MISSING**
  297      119.0000      -76.56133       195.5613
  298      120.0000        MISSING**      MISSING**
  299      124.0000        MISSING**      MISSING**
  300      125.0000       150.3031      -25.30305
  301      128.0000       133.7452      -5.745179
  302      128.0000        MISSING**      MISSING**
  303      129.0000       151.5460      -22.54996
  304      129.0000        MISSING**      MISSING**
  305      137.0000        MISSING**      MISSING**
  306      138.0000       367.1392      -229.1395
  307      140.0000       289.4104      -149.4105
  308      143.0000      -70.39526       213.3953
  309      144.0000        MISSING**      MISSING**
  310      152.0000        MISSING**      MISSING**
  311      152.0000        MISSING**      MISSING**
  312      154.0000        MISSING**      MISSING**
  313      160.0000       328.0662      -168.0665
  314      163.0000        MISSING**      MISSING**
  315      165.0000        MISSING**      MISSING**
```

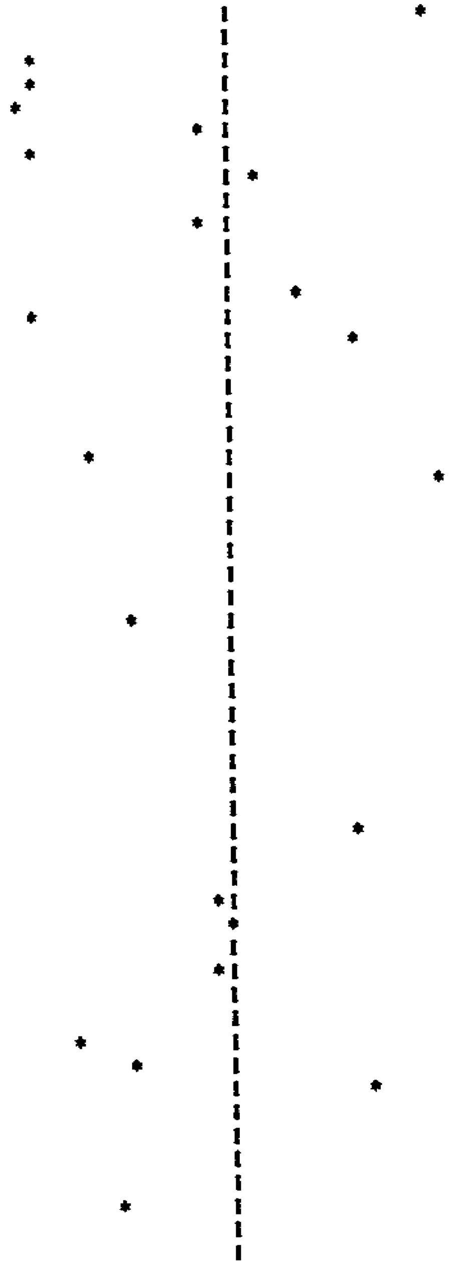

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DENSITY STATISTICS - UC1701 - ALL SPECIES
   316      170.0000           MISSING**      MISSING**                                  I
   317      172.0000           MISSING**      MISSING**                                  I
   318      192.0000          141.3735       50.62651                                    I *
   319      193.0000           MISSING**      MISSING**                                  I
   320      199.0000           MISSING**      MISSING**                                  I
   321      208.0000           MISSING**      MISSING**                                  I
   322      208.0000           MISSING**      MISSING**                                  I
   323      211.0000           MISSING**      MISSING**                                  I
   324      229.0000          321.1841      -92.18434                                *   I
   325      231.0000           MISSING**      MISSING**                                  I
   326      240.0000           MISSING**      MISSING**                                  I
   327      248.0000           MISSING**      MISSING**                                  I
   328      249.0000           MISSING**      MISSING**                                  I
   329      251.0000           MISSING**      MISSING**                                  I
   330      274.0000           MISSING**      MISSING**                                  I
   331      283.0000         -185.6461       468.6460                                    I                     X
   332      284.0000           MISSING**      MISSING**                                  I
   333      291.0000           MISSING**      MISSING**                                  I
   334      305.0000           MISSING**      MISSING**                                  I
   335      321.0000          275.5154       45.48448                                    I *
   336      325.0000           MISSING**      MISSING**                                  I
   337      378.0000           MISSING**      MISSING**                                  I
   338      393.0000           MISSING**      MISSING**                                  I
   339      416.0000           MISSING**      MISSING**                                  I
   340      568.0000           MISSING**      MISSING**                                  I
   341      798.0000           MISSING**      MISSING**                                  I
   342      1072.000           MISSING**      MISSING**                                  I
   343      1234.000           MISSING**      MISSING**                                  I
   344      1520.000           MISSING**      MISSING**                                  I
   345      1961.000           MISSING**      MISSING**                                  I
   346      2224.000           MISSING**      MISSING**                                  I


DURBIN-WATSON TEST OF RESIDUAL DIFFERENCES COMPARED BY CASE ORDER (SEQNUM).

VARIABLE LIST   1, REGRESSION LIST   1.    DURBIN-WATSON TEST    1.93555
```

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DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE   BIRDSKM2

* * * * * * *  PLOT:  STANDARDIZED RESIDUAL (DOWN) -- PREDICTED STANDARDIZED DEPENDENT VARIABLE (ACROSS)  * * * * * * *

DEPENDENT VARIABLE:  BKM2        VARIABLE LIST  1
                               REGRESSION LIST  1

      -2.0      -1.0       0.0       1.0       2.0
     .YX+---------+---------+---------+---------+XY.
     Y                      I                      Y
     X         *            I                      X
 2.0 +                      I                      +
     I                      I                      I
     I                      I                      I
     I                      I                      I
     I                      I                      I
     I        *             I                      I
     I       *              I                      I
     I       **             I                      I
     I      *2              I                      I
     I       *3**           I                      I
 1.0 +        ***   *       I                      +
     I          2  **       I                      I
     I          *42         I                      I
     I           47 *       I                      I
     I             22       I                      I
     I             *3  *    I                      I
     I              *6      I                      I
     I               74*    I                      I
     I                232 * I *      *             I
     I                 992* I                      I
-0.0 +------------------86--I-*--------------------+
     I                   25*I  2                   I
     I                     53*2                    I
     I                      I                      I
     I                      I32*       *           I
     I                      I  2                   I
     I                      I  2**                 I
     I                      I  *2** **             I
     I                      I   322    *           I
     I                      I    32 *              I
-1.0 +                      I     * *2 *           +
     I                      I        **  *         I
     I                      I         2*           I
     I                      I          *           I
     I                      I            42        I
     I                      I              *       I
     I                      I             *2       I
     I                      I             *2       I
     I                      I              *       I
     I                      I                      I
-2.0 +                      I                      +
     X                      I                      X
     Y                      I                      Y
     .YX+---------+---------+---------+---------+XY.
      -2.0      -1.0       0.0       1.0       2.0

ROWS,COLUMNS Y:  VALUES OUTSIDE (-3.0,3.0)       ROWS,COLUMNS X:  VALUES IN (-3.0,-2.05) OR (2.05,3.0)
```

```
DENSITY STATISTICS - UCI701 - ALL SPECIES

          DATA TRANSFORMATION DONE UP TO THIS POINT..

                 NO OF TRANSFORMATIONS                0
                 NO OF RECODE VALUES                  0
                 NO OF ARITHM. OR LOG. OPERATIONS     0
          THE AMOUNT OF TRANSPACE REQUIRED IS       0 BYTES



                    FACTOR          VARIABLES=BKM2 STMP SAL BDEP DNSH DSB/
                                    ROTATE=VARIMAX/
                    OPTIONS         2
                    STATISTICS      4,5,6,7,8

 ***** FACTOR PROBLEM REQUIRES    672 BYTES WORKSPACE *****




DENSITY STATISTICS - UCI701 - ALL SPECIES


  1.VARIABLE LIST

VARIABLES..         LABELS..

BKM2                NUMBER OF BIRDS PER SQUARE KILOMETER
STMP                SURFACE TEMPERATURE-TENTHS OF DEGREES C
SAL                 SURF SALINITY-TENTHS OF PARTS PER 1000
BDEP                BOTTOM DEPTH IN WHOLE METERS
DNSH                DISTANCE TO NEAREST SHORE-WHOLE NAUT MI
DSB                 DISTANCE TO SHELF BREAK-WHOLE NAUT MI


DETERMINANT OF CORRELATION MATRIX =  0.0603547( 0.60354657D-01)
```

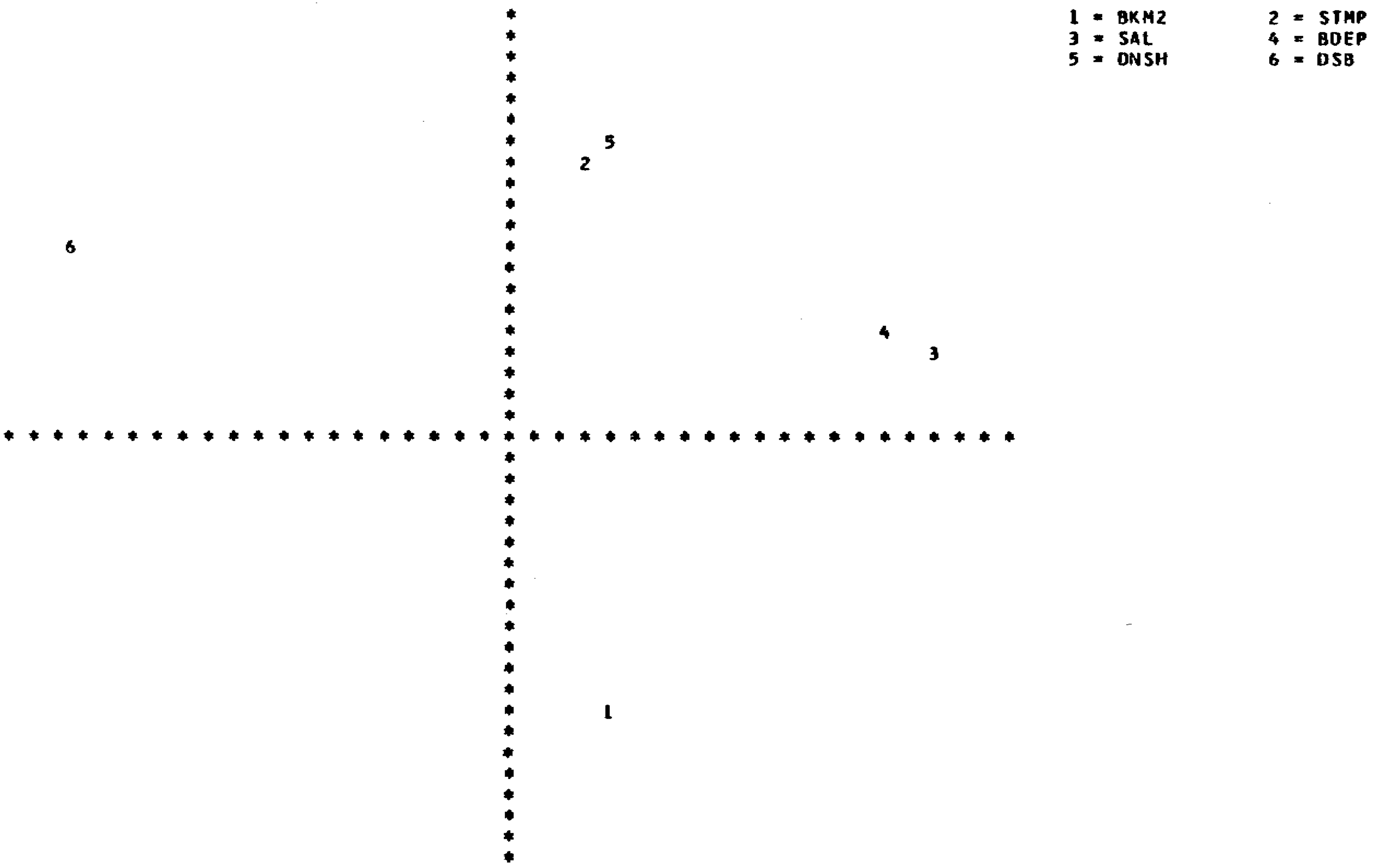
```
DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE   BIRDSKM2



VARIABLE   EST COMMUNALITY                          FACTOR         EIGENVALUE   PCT OF VAR   CUM PCT

BKM2              0.61514                              1             2.35215       39.2        39.2
STMP              0.38644                              2             1.97542       32.9        72.1
SAL               0.70256                              3             0.75248       12.5        84.7
BDEP              0.52930                              4             0.45833        7.6        92.3
DNSH              0.46716                              5             0.35571        5.9        98.2
DSB               0.80418                              6             0.10588        1.8       100.0
  AFTER  5 ITERATIONS COMMUNALITY OF ONE OR MORE VARIABLES EXCEEDED 1.0, PA2 FACTORING TERMINATED AT ITERATION #  4
```

```
DENSITY STATISTICS - UCI70L - ALL SPECIES

FILE   BIRDSKM2

FACTOR MATRIX USING PRINCIPAL FACTOR WITH ITERATICNS



                FACTOR  1   FACTOR  2

BKM2             0.16476    -0.62798
STMP             0.15749     0.62349
SAL              0.80999     0.13677
BDEP             0.73439     0.20006
DNSH             0.22353     0.67371
DSB             -0.88093     0.45751



VARIABLE        COMMUNALITY                         FACTOR         EIGENVALUE   PCT OF VAR   CUM PCT

BKM2              0.42151                              1             2.07337       57.9        57.9
STMP              0.41354                              2             1.50502       42.1       100.0
SAL               0.67479
BDEP              0.57936
DNSH              0.50385
DSB               0.98535
```

```
DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE   BIRDSKM2

      VARIMAX ROTATED FACTOR MATRIX



                FACTOR  1   FACTOR  2

BKM2             0.18803    -0.62141
STMP             0.13416     0.62892
SAL              0.80433     0.16685
BDEP             0.72643     0.22727
DNSH             0.19828     0.68157
DSB             -0.89736     0.42437



TRANSFORMATION MATRIX


                FACTOR  1   FACTOR  2

FACTOR  1        0.99931     0.03725
FACTOR  2       -0.03725     0.99931
```

```
DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE   BIRDSKM2

FACTOR SCORE COEFFICIENTS



                FACTOR  1   FACTOR  2

BKM2            -0.27101     0.01472
STMP            -0.03013     0.34586
SAL              0.03262     0.42173
BDEP             0.09556     0.26524
DNSH             0.21189     0.21687
DSB             -0.98754     0.80469
```

```
DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE   BIRDSKM2

                 HORIZONTAL FACTOR  1     VERTICAL FACTOR  2
```



```
DENSITY STATISTICS - UCI701 - ALL SPECIES



                    CANCORR         VARIABLES=BKM2 STMP SAL BDEP DNSH DSB/
                                    RELATE=BKM2 WITH STMP SAL BDEP DNSH DSB/
                    OPTIONS         2
                    STATISTICS      3,4

 ***** CANONICAL CORRELATION PROBLEM REQUIRES   1840 BYTES WORKSPACE *****






DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE   BIRDSKM2


CORRELATION COEFFICIENTS

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.


              BKM2         STMP         SAL          BDEP         DNSH         DSB

BKM2        1.00000     -0.33806     -0.04003     -0.05240     -0.29771     -0.52491
STMP       -0.33806      1.00000      0.11457      0.20940      0.56311      0.07163
SAL        -0.04003      0.11457      1.00000      0.59709      0.23986     -0.64513
BDEP       -0.05240      0.20940      0.59709      1.00000      0.27408     -0.55057
DNSH       -0.29771      0.56311      0.23986      0.27408      1.00000      0.11347
DSB        -0.52491      0.07163     -0.64513     -0.55057      0.11347      1.00000
```

```
DENSITY STATISTICS - UCI701 - ALL SPECIES

FILE   BIRDSKM2

- - - - - - - - - - - - - - - -   C A N O N I C A L   C O R R E L A T I O N   - - - - - - - - - -  RELATE LIST  1


      NUMBER        EIGENVALUE         CANONICAL          WILK S        CHI-SQUARE        D.F.     SIGNIFICANCE
                                      CORRELATION         LAMBDA

        1             0.61512           0.78430          0.38488        183.80301          5          0.0


COEFFICIENTS FOR CANONICAL VARIABLES OF THE SECOND SET


                CANVAR  1

STMP           -0.29376
SAL            -0.70180
BDEP           -0.37688
DNSH            0.20862
DSB            -1.33215


COEFFICIENTS FOR CANONICAL VARIABLES OF THE FIRST  SET


                CANVAR  1

BKM2            1.00000
```

QUALITY ASSURANCE PROGRAM

FOR

TRACE PETROLEUM COMPONENT ANALYSIS

by

William D. MacLeod, Jr.*

Donald W. Brown*

Margaret M. Krahn

Patty Prohaska

Donald Gennero

Submitted as the Annual Report
for Contract #R7120826
Research Unit #557
OUTER CONTINENTAL SHELF ENVIRONMENTAL ASSESSMENT PROGRAM
Sponsored by
U.S. Department of the Interior
Bureau of Land Management

April 1979

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I. SUMMARY OF OBJECTIVES, CONCLUSIONS, AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

A. SUMMARY OF OBJECTIVES

The objectives are to coordinate and conduct an analytical quality-assurance program that compares results among Principal Investigators (PI's) within the OCSEAP program, as well as between OCSEAP and other BLM-funded investigators, and to recommend procedural modifications for improved analytical techniques, particularly those dealing with polar organic compounds associated with petroleum.

B. SUMMARY OF CONCLUSIONS

We conclude that:

1. Our new hydrocarbon extraction procedure for marine sediment, using a ball-mill tumbler at ambient temperature, is useful for processing large numbers of samples.
2. Intralaboratory hydrocarbon analyses of the OCSEAP Interim Reference Material (sediment) using three traditional boiling-solvent extraction methods and our latest ball-mill extraction method gave comparable results, within experimental uncertainties (1σ).
3. The Interim Reference Material (sediment) prepared by OCSEAP was sufficiently homogeneous to be distributed to collaborating BLM/OCS PI's for interlaboratory calibration investigations.
4. Polar organic compounds related to petroleum can be effectively prepared for gas chromatographic (GC) or high-pressure liquid chromatographic (HPLC) analysis by a combination of adsorption and gel permeation liquid chromatography (LC).

C. SUMMARY OF IMPLICATIONS

The developments reported herein contribute to an understanding of analytical methodology for hydrocarbons and other petroleum-related compounds in marine environmental samples.

II. INTRODUCTION

A. GENERAL NATURE AND SCOPE OF STUDY

A quality-assurance program for chemical analyses of petroleum components among BLM/OCS environmental studies is an objective of the BLM/OCS and OCSEAP programs. To this end, OCSEAP prepared an Interim Reference Material (IRM) from a harbor sediment known to be contaminated with aliphatic and aromatic hydrocarbons. To characterize this IRM sediment and establish suitable criteria of homogeneity, we analyzed more than 30 100-g portions, using both traditional and new extraction procedures for hydrocarbons.

Most hydrocarbon extractions from sediment depend on solvent reflux which poses difficulties for routine processing of large numbers of samples. As an alternative, we devised an ambient-temperature, solvent extraction using a ball-mill tumbler. We compared our new procedure with three boiling-solvent extraction procedures. Aliphatic and aromatic hydrocarbons from the IRM sediment were quantitated by glass capillary GC analysis. After the sediment was dewatered with methanol, the tumbler extraction with 2:1 dichloromethane: methanol gave hydrocarbon yields comparable to the boiling-solvent extractions. A large number of samples can be routinely processed by this new method.

Once the IRM sediment met satisfactory homogeneity criteria by these analyses, we distributed six 100-g portions to each of 14 BLM/OCS PI's (see Appendix I) for interlaboratory analyses. When the PI's have completed the reports of their analyses, we will collate the analytical data and place them in a statistical context for the OCSEAP/BLM program.

B. SPECIFIC OBJECTIVES

1. Evaluation of existing methods and development of new methods to analyze hydrocarbons and petroleum-related polar compounds in environmental samples. Recommendation of procedural modifications and improvements to OCSEAP/BLM.
2. Distribution of interim intercalibration reference materials to PI's for heavy hydrocarbon analysis.
3. Tabulation of analytical results of reference material reported by collaborating laboratories for OCSEAP/BLM.
4. Submission to OCSEAP/BLM of data on the chemical composition of two typical Alaskan crude oils, one from Prudhoe Bay and the other from Cook Inlet.

C. RELEVANCE TO PROBLEMS OF PETROLEUM DEVELOPMENT

OCSEAP and BLM have regarded analyses of environmental samples for hydrocarbons as essential to their environmental studies pertaining to petroleum development on the outer continental shelf (OCS). Effective measurement of hydrocarbons in marine sediments requires standardized extraction procedures that are efficient and reproducible. Hence, our studies comparing existing state-of-art methodology with new methodology provides valuable information on this technology. Once the major procedures were interrelated statistically, using the IRM as test sample, the way was paved for interlaboratory calibration efforts. If most of these laboratories report back analytical data on most of these hydrocarbons, along with typical blank analyses, it should be possible to make useful statistical statements about the quality assurance of OCS hydrocarbon analyses.

Petroleum also contains many organic compounds more polar than hydrocarbons. Analytical methodology to extract and analyze toxic polar organics at trace levels remains largely unexplored with respect to samples from the marine environment. Hence, establishment of efficient, statistically-proven, ultra-sensitive analytical procedures for these compounds is important to the OCS program.

III. CURRENT STATE OF KNOWLEDGE

Concern over oil pollution has led to considerable interest in measuring amounts of hydrocarbons in the marine environment (Clark and Brown 1977). A number of researchers have developed specialized procedures for analyzing hydrocarbons in marine sediments (Rohrback and Reed 1975; Hilpert et al. 1978; Farrington and Tripp 1975; MacLeod et al. 1977a,b; Warner 1976; Carpenter and Bates 1977; Clark and Finley 1973; Chesler et al. 1976; Quinn 1978; and Shaw 1977). Because the various procedures have not been adequately assessed (Rohrback and Reed 1975; Hilpert et al. 1978), interpretations of analytical data from these analyses have been difficult, especially for individual aliphatic and aromatic hydrocarbons. To help overcome such deficiencies, it is desirable to compare important analytical methods for hydrocarbons in marine sediment using a representative set of individual hydrocarbons. Clearly, the extraction techniques compared should be reproducible, accurate, and efficient within meaningful limits. In addition, these techniques need to be safe and convenient for processing large numbers of samples.

Soxhlet extraction with benzene and methanol (Rohrback and Reed 1975; Farrington and Tripp 1975; Carpenter and Bates 1977; Clark and Finley 1973; and Shaw 1977) is generally considered the most efficient technique for hydrocarbon recovery. However, it may not be convenient for processing large numbers of samples (MacLeod et al.1977a,b). Recently, alternative techniques have been reported that may be as efficient as Soxhlet extraction. For example, Farrington and Tripp (1975) showed that sediment refluxed for three hours with benzene and methanol yielded about the same gross weight of hydrocarbons as did the Soxhlet extraction technique. Similarly, Rohrback and Reed (1975) reported that by shaking sediment with various solvents, they extracted almost the same weight of hydrocarbons as they did by Soxhlet extraction with the same solvents. However, MacLeod et al. (1977a) found that shaking often produced stable emulsions. To avoid emulsions, Warner (1976) suggested extracting sediments with diethyl ether/water, using a ball-mill tumbler. This approach reduced emulsion formation and was convenient for mass sample processing (MacLeod et al. 1977a,b), but Carpenter and Bates (1977) found that this technique generally extracted only about one-third the amount of hydrocarbons extracted by the conventional Soxhlet technique.

During the course of our evaluat on of existing methodology for analyzing hydrocarbons from marine sediments, Brown et al. (1979a,b) developed a new hydrocarbon extraction procedure that uses methanol and dichloromethane with a ball-mill tumbler. The extraction efficiency is generally comparable to traditional boiling-solvent methods.

IV. STUDY AREA

Nonspecific.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Set forth in Appendix II (excerpts of Brown et al. 1979b) and in Appendix III (excerpt of MacLeod et al. 1977a).

VI. RESULTS

Details of a new procedure for extracting hydrocarbons from marine sediments are described in the excerpts (Appendix II) of Brown et al. (1979b) accepted by the American Chemical Society. Appendix II also contains the results of our intralaboratory comparison of our ambient-temperature procedure with three boiling-solvent procedures. Two of the boiling-solvent procedures are analogous to those recommended by BLM in its OCS environmental research contracts.

The comparison of interlaboratory analyses by collaborating OCS PI's is necessarily incomplete because only five of fourteen PI's have reported their analyses of the IRM sediment (see Appendix I).

Our laboratory has performed several analyses of samples of Prudhoe Bay crude oil. Although the results varied somewhat from sample to sample, the results listed in Table 1 are typical.

TABLE 1. Organic composition of Prudhoe Bay crude oil used in research

Saturated compounds[a]	Wt %
n-paraffins	4.0
Pristane	0.18
Phytane	0.14
Unresolved components	44.6
	48.9

Major oil fractions[b]	Wt %
Naphtha (to 210°C)	18.6[c]
Saturates	48.9
Aromatics	19.4
Polars	13.8
Insolubles	1.4
	102.1

n-Paraffin distribution[a]	Wt %
n-C_{10}	0.03
n-C_{11}	0.08
n-C_{12}	0.15
n-C_{13}	0.21
n-C_{14}	0.27
n-C_{15}	0.30
n-C_{16}	0.28
n-C_{17}	0.28
n-C_{18}	0.25
n-C_{19}	0.25
n-C_{20}	0.23
n-C_{21}	0.23
n-C_{22}	0.22
n-C_{23}	0.20
n-C_{24}	0.18
n-C_{25}	0.16
n-C_{26}	0.13
n-C_{27}	0.11
n-C_{28}	0.08
n-C_{29}	0.04
	4.0

Aromatic Compounds[a]	Wt %
Benzenes	0.24
Indans/Tetralins	0.04
Naphthalenes	1.11
Biphenyls/Acenaphthenes	0.25
Fluorenes	0.29
Phenanthrenes/Anthracenes	0.34
Pyrenes/Fluoranthenes	0.05
Chrysenes/Benzanthracenes	0.01
Benzpyrenes/Perylenes	0.00
Benzothiophenes	0.00
Dibenzothiophenes	0.59
Unresolved components	16.49
	19.4

---

[a] Determined by capillary gas chromatography.

[b] Determined gravimetrically.

[c] Naphtha fraction includes low-boiling saturates and aromatics, which are not determined by gas chromatography.

The proportion of isoparaffins and cycloparaffins were calculated from the difference between the amount of n-paraffins in the total saturates fraction and the total proportion of saturates in the oil. The analysis of aromatic hydrocarbons revealed naphthalenes as the major components with decreasing proportions of phenanthrenes and anthracenes, dibenzothiophenes, benzenes, fluorenes, and biphenyls and acenaphthenes.

VIII. DISCUSSION

A. BALL-MILL TUMBLER EXTRACTION

To avoid unnecessary cost, inconvenience, and hazards in extracting large numbers of sediment samples with boiling solvents (MacLeod et al. 1977a), we investigated alternative procedures. Ideally, a suitable procedure should extract efficiently and reproducibly, and be simple, safe, and convenient. In particular, we needed a method that (a) used minimal benchtop or hood space, (b) could function at ambient temperature, (c) avoided freeze-drying, and (d) avoided benzene, a suspected carcinogen. After more than a year's experience with solvent-slurry extractions of sediments using a ball-mill tumbler (MacLeod et al.1977a,b),we devised a procedure using methanol and dichloromethane that largely met these criteria (Brown et al. 1979a,b).

In developing this tumbling extraction procedure, a number of solvent systems were investigated. Comparison of these tumbler solvent systems showed that if methanol was one of the solvents, hydrocarbon extraction efficiencies were 2-3 times better than without it, irrespective of the less polar co-solvent used. Dichloromethane was chosen as the co-solvent over diethyl ether or benzene because it is safer.

To optimize our tumbler method, we tested various ratios of dichloromethane to methanol at various solvent to IRM sediment ratios. When dichloromethane:methanol ratios were between 2:1 and 1:2, extraction efficiencies approximated those achieved by benzene/methanol Soxhlet extraction. Since a higher ratio of dichloromethane to methanol simplifies subsequent extract workup, a 2:1 ratio was chosen. Further study showed that when less than 100 mL of 2:1 dichloromethane:methanol were used to extract a 100-g sample of IRM sediment, extraction efficiencies decreased.

Samples that had a substantial aqueous phase floating on the dichloromethane/methanol during extraction also gave lower hydrocarbon yields. To minimize this effect, sediments were dewatered by swirling briefly with methanol twice before extracting with 2:1 dichloromethane:methanol. It is important that the methanol from the dewatering steps be combined with the subsequent dichloromethane/methanol extracts before further contact with water to avoid erratic hydrocarbon recoveries.

B. COMPARISON OF EXTRACTION METHODS

Preliminary analytical results (Brown et al. 1979a) indicated that our ambient-temperature tumbler sediment extraction was about as efficient for hydrocarbon recoveries as Soxhlet extraction. To test the tumbler extraction performance more completely, we have compared it with (a) an alkaline methanol reflux extraction (Quinn 1978), (b) a 1:1 benzene:methanol Soxhlet extraction (Clark and Finley 1973), and (c) a 2:1 dichloromethane:methanol (azeotrope 7.6:1) Soxhlet extraction (Brown et al. 1979b), using replicate analyses of the IRM sediment.

Within the experimental uncertainties (1σ), the tumbler method compared favorably with the Soxhlet extractions in the C_{13}-C_{26} alkanes; the Soxhlet extractions were generally more efficient in the C_{27}-C_{31} range. Soxhlet extraction with dichloromethane/methanol gave the least reproducible results. Usually, direct reflux extraction was least efficient, but most reproducible for both alkanes and aromatics. Recoveries for the higher polynuclear aromatics were generally greatest by benzene/methanol Soxhlet extraction. Again, dichloromethane/methanol Soxhlet extraction gave the least reproducible results.

C. POLAR COMPOUNDS

Efforts were directed toward developing efficient and reproducible trace analyses of polar petroleum-related organic compounds from marine environmental samples. We have investigated the following techniques for isolation and for analysis of oxygenated compounds:

- Silica-gel adsorption LC to separate oxygenated compounds from hydrocarbons;
- Gel-permeation LC using Sephadex LH-20 and Biobeads SX to separate weak acids (phenolics and fatty acids) from lipid;
- Reversed-phase HPLC to separate polar metabolites from parent aromatic hydrocarbons; polar compounds detected by UV absorbance, or fluorescence, or both.
- Chemical ionization mass spectrometry to identify labile, nonvolatile metabolites such as the glucoside of naphthol.

Progress on these techniques has been promising to date, and we will continue to study their proper deployment.

D. ANALYSIS OF ALASKAN CRUDE OILS

Preliminary data on Prudhoe Bay crude oil composition is presented in Table 1. We have performed other analyses on other samples of Prudhoe Bay crude oil that indicate these results may be considered typical, considering all the variables that affect the composition. For example, a crude oil may differ in composition within the barrel. Also, its composition can change after the barrel has been opened, or during the lifetime of its use from a given barrel. Finally, there is the change in composition of crude oil throughout a given oil field or even from a given well over a period of time. Under these constraints, the other analyses of Prudhoe Bay crude oil generally agree well (within ± 50%) with the analysis given in Table 1. As our analytical techniques become more sensitive and reliable we will reexamine Prudhoe Bay crude oil composition, extending the number of compounds analyzed, where possible. Upper Cook Inlet crude oil will be analyzed similarly.

VIII. CONCLUSIONS

A. Our ball-mill tumbler procedure generally can extract hydrocarbons from a marine sediment as efficiently as boiling-solvent methods.

B. Dewatering with methanol prior to extraction obviated the need for freeze-drying.

C. Soxhlet extraction with dichloromethane/methanol gave greatest, but least reproducible, yields of hydrocarbons.

D. Direct reflux extraction with KOH/methanol gave lowest, but most reproducible, yields of hydrocarbons.

E. Preliminary evidence suggests that among the OCS PI's, the most accurate and reproducible analytical results were obtained on the highest resolution GC columns, i.e., glass capillaries. Next were those using the support-coated, open-tubular (SCOT) GC columns. Least accurate and reproducible results appear from packed GC columns.

F. A combination of chromatographic and spectroscopic methods is necessary to separate and analyze polar organic compounds related to petroleum from marine environmental samples. Sequential use of adsorption and gel-permeation LC is useful in preparing extracts from marine environmental samples for analysis by GC/MS or HPLC/MS.

G. Conjugated metabolites of aromatic hydrocarbons can be identified using chemical ionization mass spectroscopy with a direct probe.

IX. SUMMARY OF THE 4TH QUARTER

A. ACTIVITIES

Last year, six 100-g portions of the IRM sediment were sent to each of fourteen OCS PI's. During this quarter Dr. James Payne, S.A.I., Inc., and Prof. I.R. Kaplan, UCLA, reported results of their analyses of this sediment. In total, only five of the PI's have reported results (see Appendix I).

Efforts continued on the development of methods for the analyses of petroleum-related polar compounds. In a seminar at the Center on February 21, Dr. Margaret M. Krahn of our staff delineated current capabilities for HPLC analysis of phenols, naphthols, and other aromatic hydrocarbon metabolites. In summary she has found:

- A newly developed reversed-phase HPLC column significantly improves HPLC analyses of phenolics and other aromatic hydrocarbon metabolites.
- Special arrangements are needed to measure ultraviolet fluorescence (UVF) of phenols. Most HPLC UVF detectors do not operate at the necessary emission wavelengths (<300 nm).
- A "square" detector cell in combination with a UVF spectrometer gave subnanogram sensitivities for phenols upon HPLC analysis.
- Small amounts of acetic acid (e.g., 2%) in the aqueous solvent of HPLC greatly improved retention time reproducibility of conjugated metabolites of naphthalene:viz, the glucuronide and the sulfate.

Don Brown was successful in obtaining chemical-ionization mass spectra of naphthyl glucuronide and naphthyl glucoside without prior derivatization. Thus the presence of these compounds can be verified in HPLC fractions suspected of containing the conjugated metabolites.

B. PROBLEMS ENCOUNTERED

Delays in reporting IRM analytical results by the OCS PI's have necessarily held up progress in our collating and evaluating the interlaboratory calibration. We recommend that only one more calendar quarter be allowed for final submission of results by the OCS PI's.

C. ESTIMATE OF FUNDS EXPENDED: 15K (out of 50K)

MILESTONE CHART

0 - Planned Completion Date

● - Actual Completion Date
(to be used on quarterly updates)

RU # 557 PI: William D. MacLeod, Jr.

Major Milestones: Reporting, and other significant contractual requirements; periods of field work; workshops; etc.

		1978					1979								
MAJOR MILESTONES	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Quarterly Reports				●			●			0			0		
Annual Report							●								
AK oil composition data				●			●			0			0		
Intercalibration results				●			●								

XI. AUXILIARY MATERIAL

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WARNER, J.S. (1976) Personal communication, Battelle Memorial Institute, Columbus, Ohio.

APPENDIX I

ORIGINAL LIST OF RECIPIENTS OF DUWAMISH RIVER SEDIMENTS

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* Have reported results

(APPENDIX I - continued)

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APPENDIX II

Excerpts from Brown et al. (1979b)

MATERIALS AND METHODS

Materials, reagents, apparatus, and their cleaning procedures have been published previously (6,12). All solvent ratios were on a vol:vol basis. Sediment dry weights were determined on 10-20 g samples (6).

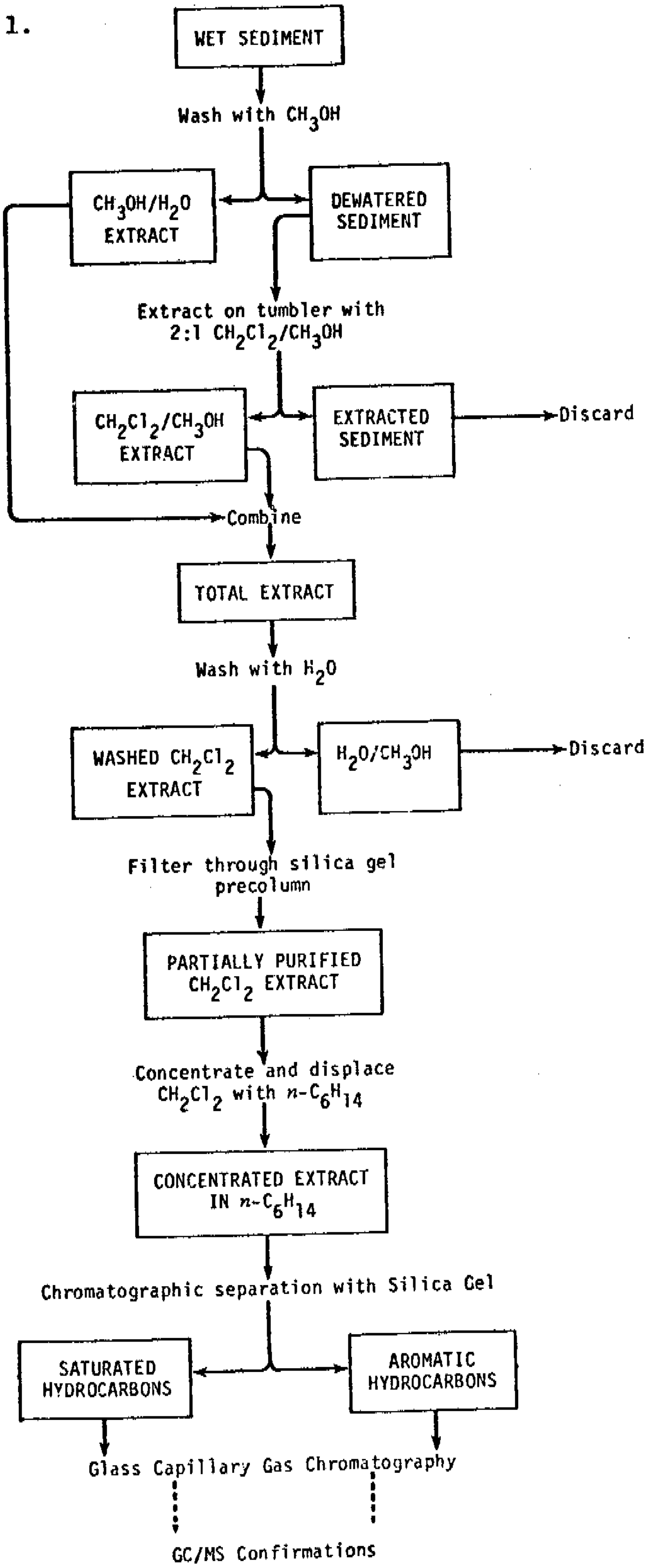
Methanol Purification

To check methanol purity, 200 mL were diluted with an equal volume of contaminant-free dichloromethane and extracted twice with 200 mL portions of distilled water. After the resulting dichloromethane phase was concentrated to 1 mL, it was analyzed for contaminants by glass capillary GC. When contaminants exceeded 0.1 ng/uL in the dichloromethane concentrate (i.e., 0.5 ug/L methanol), 1500 mL of the methanol was purified by diluting it with 500 mL of water and extracting it with 2 x 50 mL of contaminant-free hexane. Then the aqueous methanol was redistilled at 65-67°C through an efficient fractionation column and checked by GC analysis (see fig. 3).

Sediment Extraction Procedures

Ball-Mill Tumbler Extraction. Figure 1 shows the extraction scheme. A 100 g sample of wet sediment was weighed into a 1-L bottle, and 50 mL of CH_3OH were added. Aliquots of recovery standards (*n*-decylcyclohexane and 1,3,5-triisopropylbenzene) were added to each sample, except for the reagent blank. An aliquot containing the compounds to be quantitated was added to a second

Figure 1.


WET SEDIMENT
Wash with CH_3OH
CH_3OH/H_2O EXTRACT
DEWATERED SEDIMENT
Extract on tumbler with 2:1 CH_2Cl_2/CH_3OH
CH_2Cl_2/CH_3OH EXTRACT
EXTRACTED SEDIMENT
Discard
Combine
TOTAL EXTRACT
Wash with H_2O
WASHED CH_2Cl_2 EXTRACT
H_2O/CH_3OH
Discard
Filter through silica gel precolumn
PARTIALLY PURIFIED CH_2Cl_2 EXTRACT
Concentrate and displace CH_2Cl_2 with n-C_6H_{14}
CONCENTRATED EXTRACT IN n-C_6H_{14}
Chromatographic separation with Silica Gel
SATURATED HYDROCARBONS
AROMATIC HYDROCARBONS
Glass Capillary Gas Chromatography
GC/MS Confirmations

blank to estimate typical losses due to handling. The bottles containing the samples and CH_3OH were gently swirled by hand to dewater the sediment. The CH_3OH was decanted into a 600-mL beaker, and the methanol-dewatering step was repeated with another 50 mL of CH_3OH. Then 100 mL of 2:1 CH_2Cl_2:CH_3OH was added to the sediment, and the bottles were sealed with all-Teflon screwcaps and rolled on a ball-mill tumbler for 16 hr (overnight) at ca. 75 rev/min. The extract was decanted into the 600 mL beaker containing the methanolic extracts. Then the sample and bottle were washed with ca. 5 mL CH_2Cl_2 (dispensed from a clean Teflon wash bottle), and the washings were decanted into the 600-mL beaker. The CH_2Cl_2/CH_3OH sediment extraction step was repeated twice, first for 6 hr, then for 16 hr.

All extracts were combined and filtered through a 65-mm i.d., coarse fritted-glass filter-funnel into a 1-L separatory funnel. The beaker and filter were washed twice with 25-50 mL of CH_2Cl_2. The total filtrate was gently swirled for 2 min with 500 mL of distilled water to remove CH_3OH from the CH_2Cl_2 phase. After the phases separated, the CH_2Cl_2 (lower) phase was drained into a 500-ml Erlenmeyer flask. The aqueous (upper) phase was then back-extracted with 20 ml of CH_2Cl_2, and the CH_2Cl_2 phases were combined. The aqueous phase was discarded. The aqueous wash/CH_2Cl_2 back-extraction steps were repeated on the combined CH_2Cl_2 extracts prior to cleanup (below).

Direct Reflux Extraction. Wet sediments (50 g) were refluxed in 250 mL of 0.5 N KOH in CH_3OH and 35 mL of distilled water for 2 hr (13). After cooling, the mixture was poured through a 65-mm i.d., coarse fritted-glass filter-funnel into a 1-L separatory funnel. The extraction flask and the filter were rinsed with 20 mL of CH_3OH and 3 x 35 mL of CH_2Cl_2. Distilled water (150 mL) was added to the extract and the mixture was shaken. After the phases separated, the CH_2Cl_2 layer was drained into a 500-mL Erlenmeyer flask, and the aqueous phase was back-extracted with 50 mL of CH_2Cl_2. The combined CH_2Cl_2 extracts then passed to the cleanup step (below).

Soxhlet Extraction with Benzene/Methanol. The procedure of Clark and Finley (10) was employed, using two 24 hr extractions of a 100-g sample of wet sediment, each with 250 mL of 1:1 C_6H_6:CH_3OH. The combined extracts were washed with water, dried over Na_2SO_4, and evaporated just to dryness with a rotary evaporator. The residue was dissolved in CH_2Cl_2 for extract cleanup (below).

Soxhlet Extraction with Dichloromethane/methanol. Wet sediments (100 g) were extracted by a similar Soxhlet procedure using 2:1 CH_3OH:CH_2Cl_2 (15). The extracts were combined, washed and concentrated as done in the tumbler procedure prior to cleanup.

Extract Cleanup

The sediment extract in CH_2Cl_2 was filtered through a 19-mm i.d. chromatography column containing 20 mL of activated silica gel previously prepared in CH_2Cl_2 and covered with a 1-cm layer of sand (6). Then the column was eluted with one bed volume of CH_2Cl_2. The combined eluates were collected in a 500-mL Erlenmeyer flask equipped with a 24/40 outer joint. Residual CH_3OH, H_2O, particulates, and gel-forming polar materials (which could plug the silica gel chromatography column used later) were removed by this step. A Snyder distillation column equipped with a 24/40 inner joint was attached to the flask, and the assembly was placed in a heated (ca. 60°C) water bath. The CH_2Cl_2 extract and eluate were concentrated to ca. 15 mL and transferred to a 25-mL Kontes concentrator tube. After a Teflon boiling chip was added, and a Kontes micro-Snyder column (modified with indentations) was attached, the extract was further concentrated on a modified Kontes tube heater to ca. 1 mL. After adding 2 mL of hexane, the extract was reconcentrated to ca. 1 mL for fractionation into hydrocarbon classes.

Fractionation into Hydrocarbon Classes

All extracts were chromatographed on Davison grade 923 silica gel, as reported earlier (6,7). Two fractions, containing saturated and unsaturated hydrocarbons respectively, were collected in separate 25-mL Kontes concentrator tubes. These fractions were concentrated to 1 mL on a modified Kontes tube heater. After adding 2 mL of hexane, the extract was reconcentrated to 1 mL and transferred to gas chromatography (GC) sample vials. After adding 4 ug of hexamethylbenzene (GC internal standard) in hexane, the vials were sealed for GC analysis.

Gas Chromatographic Analysis

The vial contents were automatically sampled and analyzed by GC (6,7) using high-resolution glass capillary columns (see App. 3 for column parameters and operating conditions). Major alkanes ranging from decane ($\underline{n}$-$C_{10}H_{22}$) through hentriacontane ($\underline{n}$-$C_{31}H_{64}$), plus pristane and phytane, were quantitated in the saturated hydrocarbon fraction. The arenes listed in Table 2 were quantitated in the unsaturated hydrocarbon fraction.

RESULTS AND DISCUSSION

Comparison of Extraction Methods

Preliminary analytical results (12) indcated that our ambient-temperature tumbler sediment extraction was about as efficient for hydrocarbon recoveries as Soxhlet extraction. To test the tumbler extraction performance more completely, we have compared it with (a) an alkaline methanol reflux extraction (13), (b) a 1:1 benzene:methanol Soxhlet extraction (10), and (c) a 2:1 dichloromethane:methanol (azeotrope 7.6:1) Soxhlet extraction (15), using replicate analyses of the homogenized harbor sediment.

Tables 1 and 2 list individual aliphatic and aromatic hydrocarbon yields and relative standard deviations (RSD's) for the four methods. Within the

Table 1. Concentrations of Aliphatic Hydrocarbons (ng/g dry wt) found in Homogenized Duwamish River Sediment by Four Extraction Methods; $\bar{x}$ = Mean, n = Number of Analyses, RSD = Relative Standard Deviation of the Mean (100 SD/$\bar{x}$).

n-Alkane	CH_2Cl_2/CH_3OH TUMBLE		CH_3OH/KOH REFLUX		SOXHLET EXTRACTION			
					Benzene/CH_3OH		CH_2Cl_2/CH_3OH	
	$\bar{x}$ (n=14)	RSD	$\bar{x}$ (n=5)	RSD	$\bar{x}$ (n=5)	RSD	$\bar{x}$ (n=4)	RSD
C_{13}	6 ng/g	23%	4 ng/g	17%	6 ng/g	14%	5 ng/g	32%
C_{14}	11	25	8	16	11	15	9	29
C_{15}	18	19	15	12	18	16	15	29
C_{16}	23	26	20	10	23	16	20	24
C_{17}	36	16	29	7	29	24	29	15
Pristane*	51	18	40	8	40	42	37	15
C_{18}	44	15	28	9	39	17	33	22
Phytane*	39	16	33	7	33	29	32	15
C_{19}	54	15	31	5	41	33	32	7
C_{20}	40	14	30	9	38	20	28	4
C_{21}	28	24	35	12	39	15	36	4
C_{22}	29	14	22	8	30	15	30	7
C_{23}	39	15	27	7	34	12	40	20
C_{24}	36	15	31	5	35	13	46	20
C_{25}	52	15	37	9	44	8	74	51
C_{26}	43	23	34	11	47	15	69	48
C_{27}	51	32	59	15	62	23	150	63
C_{28}	54	33	45	11	110	15	170	57
C_{29}	72	30	42	11	100	17	160	46
C_{30}	98	35	36	15	98	20	180	120
C_{31}	96	55	36	10	144	23	130	87

* A branched alkane

Table 2. Concentrations of Aromatic Hydrocarbons (ng/g dry wt) found in Homogenized Duwamish River Sediment by Four Extraction Methods; $\bar{x}$ = Mean, n = Number of Analyses, RSD = Relative Standard Deviation of the Mean (100 SD/$\bar{x}$).

Aromatic Hydrocarbon	CH_2Cl_2/CH_3OH TUMBLE		CH_3OH/KOH REFLUX		SOXHLET EXTRACTION			
					Benzene/CH_3OH		CH_2Cl_2/CH_3OH	
	$\bar{x}$ (n=11)	RSD	$\bar{x}$ (n=4)	RSD	$\bar{x}$ (n=4)	RSD	$\bar{x}$ (n=4)	RSD
2-Methylnaphthalene	10 ng/g	33%	7	25%	14 ng/g	28%	11	59%
1-Methylnaphthalene	6	33	4	16	8	25	7	67
Biphenyl	2	39	1	28	9	24	2	95
2,6-Dimethylnaphthalene	8	26	5	21	9	27	6	118
2,3,5-Trimethylnaphthalene	6	58	<1	--	7	29	4	76
Fluorene	30	28	14	8	50	50	35	51
Dibenzothiophene*	28	32	20	2	50	57	51	63
Phenanthrene	330	28	180	2	610	44	370	47
Anthracene	57	26	34	7	120	50	65	49
1-Methylphenanthrene	22	24	16	8	56	38	33	48
Fluoranthene	570	23	320	3	840	40	560	41
Pyrene	760	21	280	5	1100	38	550	46
Benz[*a*]anthracene	440	23	170	3	870	71	620	31
Chrysene	270	20	200	5	530	48	370	30
Benzo[*e*]pyrene	150	26	150	5	230	31	310	38
Benzo[*a*]pyrene	170	33	180	4	410	45	300	43
Perylene	36	36	56	5	97	22	160	66

* A sulfur-substituted aromatic hydrocarbon

experimental uncertainties (i.e., the RSD's), the tumbler method compared favorably with the Soxhlet extractions in the C_{13}-C_{26} alkanes (Table 1), while the Soxhlet extractions were generally more efficient in the C_{27}-C_{31} range. Soxhlet extraction with dichloromethane/methanol was least reproducible (e.g., 7 of 21 RSD's >33%). Usually, direct reflux extraction was least efficient, but most reproducible for both alkanes and aromatics. Recoveries for the polynuclear aromatics below fluorene in Table 2 were generally highest by benzene/methanol Soxhlet extraction. Again dichloromethane/methanol Soxhlet extraction was least reproducible (highest RSD's).

Variability of Aromatic Hydrocarbons

Figure 2 shows that the unsubstituted aromatics are generally more abundant than their alkyl-substituted homologs. Recent research of LaFlamme and Hites (16) and Youngblood and Blumer (17) indicate that this pattern is characteristic of combustion by-products as opposed to spilled fossil fuels. If these aromatics had such an origin and were deposited with various types of airborne particulates, they could give uneven results for this sediment, even though it was homogenized in a mixer for 3 hours. This is consistent with the greater variability observed for the aromatic data compared to the alkane data (e.g., 28 out of 68 RSD's >33% in Table 2 vs. 10 out of 84 RSD's >33% in Table 1).

In the extreme, the overall recoveries of aromatics in 5 of 28 analyses exceeded the overall mean of their respective subsets ($n \geq 5$) by factors of 3, 3, 3, 5, and 10, while the corresponding alkane recoveries did not. These exceptional step increases in only the aromatics may be due to the presence of one or more aromatic-rich particles (e.g., soot). This possibility is not excluded since the sediment came from an active harbor in an urban industrial area. Dixon's statistical method of outlier analysis (18) was used to exclude such extreme results from Tables 1 and 2.

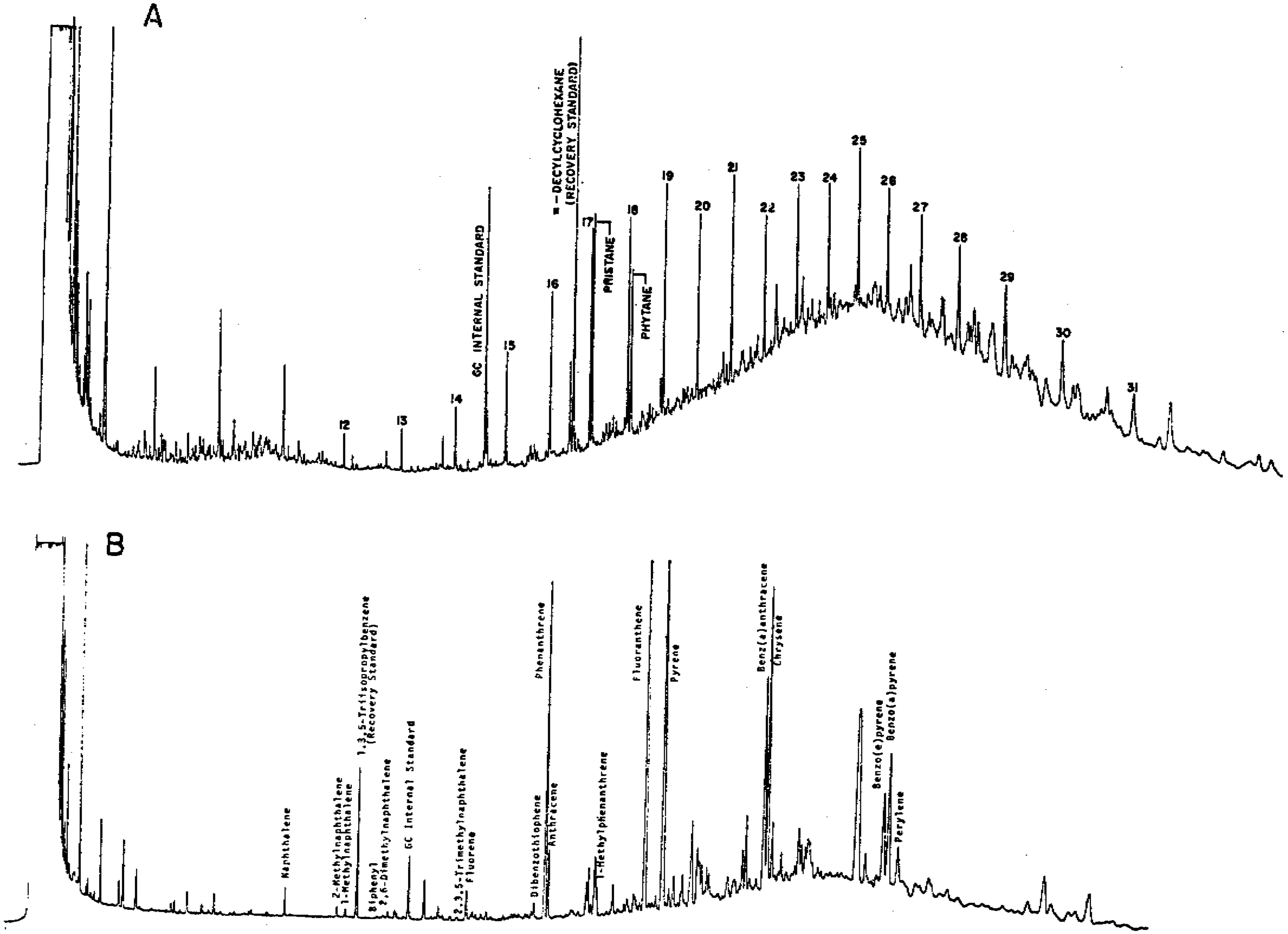

A
12
13
14
GC INTERNAL STANDARD
15
16
n-DECYLCYCLOHEXANE (RECOVERY STANDARD)
17
PRISTANE
18
PHYTANE
19
20
21
22
23
24
25
26
27
28
29
30
31
B
Naphthalene
2-Methylnaphthalene
1-Methylnaphthalene
1,3,5-Triisopropylbenzene (Recovery Standard)
Biphenyl
2,6-Dimethylnaphthalene
GC Internal Standard
2,3,5-Trimethylnaphthalene
Fluorene
Dibenzothiophene
Phenanthrene
Anthracene
1-Methylphenanthrene
Fluoranthene
Pyrene
Benz(a)anthracene
Chrysene
Benzo(e)pyrene
Benzo(a)pyrene
Perylene

Figure 2.

Impurities in Methanol

We found that methanol was an important co-solvent for extracting hydrocarbons efficiently from the wet sediment. Even the purest of more than ten top grades of commercial methanol had impurities that interfered with hydrocarbon analyses (fig. 3A). Attempts to purify such methanol by fractional redistillation removed only contaminants boiling higher than $\underline{n}$-$C_{12}H_{26}$ (fig. 3B). To reduce contaminants less volatile than $\underline{n}$-C_8H_{18} to acceptable levels (<0.5 ug/L), methanol was diluted with water, extracted with hexane and redistilled (fig. 3C).

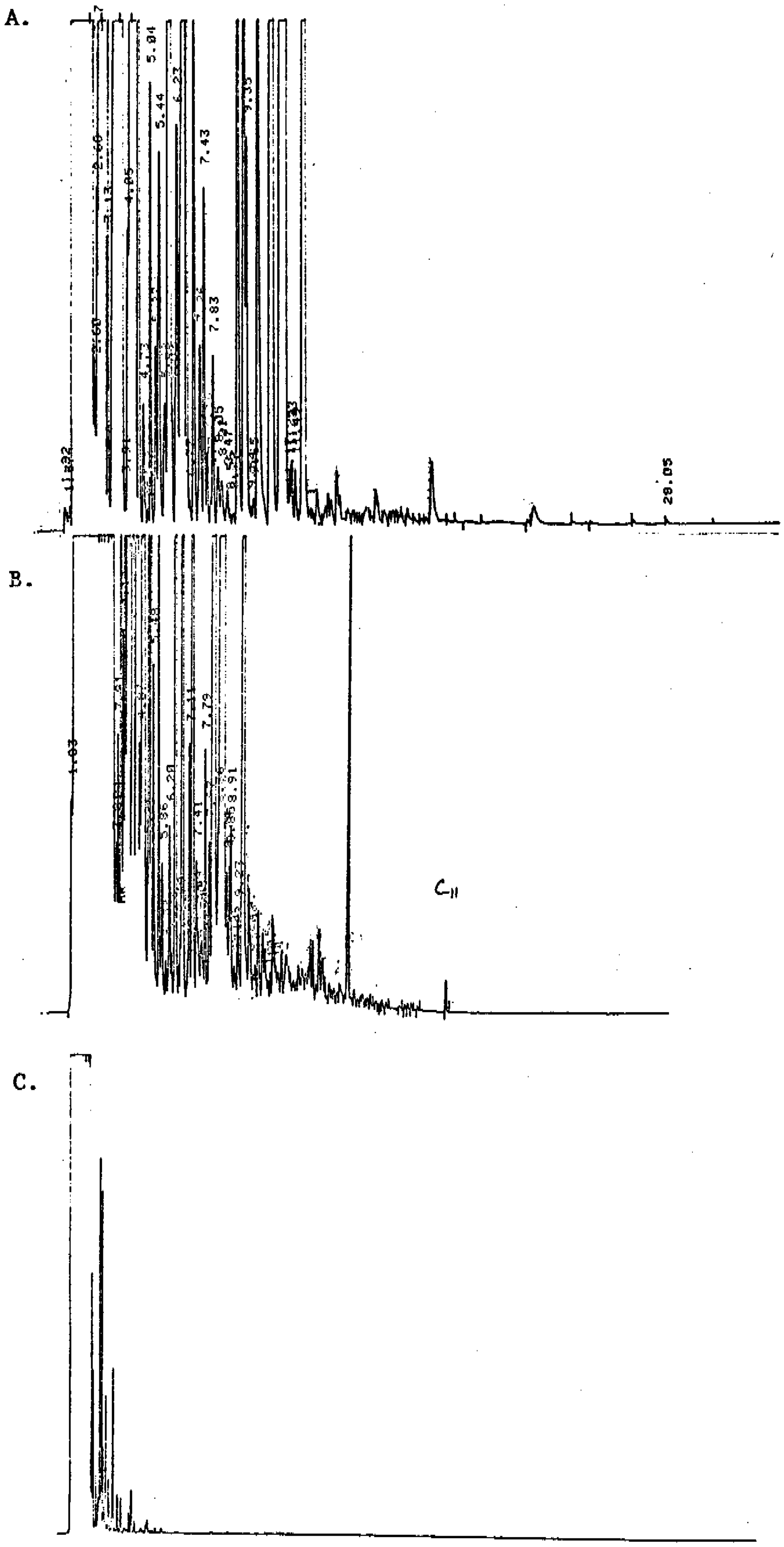

A.
5.84
5.44
6.23
7.43
2.60
3.13
4.05
7.83
9.35
28.05
B.
1.03
7.79
6.28
5.86
7.41
8.91
C_{11}
C.

Figure 3.

(6) MacLeod, W.D., Brown, D.W., Jenkins, R.G., Ramos, L.S., and Henry, V.D., "A Pilot Study on the Design of a Petroleum Hydrocarbon Baseline Investigation for Northern Puget Sound and Strait of Juan de Fuca", NOAA Tech. Memo. ERL MESA-8, National Oceanic and Atmospheric Administration, Boulder, Colo., 1977.

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(10) Clark, R.C., Jr., and Finley, J.S., "Techniques for Analysis of Paraffin Hydrocarbons and for Interpretation of Data to Assess Oil Spill Effects in Aquatic Organisms," in "Proceedings of the 1973 Joint Conference on Prevention and Control of Oil Spills," American Petroleum Institute, Washington, D.C., 1973.

(11) Chesler, S.N., Gump, B.H., Hertz, H.S., May, W.E., Dyszel, S.M., and Enaganio, D.P., "Trace Hydrocarbon Analysis: The National Bureau of Standards Prince William Sound/Northeastern Gulf of Alaska Baseline Study," NBS Technical Note 889, National Bureau of Standards, Washington, D.C., 1976.

(12) Brown, D.W., Ramos, L.S., Friedman, A.J., and MacLeod, W.D., "Analysis of Trace Levels of Petroleum Hydrocarbons in Marine Sediments Using a Solvent Slurry Extraction Procedure," in "Proceedings 9th Materials Symposium, Trace Organic Analysis: A New Frontier in Analytical Chemistry," National Bureau of Standards, Washington, D.C., 1979.

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(15) Calder, J.A., personal communication, Florida State University, 1977; current address: NOAA/ERL, Boulder, Colo.

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(17) Youngblood, W.W., and Blumer, M., "Polycyclic Aromatic Hydrocarbons in the Environment: Homologous Series in Soils and Recent Marine Sediments," Geochim. Cosmochim. Acta, 1975, 39, 1303.

(18) Dixon, W.J., Processing Data for Outliers, Biometrics, 1953, 9, 74.

APPENDIX III

Excerpt from MacLeod et al. (1977a)

ANALYTICAL PROCEDURES

Materials*

Materials contacting the sample were confined to glass, Teflon, metal or residue-free solvents and reagents. This includes the liners of caps and lids. All glassware was washed in hot laboratory detergent, dried, and rinsed in sequence with reagent grade acetone and methylene chloride solvents dispensed from previously cleaned Teflon wash bottles. Teflon and metal foil sheeting and metal implements were also rinsed sequentially with acetone and methylene chloride before use. Highest purity reagents such as hydrochloric acid, anhydrous sodium sulfate, coarse sand, sodium hydroxide, silica gel, and glass wool were extracted with methylene chloride before use. Solvents employed in this study were the highest purity obtainable from Burdick and Jackson Laboratories, Inc., or Mallinckrodt Chemical Works. They were employed without further purification because they gave no measurable residues in procedural blank analyses. Other items are listed as follows:

Teflon wash bottles, 500 ml
Laboratory scalpels
Homogenizer - Tekmar Tissumizer No. SDT-182EN or Virtis Model 23
Test tube racks - A. H. Thomas Co., Cat. No. 9266-N32
Centrifuge tubes, 40 ml, with screw caps - Corning Glass Works, Cat. No. 8122
Teflon cap liners - A. H. Thomas Co., Cat. No. 2390H
Centrifuge - International Equipment Company, Model C5
Glass bottles, 1 oz. with screw caps and Teflon liners
Concentrator tubes, 25 ml - Kontes Glass Co., No. K570050, size 2525
Reflux columns - Kontes Glass Co., Cat. No. K569251
Ebullators (boiling tubes) - Kontes Glass Co., Cat. No. K569351, or VWR 1 mm glass tubes, VWR Cat. No. 32829-020 (cut to _ca._ 2.5 cm length and flame sealed at one end in laboratory)
Tube heater, 6-tube - Kontes Glass Co., Cat. No. K720003
Tube heater control unit - Kontes Glass Co., Cat. No. 720001
Adsorption chromatography columns - Kontes Glass Co., Cat. No. 42028
Glass (Pyrex) wool - Corning Glass Works, No. 3950
Silica gel, 100-200 mesh - MCB Cat. No. SX0144-06
Copper, fine granular - Mallinckrodt, Cat. No. 4649
Sand, coarse, reagent grade
GC sample vials - Hewlett-Packard, Cat. No. 5080-8712

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* Reference to a company or product does not imply endorsement by the U. S. Department of Commerce to the exclusion of others that may be suitable.

GC Teflon lined vial caps - Hewlett-Packard Cat. No. 5080-8703
Vial capper - Hewlett-Packard Cat. No. 871-0979
Dish, aluminum, utility, 57 mm diameter
Ether peroxide test paper - EM Laboratories, Inc., Cat. No. 10061-9G
Sediment extraction glass bottle, 1 liter - Scientific Products Cat. No. B 7573-IL
Ball mill tumbler - Model 8-RA, Scott-Murray, 8511 Roosevelt Way NE, Seattle WA 98115
Automatic gas chromatograph - Hewlett-Packard Model 5840, dual FID
Automatic GC sampler - Hewlett-Packard Model 7671A
GC columns, 30 m L x 0.25 mm ID, wall coated, glass capillary (SE-30) - J & W Scientific, P. O. Box 216, Orangevale CA 95662
Gas Chromatograph/Mass Spectrometer and Data System, Dual EI/CI - Finnegan, Model 3200

Dry Weight Determination

Sediment. Thaw sediment and remove pebbles by spatula or sieve. Thoroughly mix by spatula. Add 10-20 g of the sediment to a tared aluminum dish. Weigh and record the weight of dish and sample. Cover the dish and sample loosely with aluminum foil. Dry the sample in an oven at 120°C for 24 hr, then remove and cool for 30 min in a dessicator. Reweigh and record dried weight. Calculate percent dry weight as:

$$\frac{\text{weight (final)} - \text{weight (tare)}}{\text{weight (initial)} - \text{weight (tare)}} \times 100$$

Tissue. Place *ca*. 3 g clean coarse sand and a glass spatula in an aluminum dish and dry overnight in a 120°C oven. Cool the dish in a dessicator for 30 min. Weigh and record as tare weight.

Weigh into the dish, to the nearest mg, 0.5 g of sample. Using the spatula, mix the sample thoroughly with the sand, taking care to avoid loss of sand granules. Dry the sample in a 120°C oven for 24 hr, then remove and cool in a dessicator for 30 min. Reweigh and record the dried weight. Calculate percent dry weight as:

$$\frac{\text{weight (final)} - \text{weight (tare)}}{\text{weight (initial)} - \text{weight (tare)}} \times 100$$

Silica Gel Chromatography

Column Preparation. Prepare columns immediately prior to use. Fill a column to the flare in the reservoir with methylene chloride. Push a 0.5 cm glass-wool plug to the bottom of the column with a glass rod. Measure 15 ml (7 g) of 100-200 mesh silica gel (activated at 150°C for 24 hr, then cooled in a dessicator) into a 25 ml graduated cylinder and transfer to a 250 ml erlenmeyer flask. Add 25 ml of methylene chloride and swirl vigorously to make a slurry. Place a long-stem funnel into the column such that the tip rests off-center on the bottom of the reservoir just below the surface of the methylene chloride.

Quickly pour the slurry into the funnel and wash the residual slurry into the funnel with methylene chloride from a Teflon wash bottle. The adsorbent particles should quickly settle to the bottom of the column with little turbulence at the settling front. When the settling front extends upward about 1 cm from the glass-wool plug, slowly open the stopcock to a flow of 1-2 drops per second. Collect the eluate in an erlenmeyer flask to minimize solvent vapor escape. Swirl the column reservoir gently to wash the particles into the column. When the settling front reaches the top of the suspended particles, open the stopcock all the way to complete the settling. Add about a 1 cm layer of clean sand through a funnel to the top of the gel, followed by an equal amount of anhydrous sodium sulfate.

When the methlene chloride surface is just above the top of the column, add a ml of petroleum ether with a Pasteur pipet and allow to drain. When the liquid level again almost reaches the column top, add 40 ml of petroleum ether and continue to elute. Close the stopcock when the solvent meniscus almost reaches the top of the column. Discard the rinse elutes. Cover the column with aluminum foil until use.

Sample Chromatography. The sample extract should be in 1-2 ml of hexane in the concentrator tube. Crush the ebullator with a glass rod and rinse the rod with a small amount of petroleum ether. Carefully transfer the extract solution with a Pasteur pipet to the top of the column and elute. Never allow the liquid meniscus to go below the upper surface since air will be entrapped, which will disrupt the column. Rinse the concentrator tube with 0.5 ml of petroleum ether and add to the column. Open the stopcock and collect the eluate in a clean 25 ml concentrator tube. When the meniscus just reaches the column top, carefully add 15 ml of petroleum ether. Care must be exercised not to disturb the upper surface of the column during each addition. When the meniscus again just reaches the sand, add 3 ml of 20% (V/V) methylene chloride in petroleum ether. Elute solvent at 2-4 ml/min to separate the saturated from the unsaturated hydrocarbons. When 18 ml has eluted into the concentrator tube receiver, replace it with a second tube. This 18 ml eluate, referred to as fraction 1, contains the saturated hydrocarbons. As the meniscus again just reaches the top, add 25 ml of 40% (V/V) methylene chloride in petroleum ether. This eluate, fraction 2, will contain the unsaturated and aromatic hydrocarbons. A transparent extract, when applied to the column, will elute in less than 30 minutes.

Sediment Desulfurization. Silica gel fractions of sediment extract are treated with activated, fine granular copper to remove elemental sulfur. Prior to use, activate the copper with concentrated hydrochloric acid (HCl). Rinse the activated copper five times with acetone to remove the HCl and then five times with petroleum ether to remove the acetone. Activated copper should be prepared fresh daily and stored under petroleum ether until used. Activated copper should not be washed with water or heated. To remove elemental sulfur from the sample, place the eluate (not more than 1 ml in volume) in a 40 ml conical centrifuge tube and add about 0.5 ml of activated copper. Stir for 2 minutes on a vortex mixer. Centrifuge to settle any sulfide particles in the mixture. Transfer the sample with a Pasteur pipet to a clean concentrator tube. Rinse the copper once with 1 ml of petroleum ether and combine the rinse with the eluate sample. Reconcentrate the sample to a 0.5 ml and continue to microgravimetry and GC analysis.

Microgravimetric Determinations

The first and second silica gel fractions are weighed on a Cahn microbalance. In an efficient hood, transfer 25 µl from a known volume of eluate (or extract) onto the balance pan and allow the solvent to evaporate. Record the weight and normalize the value to µg/g dry weight of sample.

Gas Chromatography (GC)

GC Sample Preparation. Attach the reflux column to the concentrator tube containing the eluate from silica gel chromatography. Evaporate the solvent in the heater block as previously described. After concentrating to 0.5 ml, remove from heat. Add 1.0 ml of internal standard solution (4 ng/µl hexamethylbenzene in carbon disulfide) and concentrate to 0.5 ml. If necessary, adjust final volume to 0.5 ml with carbon disulfide. Transfer the samples to the GC vials and crimp on the Teflon-lined septum caps. Replace the cap each time it is pierced by a syringe to avoid evaporative losses.

GC Apparatus and Modifications. GC analysis is performed on a microprocessor-controlled gas chromatograph (Hewlett-Packard model 5840A) equipped with: an automatic sample injector (model 7671A); a wall-coated, open tubular (WCOT) glass capillary column (20-30 m length, 0.25 mm inside diameter); and a hydrogen flame-ionization detector (FID).

The GC sample injection port is modified to split the carrier gas as shown in Figure 1. Inlet carrier gas (helium) pressure is adjusted to provide 2 ml/min flow through the column at 60°C, as determined on a bubble flow-meter. By adjusting the needle valve to allow 20 ml/min bypass flow, a split ratio of 10:1 is obtained. Although 90% of the injected sample is sacrificed, the inlet system is rapidly purged of injected solvent and sample. This maintains sharp solvent and sample peaks. This inlet system (Fig. 1) features low dead volume and a glass inlet liner that is readily removable for cleaning. The inlet end of the glass capillary column must be positioned inside the glass liner near the location of the inserted sampling needle tip to gain best sample transfer to the column with the least GC peak broadening. A charcoal trap absorbs compounds from the vented split stream which avoids contaminating the needle valve.

Because of the low, carrier gas flow through capillary GC columns, it is necessary to add make-up gas at the FID (Fig. 1). The flame jet has been flared to allow the GC column outlet end to be inserted about 2 cm into the jet. This effectively eliminates any potential dead volume effects with the make-up gas (30 ml/min) plus hydrogen (24 ml/min) rapidly sweeping eluted compounds directly into the flame.

GC Sample Analysis. Analysis is carried out according to conditions listed in Table 1. GC samples in crimp-sealed, septum-capped vials are loaded into the automatic sampler. Then the desired operating conditions (Table 1) are programmed into the microprocessor memory. A sample volume of 2 µl are injected per analysis with the column temperature held at 60°C. After 10 min, the column temperature is programmed at 2° or 4°C/min to 250°C and held for 30 minutes. Depending on the program rate, the compounds of interest are eluted in 1½ to 2½ hours. Separated compounds are detected by the FID as they emerge from the GC column. The gas chromatogram is constructed by the microprocessor, which prints compound retention times alongside each peak.

Peak areas are automatically computed using "valley to valley" mode baseline correction. Areas are printed in tabular form at the end of the GC run according to retention times. The quantities of compounds represented by the peak areas are also computed automatically by ratio of the individual peak areas to the area of the known amount of internal standard peak. If reference samples are available for compounds of interest, relative response factors for these compounds with respect to the internal standard should be determined experimentally under identical conditions.

Gas Chromatography/Mass Spectrometry (GC/MS). The identity and relative abundance of compounds detected and measured by GC are periodically confirmed by GC/MS analysis. A capillary column similar to that used in GC analysis is employed in conjunction with a Grob sample inlet system. Effluent from the GC column is fed directly into ion source. Table 2 lists analysis conditions. A sample of 1-2 µl is injected into the GC/MS while the ion source filament and electron multiplier voltage are turned off. Passage of the solvent peak from GC to MS is noted on the instrument high vacuum gage as a transient rise and fall in pressure. After this, the source filament and multiplier voltage are restored to normal settings and data acquisition by the computers is initiated for mass scans every 2 sec. The GC column is subjected to virtually the same analytical parameters for the GC/MS confirmation run as in the GC detection and measurement run. At the end of the run, the chromatogram is reconstructed (RGC) from the total ion current of each individual scan. Specific ion chromatograms featuring ion abundancies of ions characteristic of a particular molecular configuration may also be produced. Primarily,

Table A-1

Gas Chromatography Conditions

Column type		Column:	30 m x 0.25 mm ID wall-coated glass capillary
		Liquid phase:	SE-30 GC (dimethyl siloxane polymer)
		Film thickness:	4-5x10^{-4}mm
Gases	Inlet	Carrier gas:	He
		Split ratio:	10:1 (bypass:column)
		Column flow:	2 ml/min
		Bypass flow:	20 ml/min
	Detector	Makeup (N_2)	30 ml/min
		Air	240 ml/min
		Hydrogen	24 ml/min
Temperatures		Initial Temp:	60°C
		Program delay:	10 min
		Program rate:	2 or 4°C/min
		Final temp:	250°C
		Injector:	250°C
		Detector:	300°C

compounds shown to be present in the GC/MS chromatogram are identified by comparing their mass spectrum (background subtracted) with standard reference tables of mass spectra or laboratory spectra of reference compounds.

Table A-2

GC/MS Analysis Parameters

GC: Same as Table A-1, except no make-up gas

GC/MS interface temp.: 250°

MS:

Filament emission: 500 μA

Electron multiplier voltage: 1600 V

Electron energy: 70 eV

Data acquisition:

Mass range: 80-280 (aromatic samples)
50-300 (alkane samples)

Integration time: 6 msec/scan

Scan time: 2 sec

ANNUAL REPORT
March 31, 1979

Research Unit: 563

Contract no.: 03-78-B01-53

Project no.: RK 0000-R7120815

Archival of Voucher Specimens of Biological Materials Collected under the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Support

Period of Performance: May 1, 1978 - April 30, 1979
Subsequent support subject to availability of funding.

Period Covered by This Report: May 1, 1978 - March 31, 1979.

Institution: California Academy of Sciences
Golden Gate Park
San Francisco, CA 94118

Principal Investigator:

William N Eschmeyer

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Director of Research
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Archival of Voucher Specimens of Biological Materials Collected Under OCSEAP Support

I. Summary of Objectives, Conclusions and Implications:

The baseline data collected for the fauna and flora in the OCSEAP study area is based on extensive biological collections made by many separate research units. OCSEAP has established the California Academy of Sciences as a central repository for representative specimens from these collections. This will ensure that materials are permanently available for reference and for confirmation and upgrading of identifications made by research units. This project was initiated on 1 May 1978, and the contract awarded on 24 May 1978.

During the first 2 months of the project the voucher policy was prepared. In September 1978, the voucher specimen policy was approved and distributed by the Project Office to principal investigators of all research units. Copies are on file in the Project Office.

This document specifies the voucher policy, its applications, preservation procedures, labeling instructions, and information on shipment of specimens to the repository. Voucher specimen labels, prepared to meet NOAA's data needs, were printed on special label paper and distributed to principal investigators by November 1978.

The project processing and storage room was completed with non-BLM/NOAA funds in December 1978, with the addition of work counters, a sink, and $7,500 of metal shelving. Purchase of materials and supplies was completed during the second quarter. An IBM System 6 unit for electronically processing the data on voucher specimens was operational in the second quarter.

The first voucher specimens were received during the January-March quarter.

II. Introduction

A. General Nature and Scope of Study:

As outlined above, a voucher specimen repository was established so that extensive biological collections made by OCSEAP would be documented with voucher samples. A rather specific voucher policy was needed such that the quality and integrity of the biological data taken would be maximized. The fauna (or parts of it) are poorly known for the area under study. Field identifications need to be made by knowledgeable people, and by reference to actual voucher or reference specimens that can be saved and forwarded to the central repository. The essential point is that the voucher specimen be of the same species as the other specimens analyzed and discarded, even if the state of systematic knowledge permits only partial identification. If the field identifications are faulty then the usefulness of the data is much reduced. Upgrading identifications and changing scientific names as nomenclature improves will, through the years, increase the usefulness of the data in the NODC.

The California Academy of Sciences has had extensive experience as a repository of voucher specimens from the scientific community and from Federal, State, and some private agencies. The Academy collections are world-wide in composition, with especially strong representation of the flora and fauna of western North America, including Alaska. The Academy was selected as the voucher specimen repository and charged with the specific tasks outlined below.

Principal investigators will deposit representative voucher specimens with the Academy. All of the data will be coded on an IBM System 6/452 Information Processor and sent to NODC. The specimens will be maintained as a separate collection for a period of 5 years, marked distinctly, and then integrated into the main collections of the Academy.

B. Specific Objectives:

The California Academy of Sciences is responsible for:

1. Specifying preservation techniques for archival voucher specimens.

2. Coordinating the shipment of materials.

3. Establishing and maintaining a fully catalogued repository for the collections; and

4. Providing quarterly data summaries on the status and content of the collections.

C. Relevance to Problems of Petroleum Development:

Management decisions and monitoring that may be necessary to protect the OCS marine environment from damage during petroleum development are based on the accumulation of a data base. The permanent voucher specimen collection and policy, including the identification policy for field personnel, are aimed at increasing the reliability of the data collected. The voucher specimens are permanently available for reference and for confirmation and upgrading of identifications made by field personnel during the data gathering phase.

III. Current State of Knowledge:

The fauna of Alaska, while similar to that of other parts of the North Pacific, is not very well known. Identifications of certain groups of organisms is difficult because of a lack of adequate literature or prior studies. The utilization of the identification and voucher policy will increase the reliability and usefulness of the biological baseline data collected by OCSEAP.

IV. Study Area:

Voucher specimens will be received from studies conducted throughout the OCSEAP study area.

V. Sources, Methods and Rationale of Data Collection:

All specimens will be provided by the individual project principal investigators. Standard curation techniques will be used to process the incoming materials, allowing for the variability of the specimens received. Once each voucher specimen shipment is processed, the specimen data information will be electronically processed and transferred to NODC and the principal investigators.

VI. Results:

The final voucher specimen policy was submitted and approved. Specimen labels to be completed by project principal investigators were printed and 3000 of them forwarded to the Juneau Project Office on 30 October. On 6-7 November, the Project Office sent a covering letter of instruction, a copy of the final voucher policy, and specimen labels to research units associated with the Bering Sea-Gulf of Alaska Project Office. On 21 November similar information was sent to those principal investigators involved in current and terminated projects administered through the Arctic Project Office.

The project workroom/laboratory and storage area was completed during the quarter with the addition of counters and a sink. This and the approximately $7,500 of metal shelving was provided from non-BLM/NOAA funds.

At the end of 1978, all steps had been completed so that the voucher specimen program was fully operational.

On 14 November, Dr. McCain (RU 73) was the first principal investigator to inform the repository that his unit was ready to send specimens. Shipping containers, packing materials, and instructions were sent to him by us.

On 16 March 1979, Dr. Blackburn sent voucher specimens of fish for RU numbers 486, 512, 552. These have been accessioned (CAS Acc.#1979-III:16) and transferred to 75% ethanol. On 19 March 1979, Dr. Larrance (RU 425) sent the first shipment of phytoplankton under the revised phytoplankton policy. Each lot of phytoplankton consisted of a representative station sample with an accompanying species list. The samples were accessioned (CAS Acc.#1979-III:19B) and will be maintained in 3% buffered formalin.

VII. Discussion:

The problem of how to provide voucher specimens of phytoplankton was elicited by Dr. Horner (RU 353). It was established by the Data Manager, Horner, and the repository that since actual specimens could not be isolated because of the large numbers of samples involved and because of technical problems of specimen isolation and preservation, a subsample or the remaining plankton sample, accompanied by a species list for the sample, would serve very well as a voucher for the species encountered, identified, and counted in the subsamples analyzed.

The University of Alaska raised questions of compliance with the voucher policy for projects well underway or completed previously. Their cost estimates for each research unit to assemble a voucher series were high. It is of our opinion that much of the expense involves the completion of rather detailed voucher specimen labels. We propose that since the specimens probably already have some data with them (cruise, station, identification) and if the remaining data (cruise report data, etc.) can be provided in text form, we will prepare the specimen labels. They would need funds for personnel to select the voucher specimens and for packing the specimens.

Because of a lack of specimens to process, the full-time curatorial assistant was temporarily terminated on 19 December and employed by another Academy department to conserve project funds. She returned to the project 1 April on a halftime basis until sufficient material arrives to require full-time employment.

VIII. Conclusions:

Problems of selecting voucher specimens for phytoplankton and completing voucher specimen labels for previously completed projects have been solved. Project funds have been conserved due to delays in receipt of specimens. Specimens are now being sent by investigators, and we anticipate no problems in meeting the task objectives.

IX. Needs for Further Study:

The voucher specimen policy and field identification procedures should be continued through the OCSEAP data gathering phase.

X. Summary of January-March Quarter:

A. Laboratory Activities:

Two shipments of voucher specimens were received in March. The first shipment was received from Dr. Blackburn (RU 486, 512, 552) from the Alaska Department of Fish and Game. The shipment consisted of 90 lots and 109 specimens, representing approximately 90 species of fishes. The specimens were accessioned (CAS Acc.#1979-III:16) and transferred to 75% ethanol.

The second shipment was received from Dr. Larrance (RU 425) of the Pacific Marine Environmental Laboratory. This shipment consisted of 36 lots of phytoplankton, with each lot representing a separate station with an accompanying species list. The samples were accessioned (CAS Acc.#1979-III:19B) and will be maintained in 3% buffered formalin.

1. Ship or Field Trip Schedule: Not applicable

2. Scientific Party:

Dr. William N. Eschmeyer, Chairman and Curator, Department of Ichthyology. Principal Investigator.
Mr. Dustin Chivers, Senior Scientific Assistant, Department of Invertebrate Zoology. Invertebrate Coordinator.
Ms. Susan Gray Marelli, Collection Manager.

Other Academy curators as needed.

3. Methods:

All of the incoming voucher specimens are curated by the procedures outlined in the the Voucher Specimen Policy. Final bottle labels and data capture will be made on an IBM System 6/452 Information Processor.

D. Sample Localities:

Voucher specimens will be received from throughout the OCSEAP study area.

E. Data Collected or Analyzed:

The first two shipments of voucher specimens were received late in the quarter and processing has begun.

XI. Auxiliary Material: Not applicable at this time.

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