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Environmental Assessment of the Alaskan Continental Shelf

Annual Reports of Principal Investigators for the year ending March 1977

Volume XVIII. 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

March 1977

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

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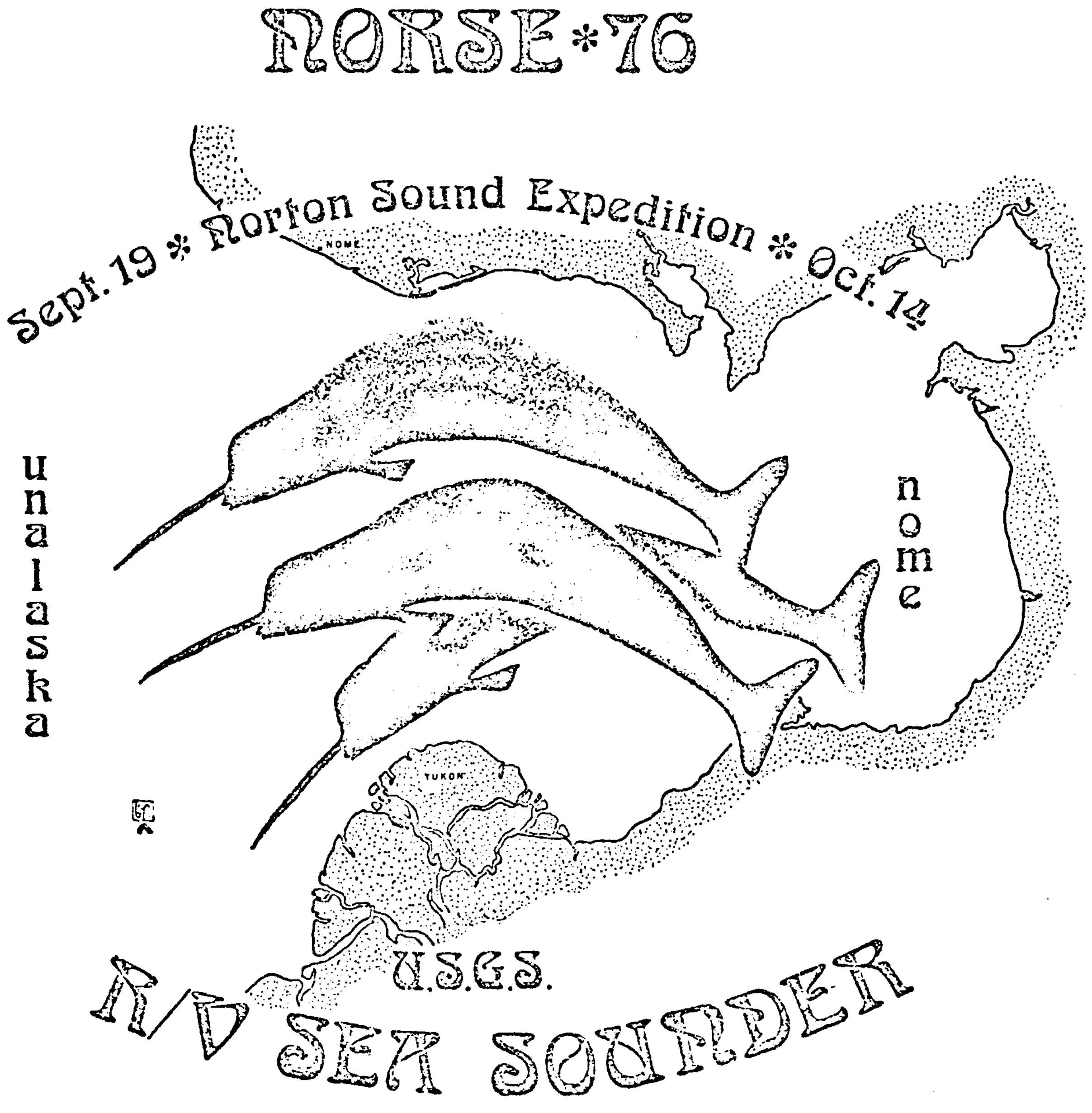
Research Unit 429

FAULTING, SEDIMENT INSTABILITY, EROSION, AND DEPOSITION HAZARDS OF THE NORTON BASIN SEAFLOOR --- ANNUAL REPORT 1977

HANS NELSON



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CONCLUSIONS and NEEDS FOR FURTHER STUDY are detailed separately in each individual report of the RESULTS section.

FAULTING, SEDIMENT INSTABILITY, EROSION, AND DEPOSITION HAZARDS OF THE NORTON BASIN SEAFLOOR --- ANNUAL REPORT 1977

HANS NELSON

I. SUMMARY

Preliminary assessment has been made on the following potential geologic hazards: faulting, ice gouging, gas cratering of surface sediments, storm surge activity, and strong bottom currents (Fig. H-1). Fault scarps break the seafloor in the region from King Island to Bering Straits; however, their activity is difficult to determine because current scour may be preserving or exhuming old scarps. Surface and nearsurface faulting south of Nome may be associated with leaking sources of petrogenic gas and further investigation of any recent displacement and gas leakage is required.

Presence of intense ice gouging that digs into the seafloor to shallow depths (< 1 m) has now been well established in the south central region of Norton Sound as well as southwestward on around the modern Yukon Delta (Fig. H-1). Elsewhere, at any water depth less than 20 meters, gouging is ubiquitous, but not of intense coverage. All areas of shorefast ice less than 10 meters depth require future research; rate of occurence also needs to be established in all environments by reoccupying the same site periodically. A complete study of ice characteristics and movement patterns needs to be initiated.

Our study recently detected widespread areas of apparent gas cratering (Fig. H-1). Its full areal extent may never be evident from side scan analysis because of obliteration of much of the seafloor surface by ice gouging. However, velocity pull downs indicate that the complete area of this phenomenon could be much more widespread than is presently confirmed by sidescan records. A much more detailed assessment of this potential hazard, in addition to complete analysis of gas quantity and sediment texture effect on liqufaction potential, is required. These studies will begin this summer. One of the key aspects to a full understanding of the nature of gas charged sediments is the collection of deep vibracoring or drilling samples. Budget cuts of OCSEAP prevented initiation of a deep vibracoring program that was planned for the summer of 1977.

Widespread areas of sand wave fields have been identified in northeastern Chirikov Basin (Fig. H-1). Migration of waves is not continual with the normally strong dynamic northward currents, but takes place only intermittently under conditions of extreme storm forcing; this may only occur every few years or more. Future studies require collection of long term current records and reoccupation of baseline stations to monitor history of bedform movement. Further areal reconaissance is also needed to outline all sandwave areas completely.

Stratigraphic history shows that storm surge activity has a severe effect on the bottom, particularly in the areas around the Yukon delta complex (Fig. H-1). Analysis of processes during these events is critically needed in southern Norton Sound and can probably only be provided by the addition of future long-term GEOPROBE stations.

Present knowledge suggests that the Yukon delta and eastern Bering Strait areas have the combination of the most severe geologic hazards. Faulting and current scour are most intense in Bering Strait. Ice gouge, bottom current and storm surge activity are all intense in the extensive, shallow area off the modern Yukon subdelta. The severity and areal extent of gas cratering cannot yet be assessed, but it may well be the greatest problem of any in Norton Basin.

The recent discovery of an apparent major petrogenic seep is likely to cause a quantum jump in interest and development schedule for Norton Basin. This points to the urgent need for a continued strong program of environmental research in this OCS area.

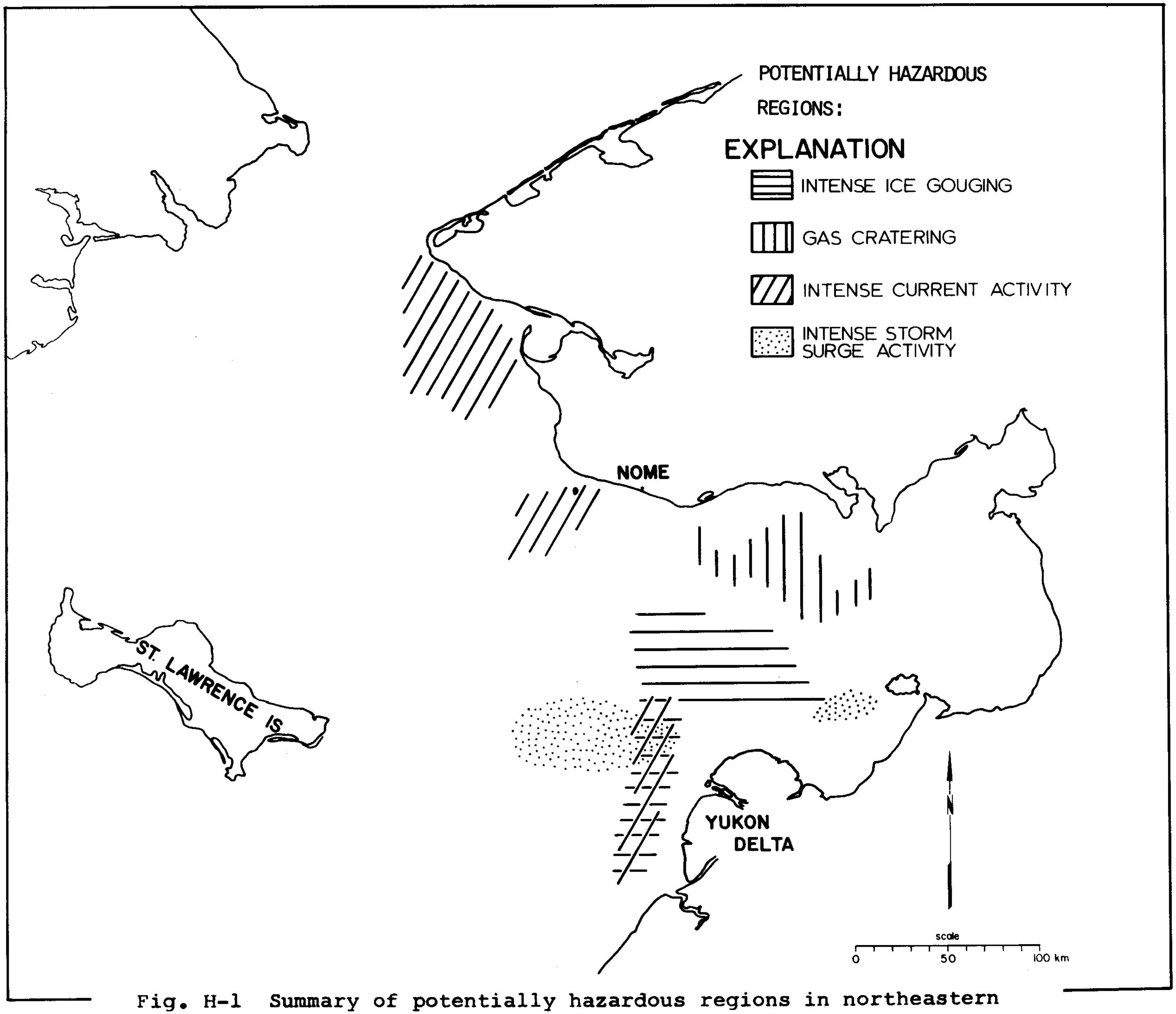

Fig. H-1 Summary of potentially hazardous regions in northeastern Norton Basin

A PRELIMINARY REPORT ON FAULTING, SEDIMENT INSTABILITY, EROSION, AND DEPOSITION HAZARDS OF THE NORTON BASIN SEAFLOOR

I. SUMMARY - see attached

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. A-1). 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 (see Fig. B-1). 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 velocity 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 seabed. Detailed analysis of the side-scan sonar records also permits assessment of regions of intense ice gouging.

C. Relevance to problems of petroleum development

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, gas charged sediments, Thixotropic sediments, ice gouging, and sediment scour caused by current and wave erosion. Potential problems of gas venting and sediment collapse during storm wave interaction with the bottom must be understood prior to development and installation of seafloor 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] The necessary reconnaissance studies with high resolution and side-scan sonar profiling plus vibracoring of sediments was completed in most of Norton Sound (Figs. A2 and A3). Some detailed knowledge of sand wave field areas also was collected in the linear shoal area of potential pipeline corridors towards Port Clarence (Figs. Al and A4). Because of the extremely large area in Norton Basin (about 200,000 km^2) the reconnaissance work was concentrated in the eastern half of Norton Sound in 1976 and will be focused on the western half, Chirikov Basin in 1977 (Fig. A5).

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. Lack of any nominated areas also influenced decisions. The consequence is a concentration on broad reconnaissance of good high resolution geophysics and side-scan sonar data and of new sampling methods of vibracoring at scattered locations over the whole region. Because of possible development of land based facilities in the only natural harbor of the Norton Basin area, and the known existence of sand wave field areas, some topical work was done in the ridge and trough area near Port Clarence (Figs. Al and A4). Last year's work has uncovered a much greater extent of sand wave fields and extensive areas of potentially gas charged sediments. These findings are resulting in some detailed topical studies for the field season of 1977 in addition to broad based reconnaissance for the Chirikov Basin in the western half of the Norton Basin Fig. A5).

Specific methods for each facet of the study are outlined in detail in the results section. The research results are subdivided into seven 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., pp. 485-516.

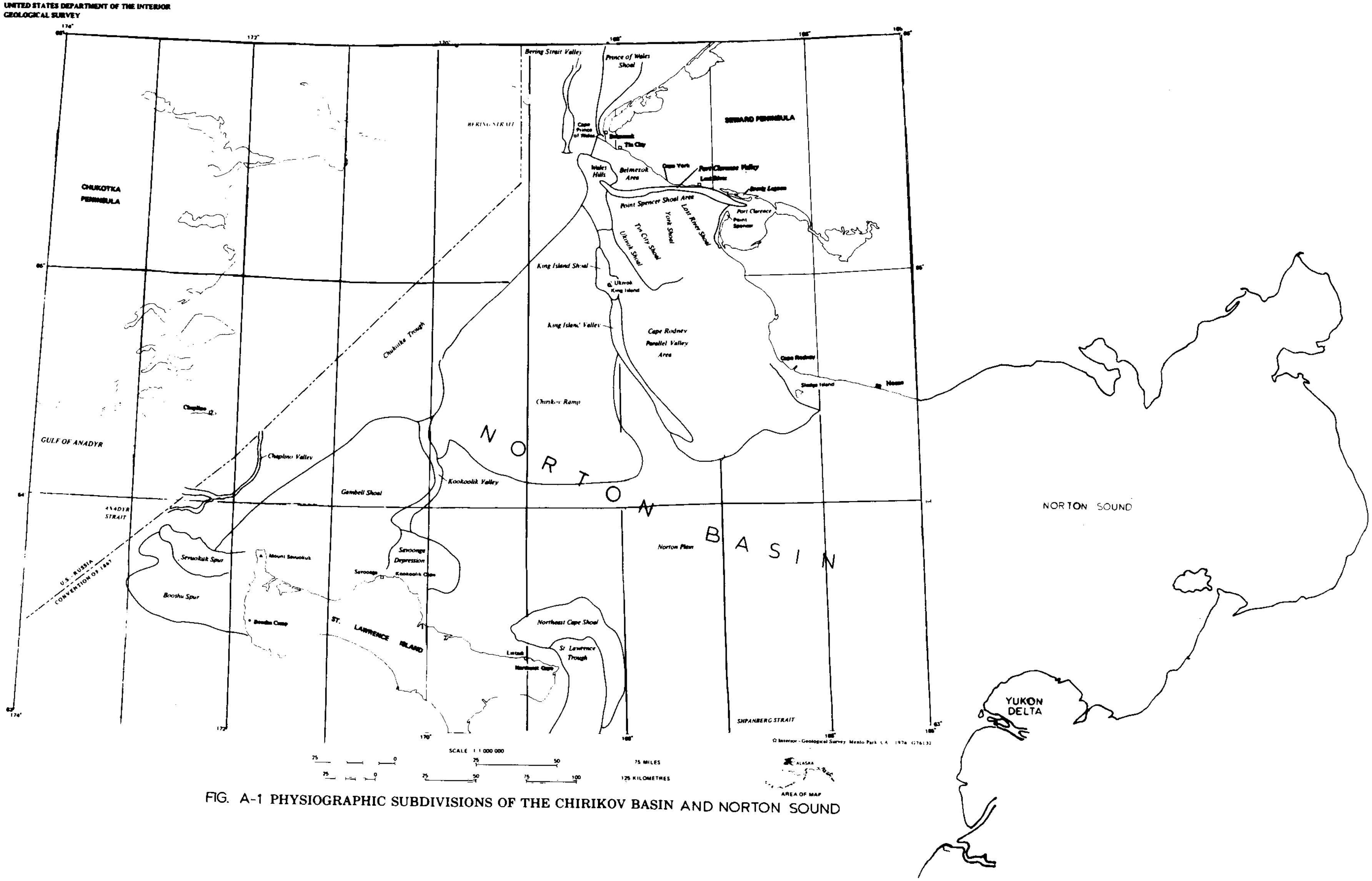

FIG. A-1 PHYSIOGRAPHIC SUBDIVISIONS OF THE CHIRIKOV BASIN AND NORTON SOUND

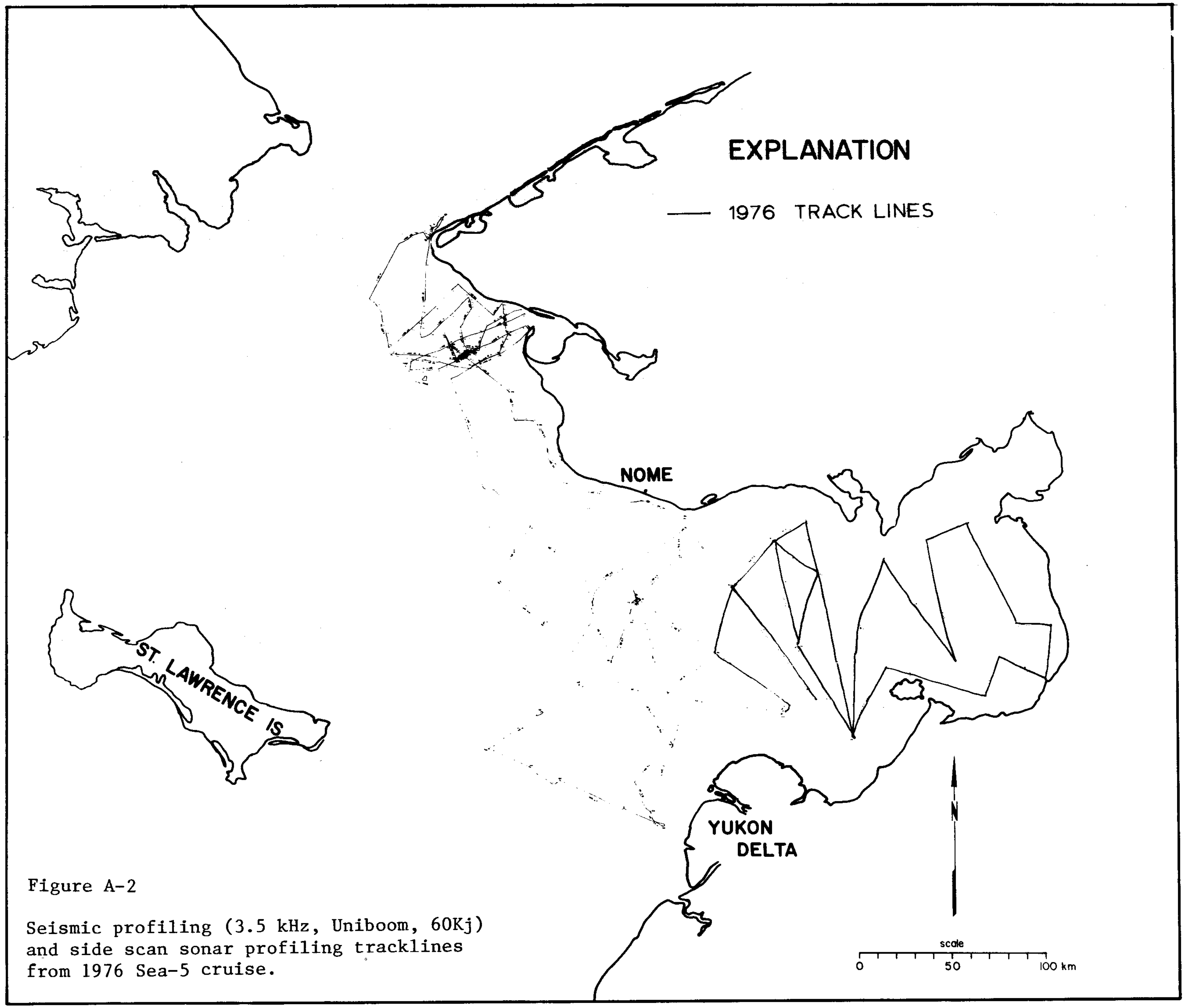

Figure A-2

Seismic profiling (3.5 kHz, Uniboom, 60Kj) and side scan sonar profiling tracklines from 1976 Sea-5 cruise.

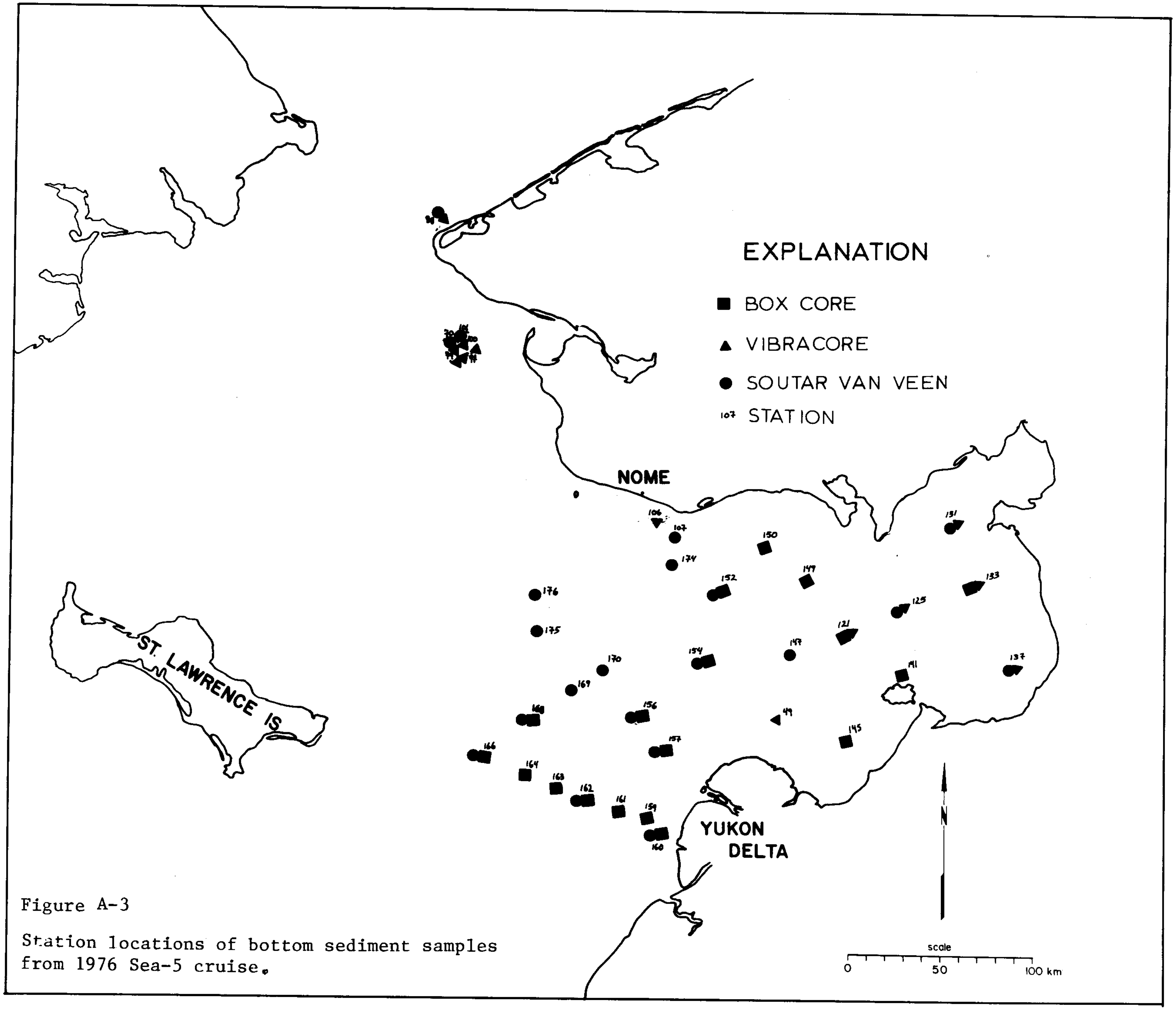

Figure A-3

Station locations of bottom sediment samples from 1976 Sea-5 cruise.

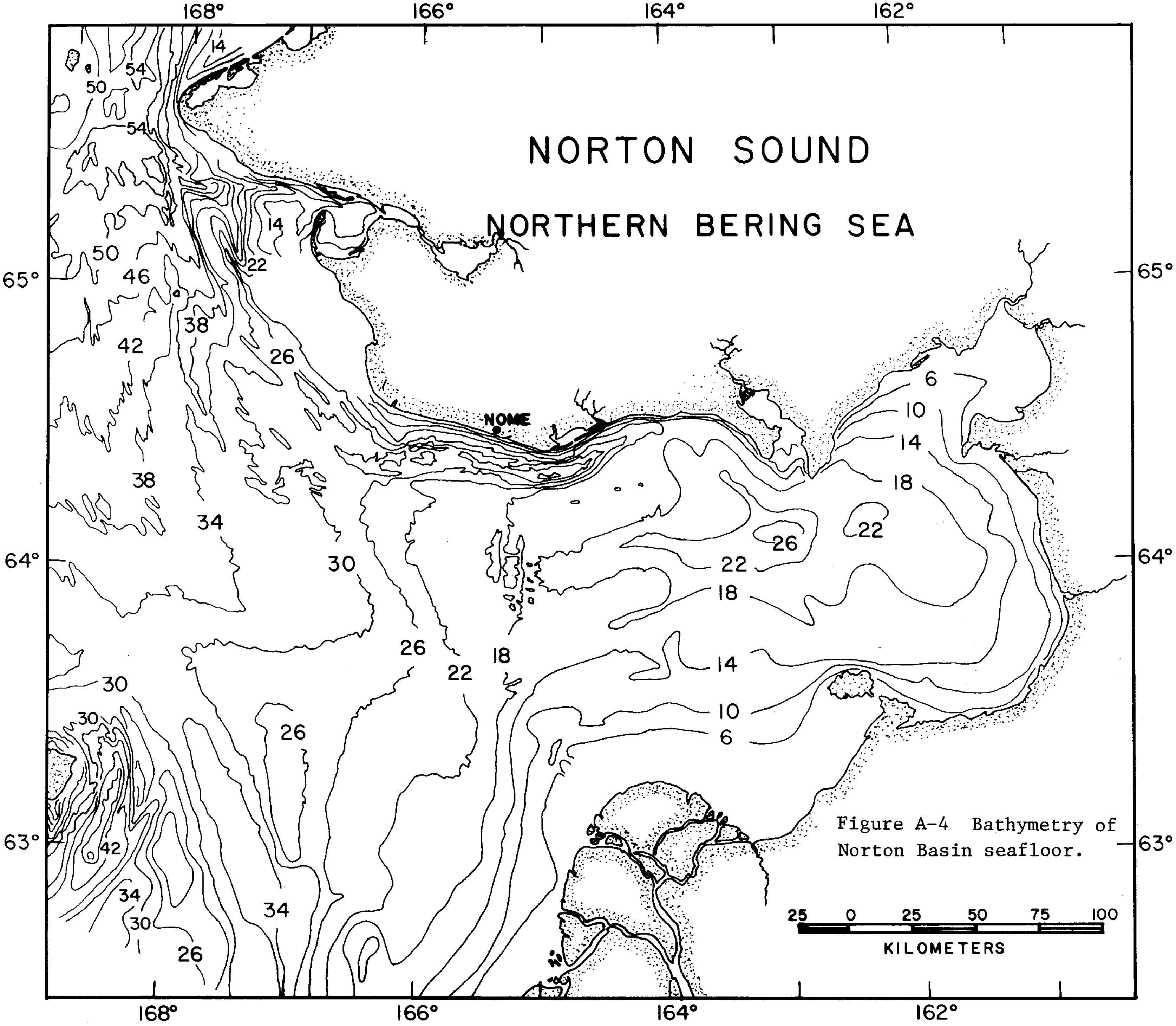

Figure A-4 Bathymetry of Norton Basin seafloor.

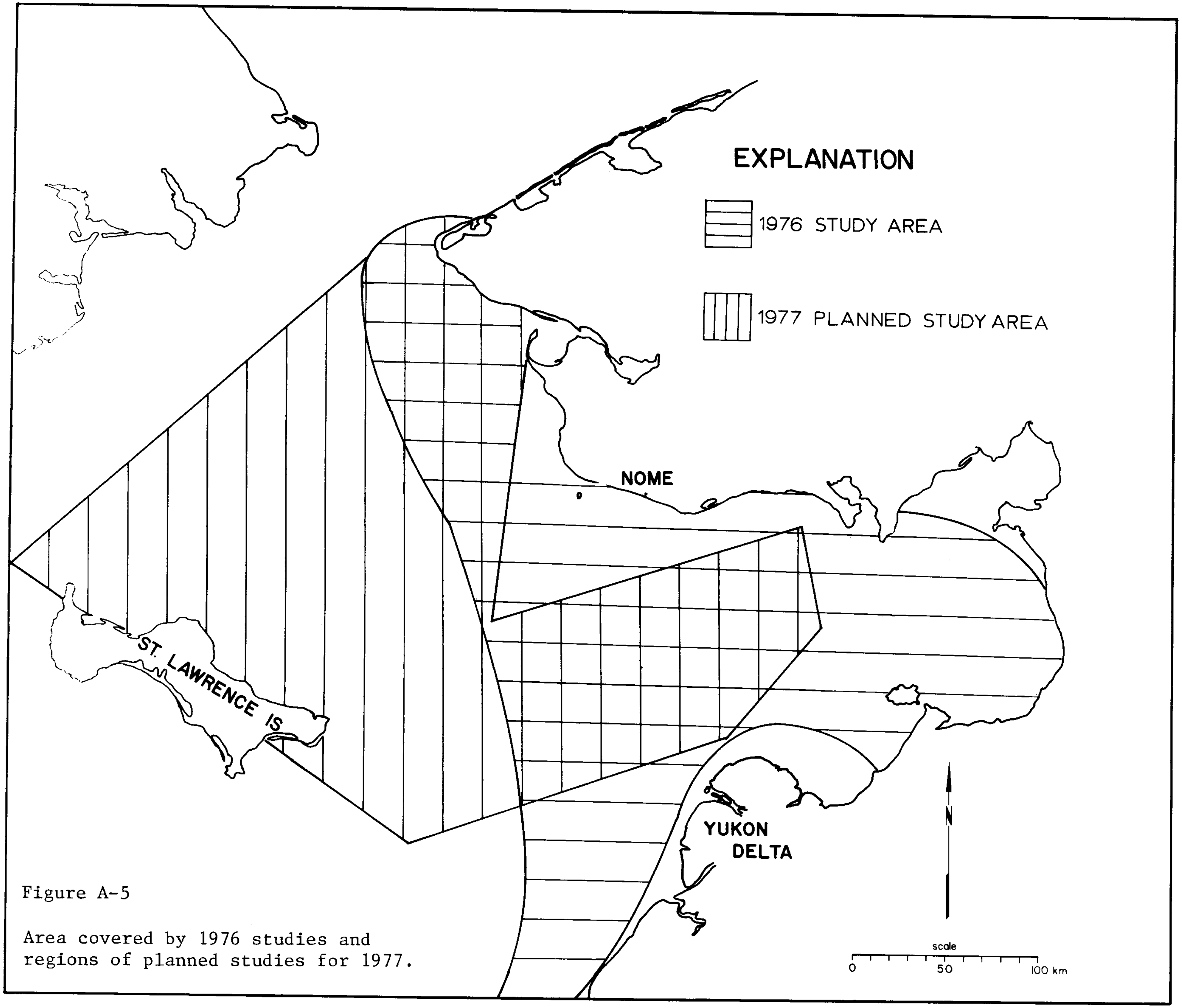

Figure A-5

Area covered by 1976 studies and regions of planned studies for 1977.

B. PRELIMINARY REPORT ON SURFACE AND SUBSURFACE FAULTING IN NORTON SOUND AND NORTHEASTERN CHIRIKOV BASIN, ALASKA

By

Janice L. Johnson and Mark L. Holmes

SUMMARY

Seismic reflection data were obtained in September and October 1976 by the U. S. Geological Survey aboard R/V SEA SOUNDER along 2900 km of track in Norton Sound and northeastern Chirikov Basin. These data and records from several previous surveys are being analyzed in order to determine the location, extent, and possible age and activity potential of offshore faulting. Acoustic survey instruments used included sparker (60 kilojoule), Uniboom (800 joule), 3.5 kHz subbottom profiler, and sidescan sonar.

Maps showing the distribution of surface, near-surface, and deeper subbottom faults show that faulting occurs most commonly within 40 km of the margins of Norton Basin, the deep sedimentary trough which underlies Norton Sound and Chirikov Basin. A smaller number of faults were detected in the central regions of the basin.

Faulting appears to occur predominantly in three areas: northern Chirikov Basin; along the southern margins of Norton Sound and Chirikov Basin north of St. Lawrence Island; and along the southern and eastern margins of Norton Sound. Surface fault scarps were seen in several places in northern Chirikov Basin. These sea-floor offsets ranged in height

from 5 to 15 m along several west-trending faults which may be associated with some of the major transcurrent faults in Alaska. The existence of these scarps indicates possible disturbance of sedimentary deposits over the fault. The scarps may have also been maintained by non-deposition or erosion by currents, however. Evidence from both onshore and offshore field studies indicate that movement along these faults may have occurred between 12,000 - 100,000 years ago.

Although no surface scarps were seen to be associated with offshore faults near St. Lawrence Island and in southern Norton Sound, horizontal (transcurrent) motions along these faults may have taken place during Quaternary time in conjunction with movements on the Kaltag Fault which displaced Pleistocene deposits in western Alaska.

Several of the faults around the margins and in the central regions of Norton Basin appear to show increasing displacement with depth and a thickening of the strata as they dip basinward away from the fault. These characteristics indicate a more or less continual movement along the faults as Norton Basin was subsiding. The lack of recorded earthquakes in Norton Basin during historical time implies that either activity along the offshore faults has ceased, or that movement is taking place at a slow but steady rate, preventing a buildup of strain and consequent earthquake - producing ruptures.

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INTRODUCTION

Geological and geophysical studies were carried out by U. S. Geological Survey personnel aboard R/V SEA SOUNDER in Norton Sound and Chirikov Basin during the period from 21 September to 14 October 1976 (Figs. A1, B1). Acoustic survey systems used included a 60 kilojoule sparker, an 800 joule (four transducer) Uniboom, a 3.5 kHz bathymetric/subbottom profiling system, and sidescan sonar. This section of the annual report deals primarily with an interpretation of the extent and hazard potential of the surface and subsurface faults shown on the sparker and Uniboom records. Discussions of the 3.5 kHz and sidescan sonar data will be found in other sections.

The geophysical data obtained on this recent USGS cruise has been supplemented in places by siesmic reflection information which was collected on previous expeditions by the USGS, NOAA, and the University of Washington (Fig. B1). In 1967 a joint USGS/University of Washington cruise obtained 4200 km of 150 joule sparker data (Grim and McManus, 1970), and 3200 km of 120 kilojoule sparker records (Scholl and Hopkins, 1969). High-resolution seismic reflection surveys were conducted in 1967 in the nearshore region south of Nome between Sledge Island and Cape Nome (Tagg and Green, 1973). Walton et al. (1969) shot 3840 km of single channel 40 in^3 air gun records during a joint USGS/NOAA (then ESSA) survey in 1969, and that same year an additional 800 km of 150 joule sparker records were collected in Chirikov Basin on a joint USGS/University of Washington cruise.

Although some data and conclusions resulting from these earlier studies have been used to supplement the information collected last summer, a thorough integration of all geophysical data obtained to date has not yet been done. Additional unpublished seismic profiles from surveys by H. G. Greene and C. H. Nelson will also be examined and the resulting interpretations will be used to augment those which will be discussed in this paper.

All seismic records, sidescan records, and navigational data from the 1976 R/V SEA SOUNDER cruise are on microfilm. Copies can be obtained from the National Geophysical and Solar-Terrestrial Data Center, EDS/NOAA, Boulder, Colorado 80302, or from the Alaska Technical Data Unit, USGS, 345 Middlefield Road, Menlo Park, California 94025.

METHODS

This section discusses the instrumentation and procedures used in collecting navigation and acoustic survey data on the R/V SEA SOUNDER cruise in September-October 1976.

Navigation

Navigational information was obtained by two independent systems. A Magnavox satellite navigator with integrated Teledyne Loran C received inputs from the ship's speed log and gyro. This system computed dead reckoning positions every two seconds and the data were stored on magnetic tape and a teleprinter. Performance of the system was degraded somewhat by proximity to the Loran C master station at Port Clarence (Fig. A1) and the high elevation of many of the satellites during transit.

A Motorola mini-Ranger system was used to obtain fixes every seven and one-half minutes which were recorded on paper tape in digital form. This system measures the range to two or more shore-based transponders which were maintained by survey personnel on land. On a few occasions the included angle between the transponders was too small to permit obtaining reliable fix information.

Fixes were plotted at least every fifteen minutes on the navigational charts with appropriate notations made at the time of major course and speed changes. Radar and line-of-sight bearings were sometimes used to augment the other navigational information, and navigational accuracy probably averaged ± 150 m.

Acoustic Survey Techniques

Figure B1 shows the tracklines for the 1976 R/V SEA SOUNDER cruise, as well as those of previous expeditions on which seismic reflection data were collected. The figure also notes which acoustic systems were used on each track. The bathymetry/subbottom profiler and sidescan sonar systems used aboard R/V SEA SOUNDER will be briefly discussed, although interpretation of these data will be, as previously mentioned, found in other sections of the report.

Seismic profiling operations aboard R/V SEA SOUNDER were carried out at speeds ranging from 4-6.5 knots. It was found that speeds greater or less than this range resulted in generation of "ship noise" by the propulsion machinery which produced a significant amount of interference on the records.

Sparker. A Teledyne SSP (Seismic Section Profiler) was used to obtain 930 km of single channel seismic reflection records in Norton Sound and northeastern Chirikov Basin. Power output was normally 60 kilojoules, but was reduced to 30 kilojoules at times because of equipment casualties. The signals were received by a Teledyne 100-element Hydrostreamer and processed through a Teledyne seismic amplifier before being printed off a modified Raytheon PFR (Precision Fathometer Recorder). Frequency pass band was normally set at 40-125 Hz, and sweep and fire rate was 3 seconds. The records were annotated at 30 minute intervals with date, time (GMT), line number, water depth, and appropriate instrument settings. Changes in course, speed, or instrumentation were noted when they occurred.

Maximum penetration achieved by the sparker was approximately 2.1 km. The quality of the records was affected adversely by the shallow water and the generally flat nature of the bottom and subbottom reflectors. The shallow depth caused the water bottom multiple to appear at small distances below the initial sea-floor reflection, thus partially obscuring signals from deeper reflectors. The flat subbottom layering produced intra-formational or "peg-leg" multiples which also obscured or interfered with the primary reflections. In only a few places was an acoustic basement detected; more commonly the reflection amplitudes slowly decreased as the signal was attenuated in the sedimentary section.

Uniboom. Approximately 2900 km of high-resolution records were obtained using a hull-mounted EG & G Uniboom system consisting of four transducer plates. Total power level for this array was 800 joules. An EG & G model 265 hydrophone streamer (10 - element) was used as a receiver. Records were printed on an EPC 4100 recorder after passing through a Krohn-Hite filter. Sweep and fire rate was 1/4 second, and filter pass band was typically set from 400-1200 Hz. Record annotations similar to those for the sparker were made at 10 minute intervals.

The quality of the Uniboom records was most affected by sea state, surficial bottom sediment type, and machinery generated ship noise. The hydrophone streamer is towed alongside the ship and only 20-30 cm below the surface. Consistently choppy seas were responsible for a significant amount of noise on the record which sometimes totally obscured subbottom reflectors. Maximum penetration achieved was approximately 100 m, but was typically less than 75 m. Whenever coarse-grained and hard sediments were encountered penetration was severely reduced, and in some instances, such as near the Yukon Delta, the records are very poor.

Bathymetry/Subbottom Profiler. These data were collected along 2900 km of track using a Raytheon 3.5 kHz CESP II system. A hull-mounted transducer array consisting of 12 TR-109A units was used to send and receive the signals. Pulse generation and correlation functions were done by a CESP II (Correlator Echo Sounder Processor) and a PTR-105B Precision Transmitter Receiver) was used as a tone burst amplifier during pulse transmission. Sweep and fire rates were normally 1/2 second, however, a 1/4 second sweep was used on occasion. The records were annotated and depth measurements taken at 10-minute intervals.

Clarity of the records and amount of penetration varied considerably over the survey area. This system seemed less sensitive to ship-generated noise than the Uniboom, but the 3.5 kHz records were more adversely affected by hard bottom sediment. The long (50 msec) pulse generated during transmission also created an internal "ringing" in the transducer array which masked not only the weak subbottom reflections but sometimes the bottom echo as well in shallow water. Penetration ranged from 0-20 m.

Sidescan Sonar. An EG & G sidescan sonar system was used to record 1425 km of good to high quality data. Scales (sweeps) of 50 m and 125 m were used, and the "fish" altitude above the sea-floor was maintained at approximately 10 percent of the scale being used. The sidescan system was used in shallow water areas of known or suspected sand waves and ice-gouge features, and at such times the sparker system was shut down and its associated arc cables and hydrostreamer were brought aboard to prevent their fouling the sidescan cable. On at least two occasions sudden shoaling of the bottom caused the fish to hit the sea-floor with resultant damage to the tow cable which necessitated its replacement.

GEOLOGIC SETTING

Tectonic Framework

The structural features and evolution of the Bering Sea continental shelf have been discussed by Scholl and Hopkins, 1969; Scholl et al., 1968; Pratt et al., 1972; Churkin, 1972; Lathram, 1973; Nelson et al., 1974; and Marlow et al., 1976. Figure B2 shows the major Cenozoic structures of western Alaska and eastern Siberia.

The general tectonic framework is characterized by large scale oroclinal bending forming two distinct flexures in central Alaska and eastern Siberia concave toward the Pacific Ocean. The Bering and Chukchi continental shelves are part of the broad intervening structural arc which is concave toward the Arctic Ocean.

This large scale oroclinal folding appears to have been completed before Oligocene time (Nelson et al., 1974), but continued activity along the major Alaskan transcurrent faults has displaced upper Tertiary and Quaternary sediment in several places on land and beneath the shelf areas (Patton and Hoare, 1968; Scholl et al., 1970; Grim and McManus, 1970). Total horizontal (right-lateral) movement along some of these large transcurrent faults has been approximately 130 km since the beginning of the Tertiary (Grantz, 1966; Patton and Hoare, 1968).

Regional Geology

Norton Basin

The geology of Norton Basin, the large sedimentary prism beneath Norton Sound and Chirikov basin, has been discussed by Moore, 1964; Scholl and Hopkins, 1969; Grim and McManus, 1970; Tagg and Greene, 1973; Nelson et al., 1974; and others. Seismic reflection data suggest that the basin area is about 130,000 km^2, and maximum depth has been recently estimated to be approximately 5.5 km (Anon., 1976). Estimates of the volume of sediment in the basin range from 100,000-180,000 km^3.

The basin fill consists of two major stratified units comprising the Main Layered Sequence (Scholl and Hopkins, 1969), which are in turn covered by a thin mantle of Quaternary sediment (Grim and McManus, 1970; Tagg and Greene, 1973; Nelson and Creager, 1977). The major units of the Main Layered Sequence are separated by an unconformity which lies at a depth of about 500-700 m near the basin axis. This erosional surface approaches to within a few tens of meters near the basin margins.

Although younger Quaternary deposits everywhere cover the older Cenozoic and Mesozoic basin fill, some onshore outcrops and drill-hole data give clues as to the nature of these deposits. Nonmarine coal-bearing strata of late Oligocene age are exposed on northwestern St. Lawrence Island (Patton and Csejtey, 1970), and several offshore holes drilled by the U.S. Bureau of Mines near Nome encountered marine sands and clayey silts of early Pliocene age at a subbottom depth of approximately 18 m (Scholl and Hopkins, 1969; Nelson et al., 1974). Late Miocene or early Pliocene marine limestone was recovered from a dredge haul 30 km south of St. Lawrence Island, just outside the basin. These facts and the regional stratigraphic patterns indicate that the basin fill probably consists of late Cretaceous and lower to middle Tertiary sedimentary rock in the lower major unit and upper Tertiary and Plio-Pleistocene sedimentary rocks and sediment in the upper major unit. All direct evidence suggests that the lower unit is nonmarine, but the size of the basin is such that unseen transitions to marine facies could occur within this unit.

Strata of the lower major unit form a broad synclinorium whose principal axis trends generally east-west (Fig. B2). The beds of the upper unit are more nearly flat-lying above the angular unconformity.

Acoustic Basement. Norton Basin is underlain by an acoustic basement surface formed on strata which are probably analogous to the diverse older rocks which occur on land around the basin margins. Sedimentary, metamorphic, and igneous rocks of Precambrian through Mesozoic age are exposed on the Chukotka Peninsula (Nalivkin, 1960); and Seward Peninsula is formed primarily of Paleozoic sedimentary and metamorphic units with some Mesozoic and Cenozoic intrusive and extrusive rocks. Mesozoic sedimentary rocks (some slightly metamorphosed) and Cenozoic volcanics have been mapped onshore in the Yukon-Koyukuk Basin east and southeast of Norton Sound (Miller et al., 1959; Patton and Hoare, 1968). At the southern margin of Norton Basin, St. Lawrence Island is constructed mainly of Paleozoic, Mesozoic, and Cenozoic intrusive and extrusive rocks with some Cenozoic sedimentary deposits (Miller et al., 1959; Scholl and Hopkins, 1969; Patton and Csejtey, 1970). The acoustic basement probably represents an erosional surface which has been steepened by tectonic subsidence during development of Norton Basin.

RESULTS AND DISCUSSION

Observed Faults and Structures

The large scale structural features observed on seismic reflection profiles from Norton Sound and Chirikov Basin trend generally east-west, in alignment with the regional tectonic framework (Fig. B2). Ridge axes and sediment filled troughs in Chirikov Basin have been mapped by Greene and Perry (unpub.) and are shown in Fig. B3. The largest of the troughs is narrow and elongated east to west and contains at least 1800 meters of Main Layered Sequence sediment. Smaller troughs occur subparallel to this. A major basement high, the King Island Ridge, extends northwest from Sledge Island through King Island, turning westward about 35 km north of King Island. A shorter ridge extends eastward from the easternmost tip of St. Lawrence Island.

Sediments of the Main Layered Sequence are seen lying unconformably on the eroded surface of the preCenozoic acoustic basement, filling in depressions and lapping up gently at the basin margins and ridge axes. Frequently, the angular unconformity between the lower unit of the Main Layered Sequence and the more flat lying upper unit can be seen. Numerous faults occur in the acoustic basement, often displacing overlying sediments of the Main Layered Sequence. Several faults occur only in the Cenozoic sediments, or extend to within 100 meters of the sediment surface. A few of these have topographic expression as fault scarps. Most faults in Norton Basin, expecially those extending close to the sea floor, occur within 40 km of the basin margins, usually in association with the large scale structural features.

Major deep-seated faults in Norton Sound and Chirikov Basin are shown in Fig. B3. These are associated with offsets in the Tertiary strata of the Main Layered Sequence, and often of the underlying erosional unconformity. Surface and near-surface faults are shown in Fig. B4. Three distinct zones of major faults can be recognized, these are: northeast of the King Island Ridge, north of St. Lawrence Island, and in southeastern Norton Sound.

On the north side of King Island Ridge, local sets of normal faults, 10 to 15 kilometers in length, drop the plutonic rocks of the ridge down to the north. A large graben northeast of King Island (Fig. B3) contains approximately 1000 meters of sediment (Greene and Perry, unpub.). Three small (1 to 2 m.) surface scarps (Fig. B4) have been identified within this feature (Grim and McManus, 1970).

A large sediment filled depression north of King Island, called the Bering Strait Depression by Greene and Perry (unpub.), is bounded by several major east-west trending fault systems (Figs. B3 and B4). The northern boundary of this depression is marked by surface scarps of about 5 meters height, which have been identified over 50 km and are assumed to be a continuous feature (Grim and McManus, 1970).

Extending east from the Bering Strait Depression is the Port Clarence Rift (Hopkins, unpub.), the northern side of which is probably equivalent to the Cape York fault of Greene and Perry (unpub.). The rift zone consists of two faults separated by a narrow sediment filled trough. The northern, or Cape York, fault has a scarp of 15 meters height (Greene and Perry, unpub; Hopkins, unpub.) and extends approximately 55 km east to where it disappears beneath the surface near Port Clarence. Displacement of bedrock beneath Grantley Harbor indicates that the Port Clarence Rift probably extends further east, and has experienced 16 km of left-lateral displacement west of Cape York (Patton, unpub. field work, 1973; Hopkins, unpub.).

The Bering Strait Fault has a surface scarp 6 m high and extends at least 25 km westward from the Bering Strait Depression; the fault may be related to the Port Clarence Rift (Greene and Perry, unpub.; Hopkins, unpub.). Another surface scarp 15 meters high is located northwest of Cape Prince of Wales (Fig. B4). The lateral extent of this fault cannot be estimated without further seismic reflection profiling.

Hopkins (unpub.) has inferred a large left-lateral fault passing through the graben located 40 km northwest of the northeastern end of St. Lawrence Island. The St. Lawrence Fault passes through the crest of the Kookooligit Mountains and turns north before reaching the northern end of St. Lawrence Island. Evidence for the existence of this fault comes from volcanic vents and faults in the Kookooligit Mountains.

Deeper subbottom faults occur along the southern and eastern margins of Norton Sound (Fig. B3). Correlation of fault traces between tracks is difficult because of the wide line spacing, but several faults appear to parallel the offshore trend of the Kaltag Fault. No surface scarps were associated with the near-surface faults which cut through upper Tertiary and Quaternary deposits along the eastern margin of Norton Sound.

Tagg and Greene (1973) mapped two surface scarps near the northern margin of Norton Basin west of Nome. A preliminary examination of seismic reflection data from detailed surveys to the east and west of these scarps indicates the existence of several other near-surface and surface faults roughly parallel to the basin margin.

Deep-seated and near-surface faults are not uncommon in the central part of Norton Basin, although no associated surface expressions have yet been identified. The increase in displacement with depth and apparent thickening of beds away from some of these faults toward the basin axis indicates that they are probably growth faults along which movement has taken place more or less continuously during the episodes of major basin subsidence. Because of the wide track spacing and poor data coverage, the lateral extent of most of these faults cannot be determined.

Fault Activity and Hazard Potential

Surface fault scarps in northern Chirikov Basin are associated with the Bering Strait Fault, the Port Clarence Rift, and other nearby faults. These scarps may have been caused by recent vertical movement on these faults, and therefore would indicate a definite hazard to engineering structures placed over or near these fault zones. There is also the possibility, that the faults have been inactive for some time, and the scarps have been maintained by nondeposition or lack of erosion. Currents west of Port Clarence flow almost normal to the trend of these scarps, however, and the persistence of the surface expression of these faults in spite of apparently vigorous erosional agents would argue for the fault scarps to be recently formed features.

Earthquake records show a complete lack of epicenters beneath Norton Basin. The Bering Strait Fault and Port Clarence Rift may represent extensions or splays of the large transcurrent faults which have been mapped in western Alaska and Seward Peninsula (Fig. B2). The lack of epicenters associated with the faults could be interpreted to indicate either inactivity or, conversely, that strain release due to continued basin subsidence is being accomplished by small but frequent adjustments along these faults.

The Bering Strait Fault must have formed between 12,000 and 120,000 years ago; evidence exists that a lake was formed during the Wisconsin glaciation when development of the fault scarp dammed a northward-flowing river west of present day Port Clarence. Marine terraces on Seward Peninsula may have been uplifted during the Illinoian glaciation as a result of movement along the fault 130,000 years ago. Although no specific age can be given to movements along these faults in northern Chirikov Basin, the area should definitely be considered as potentially hazardous to placement of structures on the bottom in the vicinity of the fault scarps.

Surface scarps have not, as yet, been noted in association with faults along the northern side of St. Lawrence Island or in southern and eastern Norton Sound. Movement may still have occurred along these faults in conjunction with known displacement in western Alaska along the large transcurrent Kaltag Fault, which occurred during the Pleistocene. Further study is necessary to determine if this represents a hazard to resource development.

CONCLUSIONS

Based on the foregoing discussion, the following conclusions may be made regarding the folding and faulting observed in Norton Sound and Chirikov Basin:

1. The many anticlinal and synclinal folds involving the strata of the Main Layered Sequence and acoustic basement are the result of tectonic activity and volcanism which occurred during subsidence and filling of the 5.5-km deep Norton Basin; the general axial trend of these structures is east-west. Initial subsidence of the basin probably began during early Tertiary time, and has continued to the present with only one apparent major interruption during late Miocene or early Pliocene.

2. Faults are most numerous in a belt 40 km wide around the margins of Norton Basin; areas where faulting appears to be concentrated include northern Chirikov Basin, the northern coast of St. Lawrence Island, and near the southern and eastern margins of Norton Sound. Near surface faults are more numerous in central Norton Basin than previously reported, but are still less prevalent than around the periphery of the basin. Most of the faults trend generally east-west, with the basinward sides downdropped, an indication of growth associated with basin subsidence.

3. Surface scarps up to 15 m high are associated with some of the long faults in northern Chirikov Basin. These scarps can indicate either recent activity or persistence due to lack of erosion or burial by sedimentation since the last movement. Scarps occur on the Bering Strait Fault and on the northern side of the Port Clarence Rift, and movement along these faults possibly occurred as recently as 12,000 years ago in conjunction with uplift of marine terraces on Seward Peninsula.

4. No faults can definitely be classed as historically active, however the area of northern Chirikov Basin west of Port Clarence should be considered potentially hazardous to any bottom mounted structures. The fault scarps in this region are still well defined in spite of the swift currents and bottom sediment transport which occur normal to the trend of the fault zones. Basin subsidence is probably still taking place, and the lack of recorded earthquakes beneath Norton Basin may indicate that strain release is being accomplished by small but frequent movement along some of these faults.

5. West-trending subbottom faults without surface fault scarps occur along the southern margin of Norton Basin. These may represent splays or displacements related to the Kaltag Fault, one of the major transcurrent faults in western Alaska. Movement along onshore portions of the Kaltag Fault have displaced Pleistocene deposits, but data regarding age of movements along the offshore portion are inconclusive.

FURTHER STUDY

Additional studies of the offshore surface and subsurface faulting in Norton Basin (Norton Sound and Chirikov Basin) should not only entail further work with existing data but also require the collection of additional seismic reflection lines where data coverage is poor or non-existent. A complete integration of all previously collected geophysical information should be made in order to give as complete a picture as possible of the fault patterns and the styles of deformation responsible for producing these patterns.

The gravity data collected by NOAA in 1968 and 1969 and the USGS in 1976 should be evaluated to further define the large scale tectonic features and permit a more detailed analysis of deep basin and basement structural trends. This will help shed more light on the types of deformation responsible for the formation of the basin and the observed fault patterns and, together with the seismic reflection measurements, may permit more firm conclusions regarding potential faulting hazards in the basin.

More high energy sparker (SSP) data are needed in Norton Sound, where existing coverage is sparse and of very poor quality. The eastern limit of the basin and the trend of surface and subsurface faults in this area are poorly defined with existing information. We estimate that 600 km of additional reflection lines are needed for adequate coverage; this represents approximately 3 days of ship time.

Consideration should also be given to the use of a mini-spark system (approximately 800 joules) in future surveys. Such a seismic reflection source would bridge the information gap between the subbottom profiler and SSP more adequately than the Uniboom, and would give better high-resolution data in rough water conditions. The mini-spark system would also be better able to provide adequate penetration (at least near the margins of the basin) for the definition of the major unconformities in the sedimentary section and would thus help to date faulting activity relative to these marker horizons whose approximate ages are known.

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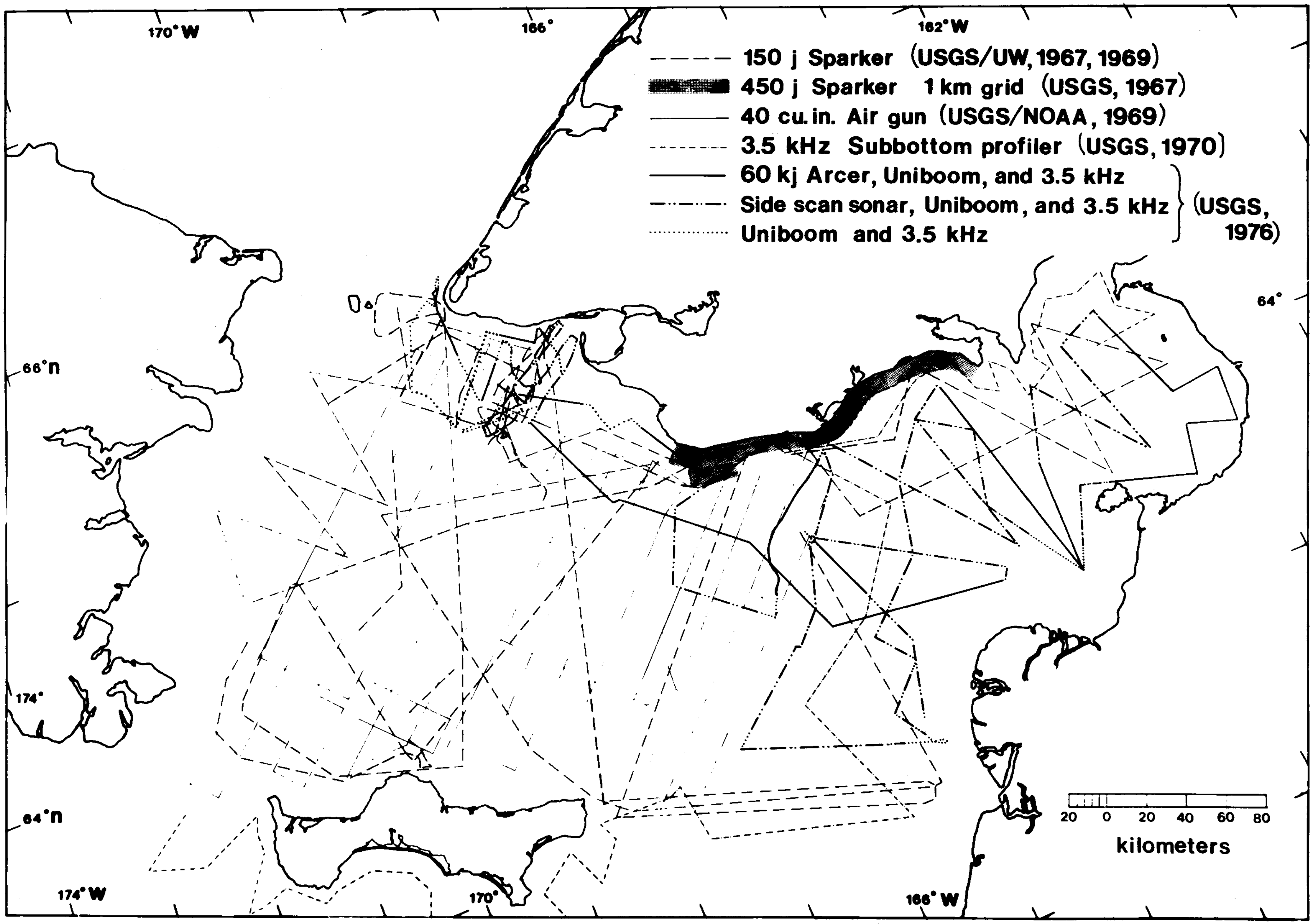


B1. Tracklines in Norton Sound and Chirikov Basin

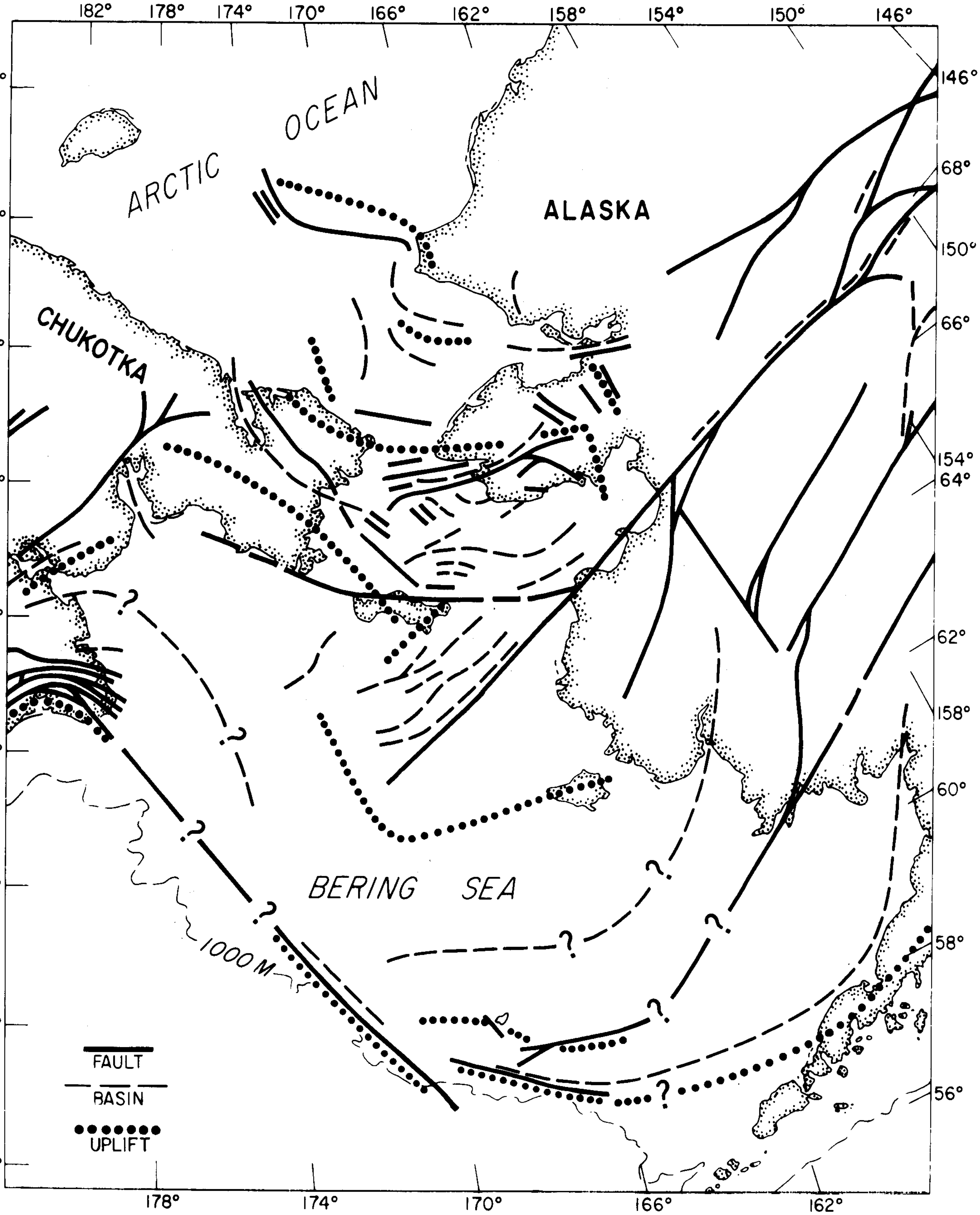
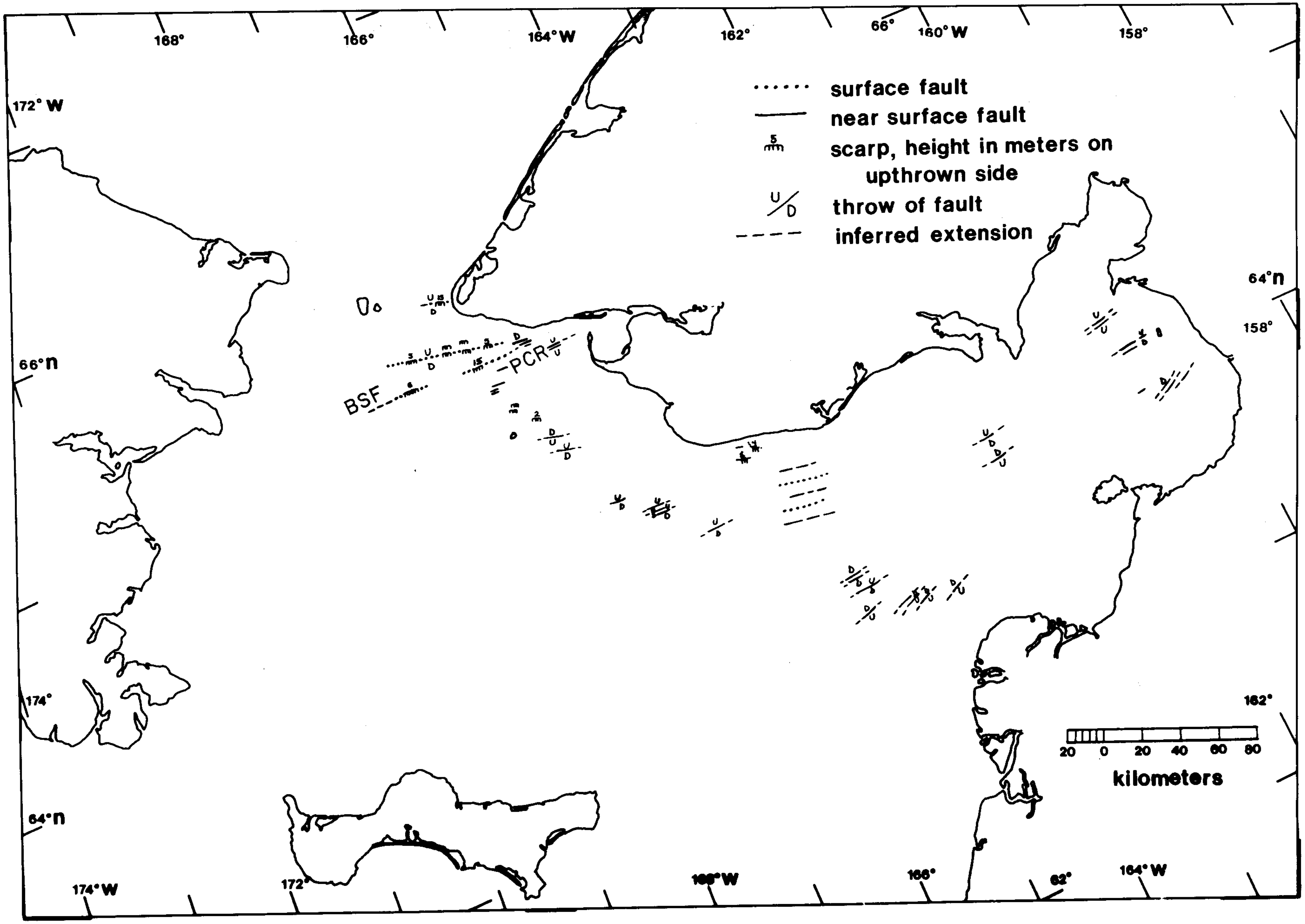
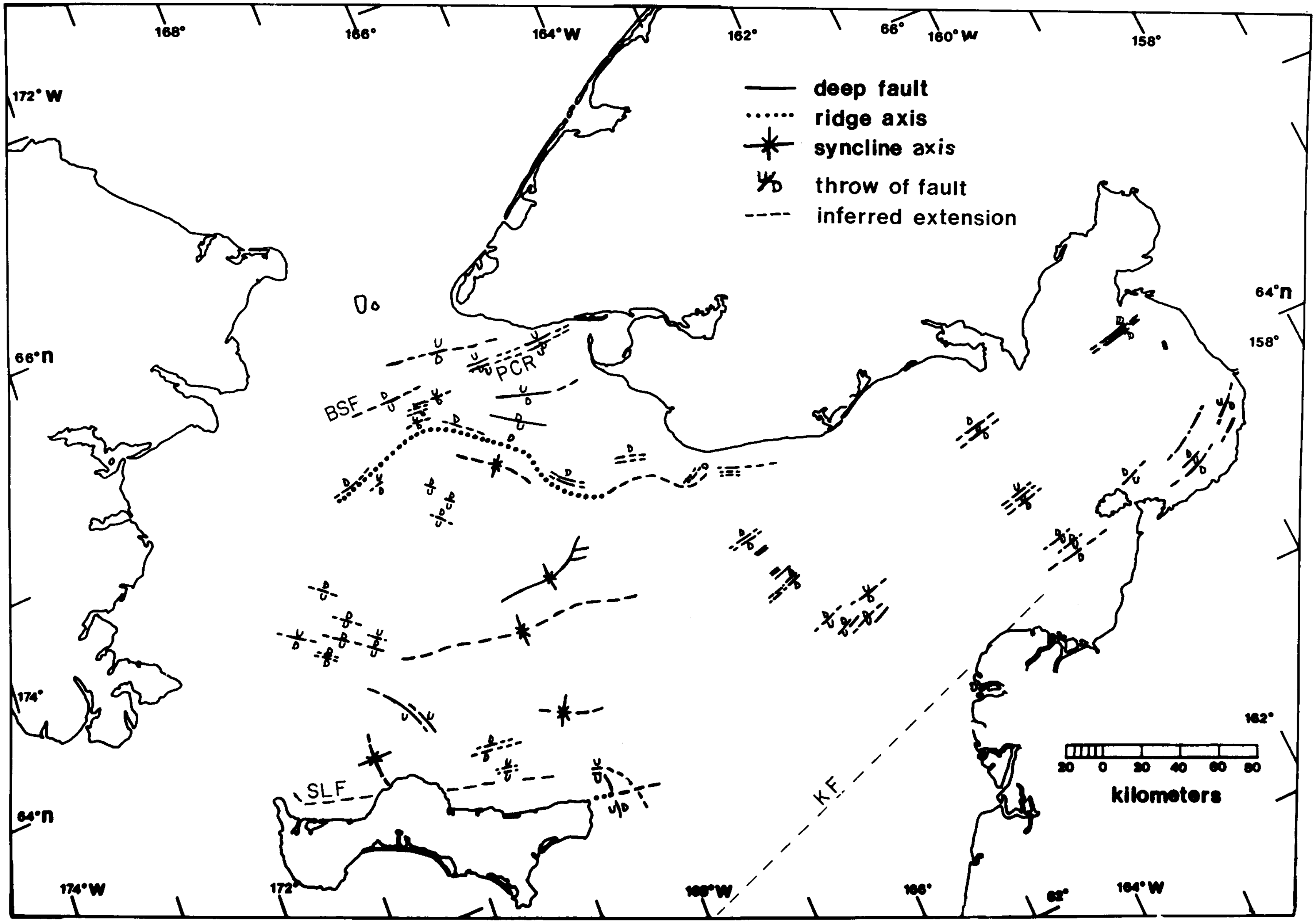


Fig. B2. Cenozoic structures of the Bearing and Chukchi shelves (from Nelson et al, 1974)



B3. Surface and near-surface faults in Norton Basin



B4. Deeper subsurface and basement faults and structures in Norton Basin

C. Preliminary Report - Physical Properties and Geotechnical Characteristics of Northern Bering Sea, Norton Sound Sediments

By: John Newby, Edward C. Clukey, and Hans Nelson

Introduction

Near surface (<2m) sediments from the Northern Bering Sea, Norton Sound area have been investigated to determine their physical properties and geotechnical characteristics. This study is part of a broader based investigation assessing possible environmental and geologic hazards to resource development in the area.

Sub-samples tested for this study were taken aboard the USGS R/V SEA SOUNDER during the early fall, 1976. The sediment samplers used were a box core, Kiel Vibracorer and UCLA van Veen. High resolution (3.5 kHz, EG&G Uniboom and 90 kJ Sparker) seismic records in addition to side-scan sonar records were also obtained to ascertain sediment morphology, thickness, and stratigraphy throughout the project area. Core lithology, radiography and gas content analyses also were completed during the cruise.

The primary objectives of the geotechnical portion of this research were to investigate the physical or mechanical properties of the sediments on a regional and stratigraphic basis (within the upper few meters) in order to identify potential engineering hazards. Knowledge of the physical properties within the upper few meters is valuable when assessing possible route selections for underwater pipelines and cable laying operations. Even though the identification of many types of potential geotechnical hazards such as massive slumps or debris slides will require investigations to greater sediment depths, offshore mooring systems and settlement as well as bearing capacity predictions for shallow founded gravity structures are significantly affected by the physical properties of the sediments in the upper few meters. Examination of available geotechnical data of near-surface sediments are also valuable when assessing what geotechnical conditions may exist at greater depths--particularly if the past geologic history is known. For example, extrapolation of near-surface data could predict the presence of underconsolidated sediments at depth if the underconsolidated characteristics were identified in the upper few meters and the rate and type of sediment accumulation were constant throughout the history of the sedimentary buildup.

We also made a preliminary assessment of the effects of ice gouging and variations in physical properties created by gas charged sediments. While more advanced studies in these areas are considered necessary and will be pursued in future research, understanding of the reasons for variances in the physical property measurements in the upper sedimentary stratum is essential before deeper studies can be properly undertaken.

The effects of dynamically induced loads, both from storm waves and earthquakes, on the sediment physical properties are considered beyond the scope of this report. Such effects are considered to be extremely important however, particularly as related to sedimentary slope stability, and should be included in future geotechnical reconnaissance.

Methods of sampling and geotechnical measurements

Shipboard sampling

During the cruise three types of sediment samplers were used: a box correr, a Soutar van Veen and Kiel Vibrocore. The location and station number for each sample is shown in Figure A-3.

The box core was capable of obtaining samples, 8 inches by 12 inches in section, up to 24 inches in depth. Due to the excellent area and length ratios (and from previous experience) high quality samples were expected. A total of twenty-four box cores of varying depths was obtained.

The Soutar van Veen is a highly modified van Veen grab sampler constructed by Andy Soutar of Scripps Institute of Oceanography for UCLA. The clamshell grab is driven into the sediment by a 400 lb. load, guided by vertical rails in a frame. The samples usually represented the top 12 inches of sediment. The top half was generally of good quality when there was complete closure of the clamshell halves. Samples were obtained on nearly every attempt for a total of thirty-two Soutar van Veen samples.

The Kiel Vibrocore is a vibratory coring device utilizing a pair of counter rotating electrically driven eccentric masses in a vibrating head. The motors, eccentric masses, and a hammer are suspended by springs on a pair of vertical rods. On each downstroke the hammer impacts an anvil at the bottom of the vibrating head driving an attached core barrel into the sediment. The vibrating head and core barrel are guided by a frame with vertical rails. A winch extracts the sample after penetration. During sampling, performance is monitored on the amount of penetration and the inclination of the sampler in the sea floor. A chart recorder was used to record depth of penetration vs. time.

The standard core barrel is a one-eighth inch steel box, 10 cm square and 2 m in length. To improve handling and the area ratio, an adaptor head was constructed for a 4.5 inch o.d. fiberglass barrel with a wall thickness of 0.125 inch. While the quality of sample from the Kiel Vibrocore was expected to be lower than that from the box core, particularly in non-cohesive sediments, the depth of sample taken was significantly greater. Twenty vibracore samples were obtained, most with fiberglass barrels.

Sub-samples were removed from each type of sediment sample and stored for later testing. Bulk sub-samples were obtained for determination of grain size distribution and Atterberg Limits in cohesive samples, and for grain size and direct shear in non-cohesive samples. The bulk sub-samples were sealed in plastic bags or plastic vials and stored in the ship's cooler. The bulk sub-samples were taken in each major stratigraphic horizon, at the top and bottom of homogeneous vibracores, and from the top of Soutar van Veen grabs. Sub-samples of known volume were taken. The sub-samples of approximately 100 cc were extruded into glass jars and sealed for later determination of water content, bulk density, and specific gravity. In addition to these samples, at selected sites in cohesive box cores and van Veen grabs, a piston sub-sampler was used to obtain 1.69 inch diameter by five inch long samples for triaxial testing.

A few 3.16 inch diameter sub-cores were also taken for consolidation testing. Each triaxial or consolidation sample was capped, sealed with tape and wax, and stored upright in the ship's cooler.

Measurement techniques of index properties

Immediately after removal from the ship's cooler water content samples were weighed to determine their wet weight. The samples and jars were dried (approximately 24 hours) and weighed. The jars were then cleaned, dried and weighed so that the water contents (salt corrected) and bulk densities (at 100% saturation) for the known volume samples could then be calculated (.1% accuracy).

According to Boyce (1975):

$$\text{Water Content} = \omega_c = \frac{\text{Weight of fluid phase}}{\text{Weight of Solids}} = \frac{W_{\text{sea water}}}{W_{\text{solids}}}$$

or

$$\omega_c = \frac{\gamma_{sw}\ (W_{wet} - W_{dry})}{C_{sw} W_{dry} - C_{sw}\ W_{wet}}$$

and

$$\text{Bulk Density} = \frac{\gamma_T = [V_T - W_{dry} - C_{sw}(W_w)]\ \gamma_{sw} + [W_{dry} - C_{sw}(W_{water})]}{V_T}$$

The measured (<100% saturation) of the known volume sub-samples were also determined according to:

$$\gamma_T = W_{wet}/V_T$$

The salt concentration for each sample was interpolated from the closest bottom reading (approximately 4 m off bottom) taken on the R/V DISCOVERER, Cruise RP4-DI-76B-V, September 1976.

After the water contents had been calculated the samples were classified according to their appearance and texture in order to evaluate the relative quality of the water content value. This classification system was used to approximate the likliehood of pore water removal, either by drainage or air drying, prior to sub-sampling. The individual categories used for classification were as follows:

Water Content Quality Designation

1. Poor Quality Sample, clean coarse sands, completely fractured.
2. Fair to poor quality, mostly sands, some cohesiveness evident, parts intact.
3. Fair quality, predominantly silty, percentage fractures.
4. Good quality, highly cohesive, silty, small percentage fractured.
5. Excellent quality sample, cohesive, clayey silt or silty clay, sample intact.

The samples classified as either 4 or 5 were then used for additional bulk density determinations by adjusting their water contents to 100% saturation (based on the average degree of saturation determined from the known volume samples, 4 or 5 classification) and inserting the adjusted water content into:

$$\gamma_T = \frac{(1 + \omega_c)\gamma_{sw}}{\omega_c + 1/G}$$

The average degree of saturation for samples classified as either 4 or 5 was determined as greater than 90%. A specific gravity value of 2.68 was used in each bulk density determination.

Actual specific gravity measurements were made on samples with an air pycnometer device. The specific volume of the solid particles was determined to .01 cc accuracy.

Atterberg Limit tests were performed on samples taken at various locations. The samples for these tests came from the bulk sample bags taken aboard ship immediately after coring. Although some sample drying probably did occur prior to testing, the samples were considered to be significantly "wet" prior to the start of each test. In some instances water was added to the sample in order to obtain the high water content value (low blow count) for the liquid limit test. Liquid limit and plastic limit tests were performed respectively as specified in ASTM D 423-66 and ASTM D424-59. None of the sediments tested contained particles coarser than 0.425 mm (No. 40 sieve) with the exception of occasional shell fragments which were removed by hand. An average of three tests was taken as the plastic limit value for each sample.

Grain size distributions were determined using three methods for different size fractions. Wet sieve splits were made at 1 mm (No. 18) and at 0.0625 mm (No. 230). The coarse fraction was sieved. A rapid sediment analyzer was used for the intermediate fraction, 1 mm to 0.0625 mm, and the mud fraction was run in a hydrophotometer giving values down to 0.0156 mm and a clay percentage finer than 0.0156 mm.

Shear Strength Testing Procedures

Immediately after coring, hand vane shear tests were performed onboard ship with 19 mm (.75 in.) 33 mm(1.30 in.) hand-vane or torvane shear devices. The torvane (0-.2 TSF, .218 kg/cm^2 capacity) was used to determine the surficial shear strengths of the sediments. The 33 mm handvane shear device (28 KPa, .286 kg/cm^2 capacity) was used in the softer sediments, while the 19 mm (122KPa, 1.244 kg/cm^2) was generally used in the stiffer sediments.

Vane shear tests were conducted only on cores that appeared to exhibit at least some plasticity, in other words not clean sands. Tests were performed at the surface and at 5 cm intervales in both the box cores and Soutar van Veens and at 10-15 cm intervals along the vibracores. The testing intervals were usually closer in the top half of the vibracore and varied according to visual changes in sediment lithology with depth. Where stratigraphic differences were apparent readings were taken on both sides of the contact surface. Remolded as well as undisturbed tests were performed in most instances at each test location.

Hand vane tests were not performed on samples that appeared to be predominantly sandy. Since the vane test is used to get an indication of the undrained shear strength properties, tests performed on sandy sediments, where particle interlocking and pore water drainage are significant, are not considered to be highly accurate.

In addition to the shipboard hand vane tests, laboratory vane (LV), unconfined compression (UC) and direct shear (DS) tests were conducted to determine sediment shear strength characteristics. The LV and UC tests were performed on undisturbed samples taken in 1.7" diameter plastic tubes onboard ship immediately after coring. The DS tests were performed on remolded wet samples carefully placed into the 2.5 in (6.35 cm) diameter x 2.0 in (5.08 cm) length testing ring prior to shear. The wet sediment was lightly tamped and distributed as evenly as possible as it was placed into the testing ring.

A standard 1/2 in (1.27 cm) laboratory vane and shear rate of 10^{o}/min (motorized unit) were used to perform the LV tests. Remolded as well as undisturbed tests were made for each test. If the sample appeared to be predominantly coarser grained with little plasticity, the LV test was not performed. As previously discussed, vane shear tests on samples of thie type will not give a true indication of the undrained shear strength characteristics of the sediment.

After the LV test was completed, that portion of the sample which had been disturbed by the vane rotation (approximately 1 in, 2.54 cm) was extruded and trimmed off for use as a water content sample. The rest of the sample was then extruded and used in the UC test. The length and diameter (top and bottom) of the sample were measured prior to testing. A length to diameter ratio of between 1 1/2 to 3 was used in all the tests (average $^{L}/D$ = 2.40). The shear rate varied between 0.5 in/min and .16in/min, depending on type of sample being tested. For example, higher shear rates were used with coarser grained sediments to more closely approximate undrained shear conditions. Tests were carried out to 15 to 20% strain. Subsequent to testing the samples were weighed and then dried in the laboratory oven for water content and bulk density determinations.

The DS tests were undertaken to determine the drained or effective stress characteristics of the sediments. After placement into the testing ring the normal load was applied hydraulically to the sample with a piston-diaphragm pressure system. The vertical deflection of the sample (.001 in, .0025 cm accuracy) was recorded both prior and during shear. The sample was sheared at a rate considered sufficient to allow total dissipation of pore pressures during shear (approx. .02 in/min). The samples were sheared until a definite peak shear strength was developed or until the sample had reached 20% strain. If more than one test was performed on a sample the bottom half of the shear ring was then manually pushed back, in the opposite direction to shear until it was approximately realigned with the top half of the shear ring; the normal load on the sample was then increased and the test procedure repeated again. The samples were then removed from the shear box and weighed.

Sediment Compressibility Testing Method

A one dimensional consolidation test was performed on a sample taken from box core 154 at 8-13 cms. The consolidation was a non back-pressured, incrementally loaded, two-way drainage test. Sea water was used as the surrounding pour fluid throughout the course of the test. The sample loading increment utilized throughout the course of the test was 1.0 with an initial load of 220 gms (6.94 gms/cm^2 stress)applied onto the sample (11 to 1 loading ratio). Initially the sample height was .75 in (1.90 cm) while the diameter was 2.5 in (6.35 cm). The vertical deflection of the sample was measured to .0001 accuracy with a laboratory dial gauge. Dial gauge readings vs time were taken for all but the first two loading increments where the degree of compression was relatively small. The sample was unloaded incrementally in reverse order to the loading sequence (maximum sample stress = 889.19 gms/cm^2).

Extrusion of the sample from the sampling ring (3.16 in, 8.03 cm) was accomplished by extruding and simultaneously trimming the sample into the testing ring. Some difficulty was experienced with this procedure and either direct extrusion into the testing ring or a more sophisticated trimming device is recommended for future tests.

Geologic Background

Sedimentary History

In late Pleistocene time of lowered sea level the eastern portion of the northern Bering Sea, including Norton Sound, was exposed. About 12,000 B. P. Sphanberg Strait (Fig. A-1) was flooded by the sea level transgression allowing Yukon River fine sands to be deposited (area A, Fig. D-4) Nelson and Creager, 1977. By about 9500 B. P. Norton Sound had been filled. The Yukon subdelta moved northward to its present location about 500 B. P. or later (area B, Fig. D-4). Isospachs of Holocene sediment deposited in Norton Sound since the transgression show maximum deposition has occurred northward of the present delta (Fig. D-4)

The Yukon presently carries over 90 million tons of sediment into the Bering Sea each year. The typical currents (Fig. D-2) carry much of the sediment into the Chukchi Sea (Nelson and Creager, 1977). Areas of low current velocities in the southern and eastern Norton Sound have thicker deposits of recent sediment with grain size distributions representative of the Yukon River load (Figs. D-4, C-2). As current velocity increases the thickness and fineness of the sediment decreases. The area near the center of Norton Sound with thin layers of recent sediment may be explained by resuspension by storm surge and waves.

Sediment Lithology

The Holocene prodelta sediments are fine sands and silts with a small percentage of clay. The Yukon sediments typically contain a percentage of fine wood fragments and other organics. The organic carbon content in surface sediments is about 1% and decreases away from the modern subdelta (Fig. D-7). Several cores penetrated through the modern Yukon sediments into the pre-transgressive sediments (Figs. C-3 to C-14). These sediments were deposited in a fresh water environment and are typified by a finer grain size, high organic content (3 to 8% organic carbon, shown in core logs) and high gas content (Fig. D-6).

Quantitative analyses of clay mineral types within the clay fraction of surface sediments show that modern Yukon sediments contain about 40% kaolinite-chlorite and illite and about 20% montmorillonite (Fig. C-2). A few analyses of pre-transgressive sediments show higher amounts of montmorillonite.

Vibracore Stratigraphy

Vibracores 69A through 103 (Figs. C-3 to C-9) are from an area of sand ridges and mud troughs off Port Clarence. The ridges are covered by sand waves and are being reworked by currents, (Vibracores 69A, 94C, and 103). Thin deposits of modern mud blanket troughs and ridge flanks. Beneath modern mud pre-transgressive organic-rich muds are penetrated (See vibracores 70, 71, 101 in Figs. C-4, 5, 8). While vibracore 72A came from a trough, the core is jumbled, possibly resulting from flow-in upon extraction. A high organic carbon content was found at the base suggesting pre-trangressive fresh water muds.

Vibracores 121B3 through 137B (Figs. C-10 to C-14) were taken in Norton Sound. Vibracore 121B3 and 131C, penetrated the modern Yukon sediment into fresh water peats, while 125E, 135B, and 137 apparently did not. The modern sediments are silts with decreasing amounts of sand and increasing amounts of clay near the eastern end of Norton Sound.

Sediment Index Properties

Specific Gravity

The specific gravity of particles was determined for a representative group of sub-samples used for water contents. The results are presented in Table C-1. The values of specific gravity fell within a reasonable range (2.67 to 2.73) with the exception of the vibracore 101 sub-sample at 90 cm. which had a value of 2.55. This low value can be attributed to the high organic content of the pre-trangressive sediments.

Atterberg Limits

The results from the Atterberg Limit tests are tabulated in Table C-2 and are shown on the plasticity chart from the standardized soils classification system (per ASTM D 2487-69) in Figure C-15.

Most of the Atterberg Limit samples tested, with the exception of those from vibracore 133 and one sample from vibracore 40C had liquid limits less than 50, and plasticity indices less than 20 (Table C-2, Figs. C-10, 11, 15) and would be classified as a low plasticity silts (ML) or low plasticity silty clays (OH). The very low percentages of clay (Fig. C-10) would tend to favor the ML classification for these sediments. Two samples (169, 0-2 cm., and 141, 0-4) plotted slightly above the A-line (Table C-2) indicating a classification of clays with low plasticity (CL). Both these samples however, with only slight variations in either the liquid or plastic limits, could also be calssified as ML type sediments. The sample tested from vibracore 40C (Table C-2) plots just slightly below the A-line and would be classified as a high plasticity silt (MH) or as organic clay or silt-clay of medium to high plasticity (OH). Grain size analysis on this sample indicates that a significant portion of this sample is coarser than .075 mm. which would favor an MH classification.

For many of these samples with either a ML or MH classification, a very large percentage of the sample fell between the sand-silt particle size break (aproximately .040-.080 mm.). This allowed samples that contained significant amounts of sand to exhibit plastic characteristics and therefore fit silty or clayey silt classifications.

Four of the Atterberg Limit tests were performed on samples from Box Core 133. All these samples plotted either on or slightly above the A-line (Fig. C-15), which would classify them as high plasticity clays (CH). The natural water contents for the upper three samples were all slightly greater than the corresponding liquid limit. This trend is considered typical of marine sediments with significant amount of clay and has been reported previously by other investigators (Silva et. al., 1976, Noorany, 1971). The average liquidity index (I_L), which is a measure of the closeness of the in-situ water content to the liquid of the closeness of the in-situ water content to the liquid limit, for core samples 133 was determined to be 1.12./Grain size analysis performed on these samples at 5 cm. and at 70 cm. indicatethat the clay percentage within the top meter of sediment is probably in excess of 50% (Fig. C-13). This unusually high clay content and resulting sediment plasticity can be attributed to low velocity currents transporting the finest Yukon silts in the very sluggish counterclockwise gyre of easternmost Norton Sound.

Water Content and Density

The water content and bulk density results for the known-volume water content-bulk density determinations (Table C-3) exhibit wide spread differences in their calculated degree of saturation values. However, the average degree of saturation for those samples which were categorized as either 4 or 5 (water content quality designation) was 93.4 and 97.8% respectively; this would indicate a relatively small loss in water content prior to sub-sampling and therefore high quality water content-bulk density determinations. Based on these results the water content-bulk density values for all the samples with either 4 or 5 quality designations were corrected to 100% saturation (Table C-4).

The water content values generally tend to decrease with depth down to approximately .25 to .50 meters and then are often constant or will occassionaly increase with increasing overburden (Figs. C-10 to C-14). Abrupt jogs or changes in the slope of the water content profile often times corresponded with changes in the sediment lithology, although such trends are also evident in some of more homogeneous material. The highest water contents (low bulk densities) occurred in easternmost Norton Sound (See Figs. C-10 to C-14, and Table C-4). The highest individual corrected water content was taken on the surface from the Soutar van Veen at station 137.

Unfortunately, vibrations created by the EG & G uniboom housed under the ships sediment lab may have created pore water redistributions within the sediment prior to sub-sampling. The effects of these vibrations are difficult to predict and may have been partially responsible for some of the water content variations present in Figures C-10 to C-14. Such vibrations should be eliminated by placing hard rubber pads along the core barrel in future testing procedures.

Shear Strength

Vane Shear Results

There is good agreement between the box core and vibracore vane shear tests from station 121B3 (Fig. C-10) with a continuous increase in shear strength present to 25 cm. The higher value for the LV (18.7 kPa) obtained at 2 cm. is considered attributable to a loss in water content between sub-sampling and testing. The UC tests performed on the same sample was more in accord with both the shipbound vibracore and box core vane shear tests. A dramatic shift in sediment shear strength for this core is apparent at approximately 80-85 cm., where the undrained shear strength values increase from 31 kPa (.316 kg/cm^2) to 77 kPa (.785 kg/cm^2). The depth of this increase coincides with a change in sediment lithology from a sandy silt to a stiffer clayey silt. An earlier penetration record also indicates that a previous vibracore stopped at approximately the same depth as the corresponding shift in shear strength.

Because the box cores or Soutar van Veens taken at stations 125, 131, and 137 did not penetrate to significant depths, comparisons with the vibracore vane shear results are limited, although there is at least one test at both stations 131 and 137 (Figs. C-12 and C-14) which would indicate that the vibracore vane shear results are partially disturbed. A reduction in the vane shear results for vibracore 131 at approximately 80-100 cm. corresponds to a very dramatic increase in the vibracore penetration rate and a change to soft clayey silt in the sediment stratigraphy.

The vane shear results from station 133 provide the most detailed information on the relative disturbance effects of vibracoring upon the sediment shear strength properties. Comparing vibracore and box cores vane shear results at station 133 (Fig. C-13) clearly indicate that the vibracore shear strength value may be significantly reduced as a result of sample disturbance. The box core results show a somewhat linear increase with depth down to 50 cm. where the measured shear strength value is approximately 19 kPa. The vibracore results conversely indicate a constant shear strength ($\simeq$ 7 kPa, .071 kg/cm^2) down to 60 cm. and then a linear increase with depth. A value of 19 kPa (.194 kg/cm^2) was not reached until a depth of greater than 1 m. The larger clay percentage (Fig. C-13) as compared with the clay percent in vibracore 121B3 (Fig. C-10) may have been responsible for the apparent disturbance evident in vibracore 133B. Other investigators (Kautsoftas, Fischer, Dette, and Singh, 1976) have also found that undrained shear tests on silty clays taken from another type of vibracorer underestimated the undrained shear strength by a factor of two and severely affected the results of consolidation tests. Although more silty sediments as evidenced by the test results from station 121B3 may not be as severly effected, additional cores are considered necessary to accurately predict degree of disturbance.

Direct Shear Results

As previously discussed in addition to the undrained shear strength results direct shear tests were performed on two remolded samples to assess the drained or effective shear strengths of the sediments. The effective stress envelopes for these tests are shown on Figures C-16 and C-17. The samples tested from Box Core (0-3 cm.) were predominantly sands (80%) and while no particle size analysis is presently available from station 147 visual inspection of the sample tested suggests that it is more fine-grained. The effects of remolding on more fine-grained sediments and the presence of some small shell fragments (most were removed by hand prior to testing) are considered to be the major factors for the differences in friction angles $\overline{\phi}$, observed between the two samples tested in Box Core 147. The two samples tested from Box Core 150 are in much better accord with four of the five tests establishing an effective strength envelope at 38.4%. There is a light downward curvature of the strength envelope at higher normal stresses, which is considered typical of sandy type samples (Lambe & Whitman, 1969).

Although a peak shear strength followed by a slight strength reduction to a residual value was observed in five of the direct shear tests, the void ratio of the samples in each test decreased steadily during shear. This indicates that even at higher normal stresses the samples were in a state above the "critical void ratio," (Castro, 1959, Casagrande, 1976). In view of the very high percentages of fine-grained sands and coarse silts in many of the cores, samples above the critical void ratio would be considered highly susceptible to possible strength reduction resulting from liquefaction after seismically induced loading. Proper determination of the sedimentary in-place density at depth is necessary to evaluate the potential for such a loss in shear strength.

Vibracore Penetration Results

The depth vs. time chart records from the Kiel vibracore were differentiated to get penetration rate vs. depth. The chart recorder used had many functional problems and in several cases poor records or no records were obtained. The results are presented with the core logs (Figs. C-3 to C-14). Once the sampling frame reached bottom and the cable tension relaxed, a small amount of immediate penetration occured due to the weight of the vibrating head. The vibrator was started and the core penetrated until a thermal sensor in the vibrating head automatically stopped vibration. Cycles of cooling and vibration were made until the core was full or no further penetration was accomplished. The maximum amount of penetration and the amount of recovery are shown on the penetration rate graphs. Often in clean sands either a portion of the core or the total core would flow out when the vibracore was brought on deck. The vibrator often drove the core into sediments from which it could not be extracted by the winch on the vibracore frame. In some cases the ships winch removed the core, in others the fiberglass core barrels broke off and were lost.

In clean sands the vibracore would penetrate rapidly to between 25 cm. and 75 cm. and then continue at a steady rate of about 1/2 meter/min. (Figs. C-3 and C-7). Where more than one attempt was made at a station as at station 70 (Fig. C-4) the penetration rates seemed to have good agreement. Organic layers seem to cause an oscillation and decrease in penetration rate (vibracore 71A, Fig. C-5).

In the cohesive sediments in Norton Sound (Vibracores 121B3 to 137; Figs. C-10 to C-14) the fiberglass barrels were unable to penetrate some sediments. The metal box barrels usually penedtrated to full depth with numerous vibrating cycles required. Measurements in the metal box vibracores indicate the fiberglass barrels stopped when the shear strength exceeded about 30 kPa. It is believed the elasticity of the fiberglass allowed much of the vibrational energy to be dissipated along the core due to skin resistance in cohesive sediments. In sands, the vibrations caused liquefaction along the barrel reducing the contribution of skin friction.

The general variations in the penetration rates correlated with changes in sediment types and strengths. Too little information is available to quantitatively correlate strength with penetration rate.

Consolidation

The consolidation test results from the test performed on box core sample 154 at 8-13 cm., suggest that the surficial sediment in this area is over-consolidated (OCR = 9.11). About 8 m. of recent Yukon sediments have been accumulated in the prodelta area during the past 10,000 years (Fig. D-4), which tends to

TABLE C-1

SPECIFIC GRAVITY SEA5-76-BS

Sample Designation	Depth (cm)	Specific Gravity	% Organic Carbon *
SUTR 47B	surface	2.69	0.91
VIBR 94C	40	2.71	0.66
VIBR 101	60	2.55	5.27
VIBR 102	25	2.70	0.37
VIBR 102	70	2.67	0.37
VIBR 102	138	2.70	0.96
VIBR 133	39	2.70	0.96
VIBR 133	36	2.73	0.96

* Taken from closest sample location

TABLE C-2

ATTERBERG LIMITS SEA5-76-BS

Sample Designation	Depth (cm)	Liquid Limit	Plastic Limit	Plasticity Index
SUTR 40C	surface	53	31	22
BOX 121	18-22	40	26	14
SUTR 125	0-5	25	17	8
BOX 133	0-5	76	29	47
BOX 133	13-17	68	35	33
BOX 133	22-24	71	29	42
BOX 133	35-40	71	30	41
BOX 141	0-4	42	24	18
BOX 141	15-18	41	30	11
BOX 145	16-19	33	27	6
BOX 147	2-9	29	25	4
BOX 152	0-4	27	23	4
BOX 154	0-3	44	30	14
BOX 154	26-29	40	33	7
BOX 161	surface	41	31	10

TABLE C-2

TABLE C-3

Sample Designation	Depth (cm)	Water Cont.% Salt Corr. (Weighed)	Water Cont.% Salt Corr. (Calculated)	Bulk Density (Weighed) gm/cm^2	Bulk Density (Calculated) gm/cm^2	Water Cont. Qual. Des.	% Sat.
VIBR 94	40	12.4	30.7	1.67	1.94	1	40.3
	140	24.1	33.4	1.78	1.91	1	72.2
	168	28.4	29.1	1.95	1.96	3	97.2
SUTR40C	3-8	70.7	80.2	1.47	1.56	4	88.2
SUTR 47B	surface	95.1	114.4	1.31	1.44	4	83.1
SUTR 49	surface	79.2	106.1	1.27	1.46	3	74.6
VIBR 101	15	21.6	22.2	2.06	2.07	5	97.3
	90	69.3	65.3	1.68	1.64	5	106.1
	142	19.4	27.3	1.71	1.99	2	71.1
VIBR 102	25	5.5	27.3	1.65	1.99	1	20.1
	70	10.1	28.8	1.68	1.97	1	35.1
	138	22.3	22.5	1.91	2.06	1	99.1
VIBR 103	8	21.1	26.4	1.92	2.00	1	79.9
	85	21.0	21.7	2.07	2.08	3	96.8
	140	20.3	23.9	1.99	2.04	3	84.9
VIBR 106A	110	27.9	33.2	1.84	1.91	1	84.0
VIBR 121B	22-24	40.6	43.7	1.76	1.70	4	92.9
	82-85	56.4	56.3	1.70	1.69	4	100.0
	140-144	29.5	29.1	1.98	1.96	5	101.4
BOX 121	3-15	31.5	31.5	1.93	1.93	4	100.0
SUTR 131	2-8	53.3	54.8	1.69	1.70	4	97.3
BOX 133	3-15	71.2	75.9	1.54	1.58	5	93.8
BOX 141	0-5	49.8	49.8	1.75	1.74	5	100.0
BOX 149	3-14	25.3	27.0	1.97	1.99	3	93.7
BOX 150	3-12	21.0	22.8	2.03	2.06	2	92.1
BOX 154	10-18	43.0	46.6	1.73	1.77	4	92.3
BOX 161	2-12	48.5	51.8	1.69	1.73	3	93.6
SUTR 174	2-7	25.3	33.5	1.97	2.10	3	75.5

WATER CONTENTS - BULK DENSITIES

TABLE C-4

(4&5 Quality Designation)

Sample Designation	Water Content Quality Desigtion	Water Content % (Weighed)	Water Content % Corrected (100% sat.)	Bulk Density Corrected (gm/cm^2)
VIBR 121B				
0-2 cm	4	47.0	50.3	1.76
6-7	5	35.0	35.8	1.90
42-44	5	47.0	48.1	1.76
66-68	4	38.0	40.7	1.85
104-106	4	31.0	33.2	1.92
128-130	4	31.1	33.3	1.92
159-163	4	32.8	35.1	1.91
BOX 121				
9-13 cm	4	33.1	35.4	1.91
VIBR 125B				
8-11 cm	4	33.7	36.1	1.90
38-42	5	21.0	21.5	2.12
63-66	4	21.7	23.2	2.09
123-125	4	32.8	35.1	1.91
VIBR 131				
20-22 cm	4	59.7	63.9	1.66
39-41	4	94.5	101.2	1.49
99-100	4	58.9	63.1	1.66
173-175	4	40.3	43.1	1.82
SUTR 131D				
0-5 cm	4	76.3	81.7	1.56
VIBR 133				
7-9 cm	5	99.2	101.4	1.51
22-24	5	73.8	75.5	1.59
35-37	5	45.7	46.7	1.79
52-55	5	66.6	68.1	1.63
68-71	5	59.8	64.1	1.66
86-89	5	43.3	44.3	1.81
116-119	5	47.4	48.5	1.77
128-131	5	47.4	48.5	1.77
145-148	5	53.9	55.1	1.72
161-164	5	49.1	50.2	1.76
VIBR 137				
25-27 cm	5	87.6	89.6	1.53
62-64	5	128.0	130.9	1.41
82-84	5	75.2	77.0	1.59
92-94	5	85.1	87.0	1.54
111-113	5	74.2	75.9	1.59
137-139	5	50.5	51.6	1.75
SUTR 137				
0-5 cm	4	128.8	137.9	1.39
BOX 141				
8-12 cm	5	44.6	45.6	1.80
15-18	4	34.9	37.3	1.88
BOX 147				
2-6 cm	5	30.2	30.9	1.97
BOX 154				
4-5 cm	4	66.5	43.0	1.62
13-14	4	52.4	56.1	1.71
26-29	4	42.0	45.0	1.81
BOX 156				
33-35 cm	4	76.3	81.7	1.56

TABLE C-5

UNDRAINED SHEAR STRENGTHS-S_u SEA5-76-BS

Sample Designation	Depth (cm)	Undrained Shear Strength (S_u) gm/cm^2	Remolded Shear Strength (S_r) gm/cm^2	Sensitivity (S_u/S_r)
SUTR 40C	0-3	37.0	9.3	4.0
	8-10	46.3	18.5	2.5
SUTR 47B	0-4	20.4	10.2	2.0
	5-9	40.8	20.4	2.0
SUTR 49A	0-4	10.2	5.1	2.0
	5-9	20.4	10.2	2.0
	12-16	51.0	25.5	2.0
VIBR 49	49-50	150.0	-	-
BOX 141	surface	0.0	-	-
	4-5	43.9	-	-
	9-10	54.0	-	-
	14-15	153.0	-	-
BOX 145	3-14	159.0	-	-
	3-14	149.0	-	-
BOX 149	2-14	99.5	-	-
BOX 150*	surface	64.3	-	-
	0-3	836.5	-	-
	6-7	120.4	-	-
	3-12	44.8	-	-
BOX 154	surface	0.0	-	-
	0-3	259.6	91.4	2.8
	4-5	23.5	0.0	-
	10-11	51.0	2.0	25.0
	15-16	78.5	20.4	3.8
	3-13	124.4	-	-
	20-21	105.1	49.0	2.1
	24-25	263.2	58.1	4.5
	29-30	189.1	43.9	4.3
BOX 159	3-14	358.0	-	-
	19-20	90.0	-	-
BOX 161	0-10	74.6	-	-
SUTR 163	surface	36.0	-	-
SUTR 170	surface	23.5	-	-

eliminate large scale removal of sediment by erosion as the primary cause for the observed over-consolidation. Nelson and Creager, 1977 have suggested that intermittant storm activity is responsible for sediment resuspension of as much as 40% of the sediment in the area. Bottom wave induced storm loading is therefore considered to be the primary factor contributing to the over-consolidation with sedimentary cementation effects alos possibly contributing. Additional studies are necessary in order to more properly assess both the effects of storm loading and cementation on these over-consolidated sediments.

The coefficients of consolidation c_V for the test were determined by using the square root of time curve fitting technique (Taylor, 1948). Because the first three points on the square root of time vs. void ratio plots were generally nonlinear, some amount of interpretation was required in order to determine C_V. Consequently the calculated average value of C_V may possibly have been slightly lower than the actual values. Higher speed recording equipment (Mccann, Darwell and Demmess, 1975) capable of recording the compression in the first few seconds after sample loading is recommended for future consolidation tests on very silty samples. Both the average coefficient of consolidation (C_V) and coefficient of permeability (k) were typically in the range of values found for silty type sediments (Lambe and Williams, 1969). The corrected compression index (C_C) which is a measure of the rate at which the sediment will consolidate with increasing stress was low (.153) and indicative of silty coarser grained sediments.

Conclusions and Needs for Further Studies

The upper few meters of sediment from the Northern Bering Sea-Norton Sound area have been investigated. Based on the information presented in this paper, the following conclusions may be drawn:

1. The sediment index properties were found to vary considerably with core location. Fine sands and silts make up most of the sediment in the Yukon area with finer grained sediments present in the easternmost portion of Norton Sound. Water contents taken from coarser grained core samples wxhibited an appreciable decrease in their degree of saturation prior to sub-sampling while samples consisting of mostly silts or clayey silts were more than 90% saturated. Known-volume samplers are recommended for all future cruises, so that a possible pore water loss may be carefully monitored. Specific gravity determinat did not vary appreciably, excpect in one instance, where fresh water peaty mud was found to have an unusually high organic content.

2. The undrained shear strengths (Su) of predominantly silty sediments at one core location did not appear to be severely reduced by the effects of vibracoring while the undrained shear strengths from another vibracore with a significantly higher clay content were considerably lower those from the box core taken at the same location. Future studies should be concerned with comparisons between vibracore vane shear test results and those obtained from other types of high quality corers to more accurately assess the disturbance effects created by vibration.

3. Changes in the vibracore penetration records in many instances corresponded to changes in the c ore stratigraphy, and undrained shear strength values, although additional information is considered necessary before quanitative analyses can be made between the penetration records and shear strength results.

4. Direct shear tests on remolded sands gave consistent results with a fairly high friction angle (38.4°). Tests on remolded silts were not as consistent and would suggest the need for undisturbed samples in future tests. Even at high applied normal stresses both the sandy and silty samples appeared to be above the "critical void ratio", indicating the possible suspectibility to loss in sediment shear strength or liquefaction potential with seismically induced loading. In view of the composition of many of the sediments taken from Norton Sound, it is recommended that sediment liquefaction potential be additionally studied in future geotechnical assessments in the area.

5. A consolidation test of a near-surface sample from the Yukon prodelta area was determined to be highly over-consolidated. The reason for the over-consolidation is believed to be related to the wave stress on the surficial sediments by intermittant storm surges. Because most of the sample compression took place in the first few seconds after the application of each sample stress, a more sophisticated consolidomiter should be used in future tests on silty samples to more accurately measure the standard consolidation parameters.

6. In view of the difficulties experienced in obtaining reliable data on the highly sandy sediments prevalent in many areas of the Northern Bering Sea and Norton Sound, in-place shear strength measurements should be made in future studies. These measurements should be made with a penetrometer type device capable of monitoring tip resistance continuously with depth.

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List of Symbols & Abbreviations

C_c, Compression Index

c_v, Coefficient of Consolidation (cm^2/sec)

C_{sw}, Salt Concentration of Sea Water (ppt/1000)

DS, Direct Shear

G, Specific Gravity of Solid Particles

I, Plasticity Index

k, Coefficient of Permeability (cm/sec)

LV, Lab. Vane

UC, Unconfined Compression

ω_t, Water content

ω_L Liquid Limit

ω_p Plastic Limit

W_{dry}, Dry Weight of Sediment (gms)

$W_{sea\ water}$, Weight of Sea Water (gms)

W_{solids}, Dry Weight of Sediment

W_{wet}, Wet Weight of Sediment

W_{water}, Weight of Water

V_T, Total Volume

γ_{sw}, Weight of Sea Water per Unit Volume

γ_T, Bulk Density

$\bar{\phi}$, Effective Angle of Internal Friction

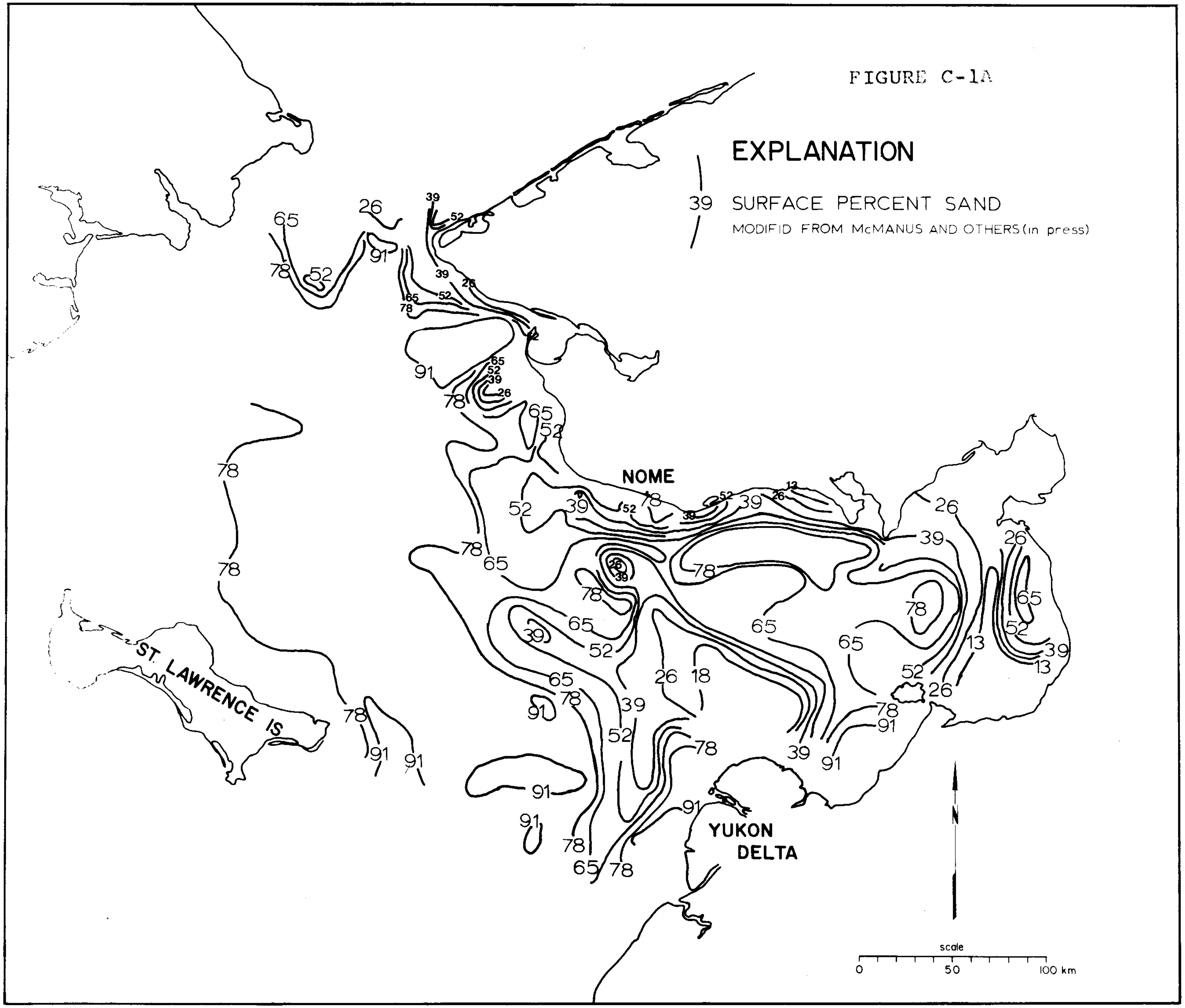


FIGURE C-1A

EXPLANATION
39 SURFACE PERCENT SAND
MODIFID FROM McMANUS AND OTHERS (in press)
NOME
YUKON DELTA
ST. LAWRENCE IS
N
scale
0
50
100 km
13
18
26
39
52
65
78
91

FIGURE C-1

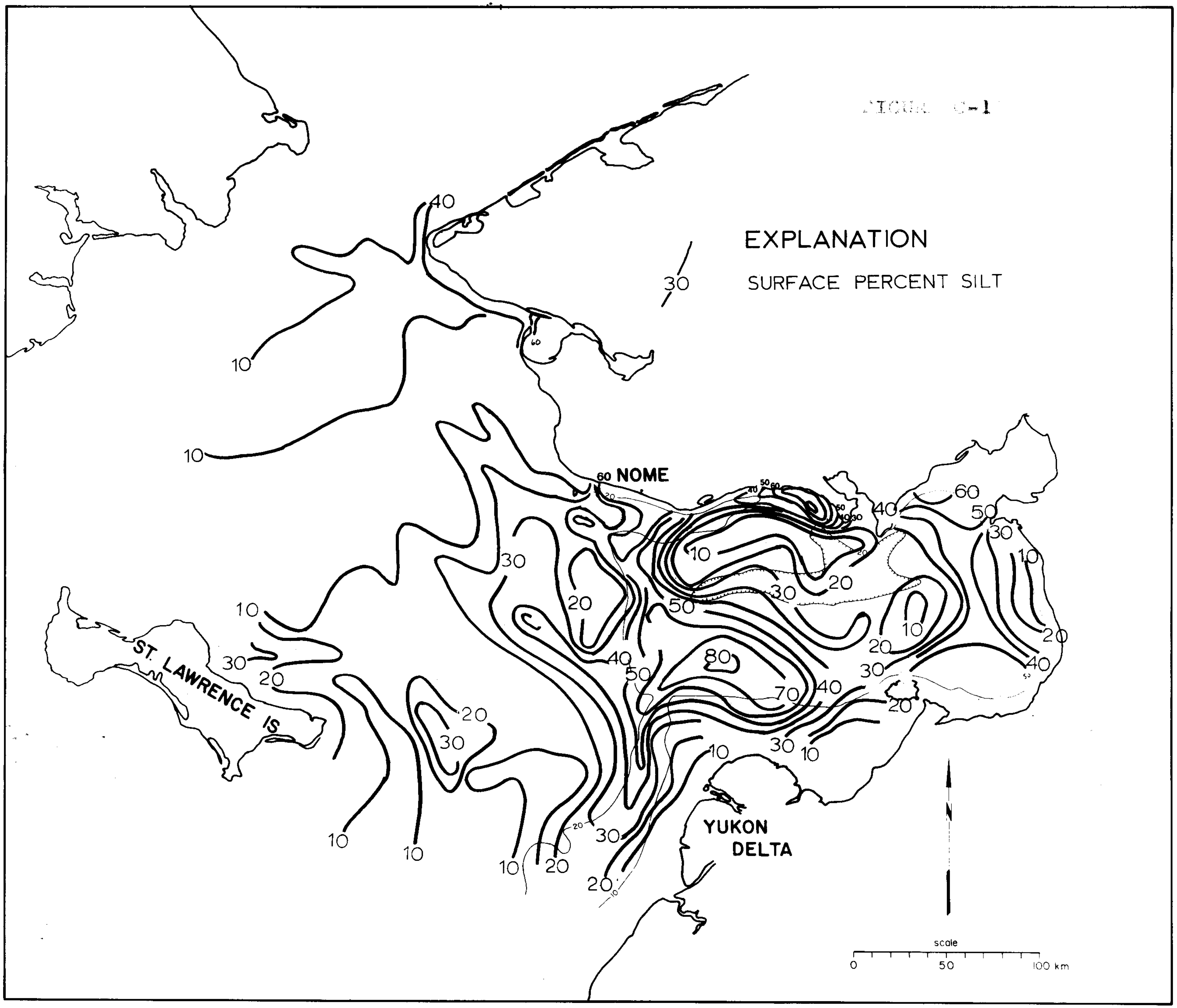
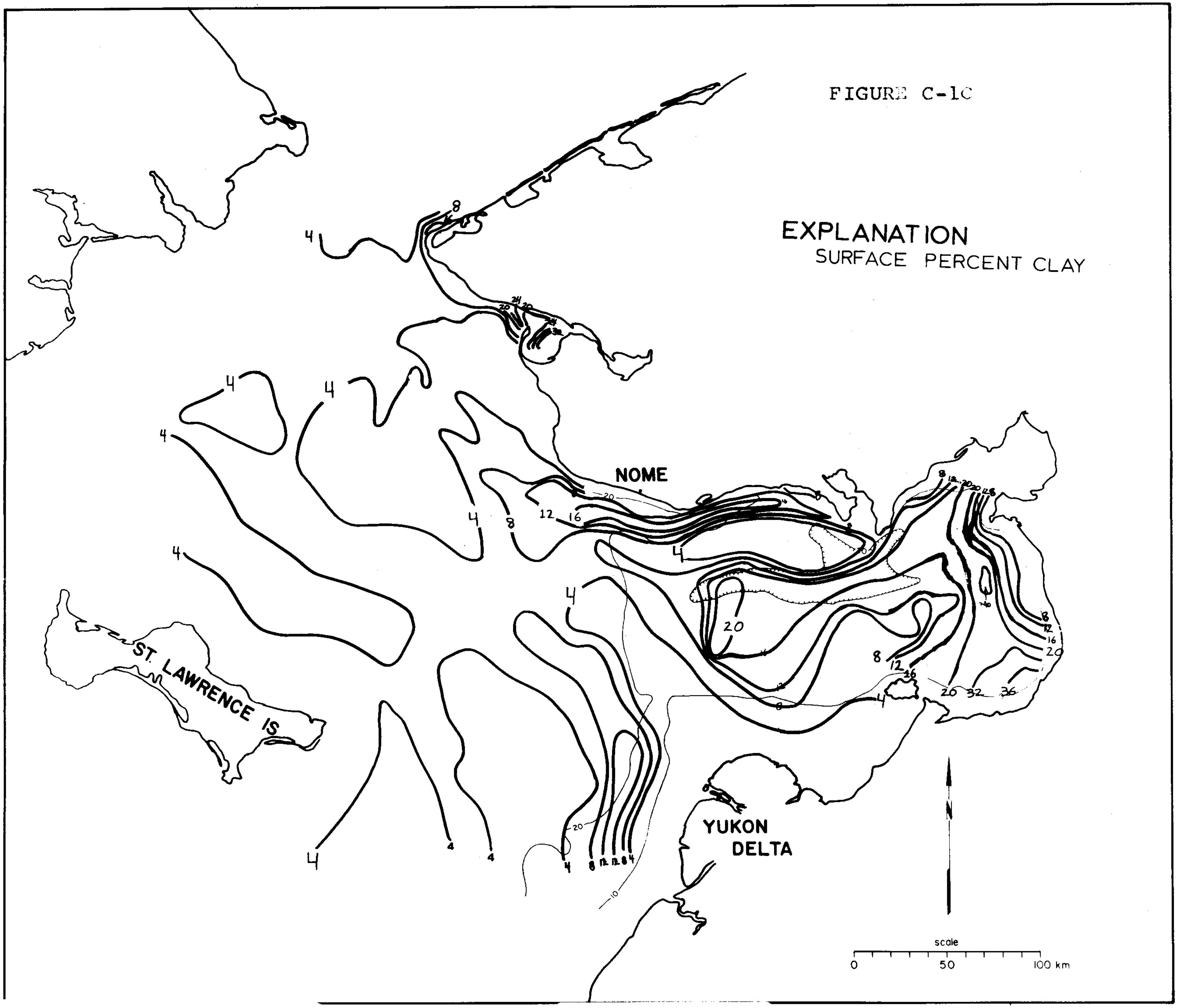

EXPLANATION
SURFACE PERCENT SILT
30
NOME
60
ST. LAWRENCE IS
YUKON DELTA
10
20
30
40
50
60
70
80
N
scale
0
50
100 km

FIGURE C-1C



EXPLANATION
SURFACE PERCENT CLAY

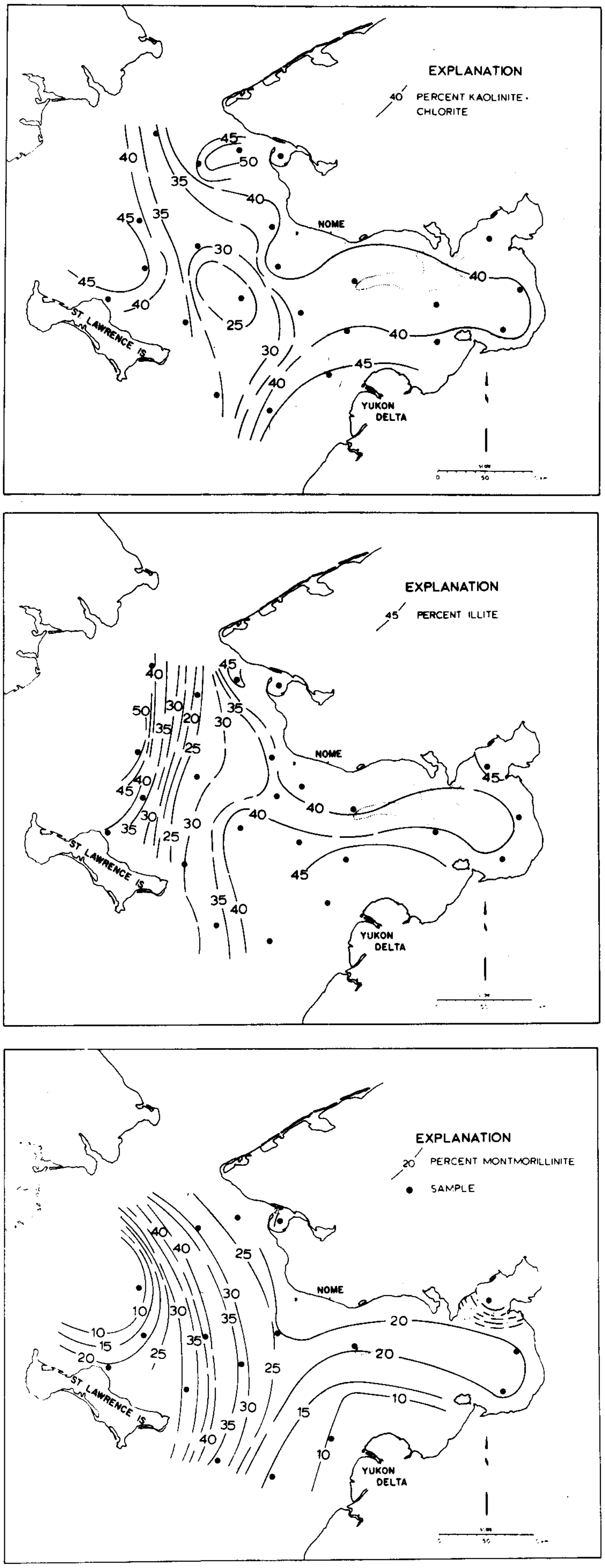


FIGURE C-2

Clay mineralogy of surface sediment in Norton Basin.

From unpublished data of James Hein, USGS, Menlo Park, CA

VIBRACORE 69 A

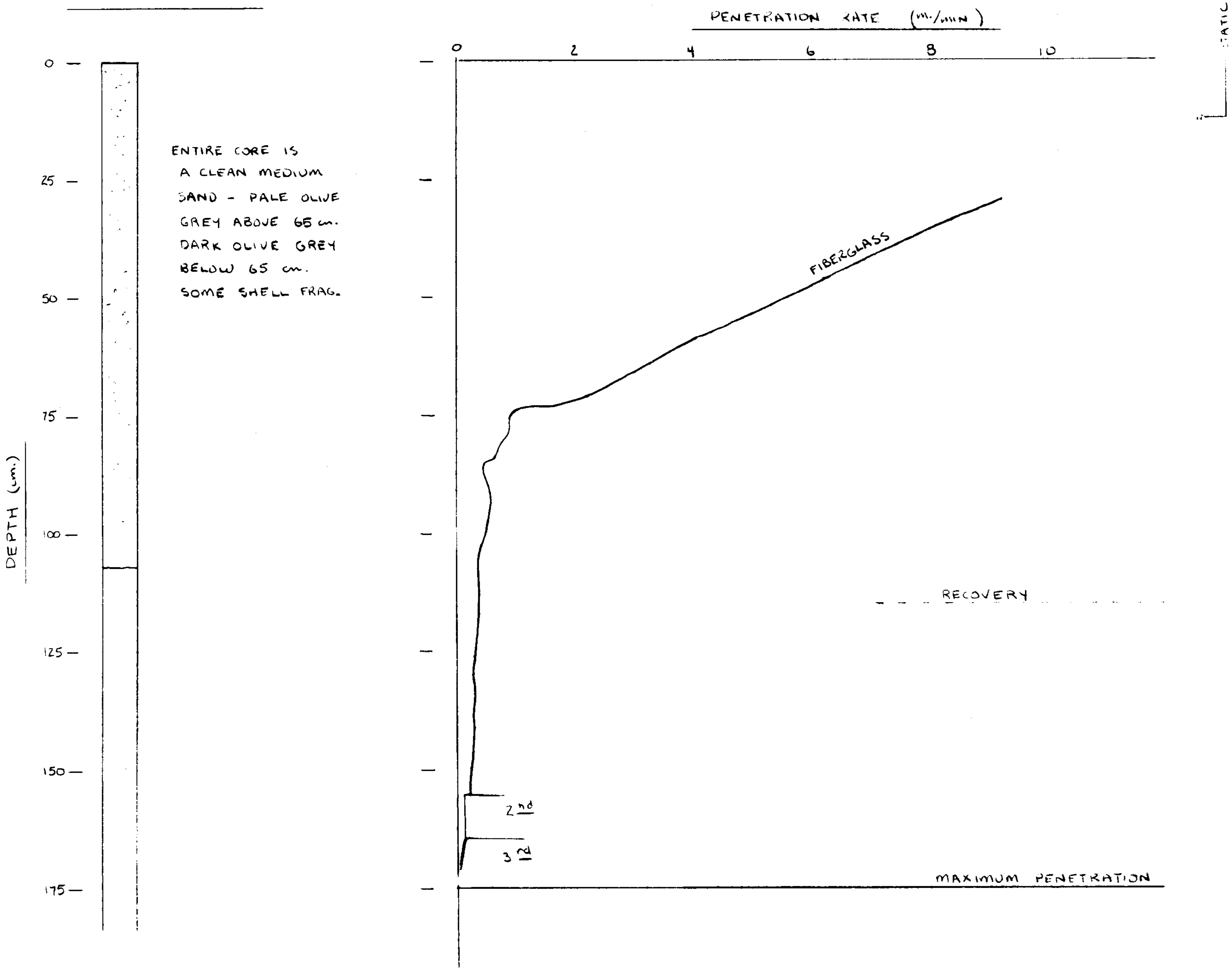


FIGURE C-3

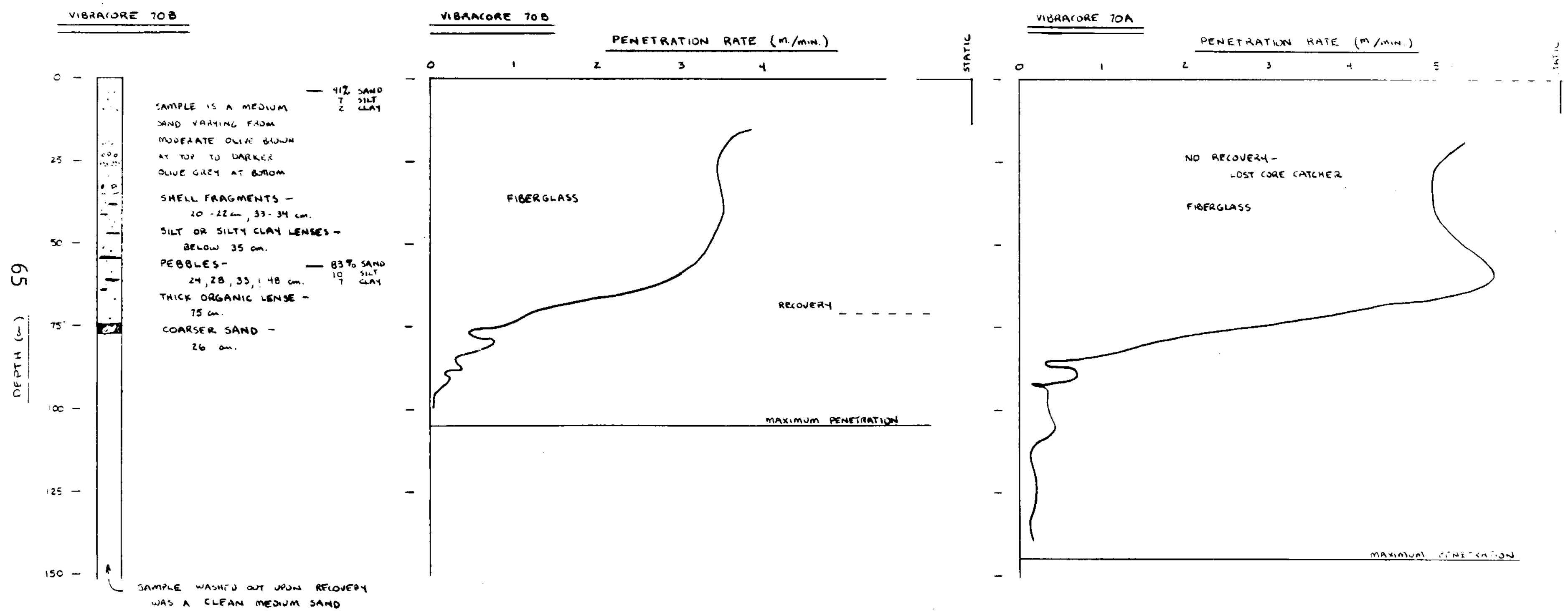

VIBRACORE 70B
DEPTH (cm)
0
25
50
75
100
125
150
SAMPLE IS A MEDIUM SAND VARYING FROM MODERATE OLIVE BROWN AT TOP TO DARKER OLIVE GREY AT BOTTOM
— 91% SAND 7 SILT 2 CLAY
SHELL FRAGMENTS – 20 - 22 cm, 33 - 34 cm.
SILT OR SILTY CLAY LENSES – BELOW 35 cm.
PEBBLES – 24, 28, 33, & 48 cm.
— 83% SAND 10 SILT 7 CLAY
THICK ORGANIC LENSE – 75 cm.
COARSER SAND – 26 cm.
SAMPLE WASHED OUT UPON RECOVERY WAS A CLEAN MEDIUM SAND
VIBRACORE 70B
PENETRATION RATE (m./min.)
0
1
2
3
4
STATIC
FIBERGLASS
RECOVERY
MAXIMUM PENETRATION
VIBRACORE 70A
PENETRATION RATE (m./min.)
0
1
2
3
4
5
NO RECOVERY – LOST CORE CATCHER
FIBERGLASS
MAXIMUM PENETRATION

FIGURE C-4

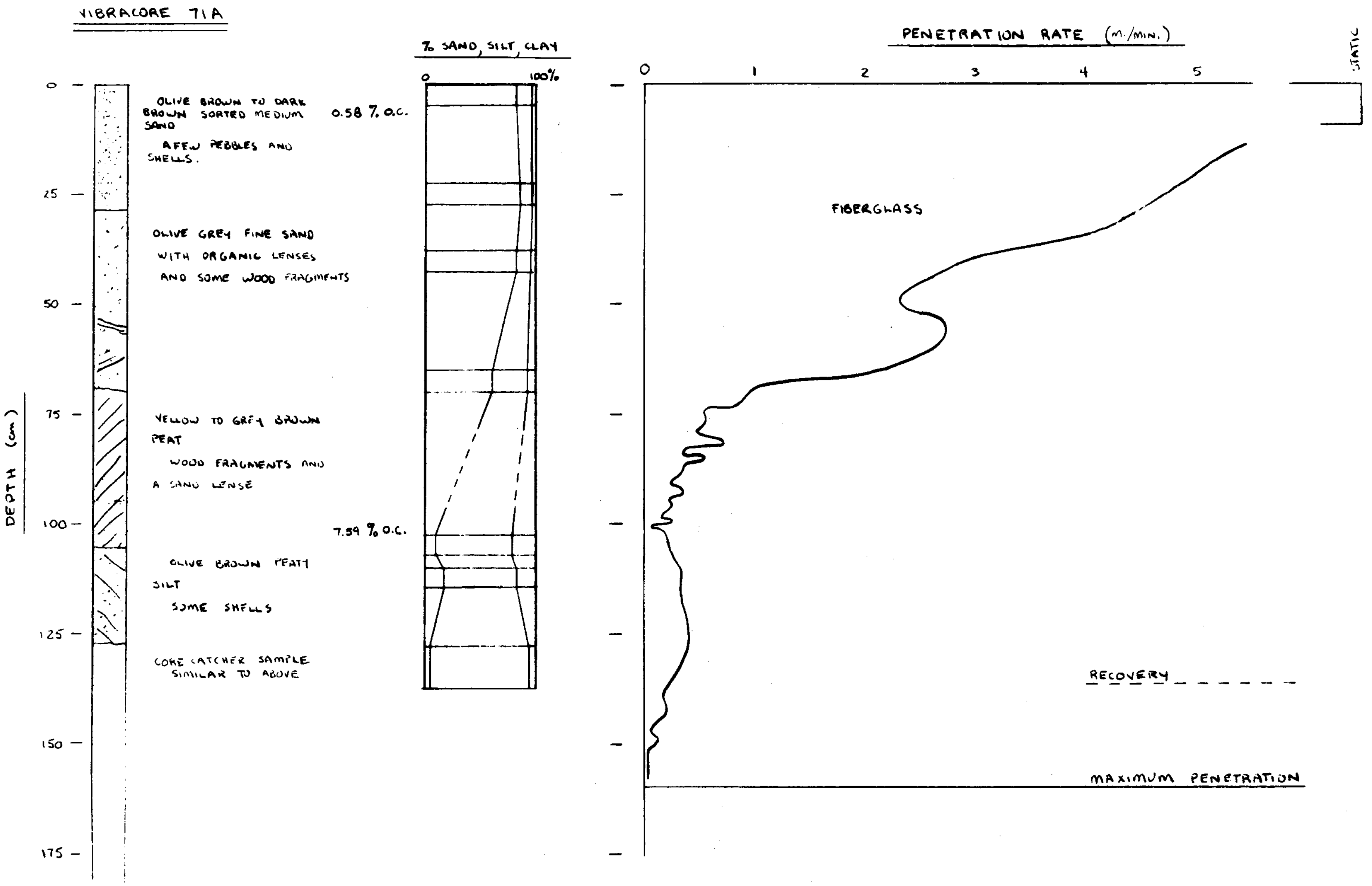

VIBRACORE 71A
% SAND, SILT, CLAY
0
100%
PENETRATION RATE (m./min.)
0
1
2
3
4
5
STATIC
DEPTH (cm)
0
25
50
75
100
125
150
175
OLIVE BROWN TO DARK BROWN SORTED MEDIUM SAND
A FEW PEBBLES AND SHELLS.
0.58 % O.C.
OLIVE GREY FINE SAND WITH ORGANIC LENSES AND SOME WOOD FRAGMENTS
YELLOW TO GREY BROWN PEAT
WOOD FRAGMENTS AND A SAND LENSE
7.59 % O.C.
OLIVE BROWN PEATY SILT
SOME SHELLS
CORE CATCHER SAMPLE SIMILAR TO ABOVE
FIBERGLASS
RECOVERY
MAXIMUM PENETRATION

FIGURE C-5

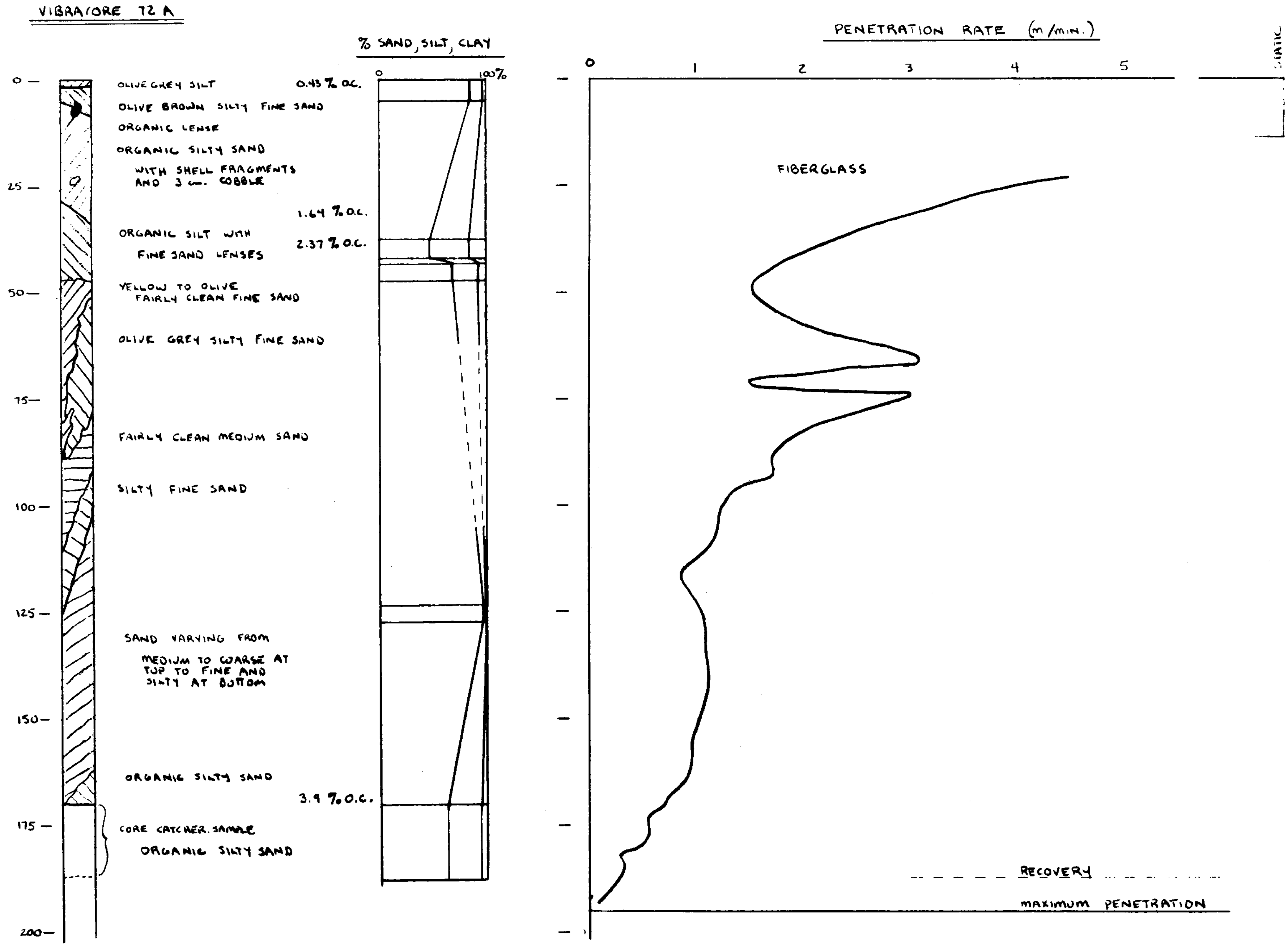

VIBRACORE 72 A
% SAND, SILT, CLAY
0
100%
0 —
25 —
50 —
75 —
100 —
125 —
150 —
175 —
200 —
OLIVE GREY SILT
0.43 % O.C.
OLIVE BROWN SILTY FINE SAND
ORGANIC LENSE
ORGANIC SILTY SAND
WITH SHELL FRAGMENTS AND 3 cm. COBBLE
1.64 % O.C.
ORGANIC SILT WITH FINE SAND LENSES
2.37 % O.C.
YELLOW TO OLIVE FAIRLY CLEAN FINE SAND
OLIVE GREY SILTY FINE SAND
FAIRLY CLEAN MEDIUM SAND
SILTY FINE SAND
SAND VARYING FROM MEDIUM TO COARSE AT TOP TO FINE AND SILTY AT BOTTOM
ORGANIC SILTY SAND
3.9 % O.C.
CORE CATCHER SAMPLE
ORGANIC SILTY SAND
PENETRATION RATE (m/min.)
0
1
2
3
4
5
FIBERGLASS
RECOVERY
MAXIMUM PENETRATION

FIGURE C-6

VIBRACORE 94C

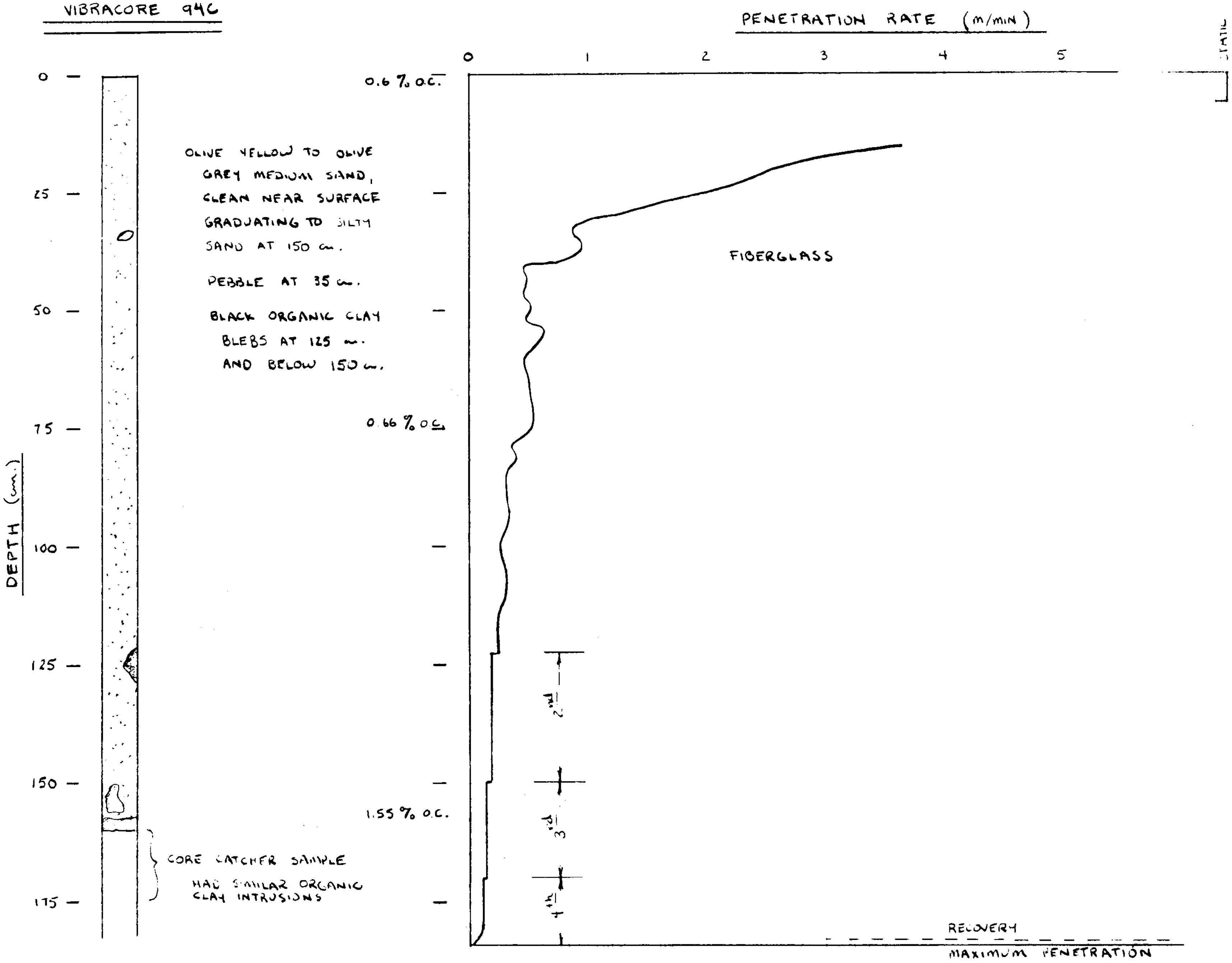
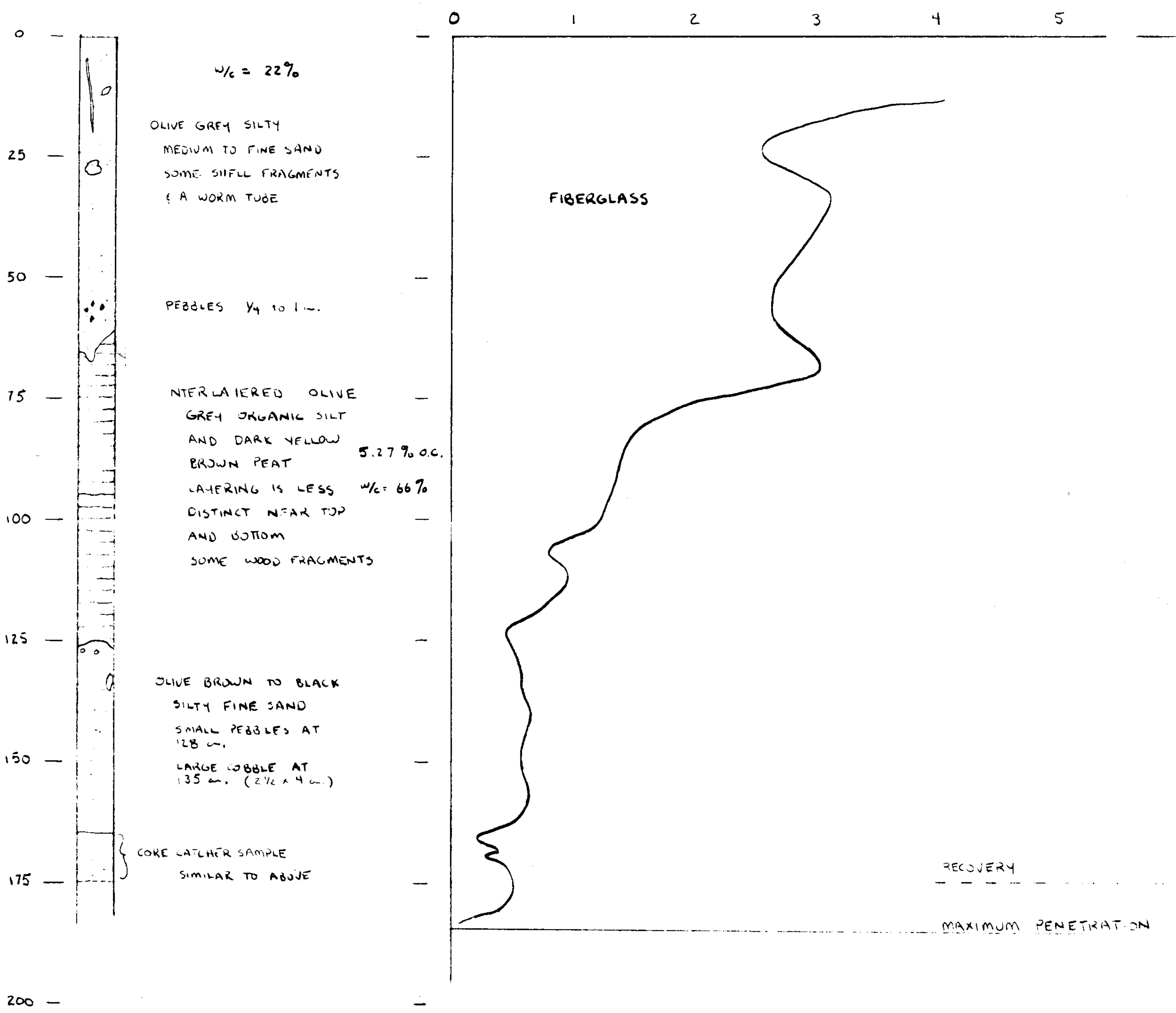


FIGURE C-7

VIBRACORE 101



w/c = 22%

OLIVE GREY SILTY MEDIUM TO FINE SAND SOME SHELL FRAGMENTS & A WORM TUBE

PEBBLES 1/4 to 1 in.

NTERLAIERED OLIVE GREY ORGANIC SILT AND DARK YELLOW BROWN PEAT LAYERING IS LESS DISTINCT NEAR TOP AND BOTTOM SOME WOOD FRAGMENTS

5.27 % O.C.

w/c = 66 %

OLIVE BROWN TO BLACK SILTY FINE SAND

SMALL PEBBLES AT 128 cm.

LARGE COBBLE AT 135 cm. (2 1/2 x 4 cm.)

CORE CATCHER SAMPLE SIMILAR TO ABOVE

FIGURE C-8

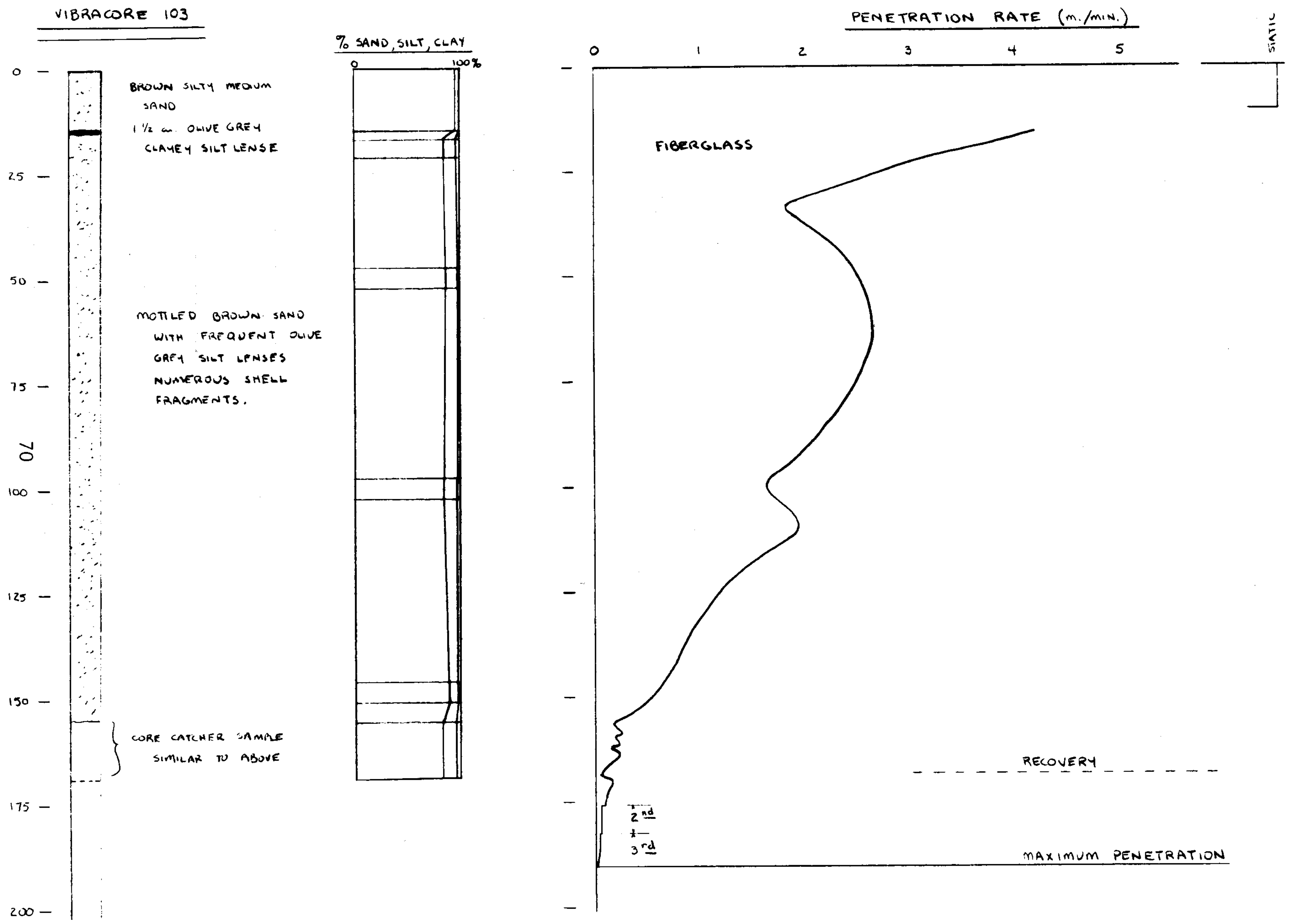

VIBRACORE 103
0
25
50
75
100
125
150
175
200
BROWN SILTY MEDIUM SAND
1 ½ cm. OLIVE GREY CLAYEY SILT LENSE
MOTTLED BROWN SAND WITH FREQUENT OLIVE GREY SILT LENSES NUMEROUS SHELL FRAGMENTS.
CORE CATCHER SAMPLE SIMILAR TO ABOVE
% SAND, SILT, CLAY
0
100%
PENETRATION RATE (m./min.)
0
1
2
3
4
5
STATIC
FIBERGLASS
RECOVERY
2nd
3rd
MAXIMUM PENETRATION

FIGURE C-9

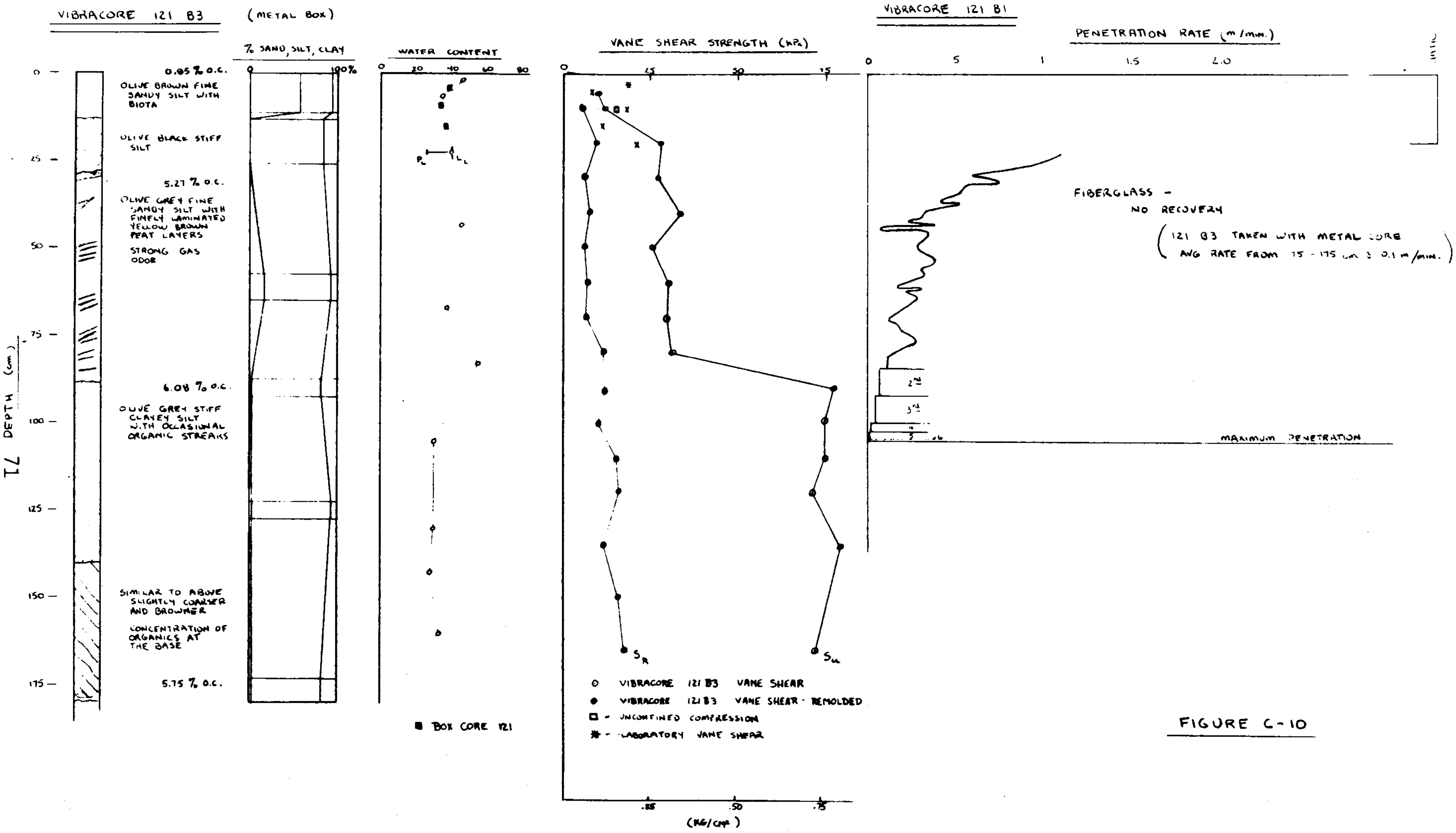

VIBRACORE 121 B3
(METAL BOX)
% SAND, SILT, CLAY
0
100%
WATER CONTENT
0
20
40
60
80
VANE SHEAR STRENGTH (kPa)
0
25
50
75
DEPTH (cm)
0
25
50
75
100
125
150
175
0.05 % O.C.
OLIVE BROWN FINE SANDY SILT WITH BIOTA
OLIVE BLACK STIFF SILT
5.27 % O.C.
OLIVE GREY FINE SANDY SILT WITH FINELY LAMINATED YELLOW BROWN PEAT LAYERS
STRONG GAS ODOR
6.08 % O.C.
OLIVE GREY STIFF CLAYEY SILT WITH OCCASIONAL ORGANIC STREAKS
SIMILAR TO ABOVE SLIGHTLY COARSER AND BROWNER
CONCENTRATION OF ORGANICS AT THE BASE
5.75 % O.C.
P_L
L_L
■ BOX CORE 121
S_R
S_u
○ VIBRACORE 121 B3 VANE SHEAR
● VIBRACORE 121 B3 VANE SHEAR - REMOLDED
□ - UNCONFINED COMPRESSION
✱ - LABORATORY VANE SHEAR
.25
.50
.75
(KG/CM²)
VIBRACORE 121 B1
PENETRATION RATE (m/min.)
0
5
1
1.5
2.0
FIBERGLASS -
NO RECOVERY
(121 B3 TAKEN WITH METAL CORE
AVG RATE FROM 15 - 175 cm ≈ 0.1 m/min.)
2nd
3rd
4
5
6
MAXIMUM PENETRATION

FIGURE C-10

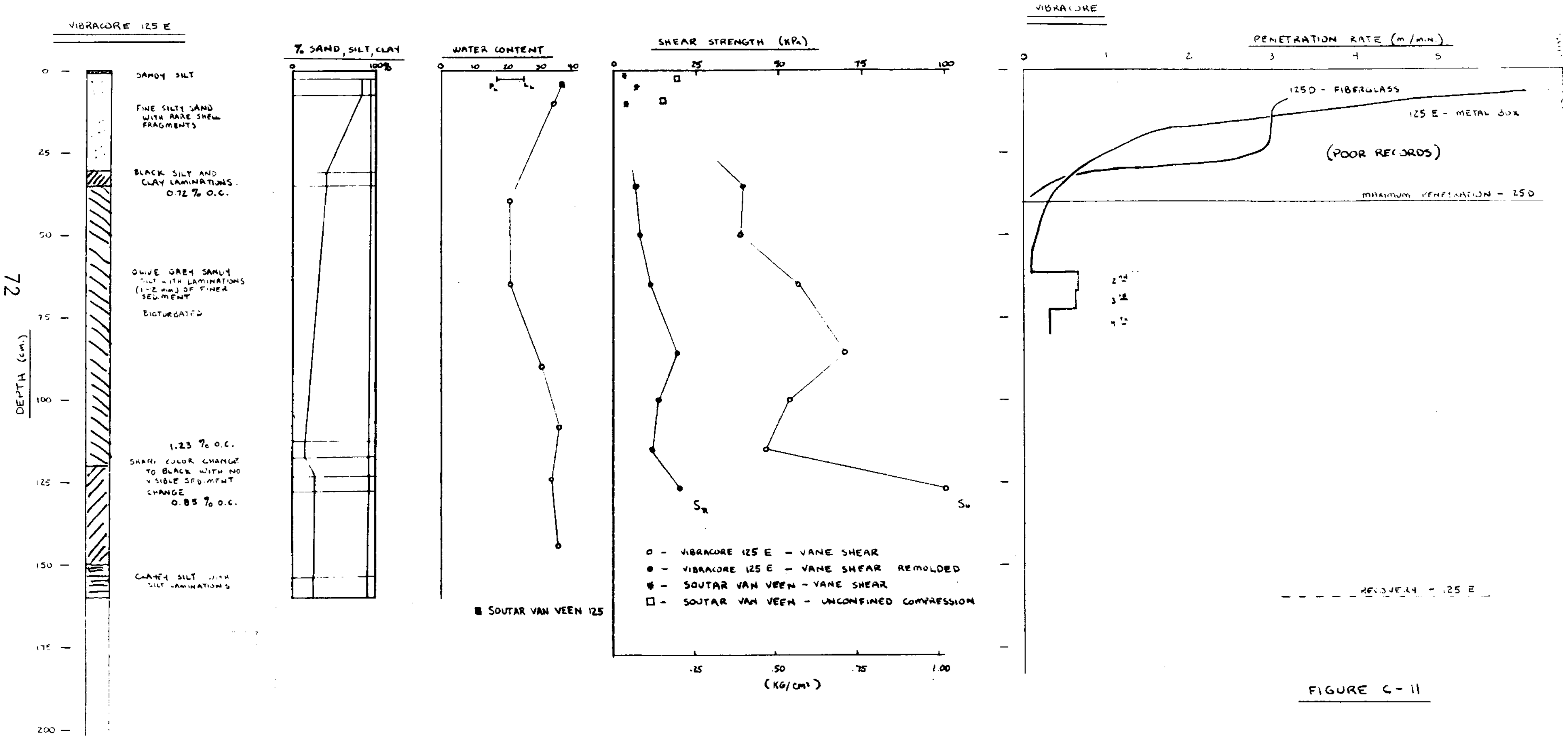

VIBRACORE 125 E
DEPTH (cm.)
0
25
50
75
100
125
150
175
200
SANDY SILT
FINE SILTY SAND WITH RARE SHELL FRAGMENTS
BLACK SILT AND CLAY LAMINATIONS.
0.72 % O.C.
OLIVE GREY SANDY SILT WITH LAMINATIONS (1-2 mm) OF FINER SEDIMENT
BIOTURBATED
1.23 % O.C.
SHARP COLOR CHANGE TO BLACK WITH NO VISIBLE SEDIMENT CHANGE
0.85 % O.C.
CLAYEY SILT WITH SILT LAMINATIONS
% SAND, SILT, CLAY
0
100%
WATER CONTENT
0
10
20
30
40
P_L
L_L
■ SOUTAR VAN VEEN 125
SHEAR STRENGTH (KPa)
0
25
50
75
100
S_R
S_u
○ - VIBRACORE 125 E - VANE SHEAR
● - VIBRACORE 125 E - VANE SHEAR REMOLDED
✱ - SOUTAR VAN VEEN - VANE SHEAR
□ - SOUTAR VAN VEEN - UNCONFINED COMPRESSION
.25
.50
.75
1.00
(KG/cm²)
VIBRACORE
PENETRATION RATE (m/min.)
0
1
2
3
4
5
125D - FIBERGLASS
125 E - METAL BOX
(POOR RECORDS)
MAXIMUM PENETRATION - 125D
2nd
3rd
4th
RECOVERY - 125 E

FIGURE C-11

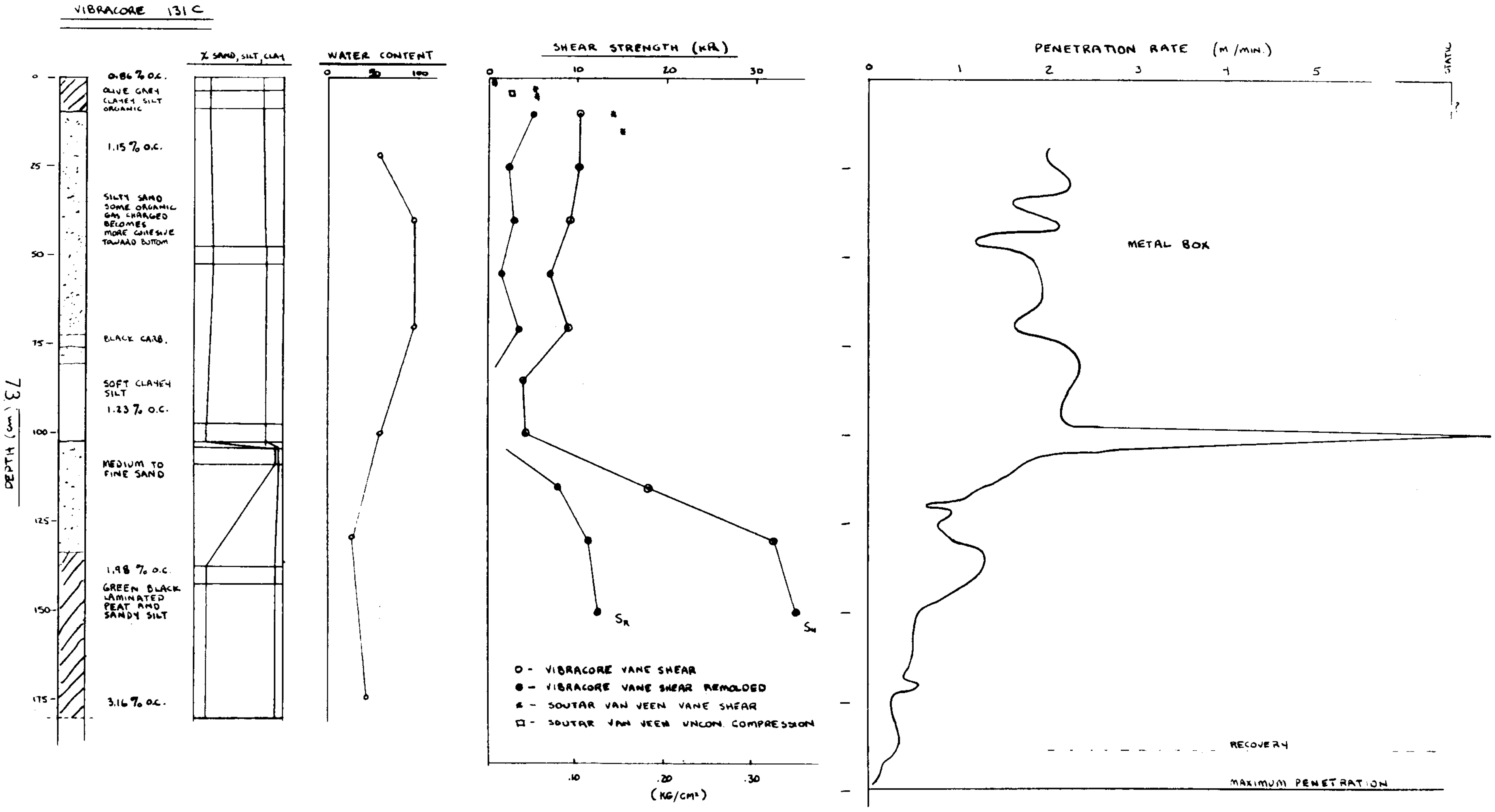

VIBRACORE 131 C
DEPTH (cm)
73
0
25
50
75
100
125
150
175
0.86 % O.C.
OLIVE GREY CLAYEY SILT ORGANIC
1.15 % O.C.
SILTY SAND SOME ORGANIC GAS CHARGED BECOMES MORE COHESIVE TOWARD BOTTOM
BLACK CARB.
SOFT CLAYEY SILT
1.23 % O.C.
MEDIUM TO FINE SAND
1.98 % O.C.
GREEN BLACK LAMINATED PEAT AND SANDY SILT
3.16 % O.C.
% SAND, SILT, CLAY
WATER CONTENT
0
50
100
SHEAR STRENGTH (kPa)
0
10
20
30
.10
.20
.30
(KG/CM²)
S_R
S_U
○ - VIBRACORE VANE SHEAR
● - VIBRACORE VANE SHEAR REMOLDED
* - SOUTAR VAN VEEN VANE SHEAR
□ - SOUTAR VAN VEEN UNCON. COMPRESSION
PENETRATION RATE (m/min.)
0
1
2
3
4
5
STATIC
?
METAL BOX
RECOVERY
MAXIMUM PENETRATION

FIGURE C-12

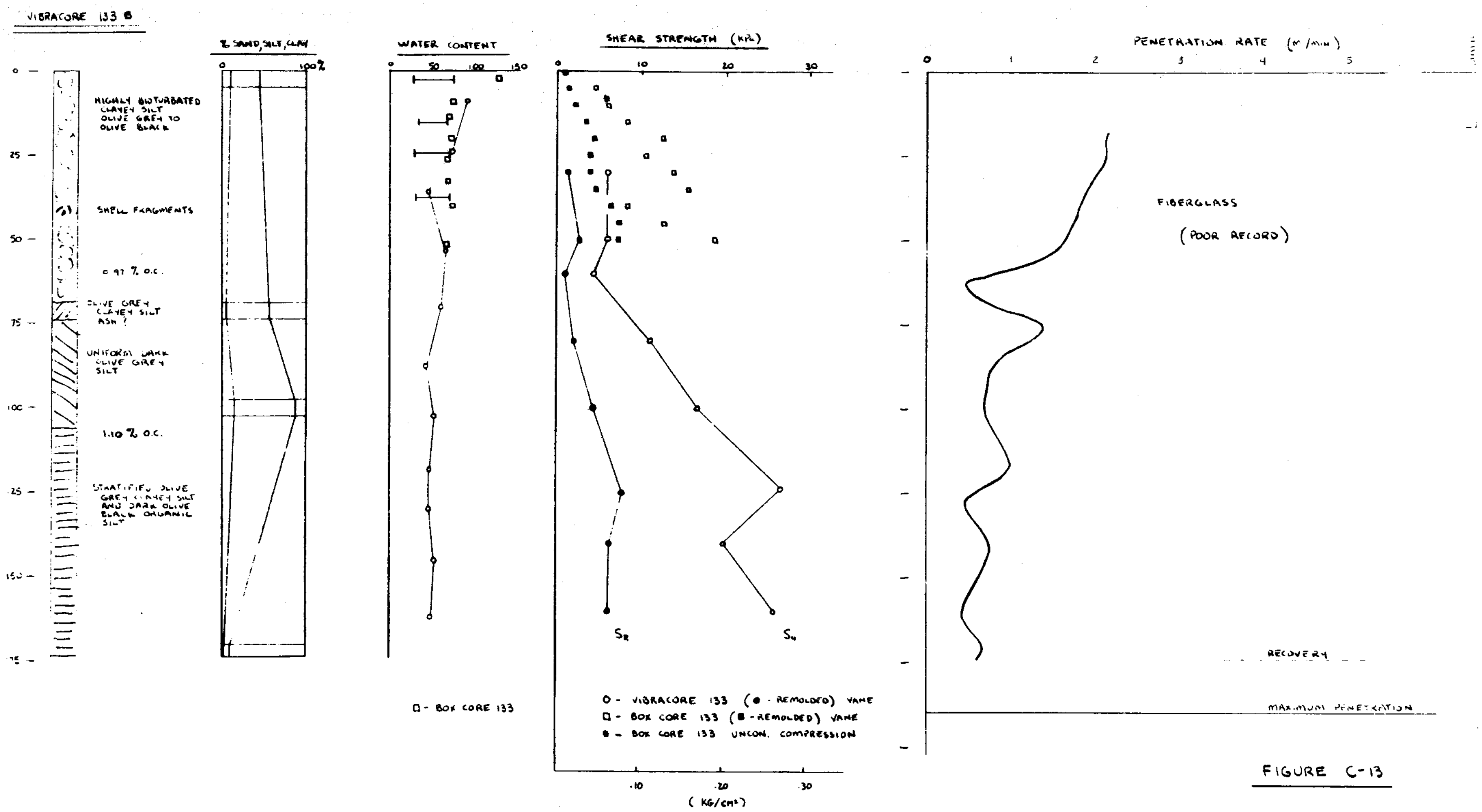

VIBRACORE 133 B
0
25
50
75
100
125
150
175
HIGHLY BIOTURBATED CLAYEY SILT OLIVE GREY TO OLIVE BLACK
SHELL FRAGMENTS
0.97 % O.C.
OLIVE GREY CLAYEY SILT ASH ?
UNIFORM DARK OLIVE GREY SILT
1.10 % O.C.
STRATIFIED OLIVE GREY CLAYEY SILT AND DARK OLIVE BLACK ORGANIC SILT
% SAND, SILT, CLAY
0
100%
WATER CONTENT
0
50
100
150
□ - BOX CORE 133
SHEAR STRENGTH (KPa)
0
10
20
30
S_R
S_u
○ - VIBRACORE 133 (● - REMOLDED) VANE
□ - BOX CORE 133 (■ - REMOLDED) VANE
● - BOX CORE 133 UNCON. COMPRESSION
.10
.20
.30
(KG/CM²)
PENETRATION RATE (m/min)
0
1
2
3
4
5
FIBERGLASS
(POOR RECORD)
RECOVERY
MAXIMUM PENETRATION

FIGURE C-13

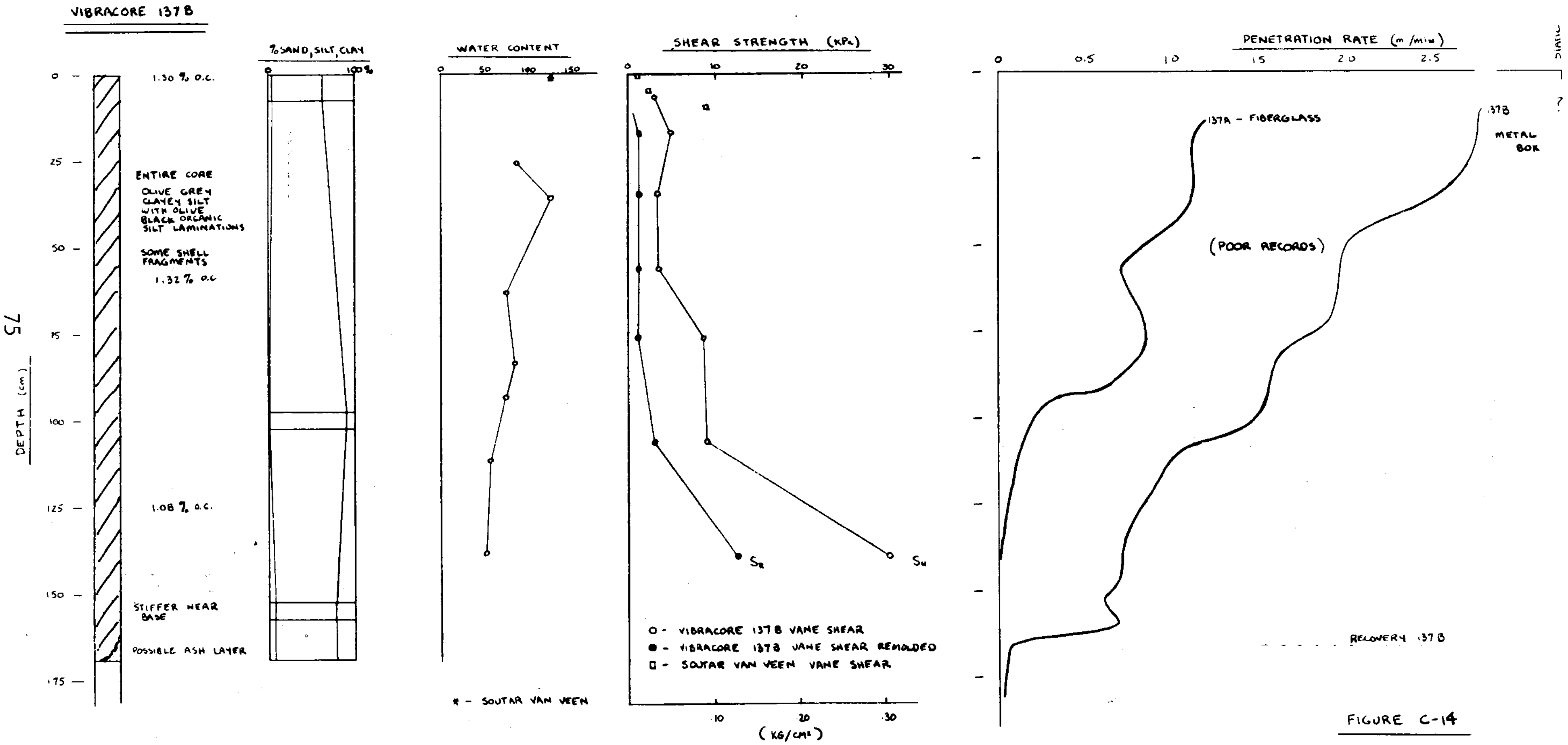

VIBRACORE 137B
DEPTH (cm)
0
25
50
75
100
125
150
175
1.30 % O.C.
ENTIRE CORE
OLIVE GREY CLAYEY SILT WITH OLIVE BLACK ORGANIC SILT LAMINATIONS
SOME SHELL FRAGMENTS
1.32 % O.C.
1.08 % O.C.
STIFFER NEAR BASE
POSSIBLE ASH LAYER
% SAND, SILT, CLAY
0
100%
WATER CONTENT
0
50
100
150
* - SOUTAR VAN VEEN
SHEAR STRENGTH (KPa)
0
10
20
30
S_R
S_u
○ - VIBRACORE 137B VANE SHEAR
● - VIBRACORE 137B VANE SHEAR REMOLDED
□ - SOUTAR VAN VEEN VANE SHEAR
.10
.20
.30
(KG/CM²)
PENETRATION RATE (m/min)
0
0.5
1.0
1.5
2.0
2.5
137A - FIBERGLASS
137B
METAL BOX
?
(POOR RECORDS)
RECOVERY 137B

FIGURE C-14

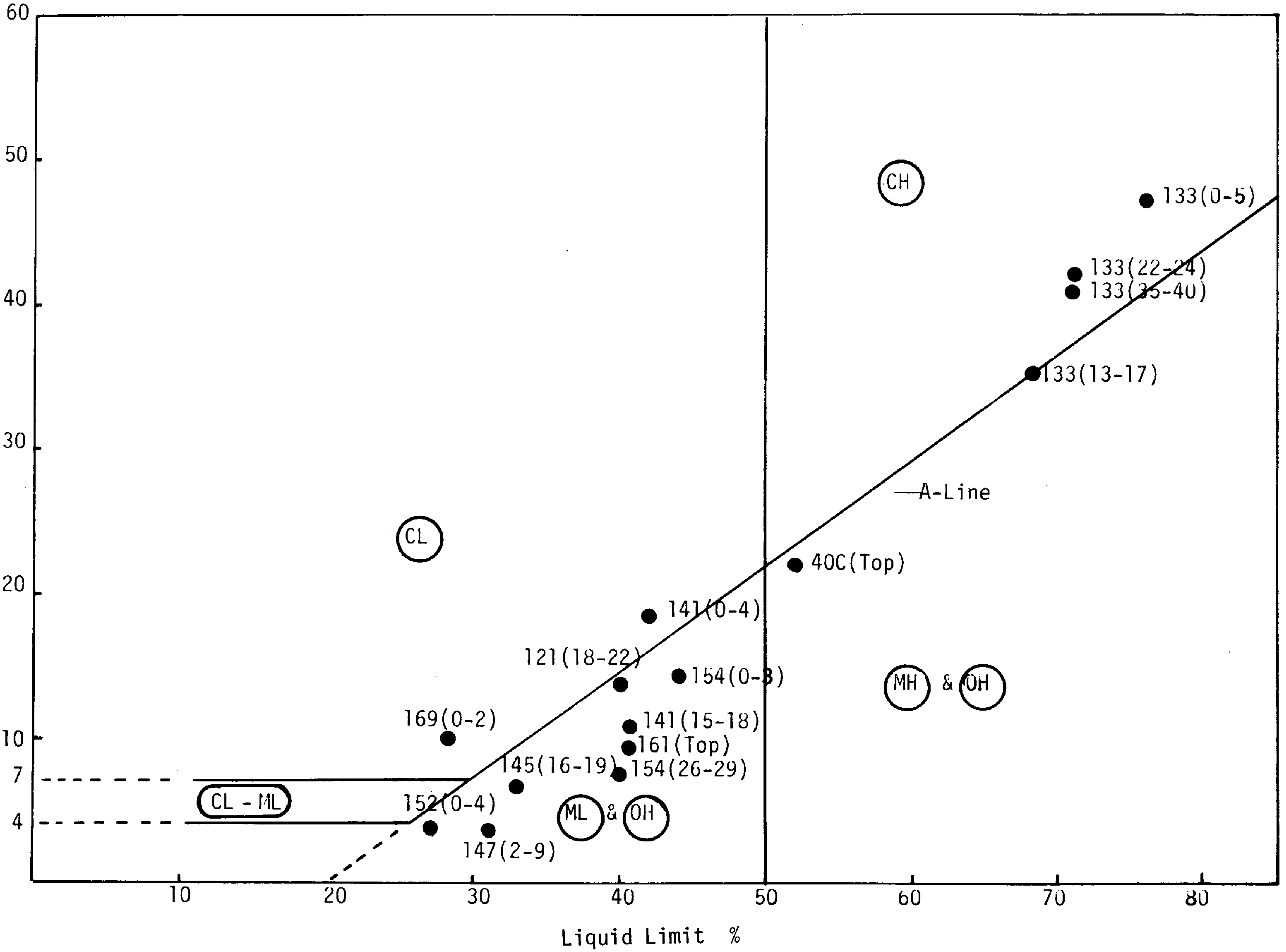


Figure C-15 PLASTICITY CHART

DIRECT SHEAR TESTS

SEA 5-76-BS

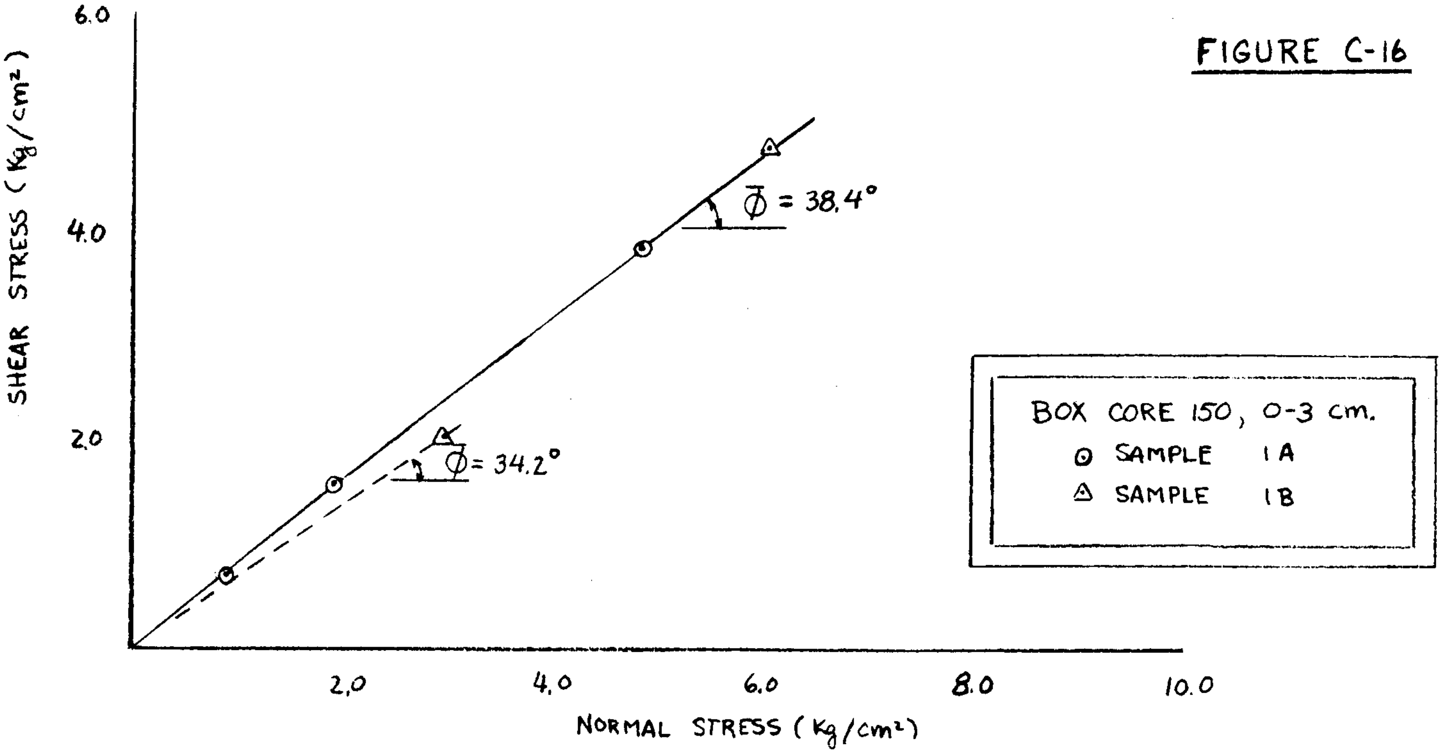


FIGURE C-16

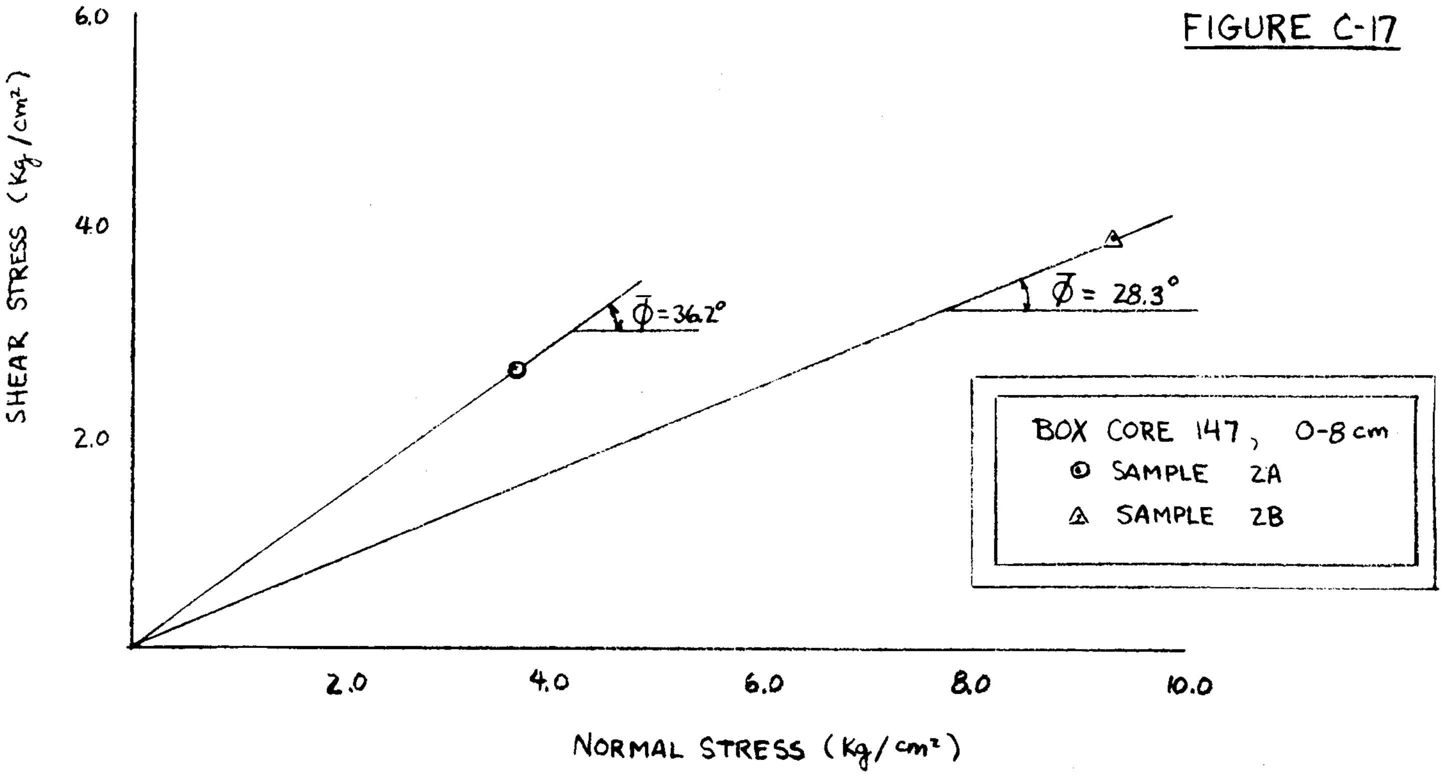
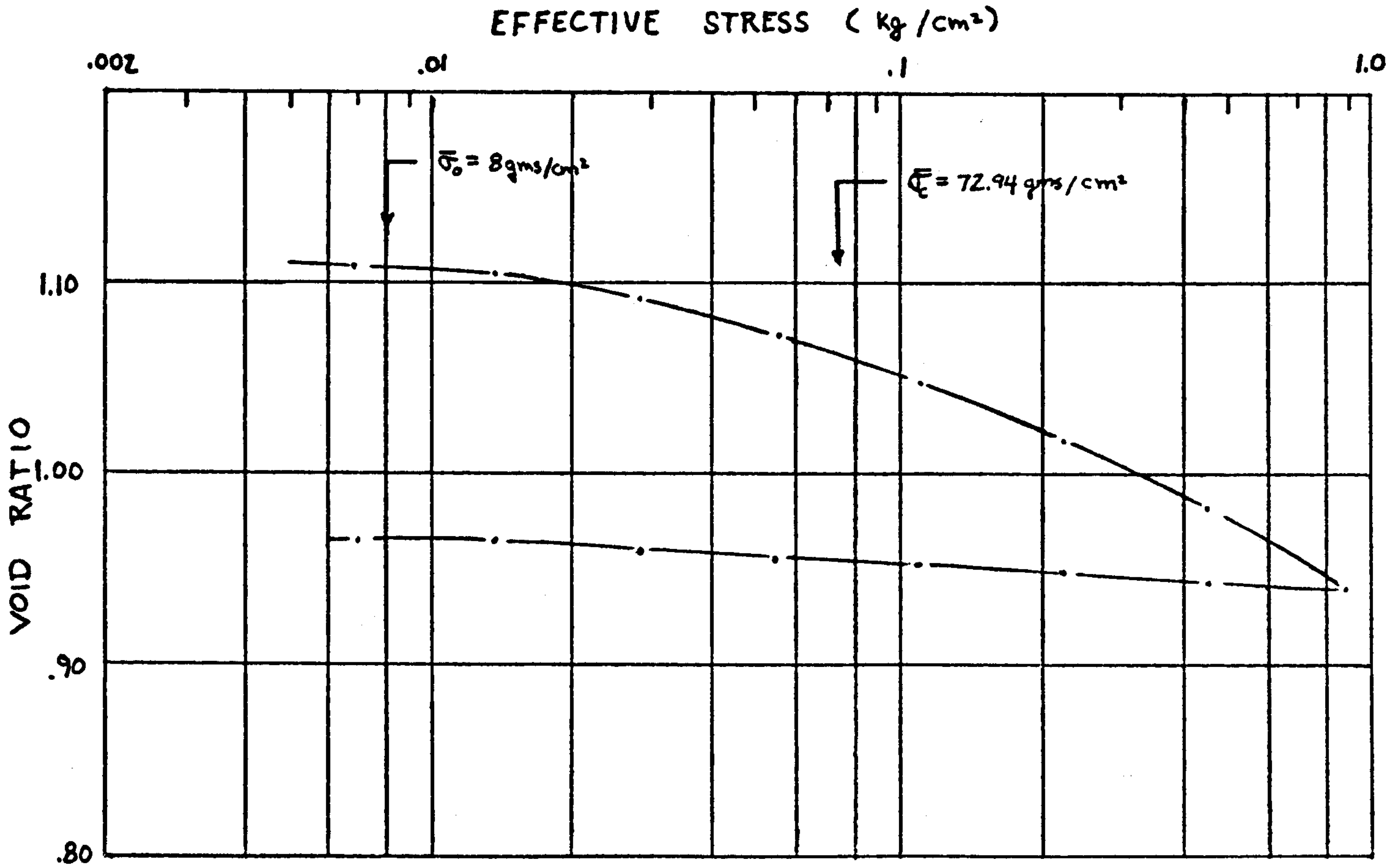


FIGURE C-17



CONSOLIDATION TEST - SEA5-76-BS

BOX CORE 154 , 8-13 cms.

OVERBURDEN STRESS ($\bar{\sigma}_o$ = 8.0 gms /cm²)
PRECONSOLIDATION STRESS ($\bar{\sigma}_c$ = 72.9 gms /cm²)
OVERCONSOLIDATION RATIO ($\bar{\sigma}_c / \bar{\sigma}_o$ = 9.11)
AVERAGE COEFF. OF CONSOL ($C_v = 3.58 \times 10^{-3}$ cm²/ sec)
AVERAGE COEFF. OF PERMEABILITY ($K = 1.20 \times 10^{-6}$ cm/sec)
COMPRESSION INDEX (CORRECTED) = .153

FIGURE C-18

D. Potential Sea Floor Instability from Gas-Rich Sediments and Sediment Depression Craters

Hans Nelson

Introduction

In the petroleum producing regions of the North Sea and Gulf of Mexico problems have been associated with sediment depression craters caused by gas venting at the sea floor (L.E. Garrison, 1974). Sediment cratering is most common at times of peak storm wave stress on the sea floor, when pipeline breaks have been detected (Terry Edgar, oral communication, U.S. Geological Survey, Reston, Va.). Mounting evidence in Norton Sound suggests that gas venting causes development of widespread small craters on the sea floor of Norton Sound. These craters are not associated with the known potential petrogenic gas seep recently reported by Joel Cline (1977) of NOAA, but occur in a different region about 50 km to the east (Fig. D-1).

Craters and Large Depressions

Small circular shaped pits are observed over a large area of north central Norton Sound and in a local area near Port Clarence (Figs. D-1 and D-2). These craters are generally circular, less than 10 m in diameter (averaging 3 - 5 m), and relatively deep compared to their width. They tend to be closely spaced and evenly distributed through the entire side-scan profiles. They are associated with velocity anomalies in the high resolution profiles (Fig. D-1).

A series of large depressions, similar to those associated with gas charged sediments in the Gulf of Mexico (L.E. Garrison, 1974), have been noted near the Yukon delta and midway between the possible petrogenic seep (south of Nome) and the large area of small craters 50 km to the east (Fig. D-1). The large depressions range from 25-150 m in diameter, are irregularly shaped, and are relatively shallow compared to their width. Acoustic anomalies in seismic profiling records are not associated with the large depressions, but increased bottom steepness and current velocities are both present in this region. The steep flanks of shoals, along which these irregular depressions are found, suggests a possible origin as slumps; however, no debris toes, disrupted bedding, or offset ice gouge traces are evident to verify a slump origin in these specific areas and slumps are not evident elsewhere in northern Bering Sea. A more likely explanation for large depressions may be intensified current scour along steep flanks of shoals.

It is important to note that depressions and craters on the Norton sea floor could be much more widespread than present side-scan records suggest. On many tracklines, particularly just to the east of the pitted sea floor, no side-scan records were taken or records were of very poor quality, in which case pits could not be recognized (Fig. D-3). In other widespread areas, especially in southern Norton Sound, intense ice gouging obliterates all other surface features.

Peat Layers

Confirmed presence of peat layers in box and vibracores provides a potential source for gas generation possibly associated with sediment craters in bottom sediments. The entire sea floor of Northern Bering Sea was emergent during the last Wisconsin glacial period (Nelson and Hopkins, 1972) and had the potential of being covered by tundra peats. In several locations of northern Bergin Sea where Holocene sediment cover is thin (Fig. D-4) sequences of pre-Holocene peat have been cored (Fig. D-5). One area of such peat, close to the sea floor surface, lies just east of the known areas of craters and could easily extend under the cratered region (Fig. D-6). These peaty muds contain organic carbon contents 5-10 times above amounts found in Holocene sediments (Fig. D-7), (see also core logs of report C). More important, qualitative amounts of gas are much greater in the Pleistocene peaty muds (Figs. D-5 and D-6). Unfortunately, box cores have not penetrated deep enough to reach possible pre-Holocene peaty muds in the cratered area and vibracores have not yet been attempted. However, seismic records (Fig. D-4) suggest that such peaty pre-Holocene muds should be within 2 m of the sea floor and within reach of the vibracore.

Seismic Velocity Anomalies

Acoustic velocity anomalies from the region of small craters are common in high resolution and sparker seismic profiles (Fig. D-1). The velocity "dropouts" are sporadic throughout records and vary from sections of several hundred meters of trackline to local events for a few tens of meters (Fig. D-8). In the larger type of anomalies reflectors are completely absent,whereas small anomalies are represented by reflector hyperbolas that are sporadic throughout records.

Several sources can be suggested for the velocity dropouts. Gravels in buried channels can have such an effect, but the general region of surface craters is covered by Yukon muds and all coring to date in Norton Sound reveals no gravels. The peat beds themselves can act as an "acoustic sponge" and this is a definite possibility; perhaps it may only be associated with the less severe disruption of the hyperbola in reflectors, whereas the complete sound absorption is related to mainly gas charged sediments.

Gas Source in Gas-Rich Sediments

Abnormal amounts of gas are generated in subsurface peaty muds of freshwater origin (Fig. D-6) and this process could provide a widespread source for gas charging of sediments. The known occurrence of ethane and propane anomalies in water reported by Cline (1977) permit the hypothesis that petrogenic sources also could cause gas charging of sediments and seismic velocity anomalies. However, Cline did not find anomalies of the potentially petrogenic gases in the area of surface craters.

All evidence from sediments suggests a biogenic rather than a petrogenic source for subsurface gas enrichment associated with small sea floor craters. The predominant gas in surface sediments throughout Norton Basin and in subsurface cores is methane (99% or more)(Figs. D-6, D-9). Some of the highest methane contents occur in surface sediments in the vicinity of the sea floor craters (Fig. 9). The ratio of methane to ethane plus propane ranges from 50 to 7,769, with all the deeper samples in peaty muds possessing ratios above 600 (M. Sandstrom, 1977, written communication, Geology Department, UC at Los Angeles). Ratios of 50 or more for these gases generally are considered to be biogenic in origin (Bernard, et al., 1976). Similarly, Carbon 13 isotope ratios of 60-90 indicate a biogenic source of gas (Bernard, ibid) and the Norton Sound values range from 69-75 (Sandstrom, ibid).

Gas Venting in Sediments

Measured geotechnical properties of peaty muds, observed subsurface gas-enrichment and documented storm surge events all point to gas venting as the origin of small surface craters in Norton Sound. Increased organic content in sediments normally increases water content and compressibility while decreasing shear strength and density (Whelan et al., 1976). This effect can be demonstrated in cores with peaty muds of Norton Sound where normal increase in shear strength and water content with depth do not occur (Fig. C-10). These characteristics together with the high compressibility of peaty muds increase the chance of gas venting and sudden sediment collapse.

The extremely low content of gas in surface sediment compared to that at depth (Fig. D-6) suggests that gas diffusion to the surface is poor, even through a few tens of centimeters of sediment. This indicates the possibility that gas generated in peaty muds will build up with time and be entrapped relatively close to the surface, particularly throughout northern Norton Sound where pre-transgressive peaty muds are only thinly buried (Fig. D-4). When this gas enriched, compressible sediment comes under increased stress from rapidly fluctuating storm wave pressures, gas venting, sediment collapse, and surface crater formation seem quite tenable.

The cratering itself suggests that gas venting is periodic rather than by slow diffusion to the surface. Such periodic gas venting on this extremely shallow shelf is most likely associated with the storm surge events of this region. Significant sea surface set-up is common in Norton Sound (Fatheur, 1975) and the immense movement of water into the region should affect bottom sediment pressures. Also, the associated storm waves can severely and rapidly disrupt the bottom pressure gradients and the sedimentation regime. In addition to rapid pressure changes, extensive sediment unloading may occur because of sediment resuspension by waves (Fig. D-44) (Nelson and Creager, 1977).

Conclusions

It appears that widespread presence of thick sequences of organic rich peaty mud results in generation of significant quantities of biogenic gas. Where peats are thinly buried, and at times of storm wave stress, gas vents through near surface sediments causing extensive cratering of the sea floor. This presents a potential hazard for petroleum development.

Future studies have been planned to study potential gas charging and sea floor features in the vicinity of the known petrogenic seep. Detailed seismic, side-scan sonar, vibracoring, hydrocarbon analyses and geotechnical measurements will be carried out in regions of petrogenic seeps, large depressions, and small sea floor craters.

Acknowledgements

Keith Kvenvolden and Mark Sandstrom provided essential data and valuable counsel for this study. Mark Holmes, Devin Thor, and James Evans assisted with compilation and interpretation of seismic reflection profiles. Drafting of figures was completed by Devin Thor, Ron Williams, and Jeff Patry. Carol Hirozawa analyzed all samples for carbon content.

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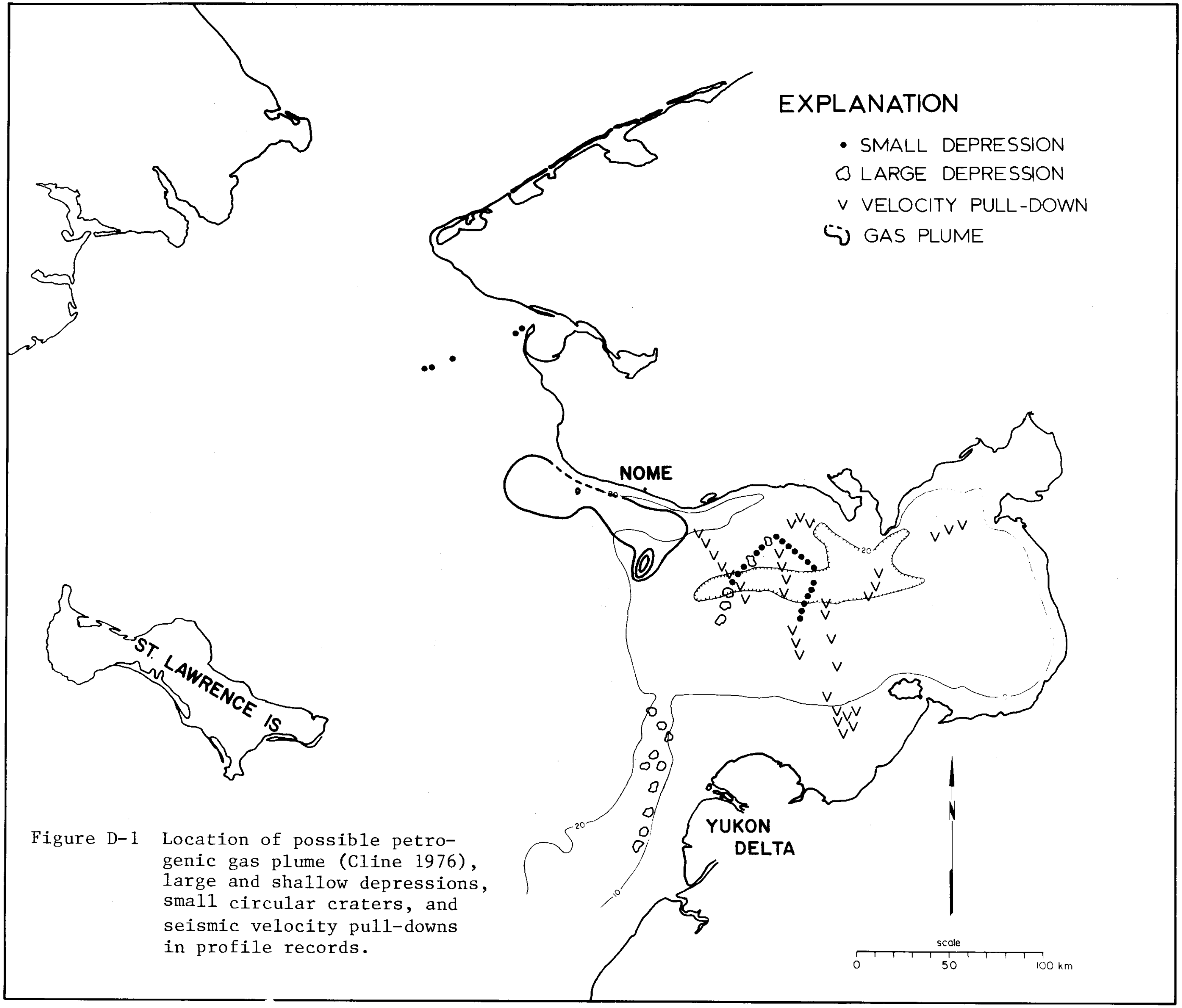

Figure D-1 Location of possible petrogenic gas plume (Cline 1976), large and shallow depressions, small circular craters, and seismic velocity pull-downs in profile records.

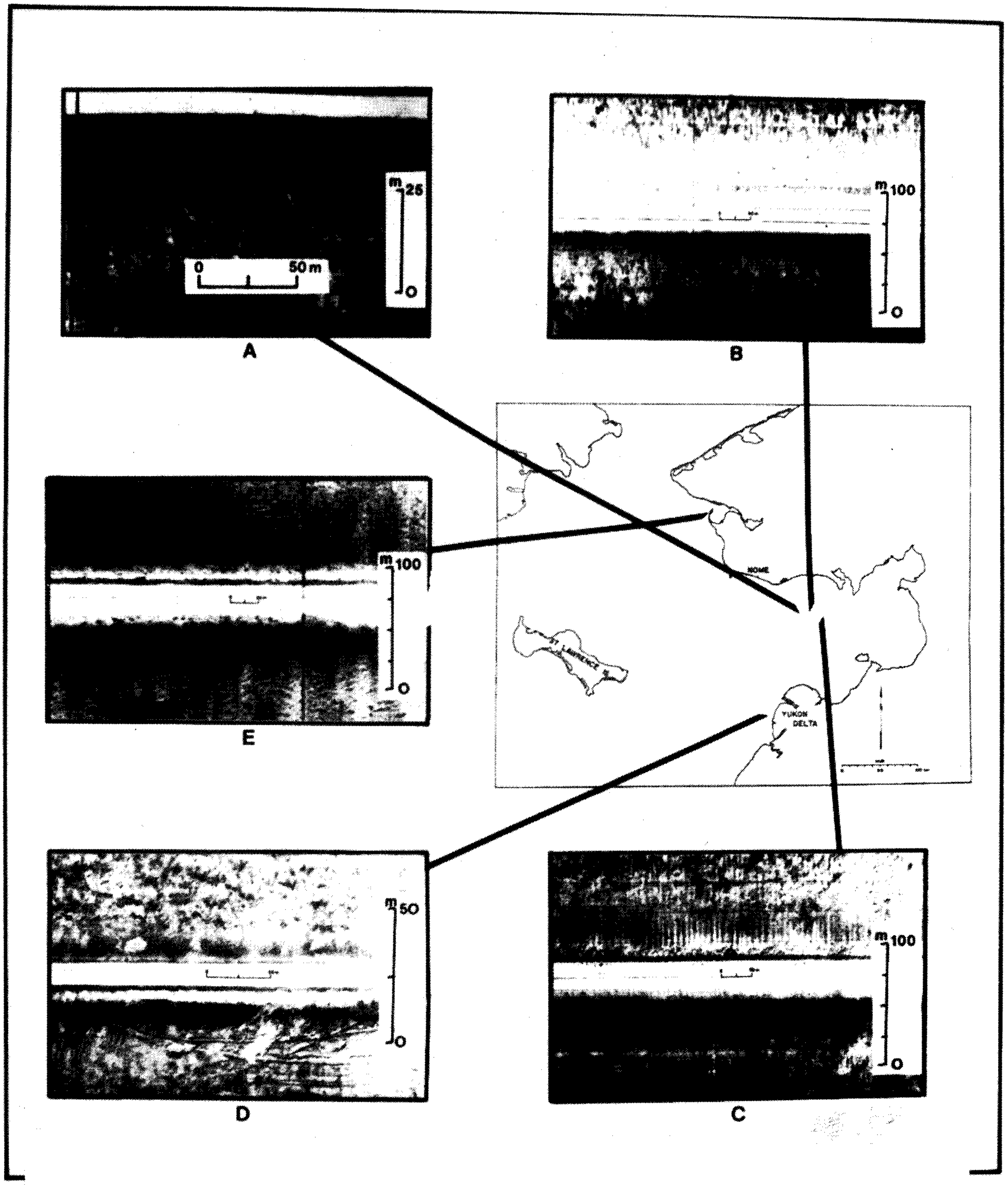

Fig. D-2 Characteristic depressions and craters shown by sidescan sonar profiles. A- large 100 m diameter shallow depression B,C,E- small circular crater-like depressions from various locations D- large irregular depressions near delta.

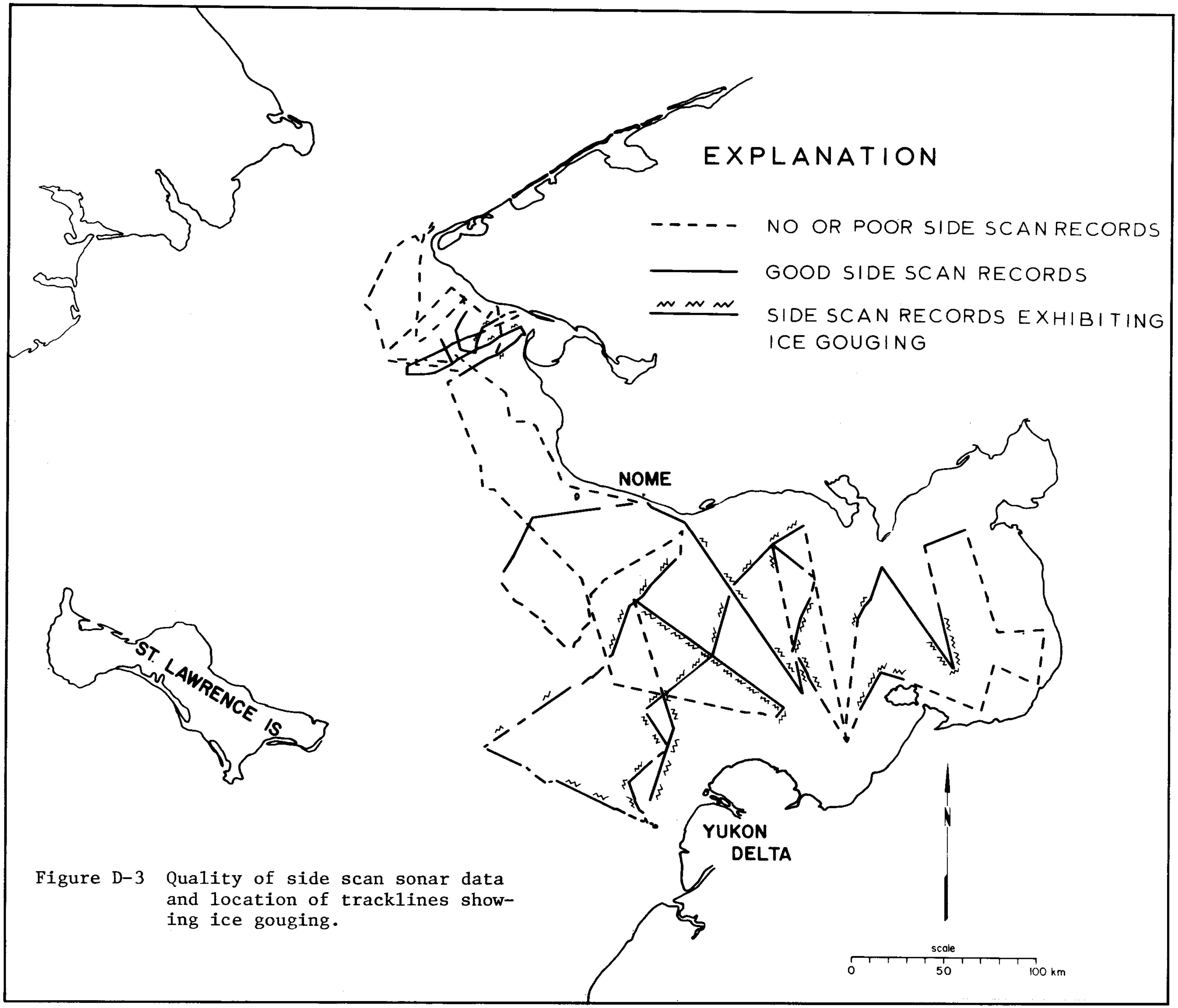

Figure D-3 Quality of side scan sonar data and location of tracklines showing ice gouging.

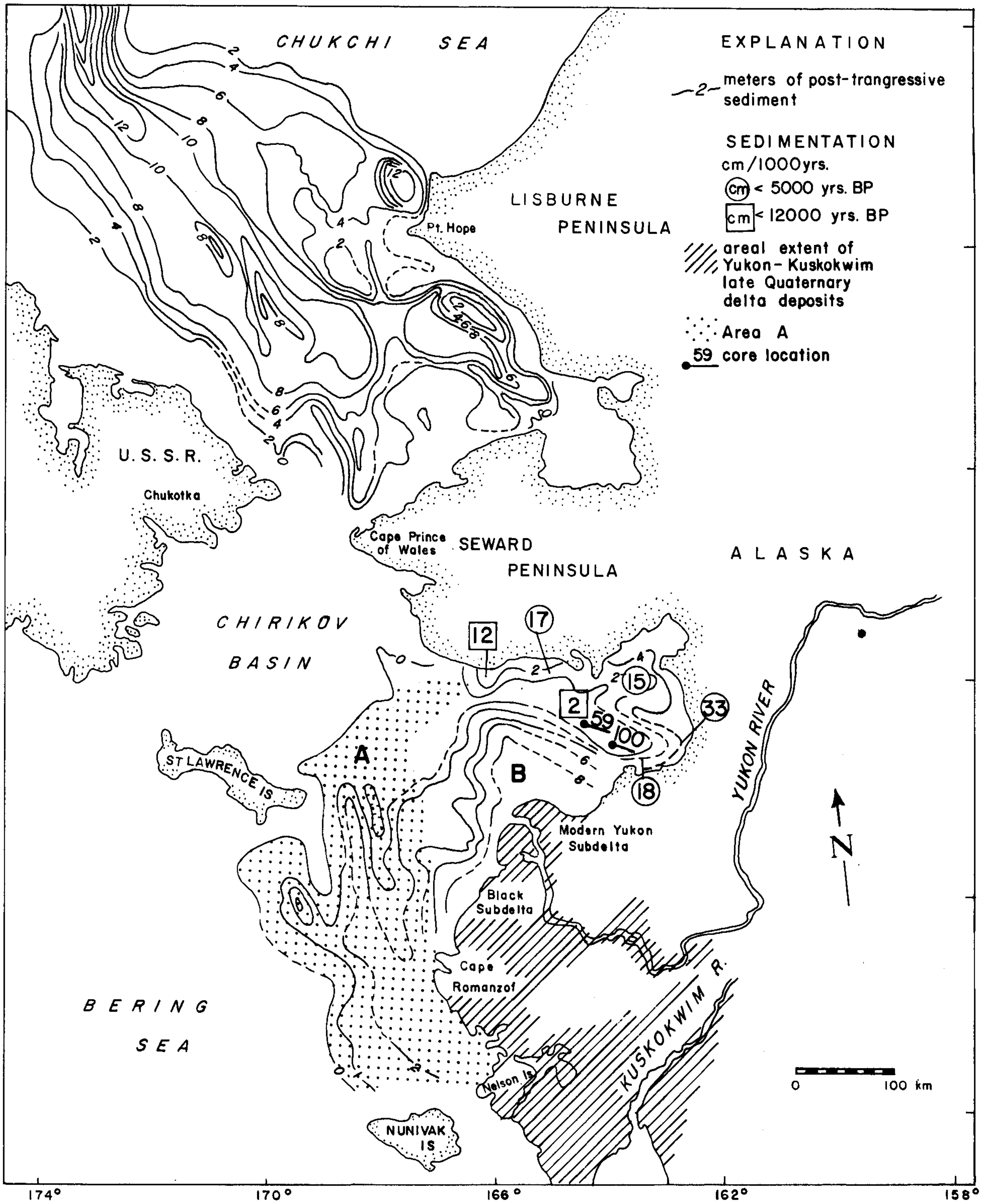

Figure D-4 Distribution and thickness of post-trangressive sediment in northeastern Bering Sea and southern Chukchi Sea. Age of sediment depends on seafloor depth and time of Holocene shoreline transgression. Offshore isopachs based mainly on thickness of uppermost transparent layer observed in high resolution records and, where possible, on independently dated peat and wood layers. Solid isopach lines represent regions crossed by seismic profiling tracks (H. Nelson, unpublished data; Moore 1964; Knebel 1972; Holmes 1975). Non-contoured area between Norton Sound and Bering Strait is covered by relict sediment derived from Chukotka, the Seward Peninsula, and St. Lawrence Island; stippled area A is covered by relict Yukon sand, B by modern Yukon silt (Nelson and Hopkins, 1972; McManus and others, 1974).

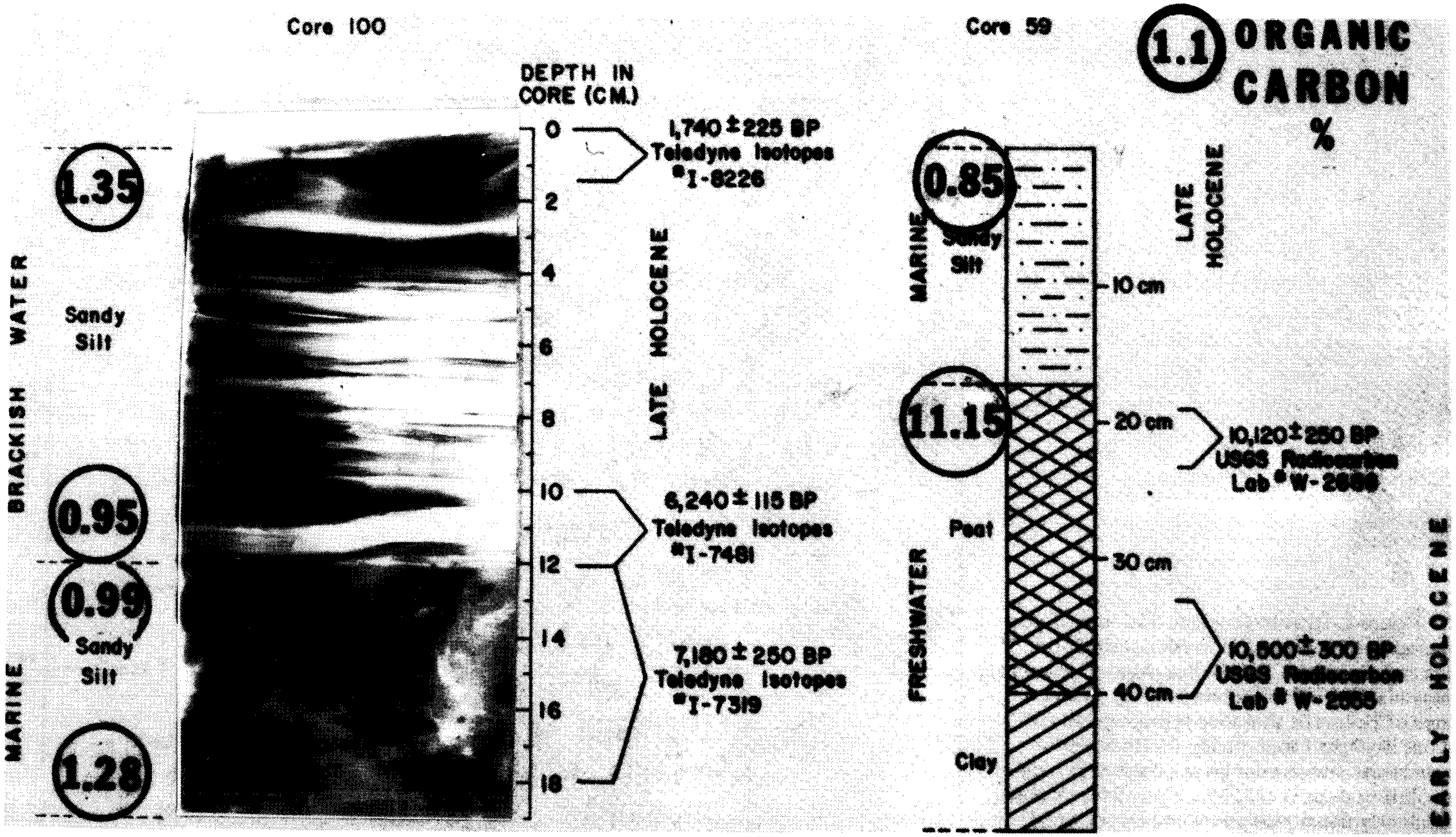

Fig. D-5 Representative core stratigraphy in Norton Sound. Core locations are shown in Figure 2. Note that from 0 to 12 cm, well-preserved thin sand beds (storm layers) are shown in white on the x-ray radiograph of core 100. Abrupt cessation of bioturbation and preservation of these sand layers began about 5000 B.P. This date is estimated by correcting subsurface dates through subtraction of surface-sediment date as follows: [(7,180 - 1,740) + (6,240 - 1,740)]/2.

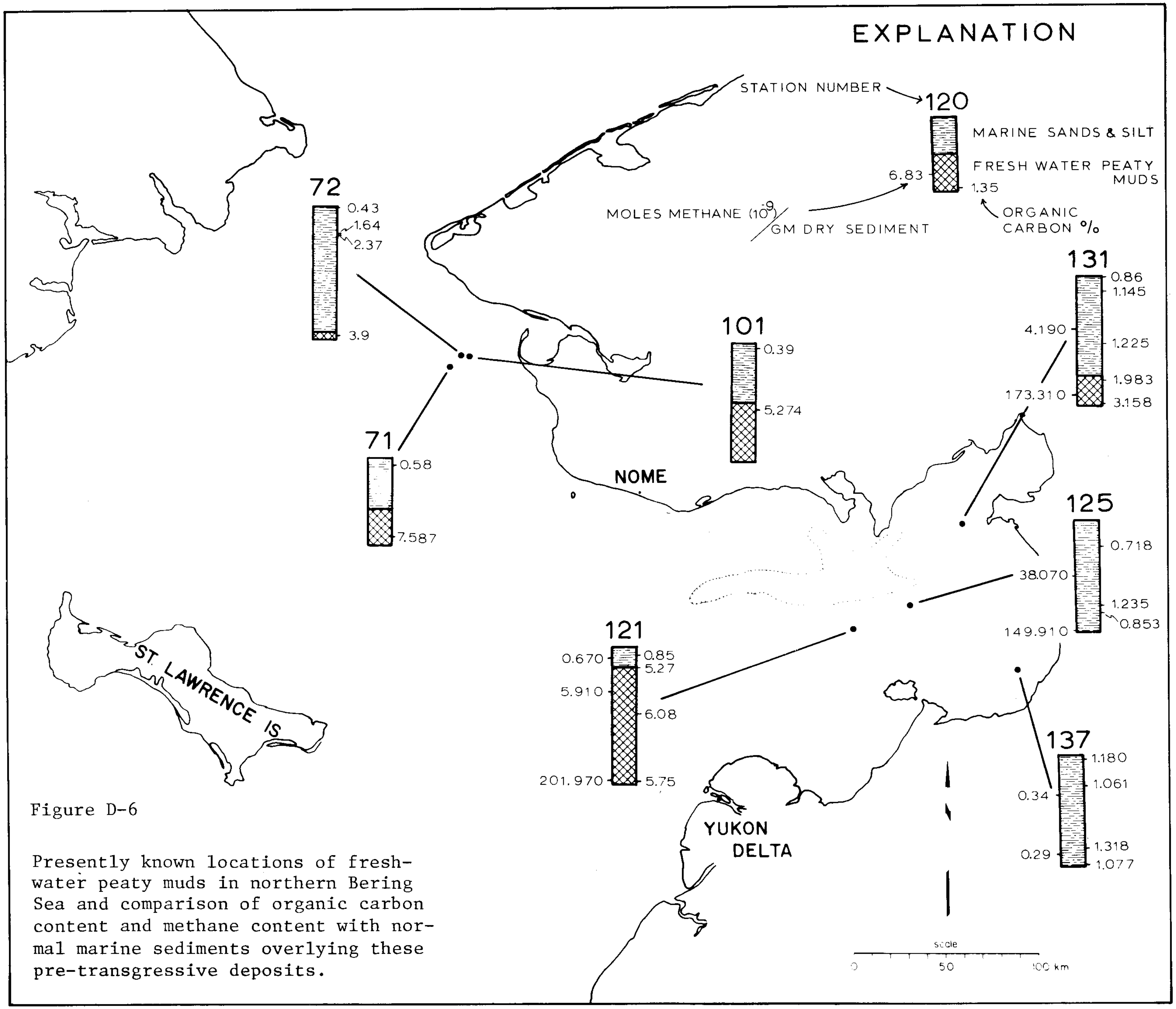

Figure D-6

Presently known locations of fresh-water peaty muds in northern Bering Sea and comparison of organic carbon content and methane content with normal marine sediments overlying these pre-transgressive deposits.

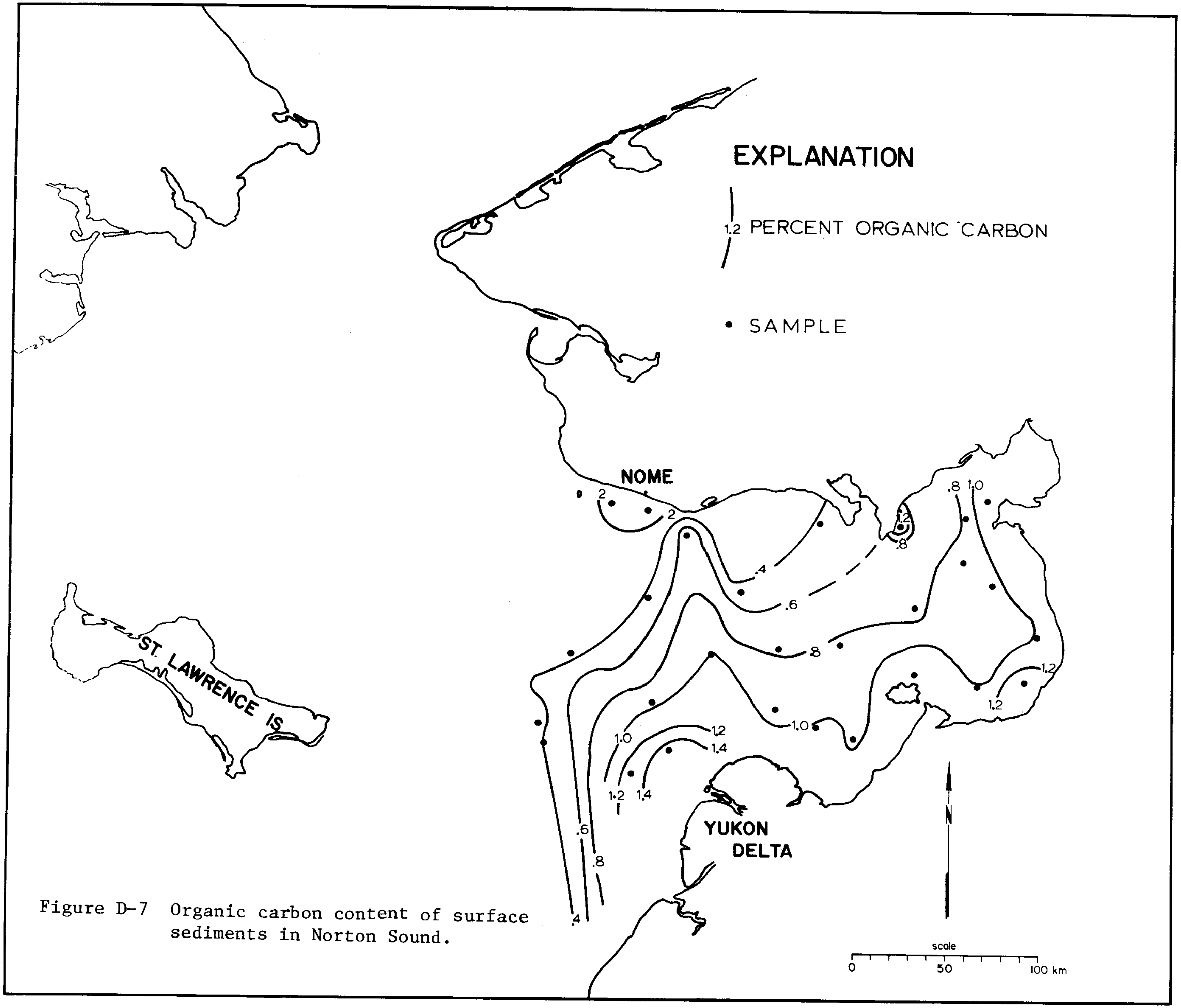

Figure D-7 Organic carbon content of surface sediments in Norton Sound.

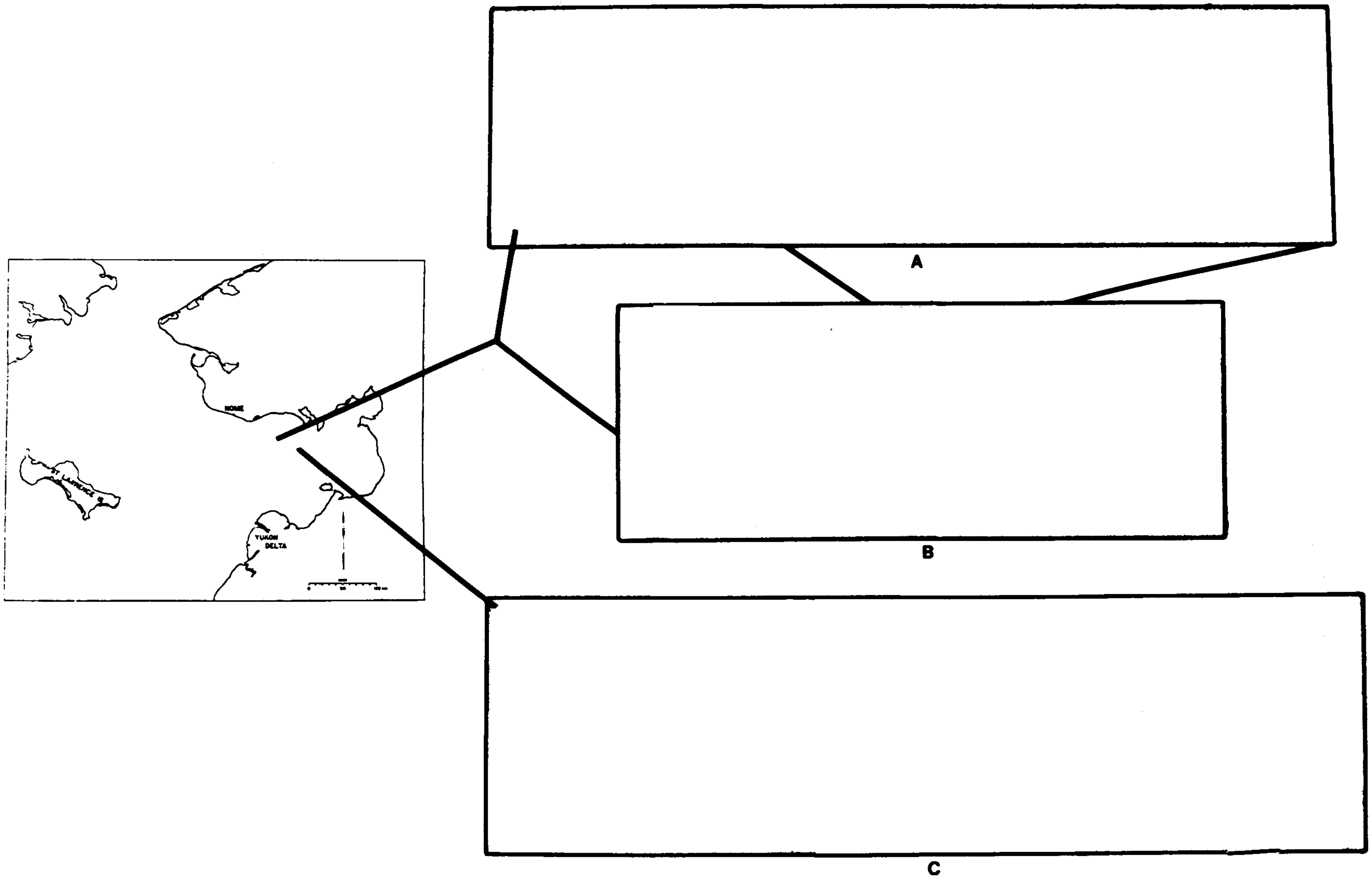

Figure D-8 Examples of velocity anomalies ("pull downs") observed in high resolution profiles in the region of numerous small depressions. A) Velocity anomalies as individual hyperbolas disrupting reflectors in EG&G uniboom profile; B) 3.5 kHz profile at same location as A, showing disrupted nearsurface reflector; C) Extensive velocity drop-out in Uniboom record.

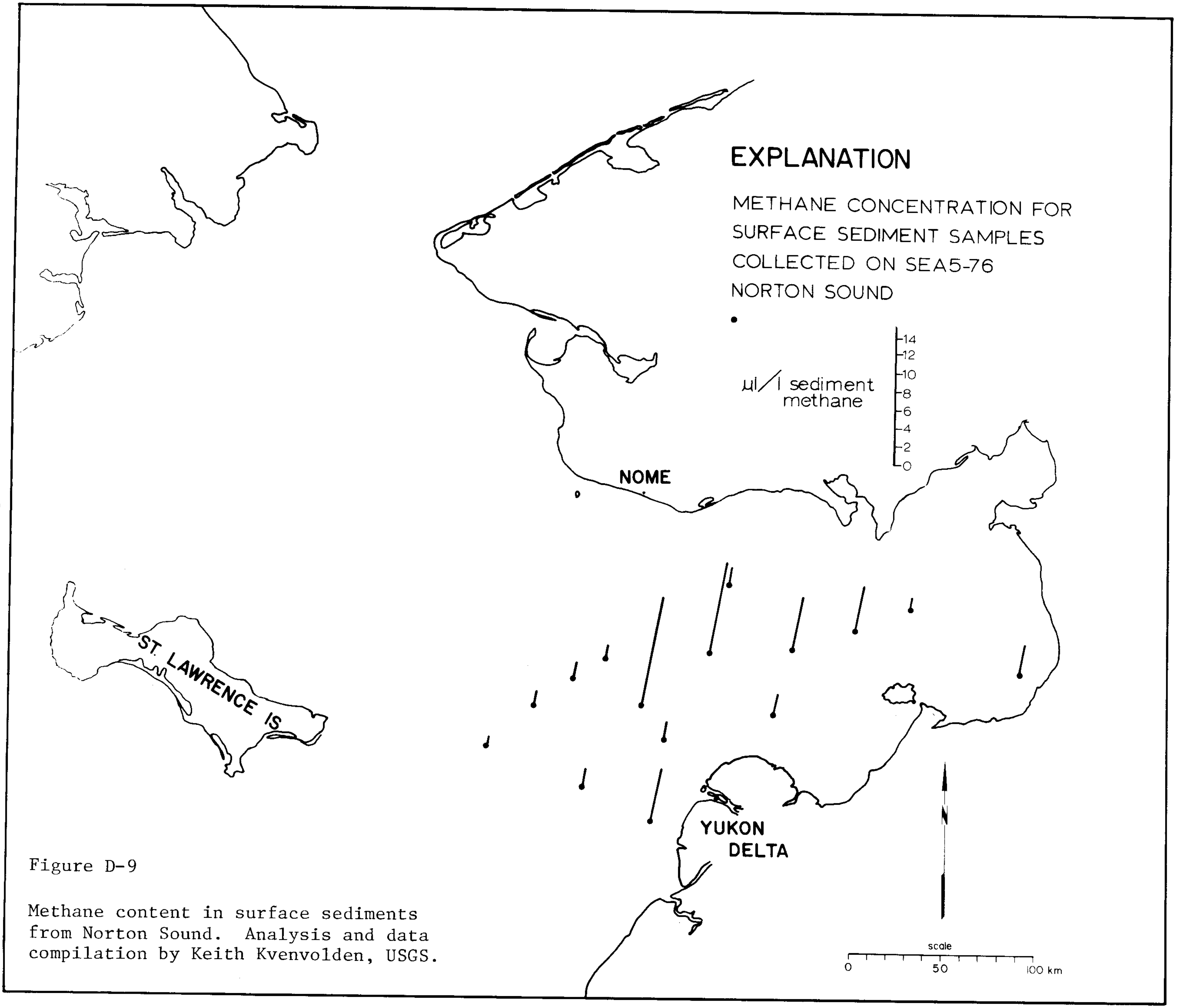

Figure D-9

Methane content in surface sediments from Norton Sound. Analysis and data compilation by Keith Kvenvolden, USGS.

VI. RESULTS AND VII. DISCUSSION

E. PRELIMINARY ASSESSMENT OF ICE GOUGING IN NORTON SOUND, ALASKA

BY

Devin, R. Thor, Hans Nelson, and Jim. E. Evans

March, 1977

INTRODUCTION

General Background and Purpose

Potential resource development in northeastern Bering Sea and the accompanying construction of underwater facilities requires knowledge of ice-related hazards.

Extensive previous research has been accomplished on ice affects in sediment of Arctic regions such as the Beaufort Sea (see The Coast and shelf of the Beaufort Sea, edited by Reed and Sater, 1974), however, no such studies have covered subarctic regions such as Bering Sea. In our new studies it is apparent that a variety of gouging features occur throughout Norton Sound. Because of the potential effects on bottom facilities, it is important to map intensity and direction of the gouges and relate them to distribution and movement patterns of the different types of pack, pressure ridge, and shore fast ice.

Geographic Setting

The study area includes Norton Sound and the offshore area southwest of Port Clarence (Fig. A1). Norton Sound is an elongate, east-west trending marine reentrant in northwestern Alaska. Most of the sound is shallower than 20 m. It is bounded on the north by the Seward Peninsula and on the south by the Yukon River Delta. The Port Clarence area exhibits a series ridge and swale features that are parallel to the shore.

Method of Study

Data were gathered during October, 1976, aboard R/V Sea Sounder, operated by the U.S. Geological Survey. An E.G.&G. side scan sonar was employed to study bottom features. Normally, uniboom and 3.5 kHz units were run simutaneously with side scan sonar for subbottom information. Ship speed during side scan operation ranged from 4 to 7 knots and averaged 5 knots. Approximately 1800 km of side scan sonar records were obtained (Fig. D3). Eighty to ninety percent of these records are of fair to good quality. Navigation is discussed in section B of Results.

Gouge data were collected from the side scan records by counting the number, measuring the compass trend, and noting the time occurrence of all gouges seen on the record. This information was then normalized to 10 km intervals by: 1) graphing the measured trends at 10 degree increments on a rose diagram and noting the average dominant and subordinate trend or trends, and 2) noting the number of gouges per 10 km interval. Each average trend per interval was then plotted on the base map to facilitate defining areas of similar trend and distribution of gouge intensity.

ICE CONDITIONS AND MOVEMENT

The northern Bering Sea and southern Chukchi Sea are overlain by annual ice during the months of November through June (Muench and Ahlnas, 1976; Shapiro and Burns, 1975). Depending on the severity of the winter, multiyear ice may also form in the southern Chukchi Sea. Ice thickness has been reported up to 12 m in the Bering Sea and up to 20 m in the southern Chukchi Sea (Anderson, 1959). There is no data on the thickness of *in situ*, Norton Sound ice, although a couple of meters may be a reasonable maximum.

Shore fast ice in the Norton Sound study area extends seaward to the 10 m isobath (Ralph Hunter, written comm., 1977)(Fig. E1). Again there is no data available on the thickness of Norton Sound shore fast ice, but a reasonable maximum might be several meters. The ice shear zone in Norton Sound also occurs at about the 10 m isobath. This zone is characterized by pack ice (i.e. any free floating ice regardless of origin) colliding, pancaking, and deforming the seaward edge of the shore fast ice zone. This interaction of ice forms pressure ridges.

Pack ice in the northern Bering Sea during the spring thaw months of March through May originates from the break-up of *in situ* seasonal Bering Sea ice (Muench and Ahlnas, 1976) and advection fo Chukchi Sea ice. Although Chukchi Sea ice usually moves in a northward direction, there are short-lived episodes of rapid deformation and subsequent southerly movement of pack ice through the Bering Strait and into the northern Bering Sea (Shapiro and Burns, 1975). These events are controlled by a combination of atmospheric and oceanographic processes.

Pack ice movement in northern Bering Sea is controlled by wind and water currents (Muench and Ahlnas, 1976)(Fig. E-2) push the ice generally southward (Fig. E-1), whereas waning May winds (Fig. E-2) allow pack ice to be carried northward by water currents (Figs. E-1 and E-3).

Norton Sound ice also contributes to the northern Bering Sea ice budget, although ice movement within the sound is more complicated than in the Bering Sea. This is due to the interplay of: 1) onshore spring winds (Fig. E2), 2) southwesterly geostrophic winds (Fig. E2), 3) cyclonic water circulation (Fig. E3). Pack ice generated within the south usually moves west and south during March and parts of April (Muench and Ahlnas, 1976; Lewis Shapiro, pers.

comm., 1977) feeding toward the main flow of Bering Sea pack ice (Fig. E1). In contrast, during parts of April and May wind and water circulation interplay to possibly move ice back north and eastward into Norton Sound, as Bering Sea ice movement is increasingly influenced by north-directed water currents.

ICE GOUGING IN NORTON SOUND AREA

Types and Geometry of Gouging

Three types of ice gouging have been recognized in the Norton Sound area: solitary gouges, ice island gouges, and pressure ridge raking.

Solitary Gouges A solitary gouge (Fig. E4) is a groove produced by a single piece of ice dragging its keel along the sediment surface (Reimnitz and others, 1973; Reimnitz and Barnes, 1974). Solitary gouges seem to be the dominant ice-related feature in Norton Sound. Solitary ice gouges are ubiquitous throughout the sound, although the highest intensity of this type of gouging occurs around the Yukon Delta.

Gouge widths range from 5-10 m to 50-60 m, although gouges 15 to 25 m wide seem most common. Gouge patterns range from straight to sinuous, to sharp-angled turns (Fig. E4). Depth of gouges are probably below the resolution range of the side scan sonar because groove profiles do not show on the horizon line of most of the records (Fig. E4). A couple of distinct, deep looking gouges which did show relief on the record are about 0.75 m deep (Fig. E4), measured from gouge bottom to projected sediment surface. Therefore, 0.75 m seems to be the maximum depth of ice gouging in Norton Sound with the majority of gouges apparently being shallower than this.

Ice Island Gouges An ice island gouge (Fig. E5) is characteristically a wide, smooth, and flat-bottomed groove produced by a large, flat bottom ice island or iceberg (Reimnitz and others, 1973; Reimnitz and Barnes, 1974). This feature is rare in Norton Sound. Those observed on the records mostly occur around the Yukon Delta. Ice island gouges are 75 to 100 m wide. As with solitary gouges, no relief of the gouge itself shows on the horizon line of the record. Therefore, it seems gouge depths are probably less than 0.75 m.

Pressure Ridge Raking Pressure ridge raking (Fig. E5) is produced by a wide base of pressure ridge keels dragging or "raking" the bottom sediments, creating numerous, parallel furrows (Reimnitz and others, 1973; Reimnitz and Barnes, 1974). Raking is sparse in contrast to solitary gouging. Most of it occurs around the Yukon Delta area. Zones of raking observed on the records are 50 to 100 m to several kilometers wide. Depth of raking is not known because of insufficient resolution of the side scan sonar.

Trend and Distribution of Gouging as Related to Ice Movement

Trend and number-of-gouge rose diagrams in figure E6 are composed of the trends from the 10 km interval normalization process. Each rose represents an area of similar trending gouges. A lack of data (i.e. observed termination of gouge grooves) made it impossible to associate absolute directional values with the ice which produced the gouging. Therefore, the rose represents a trend, not a vector.

Two major gouging trends are evident in Norton Sound area. One is a north-south trend, "parallel to isobaths" outside of the sound proper (areas I and V, Fig. E6). The other trend is in an east-west direction within the sound (areas II, III, and IV, Fig. E6). Ninety-seven percent of the gouging occurs in water 10-20 m deep, with 60 percent of that occurring in water 10-15 m deep (Fig. E7). Although ice thicknesses are not known for Norton Sound, less than 10 m would be a typical maximum thickness set by the known limits of the shore fast ice at the 10 m isobath. If would then be impossible for ice generated in Norton Sound to gouge sediments 10-20 m deep. In contrast, ice from northern Bering Sea and southern Chukchi Sea is reported to be up to 8-20 m thick (Anderson, 1959). Thus, if this ice moved southward and eastward into Norton Sound, it could account for much of the gouging in water 10-20 m deep. The interaction of Bering Sea pack ice and Norton Sound shore fast ice forming pressures rides may account for pressure ridge raking noted at these depths in the side scan records.

A possible scenario for ice activity in Norton Sound is that Bering Sea ice is caught in northward flowing ocean currents and is brought into Norton Sound by the cyclonic gyre (Fig. E3). The combined forces of the water currents, southwest geostraphic winds, and east-blowing surficial winds (Fig. E2) concentrate the ice into the southwestern and southern sound area. The high to moderate density of gouging around the Yukon Delta and eastward (Fig. E8) indicates that most of the ice brought into the sound touches bottom and grounds as it moves into the 15-20-m-deep sill across the mouth of the sound or especially into the shoal area around the Yukon Delta (Fig. E8). The low density of gouging in the eastern and northern half of the sound (even though data is sparse in the eastern portion, Fig. D3) seems to be the result of the ice grounding along the southern delta shoals and the sill area; thus it never reaches the northern and eastern parts of Norton Sound (Figs. D3 and E8). Lack of data within the shore fast ice zone, landward of the shear zone, makes it impossible to determine the type and intensity of gouging shallower than the 10 m isobath. The lower density of raking in Norton Sound, as compared to the Beafort Sea where raking may comprise 40 to 50 percent of the gouging (Erk Reimnitz, pers. comm., 1977), may be due to: 1) the lack of data within the shear zone and 2) the fact that

Norton Sound pack ice is not as thick or abundant or areally dense as Beaufort Sea ice; therefore, its interaction with the shore fast zone would not be as intense.

The shallowness of the actual grooves, less than 0.75 m, as compared to the maximum 5.5 m noted in the Beaufort Sea (Reimnitz and Barnes, 1974), attests to either (1) the lack of a thick, solid pack of multi-year and annual ice like that found in the Beaufort, which can dig deely into sediments because of pack movement (Reimnitz and Barnes, 1974) or (2) to the "rotten" or frazil-like structure of the spring-age ice which does not have the strength to deeply gouge sediments.

CONCLUSION

Preliminary conclusions, based on the evaluation of side scan sonar records from the October, 1976, cruise, indicate:

1). Most of Norton Sound is affected by some degree of gouging, although the southwestern quarter of the sound, around the Yukon Delta, has the highest intensity of gouging (Fig. E8).

2). Ninety-seven percent of the gouging occurs between the 10 and 20 m isobaths (Fig. E7).

3). Gouging is probably caused mainly by allochthanous pack ice from the northern Bering and/or southern Chukchi Seas.

4). This pack ice is brought into Norton Sound by a combination of southward and eastward blowing winds and the cyclonic water current gyre within the Sound.

5). Maximum depth of ice gouging, determined with present limited methods, is 0.75 m.

6). The seaward limit of shore fast ice corresponds approximately to the 10 m isobath.

UNRESOLVED PROBLEMS AND FUTURE WORK SUGGESTED

As in any continuing research program there are still many unanswered

1). The distribution of pressure ridge raking is not yet well defined. Most of it probably occurs around or within the 10 m isobath, which is within the shear zone. Lack of data shallower than 10 m occurs because draft of the R/V Sea Sounder restricts piloting to water deeper than 10 m.

2). What are the recurrence intervals of the gouging?

3). What is the average and maximum depth of gouging?

4). What are the thickness and keel depths of *in situ* Norton Sound ice?

5). What is the thickness of Bering Sea and Chukchi Sea ice that works its way into Norton Sound?

6). What are the movement pathways of pack ice in Norton Sound?

The following future field work is suggested to solve these problems.

1). Employ a 200 kHz fathometer system on the R/V Sea Sounder to determine depth of gouging.

2). Repeat some side scan sonar lines along 1976 cruise track-lines to check gouge recurrence characteristics.

3). Run inshore (less than 10 m) side scan sonar lines in the Norton Sound area with a shallow-draft vessel to increase the data base of gouge distribution, intensity, and trend. The boat should be equipped with:

    1). 200 kHz fathometer
    2). 3.5 or 12 kHz seismic system
    3). Uniboom
    4). side scan sonar

4). Study late winter and/or early spring ice by helicopter to directly observe pack ice movement by electronically or physcially tagging the ice.

5). Study the thickness of pack ice in Norton Sound with a portable seismic system or a portable drilling system.

6). Study ERTS photography (band 5) to try to determine ice movement direction.

7). Conduct side scan sonar and 200 kHz fathometer survey around St. Lawrence Island to determine trend, type, and intensity of ice activity.

ACKNOWLEDGEMENTS

We thank Ralph Hunter for providing data on shore fast ice, Peter Barnes and Erk Reimnitz for helpful discussions on ice processes, Larry Toimal for assistance analyzing side scan records, and Ron Williams for compilation of data. The officers, crew, and technical staff of the R/V Sea Sounder made data collection a fruitful and enjoyable endeavor.

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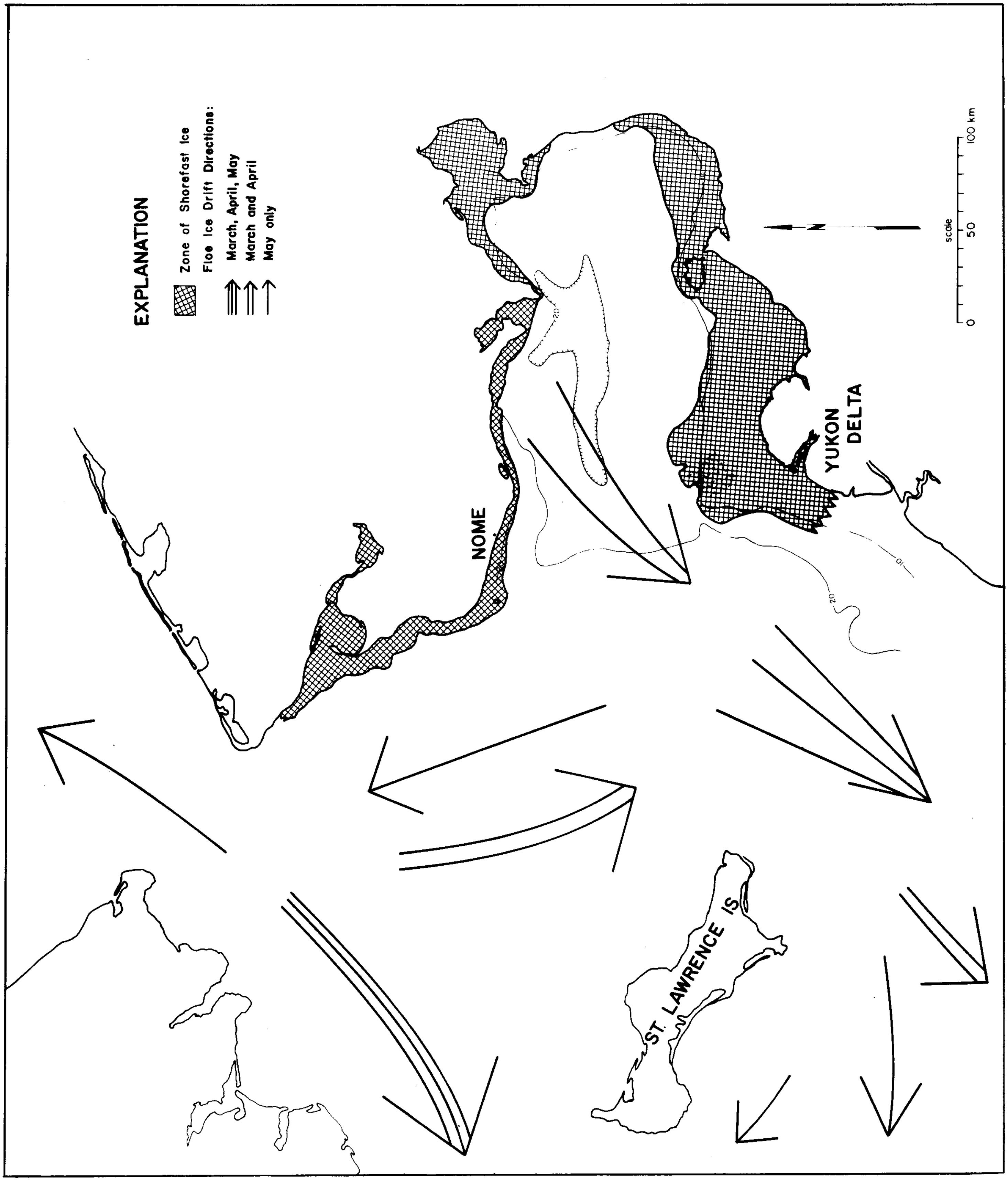

Figure E-1 Drift directions of the pack ice in the northern Bering Sea during spring, adapted from Muench and Ahlnas(1976). Note late spring (May) reversal of the pack ice. Zone of shore fast ice is based on evaluation of ERTS photography(Ralph Hunter, written comm. 1976),

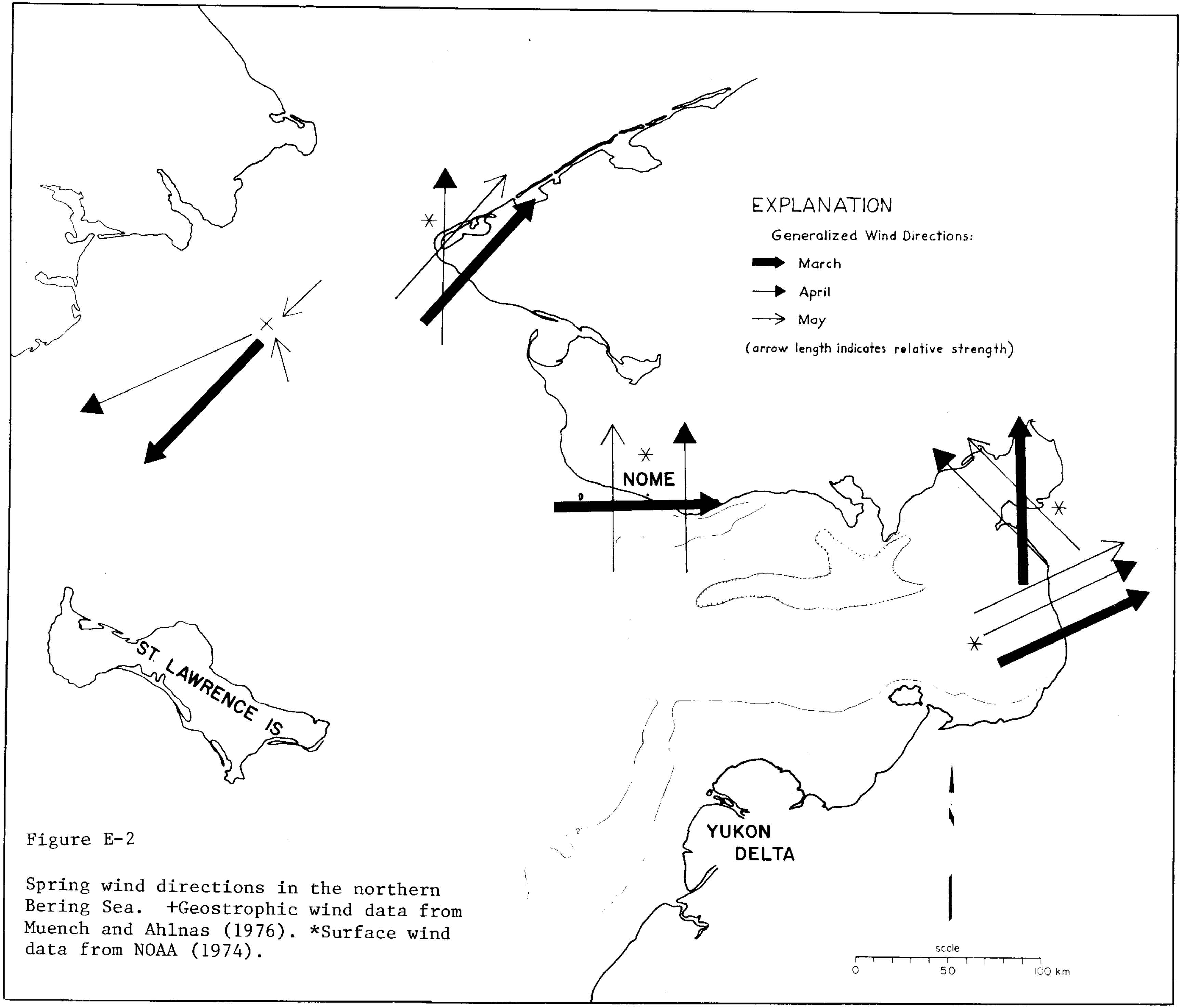

Figure E-2

Spring wind directions in the northern Bering Sea. +Geostrophic wind data from Muench and Ahlnas (1976). *Surface wind data from NOAA (1974).

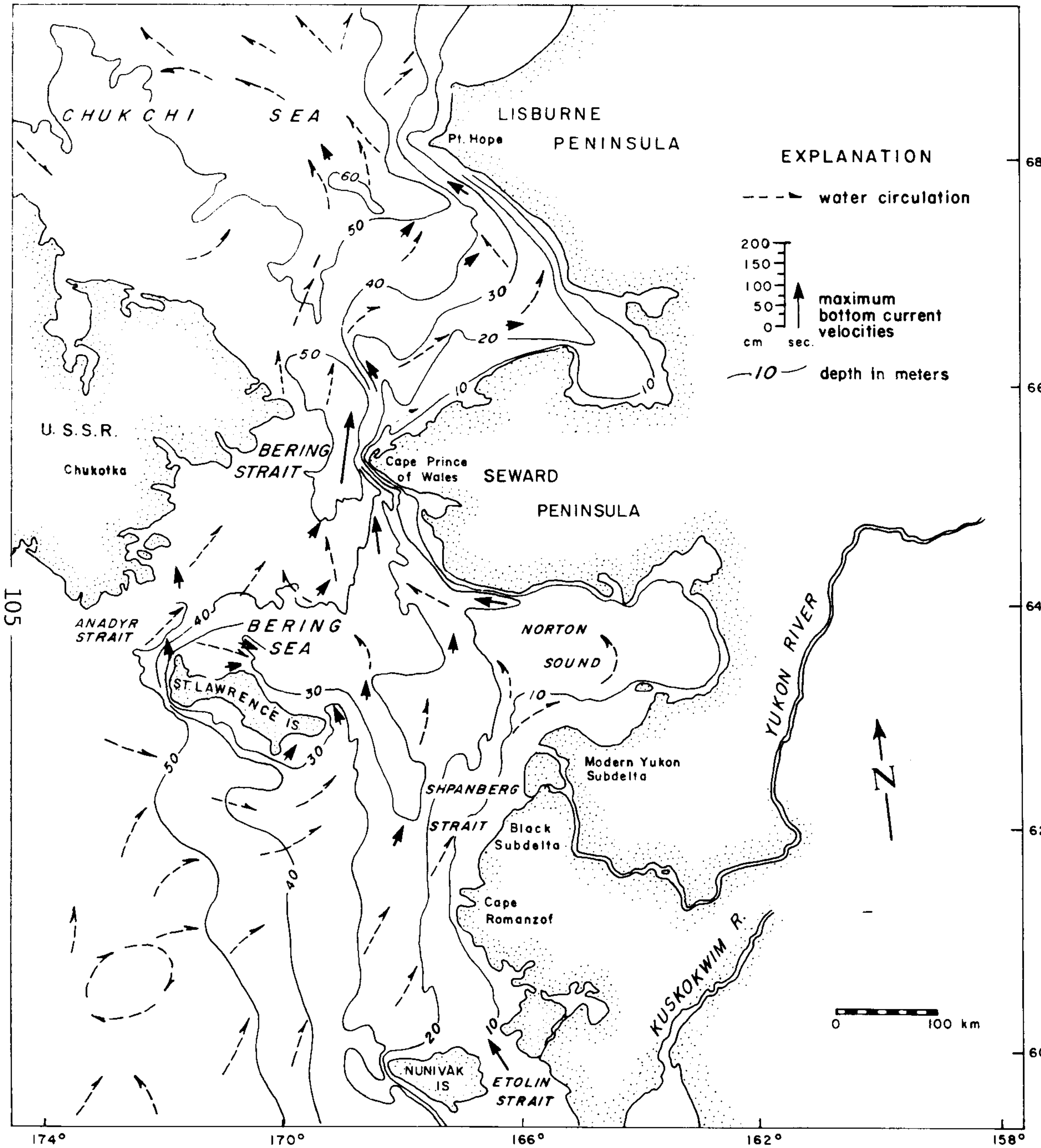

Fig. E-3 Northeastern Bering Sea and southern Chukchi Sea, showing water circulation, distribution of Alaskan Coastal Water, measured bottom-current velocities, and bathymetry. Compilation sources include Goodman and others (1942), Fleming and Heggarty (1966), Husby (1969, 1971), McManus and Smyth (1970), Nelson and Hopkins (1972), Pratt and Walton (1974), and Coachman and others (1976).

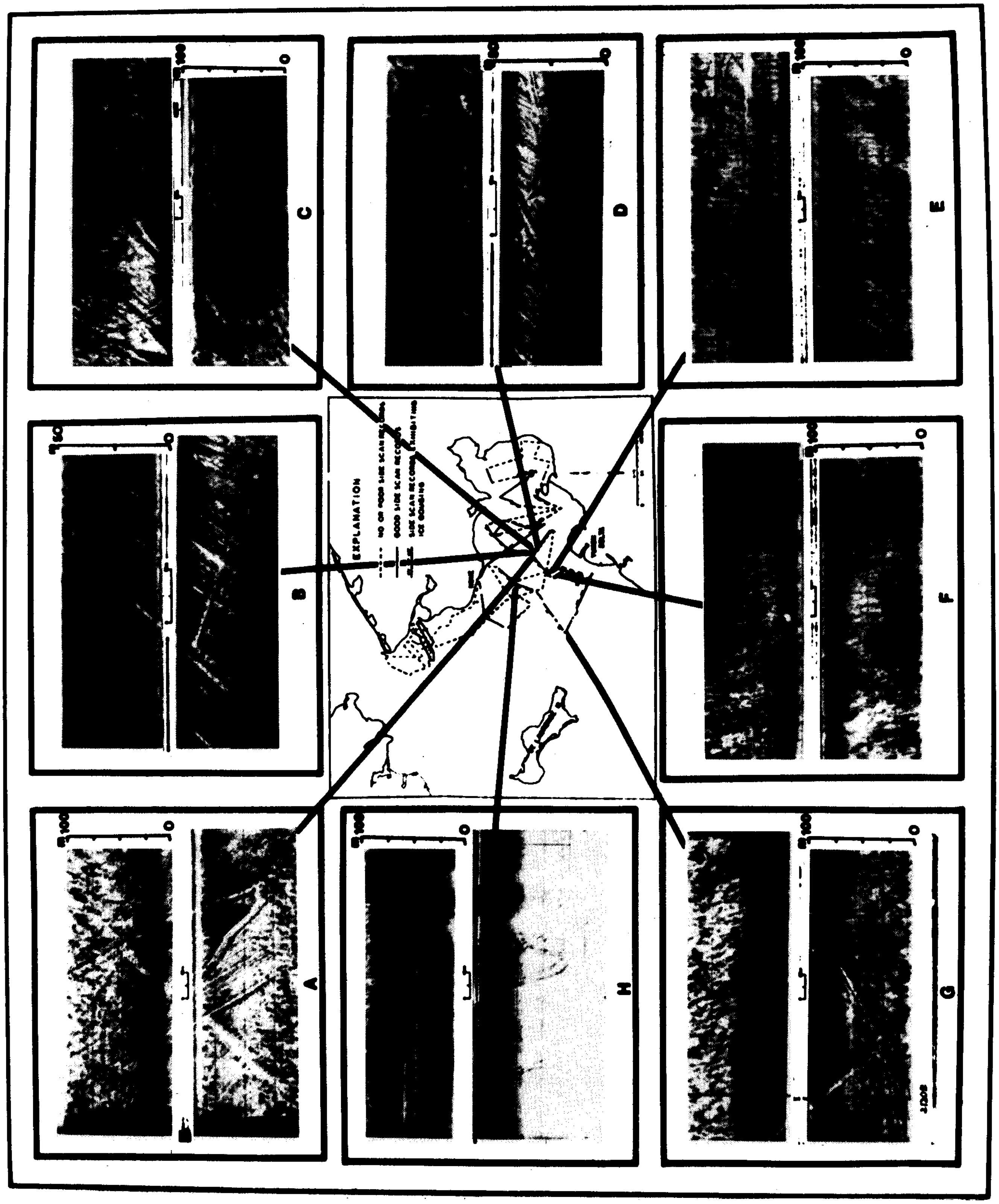

Figure E-4 Solitary type ice gouges characteristic of Norton Sound. Examples A-D, G and I show various types of gouging: solitary, isolated gouge to criss-cross intense gouging; Examples E and F seem to be gouging partially filled with sediment.

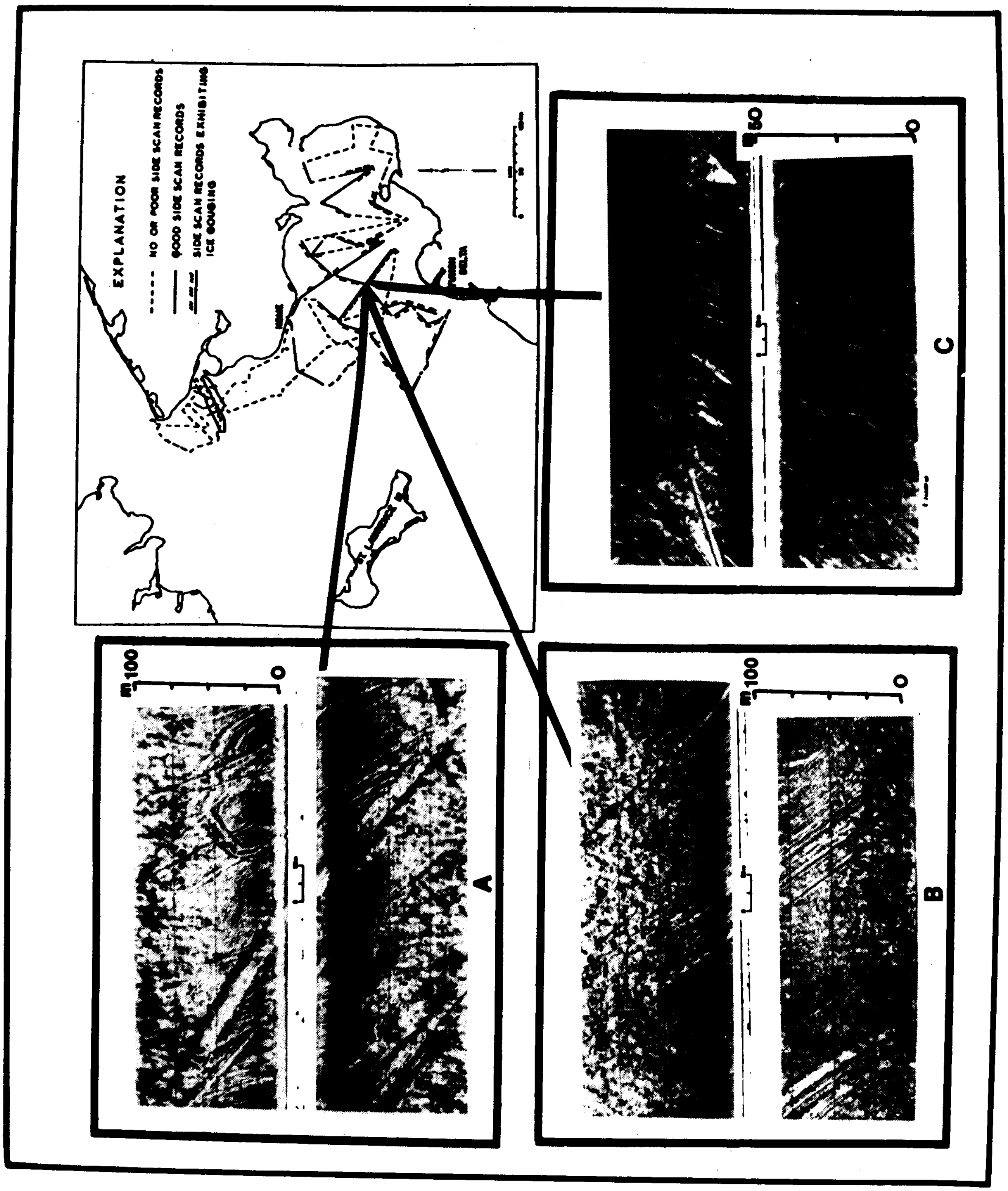

Figure E-5 Ice island gouge (A) and pressure ridge raking (B and C).

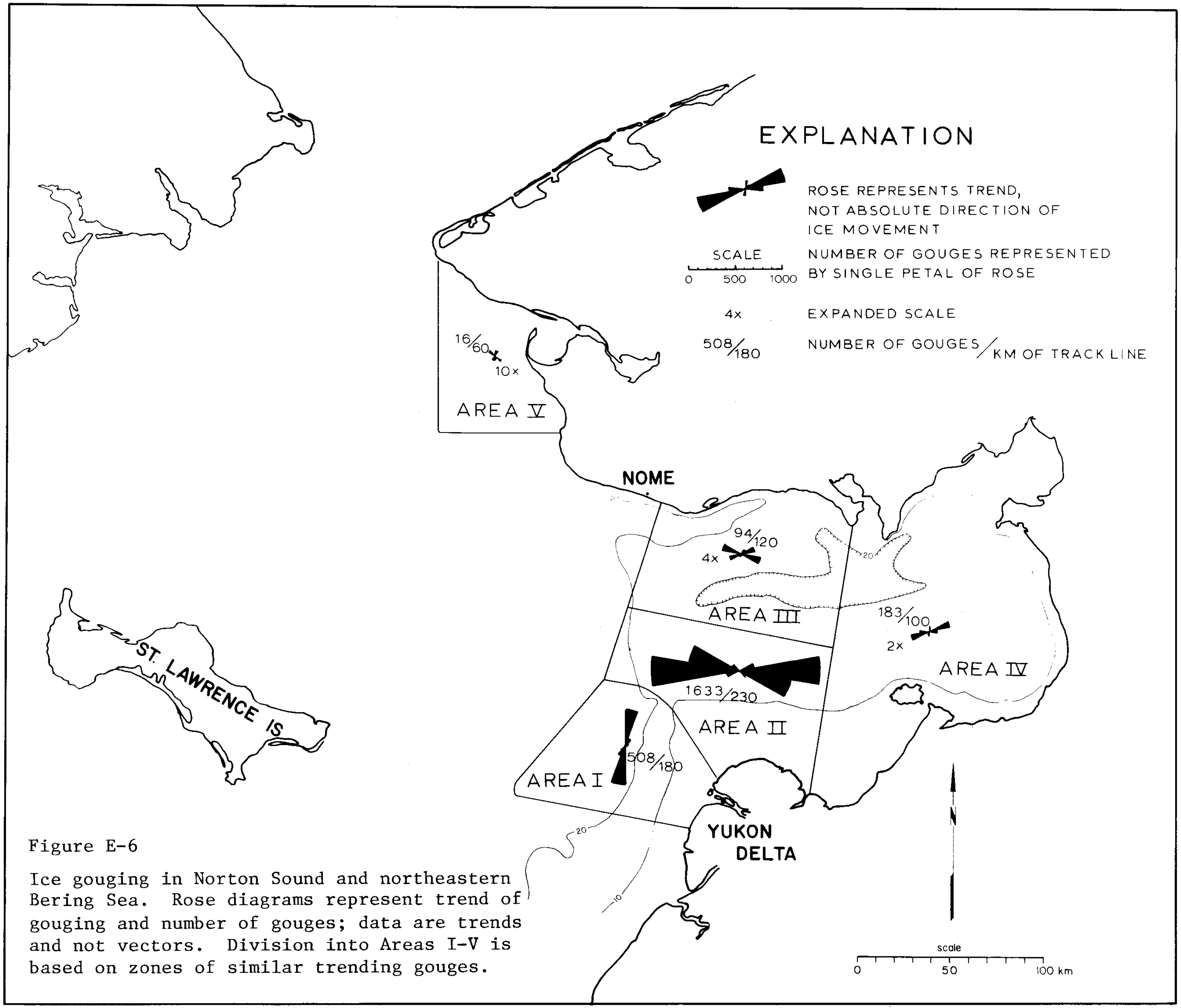

Figure E-6

Ice gouging in Norton Sound and northeastern Bering Sea. Rose diagrams represent trend of gouging and number of gouges; data are trends and not vectors. Division into Areas I-V is based on zones of similar trending gouges.

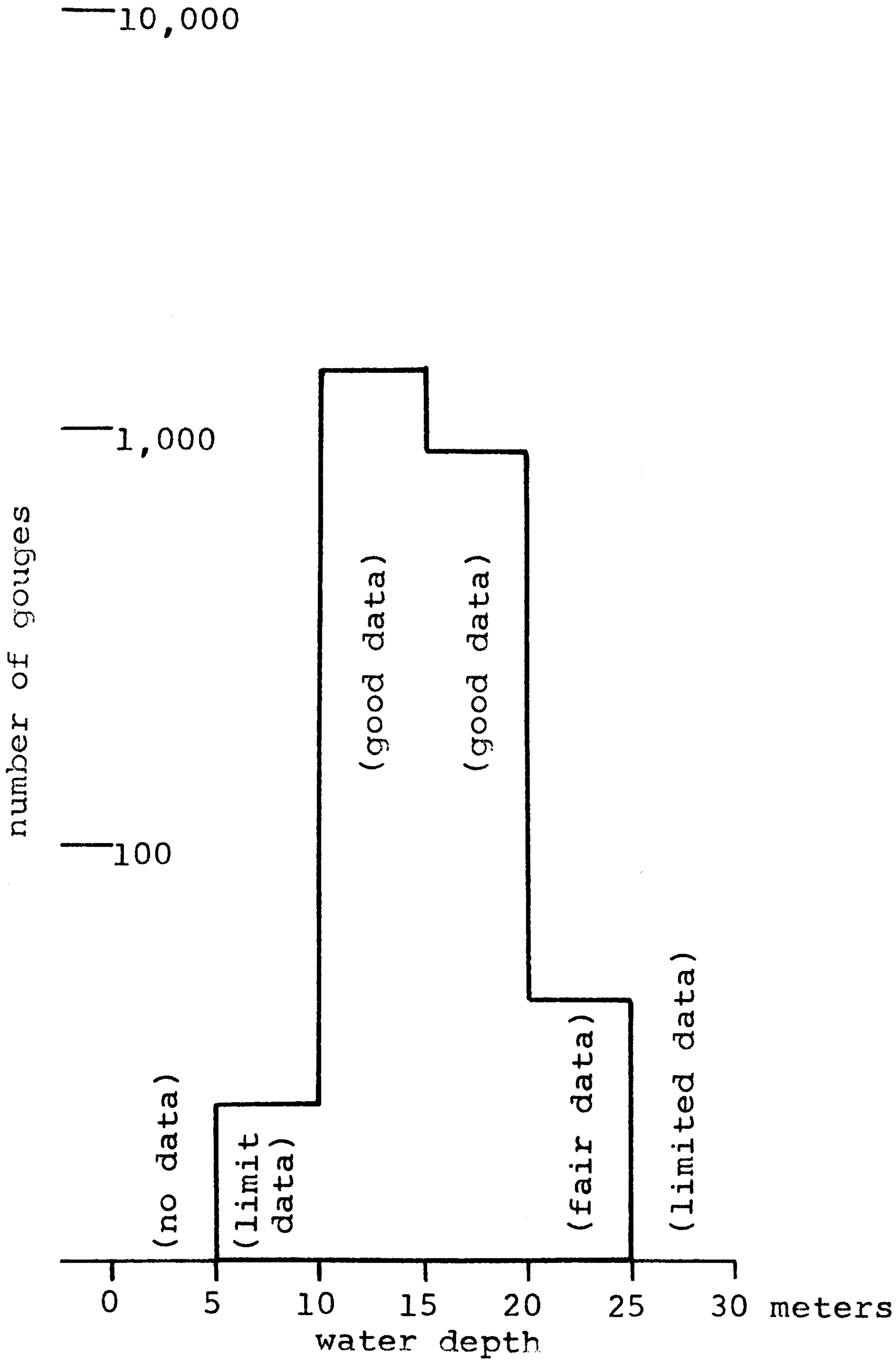

Figure E-7 Histogram of gouge intensity versus water depth. Histogram is based on a count of 2,426 gouges, plotted on semi-log paper.

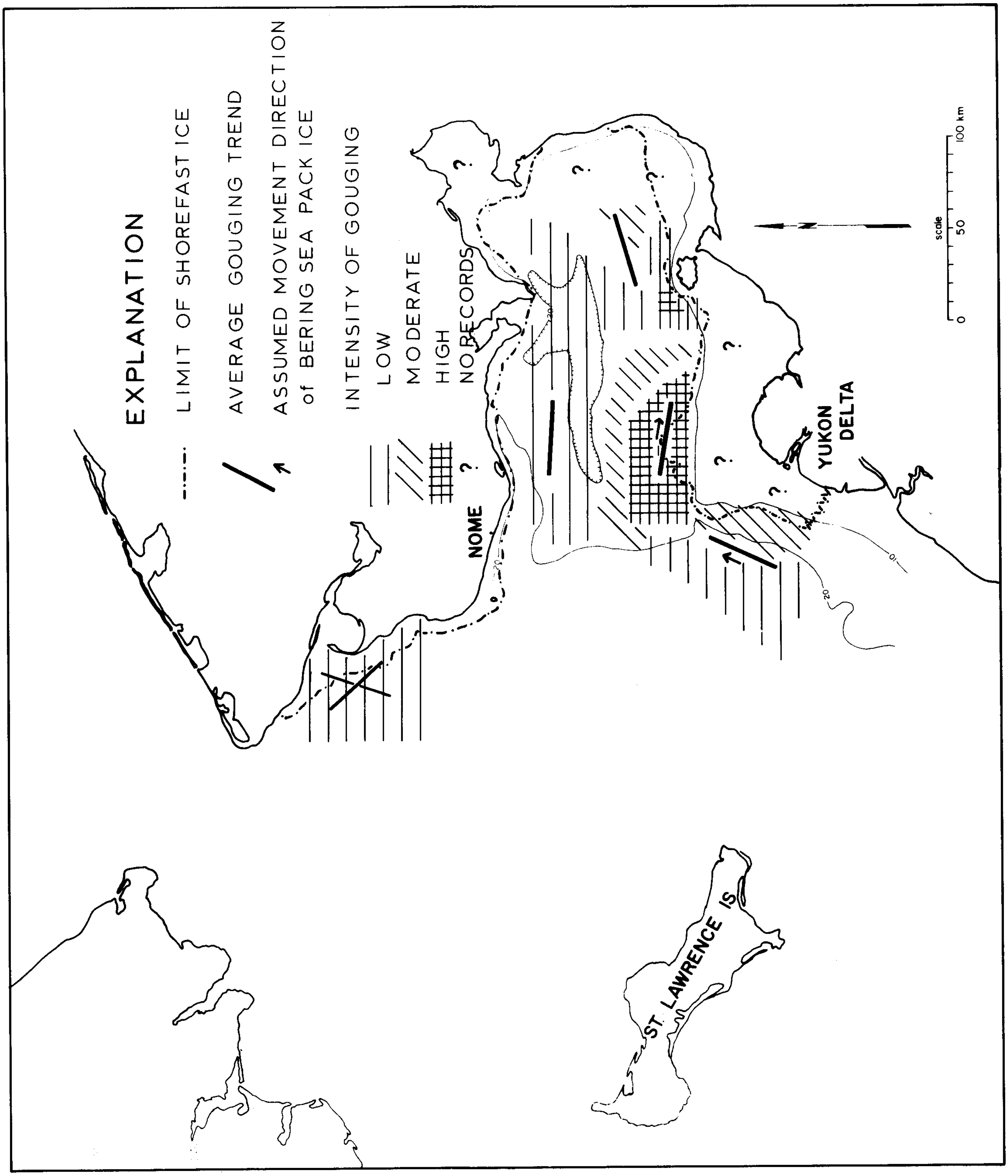

Figure E-8 Preliminary assessment of ice gouging in Norton Sound. Possible path of Bering Sea ice entering the Sound is indicated by arrows. It is this ice which grounds on the Yukon delta which accounts for the moderate to high intensity of gouging aroung the delta area.

VI. RESULTS and VII. DISCUSSION

F. Storm Surge Effects

Hans Nelson

Introduction

The Northern Bering Sea has a known history of severe storm surges. The most recent and perhaps the worst in historical times occurred in November, 1974 (Fathauer, 1975). Evidence of storm surge events is exhibited in sea-floor stratigraphy as well, and indicates that significant widespread changes in sea-floor sedimentation take place (Nelson and Creager, 1977). These changes have implications for installations on the sea floor and for mass transport of any pollutants.

Two factors in the oceanographic setting of northern Bering Sea magnify the effects of storm surge. The sea floor is extremely shallow (i.e. less than 20 m depth) over wide areas, particularly in Norton Sound (Fig. A-4); consequently, there is intense wave reworking resulting in extensive sea floor erosion, mass movement, displacement, and deposition of significant amounts of sediment during storm surges. The second factor is a system of strong dynamic bottom currents that can move large amounts of sediment northward to Chukchi Sea during normal weather, and much more sediment when current flow is reinforced by relaxing of the sea surface set upcaused by storm surge (Fig. E2)(Fleming and Heggarty, 1966; Coachman et al., 1976).

Sediment Resuspension

Isopach thicknesses of Holocene sediment in Norton Sound (Fig. D-4) and comparison of these thicknesses with total sediment input from the Yukon River during the Holocene indicate that significant amounts of sediment have been removed from the sea floor by sediment resuspension (Nelson and Creager, 1977).

Detailed stratigraphy and lithology suggest the same conclusion. The section of Yukon Holocene muds is anomalously thin in many palces immediately adjacent to the delta source region indicating sediment removal (Figs. D-5,6). Numerous lag layers of pebbles, shells, and thin sands are apparent in the Yukon muds of Norton Sound (Fig. F-1); these form when storm waves resuspend bottom mud but leave behind coarse-rafted pebbles, shell fragments, and sand. Additional new evidence occurs in the form of thick storm sands now observed at the sea floor surface of southern Norton Sound; such thick layers are not apparent in the past thousands of years of stratigraphy (Fig. F-3). This suggests that extremely thick sands of major storms gradually are eroded away by ensuing storms so that only thin sands remain in the stratigraphic record.

Resuspension of bottom sediment by waves also is suggested by underwater TV videotapes that show removal of bottom material and formation of oscillation ripples by minor storm waves in depths much greater (35 m) than those (20 m or less) encountered throughout southern Norton Sound. Ice gouges covered by sediment in regions of intense ice scouring again suggest significant sediment resuspension and movement in Southern Norton Sound (Fig. E-4).

Sediment Transport and Displacement

All evidence indicates that unusually large amounts of sediment are resuspended and then transported from Bering Sea to Chukchi Sea (Nelson and Creager, 1977); consequently, any structure impeding this movement requires careful design. The 1976 data on suspended sediment, as described by Drake in this same volume, verifies that about 10% of the Yukon River input to Norton Sound may be carried as part of the normal 3-5 mg/l of suspended sediment passing through Bering Strait. Because as much as 40% of the late Holocene sediment discharged from the Yukon River appears to be missing from Norton Sound, then as much as 20 million metric tons of sediment on the average per year may be resuspended by storms and carried to Chukchi Sea by the strong northward flowing currents. In summary, there are extremely large amounts of suspended sediment moving rapidly in the coastal water along Alaska, often in intermittent large concentrations generated by storms and seasonal runoff.

Storm Sand Deposition

Storm surges not only generate mass movements of suspended sediment, but they also appear to move large amounts of sand in bed load transport for significant distances offshore. This intensive transport and deposition could affect offshore facilities, especially pipelines. Storm sand layers, deposited by such storm events, are well preserved and widespread across southern Norton Sound (Fig. F-2). They thicken considerably toward the modern Yukon subdelta, suggesting that there are massive movements of sediment in the adjacent offshore region during storms (Fig. F-3).

Sampling in 1976 encountered a recently deposited, thick sand layer at the sea floor surface; such a layer was not encountered in sampling in field seasons prior to 1974 (Fig. F-4). It appears that this extensive deposit may be correlated with the major 1974 storm surge (Fathauer, 1975). The surface sand layer is much coarser and thicker than those encountered previously at each specific location. Oxidized grain coatings are present giving the thicker sands a yellowish color rather than the usual olive drab hue. Such coatings suggest a subaerial source and that sediment movement offshore may correlate with extensive shoreline erosion; such shoreline erosion extended up to several hundred meters inland in the 1974 storm (see

Sallenger annual report in this volume - Coastal Processes in Eastern Bering Sea). Offshore movement of extensive sand masses from delta source areas in the 1974 storm is also indicated by the gradient of thicker to thinner layers offshore.

In addition to the changes in core stratigraphy noted pre and post- 1974, extensive change in texture of surface sediment can be shown over certain areas of the sea floor (Fig. F-4). Change is most prominent closer to the shore of the modern Yukon subdelta where storm sand layers are thicker than they are far offshore. Coarser texture is found in most inshore areas where pre- and post- 1974 data is available. A 30-50% increase in sand content is noted in these regions. In the furthest offshore region of the central sound, no change is apparent, as would be expected in this distal region where storm sands are poorly develped at best (Fig. F-2).

Conclusions and Suggestions for Future Work

Storm surges and their concommitant wave and current activity have important effects on Norton Basin that must be considered in planning for offshore development. Extensive erosion of the sea floor, resuspension of sediments, and transport of materials and any attached pollutants is one aspect. A second potential effect is movement of extensive sand sheets from shoreline and nearshore sources to offshore areas. Rapid deposition of 15 cm or more of sand (Fig. F-3) can smother biota immediately and alter texture of the substrate over extensive areas for a number of years. Thus, a sea floor baseline measured at one time could change markedly in post-storm conditions.

Future studies need to monitor conditions prior to and after a storm event, but especially during an event. Research with an instrument such as a geoprobe can help determine severity of sea floor erosion at different locations during a storm. Study of deep vibrocores can help determine recurrence intervals of such events and characteristics before and after such a catastrophic episode.

ACKNOWLEDGEMENTS

Discussion with Hans Reineck and Ed Clifton has enhanced my conceptual development of storm sand layer sedimentation. Brad Larsen, Dennis Kerr, Jeff Patry, and Carol Hirozawa have assisted in compilation of data preparation of figures.

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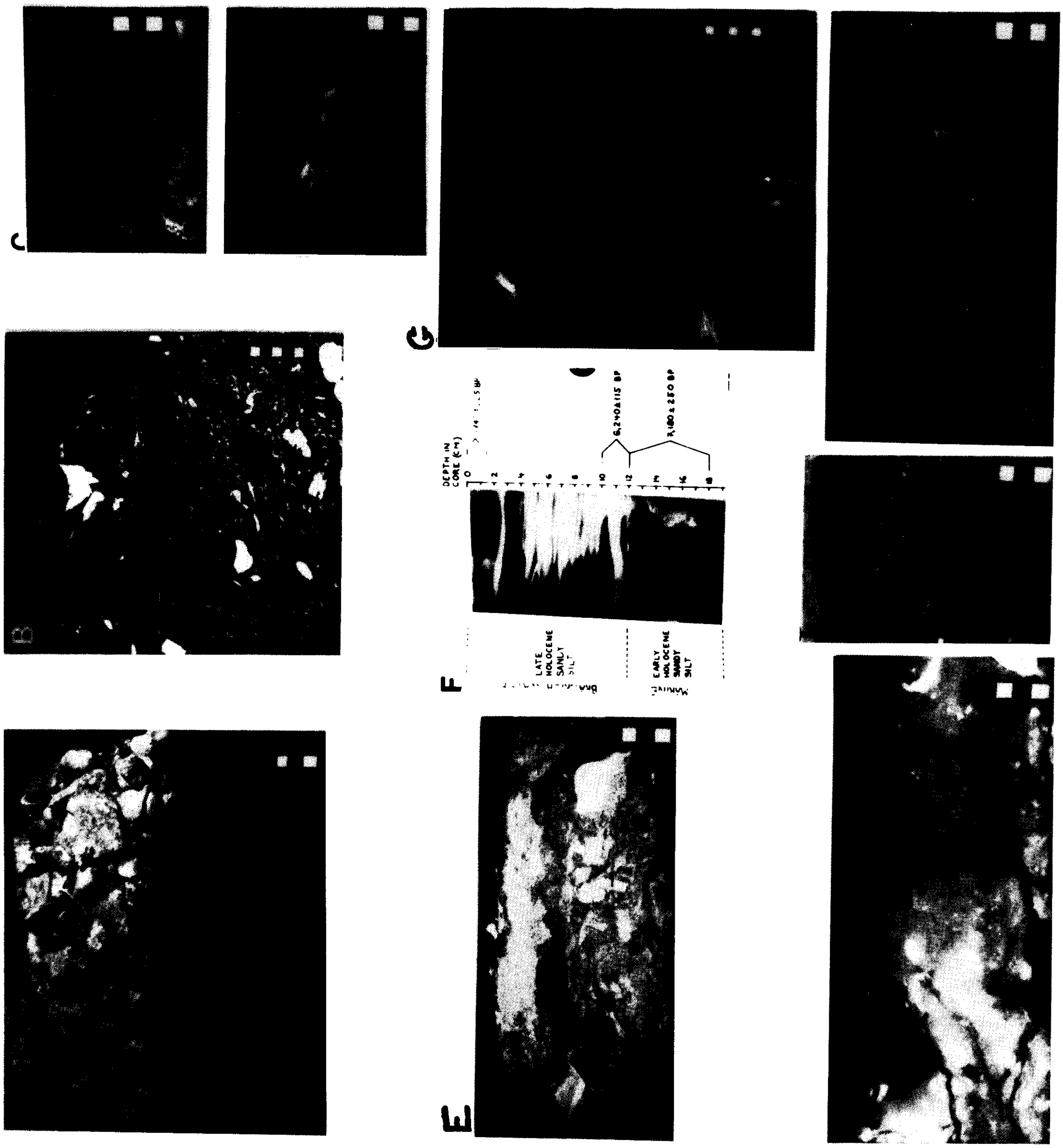

Figure F-1 Storm sand layers (see light colored layers in E,F,G), pebble lag layers (see top of G and H) and shell lag layers (see C and I light layers) in Norton Basin.

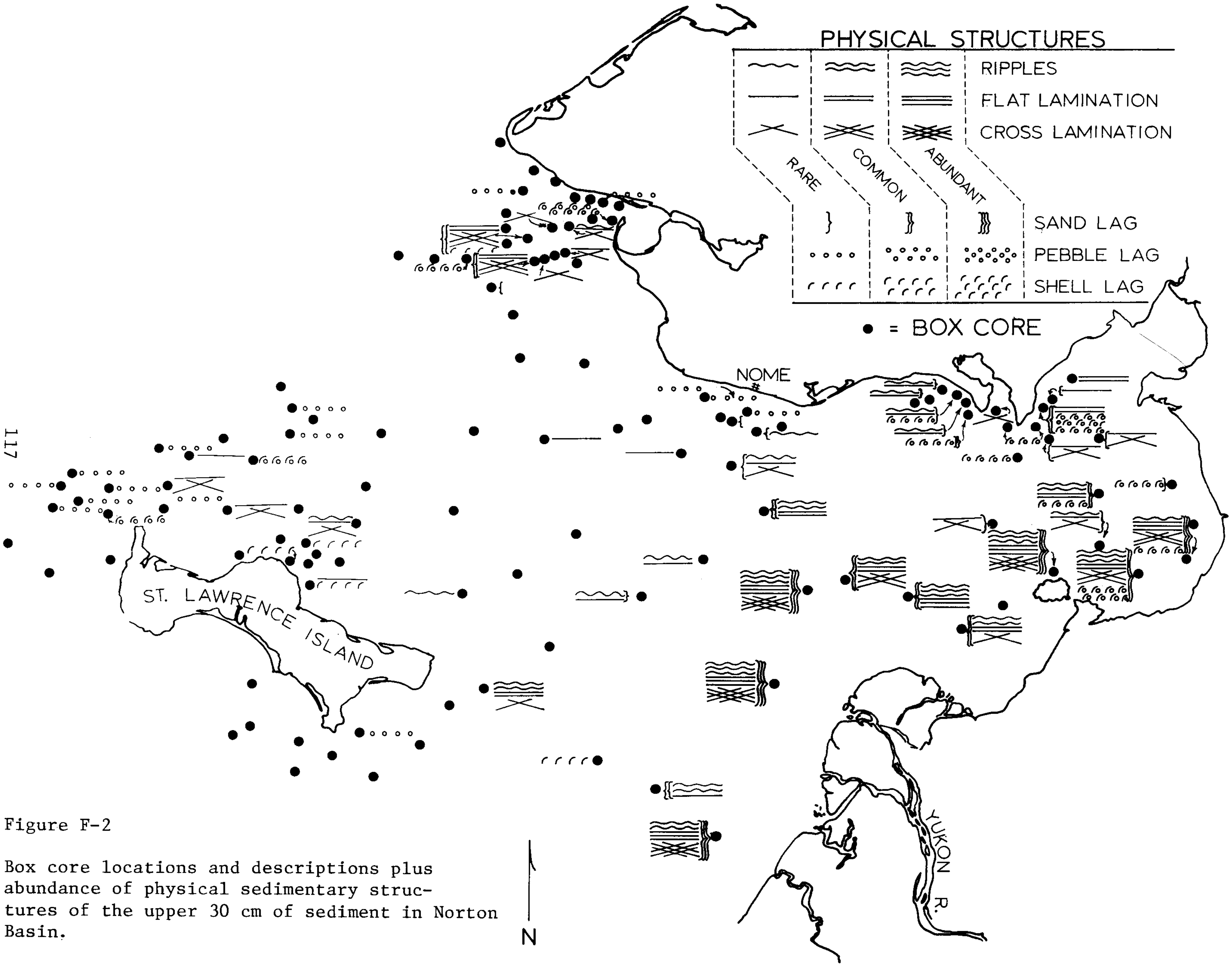

Figure F-2

Box core locations and descriptions plus abundance of physical sedimentary structures of the upper 30 cm of sediment in Norton Basin.

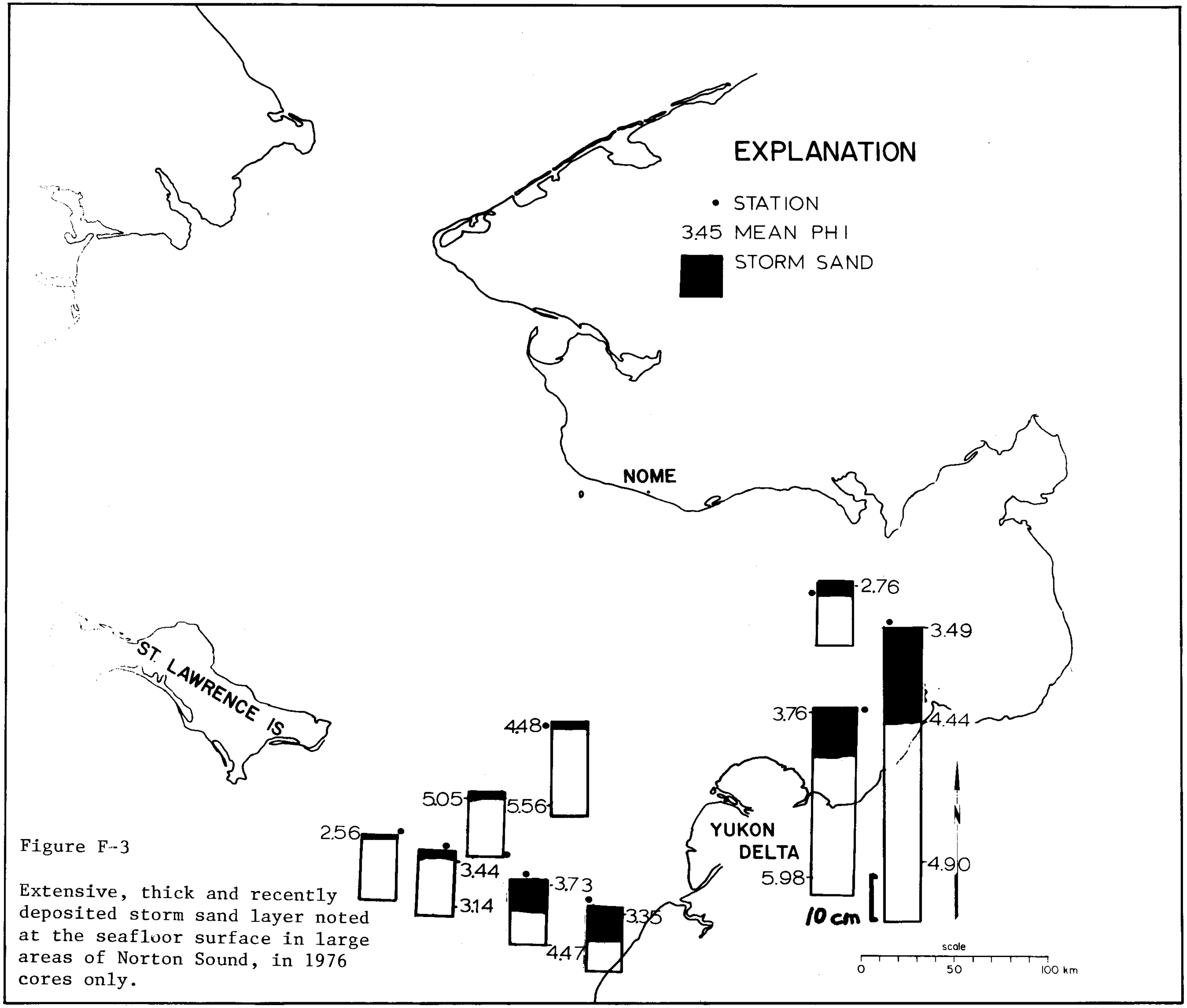

Figure F-3

Extensive, thick and recently deposited storm sand layer noted at the seafloor surface in large areas of Norton Sound, in 1976 cores only.

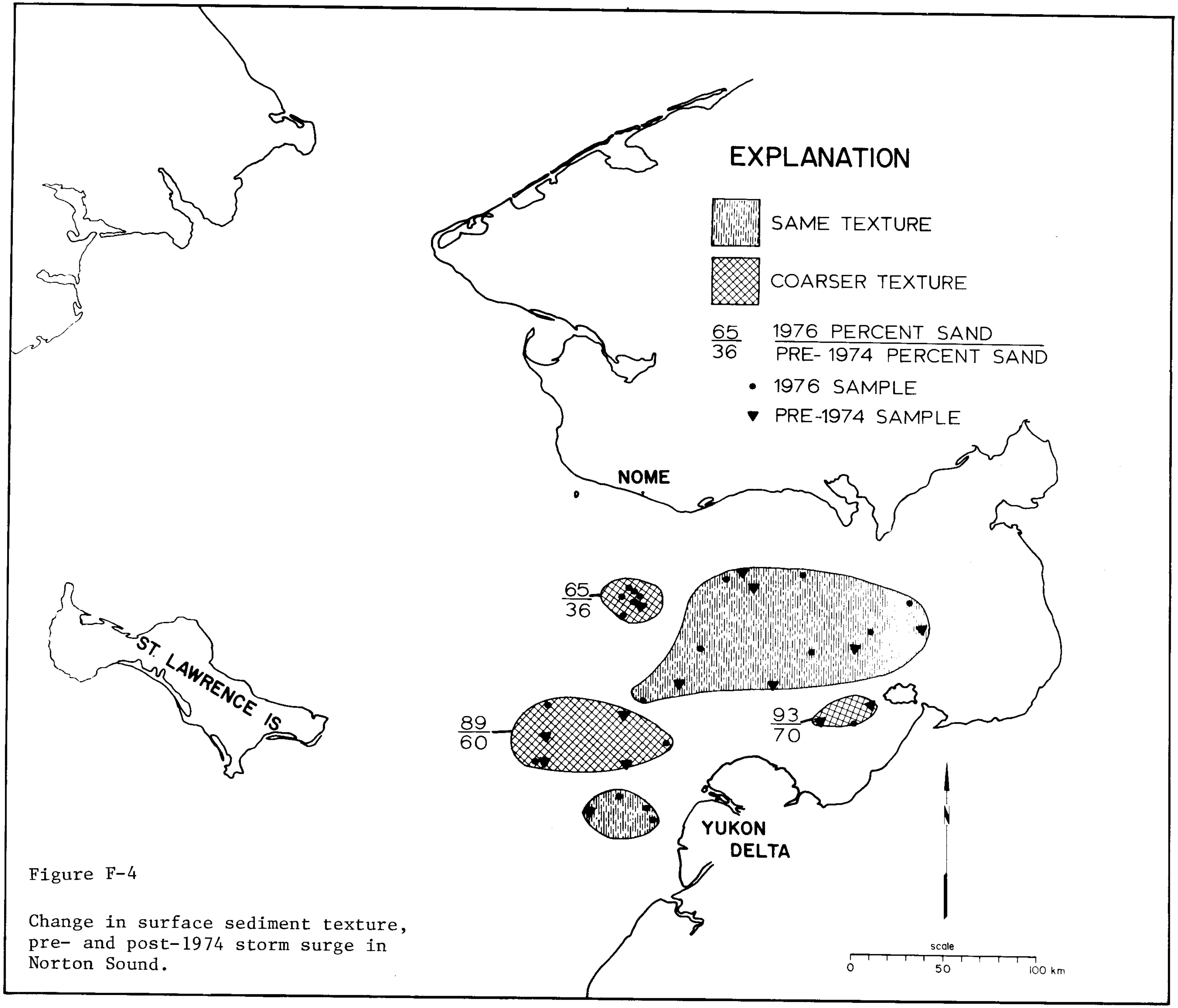

Figure F-4

Change in surface sediment texture, pre- and post-1974 storm surge in Norton Sound.

VI. RESULTS and VII. DISCUSSION

G. Large Scale Bedforms and Potential Scour Areas in Northern Bering Sea

Hans Nelson

INTRODUCTION

Platform foundations and pipelines in extremely shallow epicontinental shelf areas such as the North Sea are subject to intensive storm wave current scouring. Sediment budgets in Norton Sound suggest that sediment scour and removal are significant problems in the area (Nelson and Creager, 1977). An additional hazard are the strong dynamic currents that are present throughout the area; they are particularly intensified where westward land projections interject into the northward flow, such as in the eastern Bering straits area (Fig. E-2) (Fleming and Heggarty, 1966). In such regions large bedforms develop and migrate to form an unstable sea floor. In addition, extensive areas of sea floor scour can occur. Such potentially hazardous areas must be identified, their history assessed, and magnitude of future problems predicted.

Identification and Distribution of Bedform and Scour Features

Large bedforms and scour features can be recognized and mapped with side scan sonar profiles and basic internal structure sometimes can be determined by high resolution profiles. Detailed surficial observations can be made with underwater television, and subsurface stratigraphic history may be determined by analyses of vibracores and box cores.

In general, there is a lack of recognizable bedform and scour features in Norton Sound (Fig. 6-1). An exception is the series of large, shallow depressions on a shoal flank in the north central area of Norton Sound and along the steep NW prodelta flank off the northern Yukon subdelta.

In the vicinity of Sledge Island, most of the sea floor has been stripped bare of sediment (Nelson and Hopkins, 1972), suggesting intense current scour. Just east and west of the scoured region extensive sand wave fields are found (6-1).

From Pt. Spencer spit west to King Island a series of sand ridges and swales exist (Fig. 6-2). The crest of each shoals is covered with sand waves of varying types and sizes (Fig. 6-3). To the north of the ridge and swale area toward Bering Straits, extensive sand ribbon fiels are found with occasional sand dune areas; however, the area is poorly surveyed. The sand ribbon fields indicate a sediment-starved region and possibly one prone to current scour as the current speeds intensify toward Bering Strait (Fig. E-2). Further north within Bering Strait itself, gravel and shell pavements are noted in addition to sporadic occurrences of extremely large sand waves (Grim and McManus, 1970).

Off the eastern and western ends of St. Lawrence Island major sand ridge and swale topography is known, but it has not been studied by side scan sonar (Hopkins et al., 1976).

Character and Origin of Bedform and Scour Features

A series of large depressions, similar to those associated with gas charged sediments in the Gulf of Mexico (L.E. Garrison, 1974), have been noted near the Yukon delta and midway between the possible petrogenic seep (south of Nome) and the large area of small craters 50 km to the east (Fig. D-1). The large depressions range from 25-150 m in diameter, are irregularly shaped, and are relatively shallow compared to their width. Acoustic anomalies in seismic profiling records are not associated with the large depressions, but increased bottom steepness and current velocities are both present in this region. The steep flanks of shoals, along which these irregular depressions are found, suggests a possible origin as slumps; however no debris toes, disrupted bedding, or offset ice gouge traces are evident to verify a slump origin or event in these specific areas or anywhere else in northern Bering Sea. A more likely explanation for large depressions may be intensified current scour along steep flanks of shoals.

Large, shallow depressions similar to those observed in Norton Sound have been observed elsewhere and also have been ascribed to erosion processes (Robert Newton, 1976, oral comm., D'Appolona and Co., Houston, Texas). In some cases these depressions could be attributed to ray or skate bioturbation, but this is not possible in Bering Sea. In other areas they typically occur where there is a thin veneer of sediment over bedrock. Bedrock is not close to the surface at either site of large depressions in Norton Sound. Near the delta rapid and thick deposition of recent sediment takes place. However, in northern Norton Sound, peat layers may occur close to the sea floor. Possibly, currents strip away thin layers of modern Yukon mud overlying the peats and leave shallow scour depressions.

In the ridge and swale area between King Island and the Mainland, swale areas appear to undergo erosion, periodically. Generally a thin veneer of fine, modern mud at the surface overlies Pleistocene peaty muds (Fig. D-6). Fine muds, signifying sluggish currents, typically deposit rapidly in depressions. The lack of thick deposits, however, suggests that muds periodically are swept away so that there has been no net mud accumulation for thousands of years. In fact, a Radiocarbon date on peat 20 cm below the surface of the swale between Tin City and York Shoal was $>$ 30,000 BP, indicating that significant quantities of younger sediment had been stripped away, possibly by currents.

In contrast to swales, sand ridges are definitely constructional as is shown in the sparker seismic profiles (Fig. G-4). The morphology of inner shoals mirrors the shape of the modern Pt. Spencer spit and these shoals may be ancient analogues. Indeed, depths of shoal crests coincide with proposed still-stand depths of ancient submerged strandlines noted elsewhere in northern Bering Sea (Nelson and Hopkins, 1972). Sand ridges behind large obstructions to the northward current flow, such as King Island and Cape Prince of Wales, may be lee side accumulations of sediment unrelated to past paralic environments.

Although formation of the basic ridge structures (15-30 km long) may relate to past transgressive history, these structures also have a modern history of modification by development of sand waves. Sand waves average 2 m in height with a wavelength of 15 m; they are asymmetric to the north paralleling currents.

Growth and movement of the sand wave fields on crests is definitely intermittent, just like the apparent erosional history of the swales. Ice gouges that cut sand wave fields on inner shoals prove that no change in the sand wave fields had occurred at a minimum since the previous winter, or possibly for many years before, depending on how recent the gouge was. At the time we studied the area in the fall of 1976, essentially no bottom currents were observed and underwater TV observation showed only the development of oscillation ripples. Thus, sand wave movement was active neither then nor apparently for a considerable time before. However, a piece of wood found at 30 cm depth in a sand wave had an age of 1155 BP (Teledyne Isotopes #I-9773). This date proves that sand wave development has been active since sea level has reached its present height, and that sand waves are not relict features from some past time of lower sea level.

CONCLUSIONS

At present, there is preliminary evidence that sea floor erosion hazards exist on local flanks of steep shoals in Norton Sound and throughout swales between sand ridges in the Bering Straits region. Scour appears to be most intense where the westernmost projections of land masses occur in the Sledge Island vicinity and in eastern Bering Straits.

There is active movement of sand wave fields, but it is not continual as the presence of persistent and strong northward currents might suggest (Coachman et al., 1976). Instead, movement of sand waves on crests and erosion of swales is intermittent with long periods of inactivity inbetween. Perhaps, intense scour activity in sand wave fields takes place only during the most severe episodes of storm surge.

Future studies require reoccupation of key sites within the sand wave field to determine stability. Long measurements for several months must be made of current velocity and suspended sediment, especially during times of storm stress. Detailed side scan profiling is required at locations of suspected current scour and stratigraphic history must be investigated to determine severity of scour.

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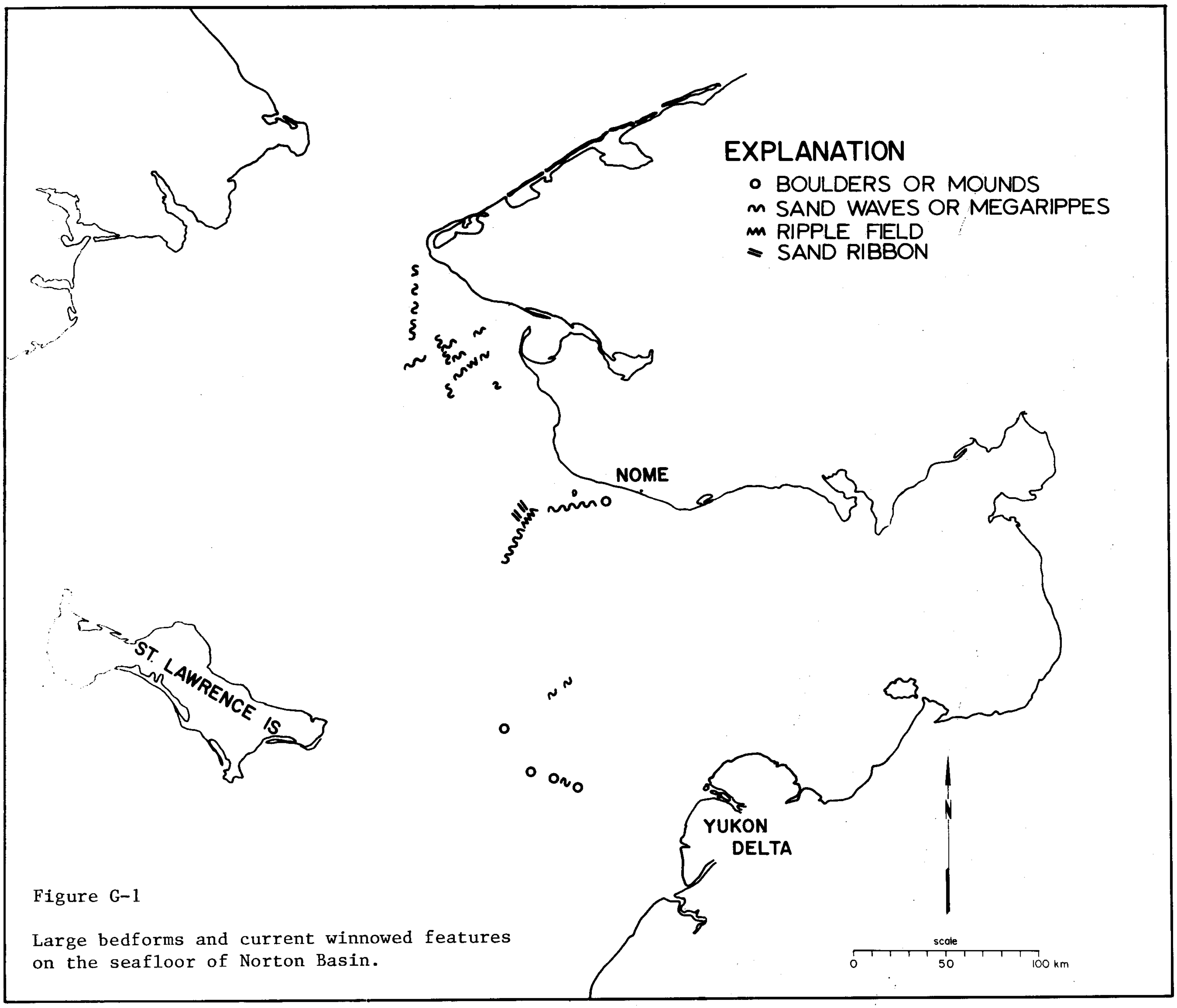

Figure G-1

Large bedforms and current winnowed features on the seafloor of Norton Basin.

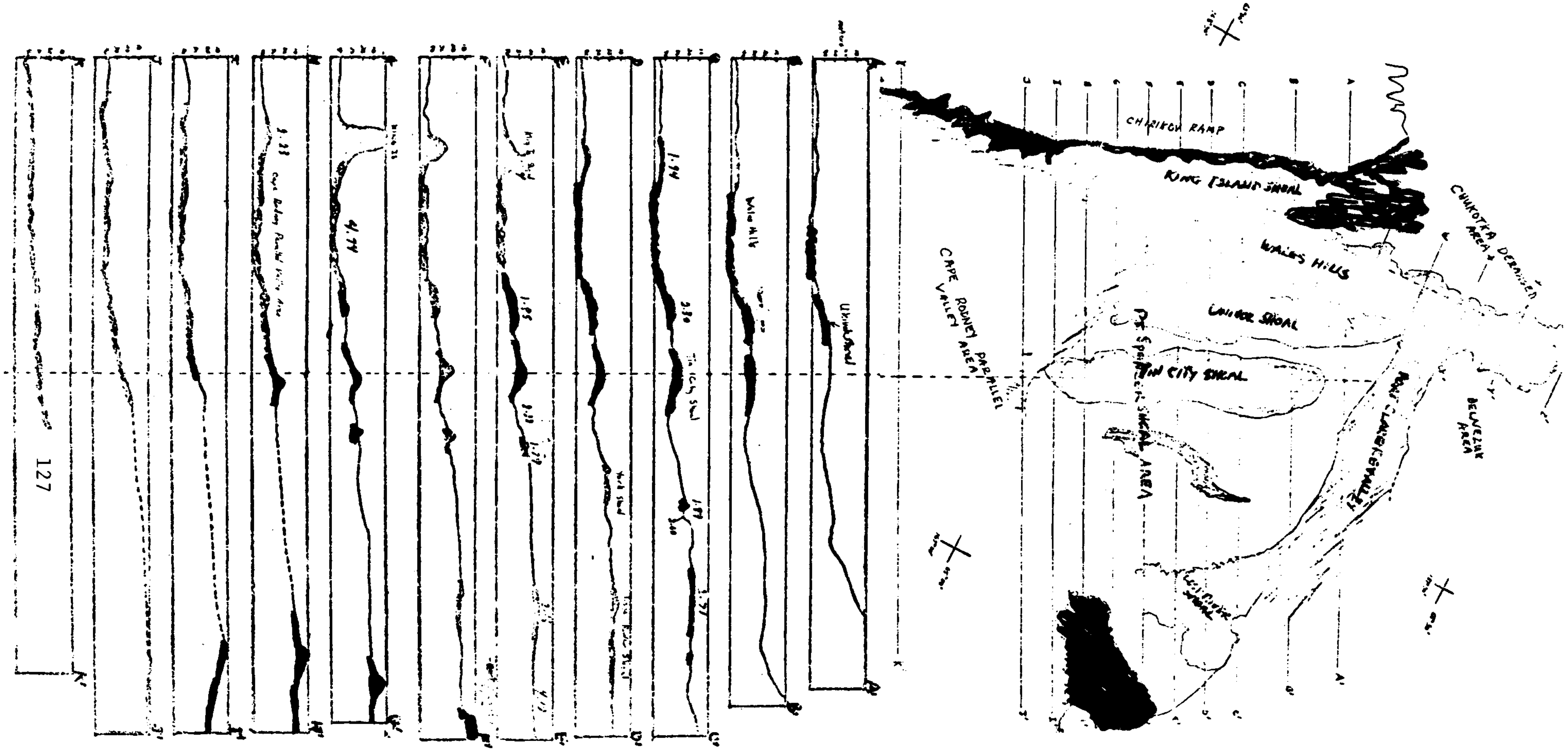

Figure G-2 Morphology of sand ridge and swale area between King Island and Pt. Spencer. See Fig. A-1 and G-4 for location.

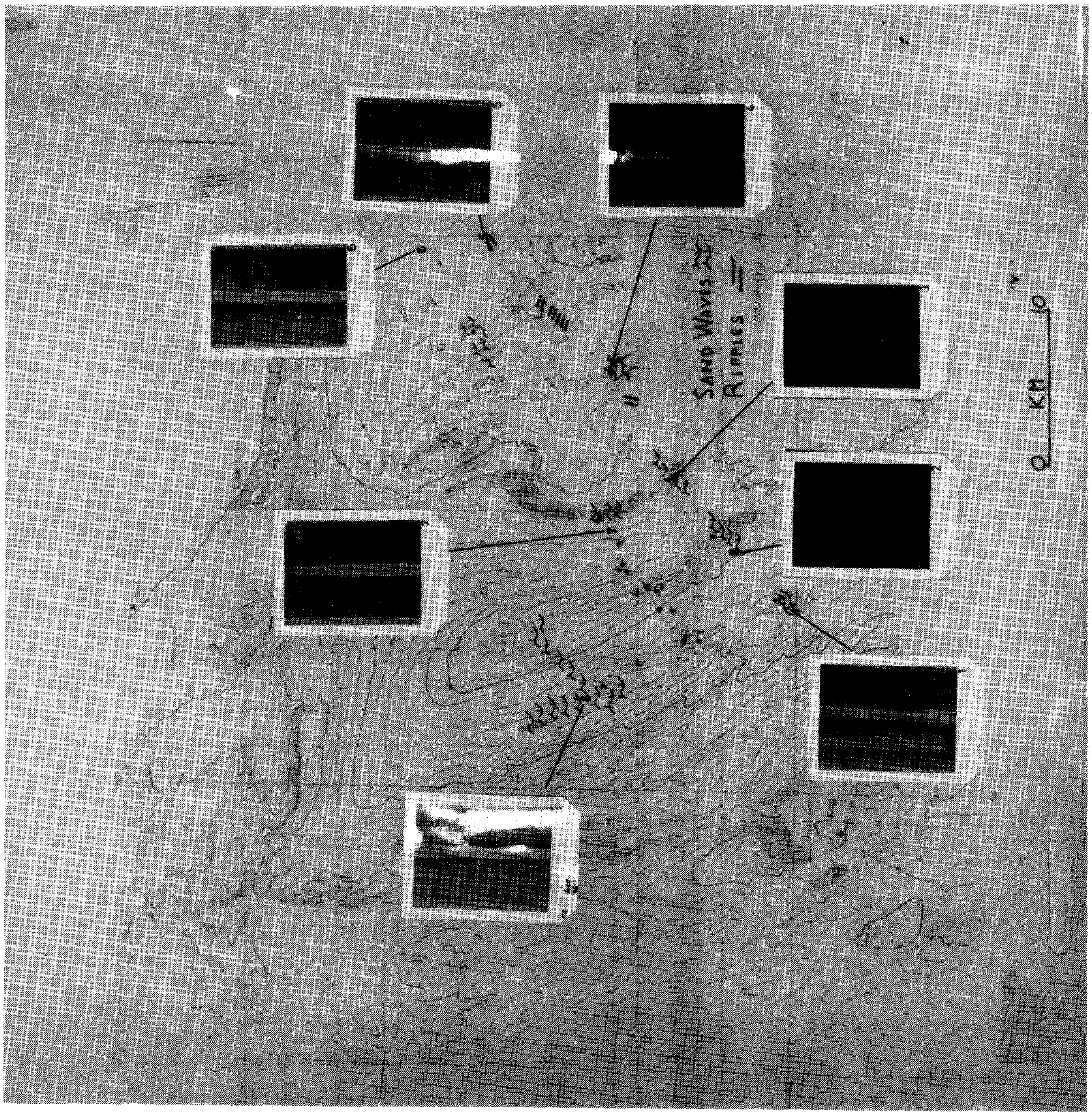

Figure G-3 Different sand wave patterns observed in side scan sonar profiles across crests of sand ridges. Note undisturbed ice gouges cutting sand waves in profiles 4 and 6.

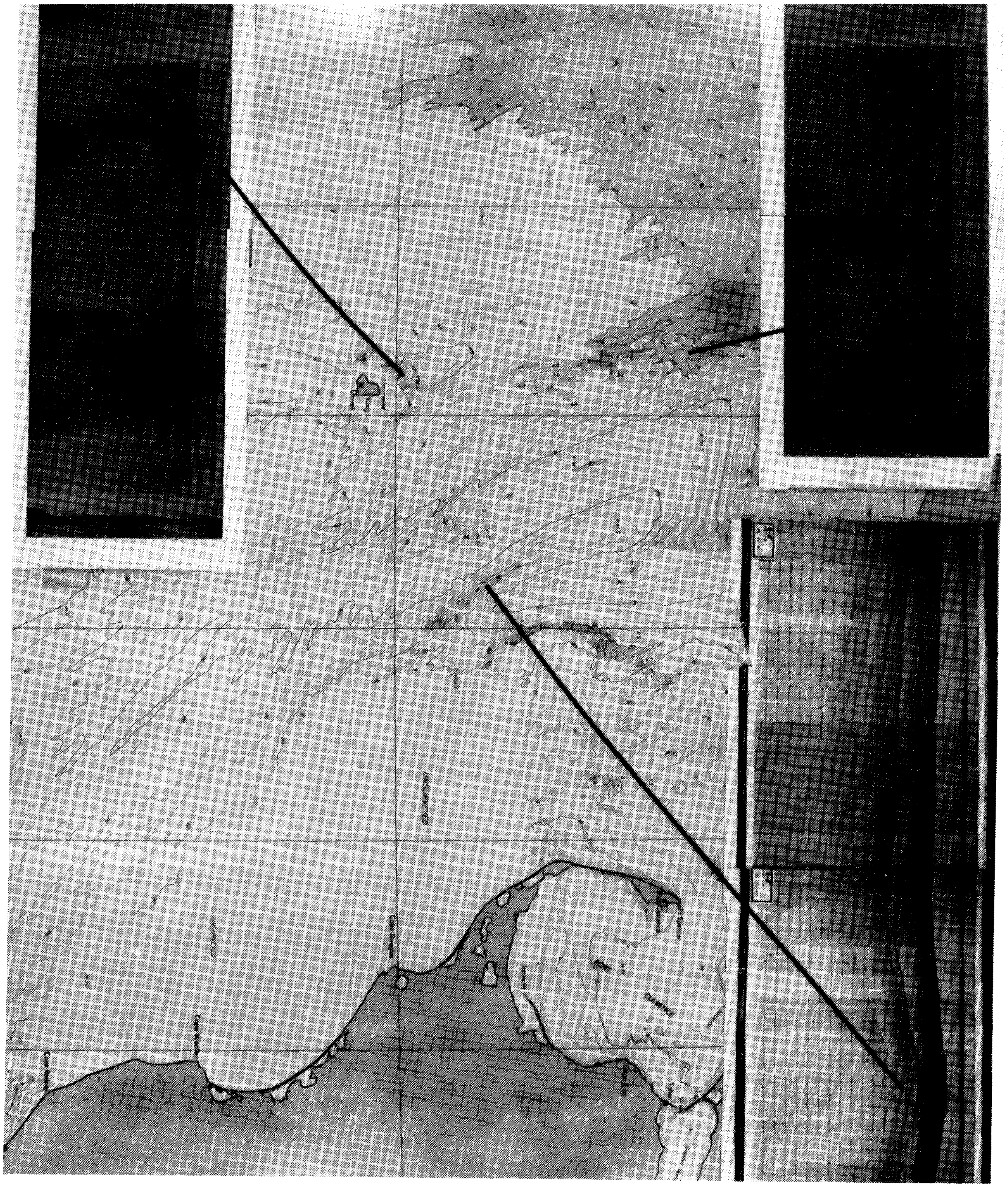

Figure G-4 Typical seismic profiles across ridge and swale topography. Note constructional reflectors across ridges pointed to by end of location lines in profile pictures.

FIRST ANNUAL REPORT

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Sediment Transport in Norton Sound - Northern Bering Sea, Alaska

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1 April 1977

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I. SUMMARY

Both standard and novel methods of obtaining data on sediment transport in Norton Sound and other parts of the Northern Bering Sea were employed during our field program in September - October, 1976. Water samples, light transmission and current profiles taken at many shipboard stations on R/V Sea Sounder during this period showed that the pattern of suspended sediment distribution in the surface and near-bottom layers reflect the high source area of the Yukon River.

Suspended silt concentrations were high throughout the water column near the Yukon Delta but surface concentrations decreased relatively rapidly away from this sediment source (to < 2 mg/l). In contrast, concentrations near the bottom were > 5 mg/l at nearly all stations in Norton Sound. The distribution of particulate matter at the surface and near the bottom defines a mean direct transport path northward across the mouth of the Sound. These northward-trending turbid plumes probably result from entrainment of Yukon sediment by the Alaskan Coastal Current. The Yukon material continues to be the predominant source of near bottom suspended matter off Port Clarence and in Bering Strait.

Our data imply that Yukon silt is available for deposition in all sectors of Norton Sound. Nevertheless, previous investigations of the bottom sediments (Nelson and Creager, 1977) show little or no recent mud accumulation in the northern portion of the Sound. This situation suggests that periodic high energy events are major factors in the sediment transport/deposition system.

A novel system for collecting long-term data on current, pressure, temperature, and sediment parameters near the sea floor was developed, tested, and utilized during this report period. This system, the Geological Processes Bottom Environmental (GEOPROBE) station, is self-contained and capable of operating on the sea floor to depths of 300 meters.

Measurements of bottom current, bottom pressure, and light transmission and scattering at a single site 60 kilometers south of NOME indicate that during periods of strong surface winds, resuspension and advection of bottom and near-bottom sediments intensifies due to the onset of more energetic wind-driven bottom currents. This relationship, if typical of other regions of Norton Sound, suggests that the highest sediment transport would occur during severe storms. Yukon River sediments that have settled to the sea floor during quiescent atmospheric periods could be resuspended during storms and advected out of this region by the storm-generated or mean circulation.

Our data also suggest that bottom tidal currents are as high as 10 cm/sec at the measurement site. If added to wave- or wind-driven currents, these tidal flows can have a significant contribution to the local total bottom stress that produces entrainment of the bottom sediment.

The data from just this three week preliminary experiment with the GEOPROBE tripod are useful for understanding transport of pollutants as well as sediments in Norton Sound. The time dependent behavior of the bottom current will in large part describe the paths of pollutant transport at specific sites. The high degree of variability in the one-half hour averages of bottom current measured with the GEOPROBE rotor/vane current meter should at least bring caution to overly simplistic views of transport in this region.

In addition, the comparison of the measured speed data, converted to a bottom stress using standard boundary layer analysis, with the measured sediment sizes at the GEOPROBE site suggests that current speeds in excess of 15 - 20 cm/sec will produce significant amounts of sediment resuspension. This computation, although only taken to be indicative and not definitive, warns that rapid, local erosion during storms could be a hazard to bottom structures and pipelines.

II. INTRODUCTION

A. General nature and scope.

This research investigates the water-born transport of sediment and other materials in Norton Sound, Alaska. The experimental program is designed to increase our understanding of the pathways, quantities, and mechanics of sediment movement in this region. The past year's efforts, our first in OCSEAP, are part of a general plan to understand the complicated relationships between hydrodynamic bottom stresses and incipient and established motion of materials in a variety of sedimentary environments. Of particular interest here is the sediment resuspension and flux caused by bottom stresses generated by the strong winds that occur during intense storms which frequently transit the Norton region. In addition, previous work by Nelson and Creager (1977) and others has shown that the enormous flux of sediment introduced into the mouth of Norton Sound annually by the Yukon River has not yielded sediment accumulation in the area commensurate with the rate of supply. The causes for this apparant exit of Yukon materials from the immediate region of Norton Sound are part of this investigation.

B. Specific objectives.

The principal objective of this work is to develop an understanding of the relationships between suspended and bottom sediment transport in Norton Sound and the hydrodynamic regime which causes this transport. Specific objectives of the past year included:

1) test and evaluation of a new in-situ instrument system, the Geological Processes Bottom Environmental (GEOPROBE) station, designed specifically for investigations of near-bottom and bottom sediment transport;

2) utilization of the GEOPROBE to obtain one month time series measurements of bottom pressure, water current speed and direction, light scattering and transmission (related to near-bottom suspended sediment changes), and bottom temperature;

3) initial development of correlations between changes in suspended and bottom sediments with fluctuations in hydrodynamic parameters like current speed and bottom pressure;

4) spatial maps of suspended sediment distribution in Norton Sound.

C. Relevance to problems of petroleum development.

As recent events have all too often proven, when a large oil spill occurs at sea near our coasts, public and private attention is immediately focused on its environmental and economic impact. Those in charge of clean-up operations, managers of offshore land programs, political leaders, and concerned citizens want to know where the spilled oil will go, how quickly will it move, and how large an area will be affected. Two specific aspects of this research project relate directly to this problem of oil spills at sea: first, excessive erosion can cause collapse of seafloor pipelines; second, the transport of oil near and along the sea floor will be controlled by those processes that also control the transport of sediments.

The ability to predict accurately the movements of pollutants in the sea is strongly dependent on our knowledge of local transport processes. Specific geographic regions, like Norton Sound, will have unique aspects to the mechanisms which control the paths and amounts of material that is moved. This study attempts to identify and elaborate upon the most important transport-producing mechanisms in this region, and to relate these mechanisms to entrainment and movement of near-bottom materials. The eventual understanding which this study has as its goal will hopefully permit an accurate description of bottom transport of sediments, pollutants, nutrients, and other particulate matter in Norton Sound.

Additionally, if zones of excessive erosion are found, or if episodic, high rates of erosion caused by storms are identified in the results of future experiments (FY 77), the potential hazards that these conditions would impose on future resource development will be assessed.

III. CURRENT STATE OF KNOWLEDGE

The suspended and bottom sediments found in Norton Sound are nearly all derived from the Yukon River, which discharges about 96 x 10^6 tons of material per year into the southwestern corner of this area (Figure 1). Despite this enormous sediment source, Nelson and Creager (1977) and McManus, et.al. (1974) show that in recent times (< 5000 years B.P.) modern Yukon fine sands and silts have been accumulating on the Yukon subdelta in southern Norton Sound at a surprisingly low rate. This thin accumulation of Holocene sediments has been attributed to the erosive action of severe storms that occur in the early Fall prior to the formation of ice cover (Nelson and Creager, 1977). The finer fraction of Yukon-derived materials is presumably transported through the Northern Bering Sea by the Alaskan Coastal Current and deposited in the southern Chuckchi Sea (Nelson and Creager, 1977; McManus, et.al., 1974).

Another interesting feature of the bottom sediment pattern is the presence of modern Yukon sediment along the southern border of Norton Sound. Nelson and Creager (1977) and McManus, et.al. (1974) show that Yukon sandy silts are found in a nearly continuous band along the southern and eastern margin of Norton Sound; the lateral extent of this material diminishes eastward from the source area. This pattern suggests a counter-clockwise circulation within the Sound. Muench and Charnell (1977) also propose this type of circulation regime based on CTD and shipboard current meter stations taken in September - October, 1976.

By contrast, the floor of the northern section of Norton Sound is covered by older relict sediments; little or no accumulation of fine-grained materials is found in this part of the region. This lack of recent sedimentation is problematic, but is probably related to the storm-induced entrainment and removal of bottom materials there.

Increased transport of sediments on continental shelves during storm periods has been discussed by Smith and Hopkins (1972, p. 143), Drake, et.al. (1972) and Butman (1976). In a body of water like Norton Sound, whose depth is everywhere

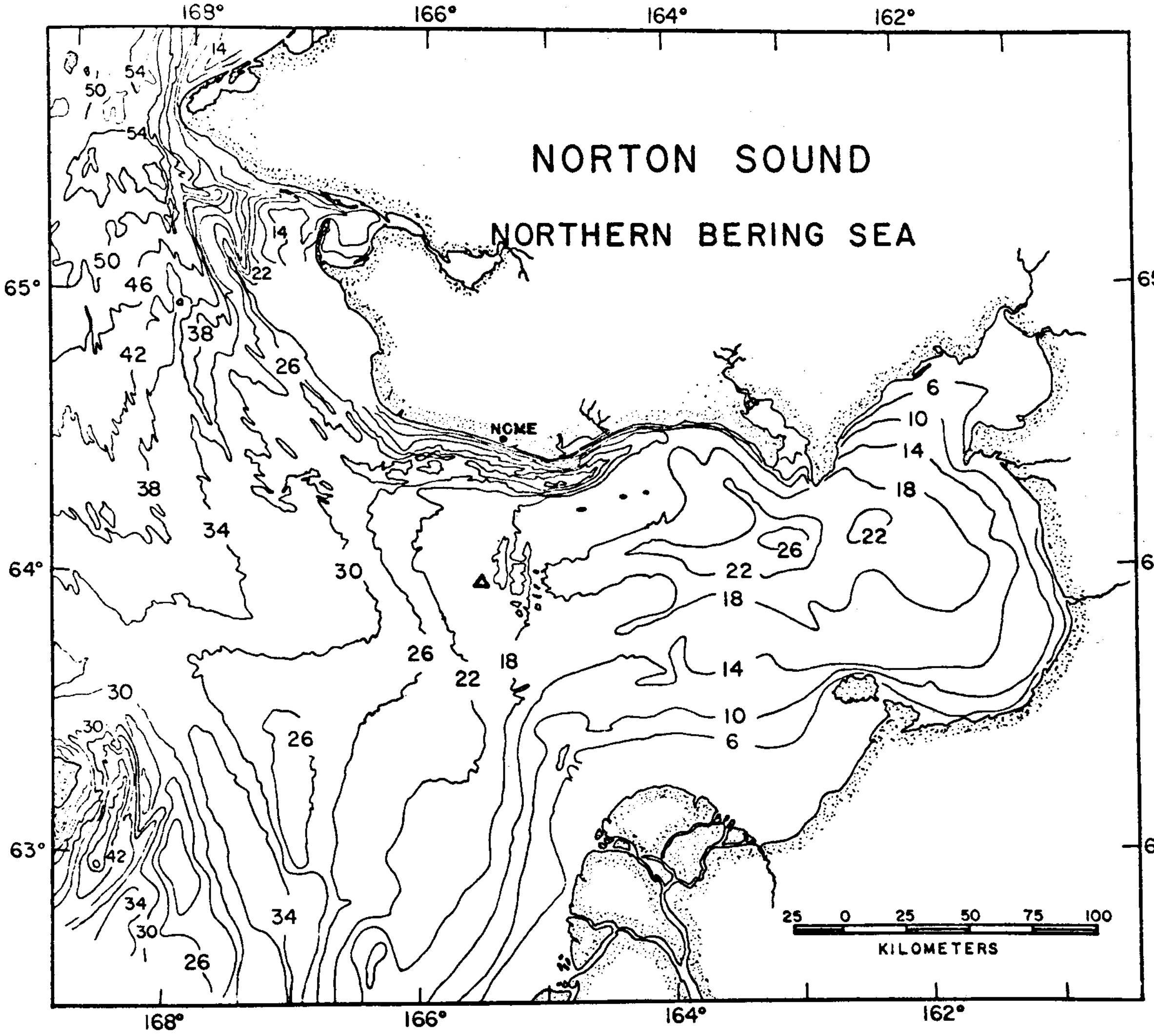

Figure 1. Bathymetry of Norton Sound. Triangle (Δ) near center of figure shows GEOPROBE site.

less than 30 meters (average depth about 18 meters), bottom stresses generated by wind-driven waves and currents can be expected to dominate the patterns of sediment movement. The added questions of whether sediment transport during the relatively longer periods of calm summer weather or beneath the winter ice cover are important must also be addressed.

The physical oceanographic measurements of Muench and Charnell (1976) provide some answers to the water movements within Norton Sound; however, their data also raise many perplexing, unanswered questions. The importance of tides, sea surface tilt, and local, rapid downwelling of the cooled sea surface adjacent to the eastern coast in generating significant contributions to the hydrodynamic bottom stresses must all be examined in more detail.

IV. STUDY AREA

Norton Sound is a shallow arm of the Northern Bering Sea, located on the western margin of Alaska, south of the Seward Penninsula (Figure 1). It is approximately rectangular in shape, 250 km long in an E - W direction, and 130 km long in a N - S direction. Water depth is everywhere less than 30 meters; average depth is 18 meters. Nome, Alaska, population 2400, is situated along the northwest coast.

The instrumented *in situ* bottom tripod, the GEOPROBE station, was deployed at 64°- 00.3'N, 165°- 29.1'W, about 60 kilometers south of Nome (Figure 1). Suspended sediment data and transmissometer lowerings were taken at various locations within Norton Sound; the locations are shown in Figures 5 through 7 in the next sections.

V. DATA COLLECTION

There were two distinct facets to the data collection effort during the past year, each related to a different aspect of the sediment transport problem. The first category of measurements involved suspended sediment sampling. Shipboard sample stations were occupied during a four-week scientific cruise, 19 September, 1977 - 15 October, 1977, on R/V Sea Sounder (H. Nelson, chief scientist) to obtain suspended sediment data. One-hundred and fifty-four water bucket samples analyzed for surface suspended sediments and surface water temperature were collected throughout the Norton Sound - Northern Bering Sea region. The locations of these data in Norton Sound are shown in Figure 5. Eighty water samples were collected in Van Dorn bottles and analyzed for suspended sediment concentrations. The station locations for these data are shown in Figure 6. Table 1 below lists the locations of the lowerings taken with the Martek transmissometer. Normally readings of percent light transmission and temperature were made at two or four meter intervals at each station.

Surface water samples for suspended matter filtration were collected at approximately two hour intervals along the ship's track using a specially-constructed PVC bottle. Additionally, surface and subsurface samples were collected with 5ℓ Van Dorn PVC bottles at stations which were established for the bottom sampling of H. Nelson. All water samples were immediately transferred to

Table 1 - Transmissometer (TR) and Current Meter (Cm) Profiles

Total Depth (m)	Latitude		Longitude		Type
	deg.	min.	deg.	min.	TR or Cm
9	64	29.20	165	25.09	TR
20	63	53.10	163	1.51	TR, Cm
18	64	0.05	162	25.10	TR, Cm
16	64	23.53	161	49.23	TR, Cm
18	64	4.62	161	35.82	TR
14	63	40.86	161	12.65	TR
6	63	22.01	163	6.64	TR
16	63	47.27	163	42.38	TR
20	64	8.68	163	30.54	TR
16	64	17.97	163	59.87	TR
22	64	4.96	164	26.17	TR
16	63	45.05	164	37.36	TR
17	63	28.33	165	19.75	TR
8	63	18.10	165	3.19	TR
14	62	58.52	165	16.55	TR
7	62	54.57	165	7.88	TR
17	62	58.98	165	34.26	TR
24	63	0.70	165	43.95	TR
20	63	2.68	165	54.34	TR
24	63	5.18	166	19.72	TR
24	63	14.74	167	1.93	TR
27	63	26.23	166	29.58	TR
24	63	34.29	166	4.37	TR
24	63	41.89	165	45.78	TR

plastic bottles which were rinsed twice with sample water. Filtration was done within four hours using preweighed 0.4 µm Nuclepore polycarbonate filters. Following filtration of 0.5 to 0.9 liters of sample, the filter was thoroughly rinsed with 50 ml of distilled water and stored in plastic petri dishes.

Profiles of light beam transmission and temperature were made at all stations (except three in the Bering Strait where the current and ship drift were such that the sensor could not be lowered). The transmissometer system consists of a 1 m optical path sensor equipped with IR rejection and blue-green filters. The instrument is calibrated by adjustment of the lamp output to achieve an air-path transmission of 85.5%. Therefore, consistent data from station-to-station and between cruises is assured.

Each sample filter was dried and reweighed using a Cahn 4700 microbalance. None of the filters contained less than 100 µg of particulate matter and weighing errors are considered negligible. Each filter was cut in half and one half was ashed at 550°C for at least six hours to determine the organic content. The remaining half was set aside for microscope work and other analysis.

Our field sampling also included current profiling with a Hydro Products Model 960 sensor equiped with a depth transducer. We had hoped to obtain vertical profiles of current speed and direction at each station. However, a variety of malfunctions forced us to curtail these measurements midway through the cruise.

The second distinct data collection effort involved the deployment and recovery of the newly constructed instrument system, the GEOPROBE tripod, in Norton Sound in a mean water depth of about 20 meters (Figure 1). The GEOPROBE tripod was on the bottom for nearly twenty consecutive days, from Sept. 23, 1976 to Oct. 12, 1976.

The GEOPROBE system is a bottom tripod that is equipped with instrumentation to measure flow field and bottom sediment parameters. The tripod is constructed from 1.5 inch diameter stainless steel pipe (Type 304); zinc collars are used to retard corrosion. Lead weights are added to each footpad. The approximate dimensions are 3.3 meters between centers of each footpad and 3.5 meters high. The various sensors forming the system are summarized in Table 2.

Sample control and recording are accomplished with a special electronics package manufactured by Sea Data Corporation, Newton, Massachusetts. Two types of sample modes are used:

1) Basic mode where certain sensors are sampled over a preselected time interval. The samples are either averaged or discretely measured once each interval, and the values recorded digitally at the end of the interval on a Sea Data magnetic tape cassette recorder. The basic time interval, I, is selectable at the discrete values given by:

$$I = (2^N)\ 1.875 \text{ min}$$
$$\text{where } N = 0, 1, 2, \ldots., 7$$

2) Burst mode where the sensors are sampled at a rapid rate over a duration shorter than at least one - half the basic interval. The burst data are recorded after each duration. Available burst periods (period is the reciprocal of burst rate) are 1, 2, 4, and 8 seconds; present available sample durations are 1 to 252 samples.

Table 2 - Geoprobe Instrumentation

Sensor	Number	Manufacturer
Electromagnet Current Meter	4 (vertical array)	Marsh-McBirney, Inc.
Rotor/vane current meter	1	Bendix
Bottom pressure	1	Paroscientific, Inc.
Temperature (thermistors)	2	Yellow Springs Instrument Co.
Transmissometer/Nephelometer	1	Montedoro-Whitney Co.
Camera/Strobe	1	Benthos, Inc.
Acoustic Release	1	Sonatech, Inc.

Eight components of horizontal water current (from the electromagnetic current meters) and pressure are sampled in the burst mode. Pressure and rotor current speed are averaged over the basic interval and recorded in the basic mode. Current vane direction, temperature, light scattering, and light transmission are measured discretely (once each interval) and recorded in the basic mode. Bottom photographs are taken both at a fixed, preselected rate and during periods of measured currents above pre-set threshholds.

The digital data is contained on a single cassette capable of storing 16.5 x 10^6 bits (450 foot tape). Bottom photographs are made from a 100 foot roll of 35 mm film.

The "cage" assembly that holds the electronics package and other sensors is located at the upper section of the tripod (Figure 2). The launch of the GEOPROBE system from the R/V Sea Sounder during the Norton Sound cruise is depicted in Figure 3. The rotor-vane current meter and the vertical array of four electromagnetic current sensors are shown below the electronics "cage" within the tripod legs. The large boom behind the GEOPROBE system in the starboard tripod boom on the R/V Sea Sounder.

The primary recovery system is an acoustic transponder-release and line bucket containing 75 meters of 5/8 inch nylon braided line that is attached to the tripod "cage". On command the acoustic release frees a glass float to rise to the sea surface trailing nylon recovery line that is attached to the tripod lifting point. A backup recovery system consisting of a surface buoy attached to a bottom anchor that is connected via a long (150 meters) bottom line to the tripod was also used.

VI. RESULTS

The results are presented in two parts: The suspended sediment measurements and the GEOPROBE tripod data.

A. Suspended sediments.

Surface water salinity and temperature were recorded continuously along the cruise track using a Bissett-Berman (Plessey) thermosalinograph. Because these data were collected over a three week period it was anticipated that only general regional trends would be reasonably depicted. In fact, the surface water temperature data are extremely difficult to interpret because of abrupt seasonal cooling which occurred during the first week in October and continued to the end of the cruise. Spatial distributions are effectively masked by the strong temporal trend. Surface salinity values do not appear to be as severely influenced by temporal variations.

Surface salinity in Norton Sound for late September - early October shows a range from 21.95 $^{o}/oo$ to 31.25 $^{o}/oo$ (Figure 4). For convenience of discussion this range can be divided into three groupings; I, < 24 $^{o}/oo$; II, 24 - 29 $^{o}/oo$; and III, > 29 $^{o}/oo$. Group I values occurred off the Yukon River and in the northeastern and eastern portion of the Sound. The intermediate group II salinities were present across the mouth of the Sound and extending southeastward to Stuart Island. West of Norton Sound salinities increased to > 29 $^{o}/oo$.

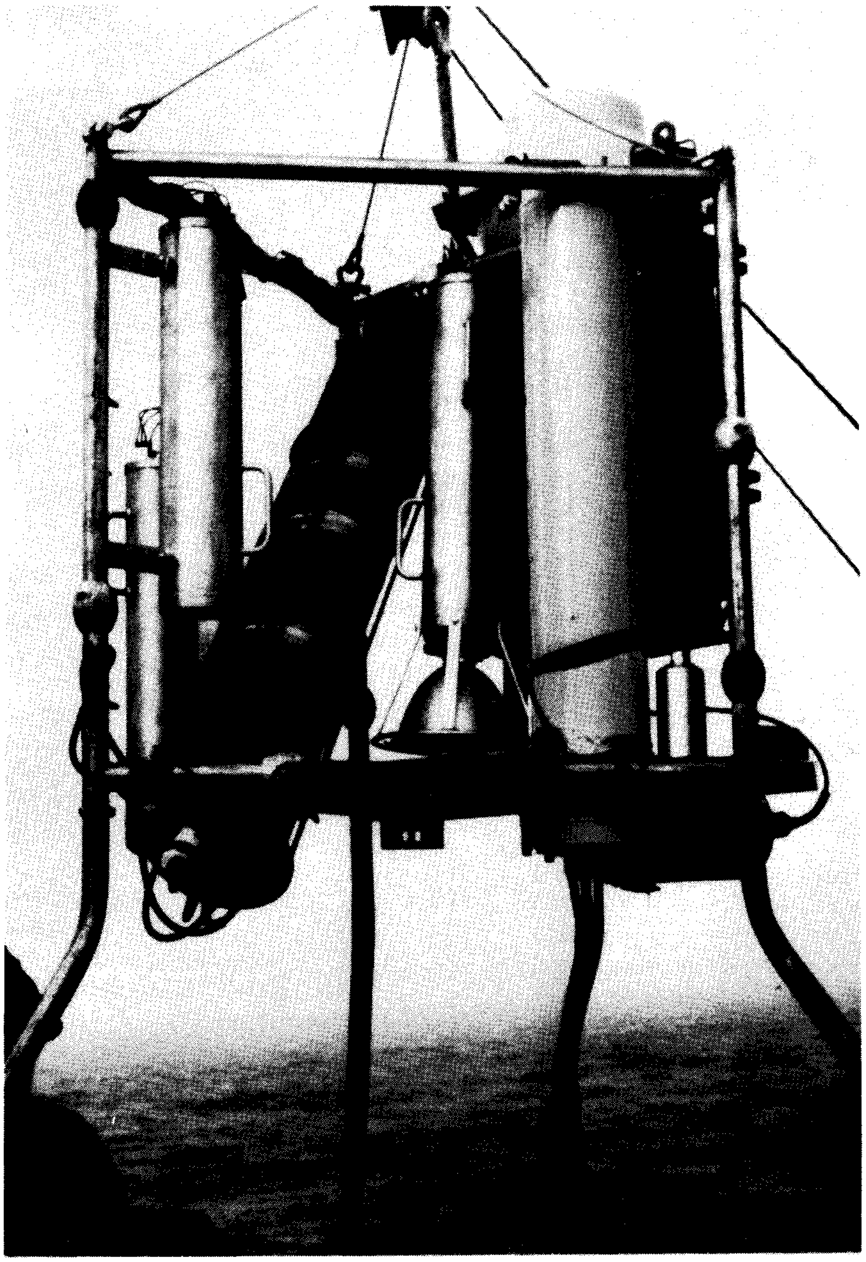

Figure 2. Instrument assembly or "cage" on GEOPROBE station. Frame is stainless steel pipe (1.5 inch o.d.). Strobe for camera is mounted vertically in center of photograph. Pressure case for electromagnetic current meters and pressure sensor (small cylinder) are to the right of strobe. Large black pressure case mounted obliquely contains electronic sampling control and recording system.

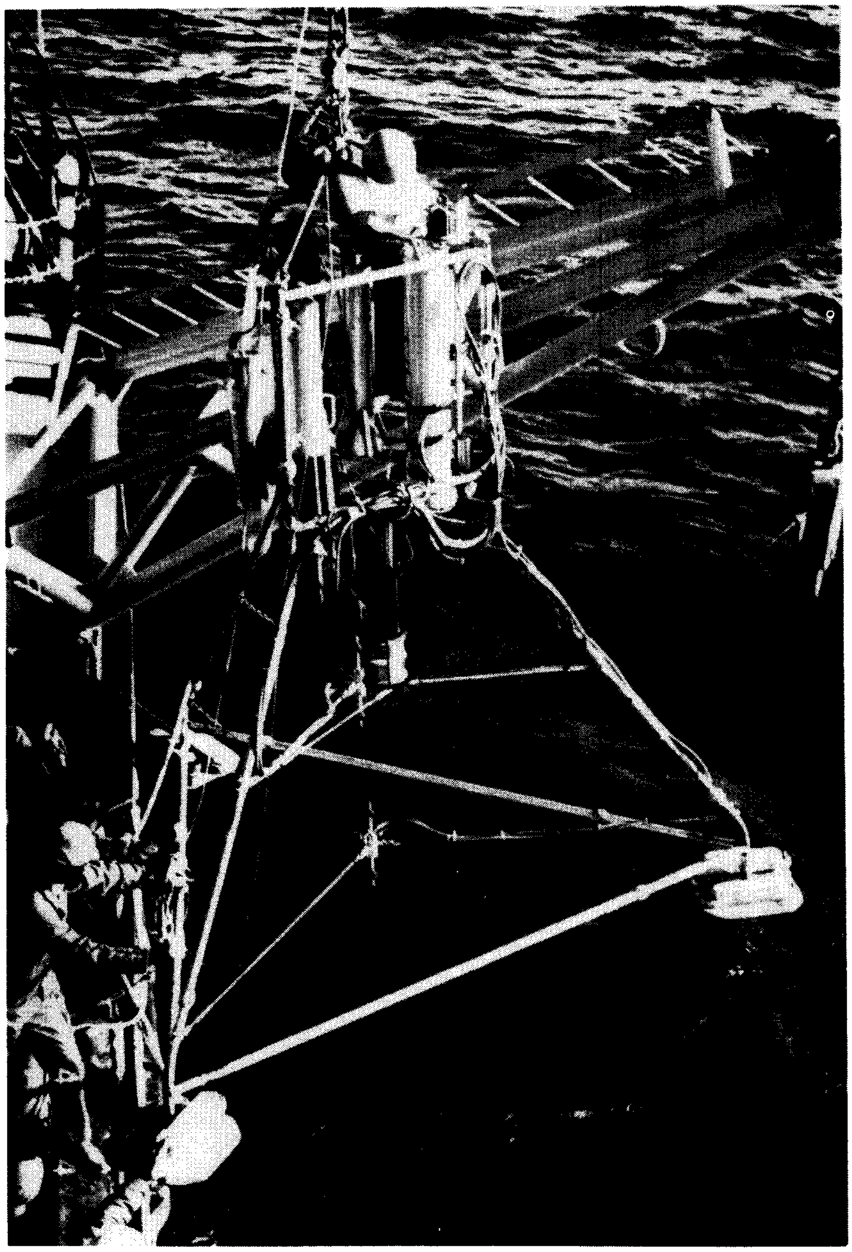

Figure 3. Deployment of GEOPROBE tripod in Norton Sound on September 23, 1976 from R/V SEA SOUNDER. Tripod is 3.5 meters high from top of lifting bridle to sea floor.

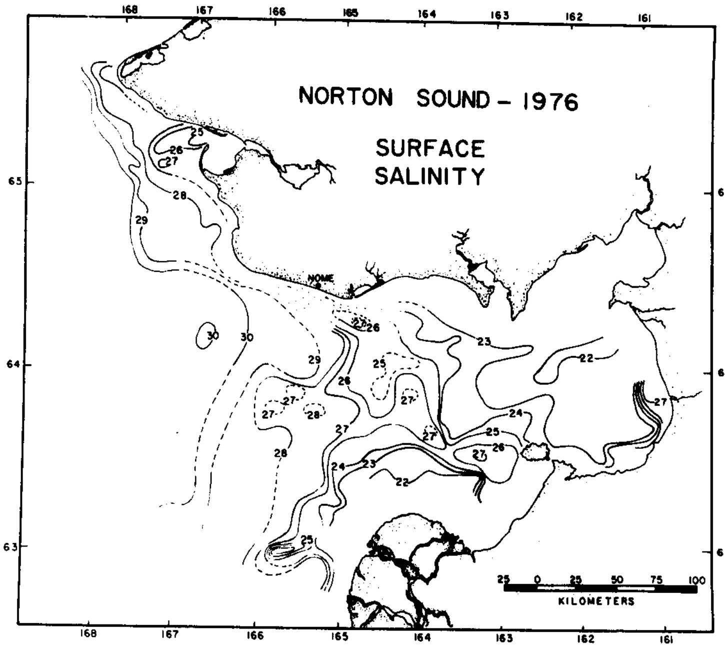

Figure 4. Surface water salinity ($^{\circ}$/oo) during September 23 - October 14, 1976 in the Norton Sound area. Data were recorded continuously along the ship's track using a Bissett-Berman thermosalinograph.

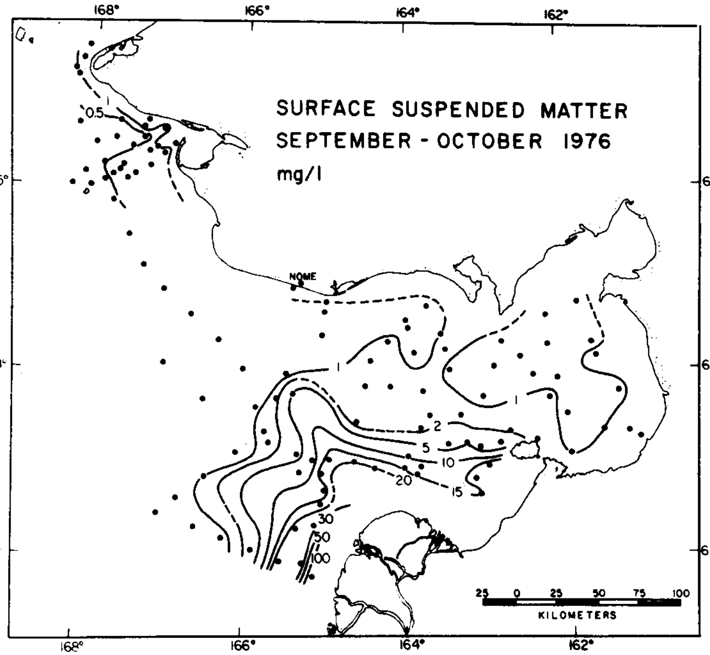

Figure 5. Total suspended matter (mg/l) in surface waters, September - October, 1976.

Several aspects of the salinity distribution should be noted:

1. the areal extent of the salinity waters near the Yukon Delta is limited. Values below 22 °/oo were confined to within 30 km of the delta distributaries.

2. the broad area of low salinity water (< 23 °/oo) present in the eastern part of the sound was apparently relatively will mixed. In addition, this water was clearly isolated from its probable source (the Yukon River) by a band of higher salinity waters.

3. the intermediate band of salinities (group II, 24 - 29 °/oo) exhibits considerable complexity indicative of active mixing between higher and lower salinity waters. The fact that these partially-mixed waters cut across the area to Stuart Island is of interest. This pattern suggests transport of surface water from the northwest toward Stuart Island.

4. a tongue of > 29 °/oo water extends east-southeast into the sound approximately 40 km south of Nome. This pattern implies transport from the northwest toward Stuart Island.

We were not equipped to obtain subsurface profiles of salinity. However, the transmissometer thermistor circuit provided data on subsurface temperatures. Essentially, our measurements agree with the results of Muench and Charnell (1977) who completed a hydrographic survey of the sound during the same time period. These investigators drew particular attention to the presence of a near bottom lens of cold (< 4°C), saline water in the eastern portion of Norton Sound. There is no obvious source for this water during the summer in the vicinity of the sound. This isolated mass of bottom water and the surface salinity pattern discussed above suggest that the interior portion of the sound is in some manner cut off from the western sound for periods of time that are presently unknown.

Total suspended matter (TSM) in the surface waters ranged from 183.7 mg/l near the major western distributaries of the Yukon Delta to < 0.4 mg/l near King Island (Figure 5). The areal TSM distribution is comparatively simple. The Yukon Delta is rimmed by turbid waters to Stuart Island and protrude slightly northwestward across the mouth of the sound. TSM concentrations decrease rapidly away from the delta and the northern one-half of the area is characterized by relatively low concentrations (< 1 mg/l). Although the individual values are not shown in Figure 5, TSM concentrations in the interior part of the sound (east of Stuart Island and Cape Darby) were surprisingly uniform, ranging from 0.7 to 0.9 mg/l.

The uniformity of the surface TSM in the eastern sound indicates relatively rapid horizontal mixing of these waters; mixing that is active enough to effectively disperse sediment plumes from local streams and the Yukon River. The character of the waters in the interior part of the sound is likely to be strongly influenced by the prevailing winds. In particular, during September and October 1976, northerly winds were predominant (data from National Weather Station, Nome). These winds would generate westward near surface water flow which would serve to prevent eastward movement of turbid Yukon Delta water past Stuart Island (Figure 5). Furthermore, westerly wind drift would contribute to the westward "skewing" of the Yukon River coastal plumes (as shown in Figure 5) and formation of a zone of shearing between the waters of Norton Sound and the northerly-flowing Alaskan coastal water (> 30 °/oo salinity).

Examination of ERTS-1 satellite imagery for 1974 and 1975 shows that the turbid water produced by the Yukon River discharge is frequently prevented from flowing eastward around Stuart Island. Nevertheless, microscope inspection of the suspended materials in the interior part of Norton Sound (east of Stuart Island) strongly suggests a Yukon River source. Additionally, Nelson and Creager (1977) have measured rapid accumulation rates of Yukon-derived silt east of the island. The timing of the required eastward transport is presently not known.

McManus and Symth (1970) presented several cross-sections of light beam transmission based upon measurements in July, 1968 in the area of Norton Sound. These data demonstrated that the bulk of the suspended matter transport occurs within a near-bottom zone several meters thick. Our results (Figure 6) confirm the existence of relatively high TSM concentrations near the bottom throughout Norton Sound. Comparison of the surface and near-bottom concentrations (Figures 5 and 6) shows that the near-bottom values were from 2 to 20 times greater except at stations which we interpret to be within the Alaskan coastal water (west of the Yukon Delta) and at two stations within 5 km of the coast near Nome.

Ash residue percentages (Figure 7) and microscope inspection of the near-bottom samples show that the suspended matter is predominantly fine to medium silt from the Yukon River. Although the simplicity of the TSM distribution near the bottom may be an artifact of our data control, we believe the gross regional trends are accurately depicted (Figure 6). Three aspects of this distribution are noteworthy:

1. northward transport of Yukon sediment across the mouth of Norton Sound is indicated, and this is confirmed by dominance of northerly water flow measured at the GEOPROBE site (Figure 1).

2. relatively high concentrations of terrigenous suspended matter were present west of Port Clarence and the the Bering Strait near the bottom.

3. with the exception of the area near Nome, concentrations of inorganic silt were high throughout the entire sound (> 5 mg/l). Preliminary mineralogical and textural analysis of the suspended matter suggests a Yukon source for the samples in Norton Sound and off Port Clarence.

B. GEOPROBE data.

The GEOPROBE data was recorded on cassette tape every 30 minutes. The basic mode data (refer to Section V) contained very few error records (< 100) and is considered to be reliable. The burst mode data has been difficult to analyze owing to electronic problems with the electromagnetic (e-m) current sensors. Post-deployment checks in the Stanford University recirculating water flume revealed three serious problems with the e-m current sensors: (1) large zero offset voltages; (2) significant signal drift; and (3) low power supply levels. Evaluation of the effects of each of these problems on the quality of the e-m current meter data collected during this report period is still progressing. Consequently, only the basic mode data is discussed in this report.

The statistics covering the recording period of 20 days are shown in Table 3. These statistics were derived from values recorded every one-half hour. The pressure and current speed (rotor) data represent 30 minute averages; the other parameters were discretely sampled during each basic 30 minute interval. All sensors except the rotor/vane were situated about 2 meters above the sea floor; the rotor/vane were about 1.25 meters above the bottom.

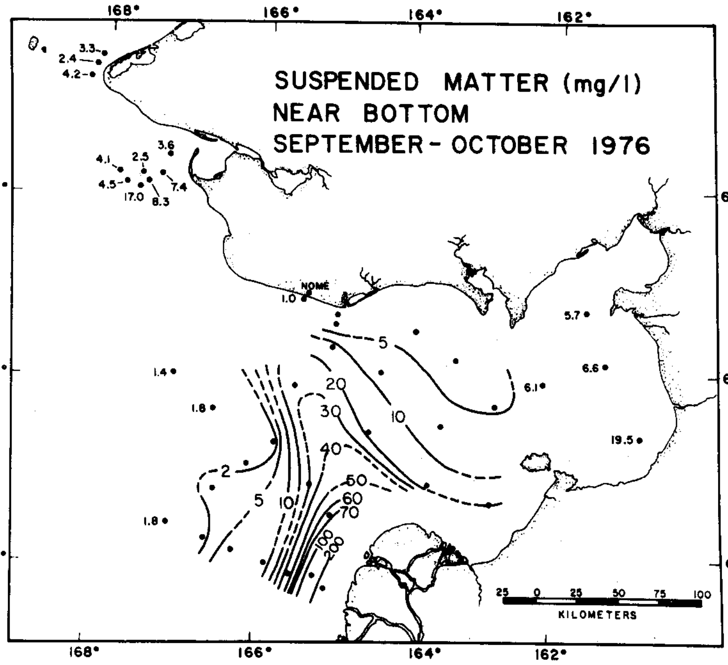

Figure 6. Total suspended matter one meter above the bottom, September - October, 1976. Values are in mg/l.

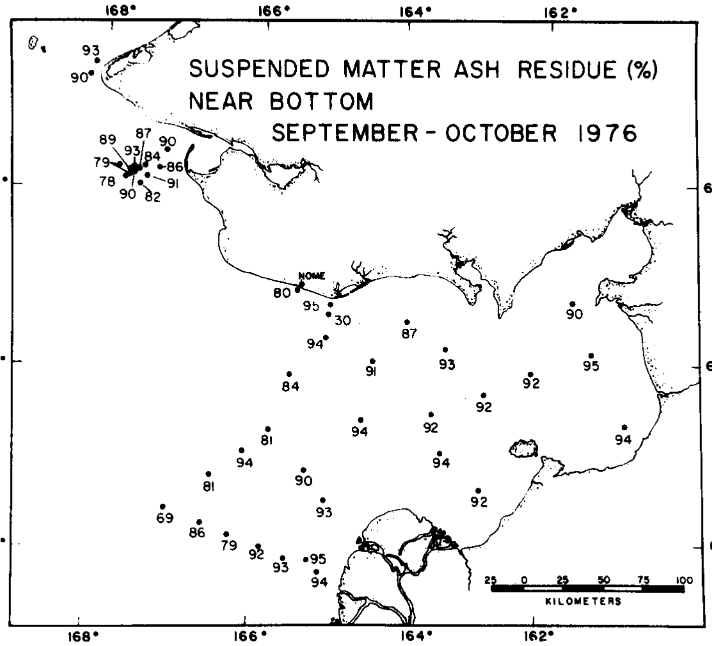

Figure 7. Noncombustible particulate matter in near bottom waters, September - October, 1976. Values are in percentage of total suspended matter (see Fig. 6).

Table 3 - Geoprobe Sensor Statistics

Sensor	Mean	Std. Deviation	Maximum	Minimum
rotor (cm/sec)	12.1	4.8	32.0	3.0
vane (degrees)	280	---	---	---
pressure (meters)	20.15	0.19	21.02	19.87
temperature (^{O}C)	8.24	0.51	8.84	7.16
transmissometer*(%)	2.0	0.02	5.8	0.0
nephelometer**	---	---	---	---

*Transmission values were extremely low due to the high suspended sediment values.

**Light scattering values obtained with the nephelometer have not been fully calibrated as of this writing.

Time series plots of each parameter listed in Table 3 were inspected for trends and significant variations in values. In particular, a comparison of the GEOPROBE data with atmospheric data (wind speed and direction, surface air pressure, and air temperature) collected by the National Weather Service at Nome was made to determine the effects of wind and air pressure on bottom transport at the GEOPROBE site.

Bottom temperature showed a decrease of about 1.7°C over the 20 day period. However, about 50 percent of this drop occurred over an 18 hour period on October 7, 1976. Shortly before that time, on Oct. 6, a significant decrease in air temperature occurred at Nome. For the first time of the season, the air temperature reached below 0°C. The drop in air temperature was probably caused by a strong northerly wind that increased in speed early on Oct. 6. The values of bottom temperature, about 8.2°C, recorded in late September compare well with those obtained by Muench and Charnell (1977) near the GEOPROBE site.

Bottom pressure (time average over 30 minutes) contains two significant fluctuations - tidal and lower frequency. The tidal signal is a mixed diurnal type, with the two daily peaks and two troughs at nearly equal levels. The tidal range at the GEOPROBE site was typically about 0.6 meters. Figure 8 shows that bottom pressure and bottom current speed are closely coupled; high tide is associated with peak currents. The tidal current speeds at 1.25 meters above the bottom are on the order of 10 cm/sec, a significant value for sediment flux estimates. Although Figure 8 does not disclose the lower frequency variation in the pressure signal, there is a suggestion in the data that bottom pressure responds to changes in surface air pressure. An indication of a general trend of falling bottom pressure is seen over the three day period in Figure 8. The data were not taken over a sufficient period to examine spring-neap tidal effects. It is possible that the low frequency variation in bottom pressure is largely forced by the spring tidal cycle.

Bottom current data is complicated and extremely variable. However, a first analysis shows that there is a strong semi-diurnal tidal oscillation in bottom current, with a speed range of about 10 cm/sec. Figure 9 indicated that from a visual comparison, surface wind speed at Nome and bottom current speed (rotor) at the GEOPROBE site were uncorrelated. Wind direction for the period shown in Figure 8 remained northerly to easterly. Over the 20 day period, bottom current speeds infrequently exceeded values of 15 cm/sec. Often the periods of highest bottom currents normally occurred when wind speeds at Nome were relatively low (less than 15 knots). However, the time of maximum bottom current (32 cm/sec - Table 3) was associated with steady 30 knot northeasterly winds.

In most cases, significant changes in transmission and nephelometer values were correlated with periods of strong bottom currents. Figure 10 shows an example of this relationship. The sudden drop in transmission after 2000, Sept. 29, apparently leads the peak current speed by 6 hours. The increase in scattering activity measured by the nephelometer occurs during the peak current activity.

The significance of the measured bottom current in producing sediment entrainment at the GEOPROBE station can be evaluated. Five gravity cores were taken in close proximity of this station (all within 2.5 miles of the site). Standard sediment size analysis of the surface sections of these cores shows that the mean grain sizes are between 0.058 mm and 0.091 mm, with a mean grain size of about 0.07 mm. Using a figure given by Bagnold (1963) and discussed by Komar (1976),

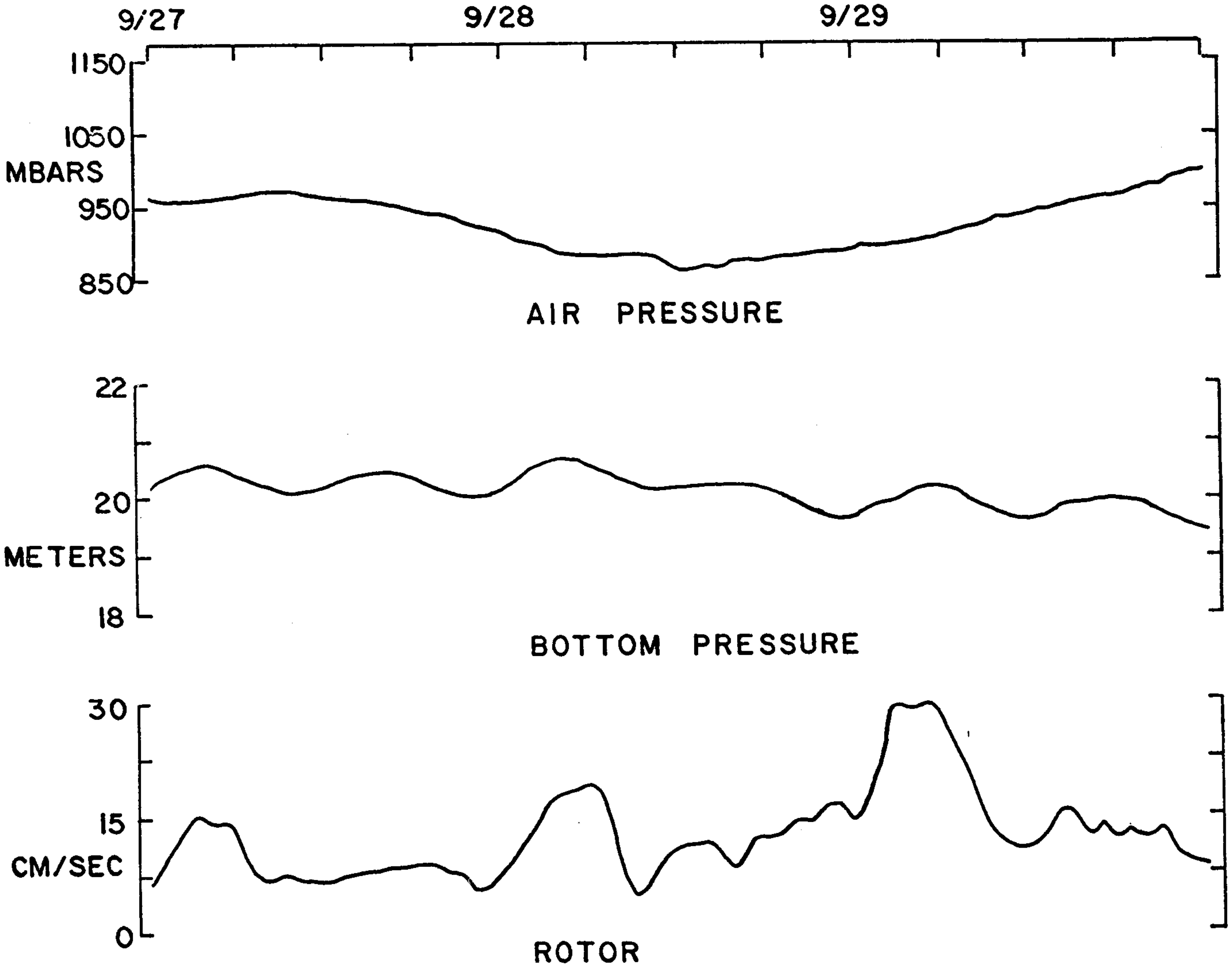

Figure 8. GEOPROBE data for bottom pressure (middle) and current speed (bottom) over 3-day period, 9/27-30/76. Air pressure (top) is taken from National Weather Service records at Nome. Data are plotted hourly.

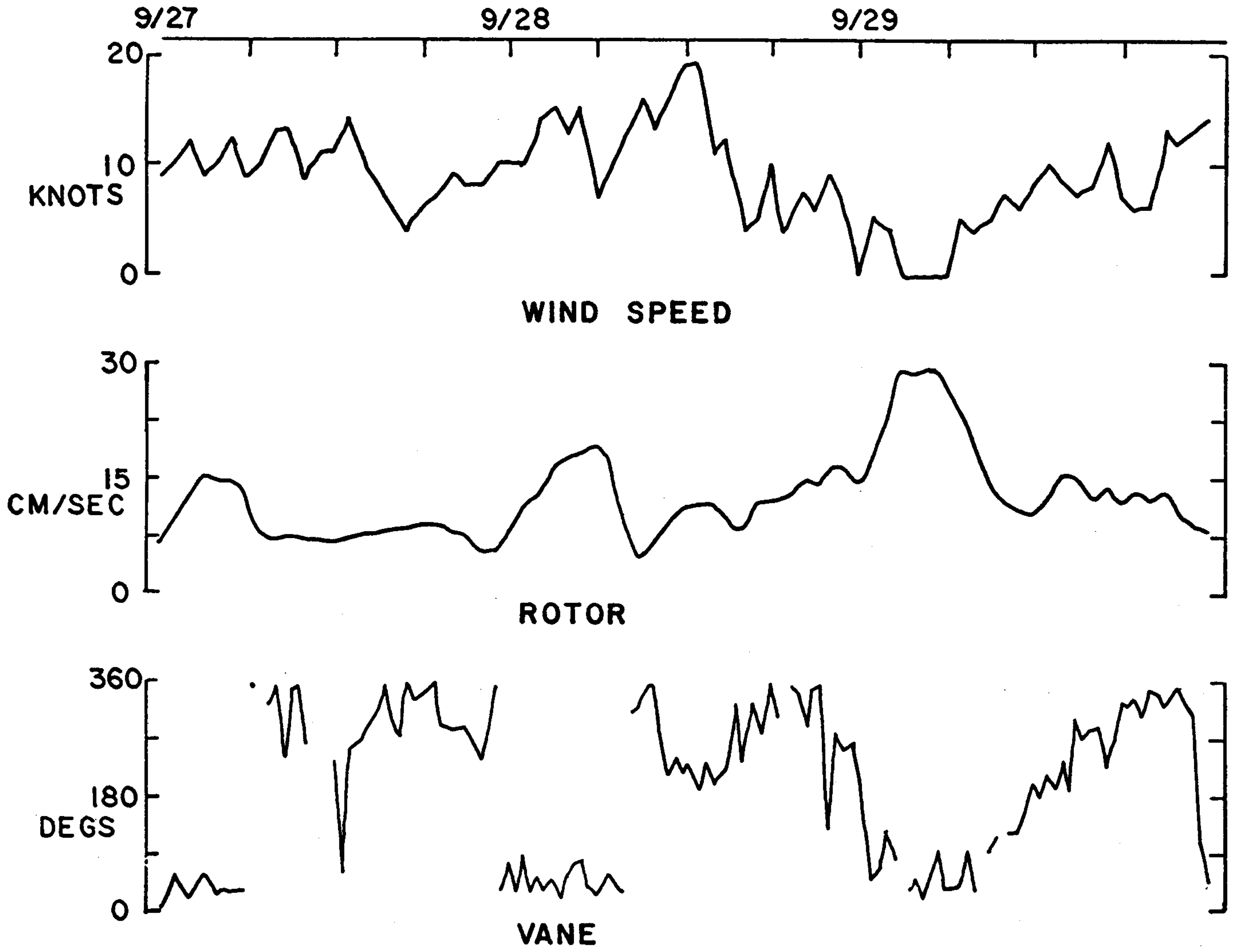

Figure 9. GEOPROBE data for current speed (middle) and vane (bottom) over 3-day period, 9/27-30/76. Wind speed data (top) is taken from National Weather Service records at Nome. Data are plotted hourly.

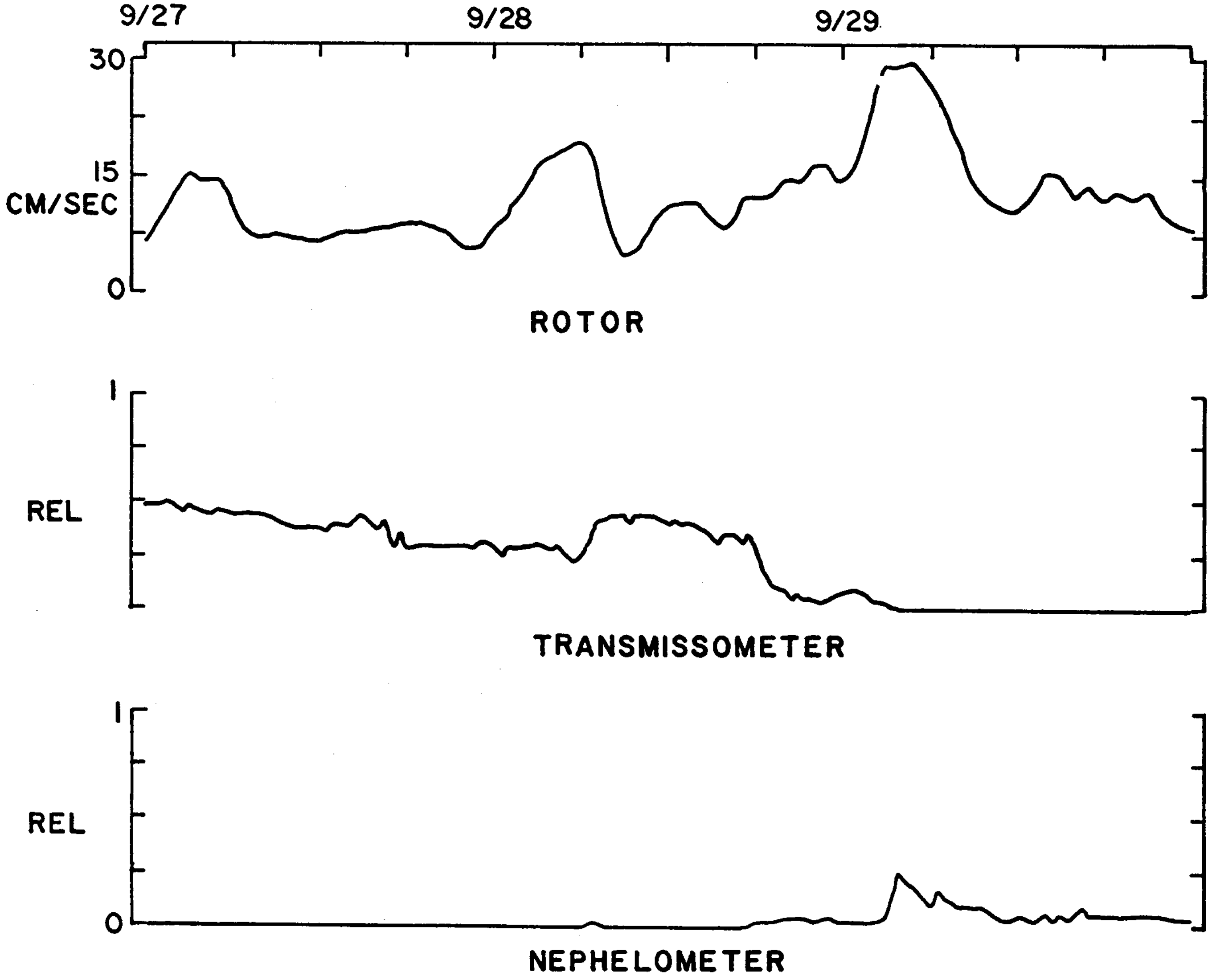

Figure 10. GEOPROBE data for current speed (top), transmissometer (middle), and nephelometer (bottom) over 3-day period 9/27-30/76. Transmission and nephelometer values are plotted on a relative scale (0-1)

this mean grain diameter of 0.07 mm can be used to derive a value of the Shield's critical entrainment function, ψ. This analysis is only strictly valid for unidirectional, fully turbulent flow. It does not consider wave induced effects.

$$\psi = \frac{\tau_0}{\rho} \cdot \frac{1}{(s-1)gD} \qquad (1)$$

where τ_0 is the critical bottom stress necessary to entrain a particle of of grain size, D;
ρ is the fluid density;
s is the specific gravity of the particle;
g is gravity.

The value of ψ given by Bagnold (1963) for D = 0.07 mm is 0.11.
If the sediment density os about 2.65 g/cc and ρ = 1.024 g/cc (Muench and Charnell, 1977), g = 980 cm/sec^2, and D = 0.07 mm then

$$\frac{\tau_0}{\rho} = \psi\,(s-1)gD = 1.198 \qquad (2)$$

The Karman-Prandtl equation for the velocity distribution in turbulent flow near rough boundaries can be written as

$$\frac{u}{(\tau_0/\rho)^{1/2}} = 2.5 \ln \frac{y}{k} + 3.4 \qquad (3)$$

(after Komar, 1976)

where u is the speed at a level y in the turbulent boundary layer,
k is bottom roughness expressed in cm.

By combining equations (2) and (3), the critical flow speed necessary to move sediments of mean size D and smaller can be found.

$$u = 2.74 \ln \frac{y}{k} + 3.72 \qquad (4)$$

The GEOPROBE current rotor was located 125 cm above the sea floor during the experiment. Based on estimates of bottom roughness made with underwater television data of the GEOPROBE site,values of k between 2 - 5 cm were obtained.

Thus from equation (4), current speeds above 15.1 cm/sec (k = 2 cm) and 12.5 cm/sec (k = 5 cm) would be needed to entrain the sediment at the GEOPROBE site. As Table 3 shows (section VI.B.) the mean rotor speed was about 12 cm/sec, maximum was about 32 cm/sec. The conclusion is that resuspension of bottom sediments did occur occasionally during periods of above average current activity.

It is important to note that the above analysis has assumed a unidirectional, fully turbulent flow, and has neglected sediment sorting and skewness statistics. Madsen and Grant (1976) and Komar and Miller (1975) show that a similar analysis can be used for oscillatory flow. When wave current data becomes available, this analysis will be redone to include these higher frequency effects.

VII. DISCUSSION

It has been established by McManus, et.al. (1974), Nelson and Creager (1977) and McManus and Smyth (1970) that significant quantities of Yukon silt are transported through Bering Strait and deposited in the Chuckchi Sea. Furthermore, the results of McManus and Smyth (1970) and the present research show that most of the suspended matter transport occurs within 5 - 10 meters of the sea floor. The TSM distributions for September - October 1976 imply relatively rapid settling of Yukon silt from surface waters to the bottom and near-bottom. Consequently, future investigations of the sediment transport system should focus on the dynamics of the near-bottom waters.

Although the results of one survey of this area obviously do not provide a complete picture, several preliminary conclusions seem justified. First, transport of substantial amount of Yukon sediment occurs along a direct path across the mouth of Norton Sound toward Bering Strait. This interpretation agrees well with the depositional pattern of recent Yukon material (McManus, et.al. 1974). Continuous by-passing of silt is indicated; however, the calculations of Nelson and Creager (1977), which are supported by the results of our research, show that major increases in the concentrations of suspended matter moving through Bering Strait must occur in order to account for the yearly sediment contribution of the Yukon River. The GEOPROBE data suggest that the bottom sediments respond quickly to relatively small increases in bottom water flow speeds. Clearly the effects of storms (for which we presently have no data) must represent the missing element in sediment budget calculations (Nelson and Creager, 1977). The timing of these high energy events, the pathways followed by the entrained sediments, and the changes which occur on the bottom are of major importance to the OCSEAP program.

Secondly, the characteristics (temperature, salinity, TSM) of the surface and bottom waters in the eastern portion of Norton Sound suggest that this area may become "isolated" from the western Sound for indeterminant periods. Nevertheless, the bottom sediments, low surface water salinities and the composition of the suspended matter show that significant transport of Yukon water and sediment into this area occurs at some time during the summer season. In addition, concentrations of > 5 mg/l of silt in the bottom waters of the eastern Sound show that the bottom currents are not insignificant. There are presently no data on currents in the eastern part of Norton Sound.

Finally, Yukon silt is widely dispersed throughout Norton Sound within the near-bottom waters. As expected, the highest concentrations of TSM are near the delta and over areas of known silt accumulation. However, our data show that the sea floor in the northern part of the Sound is also overlain by sediment rich bottom water. In particular, Nelson and Creager (1977) show that the relatively deep troughs which parallel the northern margin of the Sound are not sites of important mud deposition. This surprising result implies that these areas are periodically flushed clean of fine-grained materials that should accumulate during times of lower current energy. Here again we do not have data to resolve this problem.

The 20 day record of GEOPROBE data suggests that bottom currents in the northwestern section of Norton Sound are driven by several processes. The most obvious variation in current speed and direction is associated with tidal forcing. Tidal currents have peak amplitudes of about 10 cm/sec and semi-diurnal periodicities. Muench and Charnell (1977) state that their shipboard current meter data taken at five locations over short durations (< 26 hours) suggest that tides are relatively unimportant in this region. The data collected here suggest that tidal forcing is an important factor in controlling bottom currents. The peak tidal speeds of 10 cm/sec at 1.25 meters above the sea floor, although too low to entrain fine sand, can be significant in resuspension of sediments if added to wind- or wave-driven currents of comparable magnitudes.

Despite the apparent low correlation between wind speed and bottom current speed, the times of highest currents were associated with periods of strongest winds. This fact would support the hypothesis that stormy periods generate the highest stresses at the sea floor. It is unfortunate that no severe storms occurred during the deployment period.

A more subtle effect on bottom current generation is tilt of sea surface due to wind set-up or the passage of low pressure centers. This relationship can not be evaluated based on the available data; however, it is probably an important factor to consider in future work.

The measured correlation between decreasing light transmission and increased light scattering with increased bottom current speed (Figure 10) probably represents either active sediment resuspension or advection of nearby materials into the GEOPROBE site. If the increased current has a northward direction, it is possible that the decreased light transmission represents advection of water having higher suspended particulate concentrations (Figure 6). Our data show that the northerly flow component was important during this period of higher current speed, although the direction varied rapidly from northeast to west.

VIII. CONCLUSIONS

Norton Sound is a shallow body of water located in a highly variable subarctic climate, normally characterized by late summer - early fall severe storms and nearly continuous winter ice conditions. Suspended and bottom sediment transport studies must account for the influences of these time-dependent atmospheric conditions as well as the effects of waves, tidal currents, and mean circulation. In order to understand the patterns and mechanics of sediment transport here both advective processes and resuspension/deposition need to be investigated.

This initial attempt to obtain field measurements of those parameters important in affecting sediment movement has produced several preliminary results.

1. Bottom currents at a site about 60 km south of Nome measured over a 20 day period occasionally reached levels that exceeded the estimated threshhold values for sediment entrainment. These high current speeds were associated with times of increased surface wind speed.

2. During these periods of higher currents, light transmission and scattering measurements showed corresponding increases in suspended sediment concentrations at 2 meters above the sea floor.

3. Bottom tidal currents were about 10 cm/sec (peak) at the GEOPROBE station. These currents could be significant components in causing sediment resuspension and transport.

4. Suspended sediment values near the mouth of Norton Sound and near the Bering Strait agree with values given by McManus and Smyth (1970).

5. The distribution of suspended sediment concentrations is controlled by

the Yukon River effluent. Both surface and near-bottom data reveal sediment plumes extending from the Yukon subdelta northwestward toward Bering Strait.

6. Surface suspended sediment values decrease abruptly by about one order of magnitude in a west to east direction near Stuart Island. This apparent anomaly corresponds with changes in other parameters (temperature, salinity) measured by Muench and Charnell (1977).

7. Near-bottom concentrations of suspended sediment generally exceeded 5 mg/l throughout Norton Sound. This material contained > 90% noncombustible matter and > 80% inorganic silt and clay supplied by the Yukon River.

IX. NEEDS FOR FURTHER STUDY

Fuuture investigations of sediment transport in Norton Sound and the Northern Bering Sea must include measurements of both physical and geological parameters over a sufficiently dense spatial network and over time durations of at least several months so that the variability in both the sedimentary setting and the effective processes can be adequately sampled. For example, the problem of sediment resuspension is affected by the local bottom sediments, the nature of the bottom (roughness, bioturbation, etc.), and the dominant forcing mechanisms. As Nelson and Creager (1977) have shown the bottom sediments in Norton Sound are highly variable away from the Yukon subdelta. Muench and Charnell (1977) and our own past year's work described here have also shown that there are several physical mechanisms that contribute to the bottom stresses (winds, tides, mean flow, surface waves).

Based on this highly variable set of important factors in the resuspension problem, we suggest that the GEOPROBE stations and shipboard suspended sediment sampling be integrated with a current meter measurement scheme. In FY 77 we are planning to conduct such an experiment in Norton Sound with Charnell and Muench of NOAA (PMEL, Seattle). Two GEOPROBE stations and three current meter moorings (five current meters) will be deployed in June 1977 from R/V Sea Sounder. During the deployment period we also plan to obtain about 20 suspended sediment/CTD stations. The GEOPROBE stations and current meter moorings will be recovered in late summer or early fall.

Using atmospheric and tidal data collected at Nome we hope to expand this past year's results to include a detailed analysis of the hydrodynamics and sediment transport relationships.

X. SUMMARY OF 4TH QUARTER OPERATIONS

A. Ship and laboratory activities.

1. No ship activities occurred during the fourth quarter.

2. Laboratory analyses included:
    - a. determination of suspended sediment concentrations from 80 water bottle samples and 174 surface water bucket samples. Water samples were filtered on board R/V Sea Sounder during the third quarter cruise and weighed during this quarter.

b. determination of surface salinity for 100 surface water samples using a Plessey laboratory salinometer.

c. sediment textural parameters for five gravity cores were obtained using the rapid sediment analyzer (RSA) and hydrophotometer at the Sediments Laboratory, USGS, Menlo Park.

3. Data analysis.

The GEOPROBE cassette data tape was converted to a standard 7 track computer tape by Dr. David Halpern at PMEL (NOAA),Seattle. The 7 track tape was then processed on the new Honeywell Multics computer system at USGS, Menlo Park. Data for all variables has been analyzed for errors, and plotted on a time series graph. Standard statistical values for each basic mode data type have been calculated.

The next phase of data analysis will involve error corrections to the burst mode pressure and current data, spectral analysis of various data types, and more complex graphic plotting of available data.

4. Calibration analysis.

The GEOPROBE electromagnetic current meters have been tested and calibrated in the Stanford University recirculating water flume. Further testing will be done prior to the FY 77 experiment, and a report of the test and calibration results will be compiled. The current meters are calibrated against a DISA laser velocimeter, capable of making velocity measurements in one direction accurate to 1 mm/sec.

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ANNUAL REPORT

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COASTAL PROCESSES AND MORPHOLOGY OF THE BERING SEA COAST OF ALASKA

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I. SUMMARY OF OBJECTIVES, CONCLUSIONS AND IMPLICATIONS WITH RESPECT TO OCS OIL AND GAS DEVELOPMENT

During the first year of our OCSEAP-supported studies on the coastal processes of the Alaskan coast of the Bering Sea, we have initiated investigations on: 1) the coastal effects of the major 1974 storm in the northeast Bering Sea; 2) regional characterization of the physical coastal environment; and 3) beach and nearshore changes. Summaries of our results follow.

Storms pose major hazards to coastal developments along the Alaskan Bering Sea coast. Shallow offshore depths that characterize much of the eastern Bering Sea shelf (particularly the northeast Bering Sea) make coastal areas susceptible to storm surges of large magnitude. Such a storm surge occurred during November 1974. An objective of this study was to measure debris-line elevations resulting from this storm along the northeast Bering Sea coast. Debris-line elevations provide a combined measure of sea-level rise due primarily to wind stress, drop in barometric pressure, wave set-up and runup. Measured elevations ranged generally between 3 and 4.5 m. The highest debris lines were found along the eastern side of Norton Sound. Ice had begun developing along the shore and in shallow areas prior to the storm. Ice blocks, which were lifted by the rise in sea level, were driven ashore by wind and breaking waves and caused damage in the village of Unalakleet. Large logs floating offshore and in debris lines could also be driven shoreward and be battered against coastal structures. These potential consequences of storms in this environment pose hazards to coastal developments in addition to hazards resulting from flooding and wave activity alone. Our study on the coastal effects of this major storm will continue into FY 77 and will include computer simulations of wave characteristics and amounts of coastal change.

Much of our effort during the past year has been involved in regional characterization of the physical coastal environment. This included determination of net littoral drift directions, characterization of coastal morphology and reconnaissance of beach morphology and sediment characteristics. Results from these studies have provided baseline information on coastal processes for the region and will serve to guide future, more quantitative studies on the rates of sediment transport and rates of change of coastal morphology. Summaries of our regional studies follow:

1) Net littoral drift directions were determined for the Alaskan Bering Sea coast (enclosed maps: SHEETS 1-6). These data show the long-term directions of wave-induced sediment transport along the coast. Drift directions are generally to the north along the coast. A major storm track crosses the eastern Bering Sea from southwest to northeast during late summer and early fall. The cyclonic motion about a storm low pressure system causes winds to the north along the coast. Drift directions along the northeast Bering Sea coast appear to reflect transport by waves generated by these storm winds, rather than by prevailing winds. Along the southeast Bering Sea

coast drift directions generally correspond to both storm waves and waves generated by prevailing winds.

2) Coastal morphology was characterized for the northeast Bering Sea coast and the northern coast of the Alaska Peninsula (enclosed maps: SHEETS 7 and 8). From these data, one can make preliminary judgements on the sources and sinks for coastal sediment. For example, the relatively straight northern coast of the Alaska Peninsula is segmented by numerous embayments which are separated from the Bering Sea by barrier spits and islands (sinks for sediment). Between the embayments are bluffs and cliffs (sources for sediment) and additional coastal types. By comparing the morphology to net littoral drift directions (SHEETS 3 and 6) the pathways along which the sediment was transported can be determined.

3) Reconnaissance of beach morphology and sediment characteristics was undertaken for the northeastern Bering Sea coast and the northern coast of the Alaska Peninsula. Beaches along the northeast Bering Sea coast appear dominated by storms. Berm crest elevations were high (3-4.5 m) and could not be overtopped under non-storm conditions. Low wave energy under non-storm conditions and relatively coarse beach sediment inhibit non-storm modifications in beach morphology. In contrast, the beaches along the northern coast of the Alaska Peninsula are modified to a much greater extent under non-storm conditions. Berm crest elevations were relatively low and could be readily overtopped under non-storm conditions during spring-tide. Here, the wave energy under non-storm conditions appears higher for much of the coast, and the beach sediment is significantly finer than for northeast Bering Sea beaches.

Studies on the rates of change of the beach and nearshore were begun along the northeast Bering Sea coast. Beach and nearshore profiles were measured in July and September in the Nome, Unalakleet and Port Clarence areas. Little change was found. Presumably, this was because no large storms had occurred between the times profiles were measured (wave energy under non-storm conditions can be quite low). The profiles will be re-measured in FY 77 during June and October in an attempt to demonstrate amounts of change occurring during storms.

II. INTRODUCTION

A. GENERAL NATURE AND SCOPE OF STUDY

Very little information is available on the coastal processes of the Bering Sea coast of Alaska. This is a significant gap in our knowledge in view of anticipated coastal and nearshore developments in support of offshore petroleum exploitation.

Storms pose a major hazard to coastal developments in this region. For example, the severe November, 1974 storm caused storm surge elevations on the order of 4 m above mean sea level and waves reportedly 3 to 4 m in height along much of the northeast Bering Sea coast. Fifteen million dollars worth of damage occurred in Nome. During FY 76, the elevations of debris lines resulting from this storm were measured around the northeast Bering Sea coast. This was part of a study continuing into FY 77 on the coastal effects of this major storm. The study will include computer simulations of wave characteristics and shoreline changes.

Much of our effort during the initial year of study has been involved with regional characterization of the physical environment of the coast. This included classification of coastal morphology, determination of net littoral drift directions and reconnaissance of beach morphology and sediment characteristics. These studies have laid the groundwork for more detailed studies of coastal processes in the future.

In addition, studies on rates of change of the beach and nearshore were initiated along the coast of the northeast Bering Sea. These will be continued in FY 77. Studies on wave characteristics will be implemented in FY 77 and will aid in the interpretations of observed beach and nearshore changes.

B. SPECIFIC OBJECTIVES

1. Determination of net longshore drift directions for the Bering Sea coast of Alaska.

2. Characterization of coastal morphology for the Bristol Bay coast of the Alaska Peninsula and the northeast Bering Sea coast.

3. Measurement of debris line elevations resulting from the 1974 storm in the northeast Bering Sea.

4. Reconnaissance of beach morphology and sediment characteristics for the Bristol Bay coast of the Alaska Peninsula and the northeast Bering Sea coast.

5. Comparisons of beach and nearshore profiles measured at selected sites along the northeast Bering Sea coast at the beginning and end of the field season.

C. RELEVANCE TO PROBLEMS OF PETROLEUM DEVELOPMENT

The objectives outlined above are relevant to Tasks C-5, C-10, D-2 and D-11 of the Alaska O.C.S. Program Development Plan. Specifically,:

1. Task C-5 (rates of change in coastal morphology): objectives 2, 4 and 5.

2. Task C-10 (intensity and effects of extreme oceanic events): objective 3.

3. Task D-2 (circulation patterns and transport of petroleum related pollutants): objective 1.

4. Task D-11 (extent of transport of oil inland by storm surges): objective 3.

III. CURRENT STATE OF KNOWLEDGE

Little information related to coastal processes is available Relevant studies are listed below.

A. Greene (1970) observed longshore drift directions near Nome to be variable for June and July 1967, but predominantly to the east. Wave heights were generally low (∿ 30 cm), but storms during the late summer and fall were reported to produce high energy conditions.

B. The draft E.I.S. for the Lost River Project reports that wave heights vary from approximately 30 cm in height to 5-7 m with a theoretical maximum of 12 m at the mouth of Lost River. Longshore transport is generally from west to east. Sediment transported during storm conditions greatly exceeds that transported under 'normal' conditions.

C. The U.S. Army Corps of Engineers has conducted several studies in the area, including:

a. a report on flood protection and navigation improvement for Unalakleet (U.S. Army Corps of Engineers, 1972)

b. National Shoreline Report which reports severe coastal erosion at Dillingham (U.S. Corps of Coastal Engineers, 1971).

D. Fathauer (1975) provided a description of the meteorological characteristics of the severe 1974 storm in the Bering Sea. His results are reviewed in the section on Debris Line Elevations of this report.

E. Additional studies include work on Quaternary marine transgressions and old strand lines (Hopkins, 1957) and several studies on beach placer deposits near Nome (e.g., Greene, 1970) and along the Bristol Bay coastline (Berryhill, 1963).

IV. STUDY AREA

The study area is along the Bering Sea coast of Alaska. Specific areas for each portion of the study are outlined below.

1. Net littoral drift directions: Bering Sea coast of Alaska from Bering Strait in the north to Unimak Island in the south.

2. Coastal morphology and reconnaissance of beach morphology and sediment characteristics: Bristol Bay coast of the Alaska Peninsula and the northeast Bering Sea coast from Bering Strait to Yukon River.

3. Debris line elevations: northeast Bering Sea coast

4. Beach and nearshore profiles: selected areas along the northeast Bering Sea coast.

V. METHODS, RESULTS, DISCUSSION AND CONCLUSIONS

To meet our objectives we have prepared six separate reports and 10 maps. These are:

	page number
A. Net Littoral Drift Directions Along the Alaskan Bering Sea Coast (enclosed maps: SHEETS 1-6)	6
B. Coastal Morphology, Alaska Peninsula Coast of Bristol Bay and Norton Sound to the Bering Strait (enclosed maps: SHEETS 7-8)	15
C. Debris Line Elevations from the 1974 Storm in the Northeast Bering Sea (enclosed map: SHEET 9)	26
D. Beach Morphology: Bristol Bay Coast of the Alaska Peninsula and Norton Sound to the Bering Strait (enclosed maps: SHEETS 9-10)	31
E. Sediment Characteristics: Bristol Bay Coast of the Alaska Peninsula and Norton Sound to the Bering Strait (enclosed maps: SHEETS 9-10)	45
F. Beach and Nearshore Profile Comparisons (enclosed SHEET 9).	52

A. NET LITTORAL DRIFT DIRECTIONS ALONG THE ALASKAN BERING SEA COAST

INTRODUCTION

The maps presented here (Sheets 1-6) show interpretations of the directions of littoral drift along the Alaskan mainland coast of the Bering Sea, from Bering Strait in the north to Unimak Pass in the south. Littoral drift is the longshore transport of sediment on beaches and in adjacent shallow waters. This transport is caused largely by waves and wave-driven currents, aided locally by tidal and other currents. For a given size of wave, the transport is strongest when the waves approach shore at a moderately oblique angle, about 45° (Zenkovitch, 1967).

The littoral drift at any given point along a coast can be in either of the two longshore directions. Along many coasts the drift switches from one direction to the other many times through a year as wave conditions change. Thus, the direction of net drift over some period of time may differ from the direction of net drift in a single year. The directions shown on the summary map (Sheet 1) are the interpreted directions of long-term net littoral drift; by long-term is meant at least several years and perhaps as much as a few thousand years. The locations of the specific features used in making these interpretations are shown on Sheets 3 to 6. Symbols used on Sheets 3 to 6 are explained on Sheet 2.

Directions of littoral drift can be determined by several methods, such as monitoring the movement of artificially introduced tracer grains (Ingle, 1966), calculating the drift from known wave conditions by the use of a formula (Komar and Inman, 1970), making interpretations from longshore variations in the grain size or composition of the beach sediment, or making interpretations from the coastal landforms. All these methods have strengths and weaknesses. Monitoring the movement of tracer grains, for example, is the most reliable method for determining short-term littoral drift but would be a very time-consuming method of determining the long-term net littoral drift.

The method used in this report is the interpretation of coastal landforms. The interpretations were made by observing the landforms from aircraft during two summers and by studying maps and aerial photographs of the landforms. Only certain kinds of coastal landforms, which are described further on in this report, indicate the direction of littoral drift. Like other methods of determining drift directions, interpretations of coastal landforms involve certain problems which are discussed in general terms in the next section.

GENERAL PROBLEMS OF INTERPRETING DRIFT DIRECTIONS FROM LANDFORMS

The most serious problem in interpreting directions of littoral drift from coastal landforms is that some of these landforms mimic those produced by littoral drift but in actuality owe their form to other causes, such as the geologic structure of the bedrock. A similar problem is that some coastal landforms give ambiguous indications of drift direction, even though they are produced by littoral drift. On Sheets 3 to 6 we indicate by the symbol (?) those interpretations that we judge to be questionable.

Another problem is to estimate the length of time over which a landform indicates the direction of net littoral drift. The largest landforms develop during many centuries or millenia and thus indicate the long-term drift, whereas the smallest landforms may be produced during a single storm and thus indicate only short-term drift. Depositional landforms, which are composed of loose sediment, may develop more quickly than erosional bedforms cut in bedrock. On Sheets 3 to 6 of the report we distinguish by the symbol (m) those minor landforms that we judge could have formed in less than a year. The significance of minor landforms is increased, however, if they are numerous at any one time or if they were observed during several years; we note multiple occurrences by the symbol (s) on Sheets 3 to 6. We also note by a special symbol those short-term drift directions indicated by minor landforms that we judge to be opposite from the directions of long-term net drift (see Sheet 2).

Still another problem is that a landform may cause a change in the pattern of littoral drift as it develops. Many coastal landforms develop in ways that cause a reduction in the net rate of littoral drift (see, for example, Zenkovitch, 1967) and may eventually reach states of equilibrium, in which there is no net littoral drift. Some coastal landforms, such as spits, sometimes even produce reversals of littoral drift as they grow and shelter part of the coast from some of the waves. A few of the landforms in the Bering Sea may have reached states of equilibrium; if so, the drift directions shown on the maps indicate the directions during the development of these landforms.

TYPES OF LANDFORMS THAT INDICATE DRIFT DIRECTION

As a general rule, if the direction of littoral drift is to be inferred from a coastal landform, the landform must be asymmetric with respect to a line normal to the generalized shoreline trend. In most coastal landforms, the asymmetry of the shoreline itself provides a sufficient basis for interpretation.

Shoreline Offsets

Offsets or steps in the planform or map view of a coastline are geometrically of two kinds. In one kind, the shoreline is offset seaward in a downdrift direction. Offsets can be of either erosional or depositional origin; they occur at discontinuities in the erosional resistance of the coastal material and at channel mouths.

Offsets at groins. Groins are man-made structures placed across a beach to slow down or halt coastal erosion (U.S. Army Coastal Engineering Research Center, 1966). They produce a downdrift-landward offset (see sketch on Sheet 2) by causing deposition or lessening erosion updrift of the structure. Because groins trap relatively small amounts of sediment, the offsets visible at any one time do not necessarily indicate the direction of long-term net drift. The only examples of what might be called groins in the Bering Sea are some collections of metal junk on the beaches near Nome.

Offsets at headlands. Headlands of resistant bedrock tend to act like groins, producing downdrift-landward offsets, and in fact have been called "natural groins" (Inman and Frautschy, 1965). The offset may be produced by deposition updrift of the headland, by erosion downdrift of the headland, or by a combination of the two effects. Offsets at most headlands are large-scale features, and so the drift direction indicated by the feature is the direction of long-term net drift.

When inferring drift directions from offsets at headlands, one must take care to rule out the possibility that the offset was produced directly by faulting or folding, by differing erosional resistances of the coastal bedrock on either side of the headland, or by differing amounts of sediment suppled to the shoreline on either side of the headland. Such possibilities can most easily be ruled out where the offsets occur in a series, forming what might be called a "stepped shoreline".

Offsets at jetties. Jetties are man-made structures built into the sea at the sides of stream mouths, tidal inlets, or harbors to prevent shoaling or migration of the channel (U.S. Army Coastal Engineering Research Center, 1967). They tend to act like groins, producing a downdrift-landward offset across the channel mouth. However, exceptions can arise because of the complicated patterns of water flow and sediment transport in the vicinity of the channel mouth. The possible complications are discussed in the next section, on offsets at tidal inlets. The only example of jetties in the Bering Sea is the pair at the mouth of the Snake River in Nome.

Offsets at tidal inlets. Offsets at tidal inlets can be either downdrift-landward or downdrift-seaward. The reasons for the two types of offset have been studied by Goldsmith et al. (1975), Hayes et al. (1970), and Todd (1968), but are still not completely understood. Among the factors responsible for offsets at tidal inlets are tidal currents and wave refraction, both of which can be very complex. Another, and perhaps the main factor controlling the kind of offset is whether the inlet is a net sink or net source for sediment moving along the coast. If there is a decrease in the net drift rate across the inlet, the inlet is a net sink, just as a groin is, and will probably produce a downdrift-landward offset. If the inlet is a net source of sediment, a downdrift-seaward offset will probably be produced.

Offsets at stream mouths. If the interaction of stream mouths with the littoral drift is similar to the interaction of tidal inlets with the littoral drift, it would seem that all stream mouths should be characterized by downdrift-seaward offsets, for all streams are net suppliers of sediment to the sea. In actuality, no offset of any kind is present at the mouths of many small streams, probably because they are too small to have any significant effect. Some of the former distributaries of the Yukon River, south of its present delta, are characterized by downdrift-seaward offsets, as might be expected from their formerly large sediment discharges.

Surprisingly, many small streams in the upper part of Bristol Bay and in southern Norton Bay have downdrift-landward offsets at their mouths, the direction of net drift being indicated by other evidence. All offsets of this kind occur only on low, eroding, tundra coasts. Evidently the streams draining the low tundra carry very little sediment and somehow act as groins, perhaps by their water discharge stopping the littoral drift, as is suggested by the common occurrence of small spits at the updrift sides of the stream mouths.

Hooked Bays

Certain bays have a planform that is asymmetric relative to a line normal to the shoreline of the bay at its midpoint (see sketch on Sheet 2). The distinctive form and significance of such bays was first noted by Silvester (1960), and the tendency for the bay shoreline to approximate the form of a logarithmic spiral curve was first noted by Yasso (1965). These bays have variously been called spiral bays, headland bays, half-heart bays, crenulate bays, and hooked bays (Le Blond, 1972; Rea and Komar, 1975; Silvester, 1960, 1974; and Yasso, 1965). Hooked bays form by coastal erosion downdrift of headlands, but the reasons for their precise form are not fully understood. Despite the lack of complete understanding, they seem to be one of the more reliable indicators of the direction of long-term net drift. They are commonly associated with offsets at headlands.

Channel-Mouth Deflections

The fact that stream mouths tend to become deflected in a downdrift direction has been known for many years (Gulliver, 1898). The deflection is caused by the halting of the littoral drift on the updrift-side of the channel, the consequent tendency for the channel to be filled on the updrift side, the diversion of the stream flow to the downdrift side, followed by the erosion of the downdrift side of the channel. Deflections of many miles can be produced by the continued operation of this process. Tidal inlets can become deflected in the same way and commonly migrate to the downdrift ends of the lagoons that they drain (Price, 1952).

Channel-mouth deflections caused by littoral drift can be confused with those due to other causes. Some deflections are caused by longshore variations in wave height, these variations being most commonly caused by refraction of the waves (Bascom, 1954). Deflections of this kind are produced when storm waves build a berm or beach ridge that dams a stream mouth, whereupon the impounded water breaks through the berm wherever it is lowest. Since the berm height is proportional to wave height, the point of breakthrough is controlled by longshore variations in wave height. As deflections of this kind are produced suddenly, any evidence of a gradually increasing deflection rules out this process and suggests an origin by littoral drift.

Stream-mouth deflections take different forms on stable coasts, on straight prograding coasts, and where the stream is building a delta. A deflected stream on a straight coast flows parallel to the shoreline in back of a berm ridge for some distance, whether the deflection is produced by littoral drift or by longshore variations in wave height. Streams that flow obliquely to the shoreline across a prograded strand plain can rather safely be interpreted as having been gradually deflected by littoral drift (Allen, 1965); some well developed deflections of this kind occur on the north side of Bristol Bay between Cape Constantine and Kulukak Point. Gradual deflections of delta-building streams can also be ascribed rather safely to the effect of littoral drift; some well developed though small examples occur on the east sides of Kuskokwim Bay and of Norton Bay. A delta itself is likely to be made asymmetric by littoral drift (Komar, 1973).

Depositional Bodies

Oblique bars. Bars are ridges of sand or gravel in the intertidal or shallow subtidal zones of a beach. Only bars that are oblique to shore can be used to interpret drift directions; oblique bars trend seaward in a downdrift direction (Guilcher, 1974). If the bars are submerged, they may be visible from aircraft if the water is clear; otherwise, their form may be manifested by the pattern of waves breaking on the bar crests. Also, oblique bars can often be recognized from protuberances of the shoreline that mark where the bars are attached to the shore; these protuberances are known as giant cusps, though not all giant cusps are associated with oblique bars. Oblique bars are relatively small depositional bodies and thus may not indicate the long-term net drift direction.

Spits. Spits differ from oblique bars in being at least partly above the high-water line. Some spits protrude from a relatively straight pre-spit shoreline, whereas others continue the line of an updrift shoreline where the pre-spit shoreline bends landward into an embayment (see sketches on Sheet 2); in either type, the free end of the spit points in the downdrift direction. Most spits are large enough that they indicate the direction of long-term net drift. They are one of the most reliable indicators of drift direction.

Spits may produce a local reversal in drift direction in the area behind and downdrift of the spit. They do this by protecting the pre-spit shoreline from the dominant waves while leaving it exposed to waves from other directions. The diffraction of the dominant waves around the tip of the spit can also cause reversed drift in the area behind the spit.

Cuspate forelands. A cuspate foreland is a roughly triangular depositional plain that protrudes from the generalized shoreline. Although the term was originally restricted to pointed protuberances, it has come to be used for rounded protuberances also. Smaller features of this type have been called cuspate spits. Most cuspate forelands are composed of sediment that was carried to the depositional site by littoral drift, but some have been interpreted as having formed by other processes, such as delta growth (Hoyt and Henry, 1971). The manner of origin of cuspate forelands and cuspate spits has been a subject of much discussion (Gulliver, 1898; Zenkovitch, 1959; Tanner, 1962; Price, 1964; Voskoboymikov, 1966; White, 1966; Hoyt and Henry, 1971; Hopkins, 1971; Swift et al., 1972).

Cuspate forelands that are composed of material carried by the littoral drift can occur in two kinds of settings, either where the net littoral drift approaches the foreland from both sides or where the net littoral drift is unidirectional but decreases in a downdrift direction. An asymmetry of form is typical of the second kind (see sketches on Sheet 2). The few cuspate forelands in the Bering Sea seem to be of this type.

Downdrift-tapering barriers. Barrier islands that have one wide, rounded end and one narrow, pointed end are very suggestive of net drift in the direction of narrowing (Price, 1954). This interpretation is based on the similarity of a tapering island to a spit.

Depositional Ridges Marking Former Shorelines

Many coastal depositional bodies are covered by ridges that mark former shorelines and thereby record the stages of growth of the depositional bodies. These ridges include: beach ridges, which are formed by the wind blowing beach sand into vegetated areas behind the beach, where the sand is trapped; and cheniers, which are beach ridges separated from one another by muddy or peaty coastal deposits.

The pattern of ridges may permit the drift direction to be interpreted even where the gross form of the depositional body does not itself furnish sufficient evidence (see sketches on Sheet 2). The kind of evidence furnished by beach ridges is of the same kind furnished by repeated maps or aerial photographs of the coast. The principle involved is that a depositional landform generally grows or migrates in a downdrift direction. However, it is possible for sediment to be plastered onto the updrift side of a landform, especially if it is growing in size, and this possibility should be considered when interpretations of drift directions are made.

INTERPRETED NET LITTORAL DRIFT DIRECTIONS

General Discussion

Wave induced sediment transport along the eastern Bering Sea coast is seasonal due to ice coverage which advances south in October and covers 94% of the coast by February[1]. (Arctic Environmental Information and Data Center, 1974). Offshore ice inhibits the generation of large waves by limiting the wind fetch and ice attached to shore forms a protective rampart to wave-induced sediment movement. In general, the period over which ice does not directly affect the coast varies from three months (July-September) for the northern portion of the study area (Bering Strait to Norton Sound) to seven months (May-November) for the Alaska Peninsula coast of Bristol Bay.

Coastal weather stations in the southern Bering Sea (i.e. Cape Newenham, Port Moller) report an essentially bimodal

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[1] The coast is considered to be directly influenced by ice when ice concentrations along the coast are greater than 10%.

distribution of wind directions for the ice-free season, with the strongest component from the south and the other from the northwest (Arctic Environmental Information and Data Center, 1974). Net littoral drift directions are summarized on Sheet 1 and in general reflect transport by waves induced by winds from one of these directions. The Alaska Peninsula is protected from the south and drift along the coast is to the northeast in response to waves generated by winds from the northwest or west. Between the Alaska Peninsula and Norton Sound the transport is generally to the north in response to waves generated by southerly winds. Wind directions recorded at Nome on the Seward Peninsula in the northern portion of the study area are more uniformly distributed (Bureau of Mines, 1967). However, the north-south trending sections of coast on the eastern side of Norton Sound and between Bering Strait and Norton Sound still predominately reflect transport to the north. The east-west trending sections of coast on the north and south flanks of Norton Sound indicate transport to the east. This is in response to the considerably longer fetch to the west.

During storms considerably more sediment can be transported by waves than under normal conditions, and many of the coastal features used to interpret drift may have been largely formed during storms. A major storm track crosses the eastern Bering Sea from southwest to northeast during the latter portion of the ice-free season (late July to early September) (Arctic Environmental Information and Data Center, 1974). The cyclonic motion about the storm low pressure system causes a northerly air flow along the coast and correlates well with the interpreted dominant northward transport along the coast.

Discussion of Sheets 3-6

The nearly 3,000 km of open coastline of the eastern Bering Sea has been divided into four sections. Coastal strip maps for each section have been compiled onto Sheets 3-6. Net drift directions and the geomorphic criteria used in interpreting the directions are indicated on these sheets. Sheet 3 covers the Alaska Peninsula coast of Bristol Bay and Unimak Island. Sheet 4 includes the coastal area between the Alaska Peninsula and the Yukon-Kuskokwim Delta complex and Sheet 5 includes the Yukon-Kuskokwim Delta. Sheet 6 covers the northern portion of the study area from Norton Sound to the Bering Straight.

Alaska Peninsula Coast of Bristol Bay (Sheet 3)

This coast is relatively straight, but is segmented by six large embayments which are more or less protected from the Bering Sea by barrier spits or islands. Inbetween the embayments are subtle headlands which in many areas are bluffs eroded from unconsolidated sediment. In general, the net drift direction along this coast is to the northeast with local reversals at the embayments.

The coast can be divided into a series of coastal cells in which the convergences of drift occur at the embayments and divergences of drift are a short distance northeast of each embayment. The positions of divergence and, therefore, the points south of which the drift is to the southwest, occur most commonly on the order of 10 km to the northeast of each embayment (Bechevin Bay, Izembek Lagoon, Port Heiden, Ugashik, and Egegik Bays). The Port Moller area forms a considerably larger cell where the divergence occurs at Cape Kutuzof, 37 km to the northeast of the embayment. The long-term effect of this system of coastal cells is to straighten the coast by eroding the headlands and filling in the embayments.

High Tidal Estuaries (Sheet 4)

Between the Alaska Peninsula and the Yukon-Kukokwim Delta complex are a series of funnel shaped embayments. As the tidal bulge moves into these embayments it is amplified, creating extremely large tidal ranges. For example, the diurnal range at Clark's Point in Nushagak Bay is 5.9 m and at Kvichak at the head of Kvichak Bay is 5.0 m. Within Kvichak, Nushagak and Kuskokwim Bays are found linear shoals that are aligned parallel to the tidal currents. These shoals on the order of 10 m in height and spaced 4 km apart, are characteristic of high tidal environments.

In general, the net littoral drift directions range between northeasterly and northwesterly depending upon shoreline orientation. The embayments, which in general are not closed off to the Bering Sea by barrier spits or islands due in part to high tidal current velocities, form coastal cells where positions of convergence are at the heads of embayments and divergence points are at the headlands between embayments.

Yukon-Kuskokwim Delta Complex (Sheet 5)(1)

The Yukon-Kuskokwim Delta complex encompasses the region between Kuskokwim Bay to the south and Norton Sound to the north. It is of relatively low relief, but is punctuated by a few coastal highlands such as the Askinuk Mountains south of Scammon Bay. The coastal sediment is predominately muddy, but concentrations of fine sand are also found. Between Hooper and Scammon Bays, however, sands predominate.

The net drift direction is predominantly to the north in this region(2) In the absence of obvious coastal morphologic features indicating drift south of Hooper Bay, we have used the observation of coastal erosion to the south and beach ridge or chenier development to the north along the periphery of large lobate sections of coast to interpret drift to the north. At Hooper Bay and along the barrier spits and islands at Kokechik and Scammon Bays transport is predominantly to the north with some local reversals just north of Scammon Bay, but the drift is inferred to be predominantly to the north.

(1) We are indebted to William R. Dupré for many of the interpretations in this section.

(2) We refer primarily to the transport of fine sands or coarser material. The direction of transport of finer material may not be controlled by waves, even though waves may initially entrain and put the material into suspension.

Norton Sound to the Bering Strait (Sheet 5)

Norton Sound is a roughly rectangular embayment approximately 110 km wide and 220 km long. It has a remarkably uniform depth on the order of 20 m. The southern side of Norton Sound east of Stuart Island is a lava flow coast composed of boulders and solid rock with little indication of net drift direction. Little longshore transport is inferred for the lava flow section of coast, however, due to the lack of material fine enough to be transported. To the west of Stuart Island drift is to the east. For the north-south trending coast forming the east flank of Norton Sound the drift is to the north. Inlet migration to the north at Unalakleet threatens several houses at the southern portion of the village. Norton Bay is a relatively shallow embayment located at the northeast corner of Norton Sound. The drift is generally northeasterly, with convergence at Koyuk Inlet at the head of the bay. Golovnin Bay to the west of Norton Bay forms a closed coastal cell with northerly transport into the bay. Between Golovnin Bay and the northwest corner of Norton Sound the drift is inferred to be more variable than in most areas previously considered. Stream mouth deflections, a small sediment accumulation behind a jetty, beach ridges on the barrier spits enclosing Safety Lagoon and spit growth at Safety Lagoon inlet all generally indicate drift to the east. Analyses of vertical aerial photography of the region between Topkok Head and Sledge Island, however, show longshore bars which are slightly oblique to the shoreline and attach at their eastern ends indicating drift to the west.

Between Norton Sound and the Bering Strait lie a classic hooked bay, a recurved spit over 30 km in length encompassing Port Clarence and rocky headlands leading to the Bering Strait. Between Norton Sound and Port Clarence the long term drift is generally to the north. The morphology of the hooked bay may, however, be in equilibrium with waves coming from the south so there may now be little net drift within the bay. Two cells operate within Port Clarence, one with convergence at the southern portion of the bay and the other with convergence at the mouth of Grantley Harbor. Between Port Clarence and the Bering Strait there is a divergence point near King River, which is part of the drainage system of the York Mountains. To the east sediment is transported into Port Clarence and to the west transport is toward the Bering Strait.

B. COASTAL MORPHOLOGY: ALASKA PENINSULA COAST OF BRISTOL BAY AND NORTON SOUND TO THE BERING STRAIT

CLASSIFICATION CRITERIA

A large variety of coastal classification schemes have been proposed (Johnson, 1919; Shepard, 1963; Cotton, 1952; Bloom, 1965), but few are appropriate to relatively small areas where detailed knowledge of the coastal morphology is desired. Our approach is to establish criteria that can be applied to relatively short segments of coast (on the order of 1 km) and from which one can make preliminary judgments on whether the coast is eroding or accreting.

The criteria are based on groupings of physiographic features found along a given segment of coast. The physiographic features found within the study areas include tidal flats, beaches, barrier beaches (includes barrier spits and islands), dune or beach ridges (whether found singly or in complexes), erosional outcrops on beaches and bluffs or cliffs. Definitions for the physiographic features and symbols used on Sheets 7 and 8 are given in Table 1. Sheet 7 covers the Bristol Bay coast of the Alaska Peninsula and Sheet 8 covers the northeastern Bering Sea coast. Symbols for a given segment of coast are arranged so the physiographic feature closest to the lowtide line is described first with shoreward features following in sequence. For example, the symbol TfBeBl indicates for that segment of coast there is a tidal flat, followed by a beach, followed by a bluff or cliff. The symbol Ba/BeRc indicates a barrier spit, island or beach that is composed of (/) a beach, followed by a beach or dune ridge complex. The symbol Be(Bl-Rs) indicates a beach that is followed by either (-) a bluff (Bl) or a single dune or beach ridge (Rs). For these cases, the coast has not been divided into segments of BeBl and BeRs because either the division would result in segments of coast too small to be discernible at the scale of the maps or data was not sufficient to justify the divisions. The data compiled on Sheets 7 and 8 were gathered primarily from aerial reconnaissance flights over two field seasons. Additional data were gathered from maps and vertical aerial photography.

From these groupings of coastal physiographic features, preliminary judgments on whether the coast is erosional or accretional can be made. For example, where a bluff or cliff follows a beach (BeBl) the coast can, in general, be considered erosional or a source of sediment. However, the development of a beach ridge or dune complex seaward of a bluff (BeRcBl) would be interpreted as an area that is presently accretional, but in the past has been erosional. The presence of a barrier island or spit in general indicates that the area is or has been a sink for sediment. The composition of a barrier provides further information. For example, a barrier with no beach or dune ridge development (Ba/Be) is subject to relatively frequent overwash which would tend to move the barrier landward. Segments of barriers with dune or beach ridge complexes (Ba/BeRc) would be considered in general accretional. Related arguments would apply to other groupings of physiographic features such as BeRc (accretional) or OBeP (erosional).

TABLE 1: DEFINITIONS AND SYMBOLS FOR COASTAL PHYSIOGRAPHIC FEATURES (SHEETS 7 AND 8)

Tf - Tidal Flat: Gently sloping inter-tidal area found seaward of the beach. It is unvegetated and commonly composed of relatively fine sediments (muds or silts).

O - Outcrop: Exposure of relatively resistant material (rock, mud) on the beach foreshore indicating beach erosion of shoreward migration.

Be - Beach: Accumulation of unconsolidated sediment (sands to boulders) found between the low tide line and the next physiographic feature shoreward (e.g. beach or dune ridge, bluff).

Rs - Single Beach or Dune Ridge: Ridge of unconsolidated sediment found shoreward of the beach. It is often vegetated and oriented parallel to the present shoreline. Formed by eolian or swash processes or a combination of the two.

Rc - Beach or Dune Ridge Complex: Multiple occurrences of beach or dune or ridges. Individual ridges are oriented parallel to past shorelines.

Ba - Barrier Spit, Island or Beach: A beach that partially or completely encloses a body of water.

Bl - Bluff or Cliff: A near vertical slope shoreward of the beach eroded from unconsolidated deposit or rock.

S - Slope: A relatively steep slope shoreward of the beach. Used to characterize what follows a beach if no other physiographic features (Rs, Rc, Bl, etc.) occur.

P - Plain: A gentle or near horizontal slope shoreward of the beach. Used to characterize what follows a beach if no other physiographic features (Rs, Rc, Bl, etc.) occur.

ADDITIONAL SYMBOLS USED ON SHEETS 7 and 8

/ : To be read as the phrase composed of. For example, Ba/BeRs would be read as a barrier composed of a beach followed by a single beach or dune ridge.

- : To be read as or. For example, Be(Rs-Bl) would be read as a beach followed by a single ridge or a bluff.

m : Indicates physiographic features which are relatively small scale. (i.e. Blm).

Judgments of these types, however, are subject to complications that are not included in the classification scheme. For example, beach ridge or dune complexes even though they represent past accretion, may be truncated in places by the present shoreline indicating local erosion. Even though a barrier represents a sink for sediment, the barrier may presently be eroding due to depletion of the sediment source and/or migration landward by overwash processes. Additional studies are required to precisely determine coastal stability. These studies should also include rates of coastal change.

Brief descriptions of coastal morphology for the Alaska Peninsula coast of Bristol Bay and Norton Sound to the Bering Strait follow. For details the reader is referred to the enclosed maps (Sheets 7 and 8).

BRISTOL BAY COAST OF THE ALASKA PENINSULA (SHEET 7)

This relatively straight coastline is segmented by six large embayments (Port Moller, Izembek Lagoon, etc.) and a number of smaller embayments. In general, the embayments are separated from the Bering Sea by barrier islands or spits (Ba). Between the embayments, bluffs (Bl or BeBl) are found in addition to other coastal types (e.g. BeRs). A comparison of the morphology (Sheet 7) to net littoral drift directions for the same area (Sheet 3) (see also text in section on Net Littoral Drift Directions), shows that in general the long term trend has been to erode areas between embayments (sediment sources) and deposit sediment at the mouths of embayments (sediment sinks). The coastline has been and continues to be straightened by this process.

The percent occurrence of physiographic features is given in Table 2 and the percent occurrence of coastal types or groupings of physiographic features in Table 3. Tidal flats (23%) are extensive along the northern portion of the coast, in some areas exceeding 3 km in width and are generally absent south of Ugashik Bay. Beaches line 96% of the coast. Areas lacking beaches include a 15 km length of coast on Unimak Island and relatively short segments at headlands such as Cape Seniavin. Barriers make up 24% of the coastline. Four percent of the coastline exhibits barriers with no beach or dune ridges (Ba/Be) (Fig. 1) and these are subject to relatively frequent overwash. Eight percent exhibits a single dune ridge (Ba/BeRs) and twelve percent exhibit a ridge complex (Ba/BeRc). Erosional areas (BeBl or Bl) occur along 26% of the coastline (Fig. 2) and accretional areas that were formerly erosional (BeRcBl) along 6% (Fig. 3). Segments of coast characterized as BeRcBl occur primarily in the northern portion of the study area. Eight percent of the coast is characterized by a single dune ridge followed by a bluff (BeRsBl). The major proportion of the remainder of the coast is composed of a beach followed by a single dune or beach ridge (BeRs) or ridge complex (BeRc). Segments of coast characterized as BeRc occur primarily updrift of embayments (see Sheet 7 and section on Net Littoral Drift Directions).

NORTON SOUND TO THE BERING STRAIT (SHEET 8)

In contrast to the Alaska Peninsula study area, this region is dominated by bluffs or cliffs (greater than 49%; Table 2). Generally, these are of three types: 1) high resistant rock cliffs that are found, for

TABLE 2: PERCENT OCCURRENCE OF COASTAL PHYSIOGRAPHIC FEATURES

PHYSIOGRAPHIC FEATURE	Tf(2)	Be	Ba	Rs	Rc	0	Bl
ALASKA PENINSULA COAST OF BRISTOL BAY	23	96	24	32(2)	27	0(3)	38(4)
NORTON SOUND TO THE BERING STRAIT	16	75	16	2	11	1	49(5)

(1) Occurrences of tidal flats (Tf) were obtained primarily from maps.
(2) Includes 3% Rsm and does not include 10% Rs-Bl (some of which is Rsm).
(3) Although no outcrops (o) were observed, they may have been obscured by hightides.
(4) Includes 2% Blm and does not include 10% Rs-Bl (some of which is Blm).
(5) Includes 15% Blm and does not include 14% distributed between Bl-BeS, Be (Bl-S) and Be (Bl-P).

TABLE 3: PERCENT OCCURRENCE OF COASTAL TYPES(1,2)

	BARRIERS			OUTCROPS	
COASTAL TYPE	Ba/Be	Ba/BeRs	Ba/BeRc	OBe(P-S)	OBeBl
ALASKA PENINSULA COAST OF BRISTOL BAY	4	8	12	0	0
NORTON SOUND TO THE BERING STRAIT	7	2	7	1	<1

	BLUFFS							
COASTAL TYPE	Bl	BeBl	Bl-BeBl	BeRsBl	BeRcBl	Bl-BeS	Be(Bl-S)	Be(Bl-P)
ALASKA PENINSULA COAST OF BRISTOL BAY	4	22	0	8	6	0	0	0
NORTON SOUND TO THE BERING STRAIT	25	24	1	0	<1	11	2	1

	REMAINDER OF COAST				
COASTAL TYPE	BeRs	BeRc	Be(Rs-Bl)	BeP	BeS
ALASKA PENINSULA COAST OF BRISTOL BAY	16	9	10	0	0
NORTON SOUND TO THE BERING STRAIT	0	4	0	8	6

(1) Tf not included; see Table 2 and text.
(2) Small scale features designated as (m) are not discriminated from larger scale features.

Figure 1: Example of a Ba/Be coast (Seal Islands, Bristol Bay coast of the Alaska Peninsula).

Figure 2: Example of a BeBl coast (between Egegik and Ugashik Bays; Bristol Bay coast of the Alaska Peninsula).

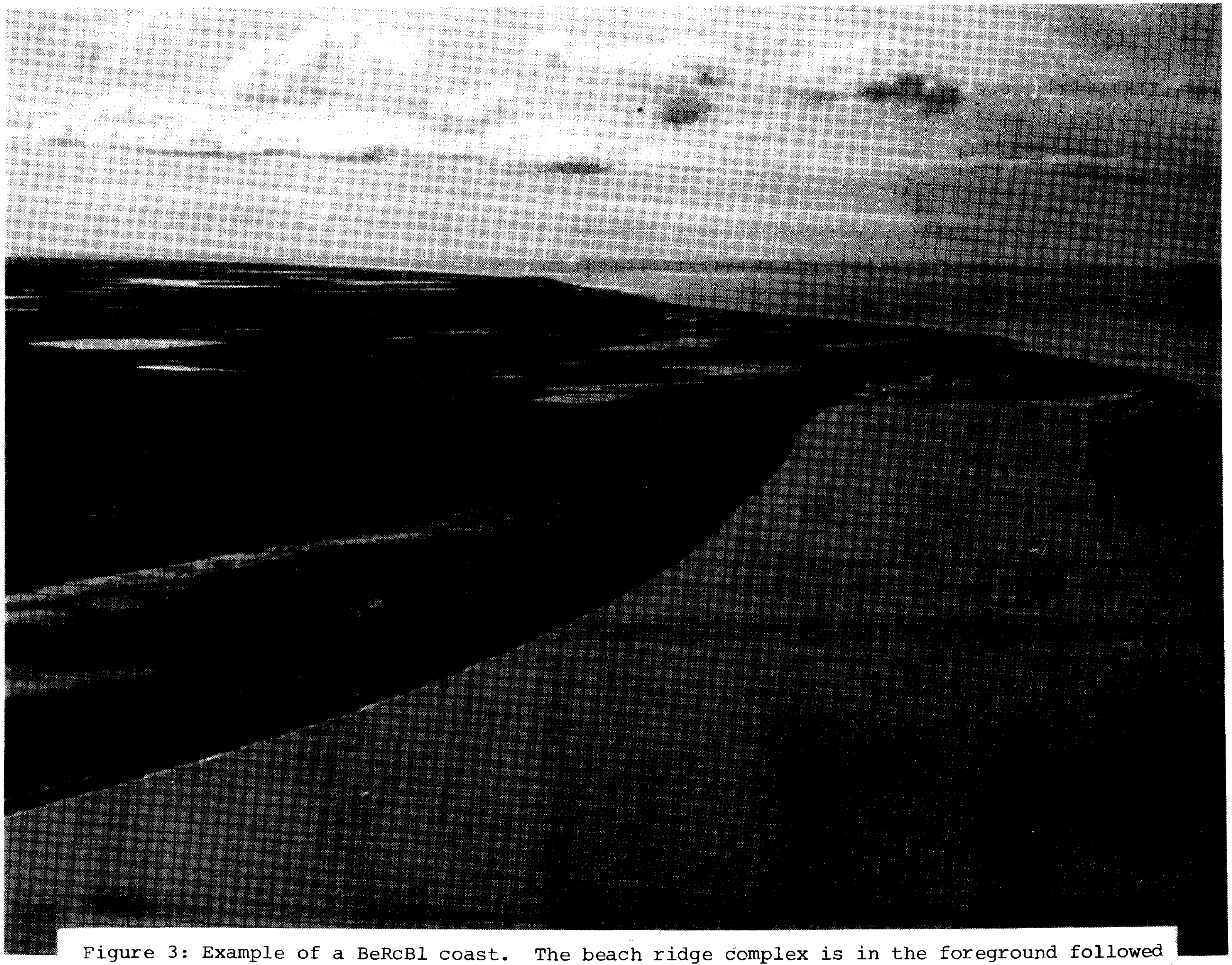

Figure 3: Example of a BeRcBl coast. The beach ridge complex is in the foreground followed landward by a bluff (between Egegik Bay and Naknek River; Bristol Bay coast of the Alaska Peninsula).

example, between the Bering Strait and Port Clarence (Fig. 4) and at the entrances to Golovnin and Norton Bays; 2) relatively low tundra bluffs eroded into muds that are found, for example, in the Nome area (Fig. 5) at the head of Norton Bay and west of St. Michael on the south side of Norton Sound; and 3) relatively resistant cliffs eroded from old lava flows east of St. Michael (Fig. 6). Each of these types of bluff or cliff coasts are considered erosional, but of course the rates of erosion of the tundra bluffs greatly exceed the other types. For example, preliminary comparisons of charts and aerial photographs from 1951 and 1976 respectively indicate that the tundra bluffs east of St. Michael have retreated on the order of 200 m which is a rate of 8 m per year! Most of this erosion probably occurs sporadically during storms. An observation of interest along the lava flow coast (east of St. Michael Island) was that boulders were found as far landward as the debris line from the 1974 storm (see section on Debris Line Elevations). In places the boulders showed a rough size grading of fining shoreward; an indication of transport by fluid forces during a storm.

Beaches line only 75% of the coast compared to 96% for the Alaska Peninsula study area (Table 2). Areas lacking beaches (Bl) are in general associated with the areas discusses above with the exception of the Nome area (BeBl).

Outcrops on beach foreshores were observed along 1% of the coast and indicate coastal retreat. These were confined to two areas: rocky outcrops (OBeBl) west of Nome and outcrops of mud along a segment of coast north of Moses Point in NOrton Bay.

Percent occurrence of potential sinks for sediment are less than on the Alaska Peninsula study area. For example, barriers occupy 16% of the coast versus 24% for the Alaska Peninsula study area, and beach ridge complexes (including those occurring on barriers) occupy 11% versus 27% (Table 2). The occurrences of beach ridges on barriers are, however, less for the Norton Sound-Bering Strait area (44% of the Norton Sound-Bering Strait barriers are Ba/Be versus 17% for the Alaska Peninsula study area).

A distinct difference between the two coasts is the negligible development of single beach ridges (Rs) in the Norton Sound-Bering Strait area (2% versus > 32%; Table 2). The ridges observed in the Alaska Peninsula study area appear to be primarily of eolian origin (foredune ridges). The beach sediment is generally coarser in the Norton Sound-Bering Strait area, which inhibits the development of this type of ridge (see section Sediment Characteristics). Observed instead, were ridges of swash origin and represent a berm stranded by coastal accretion. Consequently, relatively stable, accretional or moderately erosional coasts of low relief could exhibit a ridge in the Alaska Peninsula study area, whereas ridges in the Norton Sound-Bering Strait area in general require coastal accretion to become established.

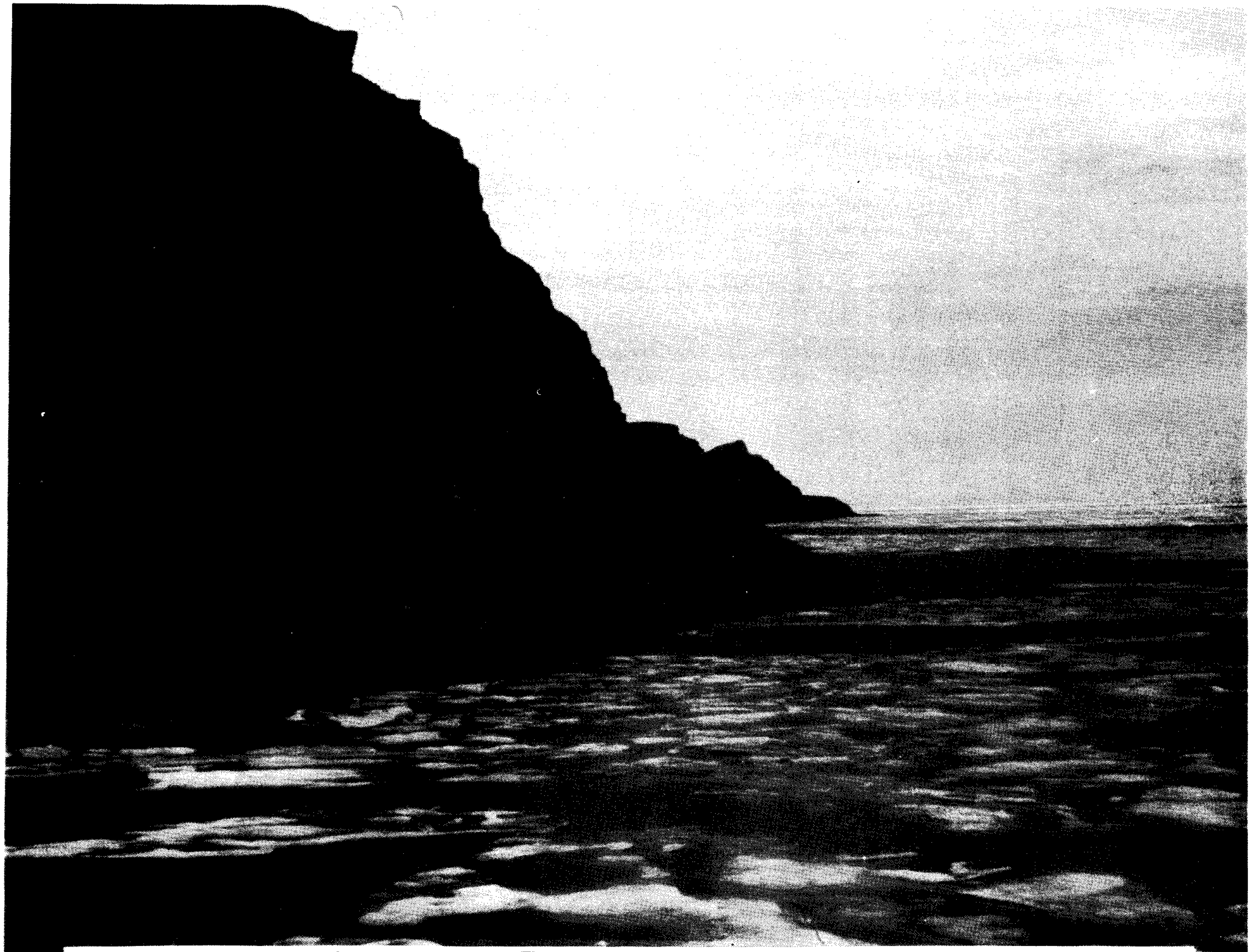

Figure 4: Example of a Bl coast on the left side of the photograph (between Port Clarence and the Bering Strait in the northeast Bering Sea).

Figure 5: Example of a BeBl coast where the bluff is eroded into fine, unconsolidated sediment (several Km east of Nome along the northeast Bering Sea coast).

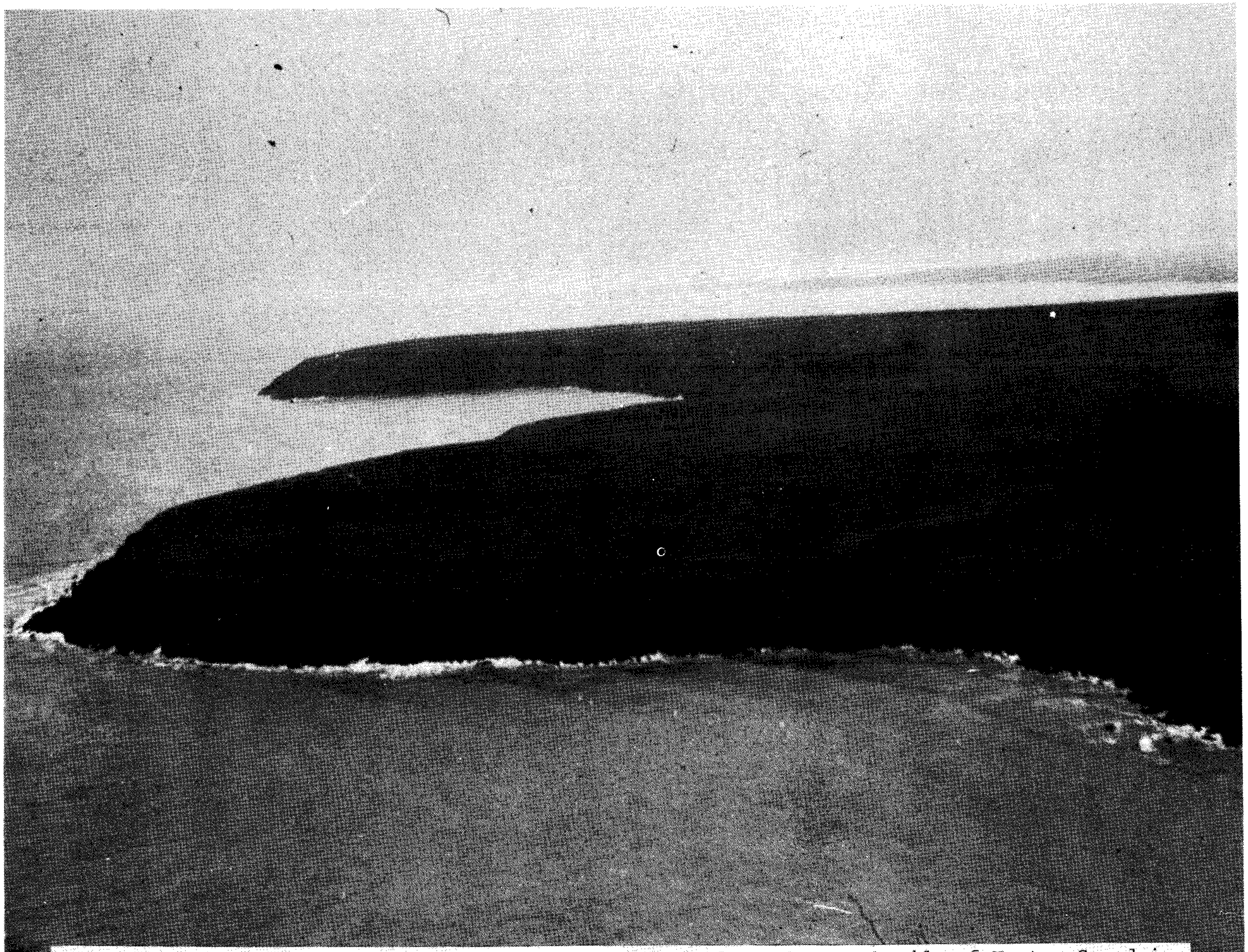

Figure 6: Lava flow coast (east of St. Michael Island on the south side of Norton Sound in the northeast Bering Sea).

C. DEBRIS LINE ELEVATIONS FROM THE 1974 STORM IN THE NORTON SOUND REGION

During November 9-12, 1974 two severe storms moved through the Bering Sea and caused extensive flooding along the coast of the eastern Bering Sea, particularly in the Norton Sound area. The second storm, the more severe of the two, originated off the Aleutians on November 10 and moved to the north, passing through the Bering Strait late on the 11th. (See Fathauer (1975) for a comprehensive review of the meterological characteristics of the storms.) Sustained winds recorded at Nome reached 40 kts from the south with gusts as high as 60 kts, and barometric pressure dropped approximately 34 mb. Disastrous coastal flooding occurred in the Nome area beginning in the late hours of the 11th, resulting in $15 million damage.

During the 1975-76 field seasons, debris line elevations resulting from this storm were measured around the periphery of Norton Sound and as far north as Port Clarence. In all but a few cases there was only one debris line observed, suggesting that the 1974 storm had incorporated older debris lines and pushed them higher. Debris line elevations provide a combined measure of sea level rise over the astronomical tide level due primarily to wind set-up, inverse barometric effect , wave set-up and run up. Wind set-up is the rise in sea level associated with wind induced mass transport of water shoreward. Shallow depths, such as in Norton Sound (depth < 20 m), in general enhance wind set-up by inhibiting bottom return flows. The magnitude of wind set-up is complicated by factors such as the dimensions of the basin and the storm, and the forward velocity of the storm. The inverse barometric effect refers to the change in sea level due to atmospheric pressure. A 34 mb drop in pressure, such as occurred in the 1974 storm, would result in about a 0.3 m rise in sea level. Shoreward of the wave break-point, mean sea level is greater than sea level outside the surf zone due to the presence of waves. This wave set-up would, for example, amount to approximately .5 m for breaking waves 3 m in height with a period of 8 seconds. Wave measurements during the storm are lacking, but wave height estimates by residents of Nome range from 3 to 5 m. Run up elevation refers to the height that the uprush of wave swash reaches. The debris line would be expected to be positioned near the upper limit of upwash.

Beach profiles were also measured at many localities around the study area. Where debris lines and well developed "storm" berms were observed, the berm crest elevations correlated quite well with debris line elevations (Fig. 7). This was true even when the debris line was considerably shoreward of the berm crest. Berm crests tend to build to the height of run up, an elevation which under storm conditions would include the additional effects of wind set-up, inverse barometric effect and wave set-up. Flooding shoreward of the berm crest, but at an elevation approximately equivalent to the berm crest elevation, would allow debris to be driven farther shoreward by wind and waves overtopping the berm. The relationship may, however, be restricted to beaches composed of relatively coarse material (such as in the study area) where sediments are generally sandy gravels (see section on sediment characteristics) because on sandy foreshores the berm is often eroded away during storms.

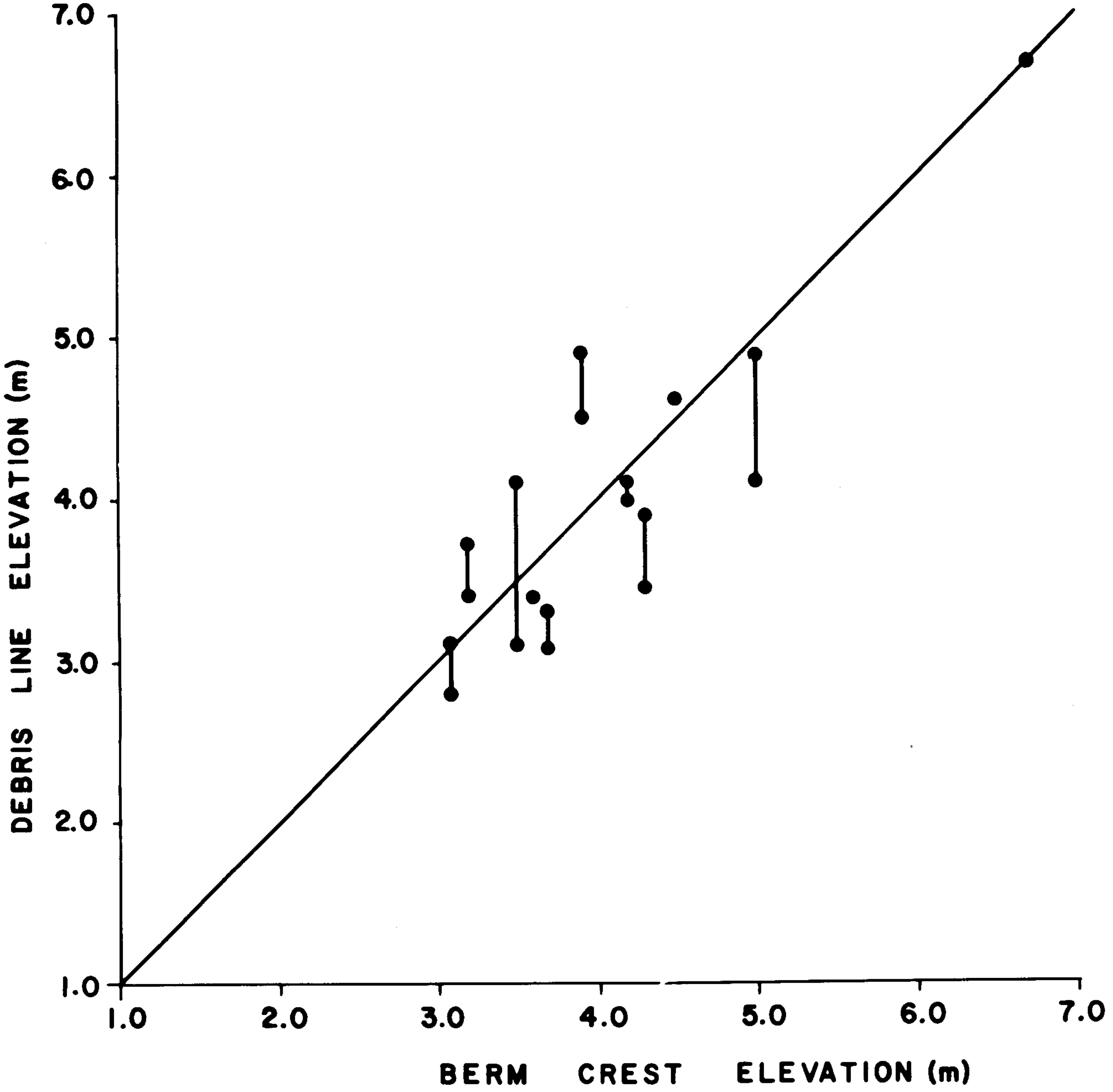

Figure 7: Debris line elevations plotted versus berm crest elevations at the same locations.

In Figure 8, debris line elevations and berm crest elevations for areas where debris lines were not observed are plotted versus profile number. The data are arranged along the abscissa from north to south along the coast. Data are tabulated in Table 4 and include distances of coastal inundation for each site. These measurements include primarily open coast observations, as opposed to debris lines observed along the shores of enclosed lagoons. The measurements shown in Figure 8 do not, however, include debris lines situated on top of bluffs where waves breaking against the bluff could throw debris considerably higher than the storm water level, (for example at N1, debris was 7.8 m above observed water level on top of a bluff) and berms situated in front of bluffs where reflected waves would inhibit berm development. Also plotted are elevations of still water marks from Nome obtained from the U.S. Army Corps of Engineers, Anchorage. The debris line and berm crest elevations are referenced to observed sea level. For much of the study area the astronomical tide level would not cause excessive errors. For example, the diurnal range at Port Clarence is 0.43 m, at Nome is 0.48 m and at Golovnin Bay is 0.55 m. For the southernmost portion of the study area, however, tide variations are greater; for example, at St. Michael the diurnal range is 1.2 m. The water marks in the Nome area are refe-

There appear to be changes in storm sea level (defined here as the maximum extent of runup) around the periphery of the study area. North of Norton Sound the elevation was on the order of 3.25 m. In the Nome area (northern side of Norton Sound) the data indicated an elevation on the order of 4 m. Three observations in Golovnin Bay indicate elevations on the order of 3.75 m for two sites (due to potential errors resulting from atronomical tides these are not considered to be appreciably different from the Nome area measurements) and an extremely high debris line over 6.5 m for one site. The anomalous measurement occurred on a pocket beach composed of cobbles on the east side of Golovnin Bay. Here, the relatively steep foreshore (9.3°) may have behaved as a bluff, so that intense wave breaking against the foreshore may have thrown debris considerably higher than the storm sea level. In Norton Bay, to the east of Golovnin Bay, elevations were on the order of 3 m. The highest measurements (obtained on the eastern side of Norton Sound) were on the order of 4.5 m. The elevations appear to decrease on the southern side of Norton Sound (< 4m), but here measurements referenced to observed sea level subject to larger errors due to astronomical tides.

Shorefast ice had begun developing in shallow areas prior to the storm. In the Unalakleet area an ice block lifted by the storm sea level rise, was driven ashore by wind and breaking waves and damaged a building. At Point Spencer in Port Clarence, ice blocks were driven ashore as much as 100 m. Measurements of inundation by the 1974 storm (defined as the horizontal distance between debris line and observed sea level) varied between 24 m for a profile on the southern side of Norton Sound to over 300 m for a profile in Norton Bay (Table 4). These measurements indicate the distance over which ice blocks could have caused damage at these sites. Furthermore, large logs were abundant in the debris line. These logs, which were presumably floating nearshore, are a potential source of damage to coastal structures. These potential consequences of storms in this environment pose additional hazards to coastal developments over what would result from flooding and wave activity alone.

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1. Interpretations are considered preliminary until better tide data are available.

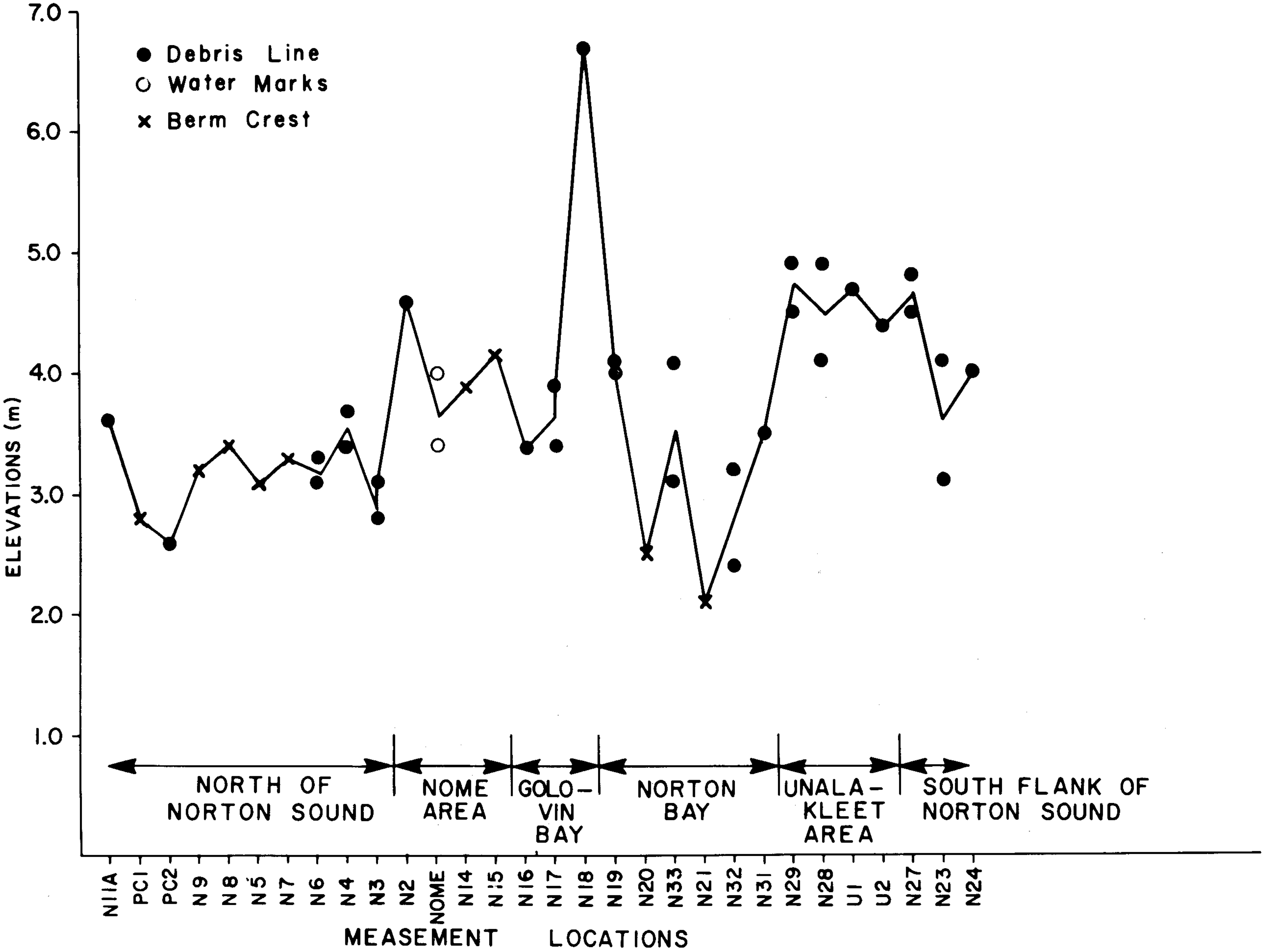

Figure 8: Debris line, water mark and berm crest elevations plotted versus location (see Sheet 9).

TABLE 4: Norton Sound to the Bering Strait: Berm Crest Elevations, Foreshore Slopes and Debris Line Elevations (z) and Distances Shoreward From Observed Sea Level (x)

Profile Number	Location Lat (N)	Long (W)	Berm Crest Elevation (m)	Foreshore Slope (°) (9)	Debris Line Seaward (8) Z (m)	x (m)	Landward (8) z (m)	x (m)
N1	64°31'45"	165°41'0"	- (1)	3.6	-	-	-	-
N2	64°33'0'	165°55'0"	4.5	5.1	4.6	50	-	-
N3	64°34'15"	166° 6'30"	3.1	3.4	2.8	43	3.1	52
N4	64°37'15"	166°20'15"	3.2	2.1	3.4	195	3.7	202
N5	64°56'8"	166°31'30"	3.1	4.1	-	-	-	-
N6	64°41'15"	166°26'15"	3.7	4.4	3.1	97	3.3	105
N7	64°50'15"	166°24'0"	3.3	3.4	-	-	-	-
N8	65°3'45"	166°46'0"	3.4	4.3	-	-	-	-
N9	65°9'15"	166°57'0"	3.2	3.7	-	-	-	-
N10	65°20'58"	166°50'0"	3.7	6.0	-	-	-	-
N11	65°29'30"	167°7'30"	- (1)	6.2	3.6 (2)	-	-	-
N12	65°26'15"	167°32'15"	- (1)	-	-	-	-	-
N13	64°53'38	166°26'30"	- (3)	4.3	-	-	-	-
N14	64°34'45"	163°56'30"	3.9 (5)	5.4	-	-	-	-
N15	64°31'0"	163°53'0"	4.2	6.7	-	-	-	-
N16	64°28'22"	163°3'30"	3.6	5.0	3.4	58	-	-
N17	64°32'45"	162°57'45"	4.3	6.2	3.4	64	3.9	72
N18	64°25'30"	162°49'15"	6.7	9.3	6.7	41	-	-
N19	64°33'15"	162°27'45"	4.2	4.8	4.0	42	4.1	45
N20	64°41'52"	161°58'30"	2.5	2.5	-	-	-	-
N21	64°50'0"	161°19'0"	2.1	2.7	-	-	-	-
N22	63°40'8"	160°53'30"	3.3	6.7	-	-	-	-
N23	63°28'15"	161°21'0"	- (4)	-	3.8	22	4.3	24
N24	63°27'30"	161°43'15"	- (4)	-	4.0	35	-	-
N25	63°16'15"	162°36'0"	- (6)	-	-	-	-	-
N26	63°9'0"	162°51'0"	- (3)	5.5	-	-	-	-
N27	63°33'45"	161°4'15"	- (4)	-	4.5	40	4.8	47
N28	64°12'45"	160°57'0"	5.0	8.9	4.9	32	4.1	40
N29	64°21'30"	161°12'0"	3.9	4.4	4.5	57	4.9	69
N30	64°30'30"	161°16'15"	- (1)	6.1	-	-	-	-
N31	64°35'30"	160°51'0"	3.5	6.4	-	-	-	-
N32	64°46'0"	160°50'30"	- (7)	-	2.4	-	3.2	-
N33	64°46'15"	161°37'30"	3.5	-	3.1	299	4.1	320

(1) No berm present; foreshore followed by bluff or cliff.
(2) Debris line measured several hundred meters east of N11 where there was no bluff.
(3) Profile did not extend to sea level.
(4) Lava flow coast; no beach present.

(5) Represents foreshore elevation; no berm present.
(6) No beach; wet tundra coast.
(7) Measured only the debris line.
(8) Refers to the seaward and shoreward extent of a single debris line.
(9) Measured between the shoreward extent of the foreshore and observed sea level.

D. BEACH MORPHOLOGY: BRISTOL BAY COAST OF THE ALASKA PENINSULA AND YUKON RIVER TO THE BERING STRAIT

Beach profiles distributed along the Bristol Bay coast of the Alaska Peninsula and between the Bering Strait and Yukon River in the northeast Bering Sea were measured during the 1976 field season. The primary objective of this part of the study was to collect a set of onshore beach profiles that will be the basis for monitoring long-term (i.e., several years) changes in regional shoreline movement. This is complemented by the study of seasonal onshore-offshore changes described in Section F. These regional profiles will be remeasured in the event of a major storm or after a period of several years, if justified. This will provide information on large-scale changes in shoreline position as opposed to short-term, cyclical changes.

Additional objectives included regional reconnaissance of beach morphology and sediment characteristics. Sediment characteristics of the beaches at each profile location are discussed in Section E of this report. Discussion of beach morphology follows.

METHODS

Forty-two beach profiles along the Bristol Bay coast of the Alaska Peninsula were measured during September 6-12, 1976 and 33 profiles were measured between the Bering Strait and Yukon River in the northeast Bering Sea during June-July, 1976. Profile locations are shown on Sheets 9 and 10 and their latitudes and longitudes are given in Tables 4 and 5.

Profiles were measured using stadia and level. Vertical distances were measured to 1 cm and horizontal distances were mesaured to 1 m using range finding stadia lines within the level. In general, profiles covered the area between the landward extent of the backshore and the swash zone. At each profile location, one or more reference stakes were driven into the ground landward of the backshore. The horizontal position and vertical elevation of the tops of stakes were measured with respect to the profiles. This datum will allow the profiles to be remeasured in the future.

TWO DIMENSIONAL BEACH MORPHOLOGY

Beaches along the northeast Bering Sea coast (Sheet 9) generally appear to be in equilibrium with storm conditions. On sections or coast of relatively low relief landward of the backshore and on barrier beaches, well developed storm berms were observed(1) (Fig. 9). Berm

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(1) The majority of profiles measured were of this type. (N4-6, 8-10, 12, 10-21, 28-29, 21, 22) (Sheet 9 and Table 4).

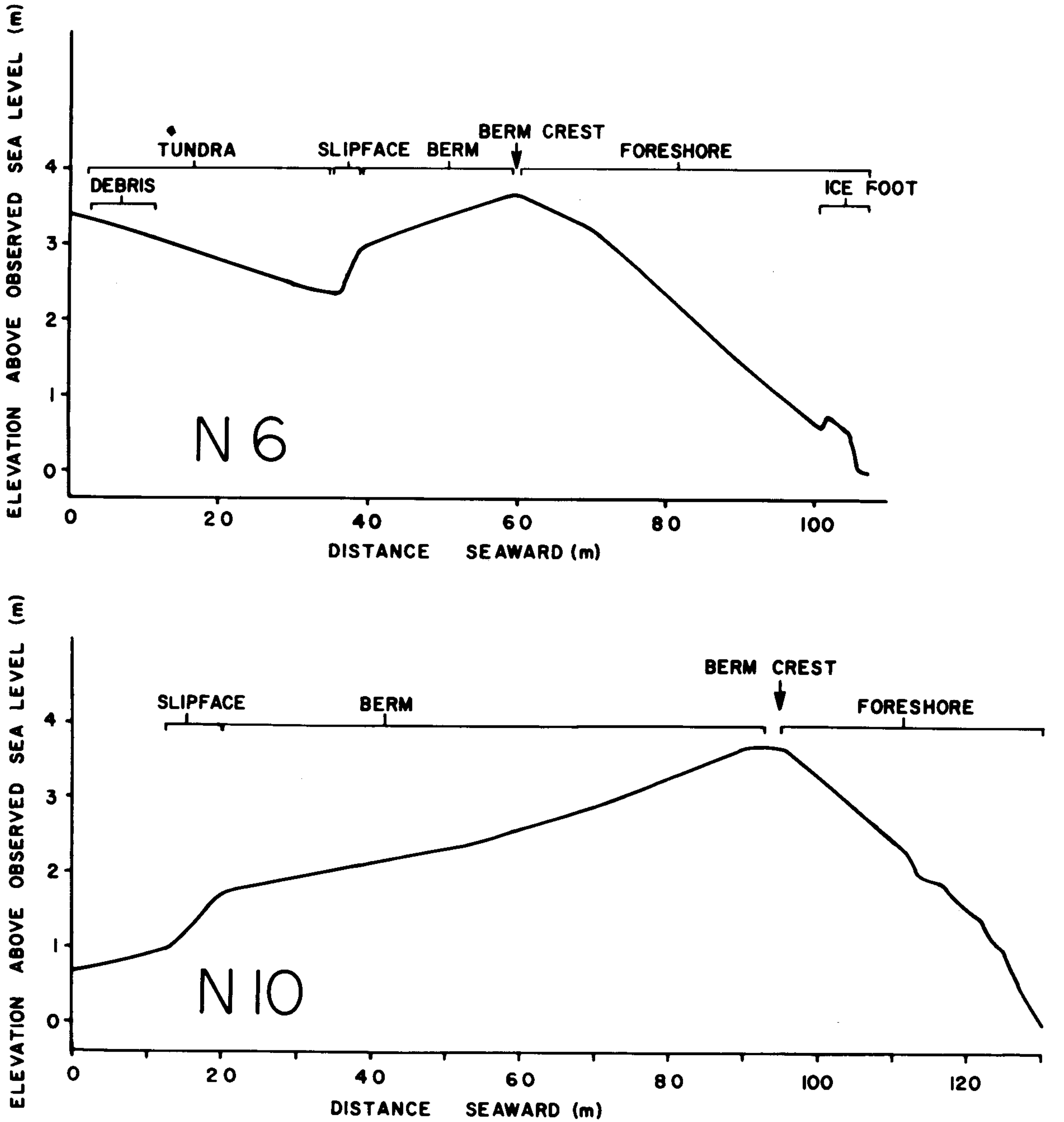

Figure 9: Examples of storm berms at profiles N6 and N10 (see Sheet 9).

crest elevations were on the order of 3-4.5 m above sea level(1) (Table 4) and (as discussed in the section on Debris Line Elevations) were at about the same elevation as the debris lines of the 1974 storm (Fig. 7). These features developed during storms; the berm crests reaching the approximate elevation of storm runup. During nonstorm conditions, wave energy appears to be quite low (wave heights on the order of .3 m). Under these conditions, runup reaches elevations far lower than the berm crests.

These storm berms were characterized by a steeply sloping slipface on their shoreward margin (Figs. 9 and 10). These slipfaces develop in response to landward transport of sediment into a standing body of water and occur on both barrier beaches (Fig. 10) and beaches not presently enclosing water (N6 in Fig. 9). For the latter case, water was ponded shoreward of the berm crest in response to storm surge and waves overtopping the berm crest. Net shoreward transport of sediment over the berm crest during storms migrates the beach landward.

Generally, where bluffs or cliffs followed a beach, no berm was present (Fig. 11). the foreshore sloped uniformly between the base of the bluff and sealevel. Again, these profiles appear to represent storm effects. During storms, waves reflect at the bluff or cliff causing reversals of transport on the foreshore. This inhibits the development of a berm. Profiles of this type are N1, 11, 12 and 30.

In most cases, the measured beach profiles could be classified as one of these types of storm profiles. That the profiles appear not to reflect fair weather conditions, such as multiple berms of lower elevations, is probably a function of the coarseness of the beach sediment and the low wave energy. In general the beaches are composed of sandy gravels and coarser material (see section on Sediment Characteristics) which resist movement by low waves. However, ridge and runnel topography(2) was observed on beaches in the Nome area following breakup in 1975 (Fig. 5). These features represented the rebuilding of the beach following the 1974 storm, which had occurred shortly before freeze up the previous season. The beaches in this area are, however, composed of finer material than most of the northeast Bering Sea coast (see section on Sediment Characteristics), which may have contributed to this modification of the storm profile.

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(1) Berm crest elevations were referenced to observed sea level. Astronomical tides are in general low and introduce relatively small errors (see section on Debris Line Elevations).

(2) Ridge and runnel topography refers to bar-like features, aligned parallel to the shoreline, that migrate onto the beach foreshore under non-storm conditions.

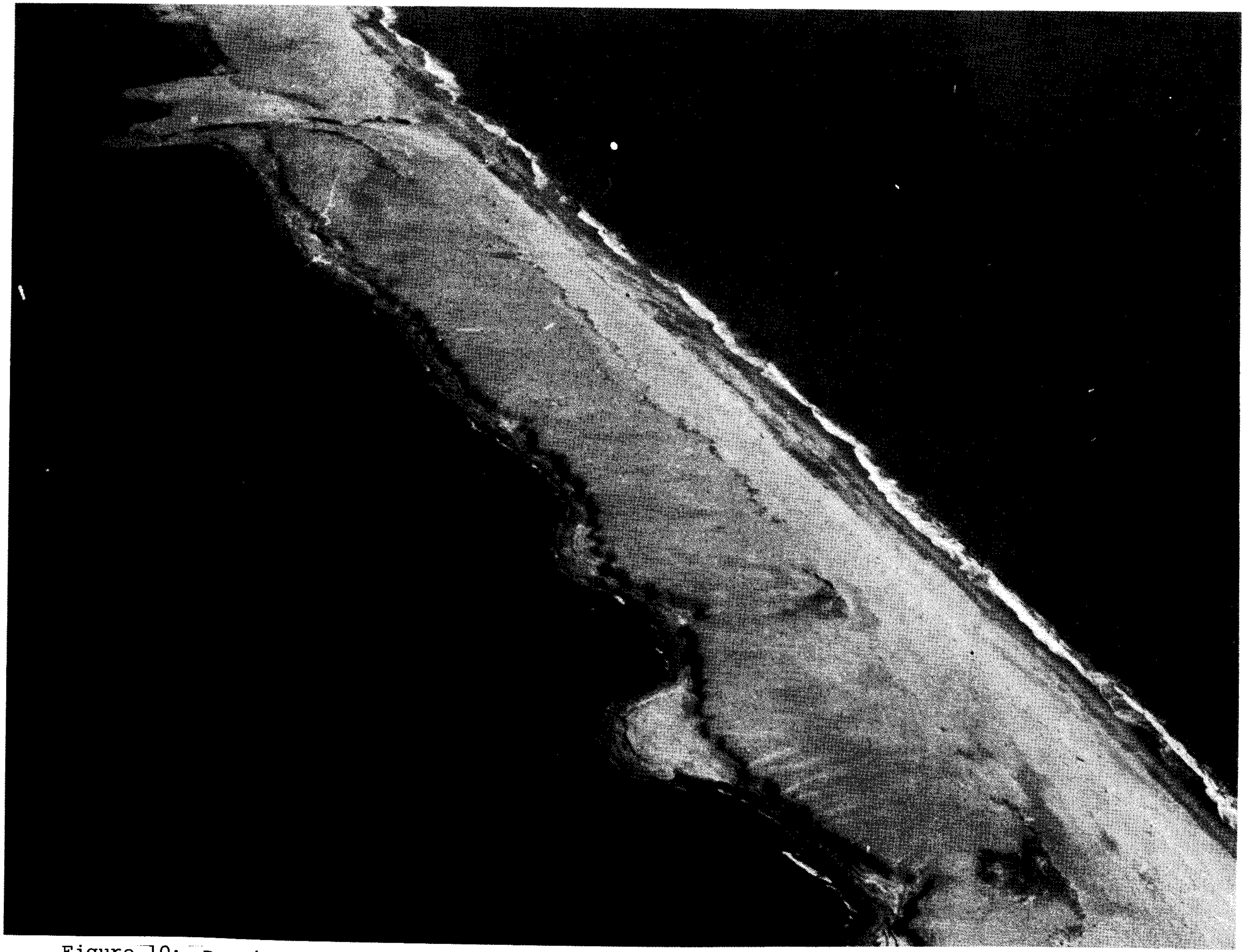

Figure 10: Barrier beach (south of Pt. Spencer in the northeast Bering Sea) showing well developed slipfaces on its landward margin. Bering Sea is to the right.

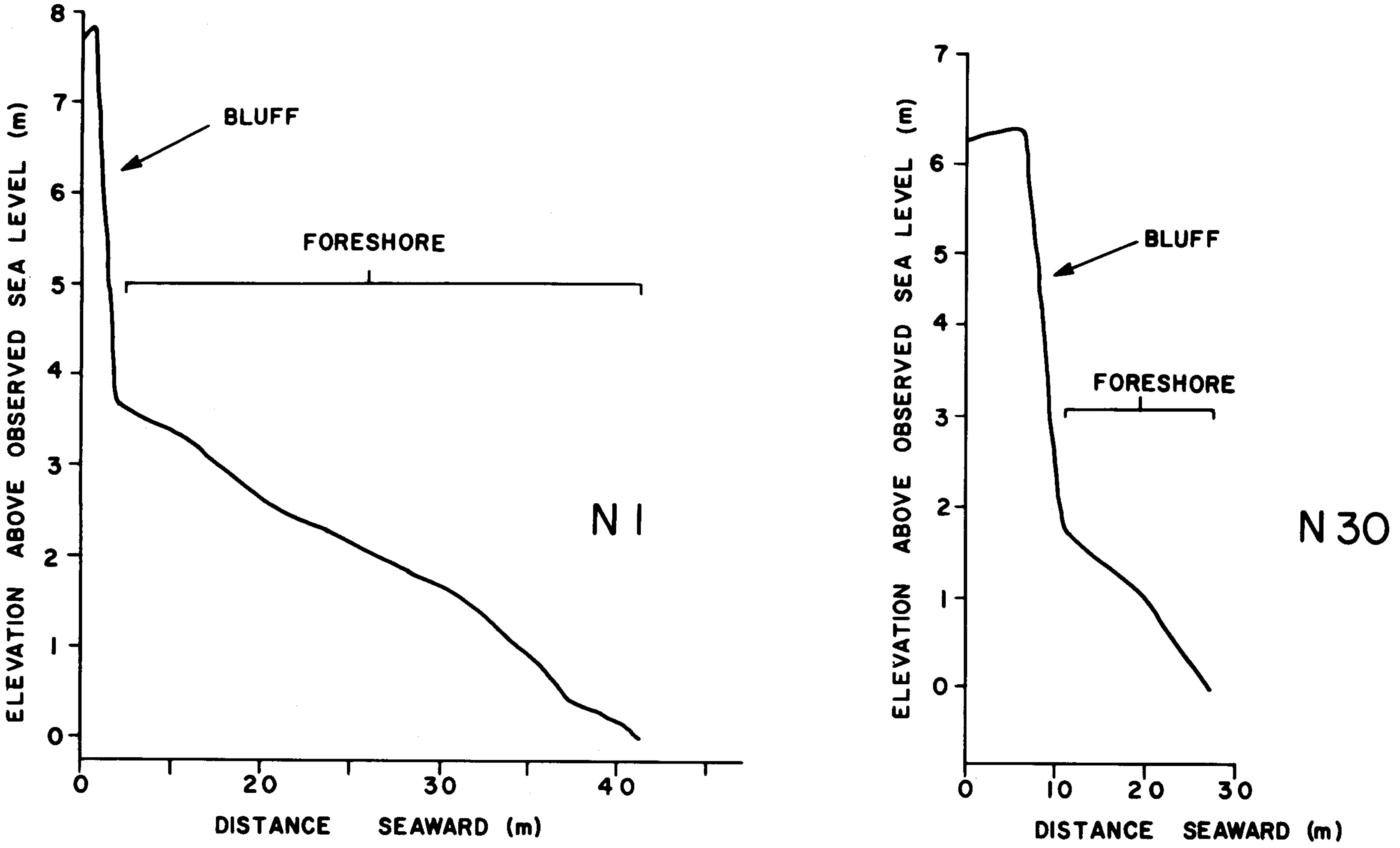

Figure 11: Examples of storm profiles shoreward of bluffs at profiles N1 and N30 (see sheet 9)

Bristol Bay Coast of the Alaska Peninsula

In contrast to the Yukon River to Bering Strait region, beaches along the Bristol Bay coast of the Alaska Peninsula are modified to a much greater extent under non-storm conditions. Two dimensional morphologies in many areas are similar to the Norton Sound region (Fig. 12), but where berms were observed, berm crest elevations were on the order of 1-2 m above mean higher high water (Table 5). Wave energy appears to be higher in this region, particularly along the southern extent of the Alaska Peninsula. Consequently, berm crests can be overtopped during spring tides, whereas the berm crests in the northeastern Bering Sea region are overtopped only during relatively severe storms. Multiple berms were observed in many areas, and berms were often observed seaward of bluffs (A16 in Fig. 13) and foredune ridges (A37 in Fig. 13). During storms wave reflection from the bluffs and dune ridges erodes the berms, but under non-storm conditions the berms build back up. The greater mobility of the beaches in this area under non-storm conditions is a function in part of the greater wave energy and the finer beach sediment (see section on Sediment Characteristics).

THREE-DIMENSIONAL BEACH MORPHOLOGY

Yukon River to the Bering Strait

Giant cusps, which are rhythmically spaced crescentic shoreline features associated with offshore bars, were observed along segments of coast between Golovnin Bay and Sledge Island, west of Nome. The cusps were best developed on the barriers enclosing Safety Lagoon where they were spaced on the order of 500 m. Examples from the Safety Lagoon area are shown in Figure 14. The photograph was taken in July 1975 after the major 1974 storm (see section on Debris Line Elevations). Overwash deposits can be seen encroaching the road that runs between Safety Lagoon inlet at the top of the photograph and the village of Solomon. A rough correspondence between the landward limit of the deposits and the position of giant cusps is apparent; the overwash deposits extend further landward opposite the embayments of giant cusps than elsewhere. This suggests the giant cusps controlled the spatial characteristics and in part the extent of overwash in this area(1).

Preliminary analyses of vertical aerial photography in the Safety Lagoon area shows that the giant cusps are quite mobile, changing form and spacing over relatively short periods of time. This represents the movement of large quantities of sediment; a large portion of which apparently is occurring under non-storm conditions. Detailed studies of these features and their effect on the coastal environment are to be undertaken in the future.

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(1) This effect is similar to what Dolan (1971) described for overwash deposits on the Outer Banks of North Carolina.

TABLE 5: Bristol Bay Coast Of The Alaska Peninsula: Berm Crest Elevations And Beach Slopes

Profile	Location		Berm (1) Crest Elevation (m)	Slope (2) (°)
	Lat (N)	Long (W)		
A1	58°48'45"	157°1'0"	- (3)	-
A2	58°38'15"	157°13'0"	- (4)	6
A3	58°28'45"	157°28'30"	1.2	5
A4	58°23'45"	157°31'30"	1.9	6.9
A5	58°14'38"	157°29'45"	1.2	4.0
A6	58°11'38"	157°31'45"	2.0	5.5
A7	58°8'15"	157°35'15"	1.3	5.7
A8	57°56'15"	157°37'45"	.8	-
A9	57°44'15"	157°41'30"	- (8)	4.2
A10	57°38'30"	157°42'30"	-	-
A11	57°32'15"	157°47'30"	.6	2.4
A12	57°28'0"	157°56'15"	- (8)	1.0
A13	57°23'30"	158°1'45"	1.2	3.3 (5)
A14	57°19'30"	158°18'0"	.9	7.0
A15	57°10'45"	158°28'0"	1.1	17.0 (6)
A16	57°0'45"	158°39'30"	1.6	3.8 (5)
A17	56°53'0"	158°53'0"	.75	6.5
A18	56°42'0"	159°20'30"	1.45	2.3
A19	56°36'45"	159°42'0"	1.0	6.9
A20	56°26'30"	160°0'0"	2.5	7
A21	56°23'45"	160°9'0"	2.0	8.6
A23	56°18'15"	160°18'30"	- (8)	9.1
A24	56°10'52"	160°25'30"	- (8)	5.4
A25	56°0'45"	160°33'0"	1.4 (6)	10.1
A26	56°1'52"	160°52'30"	1.3	7.6
A27	56°0'15"	161°12'0"	- (6)	-
A28	55°56'30"	161°36'30"	1.6	9.4
A29	55°53'0"	161°49'0"	- (8)	5.1
A30	55°48'52"	161°56'0"	- (7)	7.8
A31	55°46'15"	162°4'15"	- (8)	5.4
A32	55°43'30"	162°8'0"	- (8)	4.1
A33	55°33'30"	162°24'0"	- (8)	7.5
A34	55°26'30"	162°36'0"	.7	5.7
A35	55°23'45"	162°54'30"	- (7)	13.5
A36	55°16'45"	162°57'15"	.4	4.1
A37	55°14'8"	163°1'15"	- (4)	6.2
A38	55°10'30'	163°10'30"	2.7	10.9
A39	55°6'0"	163°22'30"	2.5	6.3
A40	55°3'8"	163°31'15"	1.7	4.2
A41	55°2'45"	163°41'15"	- (4)	20.1 (5)
A42	55°1'22"	163°55'15"	- (8)	3.5
A43	54°55'15"	164°14'0"	- (8)	6.5

Footnotes for Table 5 on the following attached sheet.

FOOTNOTES FOR TABLE 5:

(1) Berm crest elevations are in meters above mean higher high water. Measurements in the field were referenced to observed sea level. The elevations were corrected to mean higher high water using tide predictions for Kvichak River, Egegik Bay, Port Heiden, Port Moller, Amak Island and Cape Sharichef. A linear variation in tidal height with distance along the coast between two adjacent tide stations was assumed. Corrections were made only when the tide was flooding at both stations or ebbing at both stations (For a few cases, profiles were measured near the turn of the tide so one station was flooding and the other ebbing. For the most part this would introduce relatively small errors (<.3m) and these cases are included in the tabulation). The elevations are considered to be only approximate.

(2) Slope was measured in the area where sediment samples were taken (usually the upper foreshore; see section on Sediment Characteristics).

(3) Tundra bluff coast; no beach.

(4) Sealevel not measured.

(5) Several sediment samples taken. Slope measured in the area of the upper foreshore sample.

(6) Erosional foreshore.

(7) Tidal corrections were questionable.

(8) No berm present.

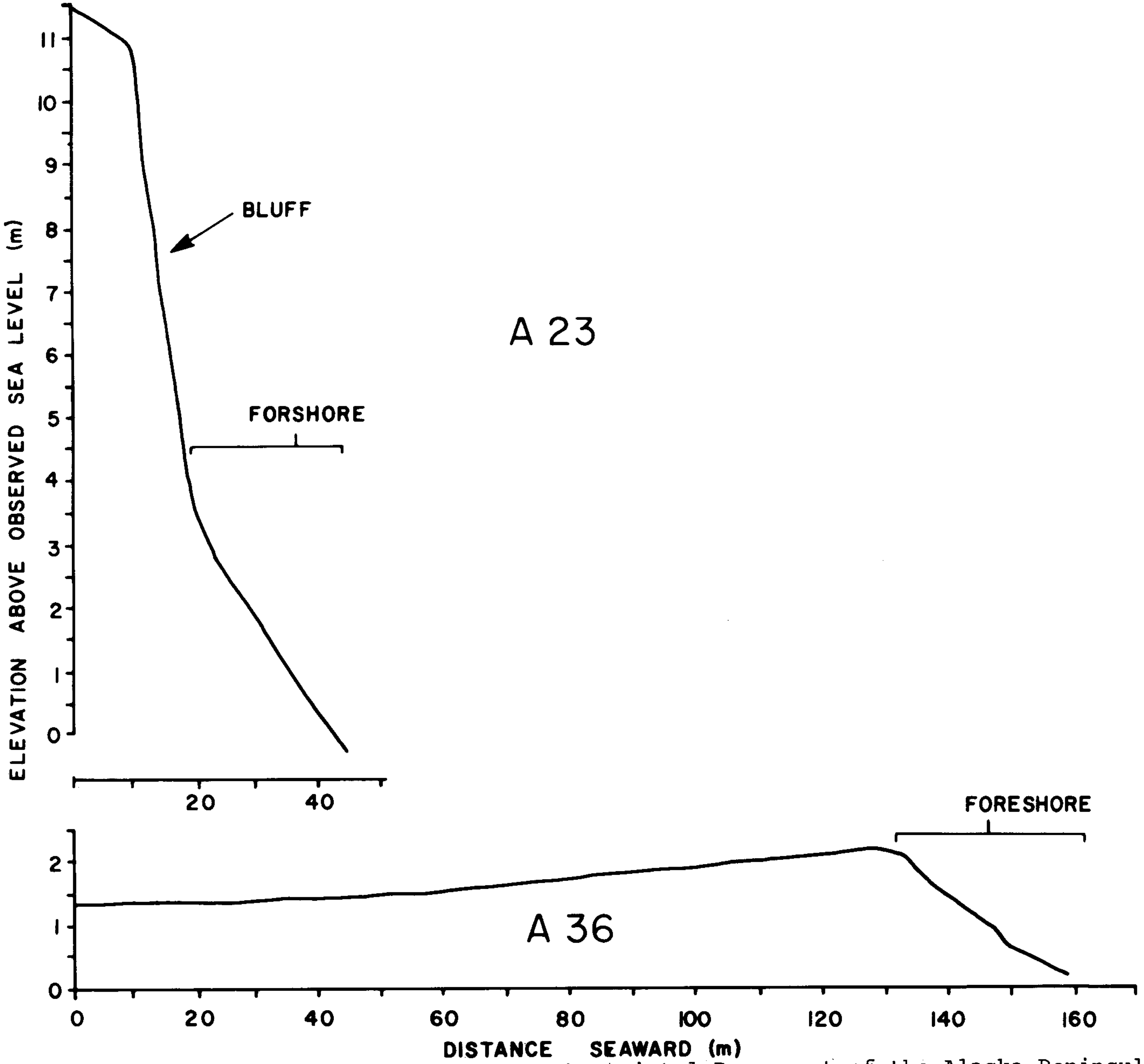


Figure 12: Examples of profiles along the Bristol Bay coast of the Alaska Peninsula (A23,A36; see sheet 10).

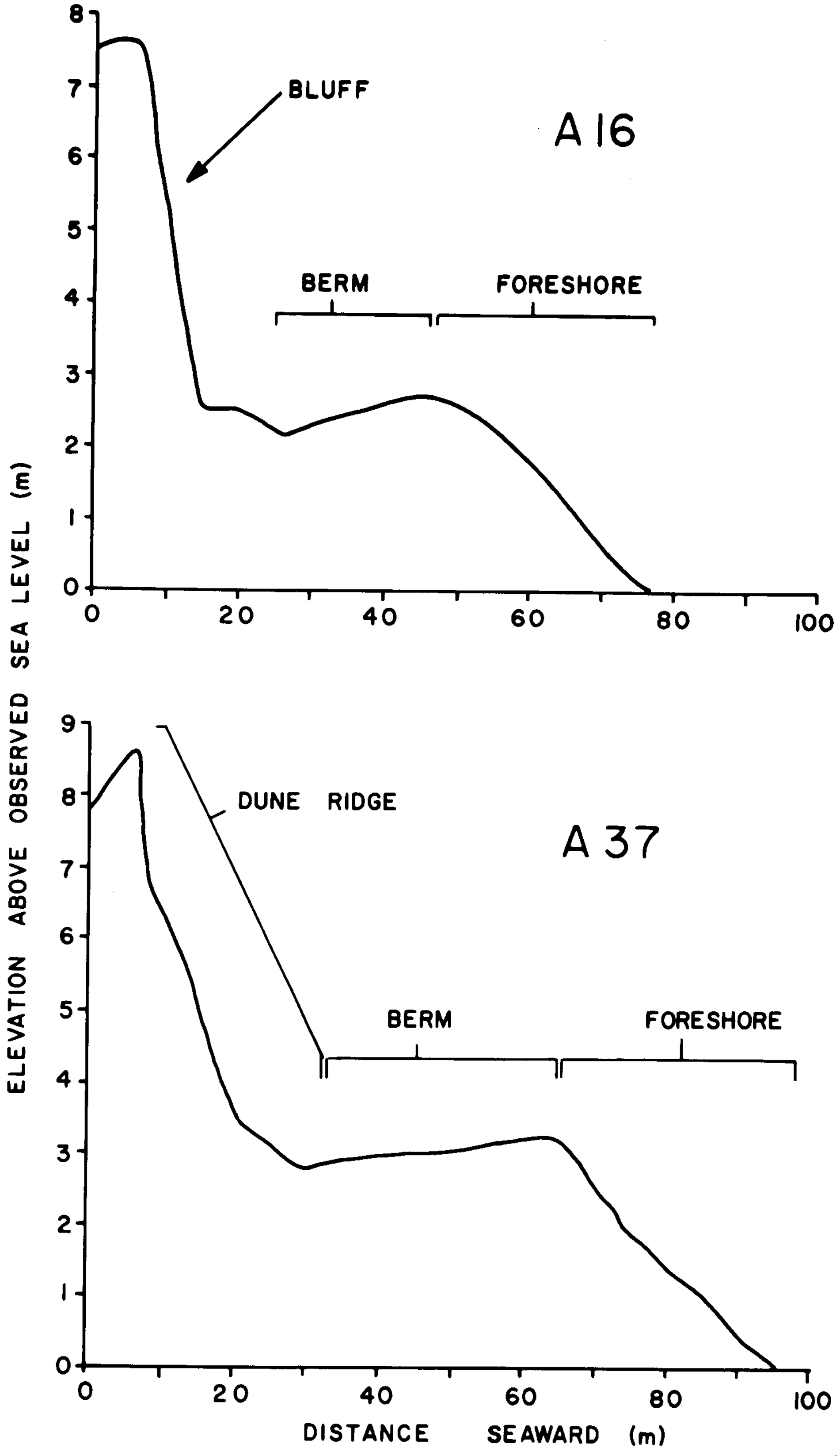


Figure 13: Examples of berm development seaward of a bluff and dune ridge (A16,A37; see sheet 10).

Figure 14: Giant cusps and overwash deposits on a barrier enclosing Safety Lagoon (northeast Bering Sea coast).

Bristol Bay Coast of the Alaska Peninsula

Giant cusps were observed along much of this coast and were particularly well developed along the barriers enclosing embayments (see Sheet 7 and section on Coastal Morphology). Another type of three dimensional feature was observed superimposed on beaches in Urilia Bay on Unimak Island and other areas as far north as Izembek Lagoon. These were large scale eolian dunes which were oriented roughly parallel to prevailing winds from the south and were rhythmically spaced along the coast (Figs. 15 and 16). The dunes attach to the foredune ridge and decrease in height seaward, tapering to a point near the berm crest. At the foredune ridge the features are on the order of 10 m in height. The features are similar in form to wind shadow dunes that develop downwind of local obstructions, but precisely how these form (and whether they are presently stable) is unknown.

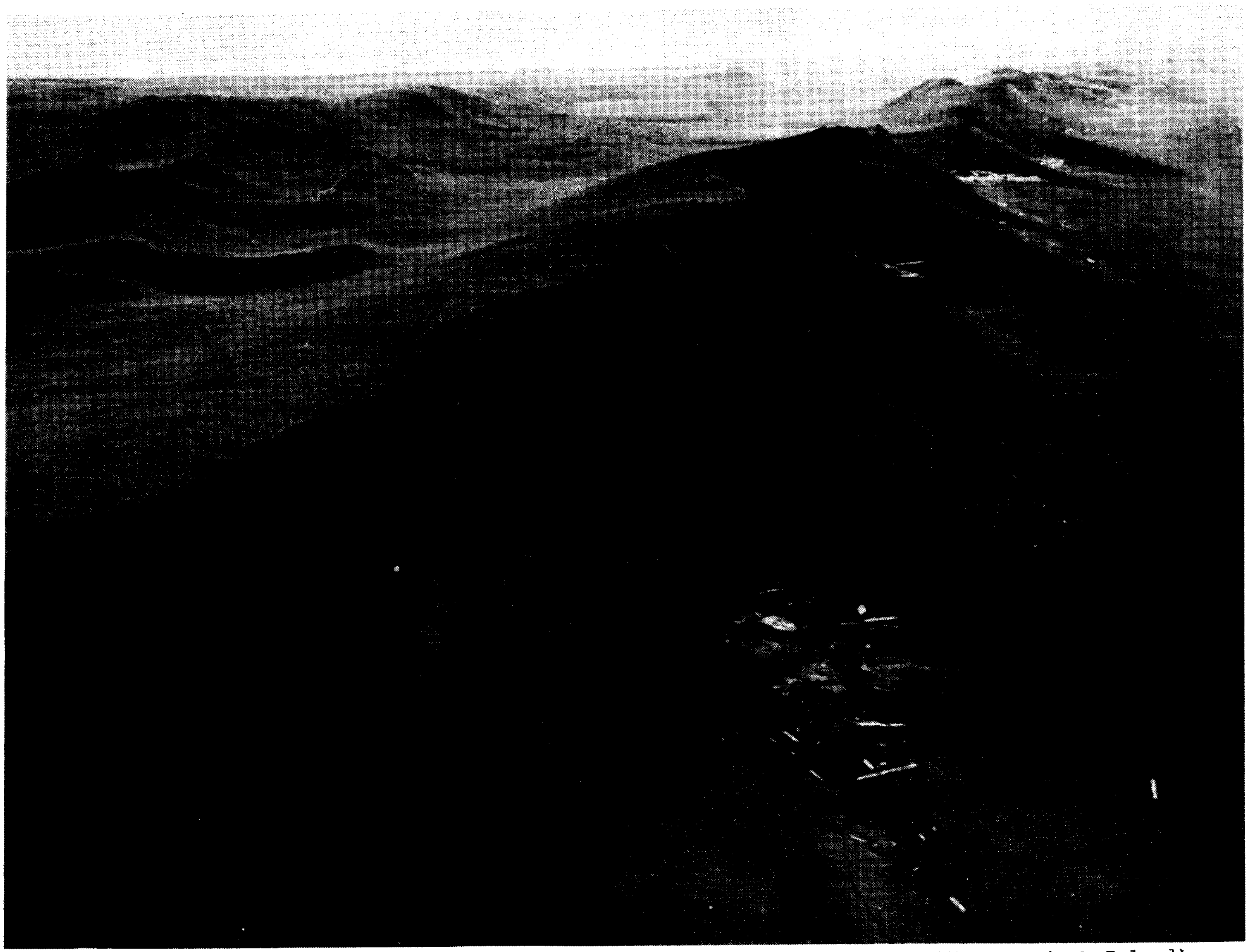


Figure 15: Large scale eolian dunes superimposed on the beach (Urilia Bay, Unimak Island).

Figure 16: Large scale eolian dune superimposed on a beach bordering Urilia Bay, Unimak Island.

E. GRAIN-SIZE DISTRIBUTIONS OF BEACH SEDIMENTS: ALASKA PENINSULA COAST OF BRISTOL BAY AND NORTON SOUND TO THE BERING STRAIT

PURPOSES OF DETERMINING GRAIN-SIZE DISTRIBUTION

The grain-size distribution of a beach deposit is important in defining the susceptibility of the beach material to wave erosion; coarse material tends to resist erosion, while fine material tends to be eroded easily. Even a small proportion of cobbles or boulders in a beach deposit may prevent extensive erosion, for moderate erosion tends to leave the coarser material exposed on the beach surface and it thus becomes "armored" against further erosion.

Whether a beach is actually eroded depends, of course, on several factors in addition to the erosional susceptiblity of the beach material. Especially important among these other factors are the wave power, the angle at which the waves approach the shoreline, the rate of sediment supply to the beach, and the alongshore variations in all these factors.

In addition to serving as a measure of erosional susceptibility, the grain-size distribution of a beach deposit is important in controlling the beach fauna and in controlling the uses to which the beach can be put by man.

Sampling Methods

The beach at each station was sampled in a way such that a single composite sample represented as well as possible the entire beach deposit at the station. However, because of time contraints the deeper parts of the beach deposit could not be sampled. In Bristol Bay, the lower foreshore was not regularly sampled because many of the stations could not be visited at low tide during the time available.

The sample taken at each station was a composite of several spot samples. Each spot sample represented the uppermost 6 inches (15 cm) of sediment at that point on the beach. In Norton Sound, 4 to 10 spot samples were collected from equally spaced points along each of 2 to 4 lines extending across the beach from the line of wave run-up to a line, such as the vegitation line, cliff, or lagoon shore, that marked the back edge of the modern beach deposit. The sampling procedure in Bristol Bay was similar except that the zone sampled was restricted to the upper foreshore. The lines across the beach were chosen to represent the alongshore variations in beach character; for example, if cusps were present the lines were chosen to run through the cusp points and bays. The total weight of the composite sample formed from the spot samples was from 11 to 25 pounds (5 to 11 kg).

Sample Processing Methods

Each of the composite samples was large enough to give a representative size analysis of all grains smaller than about 32 mm (-5 ϕ) but unfortunately was much too large to carry aboard the helicopter for laboratory processing. Therefore, each composite sample was hand-sieved into two fractions in the field, and each fraction was split to different degrees until portions small enough to transport were obtained. In Norton Sound, the coarse fraction was photographed for later visual size analysis rather than transported.

The hand-sieving was done in about 200-g increments through a sieve having openings of 4 mm (-2 ϕ), each increment being sieved about 1 minute. Both the coarser and finer size fractions were weighed by a spring scale to the closest 0.5 pound (0.23 kg). The finer size fraction was split by hand-quartering, and an approximately 200-g portion was kept for laboratory sieving. The coarser fraction was also split, and an approximately 400-g portion was either kept for laboratory sieving (in Bristol Bay) or was spread onto a canvas rectangle of known size and photographed (in Norton Sound).

In the laboratory, the finer fraction was further split, sieved through a stack of sieves on a ro-tap sieve shaker for 15 minutes, and each size fraction weighed. The coarser fractions from Bristol Bay were similarly sieved without preliminary splitting. The photographs of the coarser fractions from Norton Sound were projected onto a grid-marked background at natural scale. The photographed pebbles were placed in size classes by comparing their short diameter to circles of known size; the short diameter was chosen as an index of grain size because it is generally the intermediate of three mutually perpendicular diameters and is the diameter most comparable to the sieve diameter. The number of grains in each size class was counted.

The visually measured grain size distribution of the coarser fraction had to be converted into a distribution in terms of weight percent per size class, so that the size distributions of the finer and coarser fractions could be combined into a single distribution representing the entire beach deposit. The conversion was done mathematically by assuming a constant grain density and by using an empiracally determined grain-shape factor for each size class; the grain-shape factors were assumed to be constant for all samples.

Although the sample processing procedure used is subject to numerous random and systematic errors, a comparison with more ideal procedures for a few samples showed that the cumulative errors were relatively small and probably within the range of variability arising from the sampling itself. It was found that the hand sieving in the field was 75 to 95% efficient for the 2 - 4 mm size class, but was more than 90% efficient for sizes finer than 2 mm. When combining the size distributions of the finer and coarser fractions into a single distibution, grains finer than 2 mm in the hand-sieved coarse fraction were ingnored, but grains in the 2 - 4 mm size class were taken into account.

Methods Used on Very Coarse Beaches

Some of the beach deposits consisted almost entirely of cobbles and boulders. The grain-size distributions of these beaches were determined from photographs of the beach surface. A series of photographs across the beach surface was taken by aiming the camera vertically downward from eye level, a scale being placed in the field of view for later visual estimation of the average grain size. The average gain sizes determined from all the photographs taken at the station were then averaged to give the average grain size of the beach as a whole.

Results for Norton Sound

A summary of some size parameters and the dominant rock types in the gravel fractions are given in Table 6. A generalized description of the beach materials from north to south around Norton Sound follows (station locations given on Sheet 9 and in Tables 4 and 8).

On all the beaches, variations in grain size across the beach, along the beach, and with depth below the beach surface tend to be great and rather unsystematic. The typically large and irregular variability in grain size is probably related to the effects of ice push and ice melting on the beaches.

The beaches on the north side of Norton Sound, from Cape Prince of Wales east to Norton Bay (stations N12 to N21) contain gravel fractions made up of a mixture of Precambian and Paleozoic metamorphic rocks, including gneisses, schists, slates, marbles, and quartzites, Paleozoic carbonate rocks, Cretaceous granitic rocks, and Cenozoic volcanic rocks. The Precambrian metamorphic rocks are dominant in most areas, but Lower Paleozoic carbonate rocks are dominant from the York Mountains to Port Clarenee, and Cretacous granitic rocks are dominant locally around Golovnin Bay.

The beaches from the York Mountains to Port Clarence are mostly coarse gravels (stations N12 to N10); beaches are locally absent where cliffs rise from the shoreline. The beaches of the Port Spencer spit (stations B12 to N8) are also mostly gravels, though not as coarse as those north of Port Clarence. From the Point Spencer spit southeast to near Nome (stations N5 to N1), the beaches are mostly pebbly sands and sandy gravels. The beaches from the vicinity of Nome east to Topkok Head (stations B8 to B6) are mostly sands and pebbly sands; coarse gravelly beaches are relatively uncommon along this stretch of coast. From Topkok Head east to near Koyuk (stations N14 to N21), the beaches show much local variability, ranging from coarse gravels to pebbly sands, and beaches are locally absent where cliffs rise from the shoreline.

Beaches are absent from much of the Koyuk River delta at the head of Norton Bay. Here, the shoreline is an eroding bluff in fine-grained, peaty sediments that underlie a low, wet tundra plain. Farther south, along the east side of Norton Bay (station N31), gravelly or sandy beaches are present. On the south side of Norton

TABLE 6. - SUMMARY OF GRAIN-SIZE AND PEBBLE-TYPE CHARACTERISTICS OF NORTON SOUND BEACH SAMPLES

Sample number[1]	Percent gravel[2]	Mdϕ[3]	Dominant pebble Lithology[4]
N12	82.1	-3.1	C
N11	90.7	-4.2	C
B13	73.7	-2.9	C
N10(B14)	91.8	-3.6	C
B15	>95	-4.0	C
B12	42.2	-0.5	C
B10[5]			C
B11	51.9	-1.1	C
N9	67.0	-2.6	C
N8	35.6	-0.3	C
N5	47.7	-0.9	M
N13	43.0	-0.7	M
N7	64.9	-2.2	M
N6	56.1	-1.7	M
N4	40.2	-0.2	M
N3	27.9	-0.1	M
N2	43.7	-0.2	M
N1	64.2	-2.4	M
B8	26.2	0.4	M
B9	59.3	-2.6	M
B5	27.6	0.7	M
B7	24.0	0.8	M
B6	17.4	0.9	M
N14	30.4	-0.2	M
N15	29.7	-0.3	M
N16	33.6	0.7	M
N17	49.9	-0.9	P
N18	>95	-5.2	P
N19	30.8	0.1	M
N20	42.2	-0.7	M
N33	15.5	0.1	M
N21	40.1	-0.7	M
N32[6]			
N31	61.3	-2.3	M,S
N30[7]	4.2	1.8	M,S
N29	70.6	-2.7	S
N28[8]	21.8	0.0	S
N28	>95	-5.9	S
B1	90.3	-3.9	S
B2	80.1	-3.4	S
B3	75.4	-3.4	S
B4	58.6	-1.4	S
N22	68.6	-2.3	S
N27[9]			V
N23	>95	-5.9	V
N24[9]			V
N25[6]			
N26	75.0	-3.2	S

[1] Listed in order of location along the coast, beginning at the NW.

[2] Material coarser than -1ϕ (2 mm) in grain diameter.

[3] Median grain diameter, in ϕ units.

[4] Symbols under this headline are C = Carbonate rocks, M = Metamorphic rocks with subordinate igneous rocks, S = Sandstone, V = Volcanic rocks, and P = Plutonic igneous rocks.

[5] No sample; beach material very similar to that at station B11.

[6] No sample; shore consists of eroding tundra and associated muddy sediment.

[7] Spot sample of sandy portion of beach; beach consists of poorly sorted sand, gravel, and mud.

[8] Spot sample of sandy portion of beach; beach consists of more than 95% gravel.

[9] No sample; shore consists of volcanic rock with scattered volcanic gravel.

Bay, beaches are absent in some places and present in other places, but tend to be partly covered by mud washed from the eroding bluffs that underlie a low, wet, tundra plain (station 30). The gravel fractions of the beaches around the south and east sides of Norton Bay are composed of a mixture of metamorphic rocks and Cretaceous sandstones. The metamorphic rocks are derived from the cliffed shoreline of the Reindeer Hills.

The beaches around the east side of Norton Sound from Shaktoolik south to a point about 18 miles south of Unalakleet (stations N29 to N23) are mostly gravels and sandy gravels. The gravel fractions are composed mainly of Cretaceous sandstone.

In the southeast part of Norton Sound, from just east of Golsovia to St. Michael Island (stations N27 to N24), the shoreline is formed by Quaternary volcanic rocks. Beaches are generally absent or consist of a thin veneer of volcanic boulders over the volcanic bedrock. Some of the more protected coves contain beaches of pebble and cobble gravel of volcanic composition.

For a distance of about 23 miles southwest of St. Michael Island (station 25), beaches are generally absent and the shoreline is a bluff eroded in fine-grained, peaty sediments that underlie a low, wet tundra plain. Farther to the southwest, from near Point Romanof to the Yukon delta, which begins about 9 miles east of the Apoon Mouth of the Yukon River (station N26), the beaches are mostly gravels and sandy gravels, the gravel fractions of which are composed largely of Cretaceous sandstones.

Results for Bristol Bay

A summary of some size parameters and the dominant grain lithology are given in Table 7. A generalized description of the beach materials from northeast to southwest along the south shore of Bristol Bay follows (stations locations given on Sheet 10 and Table 5).

Beaches are locally absent from the mouth of the Kvichak River to the mouth of the Naknek River (station A1). Here, the shoreline is a bluff eroded in fine-grained, peaty sediments that underlie a low, wet tundra plain.

Between the Naknek River and Ugashik Bay (stations A2 to A10), the beaches are gravels, sandy gravels, and pebbly sands. The gravel fractions consist of a mixture of rock types, including plutonic igneous rocks, volcanic rocks, metamorphic rocks, and sedimentary rocks. The beaches become sandier and richer in volcanic rock fragments in the vicinity of Ugashik Bay.

From Ugashik Bay southwest to the western tip of Unimak Island (stations A11 to A43), the beach materials are composed largely of volcanic rock fragments. Many of the beaches are composed entirely or almost entirely of sand with median sizes generally in the coarse to medium-grained sand range; gravels, sandy gravels, and sands containing more than 10% of pebbles are restricted in occurrence.

TABLE 7 - SUMMARY OF GRAIN-SIZE AND LITHOGRAPHIC CHARACTERISTICS OF BRISTOL BAY BEACH SAMPLES

Sample number[1]	Percent gravel[2]	Mdϕ[3]	Dominant grain Lithology[4]
A1[5]			
A2	58.9	-2.0	Mi
A3	49.3	-0.6	Mi
A4	19.4	1.0	Mi
A5[6]	4.0	1.6	
A5	>95	-4.4	Mi
A6	8.9	1.2	Mi
A7	48.1	-0.7	Mi
A8	69.9	-2.4	Mi
A9	67.0	-2.9	Mi
A10	0.0	2.3	Mi
A11	36.0	0.7	V
A12	2.4	1.7	V
A13	0.0	1.7	V
A14	30.3	0.2	V
A15	1.8	1.1	V
A16	2.7	0.9	V
A17	14.5	0.5	V
A18	0.3	0.8	V
A19	37.0	-0.5	V
A20	1.1	0.7	V
A21	1.3	0.5	V
A23	2.1	0.6	V
A24	23.9	0.7	V
A25	19.1	0.9	V
A26	0.3	2.2	V
A27	0.5	1.4	V
A27 low[7]	62.8	-1.7	V
A28	1.2	1.3	V
A29	42.9	-0.2	V
A30	0.0	1.6	V
A31	0.6	1.5	V
A32[6]	0.0	1.7	V
A32	>95	-5.4	V
A33[6]	0.0	1.8	V
A33	>95	-6.3	V
A34	0.1	2.0	V
A35	1.7	0.9	V
A36	0.1	1.7	V
A37	3.2	0.6	V
A37 low[7]	15.7	0.2	V
A38	2.5	0.6	V
A39	2.3	0.9	V
A40	3.6	1.4	V
A41	0.1	1.3	V
A42	1.1	1.3	V
A43	4.9	0.8	V

[1] Listed in order of location along the coast, from NE to SW.

[2] Material coarser than -1ϕ (2 mm) in grain diameter.

[3] Median grain diameter, in ϕ units.

[4] Symbols under this heading are Mi = mixed plutonic igneous, volcanic, metamormorphic and sedimentary rocks and minerals from such rocks; V = volcanic rocks and minerals from such rocks.

[5] No sample; shore consists of eroding tundra and associated muddy sediment.

[6] Spot sample of sandy portion of beach; beach consists largely of gravel.

[7] Sample of lower foreshore.

Among the more gravelly beaches are those immediately south of Ugashik Bay (station A11), immediately south of Cinder River (station A14), immediately south of Port Heiden (station A17), near Ilnik Lake (Station A19), from Bear River to Port Moller (stations A24 and A25), near Franks Point (station A29) and near Cape Leontovitch (stations A32 and A33).

Summary

Most of the beaches around Norton Sound from Cape Prince of Wales to the edge of the Yukon delta are quite gravelly. Sandy beaches are most common in the area from Nome east to Topkok Head. Beaches are locally absent where (1) bedrock cliffs rise directly from the water's edge or (2) the shoreline is a bluff eroded in fine-grained, peaty sediments that indicate a low tundra plain.

The beaches along the south side of Bristol Bay are generally sandier than those along Norton Sound. Gravels are most common along the northeastern part of this coast. Beaches are absent in very few places.

F. BEACH AND NEARSHORE PROFILE COMPARISONS

INTRODUCTION

During the summer of 1976 several beaches in Norton Sound, Alaska were profiled as the initial part of a study to determine the factors that control the equilibrium beach profiles in the area. The profiles were first taken during the 21 June - 11 July trip ("first trip") and reoccupied during the 14-26 September trip ("second trip"). In all, 15 onshore-offshore locations were profiled during the first trip and these were reprofiled during the second trip. Six additional profile locations were added during the second trip in areas of high interest.

The onshore-offshore beach profile locations are listed in Table 8 and shown on Sheet 9; they are designated by a "B" before the profile number. At the end of the second trip there were eight profile locations around Port Clarence, eight around Nome and five around Unalakleet. The profiles range from 600 m to 2000 m in length and cover the area between the back beach and offshore depths as great as 10 m.

METHODS

The onshore part of each profile was surveyed using a level and stadia rod. A permanent marker was driven into the ground at the shoreward end of each profile to permit reoccupation of the profiles on subsequent trips. Whenever possible, this stake was located behind the beach in the tundra to minimize the chance of loss. In all cases the stake height was measured so the profiles could be vertically referenced to a fixed point (the stake top). A second stake was placed seaward of the reference stake to serve as a backup marker and to keep the stadia rod carrier on the profile line. Horizontal distances were obtained using special range finding cross hairs in the level. With this technique horizontal resolution is at least ± 1 m at all distances. Elevations were read to 1 cm. The elevation of sea level with respect to the level was measured and used to tie together onshore and offshore parts of the profile.

After the onshore profile was completed, two navigation flags were also placed on the profile line. One flag was located at the level (usually at the berm crest), and the other was (generally) placed near the water line. A perpendicular to the profile line was shot from the level to locate a third flag down the beach. This last flag was situated on the order of 100 m from the level. Then the boat, with precision fathometer mounted amidships, slowly ran at constant speed toward the beach using the two navigation flags to stay on course. At intervals of a few to tens of seconds the angle to the third flag was measured with a sextant and a corresponding mark made on the fathometer record. During the first trip offshore profiles were run in triplicate; on the second trip multiple passes were made only on occasion. Sextant readings were made to the nearest 10 minutes; resolution, therefore, varies with position.

Table 8

LOCATIONS OF BEACH AND NEARSHORE PROFILES : NORTON SOUND TO THE BERING STRAIT. (SEE ALSO SHEET 10)

Profile number	Latitude (N)	Longitude (W)
B 1	63°58'15"	160°52'00"
B 2	63°56'15"	160°50'00"
B 3	63°54'30"	160°49'00"
B 4	63°53'15"	160°48'00"
B 5	64°28'45"	165°16'15"
B 6	64°27'00"	164°48'00"
B 7	64°27'00"	165°05'00"
B 8	64°30'22"	165°29'00"
B 9	64°29'38"	165°22'30"
B 10	65°12'15"	166°55'30"
B 11	65°12'15"	166°55'45"
B 12	65°14'45"	166°54'00"
B 13	65°22'15"	166°56'30"
B 14	65°20'58"	166°50'00"
B 15	65°14'38"	166°51'30"
B 16	64°29'00"	164°41'00"
B 16 West	64°29'00"	164°41'00"
B 16 East	64°29'00"	164°41'00"
B 17	63°49'45"	160°45'45"
B 18	65°20'00"	166°43'30"
B 19	65°09'15"	166°57'00"

along the profile line. The fathometer record can be read to 0.1 m when the sea is perfectly calm. Superimposed wave motion adds uncertainty to this reading because it is not easy to completely remove the wave component from the fathometer record.

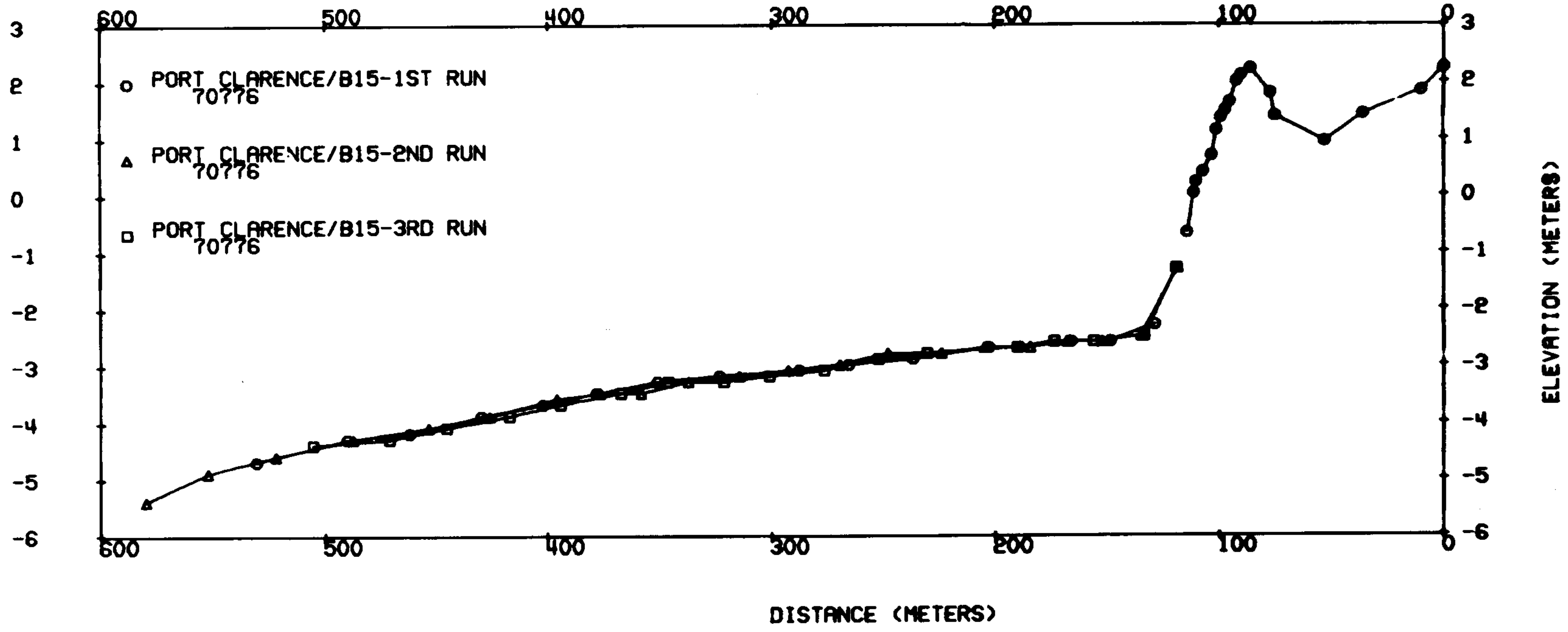
The data from the survey and fathometer records was partially reduced and then punched onto computer cards. A computer program aligned the onshore and offshore sections, relocated the horizontal and vertical axes, and plotted the profiles. Thus, for the comparative plots the origin of the horizontal axis (x) is the reference stake and the origin of the vertical axis (z) is the top of the stake. There were two choices for the z-axis origin -- sea level and the top of the reference stake. If there was good tide information, sea level would be an alternate choice, but the state of the tide is an unknown parameter in the Norton Sound area. Therefore, the z-axis was referenced to the stake top, recognizing that there is always the chance the stake will settle over time. This could be a real problem if there are frost heaves during the winter.

RESULTS

In all but a few cases the profile lines were successfully reoccupied during the second trip. As the onshore morphology in the three general areas -- Port Clarence, Nome, and Unalakleet -- is detailed in another part of this report, it will not be covered here. Instead, this section will discuss repeatablity of the fathometer profiles, observed offshore features, and changes in the profiles between the two trips. Note that in the accompanying figures there is a gap on the profile trace to indicate where one part of the profile ends and the other begins.

During the first trip, offshore profiles were run in triplicate to ascertain the reliability of the profiling technique. Typically, the correlation between passes was excellent (e.g., Figure 17). Points from the same part of the profile were generally within 0.1 m of each other. Deviations between passes occurred during times of significant wave activity (Figure 18), but the waves could usually be factored out. In the shallowest parts of the offshore, a difference in the number of points between runs can significantly alter the apparent shape of the profile especially if the points do not occur in approximately the same place (Figure 19). From this it was concluded that, when the sea is flat, one pass per profile is sufficient as long as a large number of points are taken. Interpolation of the fathometer record between sextant readings was not attempted since it was not determined whether the boat speed was constant.

As expected, the profiles from area to area were generally different because of (probable) differences in incident wave energy. All the Unalakleet profiles were similar (e.g., Figure 20). They have a steep beach face and a low angle, featureless offshore. Around Nome the becach face is still relatively steep, but the offshore drops off more rapidly and nearshore bars appear to be well developed (e.g., Figure 21). In the Port Clarence area the profiles



BEACH PROFILES - NORTON SOUND, ALASKA

Figure 17: Beach Profile number B 15 (near Port Clarence, Alaska): 7 July 1976 profile. Offshore portion taken in triplicate to determine reliability of the profiling technique. Origin of the x-axis is the onshore reference stake. Origin of the z-axis is sea level. Gap indicates break between onshore and offshore parts of the profile.

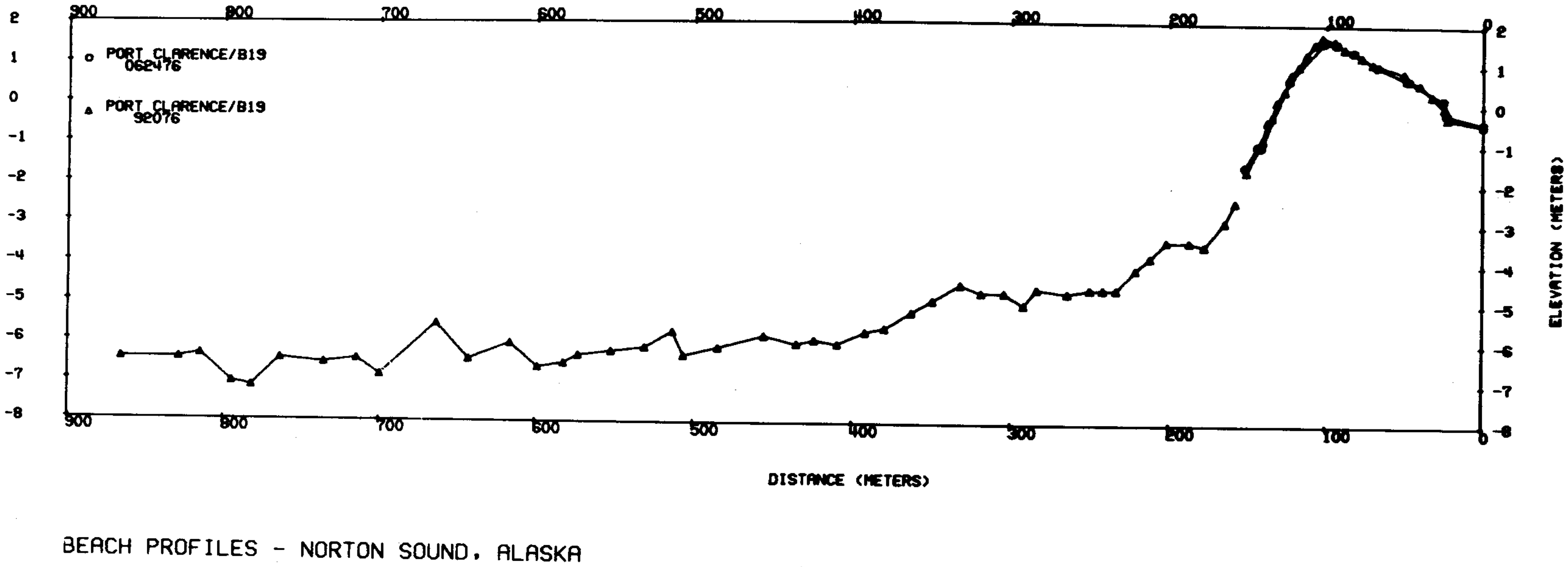
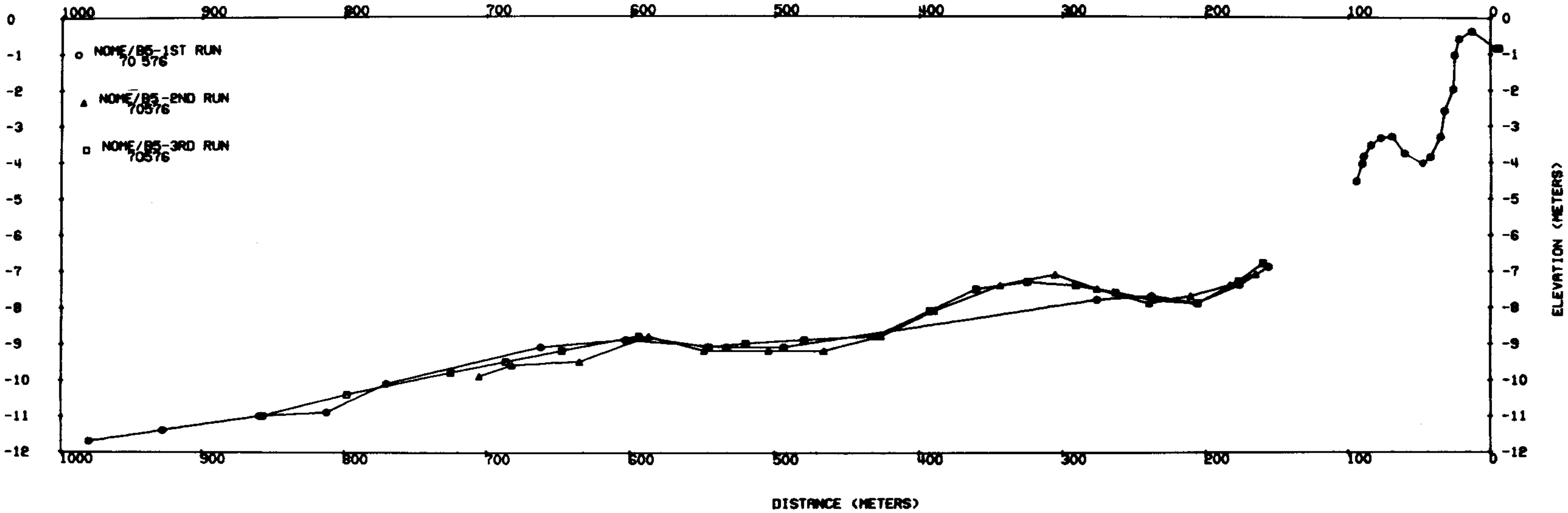
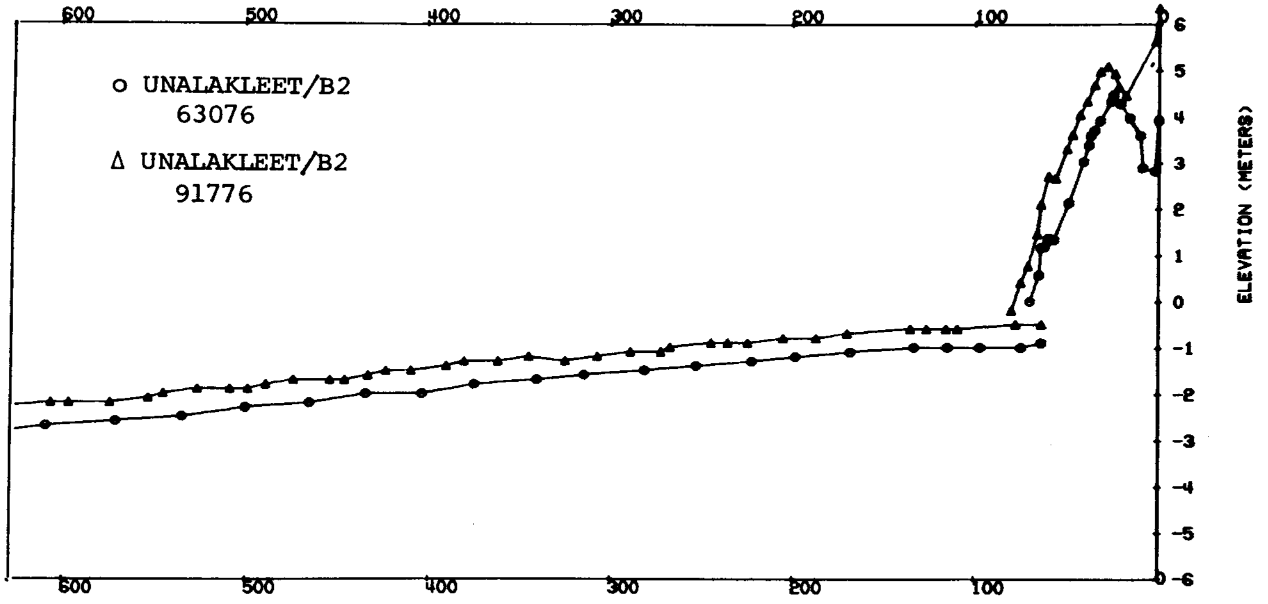


Figure 18: **Example of wave affects on the offshore portion of the profile. Note that there is no change in the onshore profile between the June and September profiles. Origin of z-axis is the top of the onshore reference stake.**



BEACH PROFILES - NORTON SOUND, ALASKA

Figure 19: Example of apparent variability between offshore passes along profile line B 5. Deviations caused by difference in number and location of data points. Origin of z-axis is the top of the onshore reference stake.



ELEVATION (METERS)

Figure 20: Typical beach slope in the Unalakleet area. Comparison of the June and September profiles indicates no change in shapes. Offset in profile lines occurs because the reference stake disappeared between passes and the z-axis origin is at this stake.

Observed profile extends to 2000 m with no change in bottom slope.

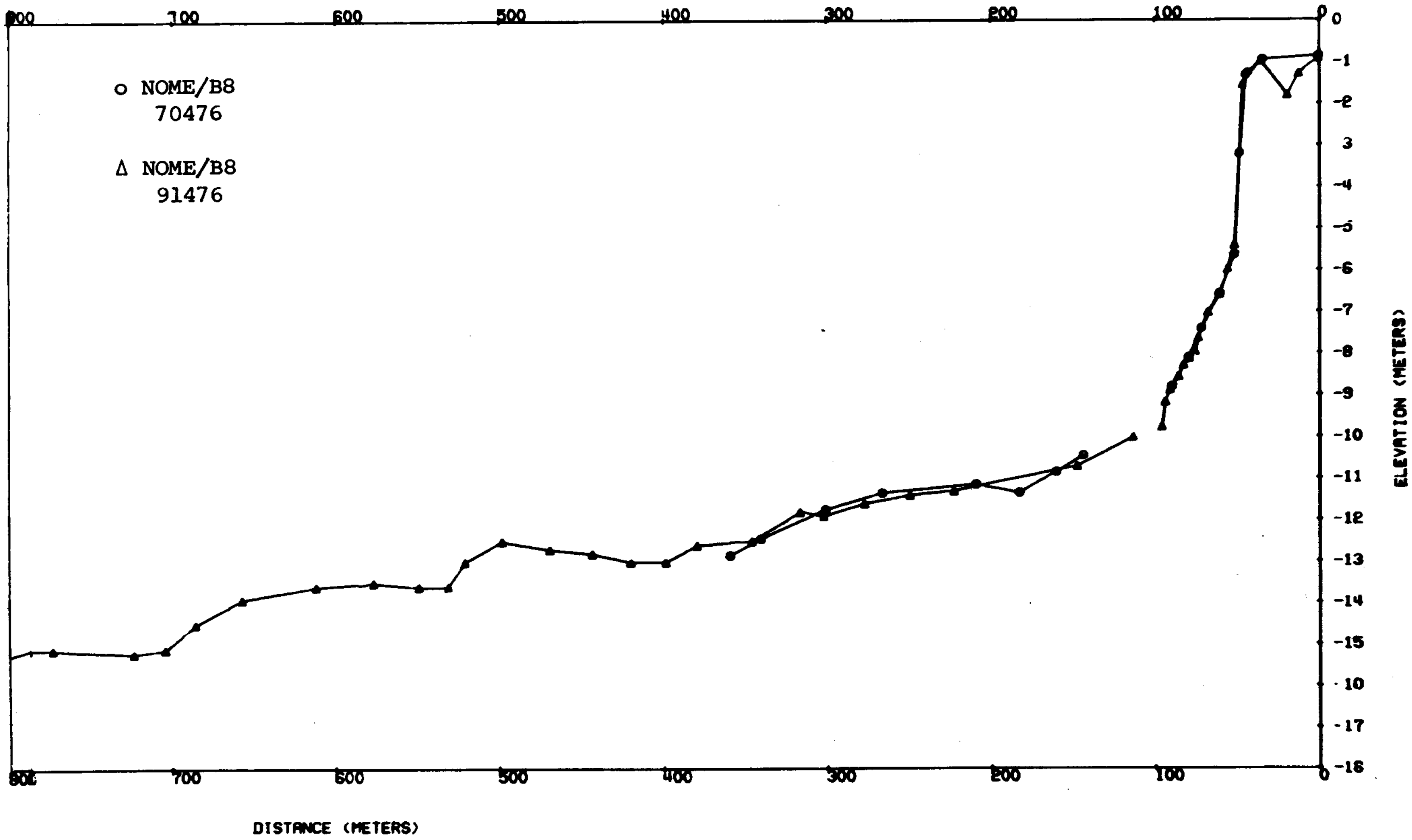


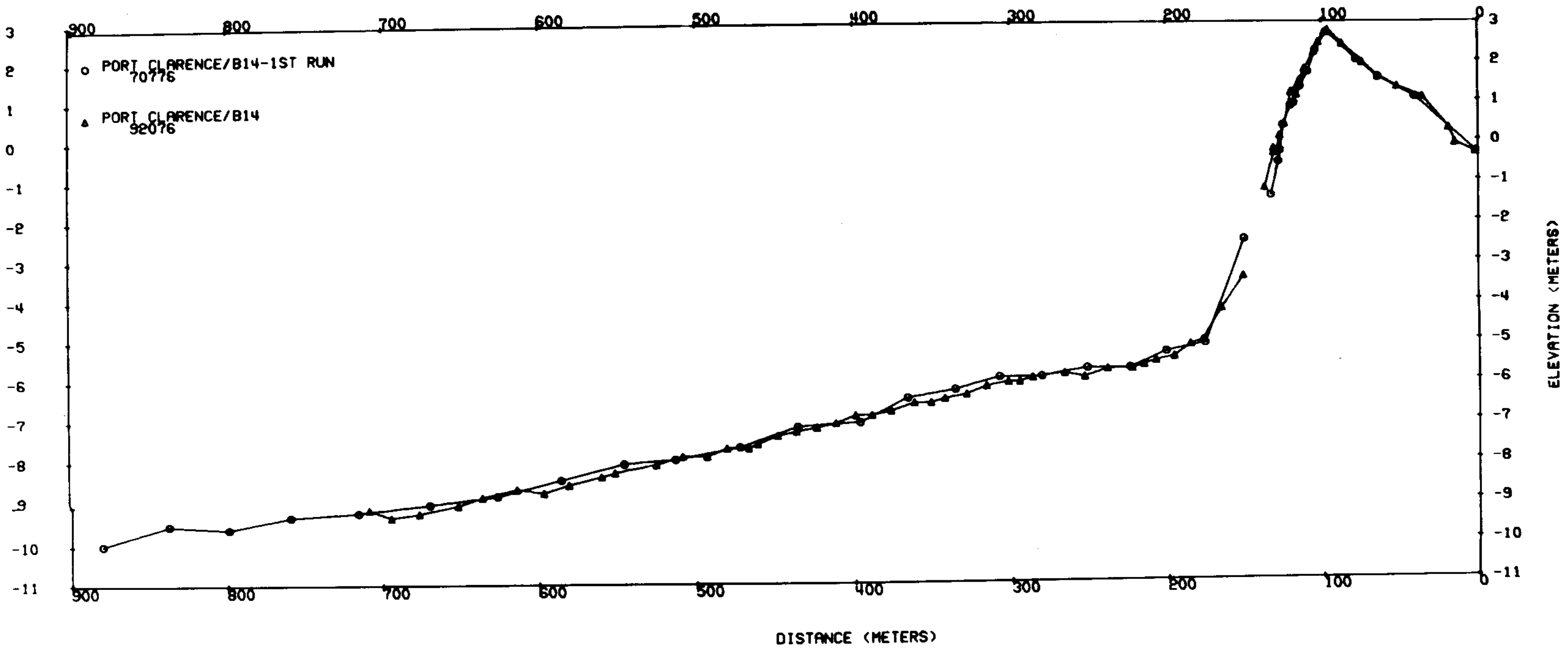
Figure 21: Typical beach shape in the Nome area, showing bluff, steep beach face and offshore bars. Comparison shows no profile changes between July and September . Origin of the z-axis is the top of the onshore reference stake.

tend to be like the Unalakleet profiles with a somewhat greater bottom slope (e.g., Figure 22 Some of the Port Clarence profiles showed bottom irregularities, but they were not well enough developed to determine if they were bars (Figure 23).

None of the profiles showed significant changes between the first and second trips (Figures 18, 20-23, for example). This is not particularly surprising in that no signficant storms occurred between the two trips, and non-storm conditions can be quite low in energy. Without continuous wave data we cannot tell if the wave energy over the summer was significant or not. It is quite possible that wave conditions were such that significant longshore sediment transport occurred without changing the equilibrium beach profile.

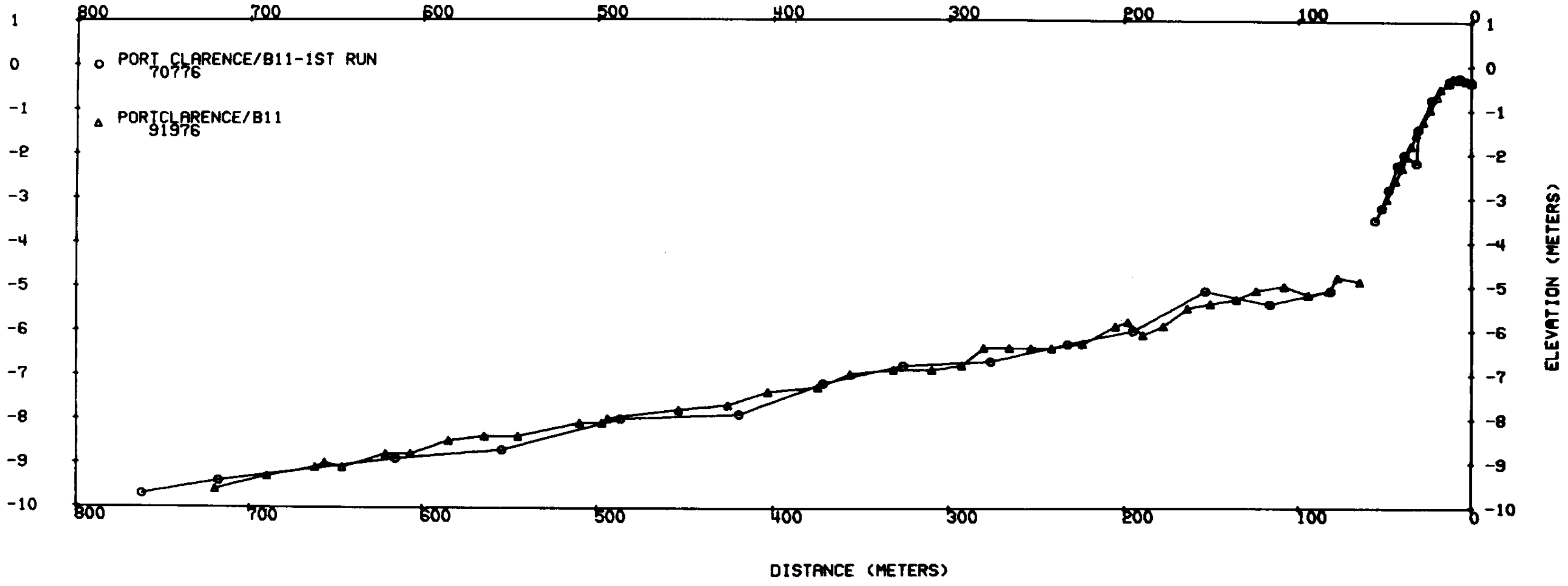
FUTURE WORK

The goals of this part of this study are to measure the onshore-offshore beach changes over time and to try to correlate the beach profiles with observed wave conditions. This field season we expect to take a large step toward completing these objectives since we will have a wave monitoring station at Nome and we will collect two more sets of profiles. One set will indicate winter changes of the beach profile. Furthermore, we are taking several steps to improve our profiling techniques. For example, we will be using an advanced surveying instrument (Hewlett-Packard "Total Station") to obtain more accurate onshore and offshore positioning and elevations. This instrument will allow us to sample the offshore part of the profile more often than we could with the sextant-flag method. We also hope to eliminate the gap between the onshore and offshore parts of the profile since this falls in an important part of the beach (the surf zone). Finally, we plan on replacing the present reference stakes with a more permanent marker.



BEACH PROFILES - NORTON SOUND, ALASKA

Figure 22: Typical beach shape within Port Clarence. Profile transects are part of the spit separating Brevig Lagoon (off right side of figure) from Port Clarence. No profile changes occured between July and September. Origin of z-axis is the top of the onshore reference stake.



BEACH PROFILES - NORTON SOUND, ALASKA

Figure 23: Profile from the Bering Sea side of the spit seaward of Port Clarence which shows offshore bedforms of an undetermined nature. Origin of the z-axis is the top of the reference stake.

VI. NEEDS FOR FURTHER STUDY

A. Storms and their effect on the coastal environment should be studied in detail. This should include studies on the frequency and magnitude of storm surges and extreme wave conditions.

B. The rates of change of beach and nearshore morphologies should be determined. This should include three dimensional changes as well as two dimensional. Studies should be designed to include changes occuring during the storm season in the early fall. Long-term changes in shoreline position should also be assessed (e.g.,chart, aerial photograph comparisons).

C. The wave climate for the eastern Bering Sea should be determined and applied to determining rates of sediment transport along the coast. Changes in beach and nearshore morphologies should be interpreted in view of the wave climate to provide a means for predicting change.

D. The intensity and frequency of ice gouging in the nearshore should be determined. The potential hazard of ice blocks being battered against coastal structures during severe storms should be assessed more completely.

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SEISMIC AND TECTONIC HAZARDS IN THE HOPE BASIN AND BEAUFORT SHELF

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TABLE OF CONTENTS

I. SUMMARY

The Hope Basin and the Beaufort Shelf, both areas of considerable petroleum potential, contain what appear to be active tectonic features which may pose hazards to petroleum development. The prime objective of this work has been to acquire a better data base with which to judge the activity of these apparent tectonic and slump features as well as basic background geologic information important for defining the potential impact of petroleum development on the shelf environment. From the existing data base, we know that Hope Basin is composed of an intensely faulted section of young sediments in a trough appearing to be of Tertiary age. The present activity of these faults is uncertain, although they appear to rise to the surface in most places, cutting sediment which is within meters of the surface. We know that the Beaufort Shelf has what appear to be active slump features on its outermost edge, both on the shelf and on the continental slope beyond. On the eastern Beaufort Shelf near Barter Island a zone of high seismicity exists which is as yet unexplained, tectonically, although it appears to be associated with a zone of young compressional folds. In general, the Beaufort Shelf is composed of prograding Tertiary sediments which in many places are cut by down-to-the-basin gravity faults.

Our field work this past summer suffered from two principal problems: 1) A failure of one engine on USGS vessel S.P. LEE reduced our planned 25-day leg to 5 days, 2) Severe ice conditions in the Beaufort Sea in August-September and environmental concerns largely hampered us from carrying out our planned 30-day seismic refraction and sampling program from U.S. Coast Guard Icebreaker GLACIER. Nevertheless, some new infromation has been gained from our limited data. Experience with the Ocean Bottom Seismometer systems purchased with OCSEAP funds during a 2-day test drop in Hope Basin has elucidated their degree of usefulness.

A four-day survey with high resolution "uniboom" seismic reflection system on LEE has shown that a series of faults which cut the Tertiary sediments in part of Hope Basin are probably not active at present. This survey revealed that the acoustically homogenous layer about 10 m thick which blankets the surface of Hope Basin and is presumed to be the 13,000 year old transgressive sequence of Holocene time is not cut by the faults which are seen in the Tertiary sediments below. Although these faults appear to have been active in upper Tertiary time, their activity ceased prior to Holocene time. The survey was done in southern-central Hope Basin where intensive gravity faulting has occurred on the north flank of a prominent ridge. Whether this present inactiveity can be extrapolated to include the rest of the myriad of faults in Hope Basin, in particular the thrust faults south and west of Pt. Hope, is uncertain. Prominent sea floor scarps seen with the 12 khz sounder south and west of Pt. Hope still may be an indication of recent activity, although these scarps could be of erosional origin.

In the same survey done on LEE, a zone of "acoustically turbid" sediments at depths from 5 to 15 m was found. The most likely explanation of this acoustic anomaly is gas-saturated sediments, gas which is presumably leaked from deeper in the sedimentary section and trapped beneath the overlying silt layer. The exact implications of this finding in terms of shelf development operations are uncertain at this point, but this feature should be further investigated.

An analysis of existing deep seismic data on the Beaufort shelf for topography and near-surface features has delineated a slump-produced physiographic pattern. The Beaufort shelf east of 148° longitude displays a double shelf break, with an inner break produced by the headwall of a regional low angle bedding plane slump and an outer break produced by the typical outer progradational edge of the shelf sediments dropping off to continental slope gradients. This double shelf break gradually converges toward the west producing a pattern which may be related to a tectonic sinking of the eastern Beaufort Shelf.

West of 148° W., the continental slope is dominated by slumps with relatively high angle slip planes. The slope here has an uppermost section of moderate inclination wherein the shelf has been down-dropped seaward on the high angle slip planes, but the slump blocks are not severely disrupted internally. Seaward of this zone, the slope is markedly steeper and characterized by slumps with large vertical displacement and severe internal disruption. Between 151° 30W and 154° 30'W very young and very likely still active slump scarps related to shallow block gliding extend at least 6 km landward from the continental shelf break.

A survey of Barrow sea valley on GLACIER north and west of Barrow revealed that the valley appears to be a presently active feature with dynamic sedimentation processes going on in it today.

The implications of these findings in terms of petroleum development is obvious in some cases and not so obvious in others. To ignore the presently non-obvious in such a unique and relatively unexplored environment would, we feel, be a mistake.

II. INTRODUCTION

A. General Nature and scope of study.

The Beaufort and Chukchi Shelves are relatively unexplored areas due to their remoteness and ice cover 9 to 11 months of the year. Their petroleum potential is probably significant and hence the need to develop these areas within the next decade is strong. Our group is engaged in studies to better define the general geology of these areas, especially Hope Basin in the southeast

Chukchi Sea and the Beaufort Shelf. The aim is to derive an understanding of the geologic history of these areas obtained through indirect geophysical measurements, principally seismic (deep, low resolution and shallow, high resolution), gravity and magnetics as well as direct sampling of the bottom. An integral part of these studies is the determination of active tectonic processes: faulting, sediment slumping and earthquake activity.

B. Specific Objectives

To investigate areas of possible active faulting in Hope Basin and slumping on the Outer Beaufort Shelf, good quality high resolution seismic reflection data is needed in these areas to combine with existing seismic data. Such data will enable a better assessment of the possible hazard which these features may pose to development activities on these shelves. The region of high seismicity near Barter Island on the eastern Beaufort Shelf was planned to be investigated by planting an array of Ocean Bottom Seismometers (OBS) to better define epicenter locations and magnitudes. Since Hope Basin is ice free earlier in the season than the Beaufort Shelf, it provides a favorable location for first development testing of the OBS systems, and this was planned for early in the field season. One of our prime objectives is to increase the data base for a general geologic description of these shelves where, due to the sparsity of data, and the uniqueness of the environment, the most limiting hazards may well be those which have not yet been specifically envisioned.

C. Relevance to problems of petroleum development

A complete description of the modern shelf environment and possible hazards inherent in the modern geologic process or in the nature of the sediments on the shelf requires a fairly complete geologic description of the area. By reducing the geologic unknowns, drilling and placement of platforms can be done with somewhat greater assurance that exploration facility foundation failures and damaging oil spills will be avoided. Active faults and fractured zones may act as unwanted conduits for oil to escape from drilled formations as occurred at Santa Barbara. Unstable sediments, capable of slumping, may disrupt drilling or production facilities, especially in high seismicity areas where slump-triggering earthquakes may often occur. Since these shelves are highly attractive as petroleum resource areas (Grantz, et al, 1975), it behooves us to come to as good an understanding of the geologic environment as is possible before development occurs.

III. CURRENT STATE OF KNOWLEDGE

Seismic data taken in the past and our knowledge of seismicity distribution from long distance seismic stations have pointed up some specific factors of interest in terms of possible tectonic hazards. The Hope Basin is a geologically youthfull down-dropped trough containing numerous faults which appear to cut most or all of the section of sediments which can be observed with seismic reflection methods. Both gravity faults and thrust faults occur, but whether they intersect the sea floor or not is difficult to discern with existing low resolution seismic data. Gravity faulting is particularly intense on the north flank of a basement ridge called Kotzebue Arch which trends westward across the basin from Cape Krusestern (see Figure 2). Thrust faults are numerous along the north and east side of the basin southwest of Pt. Hope. Although the level of seismicity of Hope Basin is low, there have been a few large earthquakes in western Hope Basin and earthquakes in eastern Hope Basin in the vicinity south of Pt. Hope, (Meyers, 1976, Barazangi and Dorman, 1968, Anon, 1970).

The outer margin of the Beaufort Shelf exhibits seaward slumping of surficial sediments, which appears to be active at present and producing a double shelf break: the first, a gentle break at the slump headwall and the second (seaward) at the true break to the steep continental slope. Slumping is the dominant geologic process on the continental slope.

As with the Hope Basin faults, it is difficult to discern whether these slumps are active at present, since we have very little or no high resolution seismic data to examine the features in detail. It seems reasonable to assume that they are a part of the presently active sedimentary processes forming the outer shelf/shelf break physiography.

Studies of epicenter distributions on the Chukchi and Beaufort Shelves is hampered by the lack, until recently, of nearby seismic stations. From the historical long distance epicenter locations available however (Meyers, 1976, Barazangi and Dorman, 1968, Anon, 1970), the shelves are characterized as being relatively quiet areas, which is consistent with their present remoteness from any presently active plate margins. An exception to this general quiescence is one highly localized zone of high seismicity on the eastern Beaufort Shelf near Barter Island, approximately 100 km from the Canadian border. The cause of this zone of active seismicity is uncertain although it occurs in an area where young (Neogene?) shelf sediments are thrust-folded. N.N. Biswas of the University of Alaska has set up a shore-based network of seismometers on Barter Island which will, in the future, better define this seismic zone as well as the Beaufort Shelf region in general.

One of the most bothersome geologic unknowns on these shelves is a lack of information on ages of the acoustic horizons mapped seismically in Hope Basin and on the Beaufort Shelf. All bottom sampling attempts up to the present have only recovered Holocene section, or perhaps in several places, the uppermost Pleistocene (Creager and McManus, 1967). Hence no direct evidence is available on ages of the sediments and rocks constituting these shelves. Ages must be interpreted on the basis of ages of possibly correlative sediments onshore. This uncertainty results in uncertainties in interpretations of the geologic and tectonic history of the shelves.

IV. STUDY AREA

Hope Basin is the southeastern part of the Chukchi Shelf which extends seaward from Kotzebue Sound. It is bounded on the north by the Alaskan coast and by a structural high called the Herald Arch, which extends offshore northwestward from Cape Lisburne. It is bounded on the south by Seward Peninsula. The Beaufort Shelf is the Arctic Continental Shelf north of Alaska. The geographic boundary between the Chukchi and Beaufort Shelves is not distinctive. Our work has involved the whole of this prograded shelf, the westernmost portion of which would be classified as the Chukchi Shelf, according to some workers.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

Since 1969, USGS has been collecting marine geological/geophysical data on the Chukchi and Beaufort Shelves. The seismic reflection data gathered (Grantz, et al., 1970, 1971, 1972a, 1972b, 1974) is the principal source of information contributing to our present state of knowledge of these shelves. One type of data which is lacking for the present task of environmental hazards assessment is high frequency seismic reflection or echo sounding data to give details of near-surface and surface geology which are not resolvable in the deep seismic data. The present plan has been to gather such data ("uniboom", 3.5 khz, 12 khz, and minisparker) on ships available to us in the Chukchi and Beaufort Seas.

Sampling of surface sediments in the Hope Basin and on the Beaufort Shelf has been fairly extensive (Creager and McManus, 1967; Naidu, 1974) giving a good knowledge of compositional distribution of modern sediment. However this sampling has not been particularly aimed at areas of deeper sediment outcrops. Our intention has been to attempt to core these older outcropping sediments, using dart corer and dredges to penetrate or break off these older, more indurated sediments. By this method we have hoped to date some of the older acoustic reflectors in order to facilitate a better interpretation of the geologic history and sedimentation rates on these shelves.

Until the present time, information on earthquake epicenter locations in the Beaufort and Chukchi Seas has been from remotely placed seismic stations, the closest being College, Alaska, more than 500 km from the nearest part of our study area. Recently however, partly under OCSEAP support, the University of Alaska (N.N. Biswas) has expanded its coverage of seismic stations to the Beaufort Coast and the Kotzebue area.

Deployment of Ocean Bottom Seismographs (OBS) was envisioned to: 1) monitor earth seismicity in areas of suspected tectonic activity and 2) to receive signals from artificial sound sources generated to provide seismic refraction profiles. The profiles were to obtain information on deep crustal seismic velocities from which the deep crustal structure of these shelves could be determined. The 2nd objective is indirectly supportive of the OCSEAP program, but its main purpose was to support our overall studied of the geologic structure of the Chukchi and Beaufort Shelves. By deploying the OBS system close to areas of possible tectonic activity it should be possible to record small earthquakes which occur with much greater frequency than large ones. (The frequency of earthquakes goes up exponentially with decreasing magnitude. The rate of occurrency of a given magnitude event is roughly 10x that of events of one magnitude higher.) Thus in the limited amount of recording time available to us with the OBS units, 10 days, it was hoped to record enough small magnitude events (magnitude 0, 1 and 2) to define patterns of seismicity hitherto impossible with teleseismic information only.

The field work plan was arranged to take best advantage of the usual pattern of ice retreat. Two ships were scheduled for the work, with 25 days on the USGS Research Vessel S.P. LEE beginning in Hope Basin and progressing into the Beaufort Sea as ice conditions allowed. Then 30 days were scheduled on U. S. Coast Guard Icebreaker GLACIER, to work mostly in the Beaufort Sea with a time overlap of 15 days with the LEE cruise. Data collected on S.P. LEE included 3.5 khz and uniboom high resolution seismic reflection and bathymetric profiles, single channel deep seismic reflection profiles, and measurements of the gravity field. The principal interests were focused on delineation of fault and slump features in Hope Basin and on the Beaufort Shelf. The OBS units were deployed from LEE in Hope Basin with the purpose of a test deployment in an area of extensive faulting in the southern central part of the basin. The original plan was to transfer the OBS equipment to GLACIER at Barrow for deployments around Barter Island in the Beaufort Sea. Due to the severe ice conditions in the Beaufort Sea this did not appear possible and the transfer was not made. The work on GLACIER was designed to survey the slump features on the outer Beaufort Shelf and slope with 2 khz bathymetric profiles as well as sample the bottom sediments with either dart core, dredge, gravity core or van veen, depending on the nature of the sediments, and judged effectiveness of the various methods to penetrate the surficial sediments.

VI. RESULTS

Due to an engine failure 4 days into our cruise on S.P. LEE, the planned 25-day work schedule was curtailed to 5 days. The 5 days involved deployments and recovery of the OBS systems in southern central Hope Basin and high resolution reflection surveying of this part of Hope Basin. Figure 1 gives a track

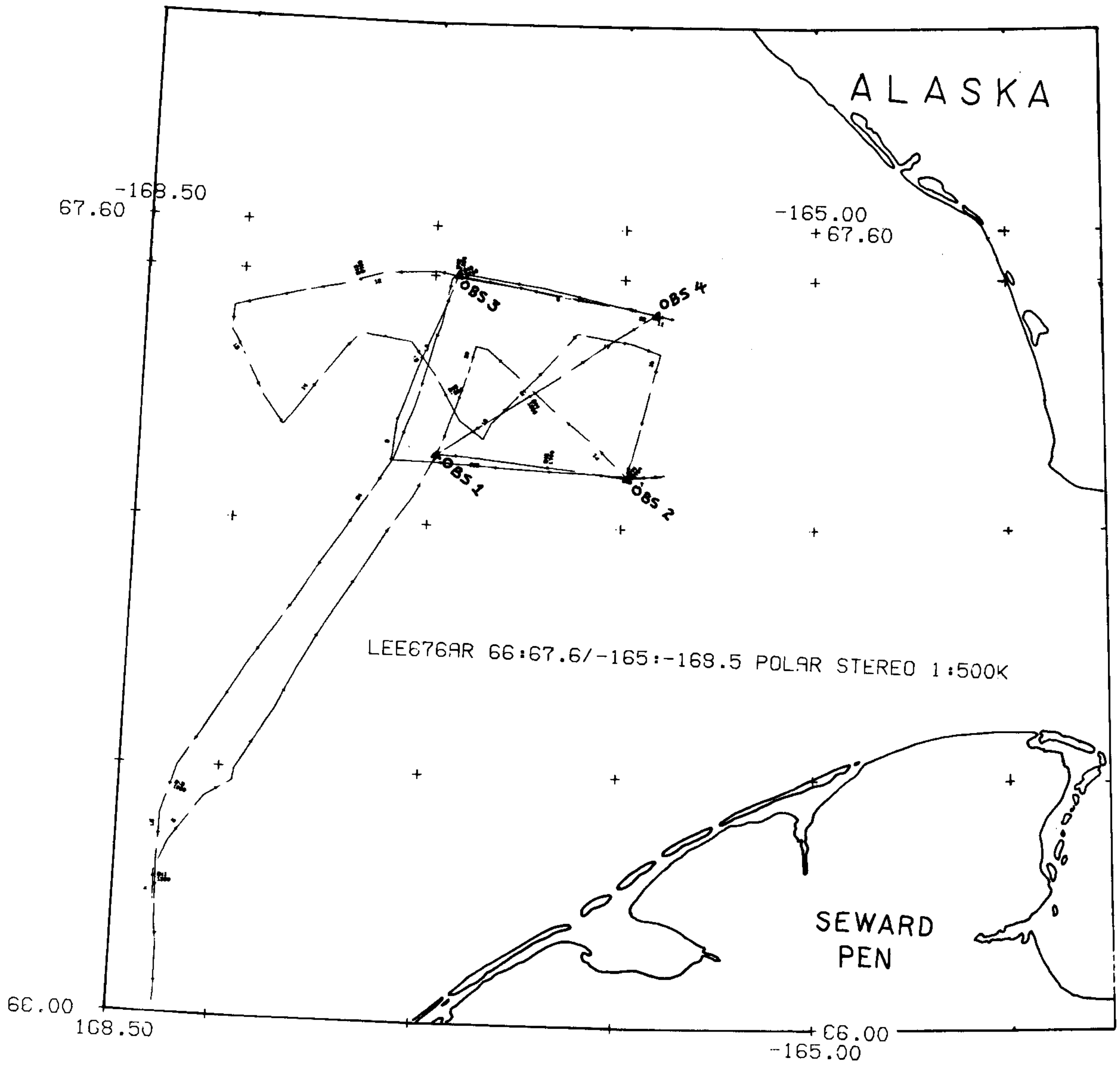


Figure 1. Track of USGS Research Vessel S.P. LEE in Hope Basin. Tickmarks every hour.

chart of our Hope Basin work. Despite the curtailment in our schedule, some new data was collected which contained information with environmental implications pertinent to OCSEAP. One point of interest is the observation that the gravity faults on the north side of Kotzebue Arch (along approximately 67° N) are apparently not active at present. Figure 2 shows a general view of the tectonic framework of Hope Basin. The zone of most recent tectonic activity lies between about 67° and 68.5° N where motion along numerous gravity and thrust faults has produced an east-west downdropped zone filled with young faulted sediments. The southern boundary of this young basin is formed by Kotzebue Arch, just north of 67° N. The extensive gravity faults along the north side of Kotzebue Arch was the target area of our survey on LEE. Figures 3 and 4 show the region of these faults and a sample of a high resolution reflection record over them respectively. The Chukchi Shelf is blanketed by a thin (averaging about 8 m) transgressive sequence representing Holocene deposition (Creager and McManus, 1967) and the evidence for fault quiescence lies in the interpretation of this layer. This layer is acoustically homogenous and very distinctive from the underlying sediments, to which they have an unconformable relationship. In our survey area the faults which displace the deeper Tertiary strata are found not to affect this overlying Holocene layer, implying that the faults have been inactive since the time of Holocene flooding of the shelf (approximately 13,000 years before present).

Another point of interest in this Hope Basin high resolution survey is the observation of an "acoustically turbid" zone in the sediments at depths ranging from 5 to 15 m. This acoustic anomaly, shown in Figures 5 and 6, is best explained as highly compressible gas-saturated sediments such as is commonly found in estuaries (e.g., Schubel, 1974). Its occurence on the north flank of Kotzebue Arch is in a pattern parallel to the east-west structural

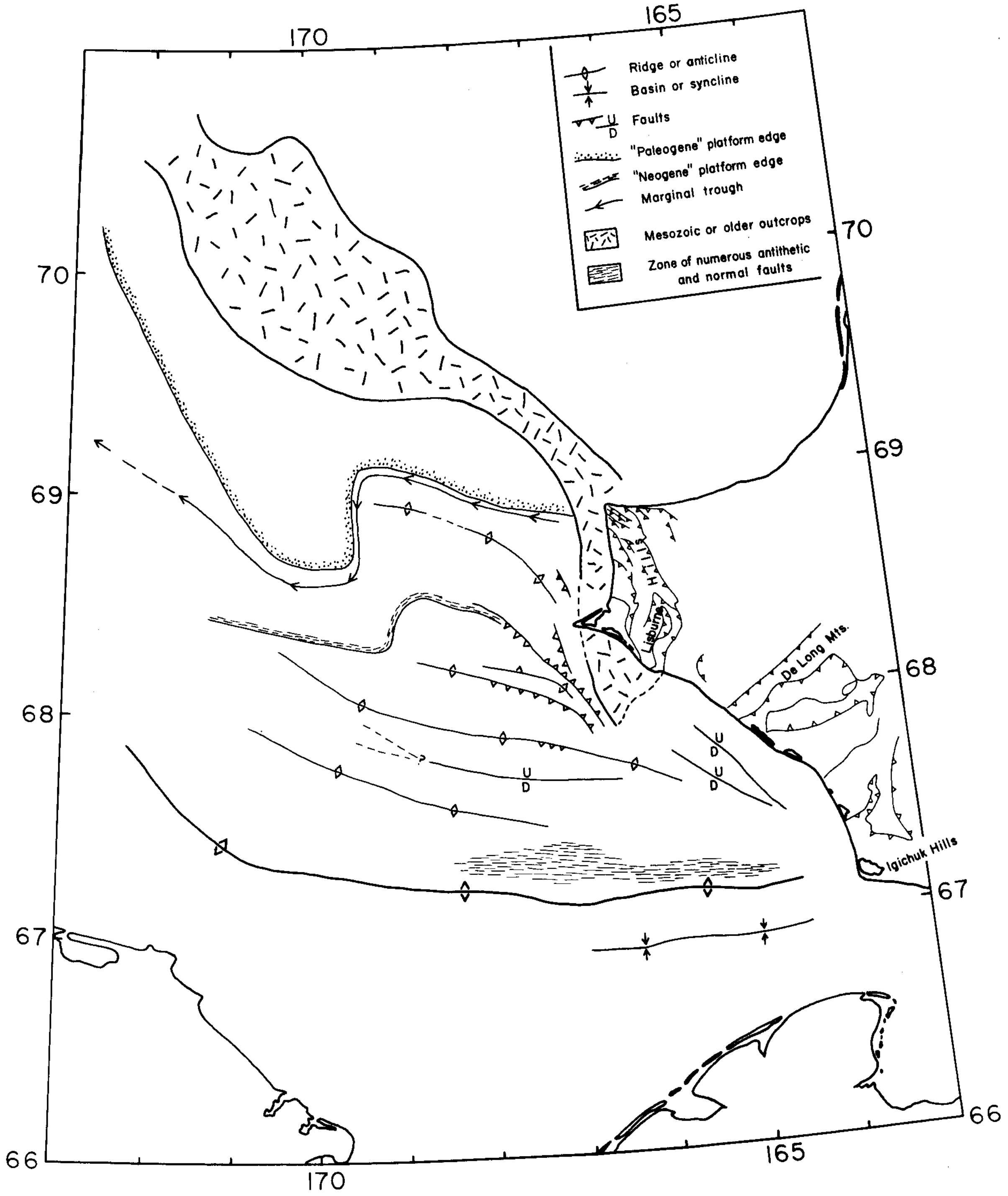


Figure 2. Hope Basin tectonic elements, from deep seismic data. The numerous faults on the northside of Kotzebue Arch along approximately 67°N are judged to be presently inactive. The recency of the thrust faults west and south of Pt. Hope is uncertain.

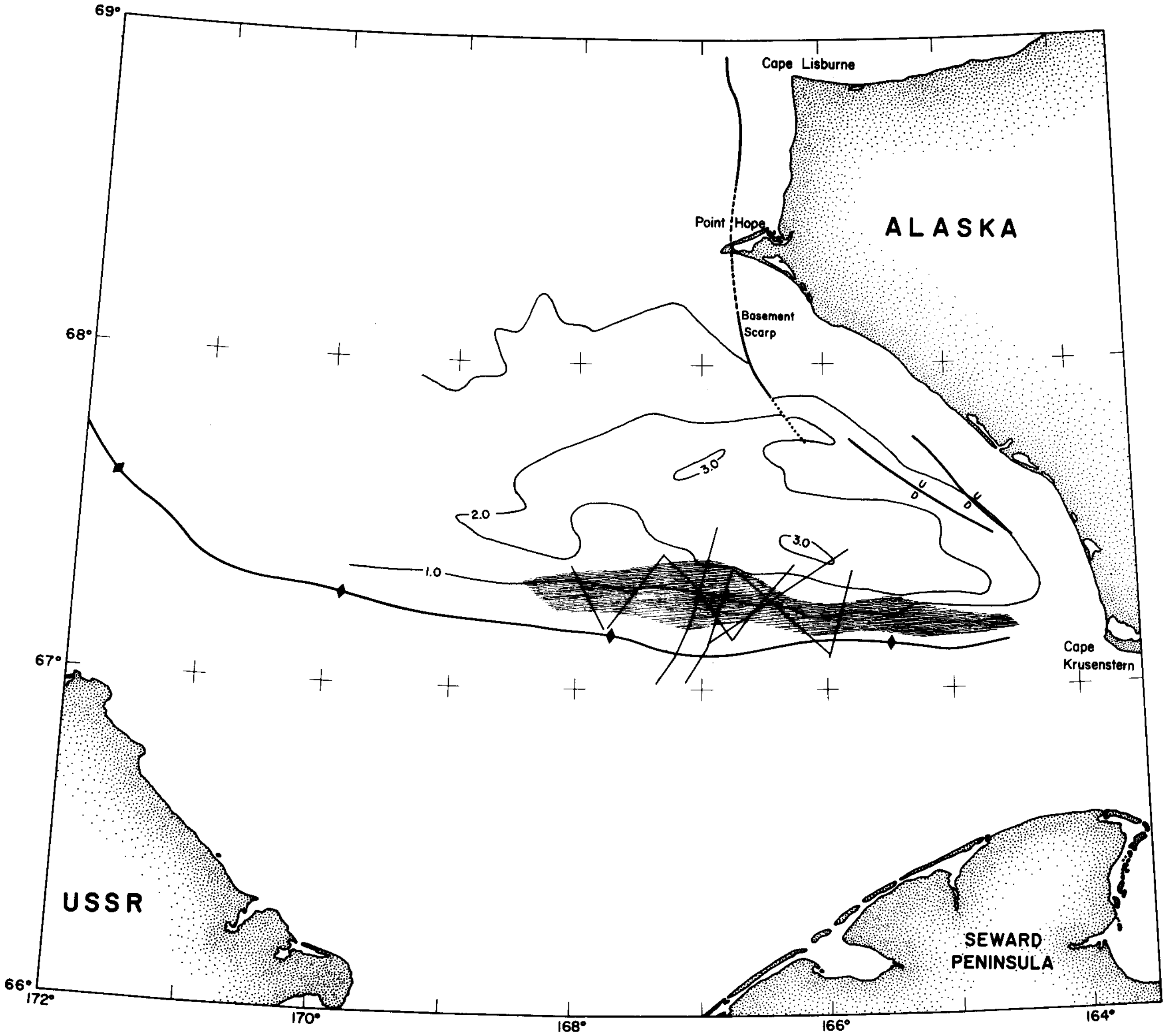


Figure 3. Contours of Hope Basin "Neogene" sediment thickness (in kilometers) and zone of numerous normal and antithetic faulting (patterned area) on north side of Kotzebue Arch. Track lines are from LEE-76 and where thickened refers to profile shown in Figure 4.

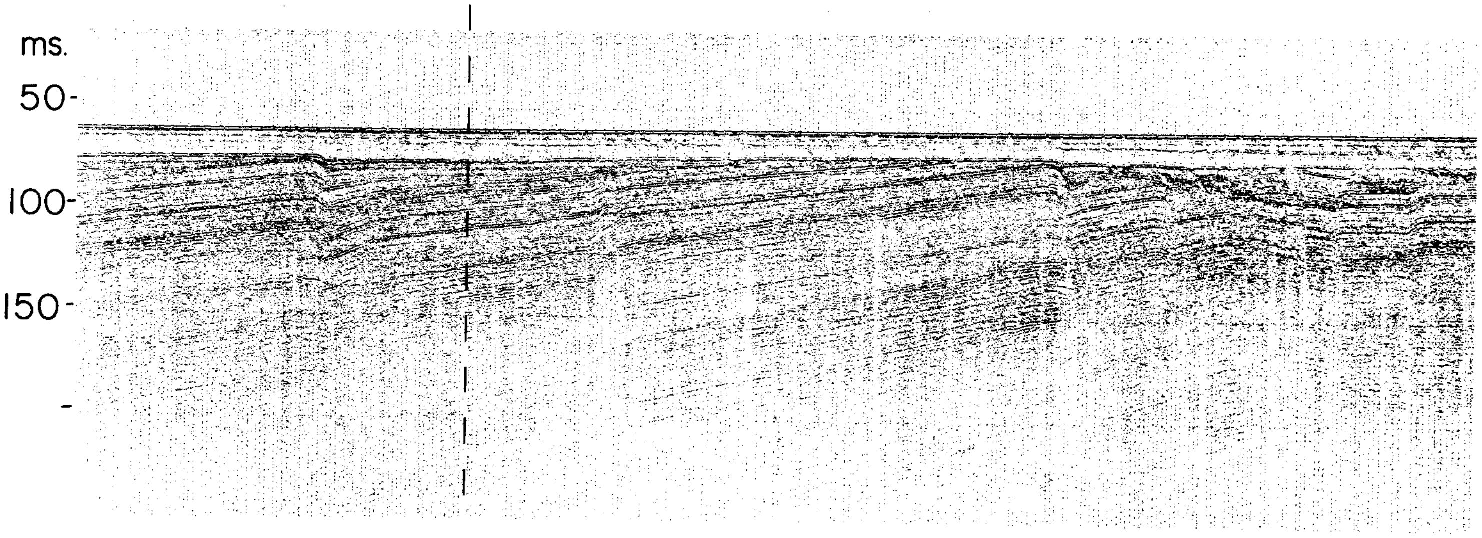


Figure 4. "Uniboom" (approximately 1 khz) reflection records across qravity faults north of Kotzebue Arch (location shown in Figure 3). Vertical scale in milliseconds. 100 milliseconds equals approximately 85 m. Horizontal length of record approximately 2.5 km.

grain of Hope Basin. Whether this may represent gas leaked upward perhaps through faults from deeper Tertiary sources or is gas generated "in situ" in the Holocene or upper Plaistocene sediments cannot be determined. Other possibilities of different causes of the acoustic anomaly, such as permafrost or gravel facies in the sediments cannot be ruled out at this point but appear unlikely.

Successful Ocean Bottom Seismograph recordings were made at the three locations shown in Fibure 1 during a 2-day period. The OBS systems used were manufactured by Polar Research Laboratories Inc. of Santa Barbara. They were designed to record frequencies in the range of interest for microearthquake and seismic refraction recording centered at about 7 hertz. Physically the systems were each composed of an in-line string of 4 components, in order of deployment:

1. danforth anchor,
2. seismometer (4.5hz),
3. pressure case for electronics and cassete recorder, and
4. call up package, utilizing a pop-up buoy actuated by a coded explosive signal. This type of component system with recorder mechanics housed separately from the seismometer sensor has the inherent quality of isolating the noise generated by the recorder from the seismometer. Also, an in-line component system has the advantage of low profile on bottom, a good quality for areas where significant bottom currents may be active and prodicing noise.

Four OBS units were deployed. One of the four was lost due to failure of a hauling line. The records obtained are in general satisfactory in terms of instrument noise levels and frequency response, although one of the recovered three instruments suffered from higher noise levels than the rest. It is not known at present whether this higher noise level is real ocean bottom noise,

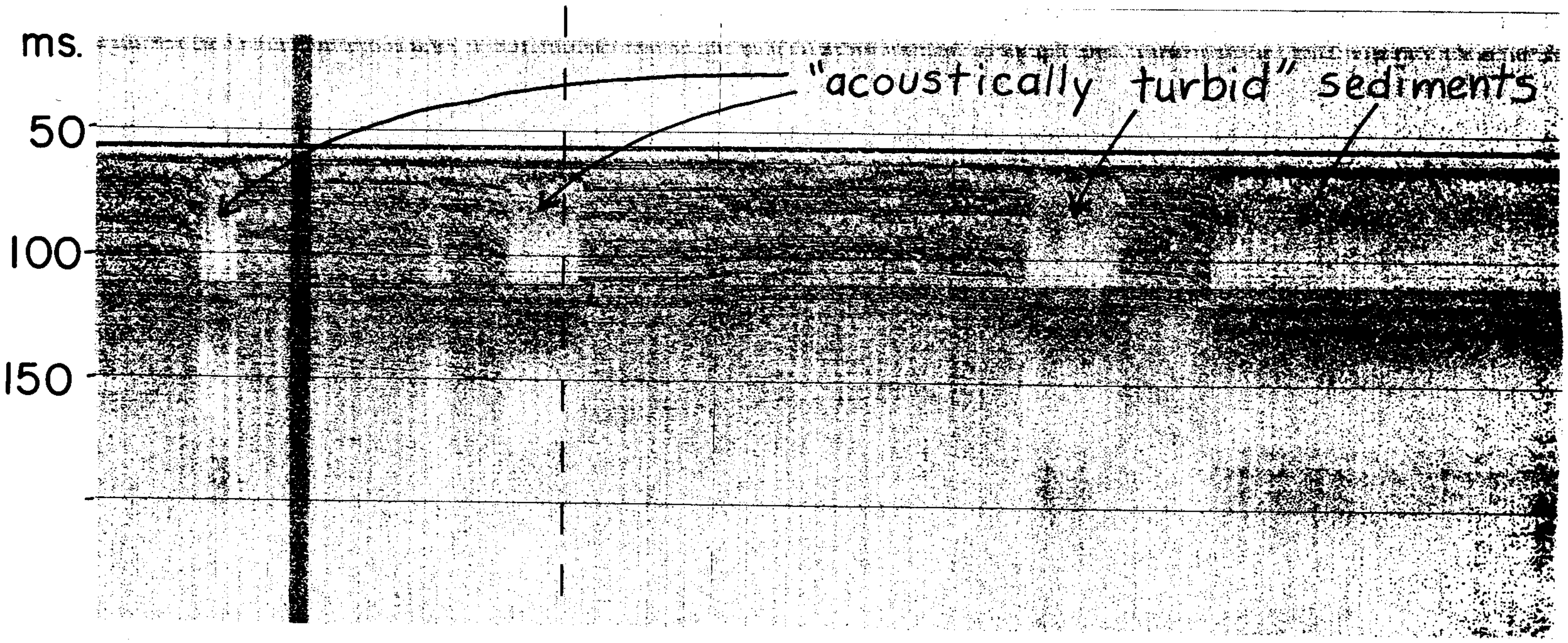


Figure 5. "Uniboom" reflection record in Hope Basin showing zones of "acoustically turbid" sediments, believed to be due to gas saturatation. Scales same as in Figure 4 caption.

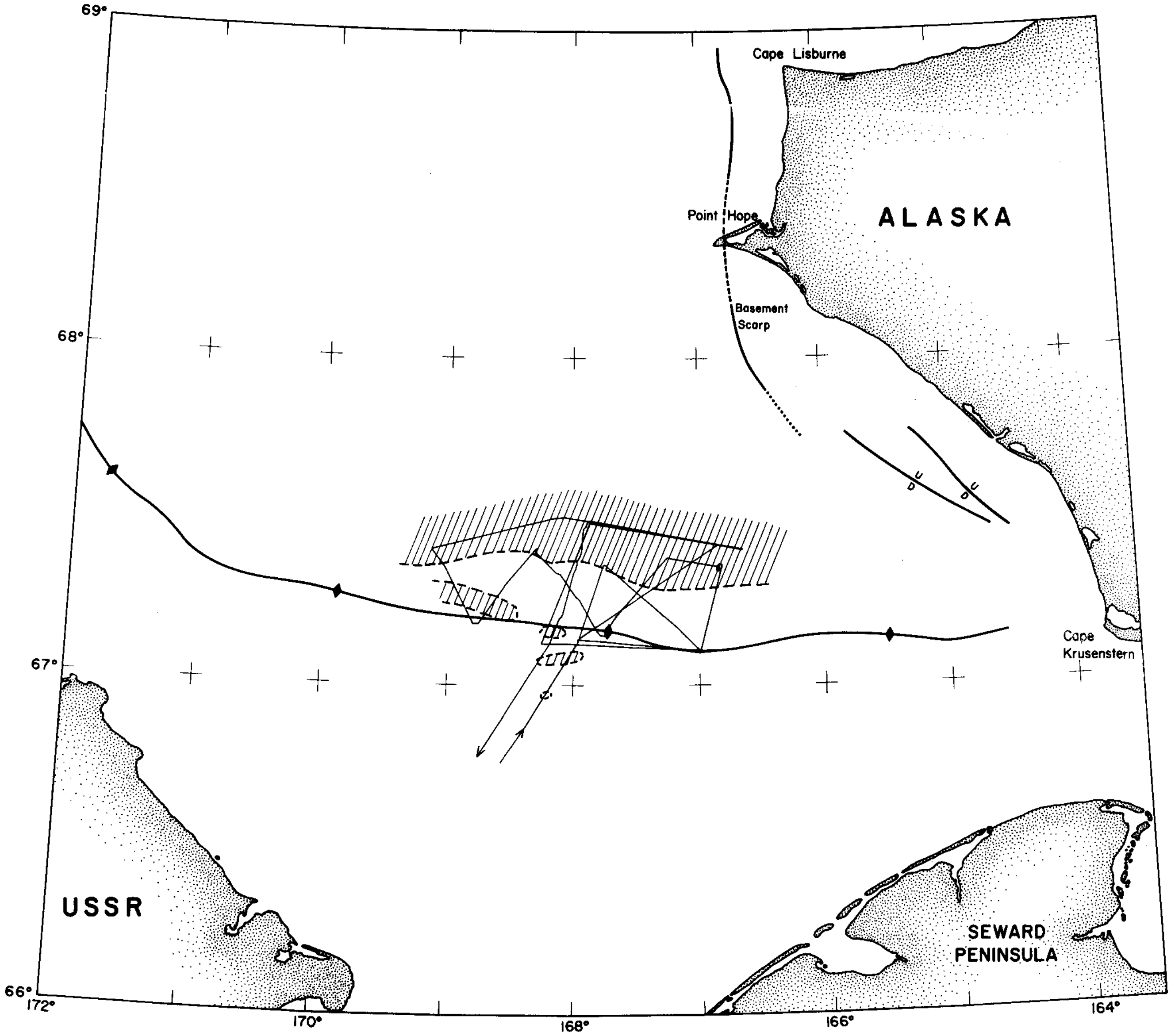


Figure 6. Distribution of acoustically turbid sediments (shaded) in Hope Basin survey area. LEE-76 track shown.

or an instrumental problem. No seismic events have been found which can be correlated from station to station, although, at present, only a small fraction of the total record lengths have been examined in detail. The principal results of the deployments and recovery were the experience gained in this test which showed that a) this type of low-cost OBS system appears capable of recording seismic data with the necessary fidelity for earthquake location studies and b) deployment and recovery of such systems with components strung out along a line is feasible from a moderate size research vessel, at least with no worse than moderate wind conditions.

Our 26-day cruise on GLACIER from Barrow to Barrow (Figure 7) was beset by the problem of very severe ice conditions which limited our work to the western Beaufort Shelf and Chukchi Sea and made seismic surveying of features of interest very difficult to do with any kind of logical areal survey pattern. Our efforts at sampling older outcropping strata with dart core and dredge (see Figure 8 for locations) apparently were futile as none of the recovered sediment samples appear older than Holocene. All samples were gray to black muds with varying amounts of sand, silt, or gravel. Core length averaged 36 cm with a maximum length of 170 cm. Samples were described and color photographed on board ship. A search was made for microfauna which might reveal a pre-Holocene age of the sediment. Subsamples were taken from most sediments for analysis for lighter hydrocarbons by gas chromatograph. This analysis is being done by K. Kvenvolden at U.S.G.S. Collection of benthic megafauna was made for transmittal to the California Academy of Sciences in San Francisco.

A good track coverage of Barrow Sea Valley with 12 khz echo sounder including its extension out onto the continental slope at 2000 m was obtained however, on GLACIER. We are in the process of examining this data in detail for its information about active sedimentary processes in the sea valley today.

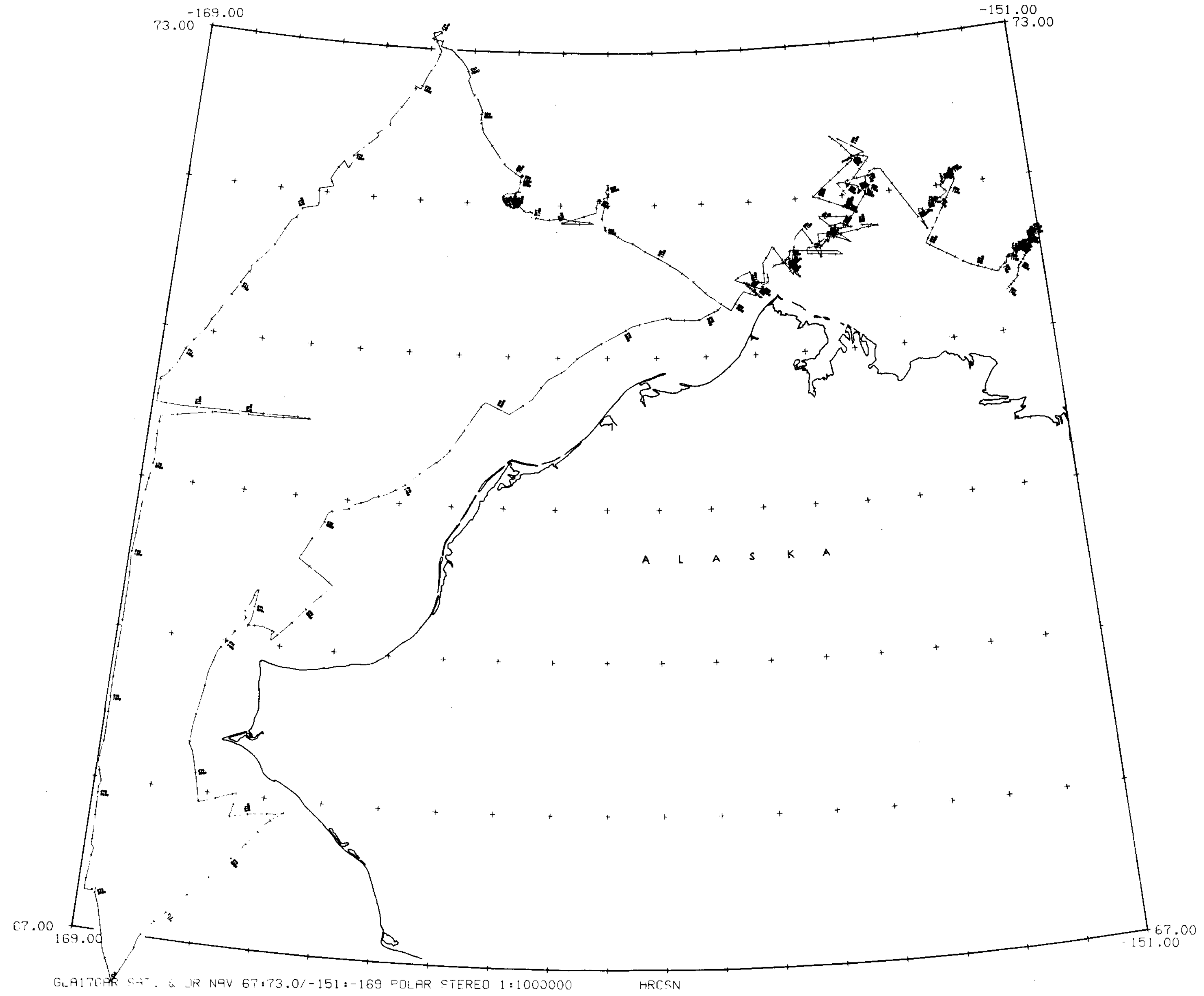


Figure 7. Track of U.S. Coast Guard Icebreaker GLACIER in Beaufort and Chukchi Sea. Tickmarks every hour.

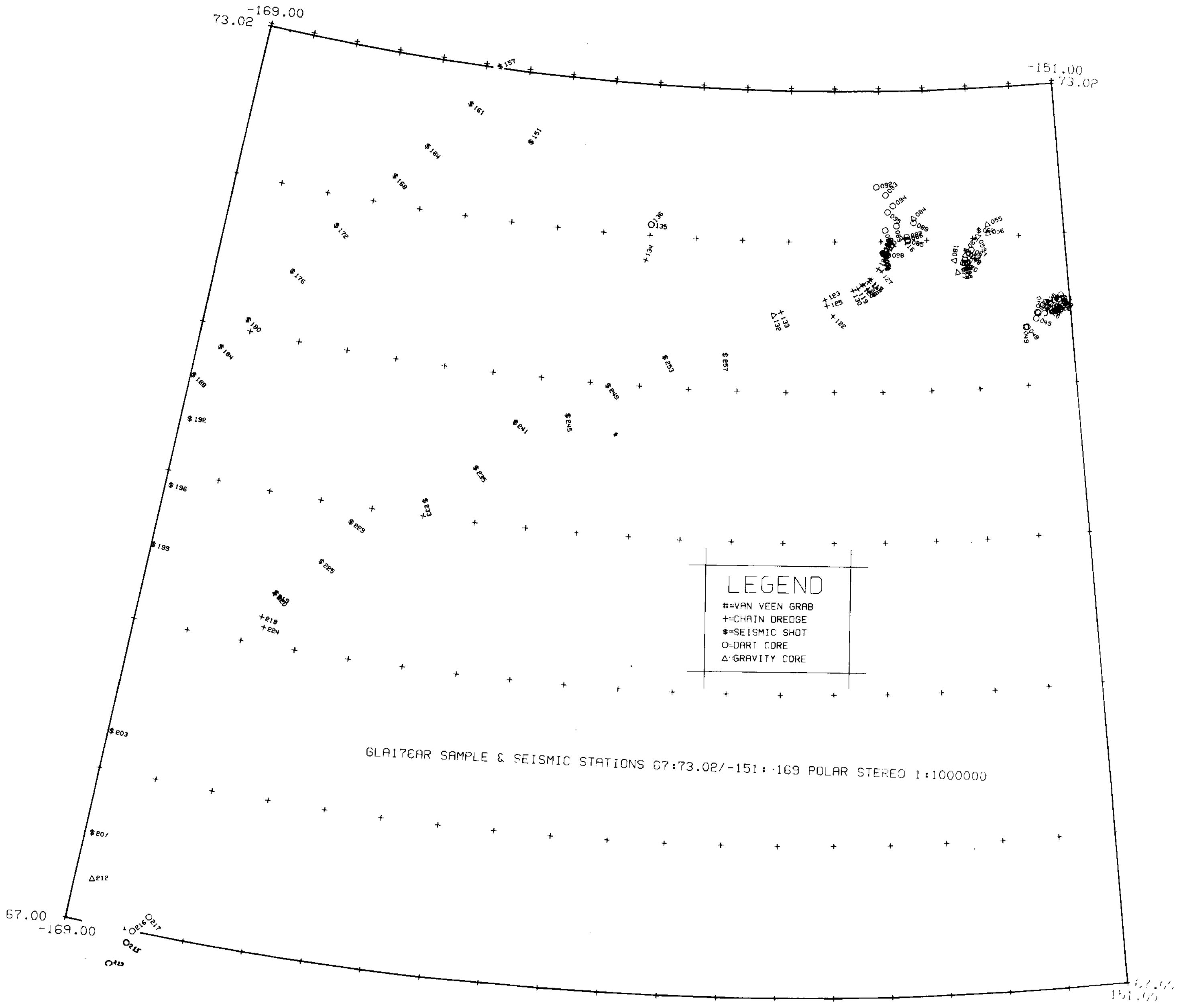


Figure 8. Sampling sites (dart core, gravity core, chain-rectangular dredge, or VanVeen grab) made from U.S. Coast Guard Icebreaker GLACIER.

The limited 12 khz data on the outer Beaufort and Chikchi shelves which we did obtain will be used to add to our studies of slumping processes active here.

Studies of existing seismic data on the Beaufort outer shelf has shown that subaequeous slumping is the dominant degradational process on the upper continental slope in the Beaufort Sea. This process, which is active today, determines the positions of the continental shelf - slope break and in places is actively sapping the outer shelf. In one large area, the outer shelf itself is disrupted by shallow, slope-directed slump scarps.

The location of the physiographic provinces of the outer Beaufort shelf and upper slope that are dominated or effected by slumping are shown in Figure 9. The location of the zone of active slump-related scarps on the shelf, which lies between 151°30' and 154°30'W, and the location of the sea valleys, canyons, and other major physiographic features of the shelf are also shown. The recency of activity was estimated from morphologic criteria. A series of cross-sectional sketches typical of the outer continental shelf and upper slope, based on seismic reflection profiles, are presented in Figures 10,11. The cross-sections were prepared from seismic reflection profiles recorded with long offsets, that is, with large separations between the seismic sources and the receiving hydrophones. This offset produced apparent depths that were too great by $\sim$16% to $\gg$ 16% in the uppermost 100 m of the profiles, 8% at -150 m, 4% at -200 m, 1% at -400 m, etc. Because of this, the uppermost part of the cross-sections from 0 to about -150 m, was reconstructed from other bathymetric data, where available, or by estimation. The dimensions, slope and estimated amount of slip of the large bedding plane slides that characterized the upper slope east of 148° W long are presented in table 1.

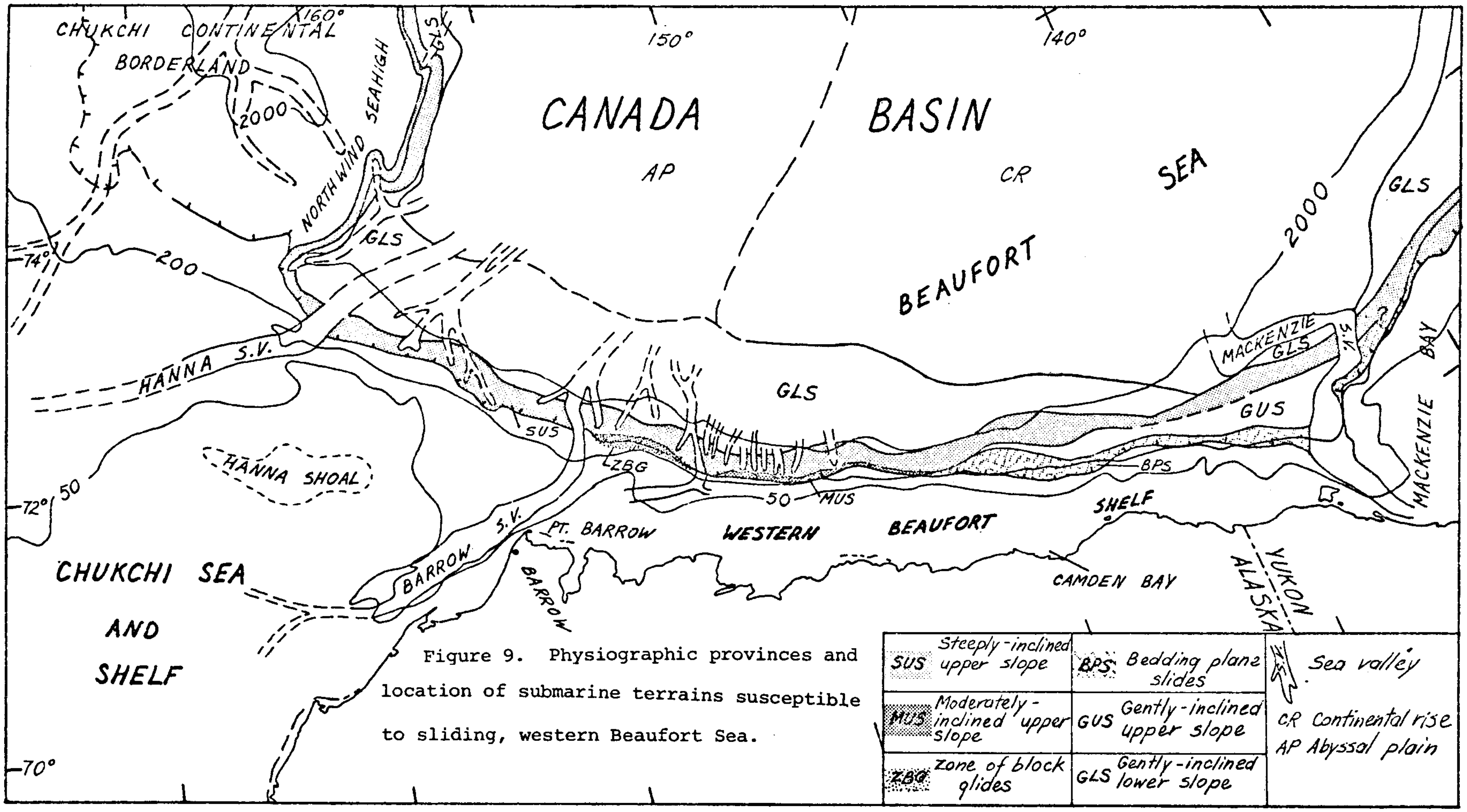
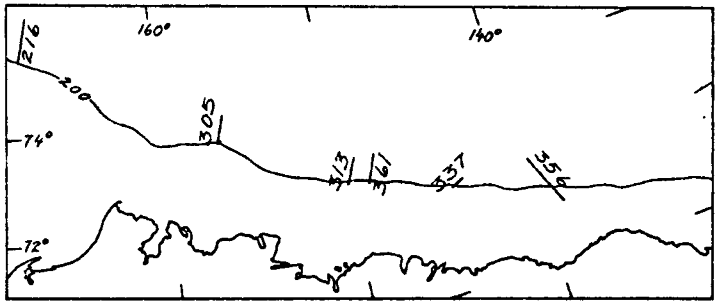


Figure 9. Physiographic provinces and location of submarine terrains susceptible to sliding, western Beaufort Sea.



Locations of seismic profiles shown in figures 10 and 11.

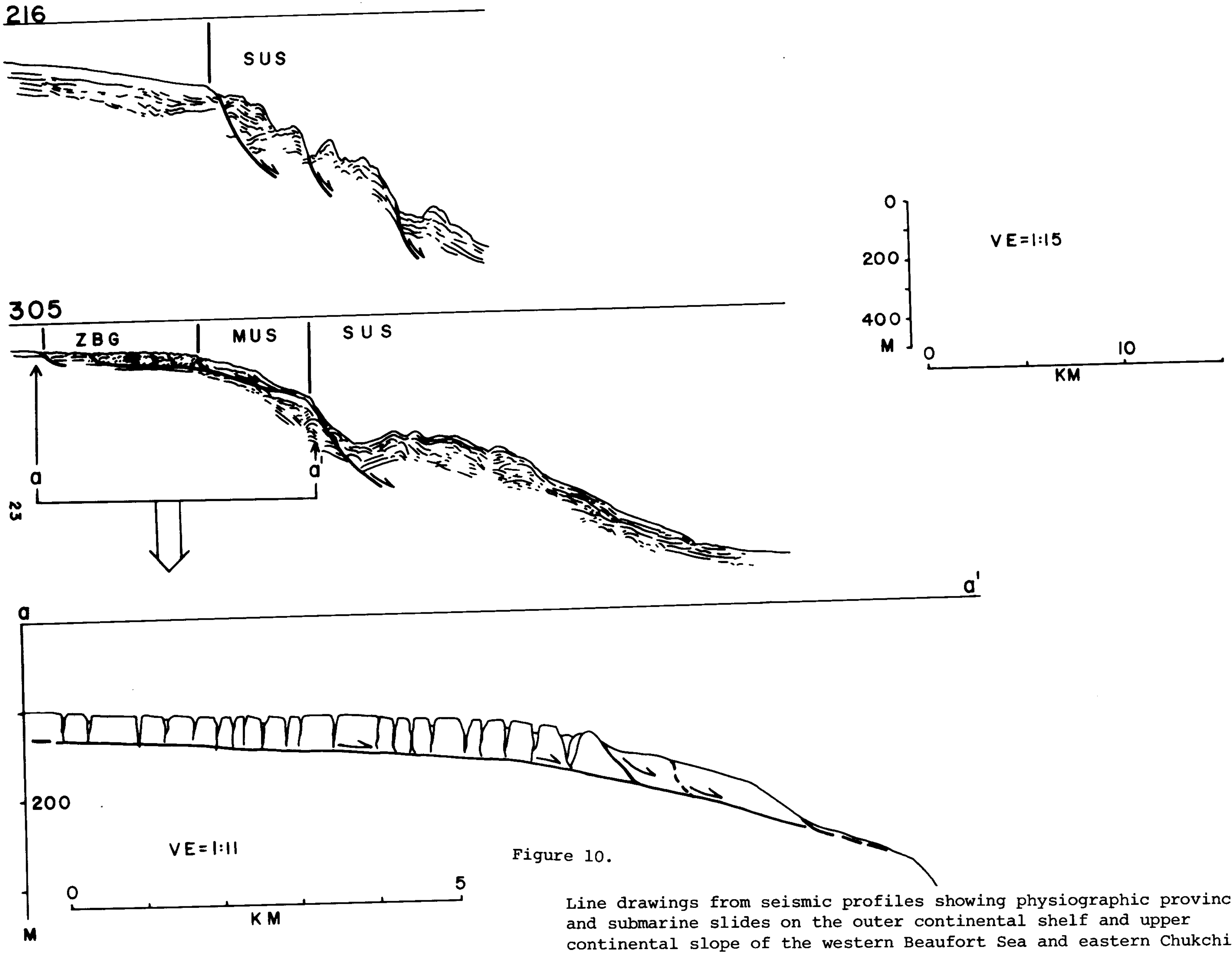


Figure 10.

Line drawings from seismic profiles showing physiographic provinces and submarine slides on the outer continental shelf and upper continental slope of the western Beaufort Sea and eastern Chukchi Sea.

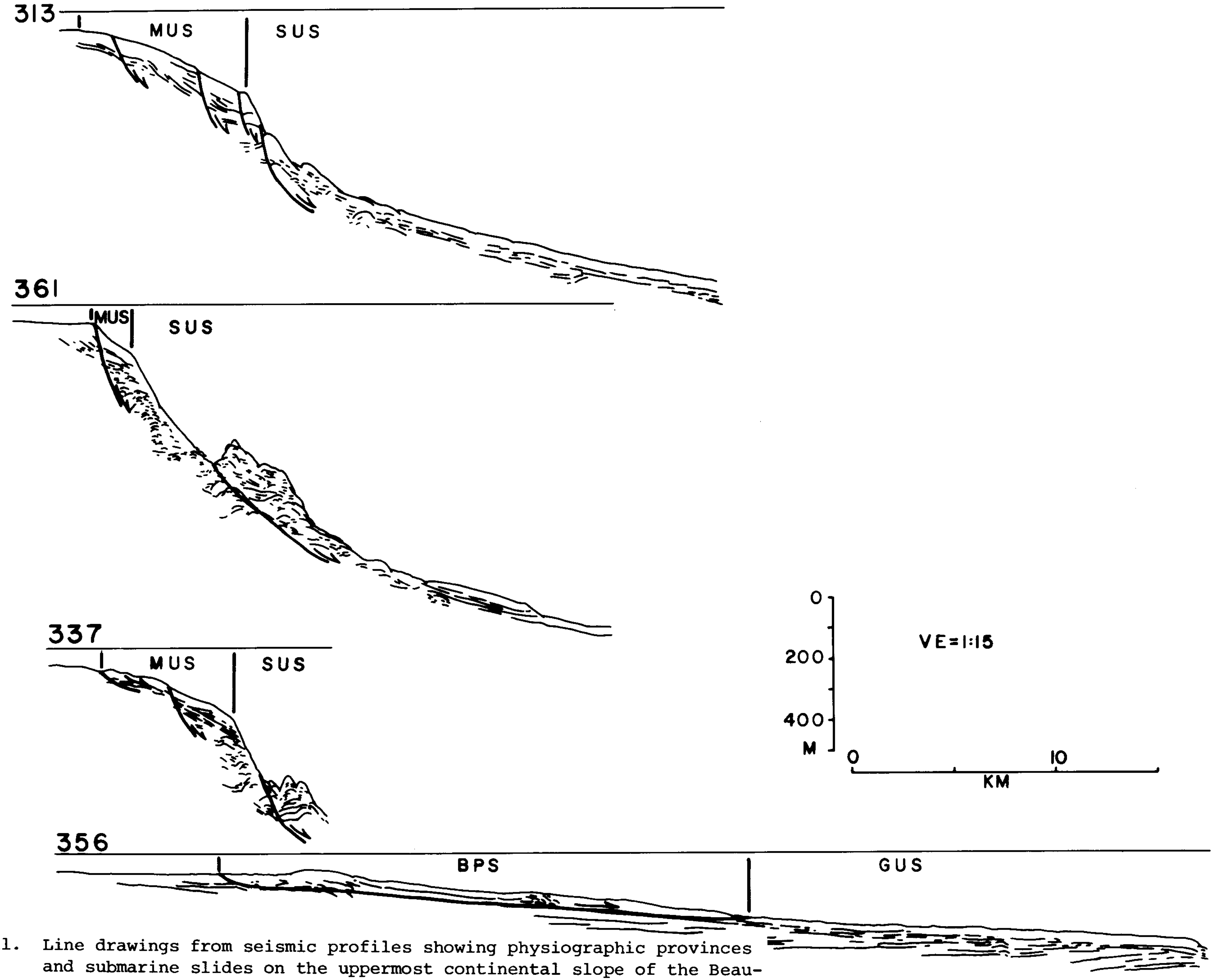


Figure 11. Line drawings from seismic profiles showing physiographic provinces and submarine slides on the uppermost continental slope of the Beaufort Sea between 144°W and 150°W long.

Table 1. Measurements on large low-angle bedding plane slides on gently-inclined upper continental slope in Beaufort Sea east of 148°W. long.

Seismic reflection section. Location on figure 9 .	Minimum extent normal to slope. Km	Most common ("average") thickness Meters	Maximum thickness Meters	Average dip(inclination) of slip plane downslope of headwall region-degrees	Rough estimate of horizontal component of slip at head of slide-taken normal to slope. Km
357-8 (Long. 145°W.)	28	100	150	0.8°	~0.8
356-7 (Long. 144.5°W.)	28(33?)	90	140	0.8°	~1.2
341-2 (Long. 144°W.)	13.5	90	120	1.4°	~1.3
343-4 (Long. 143.5°W.)	20.4	70	100	0.9°	~0.6
350-1 (Long. 139°W.)	13	110	130	0.5°	~0.2
352-3 (Long. 137°W.)	20+	230	320	Upper 1.3° plane Lower 1.3° plane	Total ~2.3

VII. DISCUSSION

Due to the unfortunate logistical problems which arose in our attempted field work last summer, only a small fraction of what we had hoped to accomplish was done, but with the limited amount of new data plus some new information from study of our existing data, a number of factors in Hope Basin and on the Beaufort Shelf have come to light as possible environmental hazards.

Hope Basin "gas saturated" sediments

The acoustically anomalous sediments in Hope Basin, which appear to be best explained as gas saturated sediments should be kept in mind in any future drilling activities. These "acoustically turbid" zones in the sediments are characterized by (see Figures 5 and 6): a) upper surfaces roughly conformable or parallel to sedimentary strata in adjacent unaffected areas, although in general they describe rougher surfaces than the latter; b) the almost total lack of any reflected energy from below this upper surface; c) apparent downbend in at least one instance of a weak reflector below this surface suggesting anomalously low velocity sediments; d) very abrupt lateral boundaries, with no instance of any gradational boundaries found; e) occurrence in a pattern parallel to and along the north flank of Kotzebue Arch. Speculation that this feature could be subsea permafrost seems unlikely to be correct based on the shallow depths observed, 5 to 15 m, compared to observations of much greater depths of subsea permafrost near shore on the older Beaufort Shelf (D. Hopkins, personal comm.). Speculation that this feature could be highly reflective gravel beds seems also unlikely to be based on the abrupt boundaries observed. Gravel facies would be expected to grade into finer material at least in some directions producing a gradational, rather than abrupt edge.

Many uncertainties about this phenomena remain which will hopefully be clarified in future field work. Samples of surface sediments taken in this region are in the process of analysis for hydrocarbon content. This analysis may shed some light on these uncertainties. Obviously, direct sampling of this material, presumably by drilling during the ice-covered season would be highly desirable, but appears beyond the scope of our program plans at present.

Hope Basin Faulting

The Hope Basin faults have been demonstrated to be presently inactive in one part of the basin where on the basis of previous data it was judged likely to find the most active faults. The faults in this area are gravity faults (both normal and antithetic) bounding the south side of the youngest downdropped basin of Hope Basin. On the north side in the vicinity of Pt. Hope the faulting is mostly thrust, or compressional type. Whether these latter faults will also prove to be inactive remains to be seen. During the passage past Pt. Hope on GLACIER last summer a few prominent scarps on the sea floor were observed with the 12 khz sounder facing southwestward with slopes exceeding 10° and heights averaging several meters, unusual for the very flat Chukchi Shelf. These scarps could be tectonic in origin or alternatively, they could be erosional features, as they lie along the path of a seasonally strong coastal current.

Ocean Bottom Seismograph Plans

For the present, plans to deploy the OBS units next summer have been dropped. For environmental reasons, we have decided not to carry out the explosive refraction profiles which we originally had planned. Hence their deployment would have to be justified in terms of shiptime, expense and effort in preparation, transportation, etc., solely on the basis of their usefulness to determine local epicenter patterns in regions of interest, a justification we would have difficulty making at present. So at this point, we consider the OBS systems tested and "ready-to-go" for future programs when they may be of use.

Beaufort Outer Shelf Slumps

Subaqueous slumping, bedding-plane slides and block glides (see Figures 9, 10, and 11) disrupt the seabed and substrata over about 500 sq km of the outer continental shelf and some 12,000 sq km of the upper continental slope in the Beaufort Sea between the Canadian border (long. 141° W.) and Barrow sea valley (long. 154°45' W.). An additional 4,500 sq km of slump-dominated upper slope lies between Barrow sea valley and 161° W., where the continental slope swings north into the high Arctic.

Slumping is a process that has operated beneath the upper slope and outer shelf of the Beaufort Sea for a geologically significant span of time, and it is a major mechanism for moving terrigenous sediments from the continental shelves to the deep ocean basins. Our low-resolution seismic data indicate that the process is still active. However, they cannot directly serve to distinguish slumps and slides that are young in a geologic sense from those that have been active on a time scale, and with a frequency of occurrence, that make them hazardous to man. The morphologic roughness, or "freshness," of many of the slump and slide features, and their position on, or at the brink of, steep slopes, nevertheless suggest that some of them may be sufficiently young to pose a hazard to petroleum exploration. The likelihood that the areas of slumps and slides will actually be tested, and perhaps developed, for petroleum depends mainly upon the development of technology for producing oil and gas wells in regions beneath the drifing Arctic ice pack. Drilling from vessels is already possible over much of the affected areas because in occasional years they are free of heavy ice for as long as several weeks.

The outer shelf and upper slope in areas of the Beaufort Sea deeper than 60 to 70 m are more amenable to the establishment of seabed oil and gas production facilities than shallower areas of the shelf seaward of the coastal shear zone of the Arctic ice pack. The shear zone lies at variable depths, usually about 20 m. Areas of the shelf and slope deeper than 60 or 70 m lie below the deepest keels of sea-ice pressure ridges and ice islands (tabular icebergs). These keels extend to depths between 40 and 50 m. As a result, if sufficiently large oil or gas pools could be found beyond the -60 or -70 m isobath, they might be produced from production facilities placed on the seabed. In the event of failures such facilities could, in theory, be reached by small submersibles deployed through the sea ice. In contrast, seabed production facilities placed between the 20 and 60 m isobaths, even if they were armored and buried beneath the seabed, would be much more difficult and dangerous, and often impossible, to reach during most of the year. In view of those considerations, we believe that attractive exploration targets on the outer shelf and upper slope are as apt to be tested as targets lying between the shear zone and the 60 or 70 m isobath.

Steep Upper Slope

The upper continental slope in the western Beaufort Sea (map unit SUS, Figure 9) has slopes that range from 5° to about 20°, with 10° being a representative average value. Its bathymetry is complex, being shaped by irregular slump masses and smooth slump slip-plane surfaces. The steep slopes, irregular bathymetry and, in places, sharp offsets of the seabed at slide or slump planes, suggest that slumping is a presently active process. The slumps tend to be large, internally chaotic, and to have comparatively steep slip planes. Bathymetric relief of the slumped masses ranges up to 300 m, and the width of the slide masses normal to the slope ranges up to 12 km.

Although the slumps as a class are young in a geologic sense, our data do not define the age of most recent slippage because of the low seismic frequencies we recorded. High-resolution seismic reflection profiles and subseabed sampling with piston cores will be required to definitely establish the age of the slumps and the recurrence interval for slumping at points along the slope.

Moderately Inclined Upper Slope

The upper continental slope between the steep upper slope and the shelf break (map unit MUS in Figure 9) is characterized by moderate slopes of 2 1/2° to 6° (average 4°), and by comparatively steep slump slip planes that in places offset the seabed. In this zone, in contrast to the steep upper slope, the slumps have small displacements and the slump blocks are typically not churned internally.

The moderately inclined upper slope is considered potentially unstable because it contains some fresh-appearing scarps that displace the seabed, and because it lies at the head of the steep upper slope. The latter represents a free face toward which the slumps that underlie the moderate slope may move. As with the steep upper slope, more detailed data are needed to define the recency and recurrence interval of slump formation on the moderately inclined upper slope.

Outermost Continental Shelf

The continental shelf break in the Alaskan portion of the Beaufort Sea is in most places the headwall scarp of the landwardmost large slump on the upper continental slope. Because slumping is causing retreat of the shelf break, the outermost shelf is potentially unstable. Where the shelf itself is not broken by slide fissures or scarps, a zone 2 km wide along the shelf break is tentatively estimated to contain the ground of greatest susceptibility to failure. Additional data will be required, however, to define the width of the potentially hazardous zone, and to estimate the recurrence interval of failures within it.

Zone of Gravitational Block Gliding on the Outer Shelf

The outermost continental shelf between 152°30' and 154°30' is broken by multiple open fratures from the shelf break south for as much as 6 km (map unit ZBG on Figure 9). The fractures are interpreted to be produced by the fragmentation of a thin sheet of sediment into blocks, and the nonrotational basinward gliding of the blocks along a liquefiable or very weak shallow bed or zone. This type of slide is called a block glide. The slip zone dips seaward about 1° (0.9° and 1.2° along our two best crossings). The blocks are about 120-130 m thick, and typically 100 to 500 m wide along lines normal to the shelf break. The blocks become increasingly separated as they move downslope. At the shelf break they lose coherency and slump out down the continental slope. The zone of block gliding is approximately 80 km long parallel to the shelf break, and as much as 6 km wide normal to it.

The gravitational block glide landslides resemble the Turnagain Heights and other landslides triggered in Anchorage during the 1964 Alaska earthquake. In Anchorage (Hansen, 1965), movement occurred in a stratigraphically controlled zone of sensitive sand, silt, and silty clay that was liquefied by the earthquake waves. A sensitive sediment is one that loses much or most of its strength after being "remolded"; i.e., kneaded, squeezed, or otherwise deformed. By analogy, we postulate that a sensitive bed or zone, possibly quite thin, and at a depth of about 120 to 130 m underlies the block glide terrain and an unknown additional area of the Beaufort outer shelf.

Present and former sedimentation patterns suggest that a large part of the shelf lying between Barrow sea valley and 152° W. long. could be underlain by the postulated sensitive layer. Sensitive sediments can be liquefied by nonseismic natural and manmade events, as well as by earthquakes. Therefore, the essentially aseismic nature of the region of block glides on the Beaufort Shelf

(Meyers, 1976) does not argue against the postulated origin. Additionally, moderately large earthquakes with large recurrence intervals may occur in the region.

The presence of an areally extensive sensitive layer beneath a large area of the western Beaufort outer shelf would constitute a serious hazard to petroleum exploration. The block glides occur in water depths greater than the Pleistocene regressions in sea level. Barring large tectonically induced fluctutations in sea level, of which we have no evidence, we must conclude that the block glides formed under conditions much like those of the present. Their bathymetric roughness, to the extent that this could be defined with lower-resolution profiles, suggests that they are young in a geological sense and very likely in an historical sense. Verification of the presence of the postulated shallow sensitive layer or zone and determination of its engineering properties, areal extent, and recency of movement should be made and analyzed before drilling rigs or other structures are placed upon, or penetrate, the seabed in the region of the block glides.

Bedding-plane Slides East of Long. 148° W.

The province of gently dipping upper continental slope with low-angle bedding-plane slides east of 148° W. long. (map areas GUS and BPS, Figure 9) extends from the shelf break at about 80 m to depths of 360 m near 147° W. and about 700 m near 141° W. The bedding plane slides underlie more than half of this province. The dimension of the slides and an estimate of their slip are given in table 1. The province appears prospective for petroleum (Grantz, et al., 1975) and water depths are within the capability of present technology. If and when techniques for coping with the Arctic ice pack are developed, the area will probably be explored.

The heads of the bedding-plane slides were emergent during the maximum

Pleistocene regressions in sea level. According to Hopkins (1973) sea level in the Bering Sea dropped to about -135 m during the penultimate Pleistocene regression, some 125,000 years ago, and to about -90 to -100 m during the late Wisconsin regression, some 20,000 years ago. No slide headwalls were found at greater depths on our eight crossings of the slide terrain. During the maximum regressions the head of the gentle slope was loaded with young sediment and exposed to wave action. The emergence produced by the regressions also increased the gravitational load on the head of the gentle slope. These conditions, perhaps augmented by earthquakes, are thought to have initiated failure in the emergent zone and thereby created the large bedding-plane slides. The very low inclination of the inferred slip planes (0.5° to 1.4°), which parallel bedding, suggests that the slides moved along a stratigraphically controlled sensitive layer, or zone.

The apparent "freshness" of the slides on our low-resolution records suggests that they formed during or after the younger, late Wisconsin major regression about 125,000 years ago. Thus, they are fairly young, geologically, and consideration should be given to the possibility that exploratory drilling or production facilities might reactivate them. However, their present submergence, the small ratio of slip to downslope fault length, the low dip, and the large downslope extent of the coherent slide sheets suggest that, except near the headwalls, the slides are no longer active. The shelf within 2 km of the headwall scarps should probably be avoided in petroleum exploration. In addition, the possibility that a sensitive layer underlies the bedding-plane slides and extends beneath the outer shelf should be investigated before the area is opened to drilling and the installation of production facilities.

VIII. CONCLUSIONS (all "reasonably firm" unless otherwise stated)

1. In southern central Hope Basin, the numerous gravity faults which displace the sediment column on the north flank of Kotzebue Arch show no evidence of activity since the Holocene flooding of the shelf approximately 13,000 years ago. Whether a similar tectonic quiescence will be found to characterize the rest of the Hope Basin faults is not certain, but it is perhaps significant that the survey was located to cover a region of Hope Basin where faults are found to be most extensive and "recent-appearing" in the sediment section.

2. Southern-central Hope Basin shows an east-west distribution pattern of the occurrence of acoustically anomalous sediments which can be preliminarily concluded to be gas saturated sediments at depths ranging from 5 to 15 m.

3. The upper continental slope and parts of the outermost continental shelf in the Alaskan portion of the Beaufort Sea appear to be unstable environments upon which to found drilling or other structures. Within these regions fresh-appearing scarps at slump or slide slip planes indicate that slumping and sliding are in many places presently active within the time (depth) resolution possible with low frequency seismic data. Structures founded on such areas, or wells drilled through them, would be damaged or destroyed by renewed slumping or sliding, or by slumping or sliding triggered by the static or dynamic loads imposed by such structures. Surge of oil or gas into the slip planes on the upper part of the sedimentary column by blowouts or other drilling mishaps might also trigger renewed or new sliding in these unstable environments.

4. In particular, the failure zone that produced block glides on the outer shelf between long. 152°30' and 154°30' W may be a shallow sensitive layer that could extend a considerable distance beyond the zone of present block glides. Disturbance of such a layer, if one is indeed present, could cause liquifaction and flowage wherever it occurred. Such disturbance could

be caused by such natural causes as earthquakes, and possibly by the vibrations or other effects of oil and gas drilling and production structures. Petroleum exploration and development of this area should be deferred until determination of the nature, engineering properties, and regional extent of the slip zone upon which the block glide landslides have moved. The age of movement should also be obtained.

5. A zone about 2 km wide along the upslope (landward) side of the subaqueous slump and bedding plane slide areas on the Beaufort shelf and upper slope should be considered to be potentially as unstable as the slump and slide areas themselves. A zone at least 10 km wide along the south side of the area of block glides, and extending at least 30 km beyond the east and west end of this area, should be closed to exploration and development until the character and engeineering properties of the underlying slip zone, and it regional extent, have been determined.

IX. NEEDS FOR FURTHER STUDY

The "acoustically turbid" sediments which appear intermittently in southern central Hope Basin have been interpreted as gas saturated. This is a speculative interpretation. More study needs to be done and gathered to answer some basic questions such as: what is its regional pattern of distribution? Does it affect differently the different frequencies of acoustic energy which are available to us for reflection studies? Are there anomalies in the spectrum of hydrocarbon occurrence in bottom samples which might relate to possible gases leaking upward to the surface? What is the nature of these gases and what might be their pressure? The scarps found in the bottom topography west and south of Pt. Hope should be further investigated with high resolution reflection data to ascertain whether they might be active fault scarps. In this same area the thrustfaults seen in deep seismic data ought to be investigated with high resolution reflection to determine whether or not they, like the south-central Hope Basin faults are also quiescent.

The slump features on the outer Beaufort shelf and slope need to be investigated with high resolution seismic equipment to better define these features. Are they active at present? Are they caused by underlying tectonic movement or are they simply a surficial sedimentary pheonomena due to low shear strengths and/or high pore pressures?

The Barrow sea valley ought to be investigated further for its role in the sediment dynamics of the shelf and its role as a conduit for exchange of water masses between shelf and the deep Arctic Basins. The latter are both questions of the understanding of basic geologic and hydrographic processes which are going on today, in order to provide a basis for understanding the present day environmental conditions on the shelf sea bottom.

X. SUMMARY OF 4th QUARTER OPERATIONS

A. SHIP ACTIVITIES

1. Ship Schedules

Aug. 27, 1976 depart Nome on USGS S.P. LEE

Sept 2, 1976 return to Nome

Sept. 6, 1976 depart Barrow on U.S. Coast Guard Icebreaker GLACIER

Oct. 2, 1976 return to Barrow

2. Scientific Party

S.P. LEE

A. Grantz, U.S.G.S., Chief Scientist

G. Boucher, U.S.G.S., Marine Geophysicist

S. Eittreim, U.S.G.S., Marine Geologist

T. Whitney, U.S.G.S., General

T. Kelley, U.S.G.S., Electronic Technician

J. Edwards, U.S.G.S., Airgun Technician

P. Twitchell, U.S.G.S., Airgun Technician

A. Montez, Seismic Engineering Inc., Streamer Technician

T. Thornton, U.S.G.S., Electronic Technician

C. Carpenter, U.S.G.S., Data Curator

B. Ruppel, U.S.G.S., Gravity and Navigation

S. Davenport, U.C., Santa Cruz, General

A. Long, U.S.G.S., Marine Seismologist

D. Aldridge, U.S.G.S., Marine Seismologist

K. Bachman, U. of Washington, General

J. Krogstad, U. of Washington, General

C. Carlson, Stanford, General

GLACIER

A. Grantz, U.S.G.S., Chief Scientist

G. Boucher, U.S.G.S., Marine Geophysicist

S. Eittreim, U.S.G.S., Marine Geologist

T. Whitney, U.S.G.S., Navigation

S. Davenport, U.C., Santa Cruz, Navigation

J. Nicholson, U.S.G.S., Electronic Technician

M. Rappeport, U.S.G.S., Sedimentologist

J. Rupert, U.S.G.S., Sedimentologist

R. Arnal, U.S.G.S., Micropaleontologist

W. Snydsman, U. of Washington, Heat Flow

3. Methods

S.P. LEE

Acoustic reflection: 3.5 khz, uniboom and single channel deep reflection with 160 KJ sparker.

Navigation: satellite integrated with continuous doppler sonar.

GLACIER

Acoustic methods: 12 khz acoustic reflection and 12 KJ sparker.

Sampling methods: dart and gravity cores and van veen surface sediment sampler; rectangular rock dredge.

Navigation satellite

4. Sample locations and ship tracklines: see Figures 1, 6, and 7.

5. Data collected or analysed

   a. 49 dart cores, 11 gravity cores, 25 rock dredge hauls and 20 van veen samples were collected from GLACIER. 2 days of continuous recording with 3 ocean bottom seismographs were made by deployments from LEE in Hope Basin.

   b. All samples subjected to the routine shipboard analyses discussed in "Results" section above.

   c. Miles of trackline:

   815 miles of trackline on S.P. LEE

   2,233 miles of trackline on GLACIER

6. Milestone chart and data submission schedules

Due to the logistics problems encountered in our field work (discussed above under IV Results), only very incomplete coverage was achieved of our study areas and hence very little of the "data products" promised in our work statements is complete in the form as originally envisaged.

Products as stated in work statement and their status:

1. Maps and intrepretive reports assessing seismic risk:

   None - no new seismicity data.

2. Maps showing surface and near surface faults: A generalized map of Hope Basin only (Figure 2 this report) based on existing seismic reflection data.

3. Correlation of surface faulting and epicenter plots:
None - no new seismicity data.

Instead, a number of other data products are being submitted which were the outcomes mostly of our existing data base, plus some new information gathered in our abreviated cruises last summer:

1. Map delineating potentially hazardous areas of slumping on the outer Beaufort shelf and slope (Figrue 9 this report).

2. Map showing parts of Hope Basin underlain by acoustically anomalous sediments (Figure 6 this report) which are probably gas-saturated sediments and hence unpredictable in their physical properties.

Seismic data are in the process of reproduction and will be sent with finalized navigation.

B. Problems encountered/recommended changes described above. Most problems were unavoidable and indeed expectable in the Arctic environment.

C. Estimate of funds expended.
All funds expended.

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ANNUAL REPORT

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SEISMICITY STUDIES:
(A) NORTHEAST ALASKA AND (B) NORTON AND KOTZEBUE SOUNDS

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Prepared Jointly for the

National Oceanic and Atmospheric Administration

Under Contract No. 03-05-022-55, Task #12

and the

U. S. Geological Survey

Under Grant No. 14-08-0001-15220

PREFACE

This report describes the seismicity studies of the following two widely separated areas in Alaska: (a) seismic zone on the south of Barter Island in the Beaufort Sea and (b) seismic zone around Norton and Kotzebue Sounds. The results obtained for the first area were presented to the U. S. Geological Survey (U.S.G.S.) grant number 14-08-0001-15220. Since the objectives of the work done under this grant is to a large extent complementary to those of NOAA, and as logistic support to operate the seismographic array around Barter Island was derived from NOAA, the results obtained for the northeastern part of Alaska have been incorporated in Section A of this report.

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SECTION A - INVESTIGATION OF THE SEISMICITY IN NORTHEAST ALASKA.

I. ABSTRACT

During the fall and spring of 1975-76, nine telemetered short period seismographic stations were emplaced in northeast Alaska. This is an area not previously instrumented, and the past record (1786 through 1974) indicates a relatively low incidence of earthquakes in this part of Alaska. During a one year recording period, data from the new network permitted the location of 69 earthquakes in the magnitude 1-4 range. This was accomplished in spite of a high incidence of station outages which considerably reduced the usable data collected during the study period. Results of the study suggest that the central Alaskan seismic zone continues uninterruptedly across the Brooks Range which previously appeared aseismic. Although the earthquakes detected are of small magnitude, their frequency of occurrence indicates that northeast Alaska is tectonically quite active.

II. INTRODUCTION

The Geophysical Institute of the University of Alaska installed a network of nine new seismographic stations during the 1975-76 field seasons to supplement the single station at Ft. Yukon which was installed earlier (1972) in the northeastern part of Alaska. The purpose was to provide adequate seismic coverage to the area in order to investigate the seismicity, the nature of seismic sources, and for a comparative study with the seismically active central Alaskan area. Investigations such as these are of special importance to possible future onshore and offshore development of natural resources in and around the area of interest.

An examination of the earthquake catalog (1786 through 1974) for Alaska compiled by Meyers (1976) reveals a conspicuously low number of earthquakes north of 66°N latitude. Also, it shows that the area along the Brooks Range which trends approximately in the east-west direction is aseismic and separates the well known central Alaskan seismic zone on the south from a localized seismic zone around Barter Island in the Beaufort Sea. In this setting of the seismic zones of the central and northern Alaska, it is difficult to explain the earthquakes in northern Alaska by the hypothesis of sea-floor spreading (Isacks et al., 1968) which, on the other hand, explains regionally those found in central Alaska.

The results presented in this report seem to resolve some of the above difficulties. The part of the earthquake catalog which is related to the northern Alaska area represents events of body wave magnitudes (m_b) greater than 3.0 that were recorded by stations at least 400 km from the source area. In contrast, the new local network is capable of locating earthquakes as small as of $m_b \approx 1.0$. With this increased capability, we can illustrate that the central Alaskan seismic zone appears to continue uninterruptedly across the Brooks Range.

III. NETWORK LAYOUT

Decisions regarding the number of stations of the network and their distribution were based on the terrain conditions and the feasibility of telemetering the data to a central recording site with reasonable cost. The recording site for the present study is located at the Geophysical Institute, Fairbanks. Instead of recording locally either at the Ft. Yukon or Barter Island DEW Line sites where dependable power (110 V) is available, we preferred this arrangement in order to avoid the high cost of labor and transportation which would be entailed by recording at the two remote sites.

The stations of the network could not be distributed uniformly due to the intervening rugged topography of the Brooks Range around 69°N latitude. This resulted in a four-station array around Barter Island and a six-station array around the Ft. Yukon-Chandler River area. The layout of the stations is shown in Fig. 1, their details are given in Tab. 1.

The network is operated on the following general principles (Lahr et al., 1974): The output (in volts) of the seismometer is amplified and frequency modulated with center frequencies between 400 and 3060 Hz by an amplifier-voltage control oscillator unit and then fed to a voice-grade telephone circuit which telemeters the signal to the recording

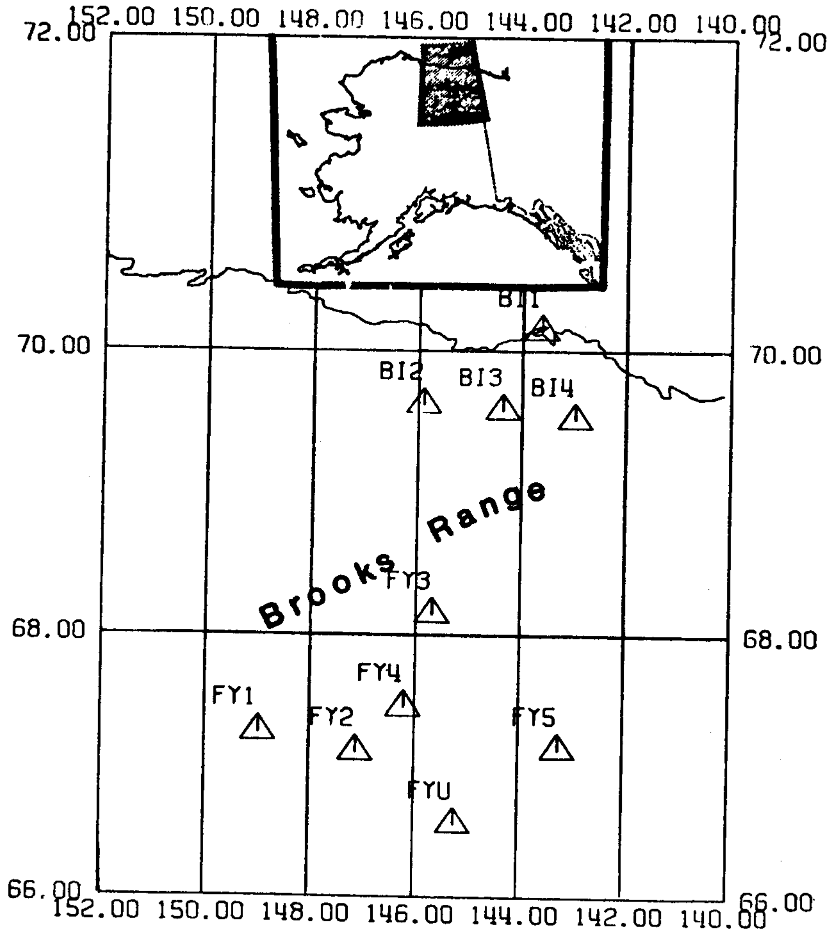


Figure 1. Map indicating locations of new stations in the Barter Island and Ft. Yukon arrays. Inset at top shows study area.

Table 1. Station details and magnifications.

Location	Station Code	Latitude (N)	Longitude (W)	Elevation (m)	Magnification (0.2-0.3 sec)
Fort Yukon	FYU	66°33.96'	145°13.90'	137	1.3×10^6
Remote	FY1	67°15.94'	148°58.53'	1040	6.6×10^5
Remote	FY2	67°07.16'	147°06.98'	670	7.0×10^5
Remote	FY3	68°08.76'	145°41.56'	1430	7.8×10^5
Remote	FY4	67°27.27'	146°12.70'	790	1.4×10^6
Remote	FY5	67°08.51'	143°14.42'	560	6.5×10^6
Barter Is.	BI1	70°07.91'	143°38.50'	10	1.9×10^6
Remote	BI2	69°37.41'	145°53.71'	1100	2.7×10^6
Remote	BI3	69°35.08'	144°22.24'	690	2.5×10^6
Remote	BI4	69°31.21'	142°58.80'	745	2.5×10^6

site. At remote locations, the frequency modulated signal is fed to a VHF transmitter (center frequency 150-160 mHz) which is received at a site where access to the telephone line is available.

A single telephone circuit is capable of telemetering eight frequency modulated signals in a mixed-mode to the recording site where the signals are demodulated and recorded in real time. Each demodulated signal represents the amplified form of the original signal. This, when normalized by the system response at each frequency, yields the true ground motion detected by the seismometers at each field site.

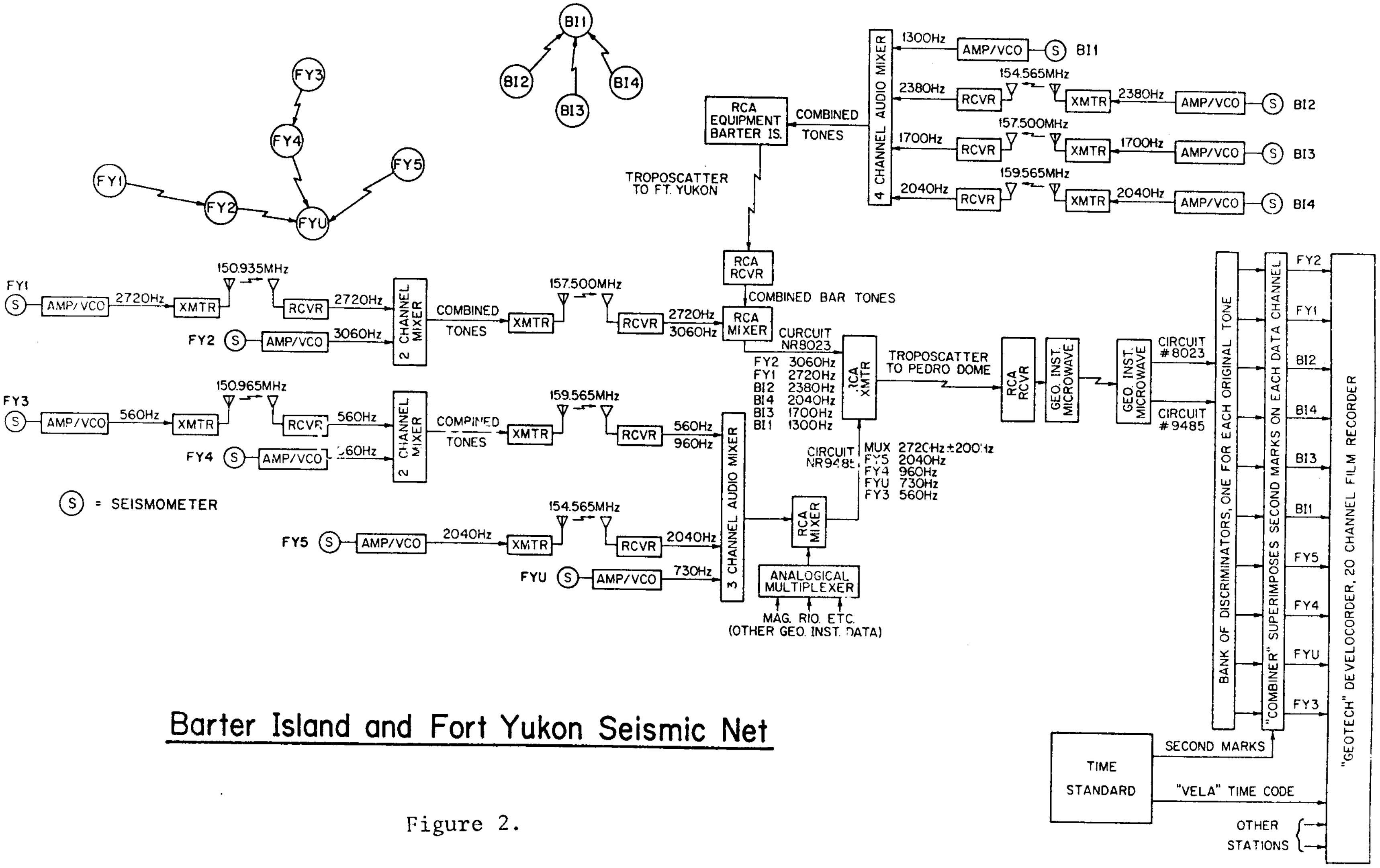
The nine new stations are equipped with matched instruments. The station at Ft. Yukon was installed in 1972 as a part of the central Alaskan array and utilizes equipment of different make. The standard equipment at each remote field site (BI2, BI3, BI4, FY1, FY2, FY3, FY4, and FY5; Figure 1) includes a vertical-component short period seismometer (Geospace, Model HS-10-1/B), an amplifier-VCO unit (Monitron, Model 2000), a transmitter (Monitron, Model T15F20), one 5-element Yagi antenna (Scala, Model CA5-150) and five aircell storage batteries (Carbonair, Model ST-22) capable of powering the electronic package for about a year.

At Barter Island (BI1) where 110 VAC power is available, the required 15 VDC is obtained from the 110 VAC by a power supply (Acopian, Model B13GT20). The station at Ft. Yukon has similar equipment (seismometer-Geotech, Model 18300; amplifier-Mendrel Industries, Model SPA-1; VCO-Dorsett Electronics, Model-0-18K-1; power supply-Power Mate, Model UNI83). In addition, as access to the telephone circuit is available at these two station sites, the signals from the remote stations of the respective arrays are received there by a set of receivers (Monitron, Model R15F) and associated antennae (Scala, Model CA5-150). The VHF-telemetered signals, including the local ones originating at BI1 and FYU, are mixed at the two sites before feeding to the telephone circuit; the mixing is done by a locally designed mixer (Appendix, Figure A1).

The recording site includes a series of discriminators (Emtel, Model 6243), a 16 mm film multichannel oscillograph (Geotech, Model 4000), a crystal controlled VELA time code generator (Chromo-Log, Model 20,648) and a WWV receiver (Hammarlund, Model SP-6000). The time code recorded on the film is maintained within ± 15 msec with respect to the WWV time signal. A 24-hour recording corresponds to 160 ft. of film which is scaled on a film viewer (Geotech, Model 6585).

The entire system linking the field site with the recording site is shown schematically in Fig. 2. A typical system response is shown in Fig. 3. The data of this figure and for other stations were obtained in the laboratory before the installation of the seismometer and the associated electronic units at the field site.

In the past, we have encountered frequent malfunction of the electronic components when exposed to the winter weather conditions of Alaska. Thus, to be assured of the expected normal performance by the different electronic units they were cold-tested by simulating operational field conditions (from room temperature to -40°C) in the laboratory. The results are given in the Appendix. After satisfactory operation was assured, the equipment were deployed at the field sites. Despite these tests, station outages were higher than expected.



Barter Island and Fort Yukon Seismic Net

Figure 2.

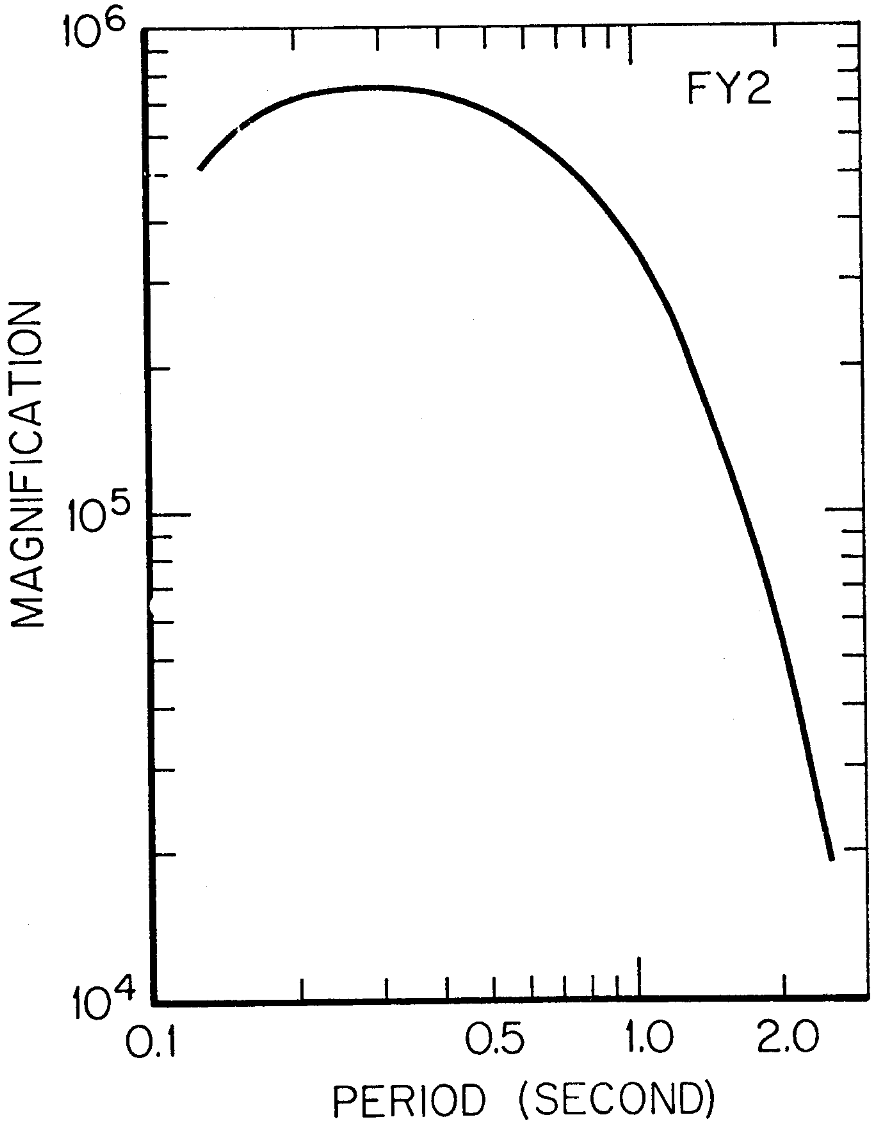


Figure 3. A typical system response of the stations of the network.

IV. PROCESSING OF DATA

Data from one station (FY4) of the Ft. Yukon array and from two stations (BI1 and BI3) of the Barter Island array, in addition to recording on film by develocorder, were recorded simultaneously on heat sensitive paper by helicorder (Geotech, Model 4983). This recording was done to separate the local earthquakes from the teleseismic ones and to obtain approximate origin times of the former for rapid scaling of the 160 ft. of daily film record. The following were scaled from the film: First arrival times of the P-wave, and whenever possible, the S-wave train, direction of P-wave first motion, and the maximum amplitude and the period of the recorded trace.

The above data for each earthquake punched in appropriate format on cards were processed by the computer program of Lee and Lahr (1975) for location purposes. Although the system response for each station was obtained as mentioned before, the required modifications have not yet been incorporated in the computer program for magnitude computation. For this reason the magnitudes (M_L) of the earthquakes listed here were computed by using the formula of Richter (1954) for local earthquakes incorporating a correction factor for the instrumentation used.

The crust and upper mantle structure underneath the area of interest is not known at this stage of our study. Thus, to compute travel times for P-waves, a plane layered P-wave velocity model for the crust obtained from the central Alaskan data from earthquakes and quarry blasts was used. The upper mantle section was taken from Biswas and Bhattacharya (1974). The details of this model are shown in Tab. 2. Also, a ratio of 1.78 between P- and S-wave velocities corresponding to Paisson's solid is used for the computation of S-wave travel times.

Depth to the Interface (km)	P-Wave Velocity (km/sec)
0.0	5.9
24.4	7.4
40.2	7.9
76.0	8.29
301.0	10.39
545.0	12.58

Table 2. P-wave velocity model obtained for central Alaska.

With the above limitations, the observed data set was used for a preliminary computer run and the output examined for reading errors. If the time residual for an earthquake (that is, the difference between the observed and computed travel times) for any station exceeded 1 sec, the records were rescaled to reduce the uncertainties to a minimum. The corrected data were then used for a final computer run; the output is given in Tab. 3 in standard form.

V. DISCUSSION OF RESULTS

In Table 3, the quality of the solution for each earthquake is indicated by the numbers listed in columns 8 through 14. The symbols NO, GAP, DMIN, RMS, ERH, ERZ and Q refer, respectively, to the number of station readings used to locate each earthquake, largest azimuthal difference between stations with respect to the epicenters, the distance of the epicenter from the nearest station, the root mean square of travel time residuals, standard error in epicenter location, standard error in focal depth and rating of the quality of the final solution. The quality factor C and D refer to fair and poor, respectively. Also, if NO is less than five, the program does not compute ERH and ERZ.

TABLE 3

Date	Origin	Time	Lat(N)	Long(W)	Depth	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
Yr.Mo.Day	Hr Min.	Sec.	Deg.Min.	Deg.Min.	Km.			Deg.	Km.		Km.	Km.	
760115	0712	32.40	66 36.47	146 23.28	36.40	2.4	5	196	51.5	0.49	80.9	146.9	D
760120	0226	44.13	66 51.42	149 01.91	4.00	3.0	6	214	170.9	0.63	3.5	27.8	D
760131	0855	17.48	66 49.10	147 14.78	1.64	2.8	9	237	93.3	0.95	24.5	29.8	D
760213	2026	21.89	67 23.19	147 35.04	5.00	2.2	7	250	137.5	2.44	56.6	79.0	D
760214	0556	28.34	66 58.50	145 45.29	0.82	2.2	8	156	51.1	1.71	24.7	22.5	D
760216	1703	02.18	66 40.03	147 37.01	3.37	2.1	4	200	106.4	0.46			D
760317	2336	57.66	66 38.62	144 10.05	106.38	3.6	4	293	48.0	0.00			C
760318	0001	02.00	66 22.77	140 55.27	5.00	2.6	3	300	193.0	0.28			C
760403	0606	11.97	66 28.27	147 20.86	2.36	2.3	6	183	94.8	0.90	17.5	30.5	D
760405	2201	45.85	69 18.26	148 51.21	1.51	1.9	4	279	121.0	0.24			C
760407	2232	24.58	69 38.25	145 03.38	1.86	1.2	5	165	27.3	0.06	1.7	18.1	D
760412	2159	21.60	69 16.19	148 46.73	0.81	2.0	4	346	12.0	1.49			D
760424	0401	10.97	69 57.67	145 40.89	5.00	1.5	4	244	38.6	1.70			D
760424	1016	22.99	69 20.61	145 19.81	5.00	1.8	5	247	38.3	1.50			D
760424	2142	20.31	69 39.98	143 34.34	4.28	1.2	4	218	28.2	0.05	30.0	87.9	D
760425	0313	10.02	69 22.75	143 41.97	0.24	0.9	4	227	32.3	0.25			C
760425	0429	16.62	69 37.51	144 53.47	5.00	1.4	4	167	20.8	2.13			D
760425	0922	37.28	69 37.51	144 53.15	5.00	1.2	4	167	20.6	2.18			D
760425	1121	18.85	69 18.68	143 38.02	11.31	1.5	4	244	34.7	0.00			C
760427	2221	18.60	66 48.93	144 58.69	5.00	3.1	4	211	167.8	0.18			C
760429	2029	20.62	66 13.11	144 58.26	2.39	2.9	5	206	40.5	2.50	2.3	1.3	D
760430	0622	37.76	68 59.38	146 17.00	5.00	2.0	4	307	72.3	0.46			D
760503	1445	04.93	69 07.02	144 40.40	8.11	1.3	5	264	53.5	0.22	54.7	363.3	D
760505	0023	33.55	67 29.38	140 38.57	18.64	3.0	4	276	225.1	1.04			D
760506	0224	42.86	68 42.87	144 22.34	5.00	1.8	5	157	97.1	1.44	31.9	31.8	D
760506	1551	55.88	69 53.15	145 39.24	14.53	1.3	4	233	30.7	0.71			D
760507	0539	20.80	66 18.69	146 42.41	5.00	2.3	4	228	71.8	1.04			D
760515	0206	07.42	69 37.57	146 07.66	14.38	1.6	4	356	9.1	0.09			C
760518	1203	40.19	70 05.38	144 30.20	5.00	1.3	5	271	56.6	0.77	434.4	767.3	D
760519	1624	35.92	69 26.45	143 47.74	8.21	1.2	6	209	27.6	0.15	16.1	27.4	D
760519	1831	07.44	70 03.57	144 42.53	5.00	1.1	5	269	53.6	0.57	29.2	297.1	D
760519	2305	13.65	69 47.99	143 59.32	35.40	1.0	4	234	28.2	0.07			C

Table 3. Listing of earthquakes located and plotted in Fig. 3. The quantities in columns 8-14 give accuracies in locations.

TABLE 3 (continued)

Date	Origin	Time	Lat(N)	Long(W)	Depth	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
Yr.Mo.Day	Hr.Min.	Sec.	Deg.Min.	Deg.Min.	Km.			Deg.	Km.		Km.	Km.	
760527	0743	06.37	67 16.23	145 05.82	1.64	1.4	4	165	78.8	0.78			D
760527	2151	32.39	68 57.39	144 40.36	3.65	2.0	4	323	71.1	1.50			D
760601	1508	54.09	69 10.75	144 14.08	1.48	1.4	4	301	45.5	0.78			D
760602	1551	20.97	67 21.55	144 15.62	3.51	2.8	4	193	98.1	0.00			C
760602	2122	59.90	67 22.74	144 33.22	5.00	2.6	3	196	95.4	0.12			C
760621	0837	35.81	69 42.62	142 42.14	10.22	2.0	4	234	23.8	0.00			C
760623	1156	00.37	69 42.45	142 45.53	10.59	2.1	4	232	22.6	0.00			C
760623	1603	04.21	68 06.03	145 57.93	38.67	2.4	4	192	174.0	1.35			D
760624	1243	36.48	66 36.90	146 29.18	5.00	3.6	5	217	55.9	1.87	152.7	258.4	D
760624	1318	28.50	66 27.18	146 00.86	47.10	3.2	6	167	37.1	0.35	11.2	16.4	D
760628	0212	42.37	66 01.01	147 46.51	94.56	3.6	5	151	129.5	0.37	17.5	88.2	D
760702	0013	04.97	67 07.33	143 14.52	11.66	2.1	4	233	2.2	0.31			D
760722	1940	06.33	67 22.64	143 41.49	0.40	2.2	4	188	32.7	0.13			C
760728	0704	41.77	69 26.08	144 22.34	5.00	1.3	6	160	16.7	2.98	116.9	202.7	D
760802	0720	0409	68 19.46	147 37.08	9.06	3.4	4	232	82.3	0.25			C
760809	1646	22.10	69 46.25	144 17.31	21.60	1.2	4	203	21.0	0.00			C
760811	1632	35.90	69 45.58	144 10.57	5.47	0.9	5	185	20.9	0.03	0.5	3.3	C
760819	1130	43.53	68 44.77	147 23.74	1.01	3.7	7	210	96.9	0.36	6.5	7.0	D
760823	0909	03.94	66 24.31	147 25.00	0.76	2.6	7	137	80.9	0.19	2.1	3.9	C
760826	0313	49.01	69 40.44	143 46.61	1.72	1.3	5	119	25.2	0.85	5.2	9.0	D
760829	1916	04.18	68 11.47	143 03.61	0.08	2.1	5	182	109.3	0.11	1.3	1.6	C
760906	0236	22.94	69 39.38	145 44.15	0.14	0.7	5	219	7.2	2.46	135.1	109.3	D
760916	2123	06.55	66 37.40	141 39.81	6.33	3.8	5	277	90.1	1.01	88.8	42.1	D
760923	2245	30.22	68 11.88	145 52.86	5.51	2.3	7	156	9.7	0.27	3.4	2.8	D
760930	1927	49.02	69 32.57	145 05.39	5.00	2.9	7	155	28.4	5.59	132.1	158.2	D
761004	0401	23.36	67 35.70	146 11.27	0.56	2.3	7	126	15.7	1.06	4.0	8.9	D
761021	1529	03.71	69 53.16	143 28.98	18.97	1.5	4	262	45.2	0.03			C
761022	1613	36.73	68 15.86	144 26.85	2.95	2.3	5	135	116.8	0.40	53.5	137.3	D
761030	1402	50.24	69 34.27	145 13.24	17.64	2.0	4	189	26.9	0.00			C
761030	1530	04.29	69 52.82	143 58.97	27.87	1.5	5	247	36.2	0.35	17.4	35.5	D
761105	0904	49.88	69 09.72	145 30.41	2.03	1.5	4	275	53.7	0.16			C
761125	2244	45.13	68 38.42	148 16.54	38.76	2.5	5	237	145.0	0.20	12.3	440.2	D
761207	1708	07.81	69 14.07	145 09.18	0.73	1.4	4	154	49.7	0.23			C
761222	1950	05.54	67 13.25	141 51.60	2.25	3.0	5	301	164.8	4.09	543.5	777.0	D
761223	1216	23.29	68 54.76	146 39.43	0.73	2.5	6	207	84.8	0.35	9.2	5.7	D
761230	1806	38.48	68 52.72	145 48.95	26.52	2.6	6	162	83.1	4.39	99.5	202.7	D
770110	2008	16.94	68 58.82	145 19.82	6.06	2.5	4	150	75.1	0.68			D

In some cases it was possible to supplement the readings from the new stations with readings from stations of other networks (NOAA and Geophysical Institute) to the west and south. Also, every effort has been made to keep the reading errors to a minimum by repeated scaling of the records. Despite this, the solutions presented in Tab. 3 are seen to be fair to poor. The average RMS value is 0.87 sec, with 56% of the solutions having an RMS value of less than 0.5 sec. It is also seen that the focii for a few earthquakes are located uncharacteristically deep. This is probably due to quality of the data, as we do not anticipate occurrences of sub-crustal events in the study area.

Part of the difficulty seems to be due to the geographic distribution of the stations with respect to the locations of the earthquakes. In about a third of the cases the earthquakes were recorded by stations in only the Barter Island array or the Ft. Yukon array but not by both. The effects of this are seen in the relatively large values obtained in the column labeled as GAP.

In addition to these difficulties, the Barter Island array went into operation several months before the Ft. Yukon array, owing to nonavailability of equipment. Also, periodically some of the stations of one or the other array would be out due to malfunction of the telemetry link. Nevertheless, despite persisting difficulties, the operation of the local network did reveal some significant results.

The Alaskan earthquake catalog (1786 through 1974) of NOAA, which is available on 9-track magnetic tape was scanned for the events of all magnitudes located in the northeastern part of Alaska. The locations of these epicenters are shown in Fig. 4 (Mercator projection). For comparison, the results (Tab. 3) of the present study are shown on an identical map

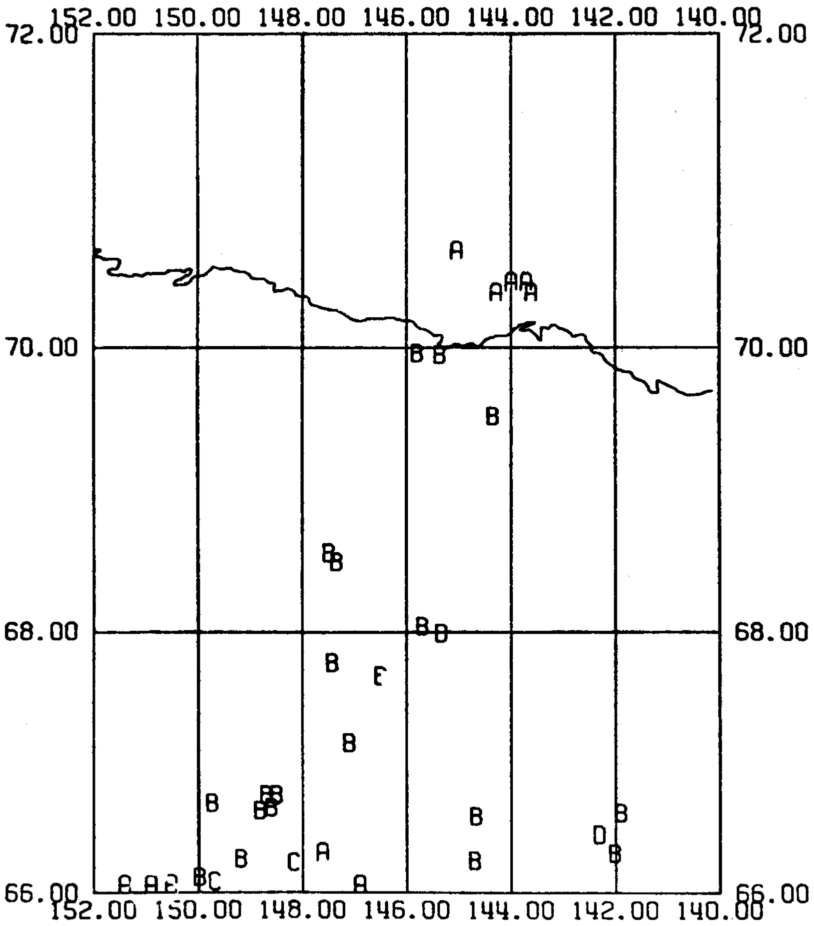


Figure 4. Same area as Figure 1 showing locations of all previously documented during 1786-1974. Data from Meyers (1976). Focal depths are indicated by letter, with 25 km increments being indicated by successive letters, i.e., 0-25 km by A, 25-50 km by B, etc.

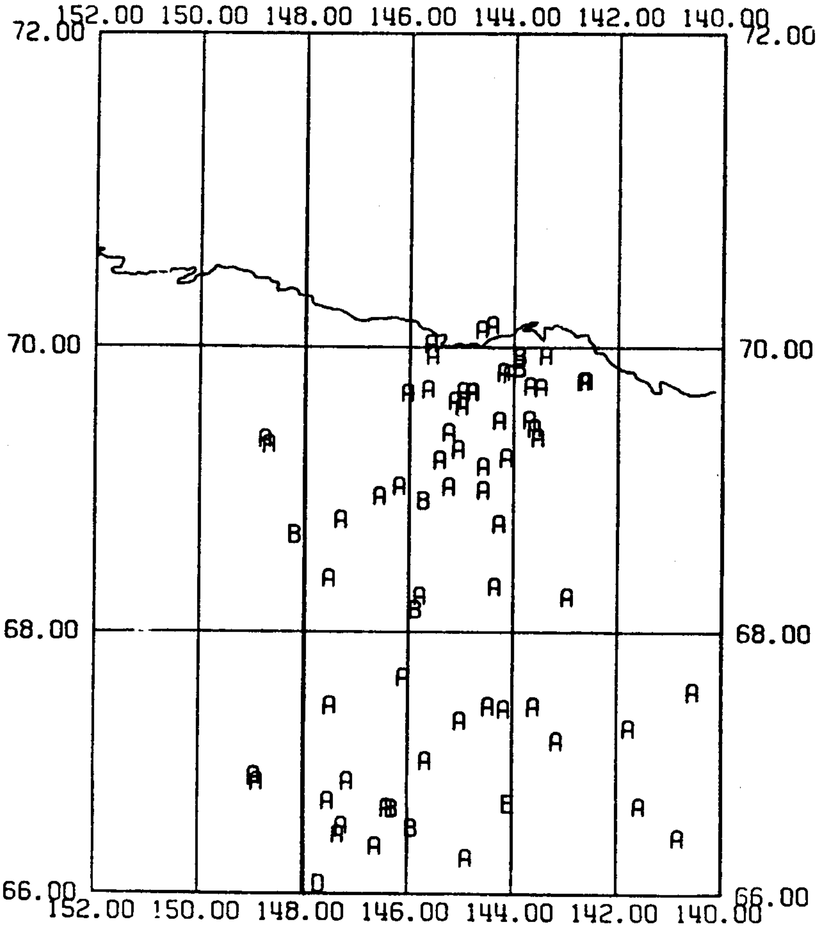


Figure 5. Plot of all earthquakes located during this study. Notation the same as in Figure 4.

in Fig. 5. In these Figures, A, B, C, D, and E refer, respectively, to the focal depth intervals 0-25 km, 26-50 km, 51-75 km, 76-100 km and 101-125 km. While fewer than a dozen earthquakes north of 68°N were recorded between 1786 and 1974, in the relatively short period represented in Fig. 5, 44 events occurred. Additionally, the new network recorded other events in the area but with too few stations to permit accurate location. Thus, these events remained undocumented.

It is apparent from the results shown in Figure 5 that the seismic activity appears to extend more or less uniformly throughout the instrumented region, including the area around 69°N which appeared as aseismic prior to the present study. Some clustering of the epicenters to the south of Barter Island is seen, but no linear patterns are apparent. The lack of linear patterns is likely due to the sparseness of the data so far recorded. However, it is now clear that this part of Alaska is characterized by a widespread and much higher level of seismic activity than known before. With further instrumental improvements and continued recording, we hope to delineate the trends of faults, the mechanisms of stress release along them and the relationship of these faults to the major known faults in the study area.

SECTION B - INVESTIGATION OF THE SEISMICITY AROUND NORTON AND KOTZEBUE SOUNDS.

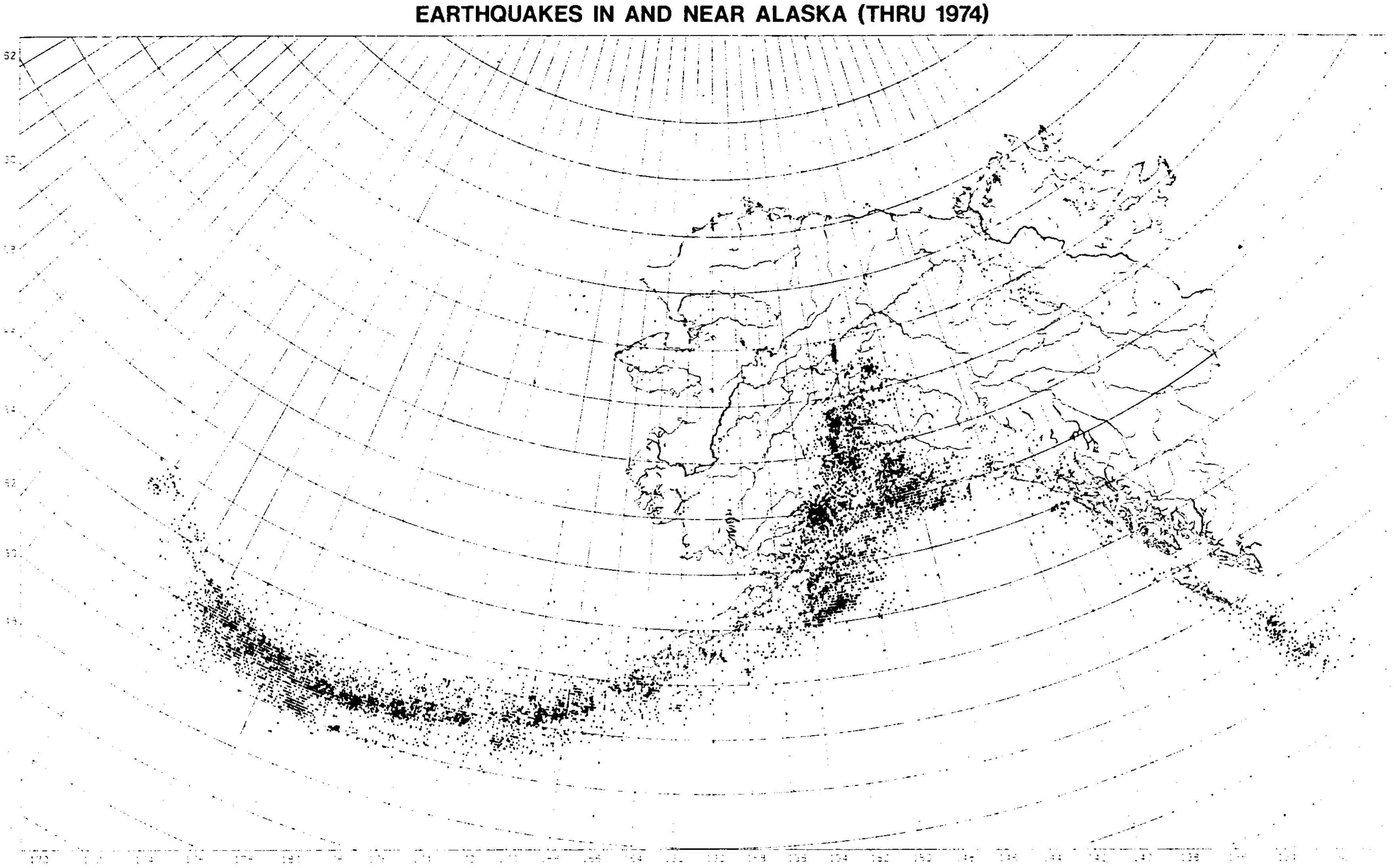
I. ABSTRACT

A six-station seismographic network was installed to provide seismic coverage to the Norton and Kotzebue Sounds during the field season of 1976. The stations of the network are operating satisfactorily for the last several months. During this time, the largest earthquake located in the study area was of magnitude 4.5. The records in general seem to indicate that the study area is seismically more active than thought previously. Detailed analysis of the data is in progress.

In addition to earthquakes, three distinct swarms of icequakes were recorded by one station (Kotzebue) of the network. Analysis of the data for the first two swarms showed good correlation between the time of the maximum icequake occurrences and the time of the largest northerly component of wind. Examination of the satellite imagery indicated a large scale ice flow from the Chukchi Sea to the Bering Sea during the swarms of icequakes. From these, the sources of icequakes have been tentatively attributed to the above meteorological changes.

II. INTRODUCTION

Meyers (1976) compiled an earthquake catalog (1786 through 1974) for Alaska and its adjoining areas. His plot of the epicenters of this catalog is shown in Fig. 6. These earthquakes were located from teleseismic data and consequently the events are of bodywave magnitude greater than 3.0. However, the distribution of the epicenters in the above figure shows that north of 64° N parallel, the seismic zone of central Alaska extends north as well as in the northwest directions. Also, it shows a relative decrease in seismic activity on the west of 154° W longitude. Around Kotzebue, the



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

Fig. 6. Map showing epicenters of all earthquakes located in and around Alaska from 1786 through 1974 (after Meyers, 1976)

seismic zone trends southward where it is characterized by epicenters distributed over the entire Seward Peninsula and offshore in Norton and Kotzebue Sounds.

A number of studies of the nature of seismicity in central and along the southern coastal belt of Alaska showed that the occurrences of earthquakes are directly related to the underthrusting of the Pacific lithospheric plate underneath these areas. Also from Cook Inlet further north, the hinge line of the underthrust plate strikes in the N17°E direction. Under this tectonic setting, it is necessary to postulate that the earthquakes located several hundred kilometers (namely, in and around Seward Peninsula) on the west from the hinge line are primarily due to stress release on pre-existing faults. The propagation of the stresses in the latter regions could be related to the underthrusting of the lithospheric plate beneath central Alaska. This interpretation seems to be consistent to an interplate region characterized by plate convergence.

In view of the above observations, the Geophysical Institute of the University of Alaska installed a network of five new seismographic stations during the 1976 field season to supplement the single station at Granite Mt. (GMA) operated by NOAA in the entire western part of Alaska. The purpose was to provide seismic coverage to the Norton and Kotzebue Sounds in order to investigate the seismicity, the nature of seismic sources and for a comparative study between these phenomena and those known for other active seismic zones located inland and along the coast of Alaska.

The new network around Seward Peninsula has been operating for the last several months. During this time, a number of local earthquakes have been recorded and tentatively located, but the detailed analysis of the data have not yet been completed. In addition to the tectonic events, three district swarms of events have been recorded by the station at Kotzebue. These swarms appeared to be of nontectonic origin. The preliminary results concerning these phenomena are discussed in this section of the report.

III. NETWORK LAYOUT

The number and the locations of the stations of the network were based on two primary considerations: (a) the feasibility of telemetering the data to a central recording site with reasonable cost and (b) accessibility to the various sites in and around Seward Peninsula. This latter factor greatly reduced the flexibility in the distribution of the stations, as the available means of transportation from the two main centers (Nome and Kotzebue) to various locations in Seward Peninsula are fixed wing planes. The entire system linking the field sites with the recording site is shown in Fig. 7 and the layout of the network is shown as an inset of the same figure. The station details are given in Table 4.

The station at Savoonga (SVG) on St. Lawrence Island could not be installed yet due to the nonavailability of the microwave telemetry link. However we expect to complete the installation of the above station during the field season of 1977. Including this station, it can be seen in Fig. 7 that despite various existing logistic difficulties, it has been possible to provide desirable seismic coverage to the study area. The recording site is located at the Geophysical Institute, Fairbanks. We preferred this central recording arrangement to avoid high cost of labor and transportation which would be entailed for recording at either Nome or Kotzebue.

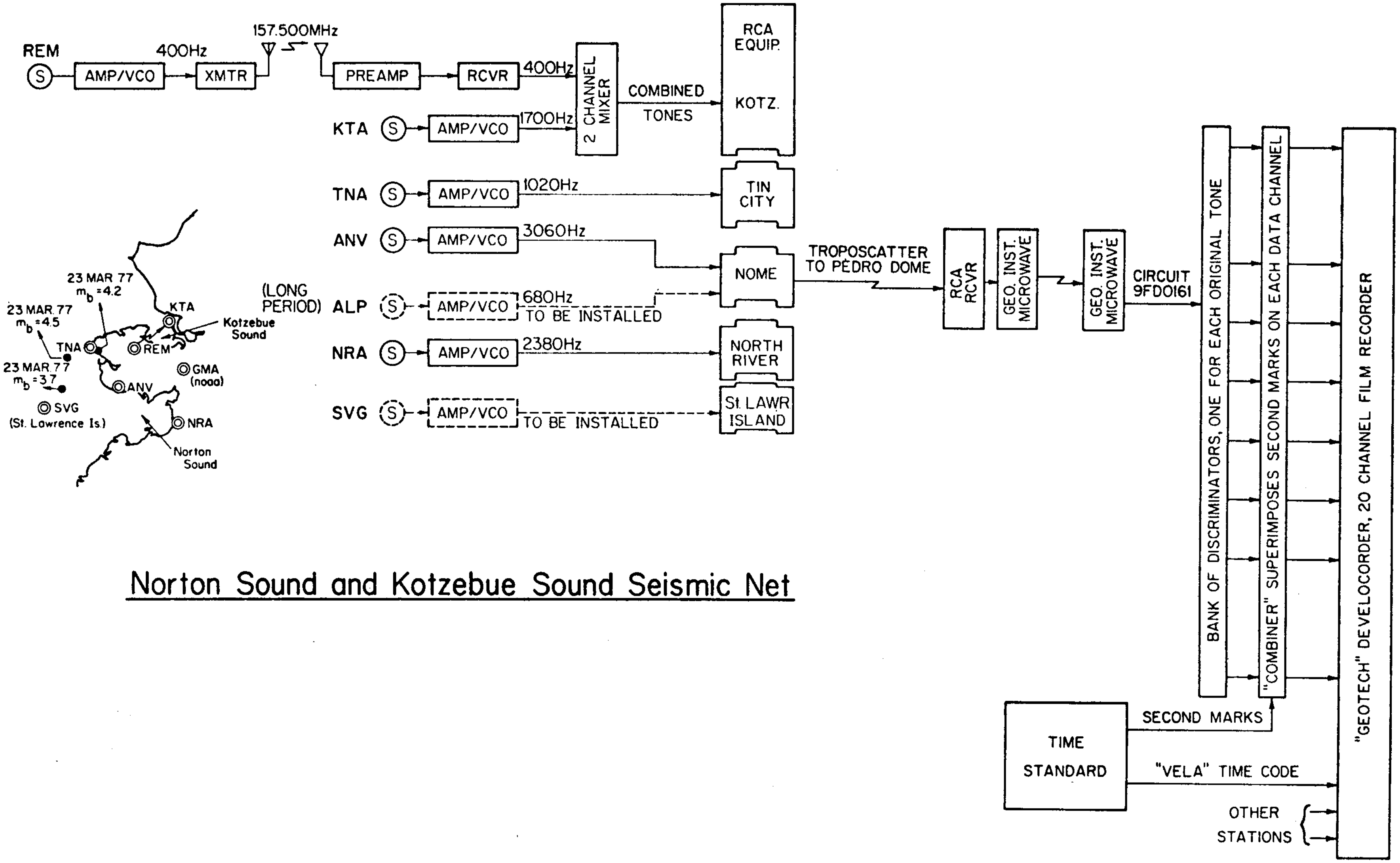

Norton Sound and Kotzebue Sound Seismic Net

Fig. 7. Outline of seismic monitoring system employed for the network. Recording is accomplished in Fairbanks. Savoonga (SVG) and long-period instrument (ALP) at Anvil Mountain near Nome not yet operational.

Location	Station Code	Latitude (N)	Longitude (W)	Elevation (m)	Magnification (0.2 - 0.3 sec.)
Kotzebue	KTA	66 51.43	162 36.67	15	7.9×10^5
Remote	REM	65 57.03	164 34.67	335	---
Tin City	TNA	65 33.72	167 26.25	64	4.0×10^5
Anvil Mt.	ANV	64 33.93	165 22.30	324	7.9×10^5
North River	NRA	63 53.51	160 30.86	219	1.6×10^6
Savoonga	SVG	63 41.9	170 29.0	15	---
Granite Mt.	GMA (NOAA)	65 25.72	161 13.92	858	1.0×10^5

Table 4. Station Details and Magnifications

All the stations of the network are equipped with matched instruments except the one (REM) at the remote site. This station is battery operated and is capable of functioning for a year without requiring fresh batteries. At other sites, the electronic units are housed inside the RCA microwave buildings and the required power is derived from the 110 VAC supply. Accordingly the electronic units at these sites are different from the remote site. The details of the equipment used are listed in Table 5.

The general principles of the operation of the network is identical to that described in Section 1. A typical system response of the stations is shown in Fig. 8. A special feature of the network consists of a long-period (natural period of 20 sec) vertical component station planned to be installed next to the short-period station (ANV) at Anvil Mt. during the field season of 1977. The combination of the short-and long-period units will permit the analysis of ground motion over a wide frequency range. The test of the long period system is nearing completion; an example of its performance is shown in Fig. 9.

IV. PROCESSING OF DATA

A number of unexpected instrumental difficulties have been encountered with the stations of the network. However, most of the difficulties have been resolved and during the last few months, the stations are operating satisfactorily. We anticipate to start routine scaling and computer-process the data in the very near future.

In order to check the performance of the stations, a few isolated events have been located. These are shown in the inset of Fig. 7. The quality of the seismograms obtained by the station (TNA) at Tin City are shown in Fig. 10. This represents recording by helicorder. Besides recording data from all the

Local Station

Seismometer: Geotech, Model 18300

Amplifier - VCO: Geotech, Model 42.21

Power Supply: Powermate, Model PT-99

Remote Station

Seismometer: Geotech, Model 18300

Amplifier: Mendrel Industries, Model SPA-1

VCO: Dorsett Electronics, Model-0-18K-1

Transmitter: Monitron, Model T15F20

Receiver (at KTA): Monitron, Model R15F

Antenna: Scala, Model C5A-150

Power Supply: Carbonaite, Model ST-22

Table 5. Instruments used at the stations of the network

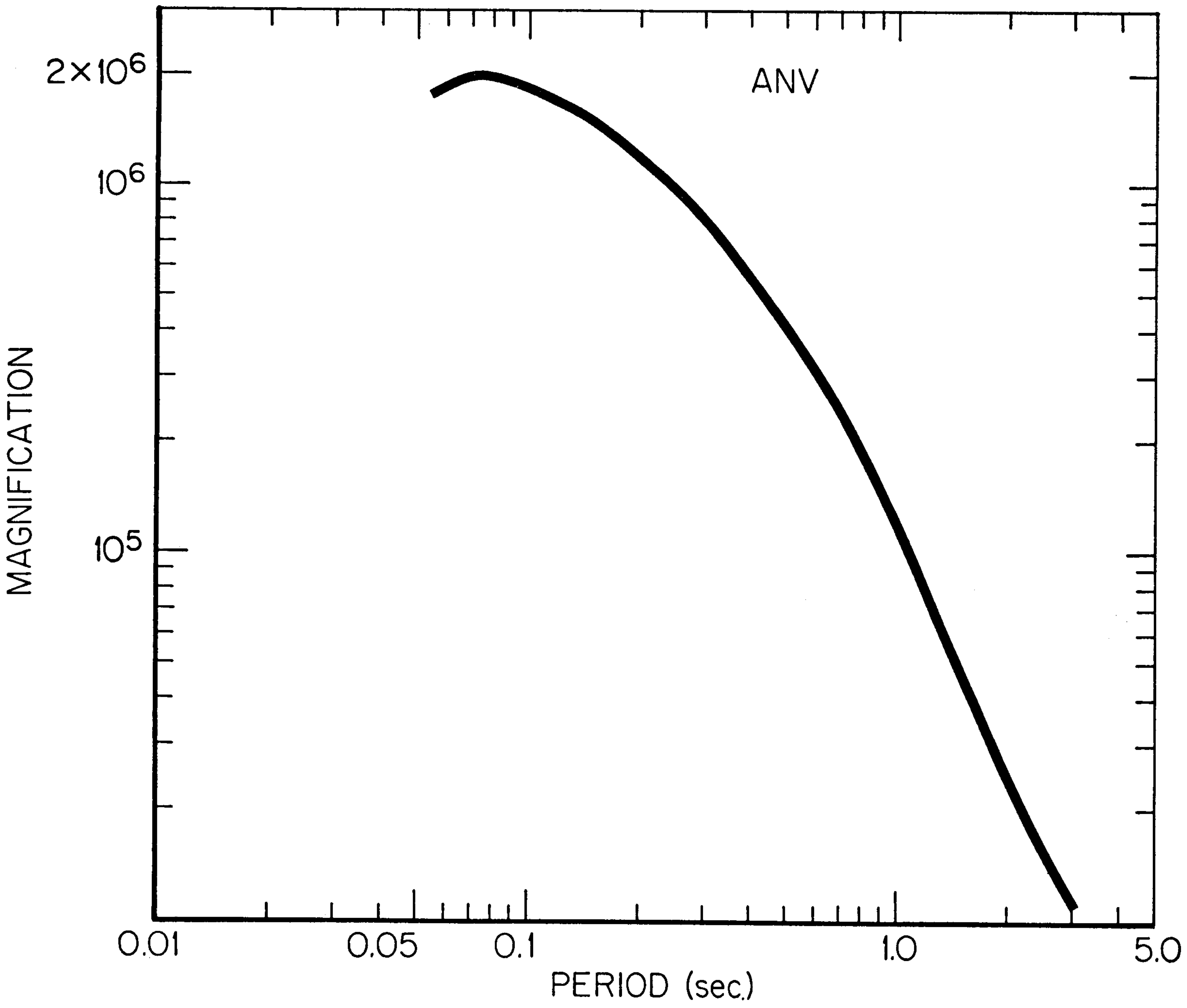


Fig. 8. Typical system magnification curve of stations of the network.

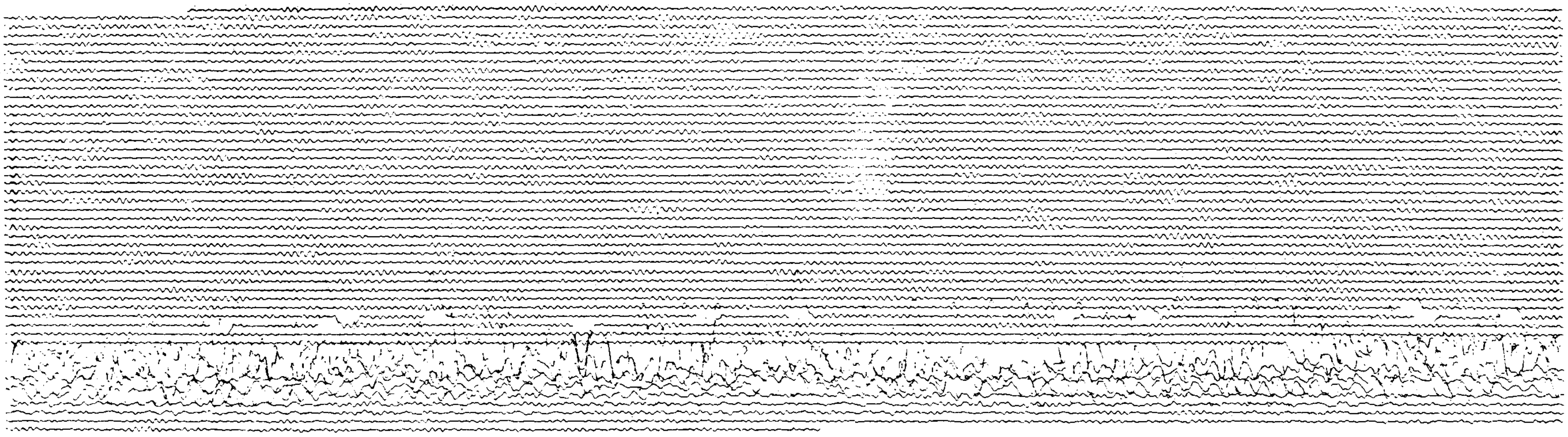


Fig. 9. Representative record from long-period instrument presently operating in the Geophysical Institute building at Fairbanks. This is a recording of the Rumanian earthquake of March 4, 1977. This instrument will be moved to a prepared location near Nome (ALP) during the summer field season, 1977.

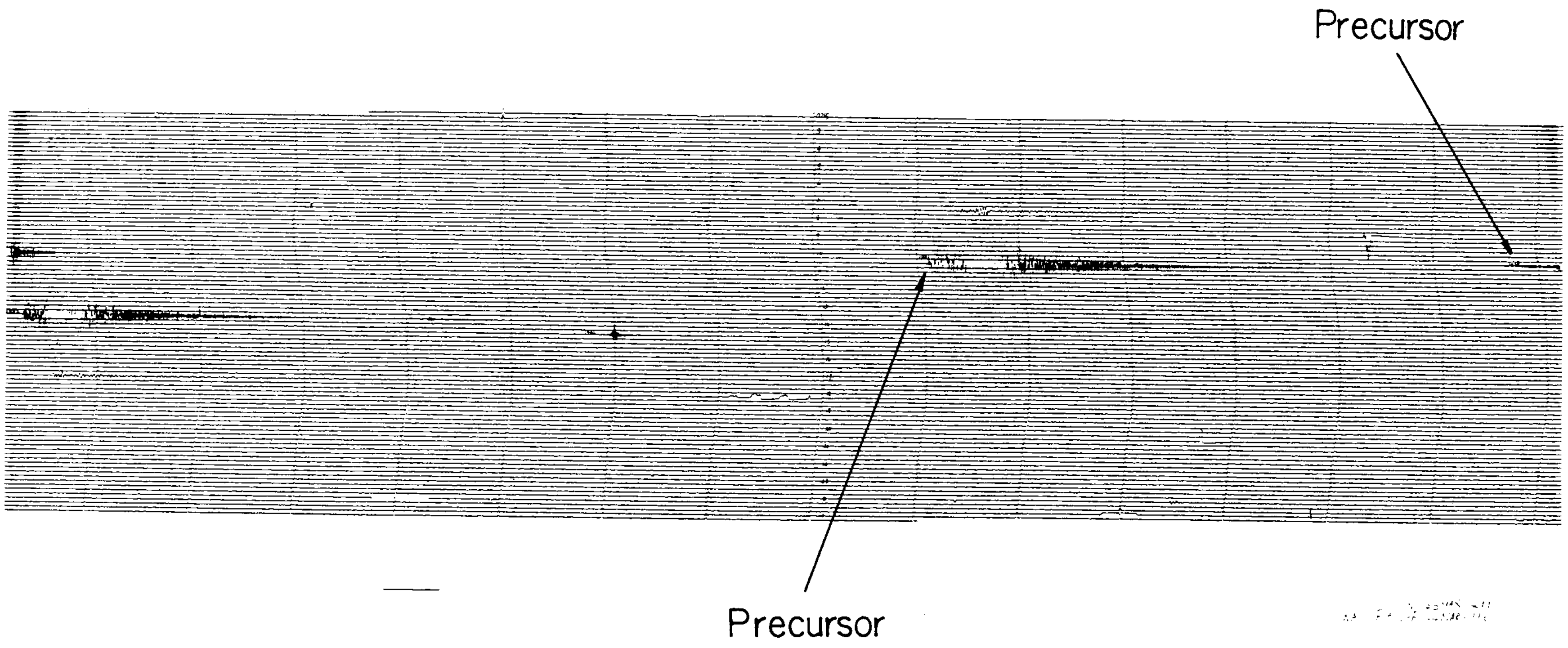


Fig. 10 Representative record from short-period instrument at Tin City (TNA) of earthquakes in Norton Sound area on March 23, 1977. These locations are shown in inset of Fig. 7.

stations of the network on 16 mm film by develocorder, the data for two stations (TNA and KTA) are simultaneously recorded on heat sensitive paper by helicorder. This is done for rapid identification of local earthquakes which greatly facilitates scaling of the daily film record.

From mid-January, 1977, the station at Kotzebue (KTA) started recording signals having relatively high amplitude in SV-phase with unusual short overall signal duration. A typical 24hr helicorder record is shown in Fig. 11. It can be seen in this figure that the signals for some events show absence of short period energy with well dispersed wave train. A typical example is labeled as S1 along the lowermost trace in the above figure. The nature of the dispersion indicates a decrease of phase velocity with increasing period. These features are quite uncharacteristic of seismic signals generated by commonly known tectonic processes having the travel paths (from sources to receivers) through the crust and upper mantle.

V. DISCUSSION: TECTONIC AND NONTECTONIC QUAKES

The signals (tectonic) generated by earthquakes located in the study area show the first arrival as characterized by a several second long small amplitude precursor to a large amplitude envelope. This is shown in Fig. 10. This phenomenon is observed often in the records of central Alaska for earthquakes located along the Aleution Island chain (Biswas and Bhattacharya, 1974). For the same source region, Jacob (1972) and Davies and Julian (1972) have related the observed precursors in records obtained in other areas to the normal P-phase that leaves the source region through the layers overlying the underthrust plate.

The available results, as mentioned before, do not indicate any tectonic similarity between the Aleution region and the study area. Thus, a detailed analysis to explain the above phenomenon will be undertaken in addition to the investigations of the other problems as mentioned in previous sections.

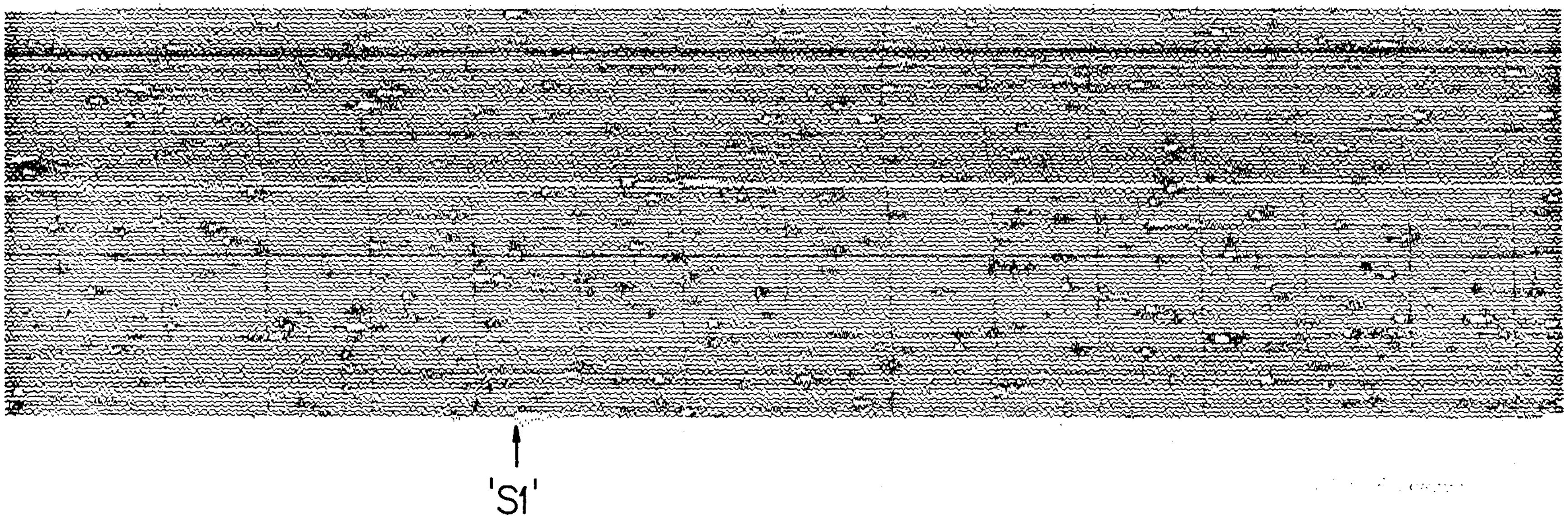


Fig. 11. Icequakes recorded at Kotzebue (KTA). An example of well dispersed wave train recorded for some events is labeled 'S1' on the bottom trace.

However, at this stage it may be mentioned that during the short recording period, the largest earthquake recorded is of magnitude 4.5 and other records appear to indicate that the study area is seismically more active than previously thought.

For the swarms recorded by the station (KTA) at Kotzebue, a preliminary qualitative attempt has been made to explain their sources. The characteristics of the recorded signals, as mentioned before, differ significantly from those recorded for tectonic sources.

Crary (1955) recorded similar swarms by a portable seismic station located on the ice sheet about 700 m off Barter Island in Beaufort Sea. Unlike the present result discussed below, he found little correlation between the swarms and wind velocity. However, he showed some correlation with the periods of maximum of the tremor activities and the times of largest change in vertical tidal movements (measured by a tidal station near the seismic recorder).

In the present study, it was inferred that the meteorological changes might be the dominant factors causing the icequakes recorded at KTA. Accordingly, irrespective of magnitude differences, the daily commulative numbers of icequakes have been compared with the net wind velocity (mph), direction of the wind and the northerly component (mph) of the wind velocity. These are shown in Figure 12.

The negative values in the last row of the above figure represents a change (π radian) in the wind direction and the accompanying number represents the southerly component of the wind velocity (mph). It is seen that the northerly component of the wind velocity (mph) correlates well with the increase in the frequency of occurrences of icequakes.

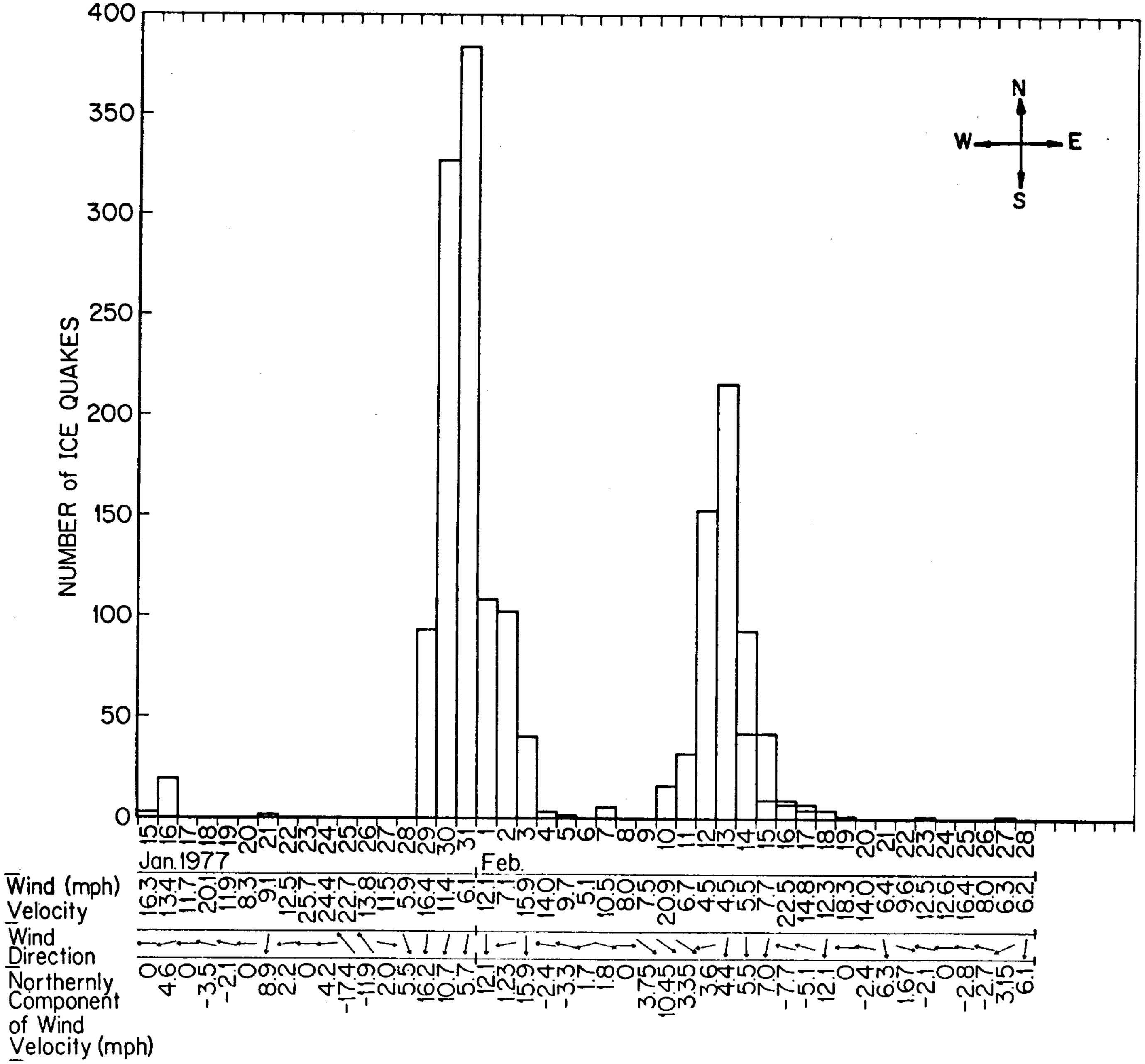


Fig. 12. Daily cummulative number of icequakes are shown in relation to the net wind velocity (mph), direction of wind and the northernly component (mph) of the wind velocity.

The ranges of P and S-wave velocities (Press, 1966) of the Arctic pack ice are 2.59 - 2.79 km/sec and 1.49 - 1.56 km/sec, respectively. Taking averages of 2.69 km/sec and 1.53 km/sec respectively, for the above intervals, and the differences in the observed arrival times between SV and P phases from the seismograms, the distances of the sources of icequakes from the station KTA were computed for selected events. Because of one station data available in the present case, the direction of the wave arrivals remained an undetermined factor. However the plot of the equidistant lines for the above events with KTA as center is shown in Fig. 13; the outermost locus is found to be at 54.5 km from KTA.

The NOAA's satellite imagery of 31 January 1977, corresponding to the occurrences of the maximum number of icequakes is shown in Fig. 14. It is seen to coincide with a large scale ice flow from Chuckchi Sea to the Bering Sea. Near Kotzebue it is also seen in this figure, that a distinct interface separating a homogeneous lightly shaded area (which occupies the entire Kotzebue Sound) from a somewhat darker area in the open sea. There are no visual indications in the imagery of the presence of fractures in the ice sheets around KTA.

By comparing the observations in Fig. 13 and Fig. 14, it may be suggested at this stage of our studies, that either the large scale ice flow in the open sea, due to the high northerly component of wind or the wind itself or a combination of both, greatly increased the conditions of stresses of the land locked ice sheet in Kotzebue Sound. Owing to this, the eventual fracturing of the ice sheet gave rise to the observed tremors recorded at KTA. The size of the fractures might have been insufficient to be resolved in the satellite

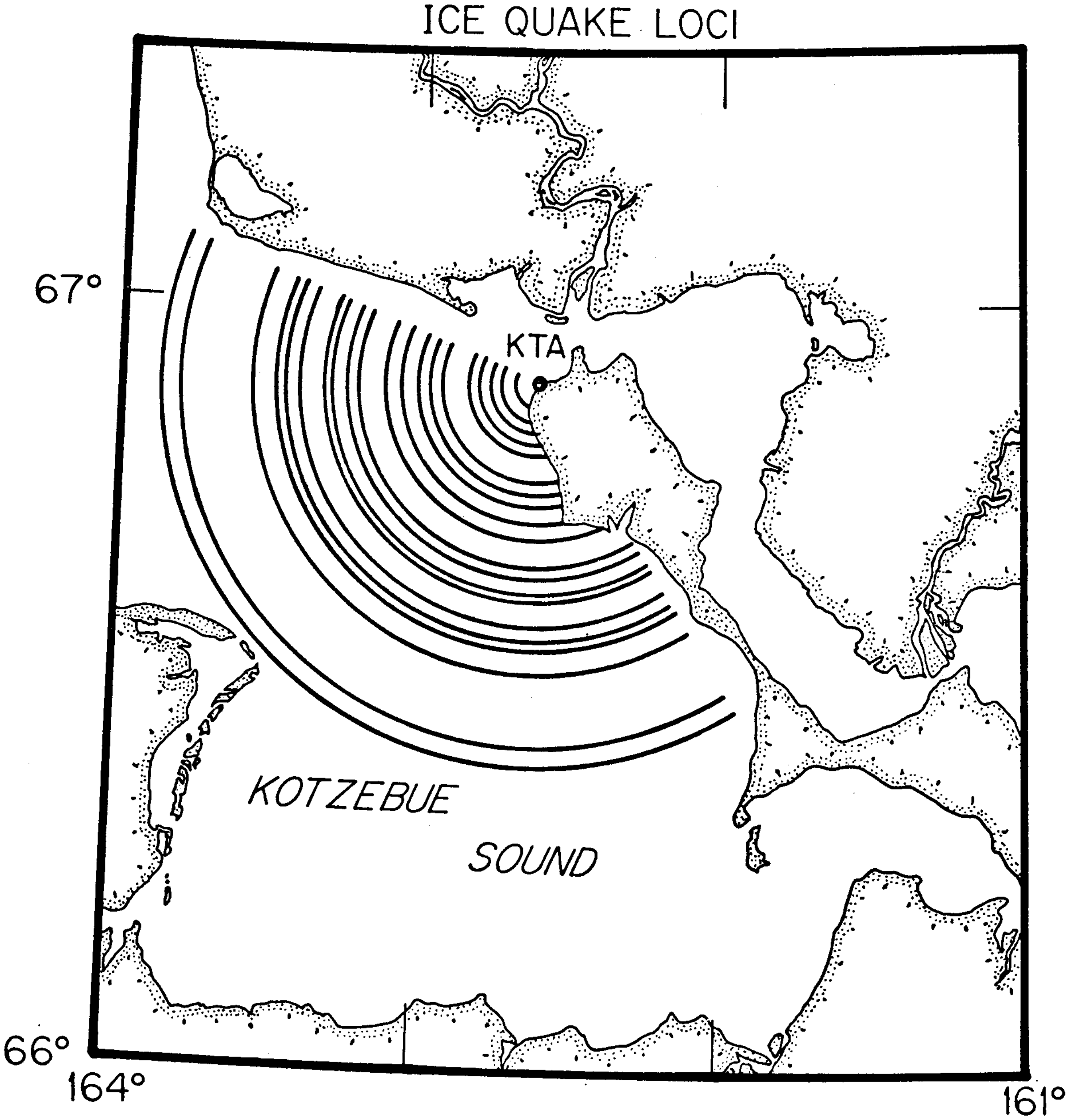


Fig. 13. The equidistant lines to the epicenters of the icequakes with respect to KTA station are shown.

Fig. 14. NOAA's satellite imagery of 31 Jan. 1977 of the study area. Note the uniform lightly shaded area within Kotzebue Sound separated from the dark area in the open sea.

imagery. For some events, the ice sheet might have acted as a wave guide thereby transmitting the radiated energy by multiple reflections from the bottom and top of the sheet. Such mechanism can account for the dispersive wave trains. However, the phenomenon of inverse dispersion seen in the records, as mentioned before, could not be explained by the above mechanism.

The icequakes posed important problems as by detailed analysis of the wave trains it would be possible to compute the displacement components of the longitudinal and transverse motions and thus the various components of stresses. These will provide an independent means to find the Arctic ice mechanics which have important implications in the offshore developments of the natural resources of the Arctic region.

ACKNOWLEDGEMENTS

We thank Drs. G. Gryc, O. Ferrians and R. A. Page of the U. S. Geological Survey and Drs. G. Weller and N. Hardin of the Arctic Project Office (OCSEAP) for their continuous support and encouragement during the study period. We express appreciation to D. Kennedy and T. R. Flesher of OCSEAP for logistic supports in time. We are indebted to O. Westwick, D. Siegrist, M. Holmgren, R. Domke, W. Gregory, J. Siwik and W. Zito for the installation and maintenance of the seismographic network. We are grateful to Drs. W. H. K. Lee and J. C. Lahr of the USGS for providing a copy of their computer program for the location of earthquakes and for participating in helpful discussions for its adoption on the University of Alaska computer. This research was supported by the USGS Grant No. 14-08-0001-15220, NOAA Grant No.03-05-022-55, Task #12, and by the State of Alaska.

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APPENDIX

The details of the multichannel audio mixer designed locally and used at the field sites are shown in Fig. A1. The experimental (laboratory) setup designed for testing the different electronic units involved at every remote seismographic station of the network is schematically shown in Figure A2. The area within the rectangle shown by broken lines is a ultra low temperature (variable) controlled box (Revco, Model No. SZR-509) having adequate space to house the amplifier-VCO unit, audio-mixer and transmitter-receiver pair. The inside temperature of the box is adjustable over a wide range by means of an exterior knob coupled to a pointer movable over a calibrated (temperature) dial.

For our tests, the temperature was lowered from 20° to -40°C in about 10°C steps. For each such step, the inside temperature of the box stabilized at the desired value in about 3-4 hr. Once the inside temperature attained a new stable value, the performance of every unit was monitored by a series of test equipment (digital multimeter, frequency counter, oscilloscope, powermeter). These were placed outside the cold box and connected to the appropriate output terminals as shown in Fig. A2.

For temperature settings below zero, a number of units had to be replaced or repaired due to malfunctions. Finally every unit was found to perform within the required specification over the entire temperature range (20° to -40°C). The maximum variations were detected only for the VHF transmitter-receiver pairs; the results are shown in Fig. A3. The maximum deviation from the center frequency is ± 1.5 KHz which is negligibly small.

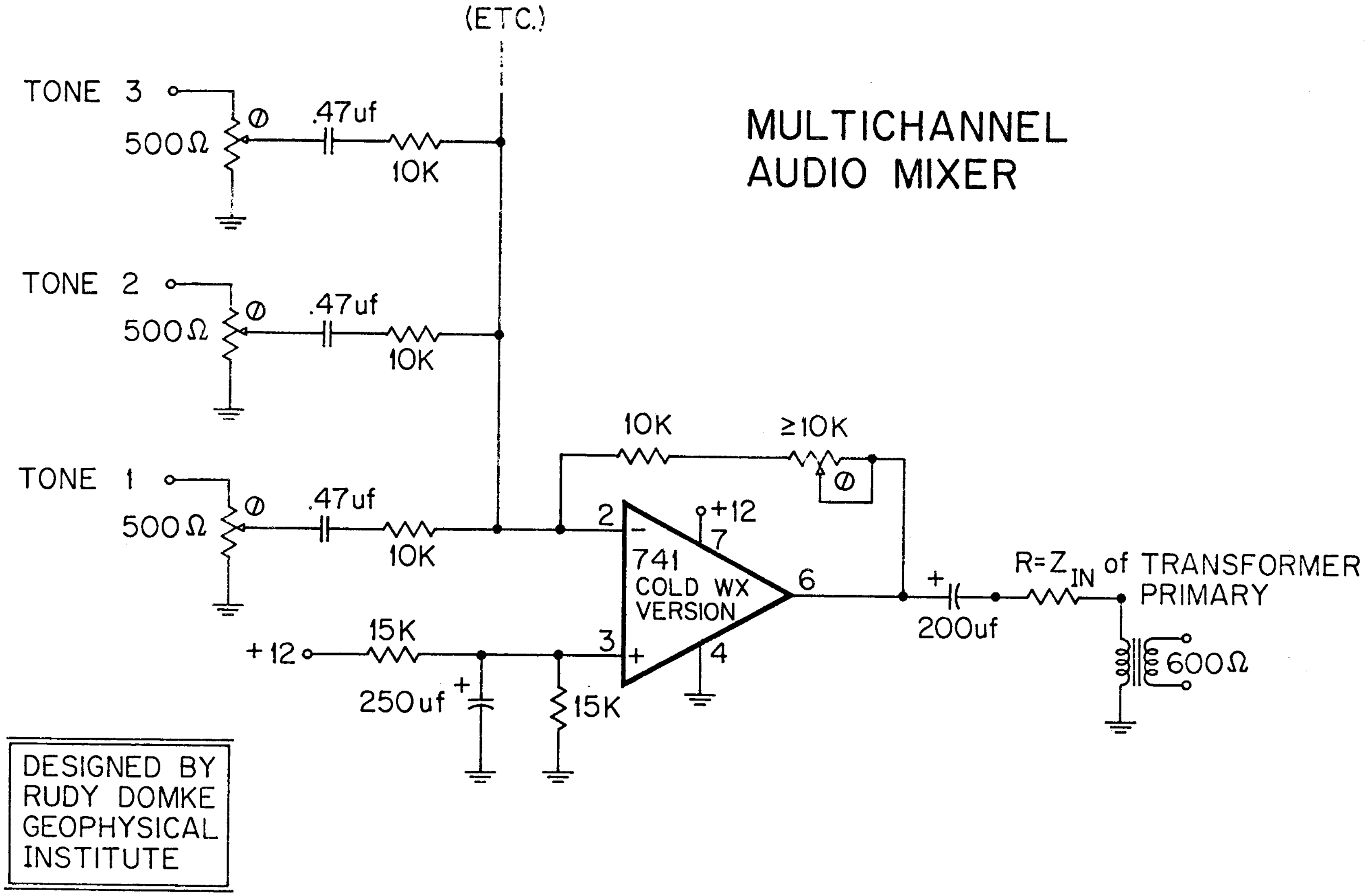

Figure A1. Mixer circuit capable of mixing 3 tones in the frequency range of 400 to 3060 mHz designed locally.

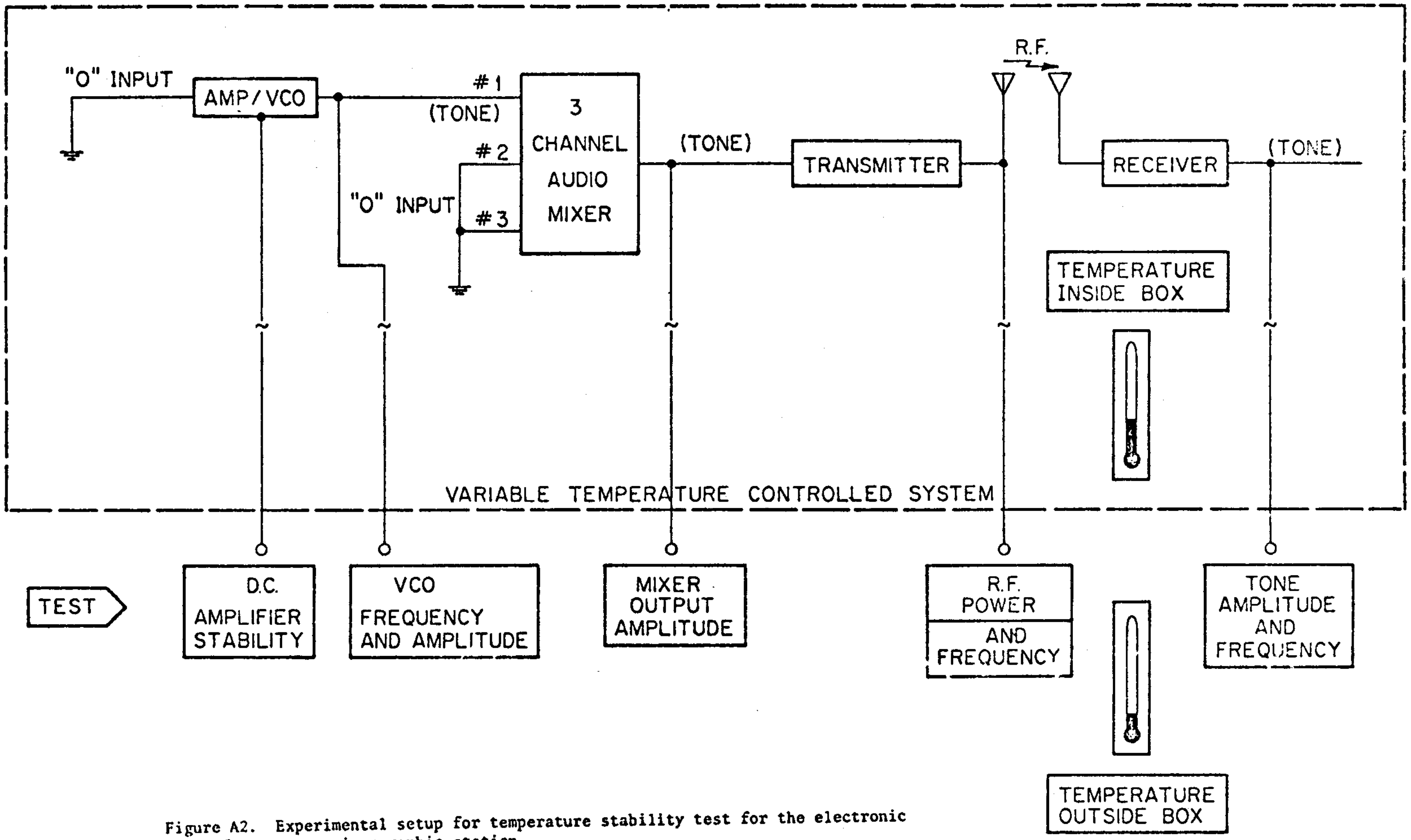

Figure A2. Experimental setup for temperature stability test for the electronic units for remote seismographic station.

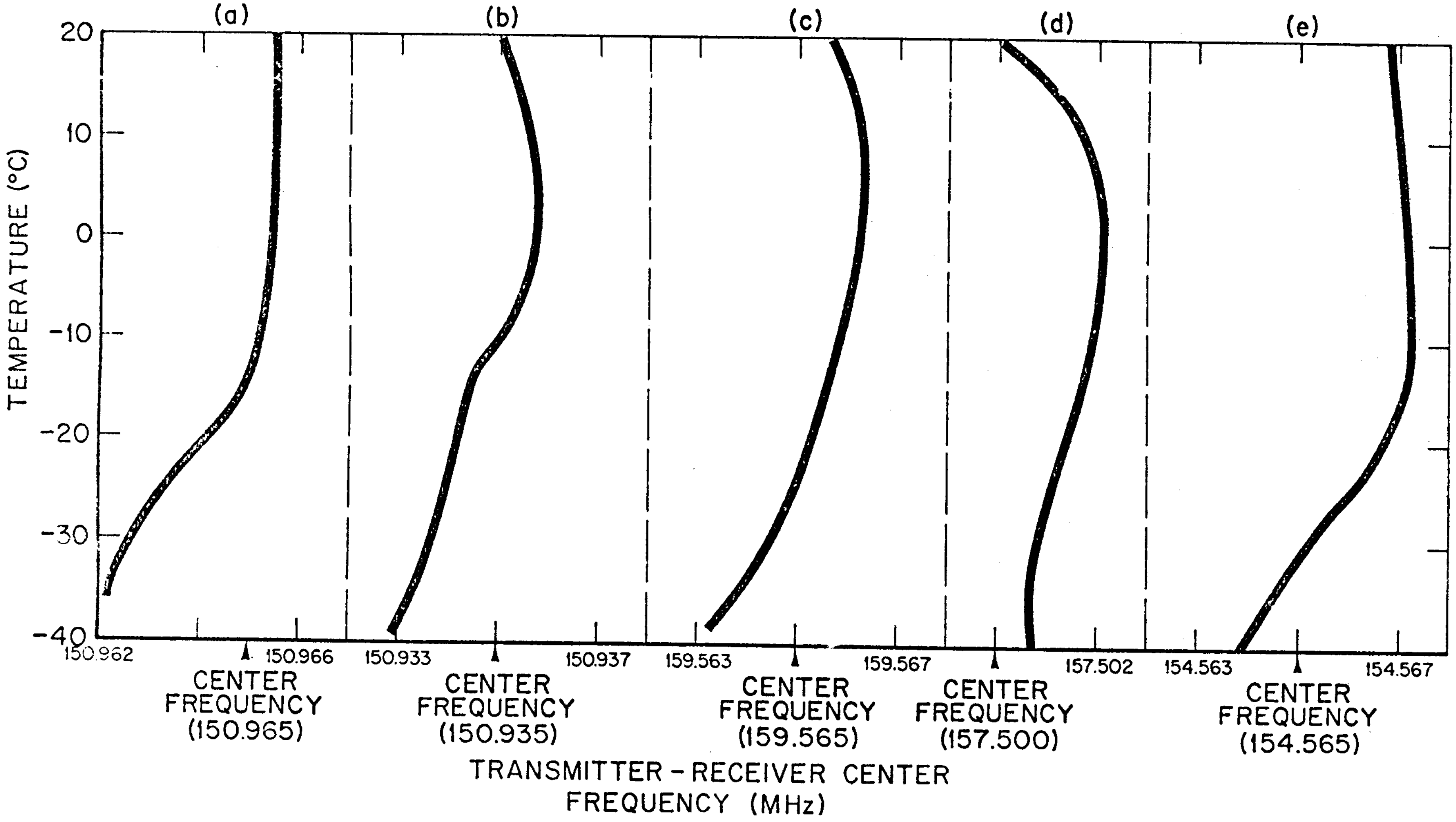

Figure A3: Deviation from center frequency of the transmitter-receiver pair.

DATA MANAGEMENT

DATA MANAGEMENT

CONTENTS

ANNUAL REPORT

Contract #03-5-022-56
Research Unit #350
Reporting Period 4/1/76-3/31/77
Number of Pages 52

ALASKA OCS PROGRAM COORDINATION

Donald H. Rosenberg
OCS Coordination Office
University of Alaska

March 31, 1977

I. Summary of Objectives

This project provides for coordination of all NOAA/OCS Task Orders within the University of Alaska. It provides for a coordinator and related support services necessary for coordination of the University program with the NOAA scientific program and the NOAA contracting office.

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. Scientific Monitoring

The University of Alaska OCS Coordination Office has monitoring authority over all Task Orders given in Table Ia and b. As noted in this tabulation, certain tasks have been finished and final reports submitted. This effort is limited to evaluation of scientific efforts related to the work statement, coordinating logistics for data collection, formating of data in accordance with Data Management Plans and submission of data in accordance with Data Submission Schedules. Also, all reports and proposals are reviewed for format and processed by this office.

In the past year this office has submitted on behalf of principal investigators the proposals listed in Table II, both solicited and unsolicited. Approved work statements for FY '77 are noted in Table II.

Contact is maintained by this office with Juneau and Arctic OCS Project Offices and with the parent Boulder OCS office, to insure that the scientific programs pursued by the University OCS principal investigators are consistant with the NOAA program plans. This office also insures that NOAA is kept aware of other University programs which are of importance to the NOAA/OCS program.

B. Management Staff

The operating management staff of this office has been streamlined during the past year. The positions are outlined in Table III.

C. Data Management

Data Management Plans were formulated and approved by the Contract Data Manager for FY '76 and FY '76T projects. The data management article (Article 9) to the parent contract (03-5-022-56) was discussed, and a mutually agreeable rewording was developed between this office and the Contract Data Manager, and forwarded to the Boulder Office on November 4, 1976. As of this report no further action has been taken to formally change the contract. Such action is necessary in order for us to proceed in formulating changes to certain Data Management Plans reflecting the FY '77 work proposed.

All formats necessary to process data for magnetic tape submission are now in hand. However, the "Trace Metals Format" was received only recently, March 21, 1977, and, though adequate, will cause great delay in submitting the data on magnetic tape since two years of hard copy data must be formated and transferred.

D. Data Submission

Contract 03-5-022-56 investigators have submitted through this office 58 batches of data to be formated and transferred to magnetic tape in the past year. We have submitted 51 of these batches and are currently working on seven others. Also, we have submitted, on behalf of the investigators, five batches of data in hard copy exclusive of quarterly reports deemed to contain sufficient information to constitute data reports. See Table IV for a complete listing of submitted data batches.

We have also furnished a data transmittal service, including keypunching, for designated investigators not under our contract. To date, we have transmitted two years of data on behalf of Dr. P. Connors, Bodega Bay Laboratory. No other requests for this service have been received from M. Pelto.

With the exception of about six data batches, exclusive of trace metals (which problem was previously mentioned and for which data have been submitted quarterly in report form) we have submitted or are currently processing all data batches due in FY '76.

E. Coordination Travel

Funds are provided under the OCS Coordination Task Order to provide for travel of management staff and principal investigators when coordinating their tasks with other investigators or meeting with NOAA project staff. These funds are actively and heavily used to attend synthesis and coordination meetings. The progress of the total project is reflected in proliferation of such meetings; these travel funds allow for a controlled method of participation by University investigators.

F. Logistics Coordination

This office continued to coordinate project logistics requirements of investigators with the NOAA Project Offices. This includes coordination with the Logistics Task Order #23 and non-University principal investigators. All cruise/field reports for OCS activities are cleared through this office and ROSCOP II forms prepared when required.

G. Facilities Modification

The new laboratories partially funded through this Task Order, have been satisfactorily completed and occupied during the past year. Moving to these new facilities caused some delay in pursuing on-going programs but most such delays have been adequately compensated for by the greater efficiency of the new facilities.

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

1. Data Management

A data batch for Task Order #12 was submitted in the last quarter. We have now received all necessary formats for reporting data due on magnetic tape.

We still await contractual approval of a few Data Management Plans as noted on the appropriate Data Submission Schedules.

We are preparing to update the Data Management Plans for those task orders that have altered the focus of their research in FY '77. This will be done when the agreed to change to Article 9 of our contract is finalized (see section VI C above).

Enclosed find the Data Submission Schedules for all Task Orders under contract 03-5-022-56.

2. Contract Monitoring

a. Modifications to the sub-contract with Battelle Northwest Laboratory are currently being prepared to reflect FY '77 costs and efforts.

Sub-contracts with both U.C.L.A. and Naval Undersea Center have been completed and a final summation of work done has been submitted.

C. Problems Encountered

1. Changes to the contract have been pending for up to six months. Data Management Plan approvals have been pending for as long as nine months. Placing the University in limbo over these change requests severely complicates the day to day operations. Correspondence on these matters, as on many others, are frequently not answered; or when responded to are often not resolved.

2. In attempting to deal with the control of sample flow through the Sorting Center; this office had apparently reached agreement that FY '77 funds appropriated for sorting would be removed from individual tasks and placed in a new task order budget under the control of this office. By so doing, the rate of sample flow and cost could be more easily manipulated to meet NOAA/OCS priorities. This mechanism was outlined in detail in the Proposed Work Statement for Task Order #2; which has been accepted. However, some difficulty in shifting monies has returned us to the old, trying system especially insofar as the sorting of intertidal samples for Dr. Zimmerman of NMFS, Auke Bay is concerned. On this last matter, we have yet to receive a final contract and are soon to run dry the pre-contract allocation. Needless to say, we feel the extra effort expended in attempting to avoid this situation and further in rectifying the resultant problems is a waste of time, money, and people.

TABLE Ia

University of Alaska OCS Projects

Contract 03-5-022-56

Task Order	R.U.#	Project Title	Principal Investigator
1	159/164	Phytoplankton Studies	Vera Alexander
	427	Bering Sea Ice-Edge Ecosystem Studies	Vera Alexander R. T. Cooney
2	350	Alaskan OCS Program Coordination	Donald H. Rosenberg
3	291	Benthos - Sedimentary Substrate Interaction	Charles M. Hoskin
4*	111	Seasonability and Variability of Streamflow Important to Alaskan Nearshore Coastal Areas	Robert F. Carlson
5	275/276/294	Hydrocarbons: Natural Distribution and Dynamics on the Alaskan Outer Continental Shelf	David G. Shaw
6	99	The Environmental Geology and Geomorphology of the Gulf of Alaska Coastal Plain	P. Jan Cannon
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
9*	318	Preparation of Illustrated Keys to Skeletal Remains of Otoliths of Forage Fishes	James E. Morrow
10*	282/301	Summarization of Existing Literature and Unpublished Data on the Distribution, Abundance and Productivity of Benthic Organisms of the Gulf of Alaska and Bering Sea	Howard M. Feder
11*	215	Avifaunal Utilization of the Offshore Island Area Near Prudhoe Bay, Alaska	George J. Mueller
12	162/163/288 293/312	Natural Distribution of Trace Heavy Metals and Environmental Background in Three Alaskan Shelf Areas	David C. Burrell

Contract 03-5-022-56

Task Order	R.U.#	Project Title	Principal Investigator
13	156/164	Zooplankton and Micronekton Studies in the Bering - Chukchi/Beaufort Seas	Robert T. Cooney
14[2]	307	Historical and Statistical Oceanographic Data Analysis and Ship-of-Opportunity Program	Robin D. Muench
15	5/303/281	The Distribution, Abundance, Diversity and Productivity of Benthic Organisms in the Bering Sea	Howard M. Feder
16*	348	Literature Search on Density Distribution of Fishes of the Beaufort Sea	James E. Morrow
17*	305	Sublethal Effects - Effects on Seagrass	John G. Pearson
18*	123	Acute Toxicity - Pacific Herring Roe in the Gulf of Alaska	Ronald L. Smith
19	289	Mesoscale Currents and Water Masses in the Gulf of Alaska	Thomas C. Royer
20[1]	281	The Distribution, Abundance, Diversity and Productivity of Benthic Organisms in the Gulf of Alaska	Howard M. Feder
21	284	Food and Feeding Relationship in the Benthic and Demersal Fishes of the Gulf of Alaska and Bering Sea	Ronald L. Smith
22*	285	Preparation of Illustrated Keys to Skeletal Remains and Otoliths of Forage Fishes	James E. Morrow
23	351	Logistic I R/V Acona	Dolly Dieter
24		Administrative Support NODC/EDS	David M. Hickok
25	347	Marine Climatology of the Gulf of Alaska and the Bering and Beaufort Seas	James Wise
26*		Identification and Evaluation of Gaps in Data and Knowledge Relevant to OCS Development of the Chukchi Sea and Coastal Region	E. F. Buck C. D. Evans J. C. LaBelle H. W. Searby and W. S. Wilson

Contract 03-5-022-56

Task Order	R.U.#	Project Title	Principal Investigator
27	441	Avian Community Ecology at Two Sites on Espenberg Peninsula	P. G. Mickelson
28	458	Avian Community Ecology of the Akulik - Inglutalik River Delta	G. F. Shields L. J. Peyton
29	P 29	The Distribution, Abundance and Diversity of the Epifaunal Benthic Organisms in Two Bays of Kodiak Island	H. M. Feder
30	502	Trawl Survey of the Benthic Epifauna of the Chukchi Sea and Norton Sound	H. M. Feder
31*		Production of an Outer Continental Shelf Assessment Atlas Series	D. Hickok E. Buck

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

[1] Task Order #20 is now combined under Task Order #15 for all work past and present. All future reporting, including final report will be under Task Order #15.

[2] Summary report of activities under this contract will be forthcoming upon receipt of guidance from the Juneau Project Office.

TABLE Ib

Contract 03-5-022-55

Task Order	R.U.#	Project Title	Principal Investigator
1	253/255	Offshore Permafrost-Drilling, Boundary Conditions, Properties, Processes and Models	T. E. Osterkamp and W. D. Harrison
2	251	Seismic and Volcanic Risk States-Western Gulf of Alaska: Cook Inlet-Kodiak-Semidi Island Region	Hans Pulpan and Jurgen Kienle
3	271	Beaufort Sea Coast Permafrost Studies	James C. Rogers
4	261/262	Beaufort Sea Historical Baseline Ice Study Proposal	William Hunt and Claus Naske
5	258	Morphology of Bering Nearshore Ice Conditions by Means of Satellite and Aerial Remote Sensing	W. J. Stringer
6	265	Development of Hardware and Procedures for *in situ* Measurement of Creep in Sea Ice	L. H. Shapiro W. M. Sackinger and R. D. Nelson
7	259	Experimental Measurements of Sea Ice Failure Stresses Near Grounded Structures	R. D. Nelson and W. M. Sackinger
8	257	Morphology of Beaufort Nearshore Ice Conditions by Means of Satellite and Aerial Remote Sensing	W. J. Stringer
9	248/249	The Relationships of Marine Mammal Distribution, Densities and Activities to Sea Ice Conditions - Bering and Beaufort Seas	J. J. Burns F. H. Fay and L. H. Shapiro
10	267	Operation of an Alaskan Facility for Applications of Remote-Sensing Data of Outer Continental Shelf Studies	A. E. Belon
11	250	Mechanics of Origin of Pressure Ridges, Shear Ridges, and Hammock Fields in Landfast Ice	L. H. Shapiro
12	483	Evaluation of Earthquake Activity Around Norton and Kotzebue Sounds	N. N. Biswas L. D. Gedney

TABLE II

Proposals Submitted to NOAA/OCS for Contract 03-5-022-56
4/1/76 - 3/31/77

Submission Date	Proposal Number	Title	P.I.	Proposal Cost
4/3/76	76-1	Dynamics of Petroleum and Metals in Sediments and the Clam *Macoma balthica*	Shaw	$149,709
4/3/76	76-2	...Barrier Island Ecosystems of the Beaufort Sea: Phase I...	Dermody	40,000
4/3/76	*76-3	Avian Community Ecology of the Akulik-Inglutalik River Delta, Norton Bay, Alaska	Shields and Peyton	82,000
4/3/76	*76-4	Avian Community Ecology at Two Sites on Espenberg Peninsula in Kotzebue Sound, Alaska	Mickelson	143,409
4/3/76	76-5	The Effects of Crude Oil, Refined Oil, Cleaning Agents, and Dispersing Agents on Sea Otter (*Enhydra lutris*) Insulation	Ohata	164,483
5/17/76	76-6	...Epifaunal Benthic Organisms in Two Bays of Kodiak Island,...	Feder	50,487
8/16/76	*76-6 Mod 1	...Epifaunal Benthic Organisms in Two Bays of Kodiak Island,....	Feder	50,487
5/28/76	76-7	Food and Feeding Relationships... Benthic and Demersal Fishes...	Smith	30,027
8/10/76	*76-7 Mod 1	Food and Feeding Relationships... Benthic and Demersal Fishes...	Smith	30,027
6/16/76	*76-8	Administrative Support NODC/OCSEAP	Hickok	13,854
11/16/76	*76-8 Amend 1	Administrative Support NODC/OCSEAP	Hickok	91,073

Proposals Submitted to NOAA/OCS for Contract 03-5-022-56
4/1/76 - 3/31/77

Submission Date	Proposal Number	Title	P.I.	Proposal Cost
6/1/76	76-9	Bering Sea Ice Edge Ecosystem Study	Alexander Cooney	$407,763
2/4/77	*76-9 Mod 1	Bering Sea Ice Edge Ecosystem Study	Alexander Cooney	352,030
6/1/76	76-10	Environmental Geology...	Cannon	15,021
5/7/76	76-11	Trawl Survey Chukchi Sea	OCS Office	40,142
8/30/76	*76-11 Mod 1	Trawl Survey Chukchi Sea	Feder	47,624
5/25/76	76-12	Geological Literature Related to Lower Cook Inlet	Sharma	30,223
6/2/76	*76-13	Hydrocarbons, FY '76T	Shaw	34,624
6/3/76	76-14	Hydrocarbons, FY '77	Shaw	366,781
11/24/76	*76-14 Mod 1	Hydrocarbons, FY '77	Shaw	366,781
6/2/76	76-15	Zooplankton - Micronekton	Cooney	58,083
8/12/76	*76-15 Mod 1	Zooplankton - Micronekton	Cooney	58,083
6/3/76	*76-16	Trace Heavy Metals FY '76T	Burrell	34,939
6/9/76	*76-17	Trace Heavy Metals FY '77	Burrell	154,972
6/4/76	76-18	Circulation and Water Masses	Royer	215,018
9/7/76	76-18 Mod 1	Circulation and Water Masses	Royer	212,016

Proposals Submitted to NOAA/OCS for Contract 03-5-022-56
4/1/76 - 3/31/77

Submission Date	Proposal Number	Title	P.I.	Proposal Cost
10/17/76	76-18 Mod 1 Amend 1	Circulation and Water Masses	Royer	83,683
1/11/77	*76-18 Mod 2	Circulation and Water Masses	Royer	261,268
6/17/76	76-19	Ecology of Birds of Ice Pack	West - Divoky	60,000
6/17/76	76-20	Biology of Benthic Organisms	Feder	280,000
8/19/76	*76-20 Mod 1	Biology of Benthic Organisms	Feder	280,000
6/22/76	76-21	Grain Size Analysis of Sediment	Hoskin	15,394
8/18/76	*76-21 Mod 1	Grain Size Analysis of Sediment	Hoskin	15,394
6/30/76	76-22	Effects of Oil on Feed of Geese	Smith	59,727
5/19/76	*76-23	Atlas Series, Phase I	Selkregg	4,990
6/7/76	77-1	R/V Acona Support	Dieter	169,551
1/11/77	*77-1 Mod 1	R/V Acona Support	Dieter	285,924
6/12/65	77-2	OCS Coordination	Rosenberg	134,472
9/21/76	*77-2 Mod 1	OCS Coordination	Rosenberg	134,472
7/15/76	*77-3	Environmental Geology	Cannon	27,500
8/11/76	*77-4	Marine Climatology	Wise	64,698

Proposals Submitted to NOAA/OCS for Contract 03-5-022-56
4/1/76 - 3/31/77

Submission Date	Proposal Number	Title	P.I.	Proposal Cost
8/31/76	77-5	Microbial Release	Barsdate	30,001
9/28/76	*77-6	Morbidity and Mortality of Marine Mammals	Fay	51,716
12/17/76	77-7	Sediments, Barrier Island Ecosystem	Naidu	40,806
12/17/76	77-8	Environ. Geology Barrier Island Ecosystem	Cannon	39,244
12/17/76	77-9	Atlas Series, Phase II	Hickok - Buck	140,000
2/17/77	77-10	Nutrient Dynamics	Schell - Button	10,353
3/3/77	77-11	Heavy Metals in Marine Mammals	Burrell	34,980

* Proposals accepted and funded in the last year.

TABLE III

University of Alaska OCS Project

Management Staff

Position	Percent Effort	Name
Coordinator [1]	Approximately 25%	Donald H. Rosenberg
Data Manager[1]	100%	Raymond S. Hadley
Contract Manager[1]	50%	William N. Case
Administrative Assistant[2]	Approximately 25%	Brenda Melteff
Typist[2]	Approximately 25%	Helen Greschke
Keypunch Operator[1]	100%	Sherry Walton

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			
Dis808	028	Discoverer 5/15-6/20/75	6/27/76
Dis810	028	Discoverer 8/9-8/28/75	6/27/76
MFR815	028	Miller Freeman 11/10-11/26/75	6/27/76
Dis808	029	Discoverer 5/15-6/19/75	9/7/76
Dis810	029	Discoverer 8/9-8/28/75	9/7/76
MF815	029	Miller Freeman 11/10-11/26/75	9/7/76
Task Order #3			
761101	073	Discoverer 5/15-6/20/75	11/12/76
761102	073	Miller Freeman 8/16-10/20/75	11/12/76
Task Order #5			
	H.C.	Special Report L. Cook Inlet	8/13/76
	H.C.	Data Report	4/29/76
	H.C.	All Quarterly Reports	
Task Order #8			
BFay75	027	1975 Field Season 5/12-8/22/75	5/21/76
BFay76	027	1976 Field Season 5/28-8/4/76	10/8/76
Task Order #12			
	H.C.	Special Report L. Cook Inlet	8/13/76
	H.C.	Special Report Trace Metal Lit. Survey	2/10/77
	H.C.	All Quarterly Reports	
Task Order #13			
RTCZ01	024	R/V Acona 7/1-7/10/74	6/17/76
	024	R/V Acona 10/8-10/14/74	6/17/76
	024	R/V Acona 11/18-11/20/74	6/17/76
	024	R/V Acona 3/21-3/27/75	6/17/76
	024	Oceanographer 2/19-2/29/75	6/17/76
	024	T. Cromwell 5/6-5/16/75	6/17/76

Submitted Data Batches

File I.D.	File Type	Cruise/Field Operation	Submission Date
RTZ02	024	Discoverer 8/9-8/28/75	8/10/76
RTZ03	024	Surveyor 3/15-4/15/76	8/31/76
RTZ04	024	Miller Freeman 11/10-11/26/75	8/31/76
RTZ05	024	Discoverer 5/15-6/20/75	8/31/76
Task Order #14			
808IMS	022	Discoverer 5/15-6/20/75	7/29/76
197IMS	022	Acona 8/20-8/30/75	7/29/76
SU2IMS	022	Surveyor 4/15-4/26/76	11/1/76
SU1IMS	022	Surveyor 3/15-4/15/76	11/1/76
PODAS[1]		Discoverer 8/9-8/28/76	6/10/76
815IMS	022	Miller Freeman 11/10-11/26/75	6/7/76
Task Orders #15/#20			
Benorg	032	Oceanographer 2/19-2/29/75	4/30/76
Benorg	032	T. Cromwell 5/6-5/16/75	4/30/76
Benorg	032	Acona 193 7/1-7/9/74	4/30/76
Benorg	032	Acona 200 10/8-10/14/74	4/30/76
Benorg	032	Acona 202 11/18-11/20/74	4/30/76
	H.C.	Special Report L. Cook Inlet	8/13/76
817	032	North Pacific 4/25-8/7/75	5/24/76
817*	032	Miller Freeman 8/16-10/20/75	11/12/76
812	032	Discoverer 10/8-10/16/75	10/7/76
MW002	032	Moana Wave 3/30-4/15/76	8/23/76
808	032	Discoverer 5/15-6/20/75	8/10/76
Task Order #19			
811IMS	022	Silas Bent 9/1-9/26/75	2/26/76
193IMS	022	Acona 7/1-7/9/74	4/9/76
200IMS	022	Acona 10/8-10/14/74	4/9/76
202IMS	022	Acona 11/18-11/21/74	4/9/76
205IMS	022	Acona 2/12-2/14/75	4/9/76
207IMS	022	Acona 3/21-3/27/75	4/9/76
MW001	022	Moana Wave 2/22-3/5/76	6/7/76
814IMS	022	Surveyor 10/28-11/17/75	6/7/76
805IMS	022	Oceanographer 2/1-2/13/75	7/29/76

Submitted Data Batches

File I.D.	File Type	Cruise/Field Operation	Submission Date
212IMS	022	Acona 6/3-6/13/75	7/29/76
MW3IMS	022	Moana Wave 4/20-5/1/76	11/1/76
MW4IMS	022	Moana Wave 5/7-5/20/76	11/1/76
814IMS (update)	022	Surveyor 10/28-11/17/75	11/1/76
PODAS		Discoverer 10/8-10/16/75	6/10/76
Task Order #21			
75100	023	Rex Sole Data 4/25-8/7/75	11/10/76

* Incorrect File I.D. submitted as 817 should be 818, correction was telephoned to J. Audet.

[1] Data submitted prior to realizing data quality control was improper; data now considered to be bad.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 1 R.U. NUMBER: 159/164/427

PRINCIPAL INVESTIGATOR: Dr. Vera Alexander and Dr. Ted Cooney

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
Discoverer Leg I #808	5/15/75	5/30/75	submitted	submitted	None	None
Discoverer Leg II #808	6/2/75	6/19/75	submitted	submitted	None	None
Discoverer Leg I #810	8/9/75	8/28/75	submitted	submitted	None	None
Miller Freeman #815	11/10/75	11/26/75	submitted	submitted	None	None
Surveyor Su/001/2	3/76	4/76	5/15/77	5/15/77	None	None

Note: [1] Data Management Plan and data Formats have been approved and are considered contractual. An update of data management plan, reflecting FY '77 Work Statement will be forthcoming shortly.

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ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

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.[1] A schedule of submission is therefore not applicable

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NOTE: [1] Data Management Plan has been approved and made contractual.

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ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 3 R.U. NUMBER: 291

PRINCIPAL INVESTIGATOR: Dr. C. M. Hoskin

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		
Discoverer Leg I #808	5/15/75	5/30/75	Submitted		
Discoverer Leg II #808	6/2/75	6/19/75	Submitted		
Miller Freeman	8/16/75	10/20/75	Submitted		

All data for FY '76 have been submitted.

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 4 R.U. NUMBER: 111

PRINCIPAL INVESTIGATOR: Dr. Robert F. Carlson

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[2].

The final report is submitted, and this task has been completed.

Note:

[1] Data Management Plan has been approved by M. Pelto; we await approval by the Contract Officer.

[2] Data Management Plan has been approved and made contractual.

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ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

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	(a)	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	(a)	(a)
Miller Freeman	5/17/76	6/4/76	(a)	None	None
Glacier	8/18/76	9/3/76	None	(a)	None
Discoverer	9/10/76	9/24/76	None	(a)	(a)
Moana Wave	10/7/76	10/16/76	None	(a)	(a)
Acona	6/25/76	7/2/76	(a)	(a)	(a)

Note: [1] Data Management plan has been approved and made contractual.

(a) These data are contained in this Annual Report, which constitutes a data submission.

OCS COORDINATION OFFICE

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ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 6 R.U. NUMBER: 99

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].

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 7 R.U. NUMBER: 178

PRINCIPAL INVESTIGATOR: Dr. Robert J. Barsdate

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[2].

NOTE: [1] Data Management Plan has been approved by M. Pelto; we await approval by the Contract Officer.

[2] Data Management Plan has been approved and made contractural.

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ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

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			
Alaska Peninsula	7/23/75	7/24/75	submitted			
Kotzebue Sound	7/17/75	7/20/75	submitted			
Kotzebue Sound	7/22/75	7/24/75	submitted			
St. Lawrence Is.	8/8/75	8/22/75	submitted			
Alaska Peninsula	Summer 1976		submitted			
Kotzebue Sound	Summer 1976		submitted			

All FY '76 data have been submitted

Note: 1 Data Management Plan has been approved by M. Pelto; we await approval by the Contract Officer.

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ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 9 R.U. NUMBER: 318

PRINCIPAL INVESTIGATOR: Dr. J. E. Morrow

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].

The final report has been submitted, this task has been completed.

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 10 R.U. NUMBER: 282/301

PRINCIPAL INVESTIGATOR: Dr. H. M. Feder

Progress on this study has indicated that there is little data in a form suitable for submission using available EDS Format (Benthic Organisms). It is suggested that the following information products be accepted; (1) key word bibliography (2) distribution maps.

Final report, maps, and key word bibliography have been submitted, this task is completed.

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 11 R.U. NUMBER: 215

PRINCIPAL INVESTIGATOR: Mr. George Mueller

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].

The final report has been submitted. This task order has been contractually completed.

NOTE: [1] Data Management Plan has been approved and made contractual.

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ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

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 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
Discoverer Leg II #808	6/2/75	6/19/75	*	*	None	*
Silas Bent Leg I #811	8/31/75	9/14/75	None	None	None	None
Discoverer Leg IV #812	10/8/75	10/16/75	*	*	None	*
Miller Freeman	8/16/75	10/20/75	None	None	Unknown	None
Discoverer Leg III #810	9/12/75	10/3/75	None	None	None	*
North Pacific	4/25/75	8/7/75	None	None	Unknown	None
Intertidal Biota		1975	None	None	Unknown	None
Discoverer #816	11/12/75	12/2/75	*	*	None	*
Contract 03-5-022-34	Last	Year	*	None	None	None
USCGC Glacier	8/18/76	9/3/76	*	None	None	None
Discoverer	9/10/76	9/24/76	*	None	None	None

Note: [1] Data Management Plan has been approved by M. Pelto, we await approval by the Contract Officer.

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 5	6	7	8
Discoverer Leg II 808	6/2/75	6/19/75	*	None	None	None
Silas Bent Leg I 811	8/31/75	9/14/75	None	None	None	None
Discoverer Leg IV 812	10/8/75	10/16/75	*	*	None	None
Miller Freeman	8/16/75	10/20/75	None	Lost	*	*
Discoverer Leg III 810	9/12/75	10/3/75	None	*	None	None
North Pacific	4/25/75	8/7/75	None	Lost	Lost	Lost
Intertidal Biota		1975	None	None	*	*
Discoverer 816	11/23/75	12/2/75	*	None	None	None
Contract 03-5-022-34	Last	year	*	None	*	*
Glacier	8/18/76	9/3/76	*	*	None	None

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 9	10		
Discoverer Leg II 808	6/2/75	6/19/75	*	*		
Silas Bent Leg I 811	8/31/75	9/14/75	*	*		
Discoverer Leg IV 812	10/8/75	10/16/75	*	*		
Miller Freeman	8/16/75	10/20/75	none	none		
Discoverer Leg III 810	9/12/75	10/3/75	none	none		
North Pacific	4/25/75	8/7/75	none	none		
Intertidal Biota		1975	none	none		
Discoverer 816	11/23/75	12/2/75	*	*		
Contract 03-5-022-34	Last	year	*	none		
Moana Wave	3/76	4/15/76	*	none		
Beaufort Sea Sediments			*	*		

* Suitable format for magnetic tape submission was received 3/21/77. Formating of data will proceed, delivery date is unknown at this time. These data have been submitted in tabular form in the Annual and Quarterly Reports for T/O 12 including the Final report of contract 03-5-022-34.

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ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 13 R.U. NUMBER: 156/164

PRINCIPAL INVESTIGATOR: Dr. R. T. Cooney

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		
Discoverer Leg I #808	5/15/75	5/30/75	submitted		
Discoverer Leg II #808	6/2/75	6/19/75	submitted		
Discoverer Leg I #810	8/9/75	8/28/75	submitted		
Miller Freeman #815	11/10/75	11/26/75	submitted		
Contract #03-5-022-34	Last	Year	submitted		
Surveyor 001/2	3/76	4/76	submitted		
Discoverer 002	8/3/76	8/17/76	3/30/77[a]		

Notes: [1] Data Management Plan has been approved and made contractual. Format has been received and approved by all parties.

[a] Data is currently being transferred to magnetic tape, keypunching has been completed.

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University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 14 R.U. NUMBER: 307

PRINCIPAL INVESTIGATOR: Dr. R. D. Muench

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			
Acona #197	7/20/75	7/30/75	submitted			
Discoverer Leg I & II #808	5/15/75	6/19/75	submitted			
Discoverer Leg I #810	8/9/75	8/28/75	(a)			
Miller Freeman #815	11/19/75	11/26/75	submitted			
Surveyor 001/002	3/76	4/76	submitted			

All data to be submitted under this task order, for this contract have now been submitted.

NOTE: [1] Data Management Plan and Data Format have been approved and are considered contractual.

(a) Parent tapes were coded in PODAS format, tapes were submitted to F. Cava as requested.

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University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 15 R.U. NUMBER: 5/303

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		
Discoverer Leg I #808	5/15/75	5/30/75	*	None		
Discoverer Leg II #808	6/2/75	6/19/75	*	None		
Miller Freeman	8/16/75	10/20/75	(a)	submitted		
Miller Freeman	3/76	6/76	(a)	5/30/77		

Note: [1] Data Management Plan and Data Format have been approved and are considered contractual.

(a) Selected samples are being processed, date of submission not yet determined.

* That portion of cruise 808 grabs sorted, were submitted. The remainder are currently being sorted.

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University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 16 R.U. NUMBER: 348

PRINCIPAL INVESTIGATOR: Dr. J. E. Morrow

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].

The final report has been submitted, this task has been completed.

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, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 17 R.U. NUMBER: 305

PRINCIPAL INVESTIGATOR: Dr. C. P. McRoy

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].

The final report is submitted, and this task has been completed.

NOTE: [1] Data Management Plan has been approved and made contractual.

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ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 18 R.U. NUMBER: 123

PRINCIPAL INVESTIGATOR: Dr. R. L. Smith

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].

The final report has been submitted, this task has been completed.

NOTE: [1] Data Management Plan has been approved and made contractual.

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ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

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	6/2/74	9/10/74	None	(c)	None	
Station 64	4/28/75	5/20/75	None	(c)	None	
Station 9	-	-	-	(c)		
Station 9	-	-	-	(c)		
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	9/22/76	8/1/76	4/15/77			
Surveyor SU 003	9/7/76	9/17/76	4/15/77			

Cruise/Field Operation	Collection Dates		Estimated Submission Dates[1]			
	From	To	Batch 1	2	3	
Surveyor	9/20/76	10/2/76	4/15/77			
Miller Freeman	11/1/76	11/19/76	4/15/77			
Moana Wave	10/7/76	10/16/76	4/15/77			

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) See following memo; copy enclosed, and problems section of Report.

UNIVERSITY OF ALASKA
INSTITUTE OF MARINE SCIENCE

MEMORANDUM

TO: Ray Hadley, Data Manager for Sea Grant

FROM: Dave Nebert, IMS Data Management DN DATE: 25 March 1977

SUBJECT: Forwarding Current Meter Data to NODC

Current meter data to be forwarded to NODC under contractual agreement are:

IMS Designation	Dates of Mooring	Translated by	Anticipated Completion Date
GASS 60	2 July-26 Aug 74	Aanderaa,Norway (PMEL)	2 May 77
GASS 64	28 Apr-11 Jun 75	PMEL	Unknown
GASS 9B	21 Apr-23 Jun 76	PMEL	Unknown
GASS 9C	23 Jun-4 Nov 76	Aanderaa,B.C.	2 May 77

We are presently developing current meter processing programs and IMS data files. Those data that have been translated by Aanderaa and subsequently processed by IMS should be delivered to you in NODC format by 2 May 1977. This will include documentation on processing. Lack of documentation from PMEL preclude forwarding data translated by that organization. We are able to forward GASS 60 data because original data tapes were returned to us after processing by PMEL. They were subsequently translated by Aanderaa, Norway and processed by IMS. We cannot forward data from GASS 64 or GASS 9B until we either receive adequate documentation from PMEL or they return the original data tapes for subsequent translation by Aanderaa.

DN/sr

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University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 20 R.U. NUMBER: 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	
Silas Bent Leg I #811	8/31/75	9/14/75	(c)	None	
Discoverer Leg IV #812	10/8/75	10/16/75	submitted[a]	None	
North Pacific	4/25/75	8/7/75	None	submitted	
Discoverer #816	11/23/75	12/2/75	(c)	None	
Contract #03-5-022-34	Last	Year	submitted		
Moana Wave	3/30/76	4/15/76	submitted		
Discoverer 001	3/17/76	3/27/76	(b)		
Miller Freeman			(b)		

Note: [1] Data Management Plan and Data Formats have been approved and are considered contractual.

(a) Only samples for Kodiak area were processed and submitted as requested.

(b) Selected samples will be processed to provide seasonal coverage as deemed necessary.

(c) Data has been keypunched, transfer to magnetic tape and submission is imminent.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 21 R.U. NUMBER: 284

PRINCIPAL INVESTIGATOR: Dr. R. L. Smith

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			
North Pacific	4/25/75	8/7/75	(a)(b)			
Miller Freeman	8/16/75	10/20/75	(a)			
Miller Freeman	3/76	6/76	(a)			

Note: [1] Data Management Plan has been approved and made contractual.

(a) Data are currently being transferred to magnetic tape for four species of predators.

(b) Rex sole data were submitted.

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University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 22 R.U. NUMBER: 285

PRINCIPAL INVESTIGATOR: Dr. J. E. Morrow

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].

The final report has been submitted, this task has been completed.

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, 1977

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.

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ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

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.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 25 R.U. NUMBER: 347

PRINCIPAL INVESTIGATOR: Mr. James Wise

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, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 27 R. U. #441

PRINCIPAL INVESTIGATOR: Dr. P. G. Mickelson

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
1976 Field Season	6/4/76	9/15/76	6/30/77	6/30/77	5/30/77	9/30/77
			Batch 5	6	7	8
1976 Field Season			5/30/77	5/30/77	4/30/77	4/30/77

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[1] Data management plan has been submitted and approved by F. Cava; we await contractual approval.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 28 R. U. #458

PRINCIPAL INVESTIGATORS: Dr. G. F. Shields and Mr. L. J. Peyton

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
1976 Field Season	6/14/76	8/24/76	5/15/77	None	6/30/77	4/15/77

	Batch 5			
1976 Field Season	4/15/77			

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[1] Data management plan has been submitted and approved by F. Cava; we await contractual approval.

OCS COORDINATION OFFICE

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ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 29

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
Big Valley 001	6/17/76	6/23/76	5/30/77			
Big Valley 002	7/18/76	7/28/76	5/30/77			
Big Valley 003	8/19/76	8/29/76	5/30/77			
Big Valley 004	3/3/77	3/18/77	6/30/77			

NOTE: [1] Data Management Plan submitted August 16, 1976, we await formal approval by Contracting Officer.

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

CONTRACT NUMBER: 03-5-022-56 T/O NUMBER: 30 R.U. NUMBER: 502

PRINCIPAL INVESTIGATOR: H. M. Feder
University of Alaska

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		
Miller Freeman	9/1/76	10/15/76	7/30/77[a]		

Note: [1] Data management plan was submitted on 8/30/76, approved by M. Pelto on 9/13/76; we await approval by the contracting officer.

[a] Raw field data was submitted at the end of the cruise. Verified and formated data will be submitted on above date.

ANNUAL REPORT

CONTRACT # 03-5-022-56
TASK ORDER #23
RESEARCH UNIT #351
REPORTING PERIOD 4/1/76-3/31/77
NUMBER OF PAGES 4

R/V ACONA AND MARINE LOGISTICS SUPPORT

Ms. E. R. Dieter

Institute of Marine Science
University of Alaska

31 March 1977

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 sea-going 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. Two marine technicians are employed 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. One technician is assigned to the Seward Station and 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. The second technician, assigned to IMS, Fairbanks, 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. A listing of cruises on which these technicians participated is given in Table I.

B. Logistics Travel

Research and vessel support travel has been provided in this project for the transportation of support personnel handling logistics. Table II summarizes the travel which has occurred in the past year.

C. R/V Acona

During the reporting period the R/V Acona has sailed in support of NOAA/OCS cruises as follows:

April 5 - 17, 1976	Gulf of Alaska	USGS
June 25 - July 2, 1976	Cook Inlet	Dr. Shaw

For OCS cruises between July 3 and August 13 and between September 20 and October 3, the information is as follows:

Lower Cook Inlet	Dr. English
NEGOA	Dr. Hoffman
Bering Sea	Dr. Coachman
Bering Sea Leg II	Dr. Coachman

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

The R/V Acona did not sail on any OCS cruises during this period.

B. Results

This project has provided sea-going and logistic support to the following cruises started in this quarter:

Surveyor	Bering Sea
Miller Freeman	GOA

C. Problems

Delay in departing from dry dock maintenance may result in a rescheduling of upcoming OCS cruises.

TABLE I

OCS Technician Sea Time

Ship	Dates	Technician
Moana Wave	4/02 - 5/21/76	Waite, Kopplin, Lunny
Miller Freeman	5/15 - 6/03/76	Kopplin
Moana Wave	7/22 - 8/01/76	Hood, Kopplin
Acona	8/01 - 8/13/76	Waite
Surveyor	9/07 - 10/02/76	Kopplin
Acona	10/21 - 10/26/76	Kopplin
Miller Freeman	11/03 - 11/23/76	Waite, Kopplin
Miller Freeman	3/28 - current	Kopplin

TABLE II

Logistics Support Travel

Dates	Reason - Place	Person
5/10 - 5/13/76	Acona meeting - Seward/Fbx	Dieter
5/10 - 5/12/76	Transport equip. - Kodiak/Seward	Gershey
5/15 - 5/22/76	Join cruise - Fbx/Kodiak	Lunny
5/17/76	Transport gear - Fbx/Seward	Elsner
6/01 - 6/08/76	Acona meeting - Seward/Fbx	Dieter
7/19 - 8/03/76	Join cruise - Seward/Kodiak	Hood
8/03 - 8/09/76	Transport gear - Seward/Fbx	Hood
9/02/76	Transport gear - Seward/Homer	Christianson
10/03 - 10/13/76	Transport gear - Fbx/Kodiak	Bradbury
12/01/76	Return fm cruise - Seattle/Seward	Waite
12/20/76 - 1/1/77	Install equip. - Fbx/Seward	Mimkin
3/08 - 3/10/77	Transport gear - Fbx/Kodiak	Bednarowicz

OCS COORDINATION OFFICE

University of Alaska

ENVIRONMENTAL DATA SUBMISSION SCHEDULE

DATE: March 31, 1977

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.

ANNUAL REPORT

Research Units: 361, 362, 363,
370 and 497

Reporting Period: 1 April 1976 -
March 1977

RU 361 - Data File Index for the Alaska MEA Program
Edgar F. Law
Environmental Data Service (NODC)

RU 362 - Establish and Service A Product Marine Baseline Data Base for the Alaska MEA Program
Edgar F. Law
Environmental Data Service (NODC)

RU 363 - Bibliographic Support to Alaskan Outer Continental Shelf Energy Program Principal Investigators
James Stear
Environmental Data Service (ESIC)

RU 370 - Administrative Support for NODC/OCSEAP Representative
David Hickok
University of Alaska/AEIDC

RU 497 - Alaskan Data Processing Facility - Environmental Data Service
Edgar F. Law
Environmental Data Service (NODC)

31 March 1977

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ADMINISTRATIVE

Five temporary positions have been filled at NODC to assist in the following OCSEAP tasks: data processing, data format development, identification and control of data sets within the processing system, updating and modification of the OCSEAP data tracking system, and production of computer products. Other NODC personnel have been reassigned to full-time duty for the OCSEAP tasks listed below.

Rod Combellick (NGSDC) has been detailed to the OCSEAP Program Office for fifty percent of his time for a period of approximately six to nine months beginning in January 1977.

Improvements in telecommunication between Anchorage, Juneau and Washington, D.C. are being investigated. A memo resulting from a meeting between Mike Crane, Jim Audet and NOAA telecommunication personnel has been forwarded to Mr. Ochinero, the Director of NODC. The memo indicates requirements and estimated usage for an improved telecommunication system.

An attempt to transmit punched card data to the Georgetown computer facility via the U.S. Geological Survey computer in Anchorage will require modification of a "Harris Box" at the Washington computer facility. Actions are being taken to complete this modification as soon as possible.

Mike Crane has implemented a pre-processing capability within his office using an IBM diskette system. Further discussions of this work and Mike's work involving the Alaska Railroad data processing activities are included in the RU 497 annual report.

Specific actions and responsibilities concerning data reports, analog data and photo storage have been developed in exchanges between the Juneau Project Office and EDS. Copies of those data reports containing specific numeric data for OCSEAP stations are forwarded from the Project Office to NODC to be accessioned, assigned a file ID and entered in the data tracking system. Those reports which are not already included in the quarter/annual reports published by ERL/BLM will be retained by the NODC Technical Records Branch; the remaining reports will be retained in the NODC Special Projects Division files.

Analog data from USGS will be routinely forwarded to NGSDC rather than through the Juneau Office. Other investigators will generally submit their analog data to the Project Office.

It was agreed that information pertaining to OCSEAP photographs, slides and film would be noted in the data tracking system where possible, including final disposition of this material. The investigator may also indicate the availability of photographs on text records or in the 'Photos Taken' field of some data formats when he submits digital data to the Project. NODC has no facilities for proper storage and retrieval of photographic material and will continue to retain only those photographs that accompany specific data reports.

An Inter-agency agreement for tracking and retrieving Dr. Atlas' microbiological data files from the National Institutes of Health data bank has been completed. Jim Audet will act as NOAA liaison and Dr. Micah Krichevsky will be the NIH contact for obtaining data tracking information, data inventories and retrieval of data and data products.

DATA PROCESSING

Detailed information pertaining to data sets and data reports received and processed by the data centers is included in the March data tracking system (distributed separately) and other summary products attached to this report (Appendices A, B, and C). The majority of data received in the earlier part of the past year were physical and chemical data. More recently, larger quantities of biological data, particularly bird and mammal data, have been submitted to the data centers. Approximately 60% of the 313 data sets received to date are biological data.

A summary of data sets, data reports and ROSCOPs received during the past year is as follows:

	Total	Apr-June 76	July-Sept 76	Oct-Dec 76	Jan-Mar 77
Data Sets*	313	20	54	175	64
Data Reports	117	23	21	40	33
ROSCOPs	196	19	37	108	32

*Total for data sets through February 28, 1977

In Processing - 196 data sets
In Pre-processing - 16
Held for further information - 35
Forwarded to NGSDC - 3
Returned to originators - 4
Final Processed - 63

Data are received at EDS in various forms. Coding sheets are keypunched under Mike Crane's Anchorage tasks (described under the annual report for RU 497), and by NODC in Washington for at least seven investigators. Punched card data are generally converted to magnetic tape by Crane before the data are submitted to NODC; some punched decks are submitted directly to NODC from the Juneau Project Office. Other data are placed on diskettes by Crane's R.U. and forwarded to NODC where data are converted to magnetic tapes for final processing.

The majority of the OCSEAP data are received by NODC on magnetic tape. NGSDC also receives analog data from OCSEAP investigators as well as digital data. The magnetic tapes are checked against the Data Documentation Forms for format and tape specifications and accompanying scientific content and data processing procedures, NODC accession numbers are assigned and dumps of the tapes are completed for the pre-processing at NODC.

When all the above steps are completed, the data are forwarded to NODC processing personnel (or NGSDC where applicable) and data inventories and final processing are completed.

Final processing of many data sets are delayed where errors are indicated by the NODC check programs designed for each file type. Problems concerning these data sets are resolved by contacting the investigator or his data processor or the Project Office. In some cases a replacement tape is requested when data problems are extensive and the original tape is returned to the investigator.

DATA TRACKING SYSTEM

The OCSEAP data tracking system which has evolved from an August 1975 data processing summary and an investigator information file has been continually updated, modified and improved during this past year. The system is now more responsive to BLM and OCSEAP Program and Project Office needs. It includes new administrative information, lease areas for each data set, the final disposition of the data sets and the medium of the data sets received (digital, data reports, maps, etc.).

The preliminary version of the present data tracking system was developed and distributed to OCSEAP data management personnel for review in May 1976. An operational version was distributed to BLM and selected OCSEAP personnel in August 1976. A major revised format version was distributed in October 1976 with an increased distribution list of 25 individuals within OCSEAP and BLM. Tracking sheets were sorted by discipline, staff scientist and Project trackers as well as research units.

Distribution of the current version of the tracking system is generally on a monthly or more frequent basis to the Juneau Project Office. Distribution to other OCSEAP and BLM personnel has been changed at the suggestion of the Program Office to a quarterly basis rather than monthly to correspond with the quarterly reports submitted by other P.I.s to the Juneau Project Office.

Currently, all coding and keypunching of the data tracking system are being completed by NODC personnel in Washington. Updates are being completed on a daily basis with interim versions of the tracking system produced weekly to provide copies with all information up-to-date within the week. Updates are received on a random basis from the Project and Program Offices, Mike Crane in Anchorage and EDS processing personnel in NODC and NGSDC.

A number of products have been provided to Project and Program Officer personnel from the data tracking system, including P.I. address and telephone lists, data submission summaries, types of data being collected and data sets and ROSCOPs overdue.

A file ID system for both digital and non-digital data was recently implemented which allows OCSEAP to determine the quantity and status of various data reports, maps, and photos, as well as digital data being submitted to OCSEAP. The data tracking system is currently being more closely oriented to other NODC inventory systems by including such fields as file ID and track number in the data processing section of the tracking system.

The most recent changes requested by the Juneau Project Office and all updates received through March 15, 1977 are incorporated in the March version of the data tracking system being distributed separately to OCSEAP and BLM personnel.

DATA FORMAT DEVELOPMENT

Since April 1, 1976, twenty-two new formats or modified versions of existing formats were distributed to OCSEAP investigators and other OCSEAP personnel; some of these formats await approval by the Juneau Project Office before distribution to investigators is completed (Appendix D). In addition, individual modifications were made throughout the year to many of these same formats prior to the distribution dates listed on Appendix D. Other format modification have been verbally approved for investigator use; documentation and distribution will be completed within the next quarter.

Formats are now being distributed to a list of approximately 100 investigators and data processors. Distribution of specific formats is determined by the investigator's discipline, information available in the data tracking system and direction from the Juneau Project Office.

A copy of all codes used with OCSEAP formats was distributed to data management personnel in EDS and OCSEAP offices during the third quarter.

One-page summaries (cover sheets) for each OCSEAP format have been completed and forwarded to OCSEAP and BLM data management personnel.

DATA REQUESTS

Since April 1, 1976, a total of 48 requests for data, data products and OCSEAP data reports have been processed by EDS (NODC, NCC and NGSDC). To date, the majority of requests are by OCSEAP investigators for archival or non-OCSEAP data, as summarized below.

Requestor	Data Type	Apr-June 76	July-Sept 76	Oct-Dec 76	Jan-Mar 77	Total
BLM	OCSEAP	0	1	1	0	2
	Archival	0	1	1	0	2

Requestor	Data Type	Apr-June 76	July-Sept 76	Oct-Dec 76	Jan-Mar 77	Total
OCSEAP	OCSEAP	0	0	4	2	6
Offices	Archival	0	1	1	0	2
OCSEAP	OCSEAP	0	1	3	6	10
P.I.s	Archival	6	5	3	5	19
Non-OCSEAP	OCSEAP	0	1	5	1	7
P.I.s	Archival	NA	NA	NA	NA	NA
Totals		6	10	18	14	48

A significant number of data requests involved NCC meteorological data and NODC oceanographic data. These requests included surface weather observations and EBO3 data, U.S. Coast Guard ocean station data, Nansen casts, BT and XBT summaries and inventories, current meter summaries and plots and OCSEAP STD data inventories. Other requests involved inventories of grain size samples, OCSEAP fish, mammal, and intertidal data listings and tapes, plots and summaries of OCSEAP marine bird data, formatted data listings of selected OCSEAP data, data tracking system information and OCSEAP ice core and benthic organism data reports.

DATA CATALOG

The data tracking system is intended to provide information for both the digital portion and the non-digital data such as reports, maps, photos and remote sensing data. The file ID scheme mentioned elsewhere in this report was designed to be utilized for a data catalog.

BLM inventory plots reduced to page-size with the accompanying station location information are planned as one of the basic inputs to the catalog. The initial plots for data sets that have been final processed at NODC have been completed for most lease areas where data have been collected; incorporation of data received and in processing will be completed in the near future. Copies of these products will be forwarded to the Program Office and BLM, Anchorage this month.

It is anticipated that other information such as procedures for requesting the different types of OCSEAP data will be included in the catalog. The actual arrangement and scope of the catalog has not yet been established.

DATA PRODUCTS

EDS visits to BLM, Anchorage in December 1976 and March 1977 provided additional details concerning the types of data products required by EDS to satisfy their EIS and permit requirements. Details include chart scales and projections as well as parameters to be plotted from the OCSEAP file types. Suggested lists of products for physical oceanography, marine birds and mammals and geology are now being reviewed by the appropriate EDS personnel. A reply to the Program and Project Offices concerning these product requirements will be forthcoming.

Discussions with NOS personnel were held to discuss OCSEAP current meter products, especially software requirements and existing products available at NOS. One version of a current rose plot of selected current meter data has been developed by NODC in response to a BLM request for the Kodiak lease area. Summaries by speed and direction groups also have been completed for selected current meter stations.

Sample plots of station locations for selected file types have been produced on a scale and projection to overlay the BLM EIS charts for NEGOA, Kodiak and Lower Cook lease areas. Similar charts have been developed for the other six lease areas but base charts are not yet available from BLM for comparison with the computer plots.

Page-size plots of the same information as that submitted to BLM are also being considered for use in the data catalog. A Mercator projection could be produced on a remote terminal with a scope to permit timely access to data inventories. An Alaskan OCS chart with all lease areas outlined on the chart is being prepared for possible use in the data catalog.

A number of formatted output listings were produced at the request of the Project Office which incorporated specific information from a specific file or record type of each data set.

Plots and statistical summaries of marine bird data have been developed for an OCSEAP investigator with data submitted on file type 035, Marine Bird Colony data.

As a result of requests by BLM and other requestors for OCSEAP data in specific areas, changes in NODC processing procedures have been implemented to accommodate these needs. As part of pre-processing at NODC, data are now assigned NODC accession numbers and a file is created on disk with file type, location, and lease information included before the data are entered in the processing system.

The data tracking system has provided a number of products which have been discussed under the achievements of the data tracking system.

TAXONOMIC CODE

The revised NODC version of the taxonomic code has been completed. Copies have been distributed to OCSEAP and other OCS personnel, BLM offices, OCSEAP investigators and data processors, and other interested individuals. The new version contains over 16,000 numeric codes and is more comprehensive than earlier Alaskan codes.

Requests for taxonomic code not available in the Alaska version have been coordinated between Dr. Elaine Collins (NODC) and George Mueller (Univ. Alaska). Codes for these species are now incorporated in the NODC version of the taxonomic codes.

A newsletter concerning taxonomic code activities, the "Nomenclature Code News Note" was established in January 1976 and four issues have been distributed to date. The last issue describes the NODC version of the taxonomic codes.

Summary of Fourth Quarter (January - March 1977)
Data Base Management Activities

Data Received This Quarter

A total of 64 data sets were received this quarter through March 15, (40 in January, 11 in February and 13 in March. Sixteen data sets were final processed this quarter, two forwarded to NGSDC and two returned to the originator when replacement tapes were received. Twenty-five data sets currently are being held for processing until additional information or replacement tapes are received from the investigator or the Project Office.

The file types received are as follows:

017 - Pressure Gauge	1	
022 - STD Data	5	
023 - Fish Resource	1	
024 - Zooplankton	1	
025 - Marine Mammal Specimen	5	
027 - Marine Mammal Sighting I	1	
028 - Phytoplankton	2	
030 - Intertidal Data	5	
032 - Benthic Organisms	2	
034 - Marine Bird (Land Census)	1	
035 - Marine Bird Colony	1	
040 - Marine Bird Habitat	11	(on diskettes)
056 - Lagrangian Currents	29	(multifile tapes)
	64	

Data Reports

Thirty-three data reports were received this quarter (20 in January and 13 in February). The types of data reports included the following:

Fisheries -	3
Benthic Resources -	3
Mammals -	5
Marine Birds -	4
Ecosystems -	2
Microbial Activity -	1
Effects -	2
Ice Characteristics/Permafrost-	6
Physical Oceanography -	1
Seismic/Geology -	4
Remote Sensing -	2
	33

ROSCOPS

Thirty-two ROSCOPS were received this quarter (4 in January, 24 in February and 4 in March). ROSCOPs were received from PMEL, Oregon State, Univ. Washington, USFWS, ADF&G and NMFS.

Data Requests

Ten requests for data and data reports were received during this quarter. Eleven requests were completed including several from preceding months.

Format Development

Final drafts of Marine Mammal Sighting II (026), Feeding Flock (037), Marine Bird Habitat (040), Trace Elements (061), and Beach Profiles (072) were forwarded to the Project Office for approval. Distribution of these formats to other OCSEAP data management personnel and selected OCSEAP investigators was completed at the same time due to the urgent need for these formats.

Modification to the Grain Size Analysis (073) and Lagrangian Current measurement (056) were completed and distributed as above.

Modifications to Primary Productivity (029), Benthic Organisms (032), Marine Bird-Aircraft/Ship Census (033), and Marine Bird Colony (035) were completed and forwarded to the Project Office for approval before further distribution is completed.

Other format modifications were verbally approved for investigator use - documentation and distribution will be completed as soon as possible.

Other Fourth Quarter Activities

Meetings with NOAA telecommunication personnel have resulted in a memo to Mr. Ochinero discussing OCSEAP justification for an improved telecommunication system between Anchorage, Juneau and Washington, D.C.

An inventory system designed to answer BLM and other requests for OCSEAP data in specific areas was completed and is in operation at NODC.

A meeting with BLM, Anchorage personnel was held in March (in Anchorage) to discuss data inventories and data products available from the OCSEAP data bank.

Visits were made by Wayne Fischer and Francesca Cava to NODC to discuss data processing and data products.

A file ID scheme for identifying digital and non-digital data being collected by OCSEAP investigators and referencing this information to lease areas has been implemented. This information is incorporated in the March 1977 version of the OCSEAP data tracking system (distributed separately).

ENVIRONMENTAL DATA INDEX
(ENDEX) -RU 361

The Environmental Data Base Directory (EDBD), the principal ENDEX file, contains descriptions of historical data bases. This inventory is intended to direct scientists, managers and decision-makers to sources of environmental data. During the past year this file has grown from 5400 descriptions to 8200. Of this total, 630 data bases have been described for states bordering the Pacific. A cross-indexed computer listing of all files containing data in the OCSEAP area has been prepared and is being distributed to the OCSEAP Office, the Juneau Project Office and Mike Crane's office in Anchorage.

Efforts toward describing additional files in Alaska, British Columbia, Washington, and Oregon have recently been completed resulting in the addition of 1643 data file descriptions. These descriptions should be loaded into the retrieval system within 30 days. At that time all data descriptions pertaining to the OCSEAP areas will be pointed out for use by the project.

During the past year, NODC has answered eleven requests for data inventories in the OCSEAP area, as follows:

Environmental Data Base Directory - 5 requests
(EDBD)

Current Meter Inventory - 4 requests

Report of Observations/Samples Collected by - 1 request
Oceanographic Programs (ROSCOP)

Bottom Photograph Inventory - 1 request

ENVIRONMENTAL SCIENCE INFORMATION CENTER
(ESIC) - RU 363

A summary of the activities of the Environmental Science Information Center in support of OCSEAP for the period April, 1976 through March 31, 1977 is as follows:

a) A letter was sent in September 1976 to each OCSEAP principal investigator to inform them of the availability of OASIS services.

b) A total of 69 retrospective searches and 96 update searches were provided at a total cost of $5,549.

To date (including FY-76 and 77) a total of $14.6K has been expended to provide 243 retrospective searches and 96 update searches.

GOALS - (Next quarter)

The major goals for RU 362 for the next quarter are as follows:

A. Determine the specific features, structure and inputs to the data catalog.

B. Generate a sample data catalog with computer plots of data for both final processed and data in processing.

C. Improve the method for receiving and updating the inputs to the data tracking system.

D. Increase data processing and product development manpower to meet anticipated demands for new data products.

E. Establish a more critical review of data sets before they enter the EDS data processing system where the impact on computer costs and manpower is significant. The Project Office's categorizing of data parameters into essential data for OCSEAP, supplementary to OCSEAP and data of interest only to the investigator may help resolve this problem in determining what data should be corrected by EDS.

F. Improve understanding and communication between investigators and OCSEAP personnel concerning data format structure and proper coding of data into these formats.

G. Improve the capability for a timely response to BLM and other requestors for OCSEAP data status and data inventories.

H. Establish the feasibility of a remote terminal for data and information access to the OCSEAP data bank from Anchorage and Juneau.

I. Complete the modification of the Georgetown computer facility to permit data transmission between Anchorage and Washington via the USGS computer system.

Appendix A - Data Set Summary By File Type - April 1976 - March 1977

File Type +		Data Sets Received			
	Total	Apr-June 76	July-Sept 76	Oct-Dec 76	Jan-Mar 77
013	2	-	-	2	-
015	20	4	6	10	-
017	5	-	-	4	1
021	2	-	-	2	-
022	43	11	13	14	5
023	7	-	1	5	1
024	13	-	6	6	1
025	29	-	2	23	4
026	36	-	3	33	-
027	29	1	3	24	1
028	10	-	4	4	2
029	30	1	8	21	-
030	6	-	-	1	5
032	10	2	4	2	2
033	6	-	-	6	-
034	3	-	2	-	1
035	1	-	-	-	1
040	17	-	-	6	11
043	4	-	1	3	-
056	30	-	1	-	29
057	2	-	-	2	-
073	2	-	-	2	-
101	3	-	-	3	-
999 (non-OC-SEAP)	3	1	-	2	-
Total	313*	20	54	175	64

*Totals through February 28, 1977

+ File Types names listed in Appendix D.

APPENDIX B - Data Set Summary by Lease Area
Data Sets Received/Lease Area Codes +

File Type	Total	1	2	3	4	5	6	7	8	9
013	2	-	-	-	1	-	1	-	1	-
015	20	14	-	2	4	-	3	-	1	-
017	5	4	-	-	-	-	3	-	-	-
021	2	1	-	1	1	-	1	-	-	-
022	43	18	3	13	13	4	11	3	1	3
023	7	3	1	3	2	1	2	1	-	1
024	13	5	3	2	6	1	8	-	-	1
025	29	4	2	2	1	10	3	11	-	9
026	36	28	-	28	30	5	30	1	-	4
027	29	19	1	21	21	-	24	1	-	1
028	10	1	5	1	3	1	3	-	-	1
029	30	11	13	12	4	2	4	-	7	2
030	6	1	1	1	-	4	-	-	-	-
032	10	2	1	3	2	4	2	-	-	2
033	6	5	5	5	4	-	4	-	1	-
034	3	-	-	-	2	-	1	-	-	1
035	1	-	-	-	1	-	-	-	-	-
040	17	5	10	4	-	-	2	-	2	-
043	4	1	1	1	1	-	1	1	-	1
056	30	-	-	-	-	29	-	-	-	1
057	2	-	2	2	1	-	2	-	-	-
073	2	-	-	-	1	-	1	-	-	-
101	3	3	-	-	-	-	-	-	-	-
999	3	1			1	1	1			
TOTALS	313*									

*Totals through February 28, 1977.
NOTE: Total data sets for all lease areas will exceed total data sets received because of more than one lease area included in a data set.

+ Lease codes are as follows:

1	Northeast Gulf of Alaska
2	Lower Cook Inlet
3	Kodiak
4	St. George
5	Beaufort Sea
6	Bristol Bay
7	Norton Sound
8	Aleutians
9	Chukchi Sea

Appendix C - Data Reports Summary By Lease Area - April 1, 1976 - March 31, 1977

		Lease Area Code +									
DISCIPLINE	Total Rpts.	1	2	3	4	5	6	7	8	9	General or all areas
Birds	7	-	-	-	4	3	2	-	-	2	-
Mammals	7	2	1	1	3	2	4	3	-	2	-
Fish/Plankton/Benthos	13	4	5	4	2	1	4	-	-	-	1
Chemistry/Microbiology	12	7	4	1	5	2	5	1	-	1	-
Effects	6	1	-	1	1	1	1	-	-	-	5
Phy. Oceanography/ Microbiology	5	3	1	2	-	-	1	-	-	-	2
Geology/Geophysics	16	8	2	4	2	2	2	1	3	-	2
Ice/Permafrost	26	-	-	-	1	24	2	3	-	5	2
Remote Sensing	3	-	-	-	-	1	-	-	-	-	2
Technology Scenerio	1	-	-	-	-	1	-	-	-	-	-
Ecosystems	1	-	-	-	-	1	-	-	-	-	-
Totals	97	25	13	13	18	38	21	8	3	10	14

+ Explanation of codes listed on Appendix B.

Note: Number of reports by lease areas will exceed total number received because of reports covering more than one lease area.

Appendix D - OCSEAP Data Format Development - April 1, 1976 - March 31, 1977

File Type	Name	Current Status
001	Trace Metals in Organisms (Abbrev.)	*Completed prior to 4/1/76
013	Fish Pathology	Final draft in distribution 8/25/76
015	Current Meter	*
017	Pressure Gauge	*
021	Trace Metals	*
022	STD Data	*
023	Fish Resource Assessment	Modified format in distribution 7/7/76
024	Zooplankton II	" " " " 9/21/76
025	Mammal Specimen	" " " " 7/22/76
026	Mammal Sighting II	Final draft in distribution 2/10/77
027	Mammal Sighting I	Modified format in distribution 7/22/76
028	Phytoplankton Species	" " " " 7/28/76
029	Primary Productivity	Modified format to Project 2/28/77
030	Intertidal Data	Modified format in distribution 7/22/76
032	Benthic Organisms	Modified format to Project 2/28/77
033	Marine Bird Sighting I (Ship/Aircraft)	" " " " 2/25/77
034	Marine Bird Sighting II (Land)	*
035	Marine Bird Colony	Modified format to Project 2/22/77
036	Marine Bird-Ship Followers	*
037	Marine Bird-Feeding Flock	Final draft in distribution 1/25/77
038	Migratory Bird Seawatch	Draft copy (*)
040	Marine Bird Habitat	Final draft in distribution 2/1/77
043	Hydrocarbon I	*
056	Lagrangian Current Measurements	Modified format in distribution 1/12/77
057	Herring Spawning	Final draft in distribution 8/24/77
061	Trace Elements	Final draft to Project 3/14/77
072	Beach Profile	" " " " 3/14/77
073	Grain Size Analysis	Modified format in distribution 2/15/77
074	Geotechnical Properties	Draft copy to Project 8/20/76
075	Permafrost	" " " " 8/23/76
101	Wind Data	Final draft in distribution 8/25/76

APPENDIX E

Major Meetings/Travel * - April 1, 1976 - March 31, 1977

*Excludes Mike Crane's Meetings/Travel (RU497)

Date	Place	Personnel	Subjects
4/76	Boulder	Combellick, Grant, Crane, Audet met with Program Office Personnel	Format Development Data Tracking Data Products
4/76	Juneau, Anchorage, Fairbanks, Seattle	Combellick met with Juneau and Arctic Project Office Personnel and several OCSEAP PIs	Geological/geophysical data requirements and products
5/76	Washington, D.C.	Audet and Collins met with Krichevsky at NIH	Microbiological data file storage/retrieval
6/76	Washington, D.C.	EDS, NGSDC, OCSEAP Project and Program Office Personnel	Data tracking Data Mgmt Plan EDS FY-77 Proposals
6/76	Hanover, N.H.	Combellick met with CRREL Personnel	Data formats and data submissions
9/76	Anchorage	Audet and Fischer met with Crane, BLM, ADF&G, AEIDC, NSFWS	Data processing, Data products, Data Catalog
9/76	Juneau	Audet met with Program and Project Personnel	Data Tracking, USGS Data Submission, Data Catalog
12/76	Boulder	Law, Audet met with NGSDC, Program, and Project Personnel	Data mgm't, Data Products, Data Requests
1/77	Boulder	Combellick met with USGS Personnel	Format requirements
1/77	Rockville, MD	Audet and Crane met with NOAA Telecommunication Personnel	Improved Telecommunications
2/77	Washington, D.C.	Cava met with NODC Data Processing Personnel	Data Processing, Data Products, Data Tracking
3/77	Anchorage	Audet, Fischer and Cava met with BLM Personnel	EDS Services, Data Inventories and Products.

Annual Report

Contract No: N/A
Research Unit No: 496
Reporting Period: April 1, 1976
through March 31, 1977
Number of Pages: 4

Maintenance of Alaskan OCSEAP Surface Marine and Coastal Station Data File

Principal Investigator:

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COMM: (704) 258-2850, x266
FTS : 672-0266

March 21, 1977

I. Summary of objectives, conclusions and implications with respect to OCS oil and gas development

This task serves to maintain the data file compiled for use in the production of the "Climatic Atlas of the OCS Waters and Coastal Regions of Alaska" (RU #347) and to provide meteorological data products and services for the Alaskan area to OCSEAP PI's.

II. Introduction

The NCC has compiled and processed for RU #347 some 600,000 surface marine observations and two million (3-hourly) observations for 49 coastal stations for the OCS waters and coastal regions of Alaska. This edited data file and the statistical computer products used in preparing the atlases are being held in a separate file designated the Alaskan Waters Atlas Project (see RU #347 annual report).

Under RU #496, this file is to be maintained and used as a source to provide data products and services to OCSEAP PI's. Copies of all new data products generated to fill requests are to be added to this file. The atlases and related data set present the single most comprehensive collection available for the Alaskan area, and serves as a source for aiding in assessing the potential environmental impact of energy development in the OCS waters of Alaska.

III. Current state of knowledge

The three Alaskan atlases (to be published in 1977), its related data file, and the US Navy Marine Climatic Atlas of the World, Vol. II, North Pacific Ocean (revision to be published in 1977), represent an authoritative reference set for large scale operrational planning and research. In addition, there are numerous miscellaneous sources archived at NCC containing marine and land-based data; e.g., manuscript forms, ditigal files, statistical summaries and publications, that contain information pertinent to OCSEAP tasks. Data products and services are available on request, through the National Climatic Center, Federal Building, Asheville, NC 28801, COMM: (704) 258-2850/ext 683 or FTS: 672-0683.

IV. Study area

The area of interest covers the Alaskan waters and coastal regions within 50° - 80°N, 130° - 180°W.

V. Sources, methods and rationale of data collection

The 600,000 marine surface observations used in the Alaskan Waters were taken from the NCC's Tape Data Family 11 (TDF-11). The data were collected by ships of various registry traveling through the study area. The marine data were subjected to a thorough computer and visual quality control before processing; this included elimination of duplicate observatons and elimination or adjustment of elements detected during internal consistency and extreme value checks. The stations' data were taken from the edited digital files of NCC and the US Air Force's Environmental Technical Applications Center (Asheville, NC).

Observations for 28 additional stations and for the marine regions have been extracted from Global Weather Central's (GWC) telecommunications unedited digital data file to supplement and update the Project's primary data file. This expands the latter file from 49 to 77 coastal stations and from 600K to 700K marine observations. Also produced from the GWC data is a computer inventory that lists the number of observations by month-year for each of the stations and MSQ (10° square) marine areas. An inventory of hourly and daily digital data is being prepared for all stations held in several tape files at NCC.

VI. Results

Data products and services provided to OCSEAP PI's include statistical summaries to support the Tanker Trials through Prince William Sound to Valdez Harbor to be held in April 1977. This comprehensive set of data products includes tables and graphs taken from the Project files for Middleton Island and Cordova and adjacent marine area and isopleth charts for the Gulf of Alaska, together with new summaries produced for Valdez and Cape Hinchinbrook. There have also been numerous lesser requests for copies of digital data and statistical summaries for select station and marine areas of Alaska.

VII. Discussion

Work on RU #496 for FY-77 has been purposely delayed because of priority work on RU #347 and the delay in receipt until December 1976, of FY-77 OCSEAP funding to NCC. This money reflected a reduction in funding for this fiscal year from $50K to $25K. Of this, only 25% were made available through January; the task was also modified to use the funds as needed to provide free data services to requests from OCSEAP PI's. As of March 15, 1977, $6K of the budgeted $25K have been expended; of this, $5K were used to provide data services for the Tanker Trials.

VIII. Conclusions

The Alaskan data file has proven to be of significant value to OCSEAP PI's and to others. Its content and availability have permitted NCC to quickly respond, at a minimal cost, to OCSEAP-related requests such as the important Tanker Trials task, and to the increasing numbers of requests from oil companies and universities.

IX. Needs for further study

It is important that the digital files of the Alaskan Waters Atlas Project be maintained and updated to provide comprehensive data products and services quickly. It is recommended that this digital file be expanded to include the marine and coastal station data held in various manuscript forms and digital formats. NCC plans to provide a FY-78 proposal to include such recommendations.

X. Not applicable

ANNUAL REPORT

Research Unit	497 and 370
Reporting Period	1 October 1976 31 March 1977
Pages	19

Alaskan Data Processing Facility

Environmental Data Service

Edgar F. Law

31 March 1977

I. SUMMARY

The support for primary data processing in Alaska has been assigned to two research units: RU 370 with the University of Alaska and RU 497 with the Environmental Data Service, NOAA (EDS). Under the agreement, the University of Alaska will staff a keyentry facility (RU 370) and Environmental Data Service (RU 497) will monitor the data flow through the facility. EDS may be assigned other specific data management duties by the OCSEAP Data Management group. This report covers the period 1 October 1976, to 30 March 1977. Because both research units are so closely linked, this report combines both research units functionally as a single entity.

The activities and tasks center on primary processing of digital data; ie, keyentry and data format verification. A summary of data coding forms and digital data activity is noted below.

Data Coding Forms Received	170 sets
Data Coding Forms Completed	111 sets
Digital Data Received 1 October 1976,to present	103 sets
Digital Data Received for correction only	56 sets
Digital Data Corrected	57 sets
Management Information Files Operational	3 files

II. INTRODUCTION

During the 1975 and 1976 field season, large quantities of environmental information were collected and an equally large volume of digital data was generated. The rate in which the data were increasing exhausted the investigators ability to process digital data.

Because of the short time required to deliver products to the Bureau of Land Management, further delay was not possible. An Alaskan facility for processing digital data was needed to handle the increasing volume of environmental data and to provide a local facility to monitor data errors.

To provide the primary processing service, this facility supports the OCSEA Program in three specific areas:

1. It provides support to OCSEAP investigators in keypunching coded data.
2. Provides support to the OCSEAP Data Base by checking the format integrity of data submitted by the investigator.
3. Provides technical support to the OCSEAP management.

A. General Nature and Scope of Study

These research units resulted from an OCSEAP management decision to provide data management support to the investigators and the OCSEAP management. The specific tasks are outlined below in three catagories: 1 - Investigator Support, 2 - Data Base Support and 3 - Management Support.

B. Specific Objectives

1. Investigator Support

a. Establish a keyentry facility to reduce the backlog of digital data.
b. Provide a keyentry facility for those investigators without such a facility.
c. Advise on technical matters such as coding requirements, keypunching aids, field form design, data checking aids and documentation requirements.
d. Advise on data analysis as to products and services.

2. Data Base Support

a. Routinely check data received for format integrity.
b. Provide a facility for correcting data errors discovered by investigators.
c. Review documentation of data.

3. Management Support

a. Design and implement management information files on IBM 3741.
b. Advise OCSEAP management on telecommunications, management information system design and operation in terms of interfacing with existing capabilities and systems.
c. Advise OCSEAP data management group on technical matters such as format modifications.

C. Relevance to Problems of Petroleum Development.

With respect to problems of petroleum development, overall timing of deliverable products to the Bureau of Land Management depends heavily on a fast and efficient flow of high quality data. These research units concentrate on the early input phases of that data flow. Close coordination with the OCSEAP Data Management group and the OCSEAP Data Base defines current priorities and agreements with the Bureau of Land Management. These research units in no way replace activities or responsibilities of the OCSEAP Data Base at the National Oceanographic Data Center (NODC). See RU 362.

III. CURRENT STATE OF KNOWLEDGE

The emphasis presently is reducing the backlog of unprocessed digital data. The goal is to improve the flow of data from the investigator to the OCSEA Program. Data are being keyentered both "in house" and by commercial firms to expedite this process.

To assist the investigators in certifying the accuracy of the processed data, plans are being made to write user summaries appropriate for that discipline.

IV. STUDY AREA

Environmental data from all lease areas are processed by this activity.

V. SOURCES, METHODS AND RATIONALE OF DATA COLLECTION.

Not applicable.

VI. RESULTS.

The results of this research unit are data sets that are checked, corrected or keypunched. Less tangible results are improved data flow, more effective records of data collected and a more sophisticated management information system. These three catagories - Principal Investigator support, Data Base support and OCSEAP Management support - can be divided in terms of specific activities.

The support for investigators centers on keyentry of coding forms and on correcting errors discovered by the investigators. For the period 1 October 1976, to 15 March 1977, 170 data sets have been received in the form of coding sheets. To date, 111 data sets have been keyentered. Data sets have been corrected for Research Units 230, 232, 3, 330 229 and 243. These total 56 sets.

In support of the OCSEAP Data Base, a total of 47 data sets have been received for checking since 1 October 1976. One data set has been corrected after reviewing the format integrity.

A management information system (MIS) has been planned for the OCSEA Program that integrates information from Fairbanks, Juneau, Boulder and Washington, D. C. Preliminary design of local file systems has begun. In Anchorage, management information files have been designed to record and distribute information on the receipt and status of data and coding forms. The tables attached to this report were generated by the Anchorage management information file system. A similiar system may be installed in the Juneau Project Office. If the system is installed in Juneau, a new task, developing files and operating manuals,will begin. Currently, three files are active in Anchorage.

VII. DISCUSSION

Each phase of data processing requires a unique level and kind of skill but all phases require a careful, patient attention to detail. The input phases were established as investigator responsibilities and included coding, keypunching, checking and documenting. To help the investigators, the OCSEA Program has established this facility to assist in keypunching. In no way was there any intention to absolve the investigators responsibility for the data. To assist the investigator in coding and checking data, this facility can design field forms and advise on data checking methods. The keyentry of environmental data is controlled only in terms of format integrity and coding adequacy. A primary function of this facility will be keyentry but the limitations are noted above. Table I in the appendix lists the data sets received for keyentry. Data sets keyentered are listed in Table II.

Another service available is the correcting of errors discovered by the investigators. The design of the machines allows efficient and effective procedures to correct errors. Table III lists the data sets received for correction.

To assist the data base, some OCSEAP data is reviewed in Anchorage before delivery to Washington, D. C. The data sets received from 1 October 1976, to present are listed in Table IV.

The management information system (MIS) for the OCSEA Program is an aggressive project and design criteria has been established. Major segments of information for the system will be generated in Juneau. The files can be incorporated into a computer compatible system in Juneau and interfaced to the Boulder system. The system operating currently in Anchorage has many attractive advantages and a similar system may be installed in the Juneau Project Office.

These research units could assist in the documenting of operating instructions or in designing files.

VIII. CONCLUSIONS

A timely and necessary service is provided by this research unit to investigators, to the data base and to the OCSEAP management.

IX. NEEDS FOR FUTURE STUDY

New information exchange requirements may come to fruition by 1 October 1977, as the Bureau of Land Management, OCSEAP or investigators demand a faster turn around time for products. To speed the delivery of data products, telecommunication capabilities will be necessary to handle the volume and volatility of the data. As the data backlogs are deminished and a steady-state is reached in "real-time" keyentry, new tasks more complex will replace earlier efforts.

Because an Alaskan facility is vital to the data processing needs of the OCSEAP, a keyentry and data control facility will continue to provide a timely, efficient service to the investigators, Data Base and management.

X. SUMMARY OF FOURTH QUARTER OPERATIONS

1. Ship or Laboratory Activities

a. Ship or field trip schedule

Field activities are limited to meetings with investigators or OCSEAP management personnel. Travel itineraries are listed below.

Travel - RU - 497

Dates	Location
1. 1 October 1976	Palmer
2. 13 October 1976	Fairbanks
3. 17 October 1976	Juneau
4. 24-30 October 1976	Denver
5. 11 November 1976	Fairbanks

6. 14-16 November 1976	Los Angeles
7. 19 November 1976	Fairbanks
8. 21-22 November 1976	Juneau
9. 1 December 1976	Fairbanks
10. 5 December-12 January 1977	Washington, D. C. Asheville, N. C. Columbia, S. C. Bar Harbor, Me. Providence, R. I. Seattle, Juneau
11. 1 February 1977	Fairbanks
12. 25 February 1977	Fairbanks
13. 28 February - 4 March 1977	Irvine, San Francisco and Juneau.

2. Scientific Party

Staff for the keyentry facility and OCSEAP support are listed below in addition to the job classification and affiliation.

Michael Crane	Environmental Data Service Physical Scientist
Joan Grant	University of Alaska Data Transcriber
Wanda McClure	University of Alaska Data Transcriber
Richard Paulson	University of Alaska Data Transcriber
James Donally	University of Alaska Data Processing Assistant
Virginia Holsapple	University of Alaska Secretary

3. Methods

Not Applicable

4. Sample Localities/Ship or Aircraft Tracklines.

Not Applicable

5. Data Collected or Analyzed

The tables attached contain the activities related to data coding forms or digital data received from investigators. Please refer to section VII, Discussion, for Details.

6. Milestones Chart and Data Submission Schedules

The milestones will be separated into each category and further subdivided into specific tasks within that category. Category number one is support to investigators. Category number two is support to the Data Base and category number three is support to OCSEAP management. The percentage of effort will be noted under each tasks.

MILESTONES

	March 31	June 30	Sept 30	Dec 31	Feb 28
1	Complete Data Backlog Data from FY 75, FY 76 75%				
1		Keyenter "real time", FY 77 Data 50%			
1	Design Field Forms, Etc 2%				
2	Correct Data 17%				
2		Check Data 25%			
2		Design Data Quality Control Procedures & Methods 15%			
3	Design 3741 files for Anchorage & Juneau 6%				
3		Implement New Management Technical Support Systems 10%			

B. Problems Encountered/Recommended Changes.

The exchange of information will become more complicated and the larger volumes of information will need faster delivery.

Action: Recommend a telecommunication network of management information be established for the OCSEA Program.

C. Estimate of Funds Expended

RU 497	Salaries	½ of total	=	16k
	Indirect	½ of total	=	5k
	Travel		=	5k
RU 370	Submitted under separate University report.			

TABLE I CODING FORMS RECEIVED FOR KEY ENTRY

RU	NAME	FILE TYPE	FILE IDENT	BATCH NUMBER	DATE RECEIVED YY MM DD
337	LENSINK	033	FW6021	29	76-12-14
337	LENSINK	033	FW6008	30	76-12-14
337	LENSINK	033	FW6050	30	76-12-14
337	LENSINK	033	FW6051	31	76-12-14
337	LENSINK	033	FW5016	32	76-12-14
337	LENSINK	033	FW5016	33	76-12-14
337	LENSINK	033	FW5010	34	76-12-23
337	LENSINK	033	FW5012	35	76-12-23
337	LENSINK	033	FW5014	36	76-12-23
337	LENSINK	033	FW5015	37	76-12-23
338	BARTONEK	035	FW6063	38	76-12-23
337	LENSINK	033	FW5020	39	76-12-23
337	LENSINK	033	FW5021	40	76-12-23
337	LENSINK	033	FW5025	41	76-12-23
337	LENSINK	033	FW5026	42	76-12-23
337	LENSINK	033	FW5027	43	76-12-23
337	LENSINK	033	FW5029	44	76-12-23
337	LENSINK	033	FW5031	45	76-12-23
337	LENSINK	033	FW5033	46	76-12-23
337	LENSINK	033	FW5034	47	76-12-23
337	LENSINK	033	FW5035	48	76-12-23
337	LENSINK	033	FW6018	49	76-12-23
337	LENSINK	033	FW6068	50	76-12-23
337	LENSINK	033	FW6066	51	77-01-31
337	LENSINK	033	FW6067	52	77-01-31
337	LENSINK	033	FW6077	53	77-01-31
337	LENSINK	033	FW6078	54	77-01-31
337	LENSINK	033	FW6085	55	77-01-31
337	LENSINK	033	FW6028	56	77-01-31
337	LENSINK	033	FW6025	57	77-01-31
337	LENSINK	033	FW6026	58	77-01-31
337	LENSINK	033	FW6027	59	77-01-31
337	LENSINK	033	FW6074	60	77-01-31
337	LENSINK	033	FW6070	61	77-01-31
337	LENSINK	033	FW6095	62	77-01-31
337	LENSINK	033	FW6064	63	77-01-31
337	LENSINK	033	FW6089	64	77-01-31
337	LENSINK	033	FW6094	65	77-01-31
337	LENSINK	033	FW6088	66	77-01-31
337	LENSINK	033	FW6029	67	77-01-31
330	DIVOKY	033	2PD976		77-01-03
330	DIVOKY	035	3C0676		77-01-03
330	DIVOKY	033	2CL676		77-01-03
330	DIVOKY	035	3C0676		77-01-03
330	DIVOKY	033	2GL976		77-01-03
330	DIVOKY	033	2GLA76		76-12-07

330	DIVOKY	033	2BI776		76-12-07
083	HUNT	033	UCI501		76-12-07
330	DIVOKY	033	3GL976		76-12-07
337	LENSINK	033	FW5011	22	76-12-14
337	LENSINK	033	FW5008	23	76-12-14
337	LENSINK	033	FW6083	24	76-12-14
337	LENSINK	033	FW6052	25	76-12-14
337	LENSINK	033	FW6019	26	76-12-14
337	LENSINK	033	FW6019	27	76-12-14
337	LENSINK	033	FW6057	28	76-12-14
330	DIVOKY	033	2BW076		77-01-03
330	DIVOKY	033	2KL676	1	77-01-03
330	DIVOKY	033	2KL676	2	77-01-03
330	DIVOKY	033	2KL776		77-01-03
330	DIVOKY	033	2BW776		77-01-03
330	DIVOKY	033	3PP776		77-01-03
330	DIVOKY	033	2WR676		77-01-03
330	DIVOKY	033	2IC676		77-01-03
330	DIVOKY	033	2WR976		77-01-03
330	DIVOKY	033	2UP776		77-01-03
330	DIVOKY	033	2CB776		77-01-03
330	DIVOKY	033	2CL976		77-01-03
330	DIVOKY	033	2IC976		77-01-03
330	DIVOKY	033	2IC876		77-01-03
330	DIVOKY	033	2PD776		77-01-03
330	DIVOKY	033	3A1976		77-01-03
330	DIVOKY	033	3A2976		77-01-03
330	DIVOKY	033	3A3976		76-12-07
330	DIVOKY	033	3A1A76		77-01-03
330	DIVOKY	033	3A2A76		77-01-03
330	DIVOKY	033	2A3976		77-01-03
330	DIVOKY	033	2A4976		77-01-03
330	DIVOKY	033	2A1A76		77-01-03
330	DIVOKY	033	2A1B76		77-01-03
330	DIVOKY	033	3A1676		77-01-03
330	DIVOKY	033	3A2676		77-01-03
330	DIVOKY	033	3A3676		77-01-03
330	DIVOKY	033	3A2776		77-01-03
330	DIVOKY	033	3A3776		77-01-03
330	DIVOKY	033	3A4776		77-01-03
330	DIVOKY	033	3A5776		77-01-03
330	DIVOKY	033	3A6776		77-01-03
330	DIVOKY	033	3A1876		77-01-03
330	DIVOKY	033	3A2876		77-01-03
330	DIVOKY	033	3AL876		77-02-02
330	DIVOKY	033	2BW576		77-02-02
337	LENSINK	033	FW6010	68	77-02-08
337	LENSINK	033	FW6012	69	77-02-08
337	LENSINK	033	FW5036	70	77-02-08
337	LENSINK	033	FW5037	71	77-02-08
330	DIVOKY	033	3DK676		77-01-03
330	DIVOKY	033	3PB876		77-01-03
330	DIVOKY	033	3BR776		77-01-03

330	DIVOKY	033	3PI776		77-01-03
330	DIVOKY	033	3BB776		77-01-03
330	DIVOKY	033	3PP876		77-01-03
330	DIVOKY	033	3OK976		77-01-03
330	DIVOKY	033	2GL876	1	76-12-07
330	DIVOKY	033	2GL876	2	76-12-07
330	DIVOKY	033	2CL876		76-12-07
330	DIVOKY	033	2WR776		77-01-03
330	DIVOKY	033	3CO876		77-01-03
330	DIVOKY	033	3CO776	1	77-01-03
330	DIVOKY	033	3CO776	2	77-01-03
330	DIVOKY	033	3OK776		77-01-03
330	DIVOKY	033	3CO776	3	77-01-03
330	DIVOKY	033	3BL676		77-01-03
330	DIVOKY	033	2PD676		77-01-03
330	DIVOKY	033	2A7676		77-01-03
330	DIVOKY	033	2A1776		77-01-03
330	DIVOKY	033	2A2776		77-01-03
330	DIVOKY	033	2A3776		77-01-03
330	DIVOKY	033	2A4776		77-01-03
330	DIVOKY	033	2A1876		77-01-03
330	DIVOKY	033	2A2876		77-01-03
330	DIVOKY	033	2A1976		77-01-03
330	DIVOKY	033	2A2976		77-01-03
330	DIVOKY	033	2A1576		77-01-24
330	DIVOKY	033	2A2576		77-01-24
330	DIVOKY	033	2A1676		77-01-24
330	DIVOKY	033	2A2676		77-01-24
330	DIVOKY	033	2A3676		77-01-24
330	DIVOKY	033	2A5676		77-01-24
330	DIVOKY	033	2A6676		77-01-24
330	DIVOKY	033	3CR776		77-01-24
337	LENSINK	038	FW6091	73	77-02-17
337	LENSINK	033	FW6092	72	77-02-17
337	LENSINK	038	FW6076	74	77-02-17
337	LENSINK	038	FW6022	76	77-02-17
338	BARTONEK	035	FW6022	76	77-02-17
337	LENSINK	038	FW6020	75	77-02-17
337	LENSINK	038	FW6056	77	77-02-18
337	LENSINK	033	FW6087	78	77-02-23
337	LENSINK	033	FW6084	79	77-02-23
481	HALL	027	FW6079		77-02-24
481	HALL	027	FW6022		77-02-24
481	HALL	027	FW6068		77-02-24
83	HUNT	033	UCI601		77-03-07
330	DIVOKY	033	2DI976	1	77-03-07
330	DIVOKY	033	2GL875	1	77-03-07
330	DIVOKY	033	2GL875	2	77-03-07
330	DIVOKY	033	2DI976	2	77-03-07
330	DIVOKY	033	2GL875	3	77-03-07
83	HUNT	035	UCISP6		77-03-07
83	HUNT	035	UCIS06		77-03-07
338	BARTONEK	035	FW6054	82	77-03-07
338	BARTONEK	035	FW6024	80	77-03-07

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338  BARTONEK       035  FW6059   81    77-03-07
338  BARTONEK       038  FW6059   81    77-03-07
337  SENNER         057  FW6080   83    77-03-09
338  BARTONEK       035  FW6061   84    77-03-09
338  BARTONEK       035  FW6060   85    77-03-09
338  BARTONEK       035  FW6023   86    77-03-09
338  BARTONEK       035  FW6053   87    77-03-09
 27  LEES           030  OKENA1         77-03-09
 27  LEES           030  OKENA2         77-03-09
 27  LEES           030  OKENA3         77-03-09
 27  LEES           030  OKENA4         77-03-09
 27  LEES           023  OKENA1         77-03-09
 27  LEES           023  OKENA2         77-03-09
 27  LEES           023  OKENA3         77-03-09
 27  LEES           023  OKENA4         77-03-09
 83  HUNT           035  UCISP5         77-03-07
 83  HUNT           035  UCISG5         77-03-07
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TABLE II CODING FORMS COMPLETED

RU	NAME	FILE TYPE	FILE IDENT	BATCH NUMBER	DATE COMPLETED YY MM DD
337	LENSINK	033	FW6021	29	77-01-13
337	LENSINK	033	FW6008	30	77-01-13
337	LENSINK	033	FW6050	30	77-01-14
337	LENSINK	033	FW6051	31	77-01-23
337	LENSINK	033	FW5016	32	77-01-27
337	LENSINK	033	FW5016	33	77-01-27
337	LENSINK	033	FW5010	34	77-02-09
337	LENSINK	033	FW5012	35	77-02-11
337	LENSINK	033	FW5014	36	77-02-15
337	LENSINK	033	FW5015	37	77-02-21
338	BARTONEK	035	FW6063	38	77-01-21
337	LENSINK	033	FW5026	42	77-02-23
337	LENSINK	033	FW5027	43	77-02-24
337	LENSINK	033	FW5029	44	77-02-24
337	LENSINK	033	FW5031	45	77-02-25
337	LENSINK	033	FW5033	46	77-02-28
337	LENSINK	033	FW5034	47	77-03-01
337	LENSINK	033	FW5035	48	77-03-01
337	LENSINK	033	FW6018	49	77-03-10
337	LENSINK	033	FW6066	51	77-03-14
337	LENSINK	033	FW6085	55	77-03-11
337	LENSINK	033	FW6028	56	77-03-02
337	LENSINK	033	FW6025	57	77-03-03
337	LENSINK	033	FW6026	58	77-03-03
337	LENSINK	033	FW6027	59	77-03-09
330	DIVOKY	035	3C0676		77-03-04
330	DIVOKY	033	2CL676		77-03-07
330	DIVOKY	035	3C0676		77-03-14
330	DIVOKY	033	2GLA76		76-12-10
330	DIVOKY	033	2BI776		76-12-09
083	HUNT	033	UCI501		76-12-17
337	LENSINK	033	FW5011	22	76-12-22
337	LENSINK	033	FW5008	23	76-12-22
337	LENSINK	033	FW6083	24	76-12-28
337	LENSINK	033	FW6052	25	76-12-30
337	LENSINK	033	FW6019	26	77-01-05
337	LENSINK	033	FW6019	27	77-01-06
337	LENSINK	033	FW6057	28	77-01-11
330	DIVOKY	033	2BW076		77-02-16
330	DIVOKY	033	2KL676	1	77-02-16
330	DIVOKY	033	2KL676	2	77-02-16
330	DIVOKY	033	2KL776		77-02-14
330	DIVOKY	033	2BW776		77-02-08
330	DIVOKY	033	3PP776		77-02-08
330	DIVOKY	033	2WR676		77-02-08

330	DIVOKY	033	2IC676		77-02-11
330	DIVOKY	033	2WR976		77-02-08
330	DIVOKY	033	2UP776		77-02-16
330	DIVOKY	033	2CB776		77-02-11
330	DIVOKY	033	2CL976		77-03-07
330	DIVOKY	033	2IC976		77-02-11
330	DIVOKY	033	2IC876		77-02-16
330	DIVOKY	033	2PD776		77-02-16
330	DIVOKY	033	3A1976		77-02-03
330	DIVOKY	033	3A2976		77-02-08
330	DIVOKY	033	3A3976		77-02-08
330	DIVOKY	033	3A1A76		77-02-08
330	DIVOKY	033	3A2A76		77-02-08
330	DIVOKY	033	2A3976		77-01-31
330	DIVOKY	033	2A4976		77-01-31
330	DIVOKY	033	2A1A76		77-01-31
330	DIVOKY	033	2A1B76		77-01-31
330	DIVOKY	033	3A1676		77-01-31
330	DIVOKY	033	3A2676		77-01-31
330	DIVOKY	033	3A3676		77-02-03
330	DIVOKY	033	3A2776		77-02-03
330	DIVOKY	033	3A3776		77-02-03
330	DIVOKY	033	3A4776		77-02-03
330	DIVOKY	033	3A5776		77-02-03
330	DIVOKY	033	3A6776		77-02-08
330	DIVOKY	033	3A1876		77-02-03
330	DIVOKY	033	3A2876		77-02-08
330	DIVOKY	033	3OK676		77-02-14
330	DIVOKY	033	3PB876		77-02-16
330	DIVOKY	033	3BR776		77-02-11
330	DIVOKY	033	3PI776		77-03-07
330	DIVOKY	033	3BB776		77-02-16
330	DIVOKY	033	3PP876		77-02-16
330	DIVOKY	033	3OK976		77-02-16
330	DIVOKY	033	3CO876		77-03-14
330	DIVOKY	033	3CO776	1	77-02-16
330	DIVOKY	033	3CO776	2	77-03-04
330	DIVOKY	033	3OK776		77-03-07
330	DIVOKY	033	3BL676		77-03-04
330	DIVOKY	033	2PD676		77-03-07
330	DIVOKY	033	2A7676		77-01-24
330	DIVOKY	033	2A1776		77-01-24
330	DIVOKY	033	2A2776		77-01-24
330	DIVOKY	033	2A3776		77-01-24
330	DIVOKY	033	2A4776		77-01-24
330	DIVOKY	033	2A1876		77-01-24
330	DIVOKY	033	2A2876		77-01-24
330	DIVOKY	033	2A1976		77-01-31
330	DIVOKY	033	2A2976		77-01-31
330	DIVOKY	033	2A1576		77-01-24
330	DIVOKY	033	2A2576		77-01-24
330	DIVOKY	033	2A1676		77-01-24
330	DIVOKY	033	2A2676		77-01-24
330	DIVOKY	033	2A3676		77-01-24

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330  DIVOKY        033  2A5676        77-01-24
330  DIVOKY        033  2A6676        77-01-24
330  DIVOKY        033  3CR776        77-02-11
481  HALL          027  FW6079        77-03-01
481  HALL          027  FW6022        77-03-01
481  HALL          027  FW6068        77-03-01
 83  HUNT          033  UCI601        77-03-07
 27  LEES          023  OKENA1        77-03-14
 27  LEES          023  OKENA2        77-03-14
 27  LEES          023  OKENA3        77-03-14
 27  LEES          023  OKENA4        77-03-14
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TABLE III   DATA SETS RECEIVED FOR CORRECTION

RU	NAME	FILE TYPE	FILE IDENT	MEDIA	DATE CONTROLLED YY MM DD
330	DIVOKY	033	30K676	CRD	77-02-02
330	DIVOKY	033	ISR376	CRD	77-02-02
330	DIVOKY	033	ISR476	CRD	77-02-02
230	BURNS	025	776SHI	CRD	77-02-09
230	BURNS	025	876GLA	CRD	77-02-09
231	BURNS	026	676P2V	CRD	77-02-09
231	BURNS	026	676HEL	CRD	77-02-09
231	BURNS	026	75RING	CRD	77-02-09
231	BURNS	026	76CI80	CRD	77-02-09
231	BURNS	026	01T076	CRD	77-02-09
230	BURNS	025	676NOM	CRD	77-02-09
230	BURNS	025	6766AM	CRD	77-02-09
230	BURNS	025	376SAV	CRD	77-02-09
230	BURNS	025	576PTH	CRD	77-02-09
230	BURNS	025	476CLI	CRD	77-02-09
230	BURNS	025	876BAR	CRD	77-02-09
230	BURNS	025	576SUV	CRD	77-02-09
230	BURNS	025	876BTI	CRD	77-02-09
230	BURNS	025	876WAI	CRD	77-02-09
230	BURNS	025	876DIS	CRD	77-02-09
230	BURNS	025	576DIO	CRD	77-02-09
230	BURNS	025	0976MF	CRD	77-02-09
229	PITCHER	025	275PWS	CRD	77-03-04
229	PITCHER	025	W75PWS	CRD	77-03-04
229	PITCHER	025	676YAK	CRD	77-03-04
229	PITCHER	025	576MID	CRD	77-03-04
229	PITCHER	025	276KAY	CRD	77-03-04
229	PITCHER	025	576ICY	CRD	77-03-04
229	PITCHER	025	575COR	CRD	77-03-04
229	PITCHER	025	776TUG	CRD	77-03-04
229	PITCHER	025	376KEN	CRD	77-03-04
229	PITCHER	025	476KEN	CRD	77-03-04
229	PITCHER	025	276KOD	CRD	77-03-04
229	PITCHER	025	476KOD	CRD	77-03-04
229	PITCHER	025	076KOD	CRD	77-03-04
229	PITCHER	025	W76KOD	CRD	77-03-04
229	PITCHER	025	W75LIO	CRD	77-03-04
229	PITCHER	025	276LIO	CRD	77-03-04
229	PITCHER	025	376LIO	CRD	77-03-04
229	PITCHER	025	476LIO	CRD	77-03-04
229	PITCHER	025	576LIO	CRD	77-03-04
229	PITCHER	025	W76LIO	CRD	77-03-04
229	PITCHER	025	N76LIO	CRD	77-03-04
3	ARNESON	040	FG7601	DSK	77-03-10
3	ARNESON	040	FG7702	DSK	77-03-10

3	ARNESON	040	FG7605	DSK	77-03-10
3	ARNESON	040	FG7607	DSK	77-03-10
3	ARNESON	040	FG7604	DSK	77-03-10
3	ARNESON	040	FG7701	DSK	77-03-10
3	ARNESON	040	FG7612	DSK	77-03-10
3	ARNESON	040	FG7606	DSK	77-03-10
3	ARNESON	040	FG7603	DSK	77-03-10
3	ARNESON	040	FG7608	DSK	77-03-10
3	ARNESON	040	FG7610	DSK	77-03-10
3	ARNESON	040	FG7609	DSK	77-03-10
3	ARNESON	040	FG7611	DSK	77-03-10

TABLE IV TOTAL DATA SETS RECEIVED

RU	NAME	FILE TYPE	FILE IDENT	MEDIA	DATE RECEIVED YY MM DD
332	MCCAIN	013	760327	CRD	76-10-07
194	FAY	027	BFAY76	MT9	76-10-12
281	FEDER	032	000812	MT9	76-10-12
332	MCCAIN	013	760327	CRD	76-10-14
425	RUFFIO	028	760701	CRD	76-10-19
425	RUFFIO	028	760515	CRD	76-10-19
307	MUENCH	022	SU2IMS	MT9	76-11-02
307	MUENCH	022	SU1IMS	MT9	76-11-02
289	ROYER	022	814IMS	MT9	76-11-02
289	ROYER	022	MW3IMS	MT9	76-11-02
289	ROYER	022	MW4IMS	MT9	76-11-03
284	SMITH	023	075100	MT9	76-11-12
240	SCHNEIDER	027	760801	DIS	76-11-12
240	SCHNEIDER	027	760802	DIS	76-11-12
240	SCHNEIDER	027	760803	DIS	76-11-12
240	SCHNEIDER	027	760804	DIS	76-11-12
240	SCHNEIDER	027	760805	DIS	76-11-12
240	SCHNEIDER	027	760806	DIS	76-11-12
240	SCHNEIDER	027	760807	DIS	76-11-12
243	CALKIN	027	080676	DIS	76-11-12
5	FEDER	032	000817	MT9	76-11-17
291	HOSKIN	073	0CS818	MT9	76-11-17
291	HOSKIN	073	OCS808	MT9	76-11-17
332	MCCAIN	013	760327	CRD	76-11-17
425	DAMKAER	024	SU7501	CRD	76-11-17
68	MERCER	027	080576	MT9	76-11-17
14	BRAHAM	026	075761	MT9	76-11-17
67	BRAHAM	026	075761	MT9	76-11-17
69	BRAHAM	026	075761	MT9	76-11-17
425	DAMAKER	024	SU7501	CRD	76-11-23
240	SCHNEIDER	027	760801	DIS	76-11-30
240	SCHNEIDER	027	760802	DIS	76-11-30
240	SCHNEIDER	027	760803	DIS	76-11-30
240	SCHNEIDER	027	760804	DIS	76-11-30
240	SCHNEIDER	027	760805	DIS	76-11-30
240	SCHNEIDER	027	760806	DIS	76-11-30
240	SCHNEIDER	027	760807	DIS	76-11-30
425	DAMAKER	024	SU7501	CRD	76-11-26
3	ARNESON	040	FG7604	DIS	76-11-29
3	ARNESON	040	FG7606	DIS	76-11-29
3	ARNESON	040	FG7603	DIS	76-11-29
3	ARNESON	040	FG7602	DIS	76-11-29
3	ARNESON	040	FG7610	DIS	76-11-29
3	ARNESON	040	FG7608	DIS	76-11-29
330	DIVOKY	033	30K676	CRD	77-01-03

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330  DIVOKY            033  ISR376  CRD     77-01-03
330  DIVOKY            033  ISR476  CRD     77-01-03
243  CALKINS           027  080676  DIS     77-01-20
426  COONEY            024  RTCZ02  MT9     77-02-02
230  BURNS             025  776SHI  CRD     77-02-02
230  BURNS             025  876GLA  CRD     77-02-02
231  BURNS             026  676P2V  CRD     77-02-02
231  BURNS             026  676HEL  CRD     77-02-02
231  BURNS             026  75RING  CRD     77-02-02
231  BURNS             026  76CI80  CRD     77-02-02
231  BURNS             026  01T076  CRD     77-02-02
230  BURNS             025  676NOM  CRD     77-02-02
230  BURNS             025  6766AM  CRD     77-02-02
230  BURNS             025  376SAV  CRD     77-02-02
230  BURNS             025  576PTH  CRD     77-02-02
230  BURNS             025  476CLI  CRD     77-02-02
230  BURNS             025  876BAR  CRD     77-02-02
230  BURNS             025  576SUV  CRD     77-02-02
230  BURNS             025  876BTI  CRD     77-02-02
230  BURNS             025  876WAI  CRD     77-02-02
230  BURNS             025  876DIS  CRD     77-02-02
230  BURNS             025  576DIO  CRD     77-02-02
230  BURNS             025  0976MF  CRD     77-02-02
229  PITCHER           025  275PWS  CRD     77-02-25
229  PITCHER           025  W75PWS  CRD     77-02-25
229  PITCHER           025  676YAK  CRD     77-02-25
229  PITCHER           025  576MID  CRD     77-02-25
229  PITCHER           025  276KAY  CRD     77-02-25
229  PITCHER           025  576ICY  CRD     77-02-25
229  PITCHER           025  575COR  CRD     77-02-25
229  PITCHER           025  776TUG  CRD     77-02-25
229  PITCHER           025  376KEN  CRD     77-02-25
229  PITCHER           025  476KEN  CRD     77-02-25
229  PITCHER           025  276KOD  CRD     77-02-25
229  PITCHER           025  476KOD  CRD     77-02-25
229  PITCHER           025  076KOD  CRD     77-02-25
229  PITCHER           025  W76KOD  CRD     77-02-25
229  PITCHER           025  W75LIO  CRD     77-02-25
229  PITCHER           025  276LIO  CRD     77-02-25
229  PITCHER           025  376LIO  CRD     77-02-25
229  PITCHER           025  476LIO  CRD     77-02-25
229  PITCHER           025  576LIO  CRD     77-02-25
229  PITCHER           025  W76LIO  CRD     77-02-25
229  PITCHER           025  N76LIO  CRD     77-02-25
337  LENSINK           033  FW6068  LST     77-03-04
  3  ARNESON           040  FG7601  DSK     77-03-08
  3  ARNESON           040  FG7702  DSK     77-03-08
  3  ARNESON           040  FG7605  DSK     77-03-08
  3  ARNESON           040  FG7607  DSK     77-03-08
  3  ARNESON           040  FG7604  DSK     77-03-08
  3  ARNESON           040  FG7701  DSK     77-03-08
  3  ARNESON           040  FG7612  DSK     77-03-08
  3  ARNESON           040  FG7606  DSK     77-03-08
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3   ARNESON           040   FG7603   DSK      77-03-08
3   ARNESON           040   FG7608   DSK      77-03-08
3   ARNESON           040   FG7610   DSK      77-03-08
3   ARNESON           040   FG7609   DSK      77-03-08
3   ARNESON           040   FG7611   DSK      77-03-08
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ANNUAL REPORT

A GEOGRAPHIC BASED INFORMATION MANAGEMENT SYSTEM FOR PERMAFROST IN THE BEAUFORT AND CHUKCHI SEAS.

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CONTENT OF ANNUAL REPORT AND "ANALYSIS OF THE SOVIET LITERATURE ON SUBMARINE PERMAFROST"

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* Chapters included in Annual Report

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* Chapters included in Annual Report

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A GEOGRAPHIC BASED INFORMATION MANAGEMENT SYSTEM FOR PERMAFROST IN THE BEAUFORT AND CHUKCHI SEAS.

I. Task Objectives

Experience obtained in the terrestrial environment has indicated the necessity for careful consideration of permafrost during OCS oil and gas development activities. The consequences of errors in planning, or design of facilities are greater in offshore complicated conditions than on land in terms of loss of human life, environmental damage, time and costs. But site-specific information on offshore permafrost from seismic or drilling methods cannot be obtained for all locations on the continental shelf. In order to meet the need for predictive information on the potential distribution and characteristics of offshore permafrost, a modeling approach must be used, drawing on all existing data, particularly locations with intensive measurements.

The first principal objective of this work is to develop a computerized system which will aid in predicting the distribution and characteristics of offshore permafrost. A special computerized system should divide the offshore territory into areas which are suitable or unsuitable for relict permafrost. Computer-based mapping of the distribution, thickness and character in modern offshore conditions will be the main part of the program.

The approach to solving this problem involves the gathering and study of all the source data about direct and indirect indicators of permafrost in the given area (depth, temperature and salinity of water, topography, bottom deposits, ice conditions, etc.)

The second objective of this work is to undertake a comprehensive review and analysis of past and current Soviet literature on subsea permafrost and related coastal processes, and where appropriate, translate selected materials for general dissemination. The available materials relate to problems of the submarine permafrost origin and development such as Quaternary Arctic history, especially Quaternary transgressions and regressions in Eurasiatic arctic shelf should be summarized and evaluated with respect to their significance.

II. Summary of Results

According to the first objective connected with the data management system, all existing data on depth, temperature and salinity of the Beaufort and Chukchi Seas shelf have been gathered. Some of the data are on magnetic tapes. It makes it possible to begin to compile the source data maps as a second step of Data Management System development.

According to another objective of the work an in-depth search of the Soviet literature has been performed and the bibliography has been compiled. We have included this bibliography and the primary part of analysis of the Soviet data and results in subsea permafrost study in this annual report.

III. Submarine Permafrost on Arctic Shelf of Eurasia (Data and Ideas Analysis and Bibliography)

A. Introduction

In view of the prospective geological exploration and commercial exploitation of oil and other-useful mineral deposits as well as the construction of hydraulic engineering structure in the shelf zone of the arctic seas and particularly its shallow-water coastal area, the comprehensive analysis of the submarine permafrost data on the Soviet arctic seas shelf is acquiring more and more importance.

The development of submarine permafrost research in Alaska shelf has much to gain from the Eurasiatic arctic shelf investigations. The early and steady northerly settlement of the USSR Arctic coast, development of the "Northern Marine Road" and shelf mineral resourses research created a growing interest in the properties of subsea permafrost and their adverse effect on construction. Expeditions to study subsea permafrost occurrences, made as early as the beginning of this century, had provided a steady, and centralized accumulation of experience and data. In 1930 the USSR, then promulgating decrees for the further settlement of sparsely populated north and east, established the first formal agency to assemble data and further permafrost investigations, the Commission for the Study of Permafrost of the Academy of Sciences of the USSR.

In 1939 the commission was reorganized and became the V.A. Obruchev Institute of Frost Studies (later changed to Geocryology). As early as 1940, the Institute maintained special permafrost laboratories at Moscow and Leningrad, as well as four field stations in the North. After several more reorganizations, most permafrost work was assigned a few years ago to two institutes of the State Construction Board (the Gosstroy): (1) The Scientific Research Institute of Foundation Soils and Underground Structures (NIIOSP) and (2) the Operations and Scientific Research Institute for Engineering Site Investigations (PNIIS). A field station at Yakutsk then became a full-fledged institute for permafrost studies under the jurisdiction of the Siberian Division of the Academy of Sciences. Most other field stations are now administered from Yakutsk or by the Gosstroy. There are other institutes, such as the Building Research Institute of the Russian Soviet Federated Socialist Republic at Krasnoyarsk, and an institute at Magadan. These institutes and others like them have their own field stations.

Permafrost investigations are also being carried out very actively at some universities, particularly at the Moscow State University. There are a Department of Permafrost and a Department of Polar Regions and Geocryology in the Faculty of Geology. In addition to instructing students, the staffs of these departments study permafrost at various arctic coast locations in Siberia and their work ranks with the investigations being carried out by the State institutes. The total result is that probably about 250 people are engaged in subsea permafrost investigations in the Soviet Union.

The list of Soviet organizations taking part in the Submarine Permafrost Study in Laptev Sea, Kara Sea, East Siberian Sea, Chukchi Sea is as follows:

1. Permafrost (Geocryology) Science Institute, Novosibirck, Yakutsk, Siberian Division of the USSR Academie of Sciences.
2. Hydrographic Administrations of the USSR Navy Ministry (Different points of the Soviet Arctic Coast).
3. Scientific Research Institute of Arctic Geology of the USSR Geology Ministry, Leningrad.
4. Moscow University, Permafrost Study Department, Department of Polar Regions and Geocryology, Scientific Research Laboratory for Problems in the Mastery of the North.
5. Geological Survey of the USSR Geology Ministry (Different expeditions), Moscow, Leningrad, Norilsk, Vorkuta, Magadan, and others.
6. Leningrad Mining Institute, Department of Marine Geology, Department of Hydrogeology and Engineering Geology.
7. Leningrad University, Geological Department.
8. State Construction Board (The GOSSTROY) Scientific. Research Institute of Foundation Soils and Underground Structures (NIIOSP) and the Operations and Scientific Research Institute for Engineering Site Investigations (PNIIS). Moscow, Leningrad, Vorkuta, Magadan, and others.
9. Northeastern Regional Scientific-Research Institute (SVKNII), Magadan.
10. Far Eastern Scientific Center (DVNTS), AS USSR, Magadan, Vladivostok.

Study of the Russian literature on submarine permafrost gives the possibility to compile the Bibliography which includes about 413 publications connected with the research and theory of submarine permafrost and the practical applications of the results of the study of the properties of the frozen deposits. In this bibliography there are 55 titles from CRREL Preliminary Bibliography and 100 from Felix Are's Bibliography sent from USSR to CRREL. All these publications demonstrated the complex nature of the cryogenic shelf formations and studied several regional features of their formation, structure and distribution. However, many aspects of this theoretically and practically important problem have either not yet been solved or are still being discussed. For example, the concepts of the thermal state and structure of submarine permafrost are not sufficiently clear, the thermodynamics aspects of the conditions for the formation, preservation and destruction of cryogenic formations on the shelf have not been explained, seasonal underwater cryogenic formations and their dynamics have been studied very little, there is little information on the physical and mechanical properties of these deposits and changes in them depending on temperature, humidity and ice conditions, the terminology has not been put in good order, methodological principle for investigating and mapping these strata have not been worked out, and so forth. All the literature may be divided on 8 parts reflecting the main aspects of submarine permafrost study in the Soviet Union: (1) Regional distribution and characteristics, composition and structure, (2) Genesis, history, paleographical conditions (changing of the sea level, regressions and transgressions, pleistocene and recetn tectonics, paleoclimatic data). (3) Geological and geomorphological environments, thermal erosion, coastal dynamics, arctic shoreline processes, shelf bottom relief and deposits, the ice processes in the coastal zone connected with the bottom freezing. (4) Hydrological peculiarities (influence of the river flow, thermal and chemical characteristics of the sea water, currents). (5) Physics, physical chemistry, mechanics, thermal processes and methods of their study, including mathematical simulation. (6) Engineering geology and principles of construction. (7) Surveying and predicting. (8) General problems connected with submarine permafrost development in the polar regions.

B. Division of the bibliography according to the different aspects of submarine permafrost study (Numbers correspond to the numbers of publications)

Regional distribution and characteristics, composition and structure; map on figure 1:
44, 62, 103, 110, 111, 124, 147, 150, 159, 235, 236, 237, 238, 239, 251, 252, 265, 267, 268, 361, 363, 405.

Genesis, history, paleogeographical conditions (changing of the sea level, regressions and transgressions, pleistocene and recent tectonics paleoclimatic data); map on figure 2:
5, 18, 19, 20, 12, 21, 25, 30, 37, 38, 39, 41, 43, 45, 46, 48, 51, 53, 59, 61, 64, 66, 72, 90, 92, 93, 104, 113, 114, 118, 130, 131, 133, 134, 135, 140, 143, 146, 148, 151, 152, 153, 154, 155, 156, 157, 158, 163, 166, 173, 176, 177, 192, 193, 194, 199, 22, 200, 202, 203, 204, 205, 213, 216, 273, 276, 297, 298, 309, 310, 332, 335, 345, 347, 349, 350, 351, 367, 376, 378, 380, 381, 386, 394, 398, 412.

Geological and geomorphological environments, thermal erosion, coastal dynamics, arctic shoreline processes, shelf bottom relief and deposits, the ice processes in the coastal zone connected with the bottom freezing; map on figure 3, 4:
4, 11, 12, 13, 15, 16, 17, 40, 47, 49, 50, 52, 69, 71, 74, 81, 84, 87, 88, 89, 106, 107, 108, 109, 117, 121, 126, 128,

136, 137, 141, 160, 168, 189, 190, 191, 195, 197, 214, 215, 223, 228, 229, 246, 247, 250, 256, 258, 261, 262, 279, 288, 283, 284, 285, 286, 287, 290, 295, 313, 314, 315, 317, 319, 320, 321, 331, 334, 335, 351, 352, 353, 375, 382, 385, 393, 399, 401.

Hydrological peculiarities (influence of the river flow, thermal and chemical characteristics of the sea water, currents): 8, 9, 10, 83, 96, 105, 129, 167, 188, 225, 242, 243, 244, 245, 260, 266, 269, 321, 336, 340, 391, 392, 400, 406, 407.

Physics, physical chemistry, mechanics, thermal processes and methods of their study, including mathematical simulation: 6, 7, 14, 26, 28, 29, 31, 32, 33, 34, 54, 55, 58, 76, 77, 78, 80, 82, 100, 125, 132, 142, 144, 145, 149, 180, 182, 187, 230, 231, 234, 235, 254, 270, 274, 282, 285, 295, 300, 301, 307, 355, 360, 372, 383, 402.

Engineering geology and principles of construction: 56, 57, 86, 94, 97, 120, 164, 172, 175, 184, 186, 264, 275, 288, 344, 366, 377.

Surveying and predicting: 35, 36, 174, 185, 233, 339, 341, 343, 348, 354, 370, 371, 388.

General problems connected with submarine permafrost development in the polar regions: 1, 2, 23, 24, 33, 63, 64, 65, 67, 68, 70, 73, 75, 85, 91, 95, 98, 101, 112, 115, 116, 122, 123, 127, 138, 139, 161, 162, 165, 169, 170, 171, 178, 179, 181, 183, 196, 198, 207, 208, 209, 210, 211, 217, 218, 219, 220, 221, 222, 224, 226, 227, 232, 240, 241, 248, 249, 253, 254, 257, 263, 271, 272, 277, 278, 280, 281, 291, 292, 293, 294, 296, 302, 303, 304, 305, 306, 308, 312, 316, 318, 323, 324, 327, 328, 329, 330, 333, 337, 338, 342, 346, 357, 358, 359, 360, 365, 368, 373, 374, 377, 379, 384, 385, 390, 395, 396, 397, 403, 404, 408, 409, 410, 411.

These eight aspects will correspond to eight chapters of our "Analysis..."

C. Submarine permafrost regional distribution, composition and structure.

In this chapter we are considering the following 5 questions, the first two of them in this Annual Report.

1. Thickness of the rock zone with subzero temperature on the Eurasia Arctic coast.
2. Data on submarine permafrost extension in Laptev and East Siberian Seas.

3. Depth and thickness.

4. Composition and structure.

5. Thermal regime.

1. Thickness of the rock zone with subzero temperatures on the Eurasia Arctic coast:

Fig. 5 shows the points of the geothermal observation. Tables 1, 2 and 3 give the temperature of permanently frozen ground in some of these points according to Grigor'iev 1966 (110). Tables 4, 5 and 6 give the geothermal gradients based on temperature observations made in Arctic coastal zone according to Oberman and Kakunov, 1973 (252). Using the geothermal gradients of the 250 - 1000 m interval and hydrogeological data (salinity and temperature of "Pegi" and "Kriopegi"), these authors made a conclusion that zero isotherm in Laptev Sea coastal zone have to be on 900 - 1000 m (Kojevnikov Bay and Chay Tumus), in Kara Sea on 500 - 900 m (Ust Port and Amderma). Later new boreholes have reached the bottom of rocks with subzero temperature in some of these coastal areas on corresponding depth.

2. Data on submarine permafrost extension in Laptev and East Siberian Sea:

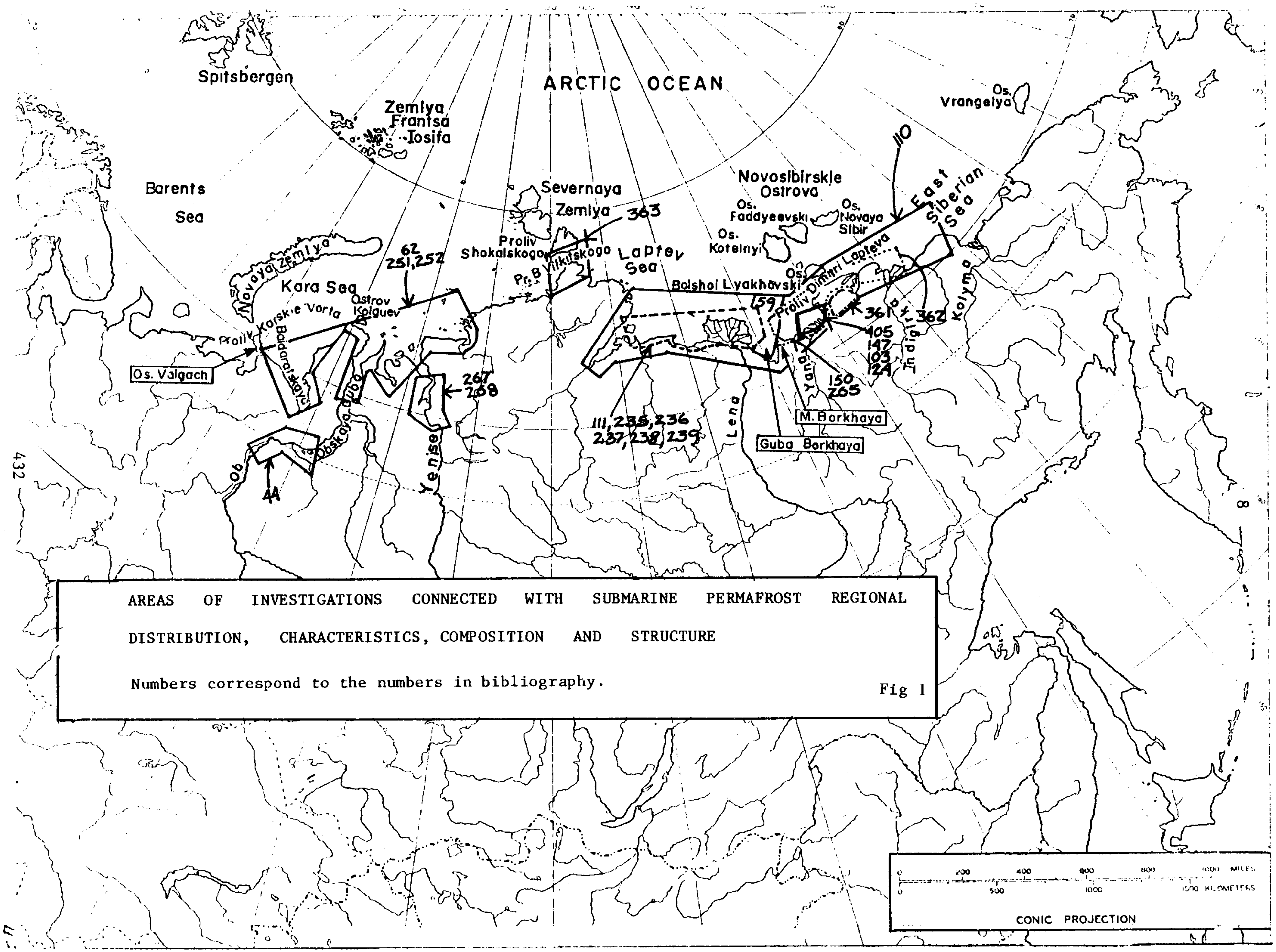
Direct Data. Permanently frozen deposits were discovered in Laptev Sea at a maximal distance about 26 km from the shore near mouth of Yana River (according to Grigor'iev, 1966 (110); Ivanov, 1969 (124) and in Dimitri Laptev Strait at a distance 25-35 km (according to Molochushkin, 1973 (239)). Fig. 6, Table 7, Fig. 7 and 8 show the results of drilling and observations in these areas.

In East Siberian Sea perennially frozen ground was met at a maximal distance about 18 km from the shore in the region of beach area at the mouth of the Indigirka River (Fig. 9, 10 and 11, according to Usov, 1965 (361) and Grigor'iev, 1966 (110). The direct data on subsea-permafrost extension in Kara Sea will be received later (Chehovsky, 1972 (62)).

Extrapolations. In 1960 a general geocryological map of the USSR was published at a scale of 1:10,000,000. It was compiled by I. Ya. Baranov and for the first time in the practice of compiling small-scale permafrost maps he defined a zone of permanently frozen ground under the bottom of arctic seas. The northern boundary of this zone within the limits of the Laptev Sea was drawn approximately along the margins of the shelf. In the west of Siberia the permafrost zone on the sea floor was shown to the region of the Yamal Peninsula in the Kara Sea and on the east to the region of Cape Billings in the East Siberian Sea. Later, in 1974, Fotiev *et al*. also had showed the permafrost extension about all the shelf on 300 - 400 km from the shore (Figs. 13 and 14).

All these maps are based on general paleogeographical estimations, and we would like to consider it in a special chapter (D).

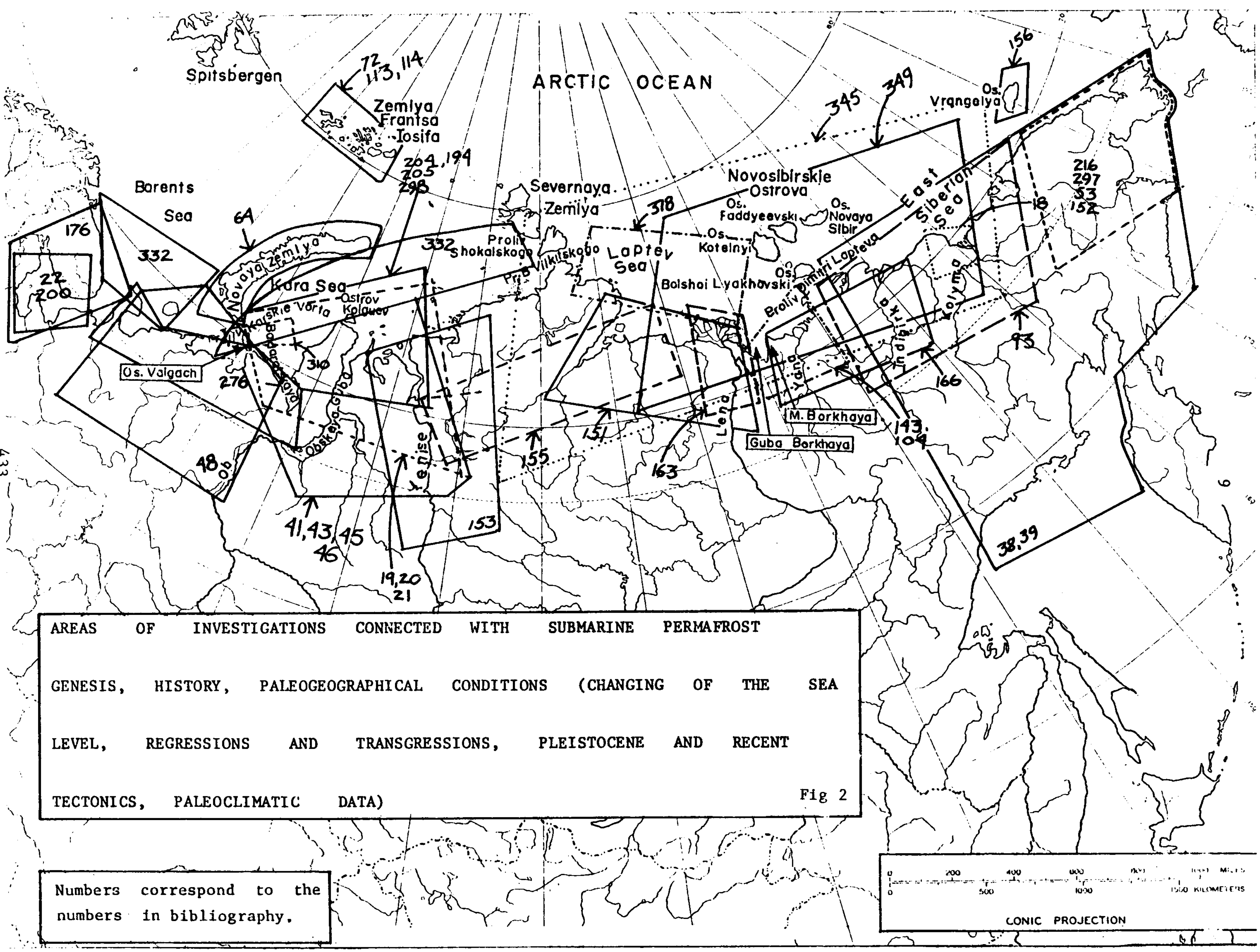
To be continued



AREAS OF INVESTIGATIONS CONNECTED WITH SUBMARINE PERMAFROST REGIONAL DISTRIBUTION, CHARACTERISTICS, COMPOSITION AND STRUCTURE

Numbers correspond to the numbers in bibliography.

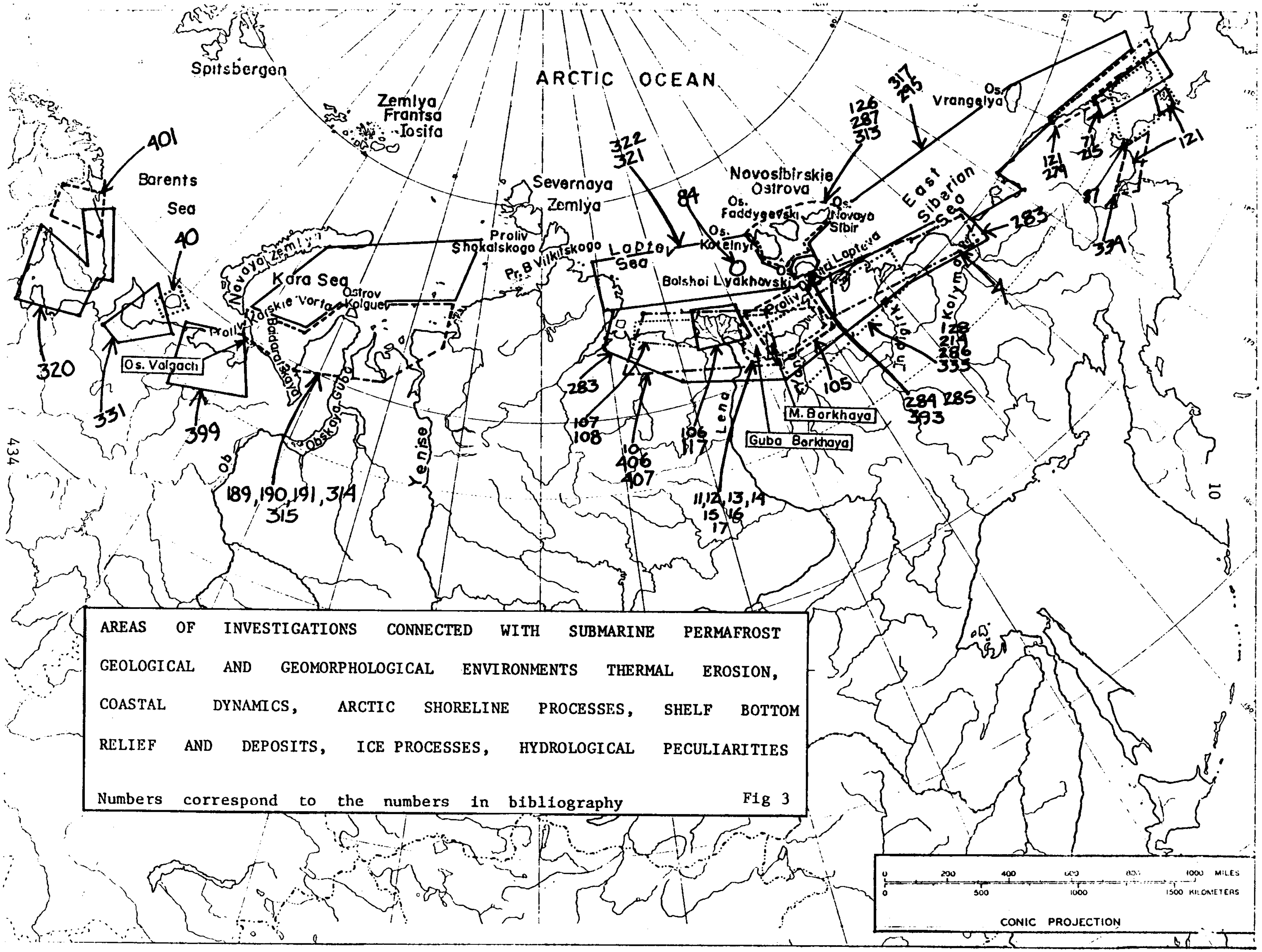
Fig 1



AREAS OF INVESTIGATIONS CONNECTED WITH SUBMARINE PERMAFROST GENESIS, HISTORY, PALEOGEOGRAPHICAL CONDITIONS (CHANGING OF THE SEA LEVEL, REGRESSIONS AND TRANSGRESSIONS, PLEISTOCENE AND RECENT TECTONICS, PALEOCLIMATIC DATA)

Fig 2

Numbers correspond to the numbers in bibliography.



AREAS OF INVESTIGATIONS CONNECTED WITH SUBMARINE PERMAFROST GEOLOGICAL AND GEOMORPHOLOGICAL ENVIRONMENTS THERMAL EROSION, COASTAL DYNAMICS, ARCTIC SHORELINE PROCESSES, SHELF BOTTOM RELIEF AND DEPOSITS, ICE PROCESSES, HYDROLOGICAL PECULIARITIES

Numbers correspond to the numbers in bibliography

Fig 3

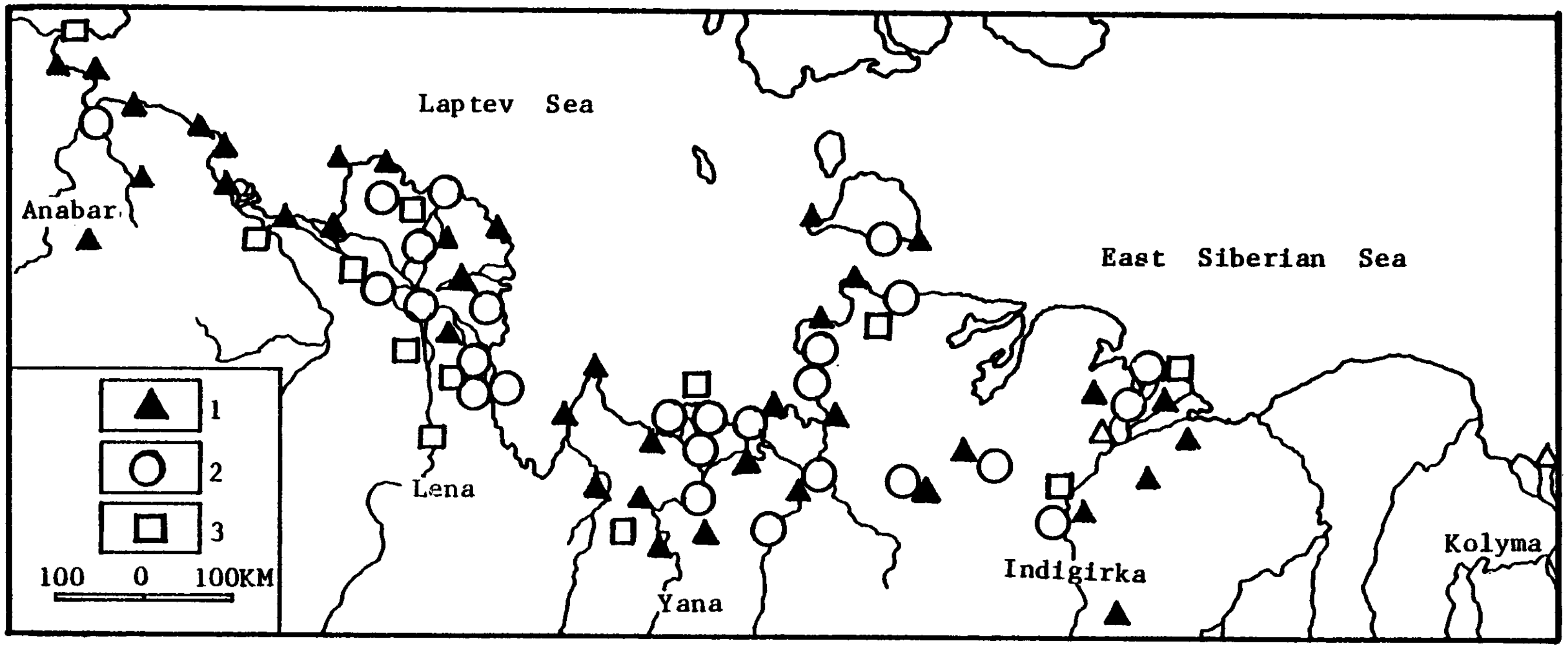


Fig. 4 Schematic map of permafrost studies of the Artic part of Yakutia, according to Grigor'yev,1966(110) 1) Regions where there have been reconnaissance permafrost-gelogical investigations by the Permafrost Science Institute USSR Acadamy of Science, 2) Regions where drilling and thermometric investigations have been made by the Permafrost Science Institute; 3) Regions where permafrost investigations have been made by other organizations incidentally with geological prospecting work.

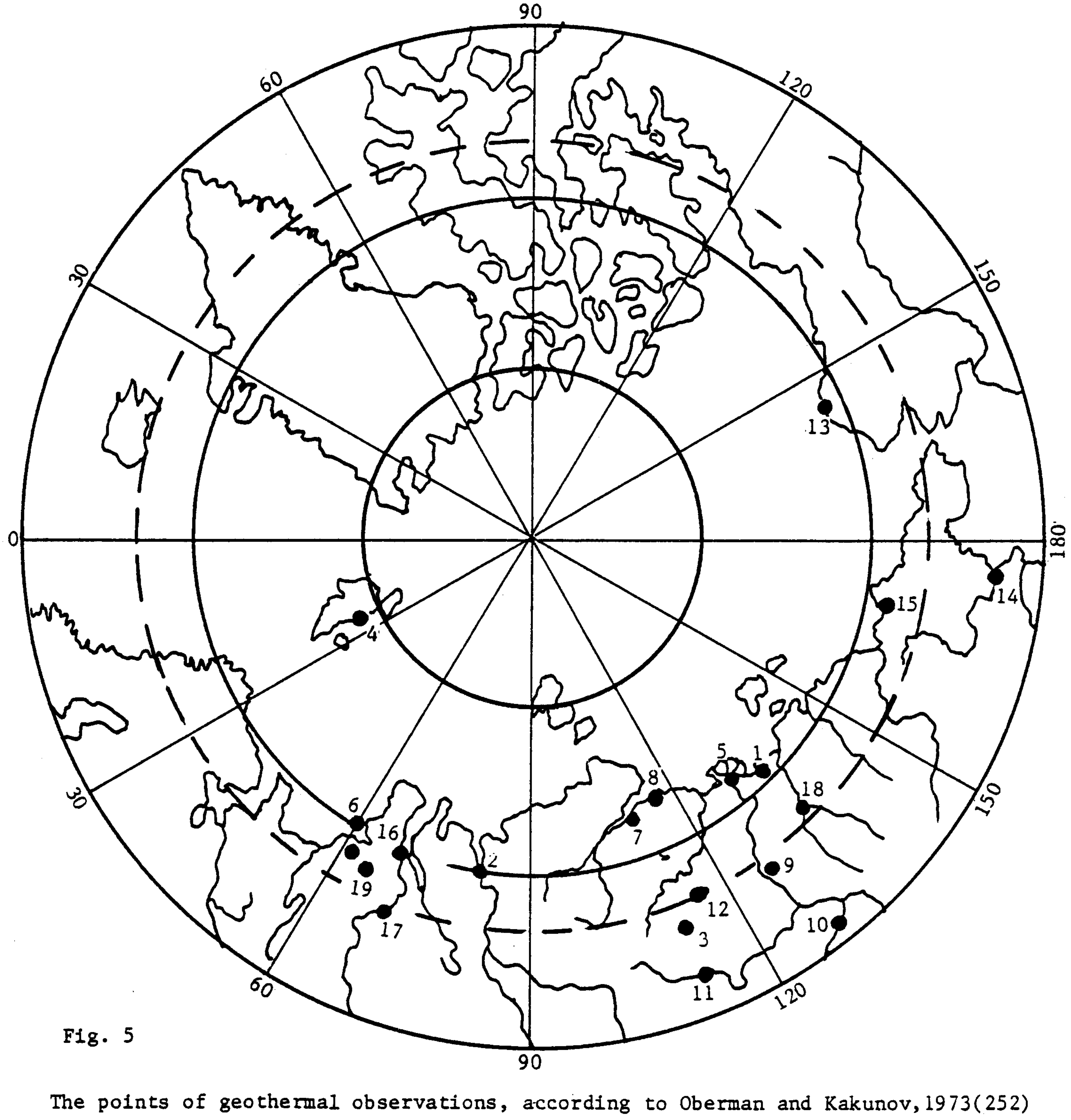


Fig. 5

The points of geothermal observations, according to Oberman and Kakunov, 1973(252)

1.) Tiksi Bay, 2.) Ust-Port, 3.) Bolshezemelskaia Tundra, 4.) Shpitcbergen, 5.) Lena mouth Chay-Tumus, 6.) Amderma, 7.) Kojevnikov Bay, 8.) Nordvik, 9.) Bahinai, 10.) Namtci, 11.) Mirni, 12.) Marha, 13.) Alaska, Barrow, 14.) Anadir, 15.) Pevek, 16.) Ob mouth, 17.) Ob Bay, 18.) Verhsyansk, 19.) Vorkuta.

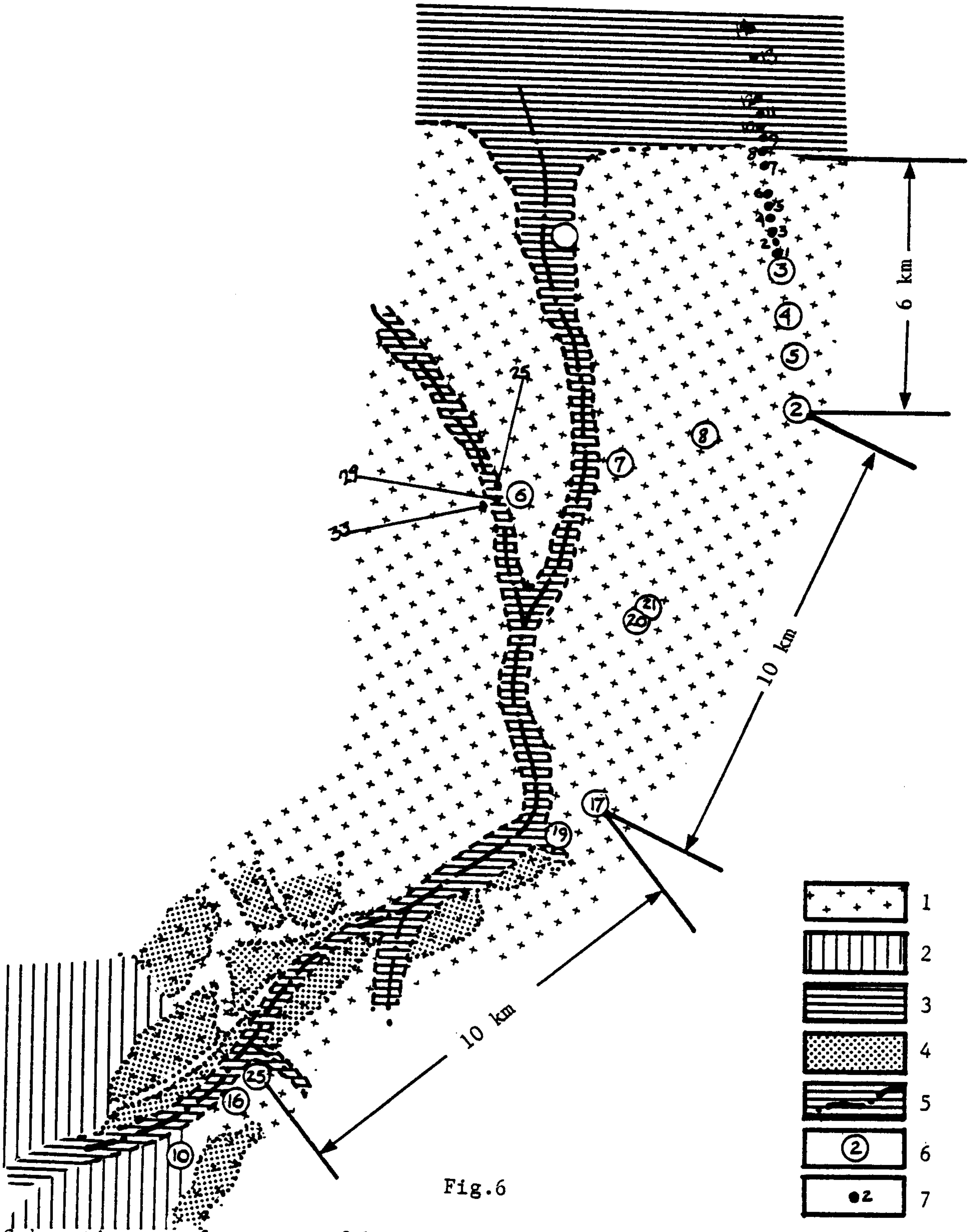
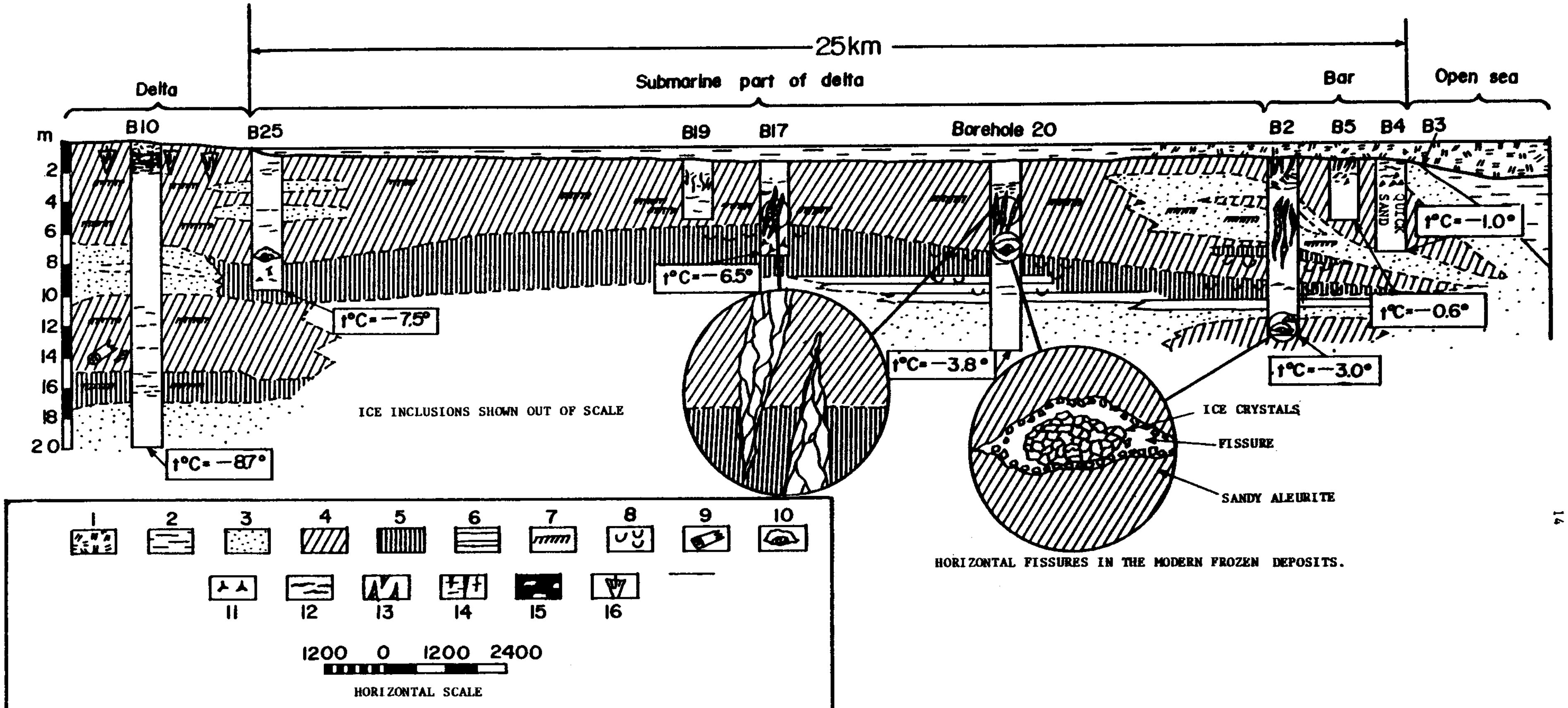


Fig.6

Schematic permafrost map of beach near mouth of Yana River, Laptev Sea, according to Grigoriev, 1966(110). 1) Underwater layer of modern perennially frozen deposits; 2) Continental Holocene-delta perennially frozen deposits; 3) Talik zone near delta; 4) above-water, periodically inundated shoals--"sands"; 5) Under-water channel and talik zone ; 6) Boreholes; 7) Points of thermal soundings.

FIG. 7 PERMAFROST-GEOLOGICAL CROSS SECTION IN THE REGION OF THE BEACH AREA AT THE MOUTH OF THE YANA RIVER, ACCORDING TO IVANOV, 1969 (124)



1) SEA ICE
2) WATER
3) SAND
4) SANDY ALEURITE
5) CLAY ALEURITE
6) SILT
7) PLANT DETRITUS
8) SHELLS
9) WOOD
10) SILTLIKE VOIDS WITH LENGTHS OF 10-30mm
11) VERTICAL TUBULAR VOIDS WITH WIDTHS OF 1-3mm
12) ICE CEMENT, ICE NEST
13) ICE INTERCALATIONS AND LENSES WITH A THICKNESS OF 1mm TO 2 cm VERTICAL VEINS OF GRANULAR ICE
14) VERTICAL VEINS OF ICE WITH HORIZONTAL INTERCALATIONS AND LENSES OF ICE
15) BASAL TEXTURE
16) SECONDARY VEIN ICE

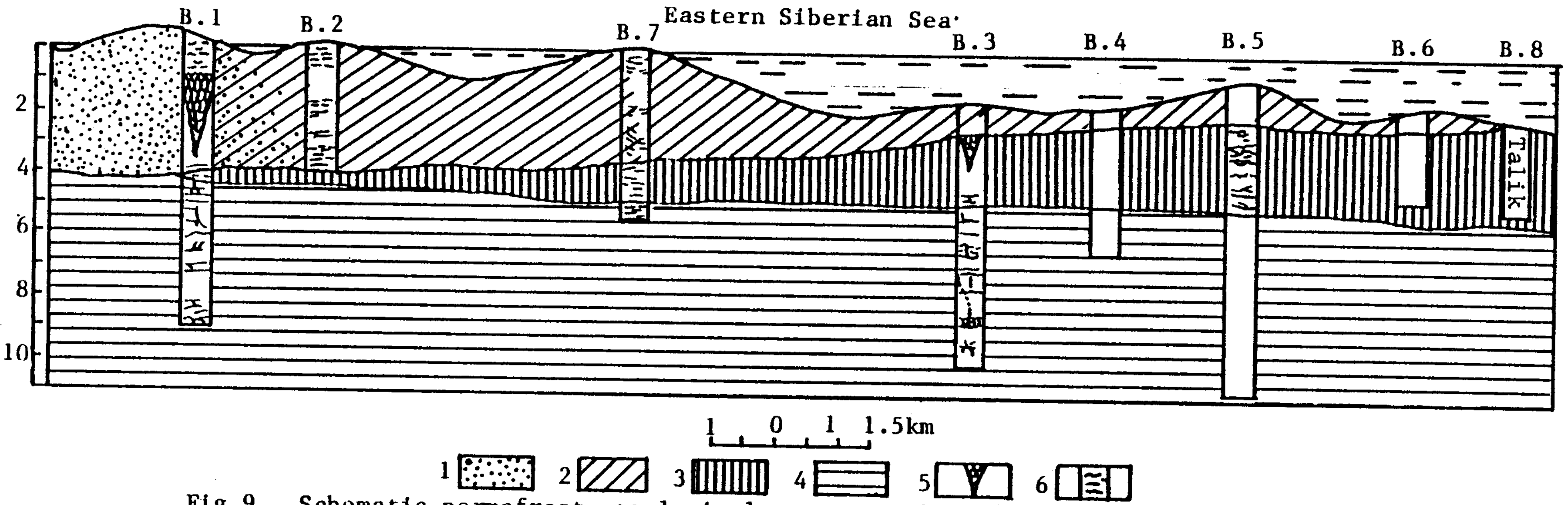
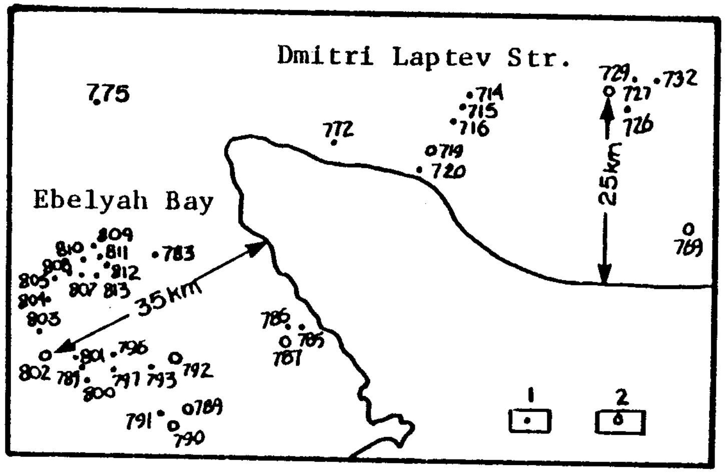


Fig.9 Schematic permafrost -geological cross section of the region of beach area at the mouth of the Indigirka River, According to Usov,1965(361). 1) Sand; 2)Sandy Aleurite; 3) Clay Aleurite; 4) Silt; 5) Vein ice 6) Ice texures

Fig.8 Areas of the Laptev Sea shelf with unsalted deposits,according to Molochuskin 1973(239)



1.Points with unsalted deposits.

2. Points with frozen deposits.

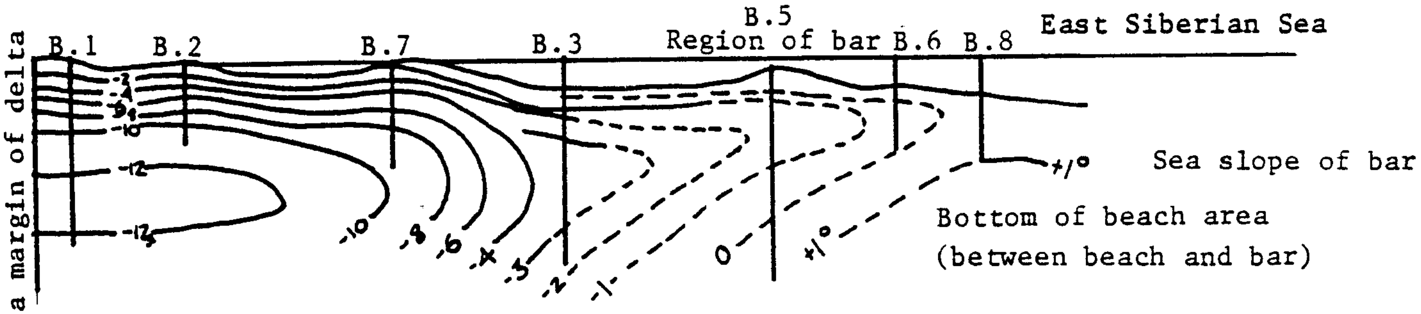
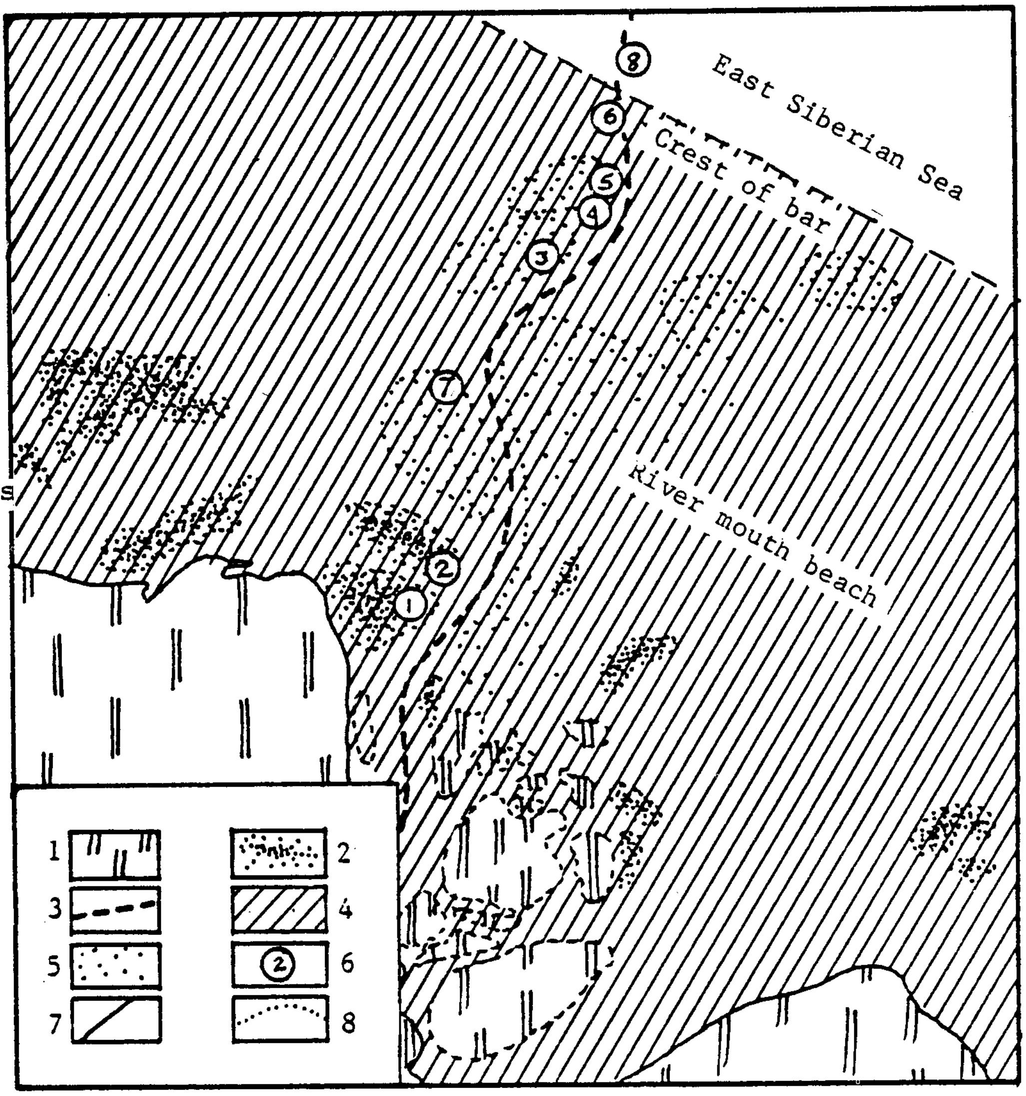


Fig 10 Schematic temperature cross section of underwater layer of perenially frozen deposits on the bottom of the beach area near the mouth of the Indigirka River, according to Grigoriev, 1966 (110).

Fig 11 Schematic permafrost-geological map of the river mouth beaches of the shore of the East Siberian Sea, according to Grigoriev, 1966(110)



1) Holocene delta permanently frozen deposits
2) Above water, periodically inundated shoals --"sands
3) Underwater channel and strip of talik beneath channel
4) Shelf delta-area underwater perennally frozen deposits
5) Underwater permanently water-covered shoal--"sands"
6) Boreholes
7) Shoreline of periodically flooded islands
8) Boundary of underwater shoals

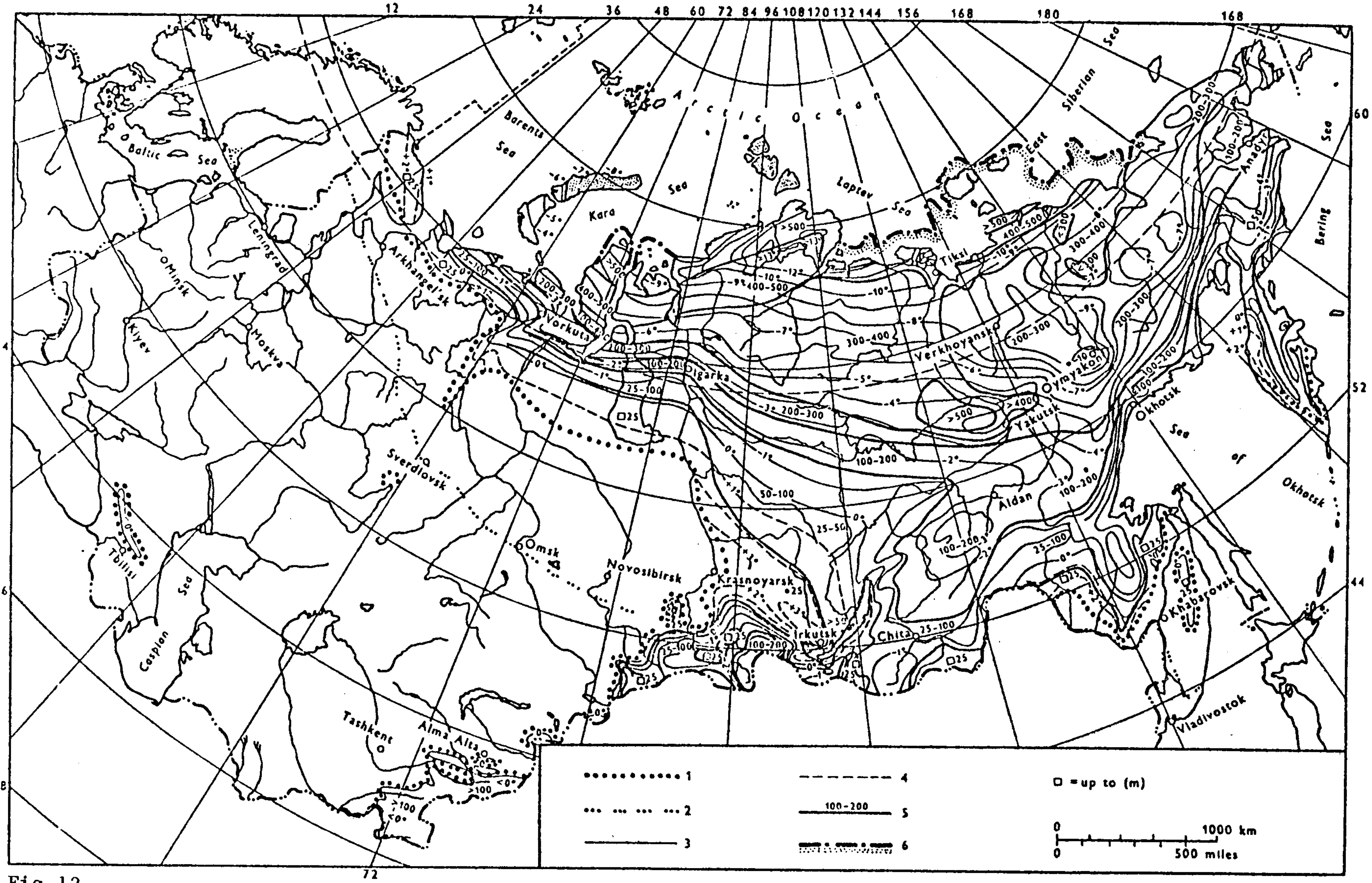


Fig 12

Permafrost in the Soviet Union
(Baranov, 1960)

From Periglacial Processes and Environments
A.L. Washburn (1973, p. 24, Fig. 3.5

1) Boundary of permafrost area
2) Boundary of zone of frequent pereltoks
3) Minimum ground temperature at level of zero annual amplitude (In mountainous regions shown for valleys)
4) Soil isotherms at 1-2m depth under natural conditions
5) Maximum thickness of permafrost (m)
6)Permafrost zone under Artic Ocean

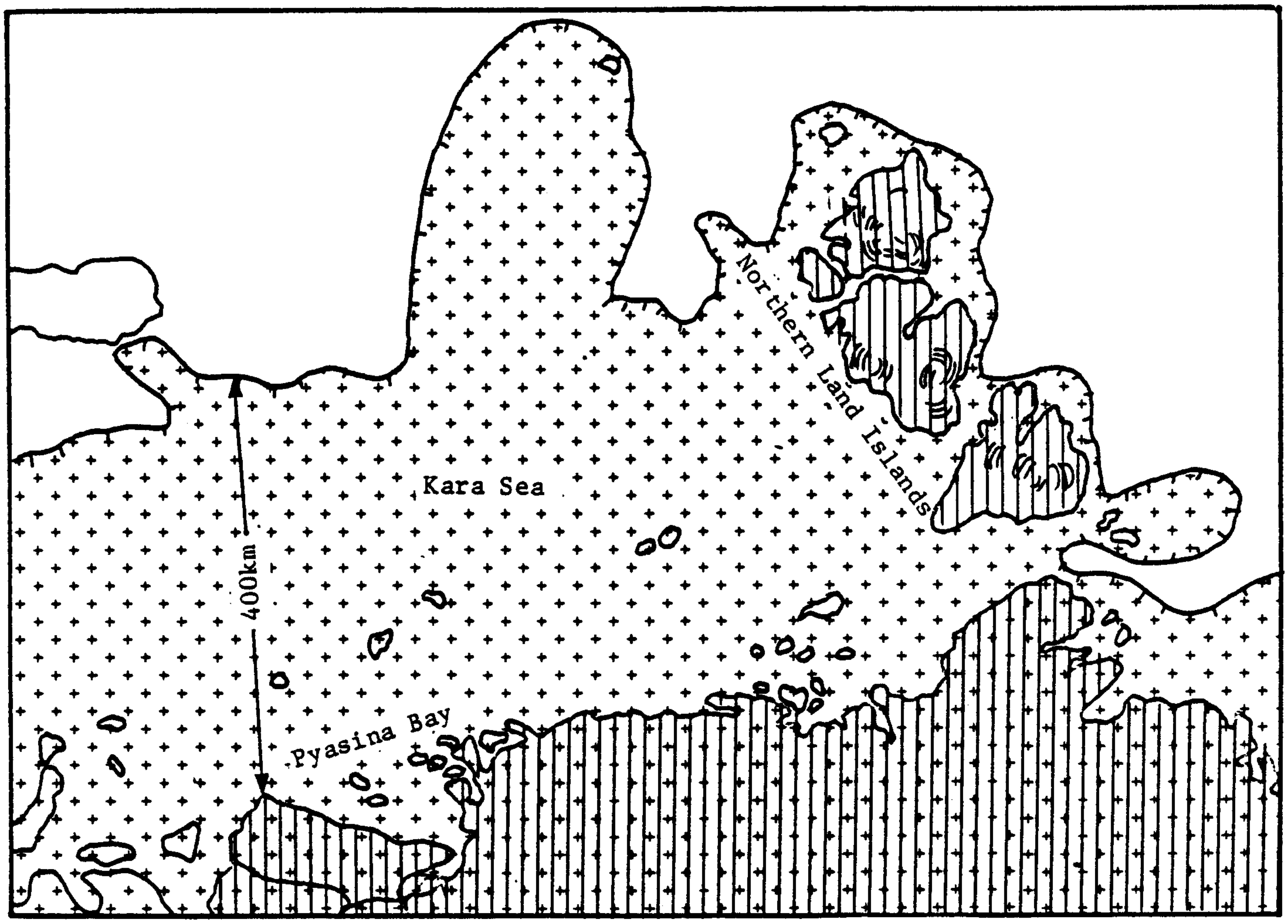
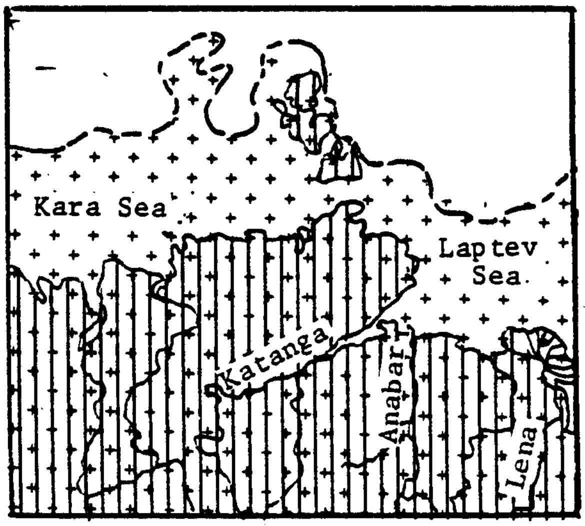


Fig 13 Boundary of submarine permafrost in the Kara Sea, according to S.M. Fotiev et al , 1974 (83)

Fig 14 Submarine permafrost extension in the Kara and Laptev Seas after Fotiyev et al 1974 (83)



⁘ 1

▥ 2

1.Submarine permafrost on the shelf

2. Continental permafrost

Table 1 Temperature of Permanently Frozen Ground in Chay-Tumus Region (Region of the Olenekskaya Channel of the Lena River, 1954), °C;

Depth m	Borehole 1	Borehole 4	Borehole 5	Borehole 9	Depth m	Borehole 1	Borehole 4	Borehole 5	Borehole 9
4	—6,6	—8,7	—8,2	—7,4	70	—	—	—10,3	—
6	—7,8	—9,8	—10,4	—9,0	74	—	—9,6	—10,3	—
8	—8,5	—	—11,3	—	80	—	—9,5	—10,2	—
10	—8,7	—10,4	—11,2	—10,0	90	—7,4	—	—9,8	—
12	—	—10,6	—11,2	—10,0	100	—	—9,1	—9,6	—
14	—	—	—11,2	—9,8	120	—6,8	—8,8	—8,6	—
16	—8,5	—10,4	—10,8	—9,8	140	—	—8,4	—7,8	—
18	—8,5	—	—	—9,7	160	—6,2	—8,4	—7,5	—
20	—	—10,4	—10,8	—9,6	180	—5,8	—7,8	—7,3	—
24	—	—10,4	—10,8	—	200	—	—	—7,0	—
30	—8,4	—10,2	—10,8	—9,6	220	—	—	—6,2	—
40	—8,4	—	—10,8	—9,6	230	—	—	—6,0	—
48	—	—10,0	—10,6	—9,5	240	—	—	—5,5	—
50	—8,3	—10,0	—10,6	—	250	—	—	—5,4	—
54	—	—10,0	—10,6	—	260	—	—	—5,3	—
56	—	—9,9	—10,6	—	280	—	—	—5,2	—
58	—	—9,9	—10,4	—	300	—	—	—5,0	—
60	—8,1	—	—10,4	—9,5	330	—	—	—4,9	—
64	—	—9,8	—10,4	—					

Table 2 Temperature of Permanently Frozen Ground in Neighborhood of Tiksi Bay (the temperature measurements were made in January-February 1962)

Depth,m	Temperature C	Depth,m	Temperature C
20	—11,1	340	—6,0
100	—10,5	360	—5,6
140	—9,8	380	—5,2
200	—8,6	400	—4,8
220	—8,2	420	—4,4
240	—7,8	410	—4,1
260	—7,5	460	—3,7
280	—7,1	480	—3,3
300	—6,8	500	—2,9
320	—6,4		

Table 3 Temperature of Permanently Frozen Ground in Neighborhood of Cape Val'kumey

Depth,m	Temperature C	Depth,m	Temperature C
50	—5,1	230	0,0
90	—4,0	255	+0,7
150	—2,5	290	+2,0
200	—1,0	348	+4,2
220	—0,1		

Table 4 Ground Temperature, °C in Region of Bar of Channel in Middle Delta of the Indigirka River (July-August 1962)

Depth, m	Borehole and observation date						
	1 22-26/7	2 20-21/7	3 23-24/7	5 30/7	6 2/8	7 3/8	8 13/8
0	—	7,2	10,0	11,8	—	7,9	4,2
0,5	—0,8	—	0,6	2,0	—0,6	3,2	4,6
1,0	—3,2	—3,6	—0,9	—0,4	—	—1,5	4,8
1,5	—5,0	—	—1,7	—1,3	—0,5	—3,9	3,8
2,0	—6,5	—7,3	—2,8	—1,6	—0,5	—5,0	2,5
2,5	—8,0	—8,9	—3,1	—1,6	—0,3	—	1,6
3,0	—9,2	—10,5	—3,4	—1,5	—0,2	—8,5	1,0
3,5	—10,1	—11,3	—3,4	—1,2	—	—9,1	—
4,0	—10,7	—11,6	—3,5	—1,2	—	—9,3	—
4,5	—11,3	—	—3,5	—	—	—9,6	—
5,0	—11,7	—	—3,5	—	—	—9,6	—
5,5	—12,1	—	—	—	—	—	—
6,0	—12,2	—	—3,2	—	—	—	—
6,5	—12,3	—	—3,2	—	—	—	—
7,0	—12,3	—	—3,1	—	—	—	—
7,5	—12,2	—	—2,9	—	—	—	—
8,0	—12,1	—	—2,8	—	—	—	—
8,5	—12,0	—	—	—	—	—	—
9,0	—11,8	—	—	—	—	—	—

Table 5 Geothermal Step and Geothermal Gradient Based on Temperature Observations Made in 1964 in Chay-Tumus Region

Depth interval	Geothermal Step m/Degree	Geothermal Gradient °/100m
	Borehole 1	
60—120	47	2,1
120—180	62	1,6
	Borehole 5	
20—120	42	2,4
120—220	41	2,2
220—320	61	1,5

Table 6 Rock Temperature at the bottom of the ground heat storage layer and geothermal gradients

	Points of observation	Permafrost thickness borehole data ,m	Depth of measurement,m	Depth interval				Rock temperature at the depth of 30m	Mineralization g.l.
				30 -250		250-1000	30-1000		
				Geothermal gradient,degree 100m					
				Negative	Positive				
To the East from Taymyr	Nordvik B.8	600(800)	320		2,40	1,31	2,10	-11,6	300
	Kojenvinkov Bay B.6	600	503		4,09	0.40	2,13	-11,5	165
	B.5	600	380		4,00	0,38	2,58	-11,0	
	Tiksi Bay	640	500		1,50	1,88	1,71	-11,1	2
	Lena mouth Chay Tumus B.5	540-560	330		2,45	0,63	1,97	-10,8	
	Anadir	>150	77		5,41		5,41	-5,8	27-70
	Pevek	230	348		2,86		2,86	-5,2	<1
	Average				3,2	0,9		-9.5	
To the West from Taymyr	Amderma B.75	400	274	-0,67	0,87	0.42	0,82	-4,7	63-133
	Ust-Port B.32	>400	400		1,00	0,40	0,76	-3,2	45
	Shpitcbergen B.248	400	310	-0,94	1,20	0,75	1,04	-3,0	34-44
	B.13	180	180	-1,00	2,00		2,00	-2,4	34-44
	Ob Bay B.U-1	120	120	-1,50	1,25		1,25	-1,9	Salt water
	Amderma B.AD-2	900	773	-0,62		0,44	0,44	-1,7	60-92
	Ust-Port B.2GBG	310	850	-1,08	0,75	1,17	0,85	-0,6	
	Bolshezemelskaia Tundra B.9	350	1060	-0,43		1,02	1,02	-0,5	10-20
	Ob Bay B. 59	250	245	-0,12				-0.3	1-18
	Average			-0,8	1,2	0,7		-2,0	

Underground water mineralization and geothermal gradients

Table 7

Points of observation	Permafrost thickness, borehole data, m	Depth of measurement, m	Depth interval				Rock Temperature at the depth of 30m	Mineralization g.l.
			30*-250		250-1000	30-1000		
			Geothermal gradient, degree 100m					
			Negative	Positive				
Tiksi Bay	640	500		1,50	1,88	1,71	-11,1	2
Ust-Port B.2GBG	310	850	-1,08	0,75	1,47	0,85	-0,6	9
Bolshezemelskaia Tundra B.9	350	1060	-0,43		1,02	1,02	-0,5	10-20
B.16	500	1000		0,85	1,16	1,05		10-20
Average			-0.8	1,0	1,3		-4,1	
Shpitcbergen B.248	>400	310	-0,94	1,20	0,75	1,04	-3,0	34-44
Lena mouth Chay Tumus B.5	540-560	330		2,45	0,63	1,97	-10,8	
Ust-Port B.32	400	400		1,00	0,40	0,76	-3,2	45
Amderma B.AD-2	900	773	-0,62		0,44	0,44	-1,7	60-92
B.75	400	274	-0,67	0,87	0,42	0,82	-4,7	63,133
Kojevnikov Bay B.6	600	503		4,09	0,40	2,13	-11,5	165
B.5	600	380		4,00	0,38	2,58	-11,0	165
Nordvik B.8	600(800?)	320		2,40	1,3	2,10	-11,0	300
Average			-0,7	2,3	0,6		-7,2	30

Table 8

Temperature of Bottom Deposits for Beach Near Mouth of Yana River Along Profile of Boreholes 10-25-17-20-2 (May-August 1963), °C

Depth,m	Borehole and observation date					
	10 17-22/7	16 13/8	25 16/8	17 30/7	20 4/8	2 8/5
1	—3,4	—3,4	—	—	—	—
2	—7,0	—7,0	—5,6	—3,6	—3,1	—
3	—9,0	—9,4	—9,4	—4,1	—4,3	—
4	—9,6	—9,8	—10,2	—6,5	—	—4,0
5	—10,0	—10,2	—9,9	—	—	—4.0
6	—10,8	—10,5	—10,2	—	—2,0	—3,5
7	—9,7	—10,1	—9,4	—	—4,1	—3,2
8	—9.5	—	—8,3	—	—3,5	—3,2
9	—9,0	—	—	—	—3,7	—3,0
10	—8,4	—	—	—	—5,2	—3,0
11	—9,3	—	—	—	—4,6	—3,0
12	—8,9	—	—	—	—3,6	—
13	—9,0	—	—	—	—	—
14	—8,6	—	—	—	—	—
15	—8,6	—	—	—	—	—
16	—9,1	—	—	—	—	—
17	—8,6	—	—	—	—	—
19	—8,6	—	—	—	—	—
20	—8,7	—	—	—	—	—

Note. Borehole 10 was drilled on the surface of the low floodplain of Pridel'tovy Island, borehole 16--on the marine periodically inundated shore of this island; boreholes 25-17-20-- under a water layer with a thickness of 0.8 m; borehole 2 was drille early in May with sea ice at a thickness of 0.8 m.

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The meaning of some Russian words, abbreviations, and terms:

Leningrad State University - *Len. gos. universitet, LGU*

Moscow State University - *MGU*

Publishing house - *Izdatelstvo, Izd-vo, Izd*.

Collection - *Sbornik, Trudy*

Publication - *Vypusk*

Publishing house of the marine transport - *Morskoy transport*

Arctic sea route - *Glavsevmorput*

Study - *Uchenie, izuchenie*

Permafrost - *Merzlotnyi, merzlota*

Hydrological and metereological publishing house - *Gydrometizdat*

Nature - *Priroda*

Science - *Nauka*

Bowels of the Earth - *Nedra*

Quaternary - *Chetvertichnich*

Arctic Ocean - *Ledovitiye okedn*

Coast - *Poberezi'ye*

Academie of Sciences of the USSR - *AN SSSR*

Report - *Doklad, Dok*.

Submarine permafrost layer - *Subacuatic cryogenic stratum, SKT*

Cold water (sources) - *"pegi"*

Water with negative temperature - *"cryopegi"*

Unfrozen ground within permafrost - *"talik"*

Needs for Further Study

One of the main ideas of this work is to involve not only the management and retrieval of relevant data but the useful packaging and computerized aids for evaluation and interpretation. The maps and other data compiled during the February synthesis meeting in Point Barrow will be involved in the management as a good source data base needed for subsea permafrost prediction and desicion making process connected with environmental problems. Another concern is to continue the analyses of the Russian data on submarine permafrost study, including the results of mathematical simulation of this phenomena. To achieve these goals we should continue this work during the 1977-1978 year.