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GEOLOGIC PROCESSES AND HAZARDS OF THE BEAUFORT AND CHUKCHI SEA SHELF AND COASTAL REGIONS

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TABLE OF CONTENTS

I. Summary of objectives, conclusions and implications with respect to OCS oil and gas development.

The present investigation is an expansion and intensification of our earlier studies on the arctic marine sedimentary environment off arctic Alaska with emphasis on rates and processes. In particular we have concentrated on phenomena involving ice and its unique influence on the shelf and inshore environment. The observations, conclusions and implications of our studies of the past year and previous years of field work and subsequent laboratory and office work have included the following regarding the arctic shelf environment. (Letters key to full topic discussions as attachments to this report.):

A. Reconnaissance surveys of parts of the Kotzebue Sound-Hope basin inner shelf revealed moderated numbers of ice gouges in places, but none were more than 0.5 m deep. Other features or evidences of geologic processes that might pose environmental hazards to petroleum development were rare.

B. Reconnaissance surveys of the Chukchi Sea inner shelf from Point Lay to Wainwright revealed locally dense ice gouging, but nowhere were the gouges more than 1 m deep. Blossom Shoals is an area of very active sand transport and sand-wave migration. Other features or evidence of geologic processes that might pose environmental hazards to petroleum development were rare.

C. Initial investigations in the Chukchi Sea between Wainwright and Skull Cliff show the sea floor to be dominated by active marine processes involving both currents and ice scouring. Currents, both wave-generated and shore-parallel, transport sediment as migrating bedforms, ripples and sandwaves; erode the substrate exposing bedrock outcrops and producing surficial gravel lag deposits which in areas of long-term erosion allows extensive benthic biological communities to develop, kelp and other algae at depths less than 15 m and invertebrate communities (barnacles) at depths greater than 24 m; mask the intensity of ice scouring by rapidly filling in the scour troughs and where shore parallel currents converge off Point Franklin results in the maximum sediment deposition of 16 m. Ice scouring results in intense disruption of the sea floor sediments by grounded ice, especially between depths of 12 to 20 m (the stamukhi zone) northeast of Peard Bay, and on the steep slopes west of Peard Bay and forms low relief ice-pushed ridges northeast of Peard at depths of 22 m and possibly at 12-14 m depth off Skull Cliff.

D. Ice-wallow.- Repeated, detailed bathymetric studies, together with coastal observations in the Beaufort Sea, enable us to recognize very large but subtle bedforms in the arctic nearshore produced by ice-wallow. In our first study of ice gouging these bedforms were recognized as being unique, but they remained unexplained until recently. Ice-wallow relief is widespread in the arctic nearshore and the dynamic processes of ice-wallow formation will pose a severe hazard to pipelines.

E. Strudel Scour.- Sources in industry point to strudel scour as a very severe engineering constraint to pipeline construction near deltas. In a recent study the rate of occurrence and the lifespan of a single crater were monitored. Results indicate rapid infilling (2 years) as well as the actual rates of bedload transport in shallow regins of the arctic.

F. Comparative bathymetric studies.- Studies in the vicinity of the West Dock causeway indicate that this artificial feature is acting as a groin, trapping sediments. Water depths have decreased as much as 2 feet since construction. Lengthening the causeway, even with a small break, will probably increase the area of sediment accumulation. The small break in the extension will probably not alter the sedimentation pattern.

G. Detailed bathymetry and seafloor sampling in the vicinity of the artificial island - Niakuk III - have shown the island to be migrating westward as do natural offshore islands, but at a much higher rate. The island is leaving behind a gravel lag and blanketing the seafloor with a fine-grained blanket to the southwest. The increased rate of changes is believed to be due to the lack of a gradual offshore slope to absorb wave energy and possibly to the lack of a permafrost core in the island.

H. Bottom drifters.- Bottom drifters released on the central inner shelf and recovered on beaches from Flaxman Island to Barrow, indicate a consistent westward net drift to bottom waters during the open-water period. Drifters released in winter showed no motion during the period of ice cover. Temporary depocenters for sediments and any associated pollutants is suggested for Simpson Lagoon, western Harrison Bay and west of Cape Halkett.

I. Canning River/Canadian border reconnaissance work.- An extensive reconnaissance survey in the area east of the Canning River is compared to our long-term detailed studies in the central Alaskan Beaufort Sea. Potentially unstable modern marine deposits are scarce in the area, while relict sand and gravel for offshore construction should be readily available even at great distances from shore. Modern ice-keel draft in the Beaufort Gyre, previously thought restricted to less than 47 m, must be increased to about 60 m, based on the new ice-gouge studies. The well documented ice-gouge patterns from the central Alaskan Beaufort Sea extend virtually unchanged to the Canadian border. No tell-tale acoustic anomalies suggesting gas-charged sediments were noted in the eastern study area.

J. Ice cores from the Fall fast ice - 1980.- These cores indicate that the ice canopy had an order of magnitude less sediment in 1980 than 2 years previously. This difference is related to a less stormy fall and the presence of more ice wave-dampening on the shelf in 1980.

II. Introduction

A. General nature and scope of study

High-latitude continental shelves, where ice is present seasonally for part of the year, comprise 25 percent of the total world shelf area. Yet the interaction of ice in the regime of sedimentary processes and the influence of geology on the ice regime on North American arctic shelves and coasts is poorly understood. Investigation of the continental shelf and shores of the Chukchi and Beaufort Seas was initiated in 1970. The primary goal of this program has been to understand the processes unique to arctic coasts and shelves. In addition the role of more conventional temperate latitude processes is studied.

B. Specific objectives

Many questions have been raised on the basis of our past investigations, which apparently hold the key to an understanding of the seasonal cycle in the marine environment. It is these tasks that we address in our current research.

Chukchi Sea Studies

1) assess the stability of shoals off major promontories and determine their relationship to sediments, currents and ice,

2) determine the ice-gouge character and distribution on the inner part of the shelf, and tie in with existing offshore data, 3) evaluate relative rates of coastal erosion as related to differing geomorphic and oceanographic settings.

Beaufort Sea Studies

1) delineate the stability and rate of change of the seabed in central and outer Harrison Bay. The 71 lease sale extends into the stamukhi zone in outer Harrison Bay. The character and rates of seabed change from the combined effects of current and ice gouging in this environment remain speculative. Data gathered by us and physical oceanographers will be used to provide characterization and changes in this environment,

2) determine the distribution, biological, physical, and geologic character of "slush ice," focusing on processes of formation, accretion, and colonization.

In response to the request for data to the east of Flaxman Island, we propose to run widely spaced survey lines in this area to:

3) determine the thickness of unconsolidated sediment accumulations for comparison with previously studied regions,

4) study ice gouge distribution and gouge anomalies for an understanding of processes, shelf morphology, and ice zonation,

5) search for major shoals and slope irregularities that may control ice dynamics and zonation,

6) search for any systematic change in sediment types toward the east, such as possible increases in the amount of surficial gravels and boulders. The presence of an extensive region of "pressed boulder clay" east of the Canadian border, and other geologic evidence, suggest that boulder patches may become increasingly common to the east.

C. Relevance to problems of petroleum development

The character of the arctic continental shelf and coastal area, with year round and seasonal sea ice and with permafrost, faces the developer with many special problems. The interaction of the arctic shelf with the arctic pack ice takes the form of ice scouring and the formation of a large stamukhi zone each winter. Furthermore, ice zonation is determined by sea bed morphology and textural character.

Oil drilling and production during the next several years will probably extend into the stamukhi zone seaward of the seasonal fast-ice zone. of critical concern are ice scour, strudel scour, gravel sources and ice zonation; all related to sea bed morphology and sea bed character. These are of concern to the government, in that an adequate understanding of arctic process is needed to assure safe development and adequate environmental protection. Any structure which is to be mated with the ocean floor requires data concerning the strength and character of the ocean floor and its effect on the ice canopy. Foundation materials in the form of gravels will be needed for work pads offshore. In addition, the offshore drilling operation may encounter unsupportive sediments with permafrost and associated gas hydrates which could be substantially altered during the process of pumping hot oil up to the sea floor or along the sea floor in gathering and transportation pipelines.

III. Current state of knowledge

The current state of knowledge for the Beaufort Sea is best summarized in the 1981 OCSEAP synthesis report, which not only treats the various past and present lines of research in the physical sciences and their results, but also considers gaps in knowledge that are of concern to NOAA/BLM. The availability of only skiffs and small boats for the past field efforts has resulted in knowledge biasing the coastal regions the very inner fringe of the continental shelf rather than the OCS. On the middle and outer shelf big ship geophysical studies by the USGS provide considerable knowledge on structural framework, the stratigraphy, and certain hazards such as slumping and sliding. But very little has been done here along the lines of research we and others conduct on modern processes and hazards relevant to the seaward thrust of petroleum development.

The current state of knowledge for the Chukchi Sea is sparce and somewhat limited especially on geologic processes and environmental hazards that may exist. Within the nearshore shelf regions the initial reconnaissance investigations are only starting to define the major elements that characterize the sea floor.

IV. Study Area

A. Chukchi Sea

The Alaskan mainland between Cape Lisburne and Point Barrow slopes generally northward. The southern part of the mainland is hilly, whereas the northern part is a gently sloping coastal plain. The edge of the mainland, which faces the open sea in some places and faces lagoons, bays or barrier spits elsewhere, is marked in most places by cliffs or bluffs, which tend to gradually decrease in height northward. Barrier islands and spits are extensive along the Chukchi Sea coast from Point Barrow southward to the Point Lay area. Barrier islands or spits form Point Barrow, Point Franklin, and Icy Cape, three of the major capes along this coastline.

Much of the Chukchi Sea north of Point Hope consists of a broad, nearly flat, shallow shelf. The average depth is 50 m. Herald Shoald, which lies in the central shelf area, rises up to 14 m depth; Hanna Shoal, on the northern part of the shelf, rises to approximately 20 m depth. The Barrow Sea Valley lies near the northern edge of the shelf. Nearshore, in depths less than 25 m, shore-parallel shoals are developed off the capes. Actively migrating longshore bars form adjacent to the beaches.

The high sea cliffs at and near Cape Lisburne are cut in bedrock of Permian and Triassic age. Cretaceus bedrock, mostly sandstone and shale, forms the sea cliffs around Ledyard Bay, east of Cape Lisburne. Cretaceus bedrock is exposed in the lower parts of sea cliffs as far north as Skull Cliff, between Peard Bay and Barrow. The upper parts of the sea cliffs at Skull Cliff and elsewhere on the coastal plain are made up of unconsolidated Quaternary deposits.

Tidal currents, wave-generated and wind-generated currents and the offshore, shore-parallel Alaska Coastal Current modify the sea floor along the eastern Chukchi Sea by erosion and transportation of sediment as migrating bedforms. The nearshore currents are generated mostly by winds, and the offshore region is dominated by northeast-directed storm currents and by the northeast-flowing Alaska Coastal Current.

The tides are small in the Chukchi Sea, and the tidal range along the eastern coast is generally less than 30 cm. The tides are of the semi-diunal type. The tidal wave moves from north to south in the Chukchi Sea. Tide-generated currents can be expected to be of limited velocity along the open coast.

Storms during the summer months usually result in winds from the southwest which move across the Chukchi Sea. The maximum fetch then develops across the open water. The resulting storm waves and storm-generated currents may erode and scour the sea floor as well as result in intense sediment transport on the shelf and on the shoals.

Wind-generated currents are extremely variable both in velocity and in direction of movement for the nearshore region. The predominant summer winds are from the northeast, generating nearshore current velocities of 4 to 20 cm/sec. The wind generated currents generally follow the bottom contours. Daily variations in the current direction are reported for the nearshore region.

The Alaska Coastal Current represents a northeast flowing "warm" water mass derived from the Bering Sea. The current bifurcates at Cape Lisburne, one branch flowing north and the other branch flowing to the northeast parallel to the coast. The current varies in width and can be as narrow as 20 to 37 km. The velocities of the coastal current vary from 50 cm/sec near Cape Lisburne, to 51 to 87 cm/sec south of Icy Cape, to 55 cm/sec north of Wainwright. Surface velocities of up to 200 cm/sec and mid depth velocities of 70 cm/sec are reported north of Wainwright. TO the northwest of Wainwright near the Barrow Submarine Canyon head, a returning southwest-directed current is reported west of the Alaska Coastal Current with surface velocities of 80 cm/sec. The southwest-flowing current is poorly defined in space and time. Large clockwise rotating spiral currents are reported west of Barrow and may represent interaction between the Alaska Coastal Current and the westward flowing current of the Beaufort Gyre.

B. Beaufort Sea

The primary study area includes the Beaufort Sea shelf between Barter Island on the east and Point Barrow on the west with emphasis on an inshore segment between Flaxman Island and Cape Halkett. The adjacent land is a broad, flat coastal plain composed mainly of Quaternary deposits of tundra-silts, sands, and gravels. In much of the area, the coast is being eroded by the sea at a rapid rate forming coastal bluffs as much as 6 m high. The line of bluffs is interrupted by low mud flats at the mouths of major rivers. Much of the coast is marked by islands at varying distances from the shore. Most of the islands are less than 3 m in elevation, narrow, and comprised of sand and gravel. Others are capped by tundra and are apparently erosional remnants of the inundated coastal plain. Coast-parallel shoals are also a feature of the inner shelf.

The shelf is generally rather flat and remains shallow for a considerable distance from shore. Off the Colville River the 2-m isobath is up to 12 km from shore. The width of the shelf is variable, ranging from, 55 km in the east to 110 km in the west. The shelf break lies at depths of 50 to 70 m. The shallowness of the shelf break and the presence of elevated Pleistocene beach lines suggests broad regional uplift. The Holocene marine sediments on the inner shelf are generally 5 to 10 m thick and composed of complex textural and compositional character. Ice and oceanographic factors interact to form a complex sediment section composed of wave and current-bedded sequences intensely churned and disrupted by ice.

The rivers flood in early June, delivering 50 to 80 percent of the yearly runoff in a 2-3 week period. The bulk of sediment input from rivers is associated with this flood. No river gravels presently reach the ocean. Initial flooding seaward of the river delta occurs on top of the unmelted sea ice, although the influx of warmer water eventually leads to ice-free areas off the deltas early in the sea-ice melt season. River drainage basins are located in the Brooks Range and the eastern rivers drain directly into the ocean while the western rivers meander across the broad coastal plain.

Sea ice is a ubiquitous feature in the study area. New ice starts to form in late September and grows to a thickness of 2 m through the winter, welding remnant older ice into more or less solid sheets. Where forces are sufficient, ice fractures and piles into hummocks and ridges. By June, sea-ice melting is well underway and usually sometime in July enough ice has melted so that the protected bays and lagoons are free of ice, and temperate latitude processes of waves and wind-driven currents are active. Ice remains on the shelf in the study area throughout the summer. Its location and concentration depend on the degree of melting and winds. The prevailing northeasterly wind tends to carry drifting summer ice away from the shore while the westerlies pile ice against the coast. Ice commonly remains grounded throughout the summer on many of the shoals on the inner shelf.

Currents and waves are a function of the winds during the open-water season. Waves are generally poorly developed due to the limited fetch which results from the presence of ice during most of the summer. Water circulation is dominated by the prevailing northeasterly winds which generate a westerly flow on the inner shelf. In winter currents under the ice are generally sluggish although restrictions of the tidal prism by ice, at tidal inlets and on the broad, shallow, 2-m bench cause significantly higher velocities.

V. Sources, methods and rationale of data collection

A. Equipment operated routinely from the R/V KARLUK includes bottom sampling and coring gear, water salinity, -temperature, and -turbidity sensors, fathometers, a high and medium resolution seismic system, and a side-scan sonar. Precision navigation is maintained to 3 m accuracy with a range-range system.

Special techniques include (a) repetitive sonar and fathometer surveys of ice gouges, (b) diving observations and bottom photography, (c) measurements of sediment thicknesses within ice gouges by combined use of narrow beam echo sounder, and (d) a near-bottom tow package incorporating sub-bottom profiler and television, (4) nearsurface stratigraphic studies using a vibracorer capable of obtaining 2-m long cores and (f) detailed surveys of bathymetry in river and lagoonal channels and in the vicinity of manmade structures. Coastal observations of rates of bluff erosion and the distribution and elevation of storm surge strand lines carried out by helicoper. Winter ice observations involve ice coring, diving observations along with modified system of upward-looking fathometer, and side-scan sonar.

B. The past and present status of data and product submission to NOAA-BIM-OCSEAP is given in the table on the following page.

VI., VII., VIII. Results, Discussion and Conclusions - (As attachments to this report)

A. Inner-shelf geology of the north side of Kotzebue Sound-Hope Basin
B. Inner-shelf geology to the Chukchi Sea from Point Lay to Wainwright
C. Reconmissance marine geologic investigations northeast Chukchi Sea, 1981.
Do Dynamic ice-wallow relief of northern Alaska's nearshore.
E. High rates of bedload transport measured infilling rates of large strudel-scour craters in the Beaufort Sea, Alaska.
F. Sedimentation in the vicinity of a causeway groin, Beaufort Sea, Alaska.
G. Erosion and migration of an artificial sand and gravel island-Niukuk III.
H. Net flow of nearbottom waters as determined from seabed drifters.

RU-205, Barnes and Reimnitz, Product Submission Status, REPORTS TO NOAA-BLM

x - data or information submitted
0 - work in progress or planned
for this period

Other sources of data
(Numbers refer to references, p.11)
See 1980 Annual Report for pre-1980 sources.

Da a P od---	1975	1976	1977	March 1978	June 1978	Sept. 1978	Dec. 1978	March 1979	June 1979	Sept. 1979	Dec. 1979	Jan. 1980	March 1980	March 1981	March 1982		Other sources of data
-core descriptions			x												x	0	
-acoustic profiles w/nav.		x	x				x				x	x		x	x	0	7
-water temp./sal.		x	x									x					
-current meter		x	x														
SUMMARY PRODUCTS																	
-Ice gouge maps			x	x	x									x	x	0	3
-Evaluation of ice hazards	x	x	x	x	x		x				x		x	x	x	0	2,3,5,6
-Interpretation of stamukhi and shoals			x	x				x						x	x	0	8
-Ice thickness morphology					x		x		x				x				2
-Sediment laden ice												x	x		o		
-Offshore gravel resources		x	x	x	x		x	x	x					x			1
-Sediment transport regime	x		x	x	x	x	x	x	x		x		x	x	x	0	3,4,7,9,10
-Boulder patch			x				x	x			x	x		x	x		9
-Sediment distribution and character	x	x	x	x	x	x	x	x					x	x		0	1,9
-Engineering properties of sediment		x	x	x				x					x			0	3,5
-Shoals and bedforms														x	x	0	
-Oceanographic observations	x	x	x				x	x	x		x		x				4
-Diving observations			x				x	x	x		x		x		x	0	2,3
-Barrier islands					x		x		x			x			x	0	7,10
-Coastal erosion and delta progradation		x	x		x				x			x			x		
-River processes		x						x									
-Storm surges							x						x		x		11
-Charts		x		x	x				x		x			x			

I. Marine geologic investigations in the Beaufort Sea in 1981, with preliminary interpretaions from the Canting River to the Canadian Border.

J. Sediment content of nearshore ice; Fall 1980, Beaufort Sea, Alaska.

K. Sagavanirktok river sediment load, 1980.

IX. Needs for further study:

Our view of the needs for future study is based on the present state of knowledge which continually improves and may well raise new questions. As seen at present, the primary emphasis of future work should include the following: Beaufort Sea: a) Assessment of seabed character and ice scour character along the outer fringes of the stamukhi zone where the deepest ice keels interact with the seabed. b) Studies of the intensity and rate of strudel scouring on the prodelta of the arctic rivers and assess how scouring will effect pipeline crossings in state and federal waters off rivers such as the Colville and Sagavanirktok. c) Studies of the engineering character of the seabed in relation to ice. In most areas of the shelf, recent sediments are very thin and thus ice has been, and structure foundations will be, influenced by the engineering character of the pre-Holocene outcrop. The variable seabed character should affect ice zonation and the character of ice scour. Chukchi Sea: d) Investigate the effects of the northward flowing Alaska Coastal Current represented by unidirectional bedforms on the sea floor which then would establish the main current and possible pollutant pathways. e) Establish the sediment transport rates of the bedform fields and determine where the sediment is going. f) Investigate the stability, origin, composition and history of Blossom Shoals in relationship to currents and sand-gravel supply. g) Define the stamukhi zone within the nearshore shelf regions. h) Determine the rates of ice scouring. The migrating bedforms rapidly eliminate the ice scours traces, repetitive surveys may establish possible rates of ice scouring for this coastal region.

Recommendations.- As petroleum development continues to press into deeper water and toward regions more distant from existing shore logistics sites, we cannot stress enough the need for a larger vessel, to give researchers access to the OCS. A larger vessel could also lead to cooperative work between disciplines, an aspect that has not been emphasized enough from the early planning stage through the field work. Areas in which we feel cooperative studies to be productive and cost effective are as follows:

1) Bottom-feeding by whales and walrus - this subject is of considerable recent interest. Gray whales feeding on the bottom are marked by tell-tale depressions of considerable interest to marine geologists. We have the experience, equipment, and expertise in monitoring changing bedforms, and the interest in becoming involved in certain aspects of such studies.

2) Sea-ice thickness/pile-up. - This subject is the focus for RU-88, and certainly has been of considerable interest to our project, as it relates to effects on the bottom. The deployment of an upward looking sonar for such studies by RU-88 should be planned with the involvement of other investigations. For instance, seabed surveys around the proposed site before and after deployment of such equipment would be beneficial. Moveover, including a variety of oceanographic sensors in one mooring and one field effort should be cost efficient.

3) Ice override. - Certain locales seem to be more prone to ice override than others. Combining our capabilities and equipment, with those of helicopter-supported subaerial investigations, should prove productive in learning a) what nearshore morphology might be conducive to ice override, and b) resulting effects on the seafloor following such an event.

4) Unique arctic nearshore ecosystems. - The existence of such ecosystems (biology) is dependent on a suitable substrate (geology), protection from ice scour (ice dynamics, seabed morphology), and a low sediment input (sediment dynamics). If planned during the proposal-writing stage, biology, ice dynamics and geology could and should be combined in such efforts.

5) Mechanical properties of ice. - These properties are important for a better understanding of ice scour as well as well as sea ice hazards. An interdisciplinary field effort studying the morphology of a particular grounded ice floe and seabed below, towing the floe and studying the effects on the ice floe and on the seafloor, would be more fruitful than indiidual project efforts.

A number of the examples for cooperative efforts suggested above would be done with a vessel at least slightly larger than the Karluk. She was designed for only four persons, in doing coastal work, and should not be pushed beyond her limits.

As our own work, and that of others progresses, new thoughts develop, and these should be incorporated into the planning for future work. The present system of preparing proposals does not leave enough flexibility for input from the working level, particularly for planning interdisciplinary efforts.

X. Summary of Annual operations

1) Ship and field trips

The 1981 field season on the R/V Karluk ran from July 10 to September 17, 1981. During this time, geologic and environmental data was collected from the Canadian Border to Nome primarily in the nearshore 20 ne.

2) Personnel involved in the project:

Peter Barnes	Principal Investigator-Geologist	U.S.G.S. , Marine Geology
Erk Reimnitz	Principal Investigator-Geologist	U.S.G.S., Marine Geology
Ralph Hunter	Principal Investigator-Geologist	U.S.G.S., Marine Geology
Larry Phillips	Principal Investigator-Geologist	U.S.G.S., Marine Geology
Ed Kempema	Geologist	U.S.G.S., Marine Geology
Peter Minkler	Physical Science Technician	U.S.G.S., Marine Geology
Doug Rearic	Geologist	U.S.G.S., Marine Geology
Tom Reiss	Physical Science Technician	U.S.G.S., Marine Geology

3) Methods Efforts for the last year have primarily been aimed at the collection and interpretation of data from broad areas in the Beaufort and Chukchi Seas that have not previously been studied. Significant project efforts during the previous year were:

a) Description and characterization of ice gouge records over large areas of the shelf.

b) Preparation of the annual report.

c) Preparation of manuscripts for internal and external publication.

d) Preparation for and execution of a 9 week field season in the Beaufort and Chukchi Seas.

e) Preliminary multi-variative analysis of gouge parameters in the Beaufort Sea.

f) **Preliminary analysis** of gouge character, sediment character, and **sub-** bottom structure in the areas between Camden Bay and the Canadian Border.
g) Reconnaissance surveys of the Chukchi Sea, with preliminary interpretations **of** the data collected this year and supplemented by a re-evaluation of data collected in 1975.
h) Continued studies of shoals in the stamukhi zone, including **side-scan-** sonar mosaics of small areas.
i) Writing and editing sections of Beaufort Sea synthesis volume. Preliminary **work** on editing volume of **OCSEAP** papers on Beaufort Sea studies.

4) Data collected or **analyzed:**

Data Type	km of records collected
Side scan sonar	1500 km
Bathymetry profiles	1500 km
High resolution seismic records	875 km

XI. Published Reports

Reports published prior to 1981 annual report

1. Barnes, P. W., Remnitz, Erk, and Ross, C. R., 1980, Nearshore surficial sediment textures - Beaufort Sea, Alaska: U.S. Geological Survey Open-File Report, 80-196, 40 p.
2. Barnes, P.W., Reimnitz, Erk, Toimil, L.J., and Hill, H.R., 1979, Fast-ice thickness and snow depth in relation to oil entrapment potential, Prudhoe Bay, Alaska: U.S. Geological Survey Open-File Report 79-539, 28 p.
3. Barnes, P.W., and Reimnitz, Erk, 1979, Ice gouge obliteration and sediment redistribution event; 1977-1978, Beaufort Sea, Alaska: U.S. Geological Survey Open-File Report 79-848, 28 p.
4. Barnes, P.W., and Toimil, L.J., 1979, Inner shelf circulation patterns, Beaufort Sea, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1125.
5* Boucher, Gary, Reimnitz, Erk, and Kempema, E.W., 1981 Seismic evidence for an extensive gas-bearing layer at shallow depth offshore from Prudhoe Bay Alaska: Cold Regions Science and Technology, no. 4, p. 63-71.
6. Grantz, A., Barnes, P.W., Dinter, D.A., Lynch, M.B., Reimnitz, E., and Scott, E.W., 1980, Geologic framework, hydrocarbon potential, environmental conditions, and anticipated technology for exploration and development of the Beaufort shelf north of Alaska, A Summary Report, U.S. Dept. of the Interior possible oil and gas lease sale, No. 71: U.S. Geological Survey Open-File Report 80-94. 42 p.
7* Kempema, E.W., Reimnitz, E.R., and Barnes, P.W., 1981, Marine geologic studies in the Beaufort Sea, Alaska, 1980; location, data type, and records obtained: U.S. Geological Survey Open-File Report, 81-421, 3 p.
8. Reimnitz, Erk, Ross, C.R., and Barnes, P.W., 1980, Dinkum Sands: U.S. Geological Survey Open-File Report 80-360, 11 p.
9. Reimnitz, Erk, and Ross, C.R., 1979, Lag deposits of boulders in Steffanson Sound, Beaufort Sea, Alaska: U.S. Geological Survey Open-File Report 79-1205, 26 p.
10, Reimnitz, Erk, and Maurer, D.K., 1979, Eolian sand deflation - A cause for gravel barrier islands in arctic Alaska?: Geology, v. 7, no. 10, p. 507-510.
11. Reimnitz, Erk, and Maurer, D.K., 1979, Effects of storm surges on the Beaufort Sea coast, northern Alaska: Arctic, v. 32, n. 4, p. 331-344.

Reports published between 1981 and 1982 annual reports

12. Barnes, P.W., (cd.), 1981, Physical characteristics of the Sale 71 Area: in: Norton, D.W., and Sackinger, W.M., (eds.) Beaufort Sea Synthesis - Sale 71, National Oceanic and Atmospheric Administration, Office of Marine Pollution Assessment, Juneau, Alaska, p. 79-113.

XII. Reports submitted for publication

1. Barnes, P. W., Reimnitz, Erk, and Fox, Dennis (in press), Ice rafting of fine-grained sediment, a sorting and transport mechanism, Beaufort Sea, Alaska: Journal of Sedimentary Petrology, v. 52, n. 2, 11 printed pages.
2. Barnes, P.W., and Ross, C.R., (in press) Ice-pushed boulder pile - Camden Bay, Alaska, (for publication in Arctic magazine).
3. Dunton, K.H., Reimnitz, Erk, and Schonberg, Susan (submitted to Arctic in February), An arctic kelp community in the Alaskan Beaufort Sea, 61-page manuscript plus 7 plates.
4. Reimnitz, Erk, and Kempema, E.W., 1981, Dynamic ice-wallow relief of northern Alaska's nearshore - a dynamic bedform: Journal of Sedimentary Petrology (in press).
5. Reimnitz, Erk, Kempema, E.W., and Ross, Robin, (in press), Observation on the mode and rate of decay of an artificial ice island in the Alaskan Beaufort Sea: Offshore Technology Conference, Houston, Texas, 1982, OTC #431, 10 printed pages
6. Reimnitz, Erk, and Kempema, E.W., (at TRU), High rates of bedload transport measured from filling rate of large strudel scour craters in the Beaufort Sea, Alaska: Continental Shelf Research.