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

Edited by

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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 northern and western 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. Now we are also studying the influence of the more traditional geologic processes. The data observations, conclusions and implications of our studies of the past year, in conjunction with previous years knowledge has resulted in the following reports on the arctic shelf environment. (Letters key to full topic discussions as attachments to this report.) :

A. Gravel Resources - A summary of the present state of knowledge about the Quarternary history of the Beaufort Sea shelf is presented in related to the potential for gravel resources. The lack of data and the extreme variability of both geophysical units and surficial sedimentary character make the prediction of gravel resources premature. Identified gravel sources are beaches and barrier islands, river valleys, outwash plains, and paleo-river valleys. Offshore sources may be covered with overconsolidated silts and clays and some gravel deposits may contain permafrost. West of the Colville River, coarse sediments could be rare while east of the Canning River surficial gravels may reach a thickness of several meters.

B. Beaufort Sea Data - Observations made during 1982 field work on the Beaufort Shelf included (1) geophysical surveys to determine recurrent ice gouging rates, (2) detailed investigations of ice gouges and strudel scours, (3) bathymetric surveys, and (4) studies of freeze-up processes around Prudhoe Bay. Approximately 500 km of geophysical coverage was obtained.

C. Southern Chukchi Sea -The northern and southern sides of the southeastern bight of the Chukchi Sea (including Kotzebue Sound and Hope Basin) differ significantly in many characteristics. Nearshore coarse sand and gravel is common on the north side, whereas nearshore fine sand dominates the barrier coast of the south side. Ice gouges are common on the north side but rare on the south side, but the reasons for this difference are not well understood. Sand waves are common on the south side near Bering Strait.

D. Central Chukchi Sea - Reconnaissance surveys of the Chukchi Sea inner shelf from Wainwright to Icy Cape show the region to contain a thin Quarternary sediment cover with possible bedrock outcrops on the sea floor. A reversing current pattern exists off Icy Cape in Blossom Shoals. Northeast-directed currents nearshore and western-directed currents offshore are indicated by the orientation of sand wave fields. Blossom Shoals represent a region of sediment deposition with the sand banks migrating in a seaward direction.

E. Northern Chukchi Sea - Reconnaissance surveys of the Chukchi Sea inner shelf in the vicinity of Barrow revealed bedrock outcrops and a thin Quarternary sediment cover below water depths of 24 to 32 m. The Quaternary sediments (Gubic Formation?) rapidly thicken toward land on the shallow shelf. Ice gouging occurs to 52 m depth with the most intense gouging between 9 m and 24 m depth on the slope of the Barrow Sea Valley. The maximum gouge depth observed was 1.7 m.

F. Ice Gouge Characteristics and Processes - Results of a study of geophysical records collected between 1972 and 1980 indicate that the intensity of ice gouge sediment interaction is greatest in the stamukhi zone (15 to 45 m water depth) and is associated with major ice ridging. Ice gouge intensities decrease both inshore and seaward of this zone. Wide, shallow gouge multiples are believed to be caused by pressure ridges of first-year sea ice and indicate that sufficient strength and integrity is attained during their formation to allow disruption of seafloor sediments.

G. Rates of Ice Gouging - Eight years of ice gouging measured from repetitive survey's along the Beaufort Sea inner shelf from Elson Lagoon to Camden Bays show rates of reworking of 3 to 6 percent per year; higher than previously known and higher than in the Canadian arctic. Rates are highest in the stamukhi zone as previously suspected.

H. Stamukhi Shoal - All available data from satellites, bottom sampling, diving, side scan sonar, fathometer, and seismic surveys on the shoal was compiled, analyzed and interpreted. Year after year, the shoal has played a key role in establishing the boundary between the fast ice and the pack ice and the shoal surface shows the intense interaction of ice processes and hydraulic reworking. The results of this study can be applied to other shoals in the stamukhi zone, and for the design and placement of artificial islands in that depth zone.

1. Ice-gouge infilling - Detailed sampling and study of a six year old ice gouge in eastern Harrison Bay shows that sediment distribution across a gouge is extremely variable. This high variability over a small area indicates that shelf sediment distribution is very complex, consisting of small packages of ice gouge fill bounded by unconformities.

J. Deepwater gouges - Ten available side scan sonar and fathometer traverses of the deep-water ice gouge limit along the shelf edge of the Beaufort Sea and the Chukchi Sea were analyzed, and the gouges interpreted in light of existing knowledge of shelf edge processes. From this we conclude that the maximum draft of sea ice is not 47 m, as previously thought, but that ice keels as deep as 64 m exist in the present Arctic Ocean.

K. Hummocky Subbottom - Side scan sonar, 7 kHz bathymetry, and Uniboom seismic data acquired along repeated track lines during 1980 and 1981 provided sufficient data to describe the characteristics of a subbottom reflector with sharp irregular hummocky topographic features of uncertain origin. Data reduction also demonstrated gross navigational inaccuracies of more than 100 m in systems designed for ± 3 m accuracy when used for repeating track line location.

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 relative importance of ice in the regime of sedimentary processes and the influence of geology on the ice regime of arctic shelves and coasts is poorly understood. The geologic environment of the Chukchi and Beaufort Seas are fundamentally different. As the Chukchi Sea experiences much longer open water and stronger currents. Thus, both ice and hydraulic processes are important while ice processes are dominant on the Beaufort shelf. Our 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 to the role of better understood temperate latitude processes).

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 sand ridges elsewhere on this shelf, as well as determine their relationship to sediment textures, current regime and ice dynamics, and general sediment transport system.
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.
4) Obtain selected sediment profiles and interpret considering potential sand and gravel sources.

Beaufort Sea Studies

1) Delineate the stability or rates of seabed change from the combined effects of current and ice gouging using studies of recent changes in seabed bathymetry.
2) Determine the thickness of unconsolidated sediment accumulations for comparison with previously studied regions.

3) Study ice gouge distribution and gouge anomalies for an understanding of formational mechanisms, shelf morphology, and ice zonation.

C. Relevance to problems of petroleum development

The character of the arctic continental shelf and coastal areas, with year round and seasonal sea ice and permafrost, faces the developer with many special problems. The interaction of the shelf with the arctic pack ice takes the form of ice scouring and the formation of a large stamukhi zone each winter. Ice zonation, is in part, determined by sea bed morphology and textural character. In addition, strong currents will be encountered along the Chukchi Coast.

Oil exploration and production during the next several years will probably extend into the grounded ice ridges of the stamukhi zone. Of critical concern are ice gouge, strudel scour, gravel sources, ice zonation, mobile bedforms, and coastal erosion; all related to seabed morphology and seabed 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 offshore work pads. 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 or along the sea floor in gathering and transportation pipelines. Pipelines and shoreline crossings will encounter hazards from coastal erosion, unsupported permafrost and ice gouge forces.

III. Current state of knowledge

The current state of knowledge for the Beaufort Sea is best summarized in the 1979, 1981, and 1982 OCSEAP synthesis report, which treats the various past and present lines of research in the physical sciences and their results. The availability of only skiffs and small boats for the past field efforts has resulted in knowledge biasing the coastal regions and the inner fringe of the continental shelf rather than the OCS per se. On the middle and outer shelf geophysical studies by the USGS provide considerable knowledge on structural framework, stratigraphy, and hazards such as gas and gas hydrates, slumping and sliding. But very little has been done 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 study area includes the Beaufort Sea shelf between Demarcation Bay on the east and Point Barrow on the west with emphasis on an inshore segment. The adjacent land is a broad, flat coastal plain blanketed with Pleistocene marine and non-marine 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 10 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 composed 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 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 are texturally and structurally complex. Ice and oceanographic factors interact to form a complex sediment section composed of wave and current-bedded sequences intermixed with 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 as sheet, frazil and anchor ice all of which may incorporate sediments in the inner shelf ice canopy primarily during fall storms. Ice continues to grow through the fall and winter and were undisturbed reaching 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. A major ridge system forms parallel to the coast in water depths of 15-45 m. The zone, the stamukhi zone, is associated with intense seafloor gouging and seabed textural and morphologic changes. 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 the common temperate latitude processes of waves and wind-driven currents are active. Ice remains on or near the shelf in the study area throughout the summer. Its location and concentration depends 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 Beaufort shelf, while the Chukchi coast is virtually ice free every summer.

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 of Harrison Bay 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 when needed.

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, (e) drifting bottom camera observations, (f) nearsurface stratigraphic studies using a vibracorer capable of obtaining 2-m long cores, and (g) 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 are carried out by helicoper. Winter ice observations involve diving operations, frazil and anchor ice sampling.

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

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

	1975	1976	1977	March 1978	June 1970	Sept. 1978	Dec. 1978	March 1979	June 1979	Sept. 1979	Dec. 1979	Jan. 1980	March 1980	March 1981	March 1982	Dec. 1982	July 1983	April 1984				Other sources of data (Numbers refer to references, p. 16-18.) See 1980 Annual Report for pre-1980 sources.
Data Products																						
-core descriptions			x												x		x	0				
-acoustic profiles w/nav.		x	x				x				x	x		x	x		x	0				7,20,24
-water temp./sal.		x	x									x										
-current meter		x	x																			
SUMMARY PRODUCTS																						
-Ice gouge maps			x	x	x									x	x		x	0				3,15,20
-Evaluation of ice hazards	x	x	x	x	x		x				x		x	x	x	x	x	0				2,3,5,6,14,15,19,20,21,25
-Interpretation of stamukhi and shoals			x	x											x			0				[illegible]
-Ice thickness morphology					x		x		x													2
-Sediment laden ice												x	x			x		0				13
-Offshore gravel resources		x	x	x	x		x	x	x					x		x	x					1,16,20
-Sediment transport regime	x		x	x	x	x	x	x	x		x		x	x	x	x		0				3,4,7,9,10,13,14,23
-Boulder patch			x				x	x			x	x		x	x							[illegible]
-Sediment distribution and character	x	x	x	x	x	x	x	x					x	x			x	0				1,9,...
-Engineering properties of sediment		x	x	x				x					x				x	0				
-Shoals and bedforms														x	x	x		0				
-Oceanographic observations	x	x	x				x	x	x		x		x									[illegible]
-Diving observations			x				x	x	x		x		x		x			0				2,3,...
-Barrier islands					x		x		x			x			x	x						7,10,21
-Coastal erosion and delta progradation		x	x		x				x			x			x			0				
-River processes		x						x									x					
-Storm surges							x						x		x							
-Charts		x		x	x				x		x			x				0				
-Permafrost/Resistivity																x						
-Strudel scour																x	x					23
-Freeze-up processes																	x	0				13
-Artificial islands																x						22

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

A. Geology Report for Proposed Beaufort Sea OCS Sand and Gravel Lease Sale, by Scott R. Briggs.

B. A Summary of U.S. Geological Survey Marine Geological Data Collected in the Beaufort Sea, 1982, by E. W. Kempema, Peter W., Barnes, Erk Reimnitz, J. L. Asbury, and D. M. Rearic.

C. Inner Shelf Geology of Southeastern Chukchi Sea by Ralph E. Hunter and Thomas F. Reiss.

D. Nearshore Marine Geologic Investigations, Icy Cape to Wainwright, Northeast Chukchi Sea, by R. Lawrence Phillips and Thomas F. Reiss.

E. Nearshore Marine Geologic Investigations in the vacinity of Barrow, Northeast Chukchi Sea, by R. Lawrence Phillips and Thomas F. Reiss.

F. Ice Gouging Characteristics and Processes, by Peter W. Barnes, Douglas M. Rearic, and Erk Reimnitz.

G. Characteristics of New Ice gouges Developed Between 1975 and 1982. Elson Lagoon to Camden Bay Alaska, by Peter Barnes and Douglas M. Rearic.

H. Pack Ice Interaction with Stamukhi Shoal, Beaufort Sea, Alaska by Erk Reimnitz and Edward W. Kempema.

I. Ice Gouge Infilling and Shallow Shelf Deposits in Eastern Harrison Bay, Beaufort Sea, Alaska, by Edward W. Kempema.

J. Sixty meter Deep Pressure Ridge Keels in the Arctic Ocean from geological hvidence by Erk Reimnitz, Peter W. Barnes and R. Lawrence Phillips.

K. Analysis of Hommocky Subbottom from Repetitive Observations North of Tegvariak Island, Beaufort Sea, Alaska, by Stephen Wolf and Peter W. Barnes.

IX. Needs for further study:

The present state of knowledge continually improves and is in constant flux and future studies should be based on this knowledge. Thus , what appears as future work in this report may be overshadowed by new information gained in the coming weeks and months or from a new field effort. As seen from the present, the primary emphasis of future work should include the following: a) determine the rates of ice gouging on the central and outer shelf from test lines and repetitive mosaics, b) study the freeze up process near the seabed, the inclusion of sediments in the ice canopy and actual formation of anchor ice on the seabed, c) study the instability of major bedforms along the Chukchi coast and their relation to ice and currents, d) determine the engineering character of seabed sediments in the vicinity of ice gouges and determine the variability of these characters in the vicinity of a single gouge, e) determine the control on seabed morphology from ice interaction and ascertain the feed-back loops that control the stamukhi zone, f) study Holocene stratigraphy as it relates to permafrost history, gravel resources, and maximum ice events on the Chukchi and Beaufort shelves, g) develope cooperative programs with the Canadians to compare processes and problems they have encountered on their arctic shelves and relate these to questions we have on Alaskan shelves.

Petroleum development is proceeding into deeper and deeper water, an area where our knowledge is limited because of limited data base. ‘Thus, as we have noted in past years, a larger vessel will be needed to properly assess the environment of the outer shelf of the Chukchi Sea and the outer shelf and upper slope of the Beaufort Sea planning areas.

We would hope that the use of a larger vessel would lead to more cooperative interdisciplinary studies. We would suggest the following study areas which would be productive for OCSEAP and for inter-disciplinary science. The planning for such cooperative studies if they are to be successful will require a year or more of lead time and extensive communication among Principal Investigators.

1) Bottom-feeding by whales and walrus - this subject is of recent interest in the Bering Sea and similar marks appear to be present in the Chukchi. 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 the geologic 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) 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.

4) 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.

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 (Ship and field trips)

1.)' Ship and field trips

The 1982 field season on the R/V KARLUK ran from July 10 to October 7 1982. During this time, geologic and environmental data was collected from the Canadian Border to Nome primarily in the nearshore zone.

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
Steve Wolf	Geologist	U.S.G.S., Marine Geology
Ed Kempema	Geologist	U.S.G.S., Marine Geology
Scott Graves	Geologic Field Assistant	U.S.G.S. , Marine Geology
Doug Rearic	Geologist	U.S.G.S., Marine Geology
Jeffrey Asbury	Geologic Field Assistant	U.S.G.S. , Marine Geology
Tom Reiss	Physical Science Technician	U.S.G.S., Marine Geology
Tony Campbell	Geologic Field Assistant	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 areas in the Beaufort and Chukchi Seas that have not previously been studied, or addressing specific topical questions. Significant project efforts during the previous year were:

a) Determination of rates of ice gouging of the inner shelf.
b) Preparation of the annual report.
c) Preparation of manuscripts for internal and external publication.
d) Preparation for and execution of a 12 week field season in the Beaufort and Chukchi Seas.
e) Editorial chores associated with multi-disciplinary volume on OCSEAP Beaufort Sea Studies.
f) Surveys of the Chukchi Sea, with preliminary interpretations of the data collected this year and supplemented by a re-evaluation of data collected in 1982 and 1975.

g) Continued studies of shoals in the stamukhi zone, including side-scan-sonar mosaics of small areas.
h) Writing and editing sections of Beaufort Sea synthesis volume.

4) Data collected or analyzed:

Data Type	km of records collected
Side scan sonar	1000 km
Bathymetry profiles	1150 km
High resolution seismic records	700 km
Occupied dive observatory	7 sites
Sediment samples	63 sites
Ice samples	44 sites

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.

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