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GEOTECHNICAL PROPERTIES OF SEDIMENTS FROM THE CONTINENTAL SHELF SOUTH OF ICY BAY, NORTHEASTERN GULF OF ALASKA

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This report is preliminary and has not
been edited or reviewed for conformity
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Geotechnical properties of sediments from the continental shelf south of Icy Bay, northeastern Gulf of Alaska

by

Paul R. Carlson, William P. Levy, Bruce F. Molnia
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INTRODUCTION

Studies of geotechnical properties of marine sediments have recently intensified as the search for natural resources has expanded on the continental shelf. The U. S. Geological Survey has begun a detailed evaluation of geologic environmental conditions in continental shelf regions in order to facilitate safe development of continental shelf resources. Investigations of geohazards in the northeastern Gulf of Alaska (Fig. 1) began in 1974 when 6500 km of high and medium resolution seismic reflection data were collected from the eastern gulf between Yakutat and Montague Island (Carlson, Bruns and Molnia, 1975; Von Huene and others, 1975). The first extensive sediment sampling program was begun in 1975 when approximately 400 samples of continental shelf sediments were collected from the same area of the gulf (Carlson and others, 1977b). A limited number of geotechnical measurements were made from these samples and samples collected by subsequent programs, however, systematic measurement of geotechnical properties was not started until the 1977 cruise of the NOAA ship DISCOVERER. Once unstable environments or "geohazards", such as slumps and slides, are delineated, geotechnical testing is an important means of quantifying such geologic processes and consequently furthering our understanding of them.

The purposes of this report are two-fold: (1) to report variations of physical properties in 1-2 meter gravity cores and (2) to recognize any variations in the areal distribution of these properties within and adjacent to an area of mass movement in the northeastern Gulf of Alaska.

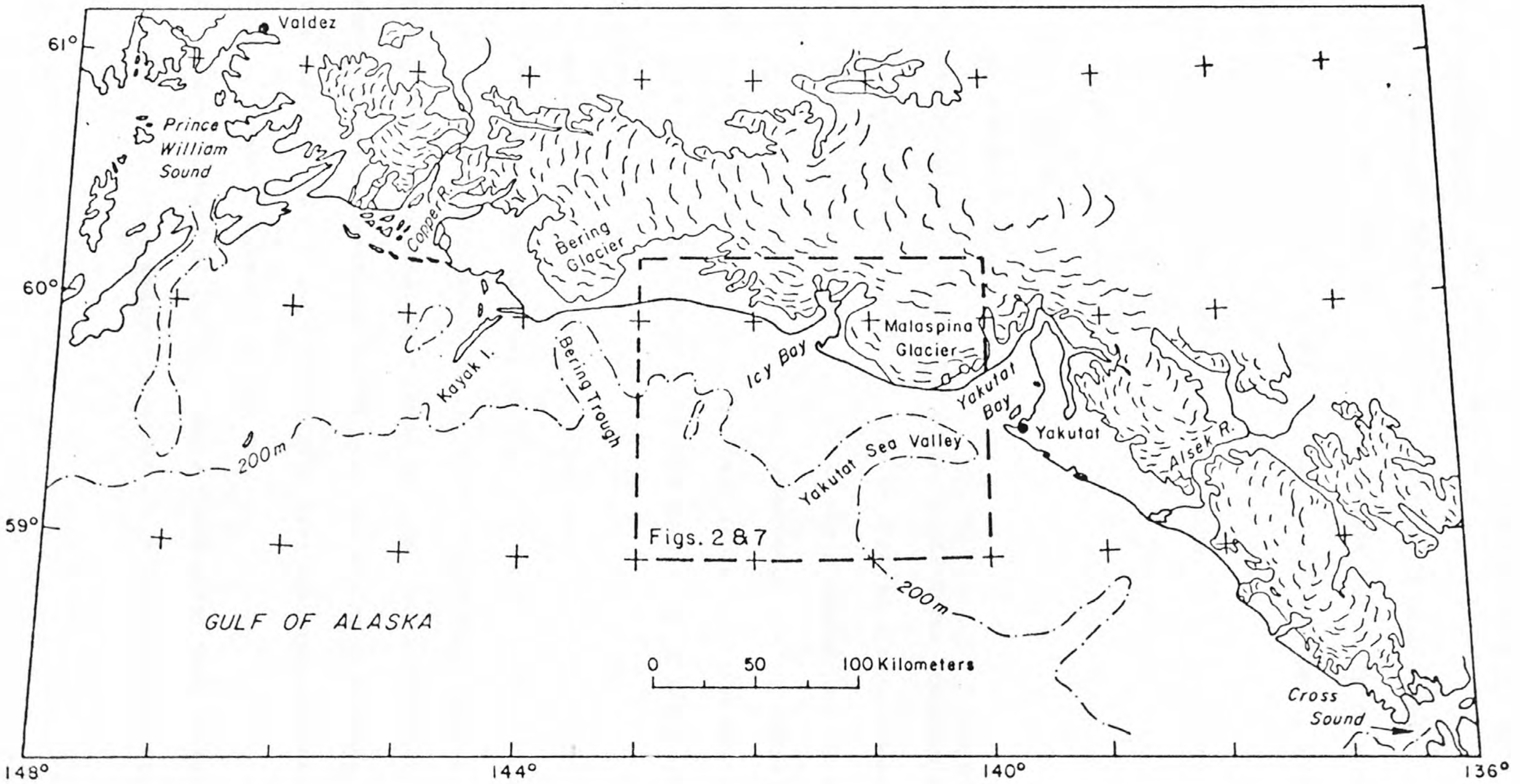

Figure 1. Location map of the northeastern Gulf of Alaska.

Geologic Setting

The northeastern Gulf of Alaska is an area of high seismicity due to its proximity to the intersection of the Pacific and North American crustal plates. To the west of this area, the Pacific plate is being subducted beneath the North American plate along the Aleutian Trench, to the east a strike-slip motion persists between the two plates. Oblique underthrusting predominates in the study area itself (Plafker, 1971). The result is a complex series of faulted and folded structures underlying the continental shelf (Bruns and Plafker, 1975). Many of these Tertiary units have been truncated, perhaps by the glacially controlled rise and fall of sea level. Both seismic and sedimentologic evidence point to glaciation of the shelf during the Pleistocene (Carlson and others, 1977a; Molnia and Carlson, 1978). Glacially derived gravels, sands, and muds presently crop out on the outer edge of the shelf whereas on the middle and inner shelf, the till-like materials are covered by a wedge-shaped, Holocene-aged unit that grades from sands in the near shore to clayey silts which is the dominant sediment type over the bulk of the shelf (Carlson and others, 1977b, Molnia and Carlson, 1975).

Fine sediment (glacial flour) is being carried into the gulf by rivers and streams that drain glaciated areas of the Bering and Malaspina Glaciers. The concentration of suspended sediment can reach exceedingly high values during late summer, the time of maximum glacial melting. Values as high as 4000 mg/l have been measured by Gustavson (1975) near the mouths of streams draining the Malaspina Glacier. Feeley and Cline (1977) have measured concentrations of 23 mg/l in the nearshore waters of the gulf. .

In the area seaward of Icy Bay, where these cores were collected (Fig. 2), the thickness of Holocene sediment reaches 225 m (Carlson and Molnia, 1975).

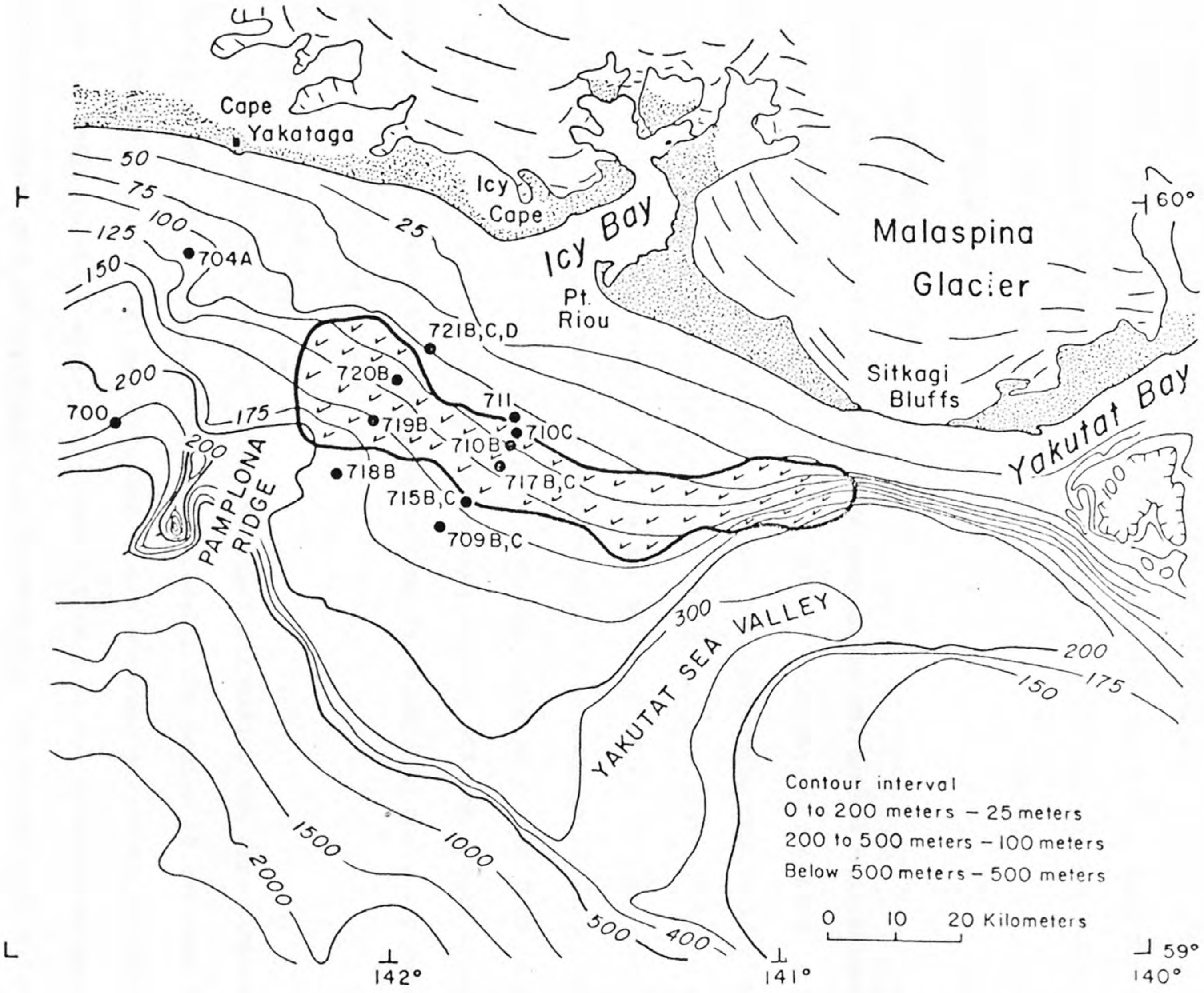

Figure 2. Bathymetric map showing location of Icy Bay - Malaspina slump zone (modified from Carlson, in press) and locations of gravity cores taken from NOAA ship DISCOVERER, March 1977 (see Table 1 for descriptions).

Pb-210 measurements on core 717 yielded an accumulation rate of approximately 6 mm/yr (C. Holmes, oral communication, 1977).

Of all the slumps and slides described in the Gulf of Alaska, the Icy Bay-Malaspina slump is the largest covering an area of about 1080 km^2 (Carlson and Molnia, 1977; Carlson, in press, Hampton, and others, 1978). This large volume of sediment (32 km^3) has moved on a slope of less than 0.5°. Mass movement occurs when the combination of forces acting on a sediment mass exceeds the resistance offered by the sediment strength. In the Gulf of Alaska, it has been shown that the build up of excess in-situ pore pressure is the controlling factor in reducing the shearing resistance of the sloping sediment and consequently decreasing its stability, thus accounting for such a mass movement on so gentle a slope (Hampton and others, 1978). High rates of sedimentation are a significant factor in producing the excess pore pressures that render submarine slopes potentially unstable (Morgenstern, 1967; Sangrey, 1977). Rapid accumulation of sediment plays a major role in the build-up of excess pore pressures in the Icy Bay-Malaspina slump area that results in an underconsolidated condition of the sediment. Excess in-situ pore pressure can also result from periodic shaking caused by earthquakes and from wave loading effects. Both these effects are considered likely triggering mechanisms for slumps in the study region (Carlson, in press; Hampton and others, 1978).

Acknowledgements

We thank Richard Feeley (NOAA, Seattle) for making the arrangements that permitted one of us (Hampson) to participate in the cruise of the NOAA ship DISCOVERER. Thanks also are extended to the numerous personnel on the cruise who assisted in the sampling processes. Edward Clukey provided advice about the measurement and interpretation of geotechnical properties and critically reviewed the manuscript. Thomas Atwood and Charles Fitts assisted in the laboratory analyses.

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DATA COLLECTION

Shipboard sampling and analyses

The cruise of NOAA's DISCOVERER, March 14 to 23, 1977, to the northeastern Gulf of Alaska concentrated on the region between Bering Trough and Yakutat Sea Valley (Figs. 1 and 2). An attempt was made to collect 1-2 m length gravity cores at stations planned for geochemical and suspended matter sampling. It was necessary to substitute a grab sampler at some locations because of sediment type. This report only shows the locations of the gravity cores (Fig. 2). The locations and descriptions of all samples will be included in another open-file report to be released at a later time.

Sixteen cores were collected in three transects across the continental shelf: (1) southwest of Cape Yakataga, (2) southwest of Icy Bay and, (3) southwest of Malaspina Glacier. Water depths of the samples ranged from 50 to 200 m (Fig. 2) and transects 2 and 3 were across an area of mass movement found on the middle to outer shelf seaward of Icy Bay and the Malaspina Glacier (Carlson and Molnia, 1977; Carlson, in press).

Descriptions of the sediment in the core catcher and cutting head were made after recovery. A hand-held vane shear apparatus was used to obtain undrained strength measurements on board the ship immediately after the samples were recovered. A known volume piston-type subsampling device was used to determine bulk density. These data are included in Tables 1-4.

Laboratory sampling and testing

The gravity cores, were kept in their original liners and tightly capped at both ends. They were stored upright and kept in cold storage both on board the vessel and in the laboratory to prevent flow-induced deformation and retard growth of bacteria. The cores were split in half longitudinally. Half the core was thoroughly described lithologically, X-rayed, sealed, and put back in cold storage for preservation as an archival sample. The second half was used for sediment subsampling.

All subsamples were taken from the center portion of the working half to avoid the outer rind that may have been disturbed by the coring process. Moisture content subsamples were taken immediately after splitting the core. They were placed in pre-weighed sealed bottles and then oven-dried at 105°C. The values calculated for percent dry weight were corrected for a 33.5 ppt. average salt content based on recent regional oceanographic studies of the area (Royer, 1977).

Undrained shear strength was measured in the laboratory at various depths in the core using a laboratory hand-cranked vane shear apparatus (Wykeham Farrance Eng. Ltd.[1/]). Predominantly sandy layers were not measured, as vane shear results in such materials are generally not considered reliable indicators of undrained shear strength. A standard rotation of the vane of 90 degrees/minute was used (Monney, 1974). Peak undisturbed shear strength as well as remolded shear strength was recorded at each depth.

Subsamples taken for grain size analysis were wet sieved to separate the sand sized fraction (2,000 μ to 62 μ) from the silt (62 μ to 4 μ) and clay (< 4 μ) sized fraction. Size analysis of the sand grains was obtained by using a 2 meter settling tube (Gibbs, 1974), whereas the silt and clay sizes were

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[1/] Any use of trade names and trademarks in this publication is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

analyzed using a hydrophotometer (Jordan and others, 1971). Mean grain size and sorting were calculated using Folk and Ward (1957) graphic solutions.

Atterberg limits were determined for two or three depths in each core using the standard methods for liquid limit and plastic limit tests as specified in ASTM (1972) D 423-66 and D 424-59 respectively.

INDEX PROPERTIES OF THE SEDIMENTS

Structures within the cores were observed by comparing visual core descriptions (Table 1) with X-rays taken of the same half. Deformation due to the coring process seemed minimal in these cores, confined primarily to edge effects and induced deformation at the very top surface and bottom of each core. The moisture contents covered a wide range of dry weights with a low of 29% and a high of 105%. Average moisture content was 56% (Table 4). Moisture content samples were assumed to be reflective of in-situ values as little de-watering was observed in the cores.

Shear strengths, as expected with such high moisture contents, were low. Peak strengths measured with the hand cranked vane averaged .04 kg/cm^2 in the cores and ranged from .01 kg/cm^2 to .13 kg/cm^2. Remolded strength values were close if not identical to peak shear strengths, suggesting that the sediments are insensitive in nature. Shipboard shear strength measurements with both the Torvane and hand-held vane (Table 4) suggest a weak surface layer in many of the tested cores. The weak surface layer in many instances corresponded with the highest moisture content in the core.

Nine of the cores were selected for further testing. Grain size analysis as well as Atterberg limit testing was performed in addition to the tests previously mentioned. These nine were chosen as representative samples as they were collected inside and outside the Icy Bay-Malaspina slump zone (Fig. 2).

A comparison of the engineering properties of cores collected within the slump with those collected in the adjacent area not subject to the movement was the objective of this testing.

Silt was the dominant grain size class in the selected cores averaging 71%, whereas clay averaged 28% and sand only 1%. Two cores contained layers that measured 9% sand - cores 710C and 711 - both within the slumped sediment. Mean size and sorting statistics were quite uniform with depth. The mean size ranged from 5.0 Ø to 8.9 Ø and averaged 7 Ø. All nine cores showed poor sorting with only three subsamples having sorting coefficients of less than 2 (Table 2).

The high silt percentages help to explain the low plasticity indexes observed from Atterberg limit tests. A low mean value of 10.3 and narrow range from 3.5 to 19.5, again suggests the insensitive nature of the sediments. As was the case with the grain size distribution, no significant change with depth in the core was recorded.

DISCUSSION

Our examination of cores collected in the slump mass and outside of it, show no significant variation in geotechnical properties. Looking at the statistics derived from Atterberg limit testing (Table 3), we see little variation with depth in the cores and little variation between cores tested. All cores tested show high liquidity indices which indicate a possible underconsolidated condition; a logical finding for this area where the rate of sediment accumulation is about 6 mm/yr (C. Holmes, 1977, oral communication). On the standard Plasticity chart (Casagrande, 1948), all nine cores plot parallel to the A-line and can be characterized as low plasticity silts, (ML group of the Unified Soil Classification, Fig. 3). This plot tends to indicate that the sediments are from similar geologic origins and compositions. This type of general sediment classification correlates well with the actual grain size distribution of the cores (Table 2).

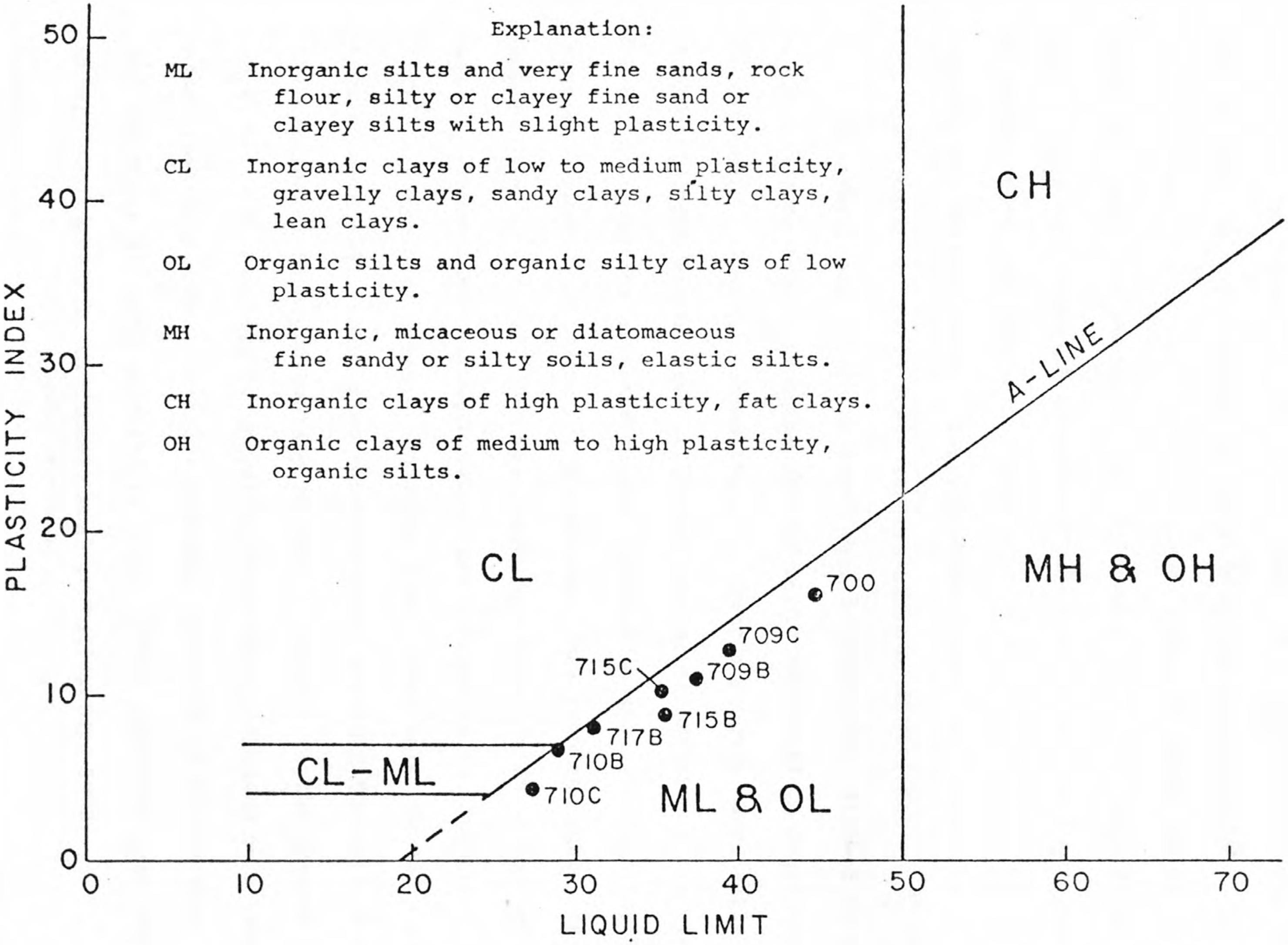

Figure 3. Average Atterberg liquid limits and plasticity indices for tested cores plotted on standard plasticity chart (after Casagrande 1948).

Using the clay percentage (Table 2) and plasticity index (Table 3), Skempton's (1953) activity ratio (plasticity index/clay fraction) was calculated (Fig. 4). The average of all the activity ratios is 0.34, which classifies the clays as "inactive" according to Skempton's ratio. He found that the smaller the activity, the smaller the contribution of cohesion to the shear strength. A plot of the clay fraction versus the plasticity index (Fig. 4) shows the sample points falling about the kaolinite standard, ranging toward the illite clay group. X-ray diffraction of the clay minerals from the Icy Bay-Malaspina shelf area supports this classification with measured values of 30-40% illite and 60-70% kaolinite-chlorite (Molnia and Fuller, 1977). X-ray analyses show little smectite[2/] in the area and the low Atterberg limits again support these observations.

At several stations, two cores were obtained that allowed us to compare the miniature vane shear strengths for sediments collected in nearly the same location on the shelf. Figure 5 shows that the shear strengths vary nearly as much in the duplicate cores as in cores collected several kilometers apart. In most of the cores, there is the expected slight increase in strength with depth in the sediment from about 0.02 kg/cm^2 (2 kiloPascals (kPa)) in the upper one-half meter to about 0.5 - 0.08 kg/cm^2 (5-8 kPa) below one meter depth in the sediment (Figs. 5 and 6). These shear strength values are comparable to those reported by Schuh (1977) for the near surface sediments from a bore hole located a few kilometers east of core 704. Schuh also reported shear strength for Gulf of Alaska sediments that increased to approximately 35 kPa at sediment depths greater than 40 m (Fig. 6b). An estimate of undrained shear strength based on a representative mean plasticity index of 15 for normally consolidated marine muds (Osterman, 1959) and the shear strength measured by Schuh (1977) indicates that the sediment is underconsolidated (E. C. Clukey, oral communication, 1978).

[2/] Smectite is a general term for a group of clay minerals that include Montmorillonite, Nontronite, Saponite, etc.

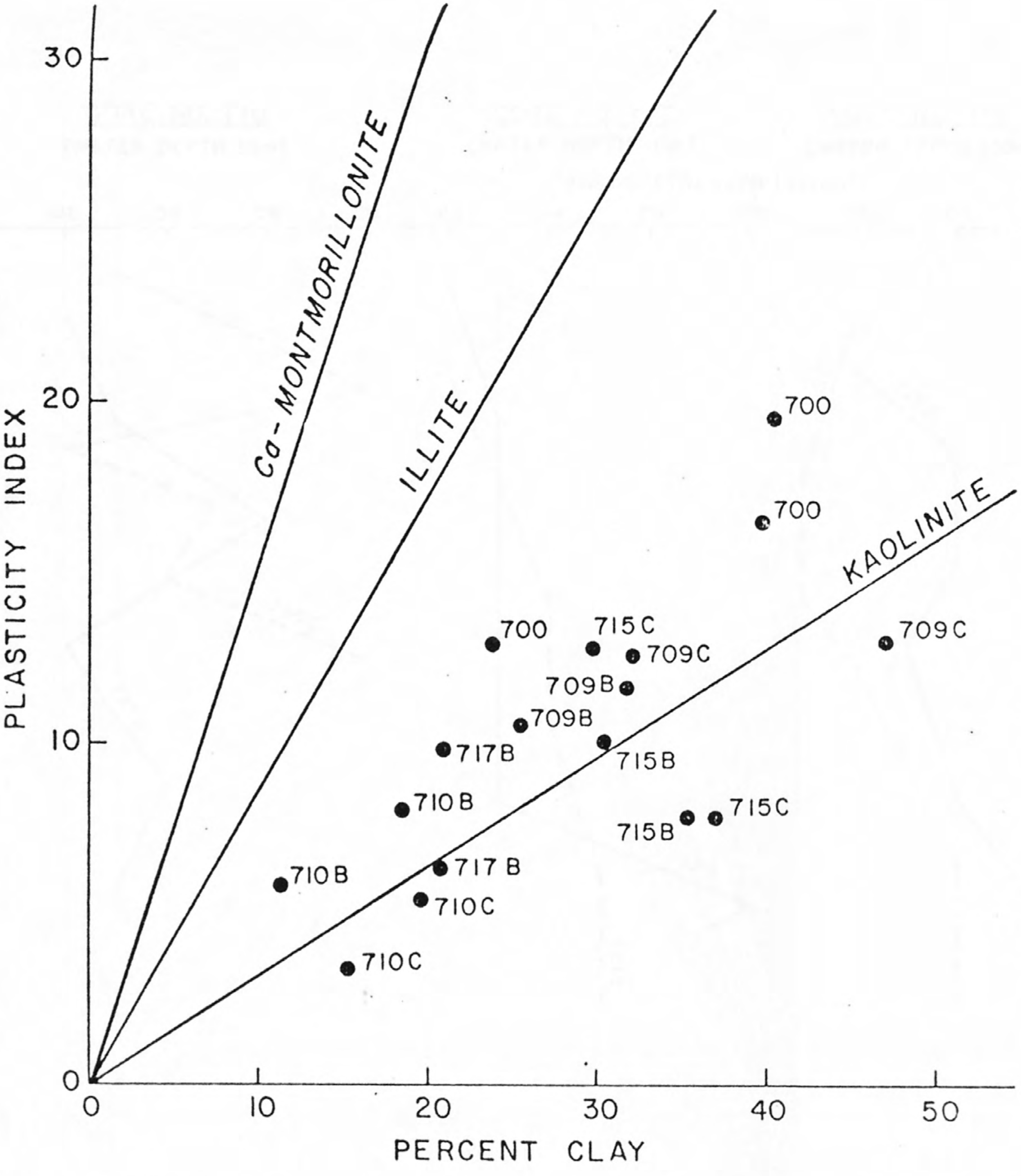

Figure 4. Activity ratios (plasticity index/clay fraction) for tested cores shown with clay standards (after Skempton, 1953).

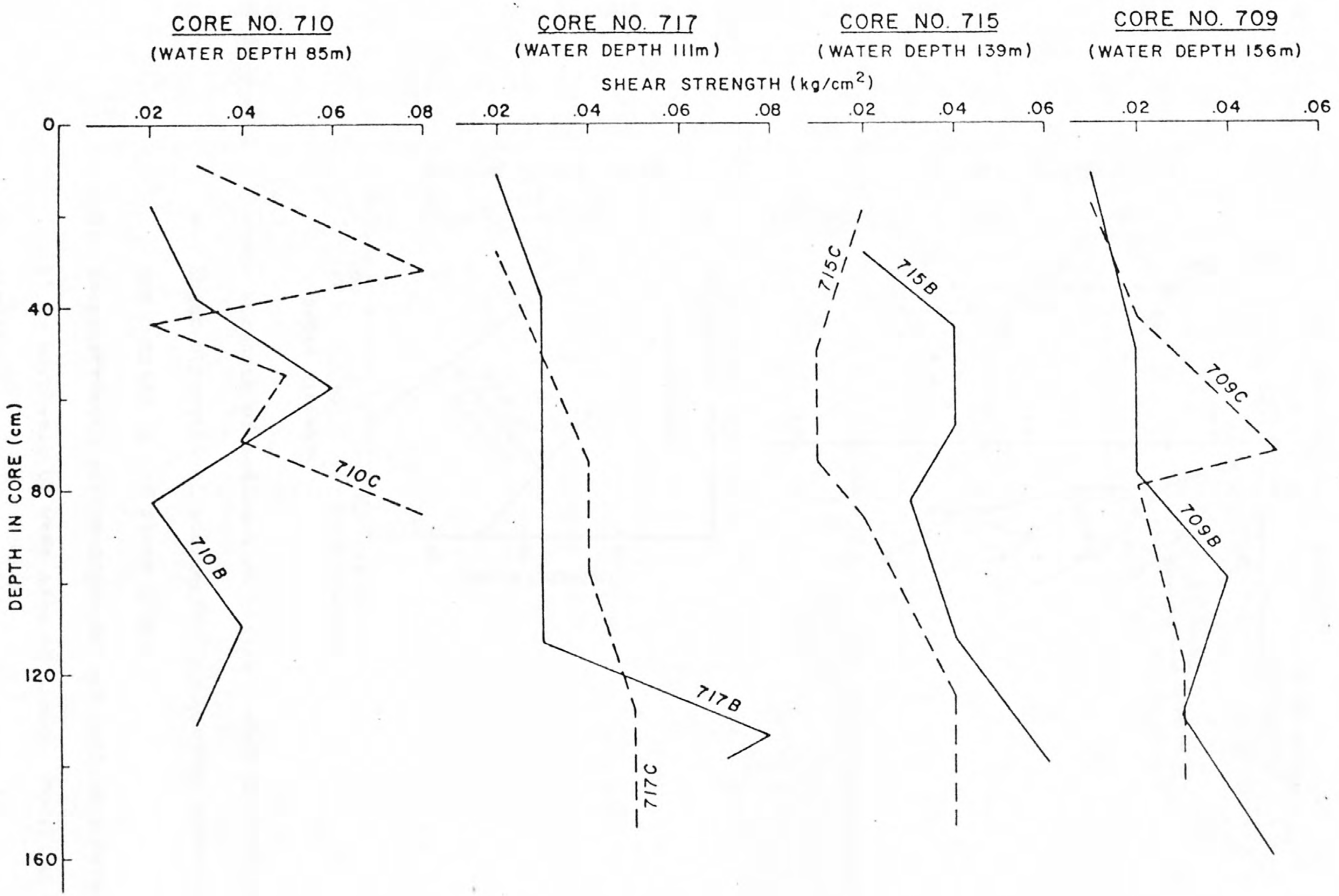

Figure 5. Comparison of vane shear strengths measured in the laboratory for cores at approximately same locations.

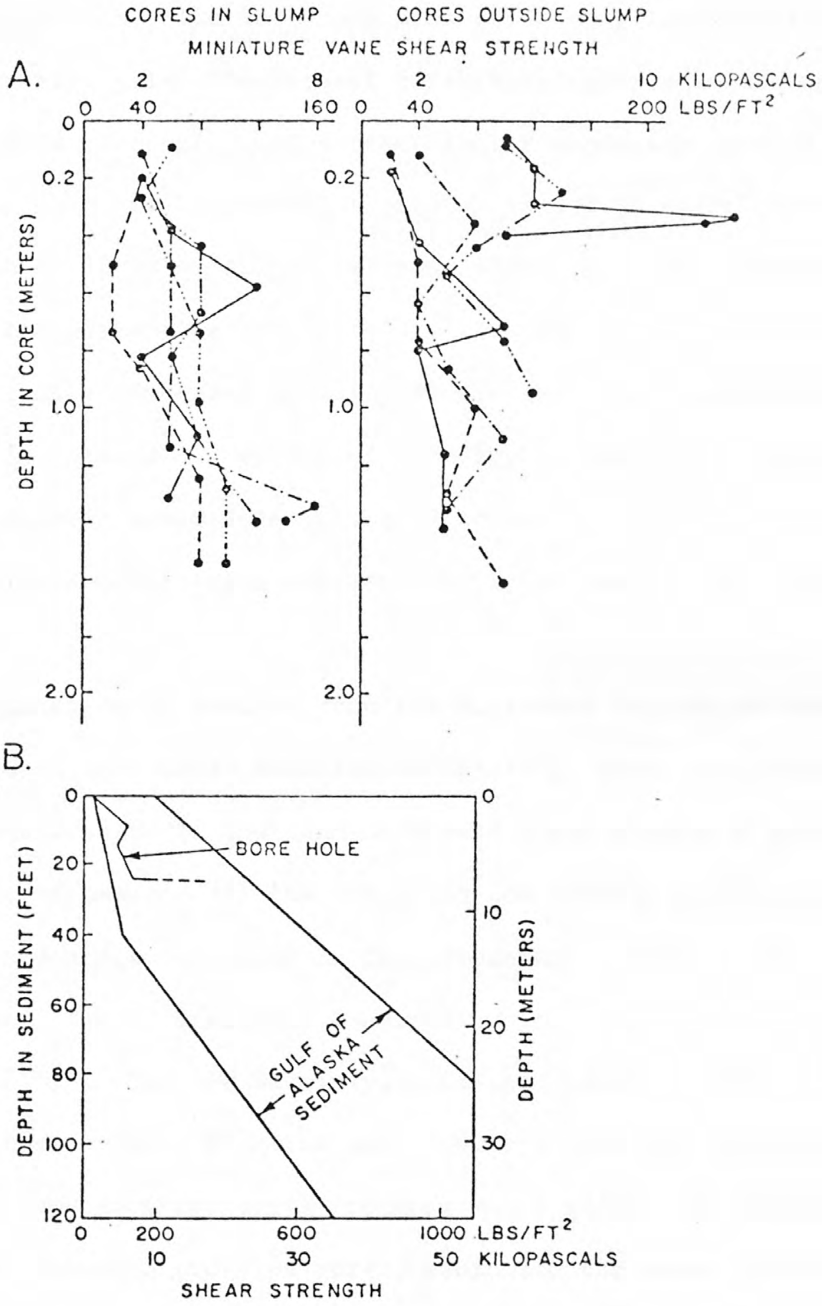

Figure 6. Shear strength of sediment in the northeast Gulf of Alaska

a. Shear strengths of sediments from gravity cores collected in and outside of the slump area.

b. Shear strength versus depth of sediment in a bore hole about 15 km northwest of west edge of slump. Modified from Schuh (1977).

A comparison of cores collected within the limits of the slump mass to cores collected outside the slump area shows very little difference in shear strengths (Fig. 6a). The largest difference appears in the upper 0.5 m of core 721 D, a core collected in the sandier substrate located landward of the slump. In core 721 D, values of greater than 0.10 kg/cm^2 (10kPa) were measured at a depth of 33-35 cm in the sediment (Table 4). This increase in peak shear strength can perhaps be attributed to the increased amount of sandy silt present as thin laminae, observed visually (Table 1) and corroborated by X-radiographs. However, in core 721 C, collected from approximately the same location as 721 D, the largest peak shear strength, 0.07 kg/cm^2 (6.9 kPa), was measured at about 25 cm depth, showing again the variability of peak shear strengths in these sediments.

A comparison of results from the miniature vane shear measured in the lab, and hand-held vane shear measured on the ship, shows very close agreement (Table 4). This suggests that (1) the hand-held vane shear apparatus produces reasonable peak shear values and (2) the cores did not undergo excessive drying out before being opened and sub-sampled in the laboratory. These cores would be classified as low-sensitive to insensitive according to a scale derived by Skempton and Northey (1952). The low sensitivity values (Table 4) again suggest uniformity between these cores. With low sensitivity values such as these, the extensive burrowing seen in these cores probably won't effect the strength too significantly.

Shear strength profiles rarely exhibited the usual inverse relationship between moisture content and shear strengths (Table 4). This may be attributed to the many minor grain size variations in the sedimentary column.

Sediment size characteristics (Table 2) in selected cores showed no visible trends with depth. Percentages of sand, silt and clay in the cores categorize the sediments as clayey silts with some silty clay present in core 700. Sorting is in the poor to very poor range and would be considered texturally immature according to Folk (1951). This is common in environments which typically have relatively low mechanical energy exerted on the deposited sediments. Mean grain size also varies little at depth or between cores.

Comparison with earlier work done by Carlson and others (1977b) showing distribution of surface sediments in the same region (Fig. 7), indicates little difference in overall sediment types. Both sets of data indicate clayey silts at the surface in approximately the same percentages and comparable mean sizes and sorting.

X-radiographs taken of the cores to observe sedimentary structure for comparisons with visual observations of the core (Table 1) showed three different types of features. The first type is a relatively undisturbed parallel lamination of the clayey silts with some pinching out of laminae. The second type consists of areas that are seemingly bioturbated, probably by worm burrowing. The X-radiographs show no laminations in these areas, or show laminae that are truncated. Sometimes elliptical pods of a different density than the surrounding material are clearly seen in X-radiographs. From examining these features after we split the cores, we believe them to be burrows filled with sandy silt and saturated with water. The third feature seen in the X-radiographs of these cores consists of sandy-silt layers that are seemingly deformed. These appear as sandy silt beds that generally are truncated and jumbled, often with sandy silt and clayey layers intermixed. The sandy silt might also appear as sub-rounded to angular forms in such a deformed area. In many cases, these areas are difficult to distinguish from the bioturbated areas. Here again laminations are absent as if bioturbated, but in some cases they may appear to be present as swirls or folds. The distinct elliptical burrow pods are gone, replaced by the above mentioned forms that are

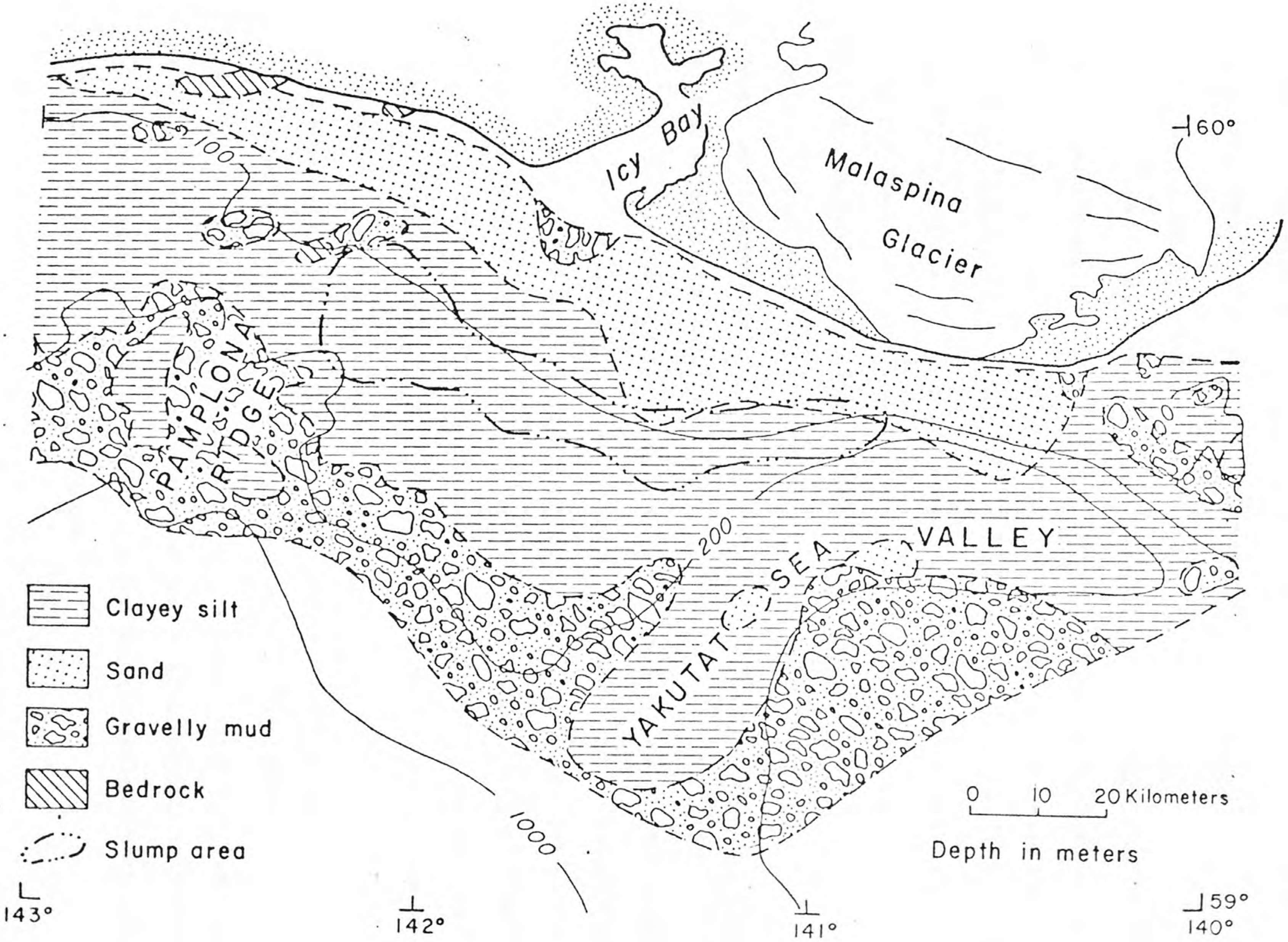

Figure 7. Sediment distribution map showing location of Icy Bay - Malaspina slump zone (after Carlson, in press).

always sand or sandy silt. This deformed case was seen much less frequently than the bioturbated structures in these cores.

SUMMARY AND CONCLUSIONS

This report is a preliminary evaluation of the index properties of northeast Gulf of Alaska shelf sediments. Results indicate these shelf sediments to be of a relatively weak nature. The samples were water saturated with average moisture contents over 50% and were characterized by poorly sorted clayey silts with slight plasticity. Undrained vane shear strength measurements suggest that the samples are insensitive with peak strengths averaging a weak .04 kg/cm^2.

The measured index properties suggest that the sediments in this area of the continental shelf are in an underconsolidated state. The high rate of sedimentation (6 mm/yr)when associated with a build up of excess pore pressure, leaves the sediment prone to failure.

No differences were recognizable in data from samples collected within the Icy Bay - Malaspina slump mass when compared with those from surrounding sediments pointing up the need for deeper cores that penetrate below the base of the slumped sediment. Deeper cores are also needed as the upper few meters are commonly affected by factors such as densification due to the coring process, chemical bonding and bioturbation effects. At depth, these factors become less of an influence.

More extensive testing is the obvious next step in a detailed study of these offshore phenomena. Geotechnical engineering techniques prove very important as tools to quantify sediment properties that are associated with submarine slumps and slides. Further testing using standard geotechnical methods to correlate with other similar studies, will bring a better understanding of shelf sediment dynamics to engineer and geologist alike.

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Table 1. Location, Depth, Length, and Description of Cores.

Core No.	Latitude Longitude	Water Depth (Meters)	Core Length (Meters)	Description of Sediment
*700	59°42.3' 142°41.3'	278	2.00	Homogeneous green-gray mud, slight organic staining a few burrows.
704B	59°55.1' 142°31.1'	104	1.49	Olive-black mud, much burrowing some hollow, some mud or sand filled. Much organic staining. Few plant stems and shell frags.
*709B	59°34.5' 141°51.5'	156	1.68	Green-gray mud, some sand-silt filled burrows and slight organic staining. Some sand-silt horizons and lenses.
*709C	59°34.6' 141°51.5'	156	1.51	Olive-black mud with sand-silt and mud filled burrows. Deformed sand-silt horizon. Moderate organic staining, some plant stems.
*710B	59°41.3' 141°40.4'	85	1.42	Green-gray mud, sand-silt filled burrows. Organic staining. Lower 1/3 much interfingering sand-silt lenses.
*710C	59°41.8'	85	1.05	Same as 710C with larger basal sand-silt layer.
711	59°42.6' 141.39.7'	82	.33	Same as 710B and C only sand-silt lenses interfingering throughout whole length of core.
715B	59°36.4'	139	1.49	Gray mud, some sand-silt filled burrows, shells and shell fragments, and slight organic staining. Deformed sand-silt layers.
715C	59°36.4' 141°47.6'	139	1.60	Green-gray mud, hollow, sand-silt and mud-filled burrows. Moderate organic staining.
*717B	59°39.3' 141°42.2'	111	1.56	Gray mud, few sand-silt filled burrows, some distinct and some interfingering sand-silt and mud lenses. Much organic stain.
717C	59°39.3' 141 42.2'	111	1.61	Same as 717B only color grades from olive-black to gray.
718B	59°38.6' 142°07.3'	191	.73	Gray mud, slight, burrowing, plant stems. Some distinct sand lenses in lower half, very slight organic staining.
719B	59°42.7' 142°01.9'	141	1.48	Olive-gray mud with a few burrows and plant stems, sandy-silt lenses and much organic staining..
720B	59°45.7'	100	1.45	Green-gray mud, mud and sand-silt filled burrows. Interlayered mud and deformed, possibly burrowed, sand-silt lenses. Little organic stain.
721C+B	59°48.1' 141°53.0'	70 m	1.00	Interfingering olive-gray sandy-silt and mud lenses throughout. Distinct sand-silt lenses. Dense organic staining, some burrows and shell fragments.
721D	59°47.9' 141°52.9'	70 m	.44	Gray mud with sand-silt lenses and laminae, some burrowing. Moderate organic staining.

*Cores analyzed for size analyses and Atterberg Limits (see Table 2 and 3).

Table 2. Sediment Size Characteristics. (*Equations of Folk and Ward, 1957).

Core No.	Depth in Core (cm)	% Sand	% Silt	% Clay	Mean Size* (ø)	Sorting* (ø)
700	17-19	2.3	58.1	39.6	7.6	2.5
	61-63	0.0	44.5	55.5	8.8	2.3
	78-80	0.0	59.9	40.1	7.9	2.3
	142-144	.7	72.9	26.4	7.1	2.2
	158-160	1.3	74.9	23.8	6.8	2.2
	191-193	0.0	40.0	60.0	8.9	2.3
709B	15-17	0.0	74.5	25.5	6.8	2.4
	76-78	0.0	75.7	24.3	6.9	2.1
	104-106	0.0	61.6	38.4	7.7	2.5
	160-162	3.4	64.7	31.9	7.5	2.2
709C	16-18	0.0	62.5	37.5	7.7	2.4
	42-44	0.0	53.0	47.0	8.3	2.3
	71-73	0.0	77.6	22.4	6.5	2.1
	79-81	.1	61.7	38.2	7.8	2.4
	117-119	0.0	61.7	38.3	7.7	2.5
	143-145	0.0	67.8	32.2	7.5	2.3
710B	17-19	2.3	79.2	18.5	6.2	2.0
	57-59	0.0	78.9	21.1	6.5	2.1
	82-84	1.6	71.8	26.6	7.1	2.3
	127-129	0.0	88.7	11.3	5.6	1.5
	131-133	0.0	74.5	25.5	7.1	2.1
710C	9-12	1.7	78.6	19.7	6.4	2.0
	27-30	0.0	82.3	17.7	6.2	2.0
	41-44	0.0	71.3	28.7	7.2	2.3
	68-71	0.0	66.5	33.5	7.6	2.3
	83-86	9.0	75.9	15.1	6.0	2.0
	98-101	5.9	87.3	6.6	5.0	1.1

Table 2. (cont'd) Sediment Size Characteristics. (*Equations of Folk and Ward, 1957).

Core No.	Depth in Core (cm)	% Sand	% Silt	% Clay	Mean Size* (ø)	Sorting* (ø)
711	3-5	9.8	72.4	17.8	6.0	2.2
	13-15	.7	78.1	21.2	6.4	2.2
	26-28	0.0	74.4	25.6	6.7	2.4
715B	80-84	0.0	69.7	30.3	7.3	2.3
	86-90	2.1	76.0	21.9	6.4	2.2
	128-141	0.0	64.9	35.1	7.8	2.2
715C	17-20	.1	70.1	29.7	7.2	2.4
	85-87	0.0	63.0	37.0	7.5	2.6
	124-126	0.0	72.9	27.1	7.0	2.4
	154-156	0.0	73.9	26.1	7.0	2.4
717B	10-12	1.1	80.7	18.2	6.0	2.1
	74-76	0.0	78.7	21.3	6.7	2.1
	100-104	0.0	71.1	28.9	7.2	2.3
	133-136	2.1	77.0	20.9	6.7	1.9
	147-150	0.0	79.7	20.3	6.5	2.2

Table 3. Atterberg Limits

Core No.	Depth in Core (cm)	Liquid limit W_l	Plastic limit W_p	Plasticity Index $I_p = W_l - W_p$	Liquidity Index $I_l = \frac{W - W_p}{W_l - W_p}$
700	19-37	46.20	29.70	16.50	3.62
	84-103	46.30	26.80	19.50	2.09
	151-167	42.00	29.05	12.95	2.83
709B	22-41	35.30	24.80	10.50	4.60
	125-150	39.91	28.28	11.63	2.80
709C	26-42	39.51	26.51	13.00	3.80
	119-149	39.50	26.84	12.66	2.68
710B	26-45	30.50	22.41	8.09	2.53
	104-122	27.58	21.77	5.81	5.17
710C	13-26	28.15	22.68	5.47	3.78
	71-83	26.51	23.06	3.45	7.97
715B	39-63	36.40	26.23	10.17	2.33
	110-133	34.75	26.92	7.83	2.82
715C	24-38	36.72	23.88	12.84	3.31
	94-104	34.08	26.24	7.84	6.46
717B	35-55	32.30	22.42	9.88	2.90
	115-133	29.95	23.50	6.45	4.80
Range		27.58-46.30	21.77-29.70	3.45-19.50	2.09-7.97
Average		35.05	25.16	10.27	3.79

Table 4. Shear strength, water content and bulk density.

	Laboratory Measurements					Shipboard measurements			
			Miniature Vane Shear						
Core No.	Sample Location (cm)	Moisture Content (% dry wt.)	Peak (Su) kg/cm^2	Remolded (Sr) kg/cm^2	Sensitivity (Su/Sr)	Sample Location (cm)	Hand held vane shear kg/cm^2	Torvane* (kg/cm^2)	Bulk Density (g/cc)
700	18.0	89.38	.01	.01	1.0	5.0	.01	.01	1.58
	37.0		.01	0	0.0	10.0	.01		
	62.0	104.07	.01	0	0.0	15.0	.01		
	79.0	67.65	.02	.02	1.0	20.0	.01		
	103.0		.03	.03	1.0	25.0	.01		
	126.0	72.75	.03	.03	1.0	30.0	.01		
	143.0	65.76	.05	.05	1.0	35.0	.01		
	167.0		.04	.04	1.0	40.0	.01		
	192.0	65.79	.03	.03	1.0	45.0	.01		
704B	22.0	63.88	.03	.02	1.5	5.0	.01	.03	1.59
	46.0		.05	.04	1.3	10.0	.01		
	67.5	50.22	.08	.07	1.1	20.0	.02		
	89.5	57.01	.05	.05	1.0	30.0	.01		
	116.0		.03	.02	1.5	40.0	.03		
	142.0	62.66	.03	.02	1.5				
709B	16.0	73.07	.01	.01	1.0	5.0	.01	.03	1.59
	49.0	55.98	.02	.03	0.7	10.0	.01		
	77.0	58.88	.02	.02	1.0	20.0	.01		
	100.0	60.89	.04	.04	1.0	30.0	.02		
	125.0		.03	.03	1.0	40.0	.02		
	161.0	61.35	.05	.04	1.3	50.0	.03		
709C	17.2	75.97	.01	.01	1.0				
	42.5	71.89	.02	.02	1.0				
	72.0	60.98	.05	.03	1.7				
	79.5	78.61	.02	.02	1.0				
	118.0	60.76	.03	.03	1.0				
	144.0	61.30	.03	.04	0.8				

*On Shipek grab samples only.

Table 4 cont'd. Shear strength, water content and bulk density.

	Laboratory Measurements					Shipboard Measurements			
Core No.	Sample Location (cm)	Moisture Content (% dry wt.)	Miniature Vane Shear Peak (Su) kg/cm^2	Remolded (Sr) kg/cm^2	Sensitivity (Su/Sr)	Sample Location (cm)	Hand Held Vane Shear kg/cm^2	Torvane* (kg/cm^2)	Bulk Density (g/cc)
710B	18.0	42.89	.02	.02	1.0	5.0	.01	.01	1.74
	38.5		.03	.03	1.0	10.0	.01		
	58.0	39.97	.06	.04	1.5	20.0	.03		
	83.0	51.78	.02	.02	1.0	30.0	.02		
	110.0		.05	.04	1.3	40.0	.03		
	132.0	49.02	.03	.03	1.0	50.0	.04		
710C	9.0	43.35	.03	.03	1.0				
	32.0	36.61	.08	.07	1.1				
	44.0	59.07	.02	.02	1.0				
	55.0	51.29	.05	.05	1.0				
	69.5	50.55	.04	.04	1.0				
	85.5	29.42	.08	.07	1.1				
711	14.0	44.98	.03	.03	1.0				
	27.0	43.03	.02	.02	1.0				
715B	28.0	49.90	.02	.02	1.0	5.0	.01	.05	1.68
	44.0		.04	.03	1.3	10.0	.01		
	66.5	47.33	.04	.04	1.0	20.0	.02		
	82.0	48.27	.03	.03	1.0	30.0	.02		
	113.0	53.17	.04	.04	1.0	40.0	.02		
	140.0	55.70	.06	.05	1.1	50.0	.02		
715C	19.5	66.36	.02	.02	1.0				
	45.0	85.38	.01	.01	1.0				
	73.5	85.41	.01	.01	1.0				
	86.0	76.90	.02	.02	1.0				
	125.0	55.35	.04	.04	1.0				
	154.0	55.78	.04	.04	1.0				

Table 4. cont'd. Shear strength, water content and bulk density.

	Laboratory Measurements					Shipboard Measurements			
			Miniature Vane Shear						
Core No.	Sample Location (cm)	Moisture Content (% dry wt.)	Peak (Su) kg/cm^2	Remolded (Sr) kg/cm^2	Sensitivity (Su/Sr)	Sample Location (cm)	Hand Held Vane Shear kg/cm^2	Torvane*	Bulk Density (g/cc)
717B	11.0	48.96	.02	.02	1.0	5.0	.01	.02	1.68
	38.0	51.08	.03	.03	1.0	10.0	.02		
	74.5	52.12	.03	.03	1.0	20.0	.02		
	102.0	54.46	.03	.03	1.0	30.0	.02		
	124.0		.03	.02	1.5	40.0	.03		
	144.0	40.27	.08	.07	1.1	50.0	.02		
	149.5		.07	.07	1.0	80.0	.05		
						90.0	.05		
						100.0	.05		
						110.0	.04		
717C	28.0	56.13	.02	.02	1.0				
	50.0		.03	.02	1.5				
	74.0	47.35	.04	.03	1.3				
	98.0	43.73	.04	.03	1.3				
	128.5		.05	.04	1.3				
	54.5	49.02	.05	.04	1.3				
718B	30.0	77.57	.03	.03	1.0	5.0		.01	1.59
	52.0	69.46	.02	.02	1.0				
	67.5	56.86	.03	.03	1.0				
719B	3.0	62.84	.02	.01	2.0	5.0		.02	1.63
	21.0	56.96	.02	.02	1.0				
	50.0	68.57	.03	.02	1.5				
	63.0	77.24	.01	.01	1.0				
	72.5		.01	.01	1.0				
	83.0	67.22	.02	.02	1.0				
	117.0	59.15	.02	.02	1.0				
	148.0	59.57	.04	.03	1.3				

Table 4. cont'd. Shear strength, water content and bulk density.

	Laboratory Measurements					Shipboard measurements			
			Miniature Vane Shear						
Core No.	Sample Location (cm)	Moisture Content (% dry wt.)	Peak (Su) kg/cm^2	Remolded (Sr) kg/cm^2	Sensitivity (Su/Sr)	Sample Location (cm)	Hand held Vane Shear (kg/cm^2)	Torvane* (kg/cm^2)	Bulk Density (g/cc)
720B	12.5	47.91	.02	.02	1.0	5.0		.12	1.67
	35.5		.04	.03	1.3				
	64.0	59.68	.02	.02	1.0				
	86.0	46.50	.03	.03	1.0				
	111.0	50.67	.05	.05	1.0				
	136.0	61.36	.03	.03	1.0				
712B*	3.0		.05					~0.0	1.59
	6.0		.08						
	13.0		.09						

*All Torvane measurements.

Core No.	Sample Location (cm)	Moisture Content (% dry wt.)	Peak (Su) kg/cm^2	Remolded (Sr) kg/cm^2	Sensitivity (Su/Sr)
721C	8.5	37.61	.05	.04	1.3
	24.5	36.84	.07	.07	1.0
	44.0	41.21	.04	.02	2.0
	53.5	47.17	.03	.03	1.0
	77.0	52.01	.05	.04	1.3
	95.0	46.26	.06	.05	1.2
721D	6.5		.05	-	-
	16.5	40.76	.06	-	-
	29.0		.06	.05	1.2
	33.0		.13	.05	2.6
	34.5	33.19	.12	.03	4.0
	39.5	36.09	.05	.03	1.7