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Some physical properties of shelf surface sediments, Beaufort Sea, Alaska

by

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LAYMAN'S SUMMARY

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The physical properties of sediments presented in this report include their resistance to deformation (shear strength) and penetration (penetration rate), and values of salinity within their pore water. This data, covering large areas of the Beaufort Sea shelf off Alaska, has been gathered over the years, but especially during the 1976 field season.

Shear strength and penetration rate, occasionally determined at the same station, are of value to the designer of offshore structures, in evaluating feasibility of dredging operations, the potential for slumping of sediments, and in studies of ice forces involved in producing the gouges found on the high latitude shelf areas. Shear strengths of surficial sediments were measured with a simple, hand-held shear vane, either on board ship from samples that appeared to be relatively undisturbed, or directly on the bottom by divers. The penetration rates were obtained during sediment sampling operations using a vibratory coring device with 2-m long core barrels. The resistance of sediments to shearing and penetration are not interpreted in this report, except by noting that ice-cemented sediments may occur at two shallow water stations.

Since the average annual water temperatures in the study area are below the freezing point of fresh water, the absence of ice-cemented surficial sediments may be explained by the presence of antifreeze in the form of sea salts within the sediments. Our study of the salinity of pore waters within the sediments was done to learn at what temperatures the sediments should freeze,and to evaluate in what environments and at what times of the year this may occur. This problem is of utmost importance to many aspects of offshore developments, and to the study of related environmental problems. Using the relation between the salinity of sea water and its freezing point, most of the localities sampled should freeze during the winter. An equation from the Russian literature, using the salinity of pore water and moisture content, appears to give reasonable results on the temperature at which bottom sediments become ice cemented.

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So far almost no data on mass physical properties of shelf sediments in the Alaskan Beaufort Sea has been published. This type of data is important for several reasons. For example, Kovacs and Mellor (1974) attempted to calculate the driving forces on grounded ice producing gouges on the sea floor. Such calculations require knowledge of the mechanical properties of surface sediments encountered by the ice. An understanding of the mechanical properties is also valuable in dredging and offshore construction projects.

For these reasons we have compiled pertinent information obtained in previous operations, and made additional measurements on the physical properties of sediments during the 1976 field season. The data is reported herein without attempts to interpret the results. For a general description of sediment types found on the shelf within the study area the reader is referred to Barnes and Reimnitz (1974). A compilation of mean diameter particle size of the surficial sediments is shown in Figure 1.

Shear Strength Values from Bottom Samples

During bottom sampling operation in the past, undrained shear strength values (S_u) of relatively undisturbed samples have been measured aboard ship with a simple hand held vane shear device (Dill and Moore, 1965). These results, along with on-site location, water depth, sampler type, and sediment type have been compiled in Table 1. The station locations are shown in Figure 2.

In Situ Shear Strength Values Obtained by Divers

A few in situ vane shear measurements, using the same hand held instrument, were obtained during diving operations in 1972. A number of additional measurements were made in the same way during summer 1976 diving operations.

On a number of dives more than one reading was taken. This was done particularly in ice gouged areas, where differences are to be expected between flat, undisturbed bottom, gouge flanks, and gouge floors. At each site the maximum reading (peak) and the reading obtained during the shearing event (residual) were recorded by the diver. See Table II. All these values along with information on station location, water depth, depth below sea floor, bottom type, sediment type, etc. are presented in Table II. Station locations are shown in Figure 2.

Although care was taken by the divers to increase torque slowly and evenly to obtain reliable readings (Fig. 3), currents and other factors did not allow them to do so in all cases. These in situ shear strength values still are considered to be more accurate than those obtained from partly drained and possibly disturbed bottom samples aboard ship. It should be noted that vane shear readings obtained in sandy and gravelly sediments with little or no plasticity are not considered to be good tests due to particle interlocking and other factors.

Penetration Rates of Vibrocore Barrels

Twentyfour vibrocore samples were obtained during the summer of 1976 (Fig. 4), with core length of up to 1.80 m. The rates of penetration were recorded for most stations. These rates provide a qualitative measure of the soil properties in different environments of the inner shelf. In several instances divers using a vane shear measured in situ shear strength of surface sediments near vibrocore stations (Fig. 2).

The vibrocorer is driven by two electric motors producing a combined driving force of 700 kg at a rate of 2,840 impulses/min. Square steel barrels and tubular fiberglass barrels were used in all instances. The steel barrels propagated the vibratory impulse more efficiently to the core nose than the fiberglass barrels, because of the greater damping characteristics associated with the fiberglass barrels. Along with the penetration rates, the barrel type used at each station is shown in Figure 5. Station locations and water depths are listed in Table 3.

Only preliminary core studies have been performed so far and we therefore did not include sediment descriptions with the penetration rates. However, by comparing sediment characteristics in the penetrated section with penetration rates, we feel fairly certain that cores 19 and 20 from the Colville Delta were stopped at the top of the underlying ice bonded sediments.

Salinity of Insterstitial Water, Sea Floor Temperatures, and Sediment Freezing Points

A variety of data pertinent to offshore permafrost problems has been gathered by our Beaufort Sea project over the years. During the 1976 summer field season on the R/V KARLUK we made a special effort to obtain reliable data on the salinity of interstitial waters in surficial sediments on the inner shelf.

Our main objectives in this study are to gain an understanding of the sedimentary environment on the arctic shelf. The shelf surface is affected and modified by waves, currents, strudel scour, ice gouging, small critters, and many other factors. Our thinking about bottom processes has been based on the assumption that the sediment surface is unfrozen (Reimnitz and Barnes, 1974). There is some justification for this assumption, at least for summer conditions. In our sampling, driving of thermoprobes, diving, boat anchoring, etc., we apparently have never encountered ice bonded sediments, (except possibly at several vibrocoring stations in very shallow water near the Colville River, as stated earlier in this report. Even during the driving of a thermoprobe in bottom-fast ice off the Kuparuk River, when some of the data reported herein was obtained, penetration was not prevented or retarded by ice bonding within the sediment, as far as we can determine.

If the surficial sediments did become ice bonded in certain environments during the peak of the winter, this would be very important for studies of bottom processes, for biological studies of bottom dwelling organisms, and for offshore construction projects. For example, high flow velocities recorded by current meters could indicate that sediment transport is taking place, while in fact the seabed may actually be frozen. An example of potential environmental impact may be envisioned by considering the influence of a cold pipe line carrying natural gas buried on the shelf. If the shelf sediments are close to the freezing point, the cooling effect of such a pipe line may result in the freezing of overburden. Bedload transport of sediment might be affected such that individual grains in transit, temporarily contacting the bottom, may become adfrozen. This in turn could result in the formation of a sediment dike along the pipeline corridor.

Sediment Salinity

Interstitial salinities were determined from sediment samples collected in 1972 and 1976. In 1972, deep water samples were obtained by gravity corers on the outer shelf (Table IV, stations 1-5). From these cores 10 cm sub-samples were taken, squeezed, and processed on board by diluting 40 ml of interstitial water to 200 ml, on which the conductivity was measured. The 1976 values (Table IV, stations 6-21) were obtained from samples collected in plastic tubes by divers, and stored at $0^{\circ}C$ until processing. Since these inner shelf samples were quite variable in composition, different methods had to be used for water extraction and salinity determination. Some of the samples were centrifuged for 15 minutes at 15,000 rpm. 20 μl of interstitial water were titrated against a Copenhagen Standard seawater of known chlorinity, using a London Co. Automatic Chloride Titrator. Values obtained by this method are given in Table IV.

The remainder of the samples required a dilution method to obtain an adequate volume for titration. A portion of the subsample was oven-dried at $110^{\circ}C$ to determine moisture content. The remainder was diluted with 2 ml of distilled water, shaken on a wrist action shaker for 20 minutes, and centrifuged for 15 minutes at 2,000 rpm. Again, 20 μl were titrated using the automatic titrator. The values obtained by this technique are identified in Table IV by asterisks (*). Chlorinities were converted to salinities using the relation

$$\text{Salinity}(^{o}/oo) = 0.03 + 1.805 \times \text{Chlorinity}\ (^{o}/oo).$$

Using the salinity values of interstitial water, we calculated the hypothetical freezing temperatures of the sediment from two different relationships:

1) Molochushkin and Gavuliev (1970) show that:

$$T_f = 28.4 \times (e^{0.22 \times S/W} - 1) - 5e^{-35 \times (W - 0.035)},$$

where T_f is the freezing temperature in degrees Centigrade, S is the salinity of pore water in parts per hundred, and W is the moisture content in "relative units" (from our translation), and e = 2.7. For the simple-minded geologist this relation has only one minor problem: it gives positive freezing temperatures. Changing the term

$e^{0.022 \times S/W}$ to $e^{-0.022 \times S/W}$

we obtain what appear to be reasonable values for freezing temperatures, and therefore assume a printing error was made. The equation now reads:

$$T_f = 28.4 \times (e^{-0.022 \times S/W} - 1) - 5e^{-35 \times (W - 0.035)}.$$

Only for the samples processed by the dilution method did we obtain values for moisture content (Table IV). In our calculations of freezing temperature we assumed a moisture content of 50% for the remaining samples. This assumed value was slightly greater than the measured, which averaged between 35 and 40% in moisture content. Possible deviation of $\pm$ 20% in moisture content from the assumed 50% value would result in freezing point errors of $\pm$ 1.5° C for the most saline samples to $\pm$ 1.0° C for the least saline samples.

2) Osterkamp and Harrison (1976), working on offshore permafrost problems in the Prudhoe Bay area, calculated the freezing temperature of sediments using an equation that applies to seawater alone (Doherty and Kester, 1974), and disregards the fact that the deposit is a mixture of water and sediment:

$$T_f = 1.37 \times 10^{-2} - 5.199 \times 10^{-2} S - 7.225 \times 10^{-5} S^2.$$

Where S is salinity in parts per thousand. For the soil samples they obtained, the error in this procedure was estimated to be less than 20%.

A two-meter long thermoprobe, with thermistors, coupled to a Wheatstone Bridge, was used in two different field operations to measure sea floor temperatures. Nine measuring stations occupied by the R/V LOON during the middle of September in 1976 are shown in Figure 6 (inset, black dots). The values obtained at these stations, shown in Figure 7, represent sea floor conditions close to the end of the open water period, probably slightly past the time when the sea floor is the warmest. The measurements around the mouth of the Kuparuk River were made in late May, 1972, using the sea ice as a base of operations. These values represent temperature conditions just prior to river flooding of the sea ice, shortly after the temperature-low of the winter. Thus, the temperature data shown in Figure 7 does not represent the extremes encountered from winter's low to summer's peak. The sediment surface temperatures were extrapolated and the results are shown in Table V. These extrapolated sea floor temperatures are plotted with the respective station locations in Figure 6. Sea floor temperatures extrapolated by Lachenbrach and Marshall (1977) from May, 1976, data are in general agreement with these values.

Speculating on the implications of the presented data, we sketched in Figure 8. This is based on the assumption that the average annual temperature and environmental conditins fro the thermoprobe stations off the Kuparuk River are rather similar to those in the Prudhoe Bay vicinity, occupied at a different time of the year. From this assumption, we sketched a hypothetica cross-section through a shallow lagoon or bay across a sill with a depth less than the maximum fast ice thickness (approx. 2 m), and into the open ocean (Fig. 8). Winter and summer bottom temperatures (Fig. 8) measured in the very shallow lagoon, in the deepest part of the lagoon, at the shallow sill, and at several water depths offshore are shown. Note that no values are available for the shallow sill during winter conditions. In the deepest part of Prudhoe Bay and near the sill, the summer temperatures show a considerable range of values. These are shown as vertical bars in Figure 8. Also shown in Figure 8 are the freezing temperatures for the seabed calculated from our data on salinity of interstitial waters and moisture content, using the two different equations.

Freezing temperatures calculated from the equation applying to pure sea water suggest that the seabed from shore to a water depth of about 7 m would become ice-bonded during the winter. This equation therefore probably should not be used. The equation from Molochushkin and Gavuliev (1970) shows that only those areas shallower than 2 m of water depth are close to the freezing point during the winter, and this seems reasonable.

Plans are being made to obtain more of this type of data during the coming field season.

ACKNOWLEDGMENT

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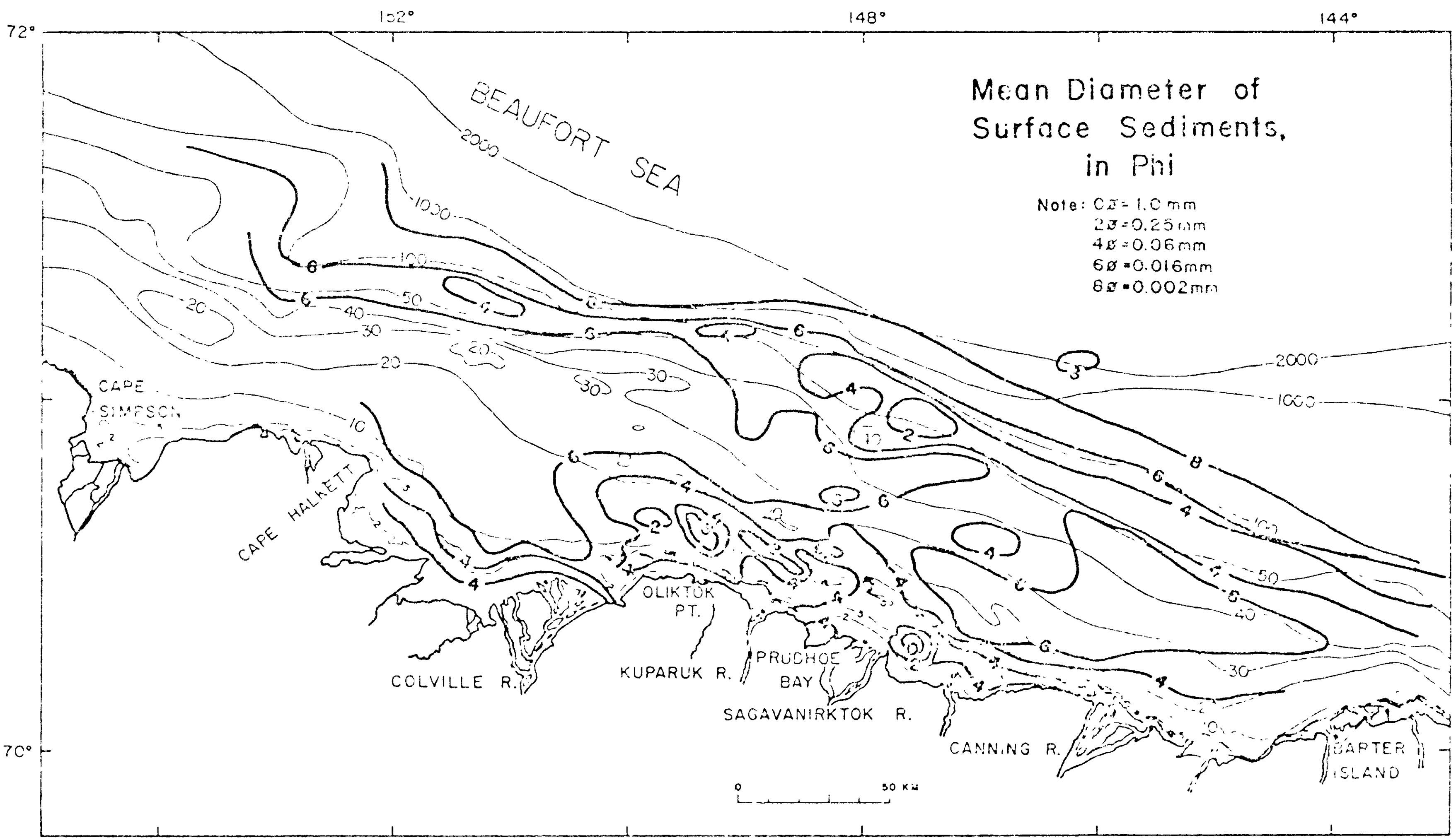

Figure 1. Map contouring mean diameter of surface sediments, From Barnes and Reimnitz, 1974.

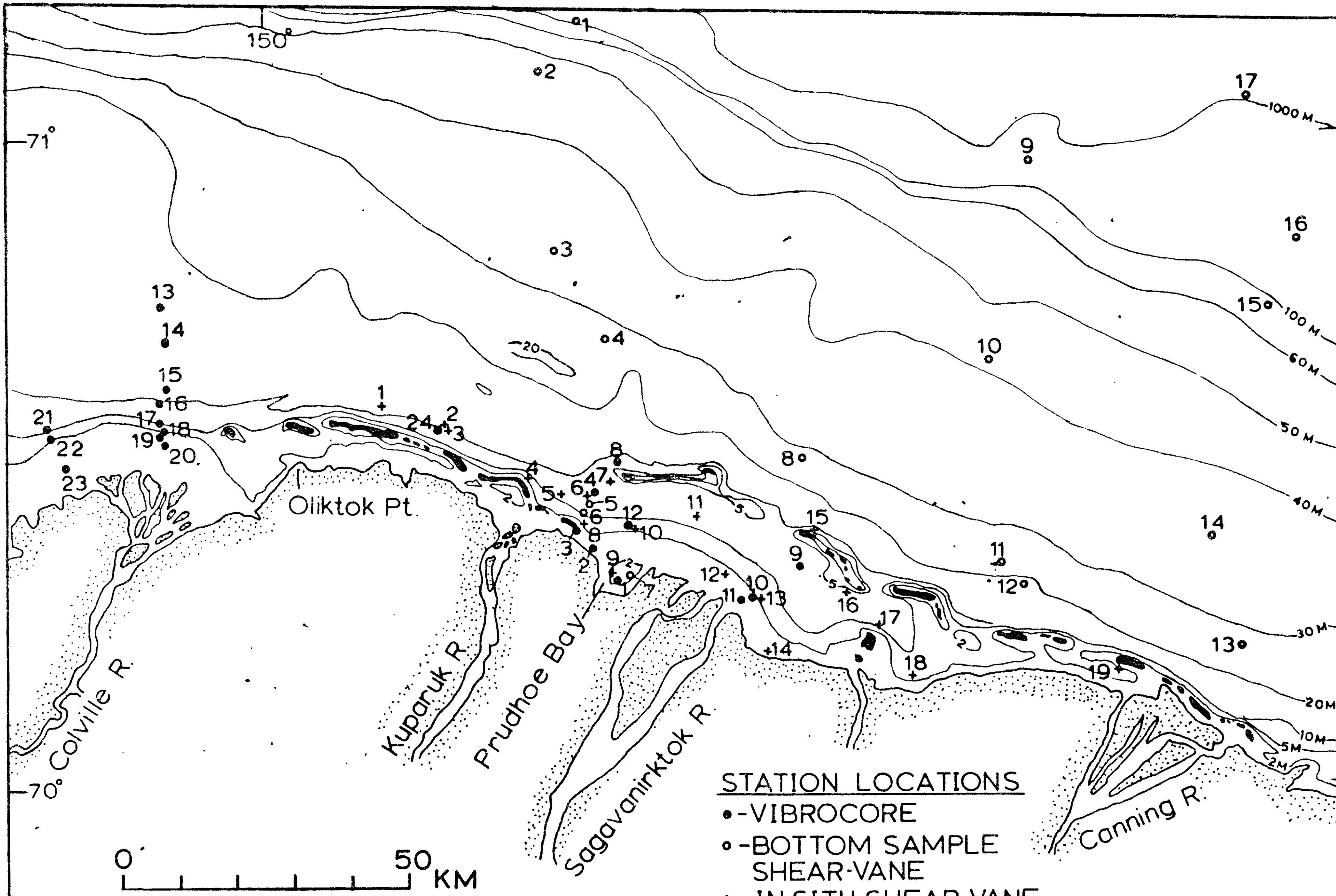

Figure 2. Location map showing vane-shear strength and vibrocore stations.

Figure 3. Diver taking in situ shear vane measurements.

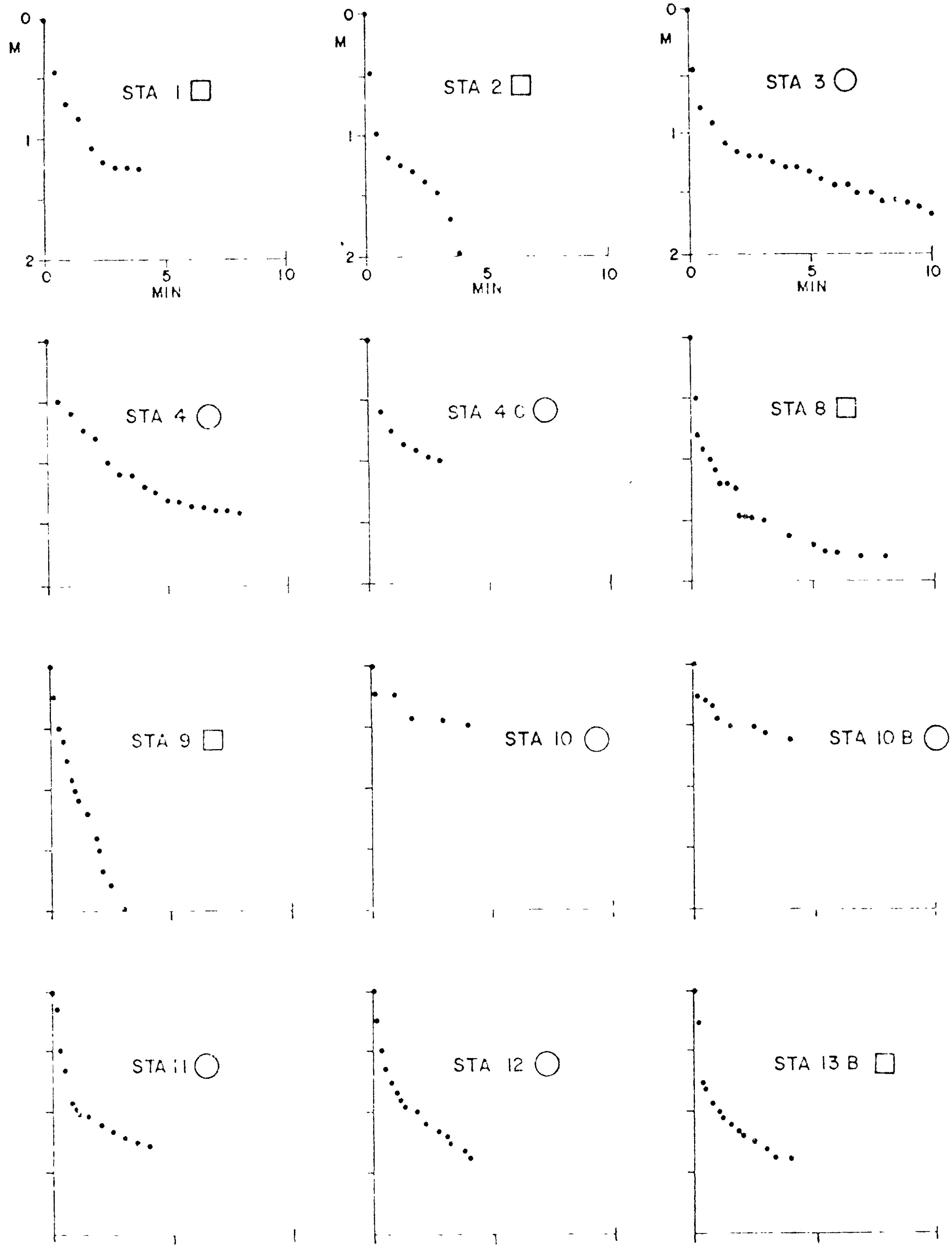

Figure 5. Penetration rates of vibrocore barrels. Barrel type used (square steel or round fiberglass) identified by symbol.

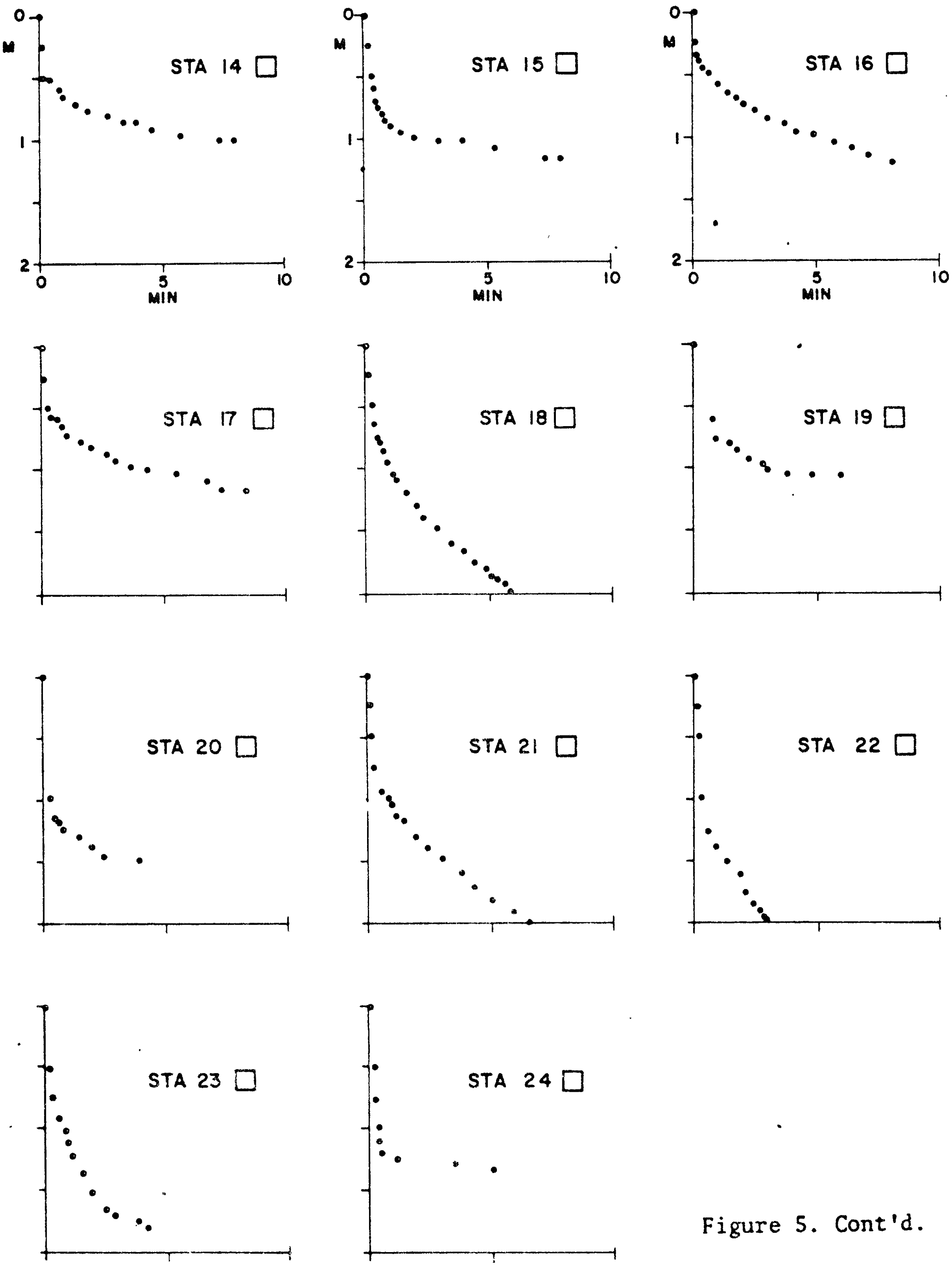

Figure 5. Cont'd.

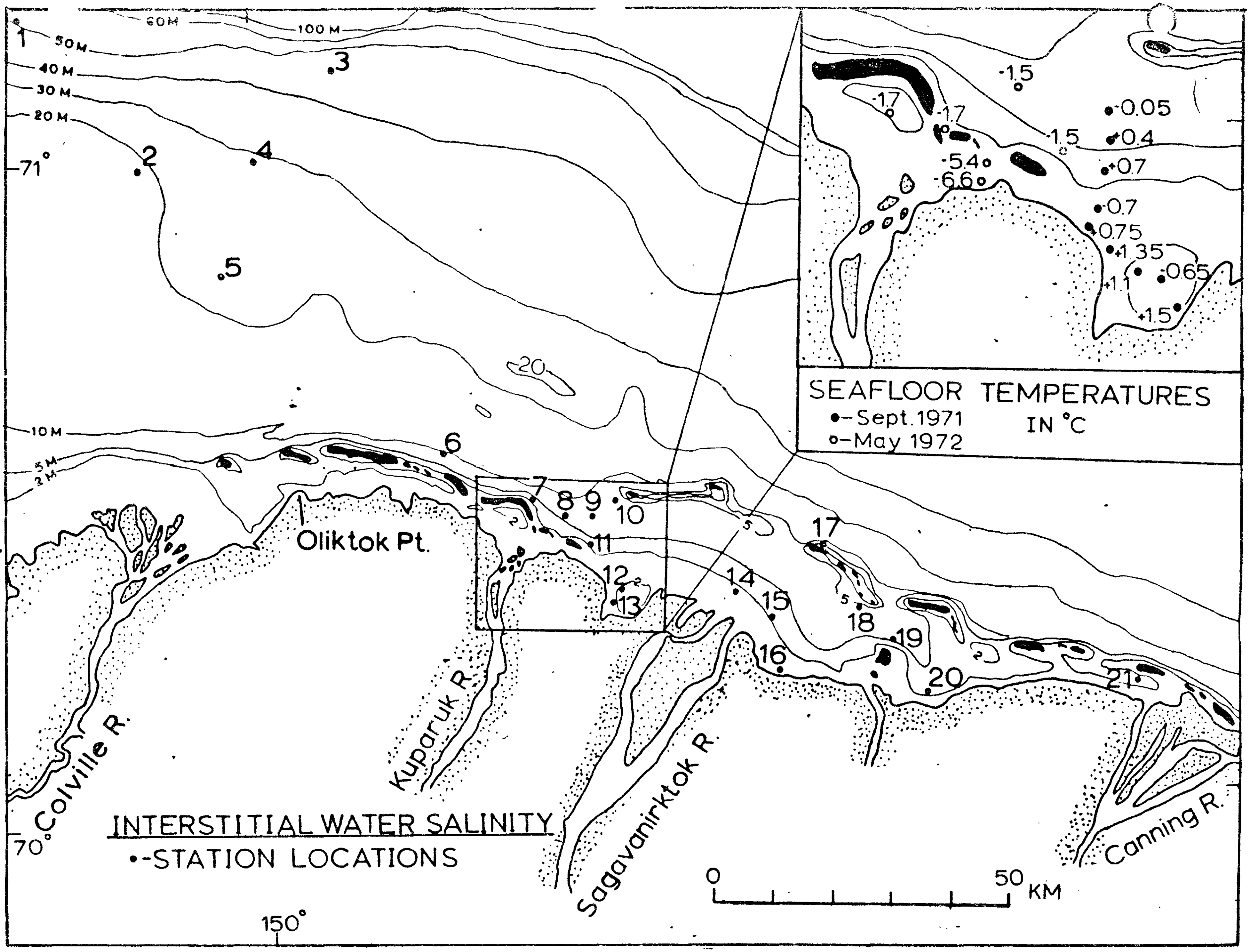

Figure 6. Location map for stations at which the salinity of interstitial waters in bottom sediments were determined, and extrapolated seabed temperatures at the thermoprobe stations (Inset).

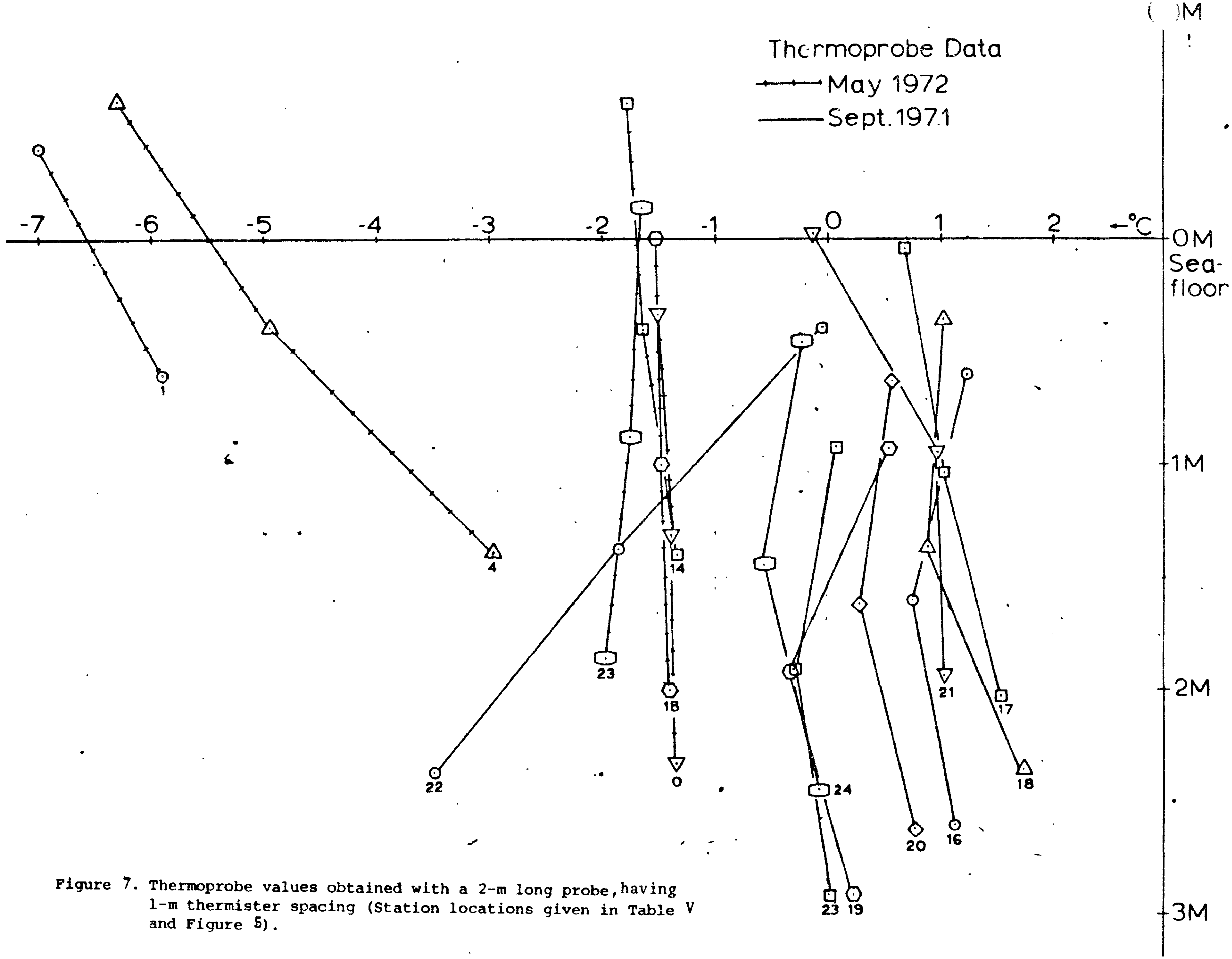

Figure 7. Thermoprobe values obtained with a 2-m long probe, having 1-m thermister spacing (Station locations given in Table V and Figure 5).

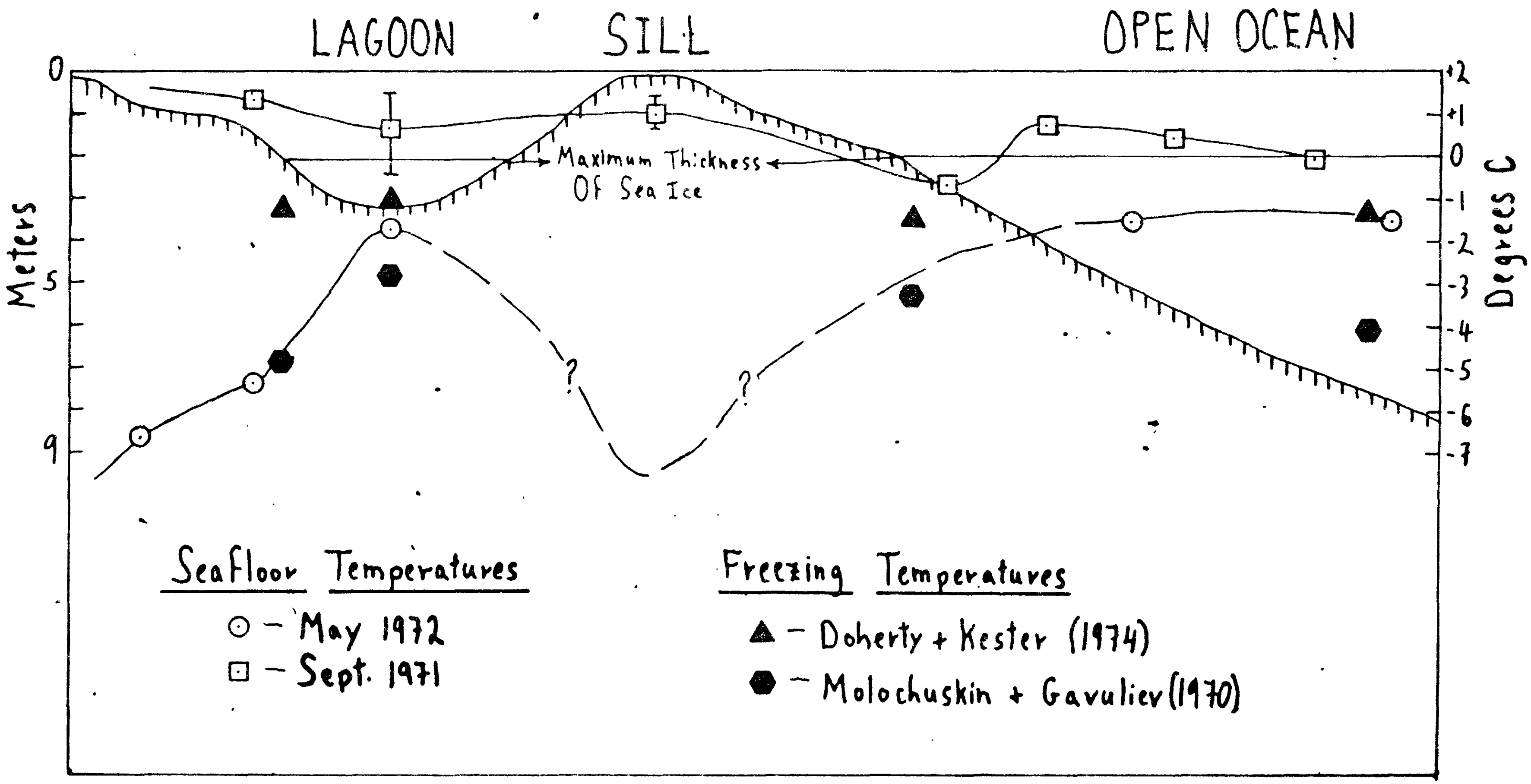

Figure 8. Hypothetical seafloor profile extending from beach through a lagoon or bay, across a shallow sill to the open ocean. Representative extrapolated bottom temperature values during summer and winter conditions and calculated seabed freezing temperatures from two different equations.

TABLE 1 SHEAR STRENGTH VALUES FROM SAMPLES

PSI - pounds per square inch

KN/M^2 - kilo newtons per square meter

Station Number	Location	Water Depth (m)	Shear Strength Peak PSI (KN/M^2)	Shear Strength Residual PSI (KN/M^2)	Depth of Measurement, cm below sediment surface	Sample type	Sediment Description
1	71°10.9'N 148°34.0'W	307	0 0.32 (2.21)	- -	2 5	Van Veen Grab	Soft mud Stiff mud
2	71°6.2'N 148°42.0'W	43	0.21 (1.45) 1.33 (9.17)	- -	2 5	Van Veen Grab	Pebbly, sandy, mud Gravelly Mud
3	70°49.6'N 148°31.0'W	33	0.21 (1.45) 2.01 (13.79)	- -	2 5	Van Veen Grab	Soft, fine-grained sandy mud Stiff, fine-grained sandy mud
4	70°41.6'N 148°30.0'W	27	0.01 (0.69) 1.11 (7.05)	- -	2 5	Van Veen Grab	Soft, Fine-grained Mud Gravelly mud
5	70°26.05'N 148°29.26'W	7	1.11-1.33 (7.65-9.17)	0.1 - 0.21 (0.69-1.45)	6	Undisrupted snapper sample	Brown/grey, medium-grained silty sand w/worm tubes
6	70°25.25'N 148°30.15'W	6.5	1.11 (7.65)	0.1 - 0.21 (0.69-1.45)	2	Undisrupted snapper sample	Brown/grey medium-grained silty sand w/worm tubes
7	70°18.92'N 148°20.3'W	3.3	>2.67 (>18.39)	0.88-1.11 (6.07-7.65)	8	Gravity core	Dark grey silty clay
8	70°31.4'N 147°33.0'W	26	<0.10 (<0.69) 0.71 (4.90)	- -	2 5	Van Veen Grab	Fine-grained sandy mud Stiff medium to coarse-grained sandy mud
9	70°58.3'N 146°30.1'W	364	0 0.38 (2.62) 0.66 (4.55)	- - -	2 5 5 - 10	Van Veen Grab	Soft, brown mud Stiff, grey mud Stiff, grey mud
10	70°40.0'N 146°40.0'W	47	0.44 (3.03)	-	2	Van Veen Grab	Muddy sand
11	70°21.4'N 146°36.0'W	26	0 >2.67 (>18.39)	- -	2 5	Van Veen Grab	Soft, fine-grained sandy mud Stiff, coarse-grained sandy mud
12	70°19.6'N 146°30.0'W	17	2.0 (13.79) 2.0 (13.79)	- -	2 5	Van Veen Grab	Stiff, grey clay
13	70°13.2'N 145°31.0'W	25	0.88 (6.07) 1.33 (9.17) 2.0 (13.79)	- -	2 5 5 - 10	Van Veen Grab	Soft, muddy sand Stiff, gravelly mud Muddy sand
14	70°23.4'N 145°34.0'W	37	0.10 (0.69) 2.22 (15.31)	- -	2 5	Van Veen Grab	Sandy, gravelly, mud w/coarse, 20 cm diameter rocks Stiff, sandy, gravelly, mud
15	70°44.8'N 145°31.0'W	87	0.21 (1.45) 0.76 (5.24)	- -	2 5	Van Veen Grab	Pebbly mud Mud
16	70°54.1'N 145°20.0'W	300	0.44 (3.03) 0.76 (5.24)	- -	2 5	Van Veen Grab	Soft mud
17	70°02.3'N 145°32.0'W	1062	0 1.33 (9.17) >2.67 (>18.39)	- - -	2 5 5 - 10	Van Veen Grab	Pebbly mud Grey mud Stiff Clay

TABLE II IN SITU SHEAR STRENGTH VALUES

* - average of several readings
PSI - pounds per square inch
KN/M^2 - Kilo Newtons per square meter

Dive Site	Location	Water Depth(m)	SHEAR STRENGTH Peak PSI(KN/M^2)	Residual PSI(KN/M^2)	cm below sediment surface	Bottom description at point of measurement	Sediment description	Comments
1	70°35.6'N 149°27.1'W	12	1.55(10.69) 2.55(17.58)	0.34(2.34) 0.55(3.79)	5 10	Bioturbated flat bottom	Bioturbated mud	Soft to 10 cm stiffer below
2	70°33.2'N 149°11.0'W	11.5	1.38(9.52)	0.69(4.76)	2	Seaward foot of major shoal, between gouges	Muddy Sand	
3	70°33.12'N 149°11.5'W	5	0.23(1.59)	0.11(0.76)	2	Flat bottom on major shoal	Clean, medium-grained sand w/clam fragments	Intensely gouged
4	70°28.4'N 148°47.2'W	4.5	0.34(2.34)	0.34(2.34)	2	Undisturbed sediment near gouge	Muddy sand	Trough of gouge impenetrable with veins
			0.69(4.76)	0.46(3.17)	15	Flat bottom near gouge flank	Sandy, muddy gravel	
5	70°26.9'N 148°37.5'W	6.4	>1.38(>9.52) >1.38(>9.52)	1.03(7.10) >1.38(>9.52)	2 15	Flat bottom	Gray, cohesive mud Very stiff, muddy, sandy gravel w/some shells	
6	70°26.9'N 148°30.5'W	8.5	0-0.34 (0-2.34)	0-0.34 (0- 34)	2	Floor of gouge	Very soft surficial sediment underlain by fairly stiff layer	
			>1.38(>9.52)	0.69(4.76)	2	Flat bottom		
			1.03(.10)	0.57(3.93)	2	Flat bottom		
7	70°26.1'N 148°24.0'W	8.5	1.03(7.10)	0.46(3.17)	2	Floor of gouge	Mud	Stiff boundary at 2.5 cm depth covered by fairly soft mud w/numerous clams
			0.69(4.76)	0.34(2.34)	2	Gouge trough		
			0.69(4.76)	0.46(3.17)	2	Gouge flank		
			0-0.34* (0-2.34)	0-0.34* (0-2.34)	2	Gouge flank		
			0.69(4.76)	0.23(1.59)	2	Flat bottom		
			>1.38(>9.52)	>1.38(>9.52)	5	Flat bottom		
8	70°24.2'N 148°31.5'W	3.0	1.03(7.10) 0.69(4.76)	0.86(5.93) 0.46(3.17)	2 15	Flat bottom	Fine, muddy sand	
	70°19.8'N 148°23.5'W	2.5	0.54(3.72)	0.44(3.03)	8	Flat bottom	Fine, muddy sand	
10	70°24.0'N 148°17.3'W	3.1	1.15(7.93) >1.38(>9.52)	1.03(7.10) >1.38(>9.52)	2 15	Flat bottom	Slightly muddy medium-fine grained sand	
11	70°24.9'N 148°01.0'W	7.0	>1.38(>9.52)	>1.38(>9.52)	2	Rippled flat bottom	Muddy sand	Ripples of 15 cm wavelength
12	70°19.5'N 147°51.5'W	2.5	>1.38(>9.52	>1.38(>9.52)	2	Flat bottom with ripples	Muddy sand	Ripples of 15-20 cm wavelength, 1-2 cm high
			>1.38(>9.52)	>1.38(>9.52)	3	Flat bottom with ripples	Very stiff mud	
13	70°17.2'N 147°42.8'W	3	1.09(7.52) >1.38(>9.52)	0.69(4.76) >1.38(>9.52)	2 15	Ripple field-flat bottom	Muddy sand	Ripples of 20 cm wave-length. 2-3 cm height. Old, weathered gouges creating broad bottom undulations
			0.69(4.76)	0.46(3.17)	2	Exposed underlying gravel on flat bottom	Angular, pea-size gravel	
14	70°12.8'N 147°41.0'W	1.6	1.15(7.93)	0.92(6.34)	6.5	Flat bottom	Highly muddy, medium grained sand	
15	70°23.8'N 147°28.7'W	1.5	0.69(4.76)	0.46(3.17)	2	Flat bottom	Sand	
			<0.34(<2.34)	<0.34(<2.34)	2	Gouged flank and floor	Sand	
			1.38(9.52)	-	2	Flat bottom	Muddy sand	
			1.03(7.10)	0.71(4.90)	2	Flat bottom	Muddy sand	
			1.03(7.10)	0.71(4.90)	10		Pea-size gravel	
16	70°18.2'N 147°18.7'W	6	0.34(2.34)	0	2	High ground covered by worm tubes	Soft mud	Hummocky relief related to distribution of worm tube patches
			>1.38(>9.52)	>1.38(>9.52)	2	Depression between worm tube patches	Muddy sand	
17	70°14.7'N 147°10.5'W	5.5	>1.38(>9.52)	1.09(7.52)	2	Flat bottom	Sandy mud	Dive site is marked by exposure of firm gravel in depressions
18	70°19.3'N 147°01.0'W	4.5	>1.38(>9.52)	>1.38(>9.52)	2	Flat bottom with decayed ripple train	Sandy mud	Burrowing activity
19	70°10.8'N 146°03.4'W	2.5	>1.38(>9.52)	1.15(7.93)	2	Slightly undulating bottom	Sandy mud	Small scale relief from bioturbation

TABLE III VIBRO CORE STATIONS

Station Number	Location	Water Depth (m)
1	70°19.0'N 148°22.0'W	3
2	70°22.3'N 148°28.4'W	1.7
3	70°24.0'N 148°33.2'W	1.5
4	70°27.3'N 148°28.2'W	6.5
8	70°29.8'N 148°20.8'W	8
9	70°20.1'N 147°31.1'W	6.5
10	70°17.1'N 147°44.3'W	2.7
11	70°17.7'N 147°47.0'W	1
12	70°24.1'N 148°18.5'W	3
13	70°44.8'N 150°28.1'W	19
14	70°41.5'N 150°27.2'W	15
15	70°37.0'N 150°27.0'W	12.4
16	70°36.3'N 150°28.2'W	11.5
17	70°34.0'N 150°28.2'W	8.5
18	70°33.3'N 150°27.9'W	3.3
19	70°33.6'N 150°28.1'W	2
20	70°32.7'N 150°27.5'W	1.5
21	70°33.8'N 151°01.0'W	4
22	70°32.5'N 150°59.6'W	0.6
23	70°29.5'N 150°55.9'W	1
24	70°33.2'N 149°11.2'W	17.5

TABLE IV

FREEZING TEMPERATURE OF BOTTOM SEDIMENTS

' - Conductivity Method
* - Dilution Method
" - Centrifuge Method

1. Molochushin & Gauvliev (1970)
2. Doherty & Kester (1974)
#-Assumed Moisture Content = 50% dry weight.

Station #	Location	Water Depth (M)	Depth of Sample below Sediment Surface (CM)	Interstitial Salinity (0/00)	Water Content 0/0	T_f [1] (°C)	T_f [2] (°C)	Sediment Description
1	151°00.0'W 71°12.2'N	53	2.5 - 12.5	38.0'		#-4.37	-2.09	Sandy Mud
			12.5 - 22.5	37.7'		#-4.34	-2.07	
			22.5 - 32.5	33.4'		#-3.88	-1.95	
			32.5 - 42.5	32.9'		#-3.83	-1.79	
			42.5 - 52.5	33.6'		#-3.90	-1.84	
			72.5 - 82.5	32.8'		#-3.82	-1.80	
2	150°58.0'W 70°58.8'N	19	12.5 - 22.5	24.4'		#-2.89	-1.32	Stiff clay with Sand Pockets
3	149°37.1'W 71°07.8'N	46	0 - 10	33.8'		#-3.92	-1.85	Mud with Fine Sand Patches - Scattered pebbles
			10 - 20	39.9'		#-4.57	-2.21	
			20 - 30	32.5'		#-3.78	-1.78	
4	150°00.0'W 71°00.0'N	28	0 - 10	25.9'		#-3.06	-1.41	Oozey mud
			10 - 20	33.0'		#-3.84	-1.81	Very stiff - fine-grained sandy mud
			20 - 30	33.3'		#-3.87	-1.82	
5	150°00.0'W 71°52.5'N	24	0 - 10	33.1'		#-3.85	-1.81	Fine mud grading into very sticky mud with very fine to fine clean dark sand at bottom
			10 - 20	33.3'		-3.87	-1.82	
			20 - 30	33.3'		-3.87	-1.82	
6	149°11.0'W 70°33.2'N	11.5	15	26.5*	21.99	-6.61	-1.44	Very clean medium grained sand
7	148°47.2'W 70°28.4'N	4.5	10	20.8*	26.35	-4.50	-1.11	Muddy, gravelly sand with sub-rounded granules
8	148°37.5'W 70°26.9'N	6.4	5	21.3*	74.83	-1.68	-1.13	Grey Mud
			15	26.8*	36.93	-4.19	-1.46	Stiff, very fine sandy mud
			-	24.3*	36.89	-3.83	-1.32	Dark grey mud
9	148°30.5'W 70°26.9'N	8.5	6.5	24.7*	35.27	-4.06	-1.34	Fine grained muddy sand
10	148°24.0'W 70°28.1'N	8.5	-	22.1*	40.59	-3.21	-1.20	Fine-grained muddy sand with wood fragments
11	148°31.5'W 70°24.2'N	3.0	15	27.9		#-3.28	-1.52	Fine-grained muddy sand
12	148°22.5'W 70°20.2'N	2.0	-	24.0"		#-2.80	-1.30	Very fine-grained muddy sand
			-	18.9*	40.79	-2.85	-1.05	Light grey very fine muddy sand
13	148°25.3'W 70°19.0'N	2.0	-	34.[illegible]*	41.71	-4.75	-1.91	Light grey very fine muddy sand
			-	24.4*	74.45	-1.98	-1.28	Grey mud
14	147°51.5'W 70°19.5'N	2.5	14	18.9*	24.36	-4.46	-1.03	Clean fine sand
15	147°42.8'W 70°17.2'N	3.0	16	25.5"		#-3.01	-1.39	Medium grained Muddy Sand with shell fragments
16	147°41.0'W 70°12.8'N	1.6	5	18.8"		#-2.25	-1.02	Muddy fine grained sand
			20	27.3"		#-3.21	-1.43	Muddy very fine-grained sand
17	147°28.7'W 70°23.8'N	1.5	10	22.3"		#-2.65	-1.21	Clean medium-grained sand
18	147°18.7'W 70°18.2'N	6.0	14	30.2"		#-3.53	-1.65	Grey mud
19	147°10.5'W 70°14.7'N	2.5	5	24.9*	25.66	-5.46	-1.35	Fine-grained muddy sand
20	147°01.0'W 70°10.3'N	4.5	17	29.4"		#-3.45	-1.60	Dark grey fine sandy mud
21	146°03.4'W 70°10.8'N	2.5	14	23.7"		#-2.81	-1.29	Medium to coarse-grained muddy sand

TABLE V

Thermoprobe Stations:

*May, 1972

'Sept., 1971

Station	Location	(M) Water Depth	(°C) Sea Floor Temperature
0*	70°25.0'N 148°30.8'W	5.5	-1.5
1*	70°23.8'N 148°41.0'W	1.0	-6.6
4*	70°24.4'N 148°40.5'W	1.4	-5.4
14*	70°25.9'N 148°45.3'W	3.2	-1.7
18*	70°27.4'N 148°34.0'W	5.1	-1.5
23*	70°26.6'N 148°50.2'W	1.8	-1.7
16'	70°18.2'N 148°19.0'W	3.2	+1.5
17'	70°19.2'N 148°20.5'W	3.2	-0.65
18'	70°19.9'N 148°23.0'W	2.7	+1.1
19'	70°20.6'N 148°26.0'W	1.5	+1.35
20'	70°21.6'N 148°28.5'W	1.7	+0.75
21'	70°22.4'N 148°27.6'W	2.6	-0.7
22'	70°24.7'N 148°26.0'W	4.1	+0.7
23'	70°25.0'N 148°25.1'W	5.5	+0.4
24'	70°26.1'N 148°25.1'W	6.8	-0.05