Environmental Assessment of the Alaskan Continental Shelf

Annual Reports of Principal Investigators for the year ending March 1981

Volume VIII: Hazards & Data Management

US DEPARTMENT OF COMMERCE
National Oceanic & Atmospheric Administration
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US DEPARTMENT OF THE INTERIOR
Minerals Management Service

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The facts, conclusions and issues appearing in these reports are based on interim results of an Alaskan environmental studies program managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, and primarily funded by the Bureau of Land Management (BLM), U.S. Department of Interior, through interagency agreement.

Volume 8
HAZARDS

Grain Size and Composition of Seafloor

Sediment, Kodiak Shelf, Alaska

by

Monty A. Hampton

U.S. Geological Survey Open-File Report 81-659

GRAIN SIZE AND COMPOSITION OF SEAFLOOR SEDIMENT, KODIAK SHELF, ALASKA

Environmental geologic studies of Kodiak Shelf, western Gulf of Alaska (Fig. 1), have been conducted in support of the Federal government's outer continental shelf petroleum leasing program. Geological and geophysical data were gathered aboard the R/V SEA SOUNDER on four cruises in 1976-1979, and aboard the R/V S.P. LEE and NOAA ship DISCOVERER in 1980. Samples of seafloor sediment were collected at 203 stations (Fig. 2). The purpose of this report is to present the grain size and compositional data for these samples.

A modified grab sampler was used to collect most of the sediment samples. The grab moved along vertical rails housed in a four-legged frame and was driven by a 400-lb weight. The grab retrieved samples in coarse sedimentary deposits where other devices failed. A gravity corer was used to collect samples of soft sediment. Samples were collected from the DISCOVERER using a standard Shipek grab sampler.

Subsamples were taken from the upper few centimeters of each grab sample or core, removing material only from the uppermost sedimentation unit. Each subsample was wet sieved into coarse (>2mm), sand (2-0.062mm), and fine (<0.062mm) fractions. The fine fraction was pipetted to distinguish the silt (0.062-0.004mm) and clay (<0.004mm) size fractions. The relative weight percentage of each fraction was calculated (Table 1, Appendix 1).

Visual estimates were made of the (volume) percentages of compositional elements in each sieved size fraction (Appendix 1). These proportions have been recalculated as whole-sediment weight percentages in Table 1.

Q-mode factor analysis was performed on the combined textural and compositional data for all samples. Factor analysis is used mainly as a mapping tool for the purposes of this report, but it can also be used as a basis for interpreting sedimentary history. Twelve variables were used in the analysis. These particular variables seem to best represent the distinct elements of the seafloor sediment on Kodiak Shelf, as decided after extensive subjective examination of the samples. Textural variables include coarse, sand, silt, and clay size fractions. Compositional variables include terrigenous minerals, volcanic ash, whole or broken megafaunal carbonate shells (all in the coarse fraction and much larger than 2mm), crushed megafaunal shells (predominantly in the sand size fraction), fine carbonate (in the silt and clay size fraction), foraminifera shells, clay minerals, and siliceous microfossil shells.

Data for each variable were scaled on a range between zero and one. This normalization represents the relative percentage of each measurement in the range between the minimum and maximum values of that variable. Varimax loadings (proportional contributions of each factor to a given sample) were computed for five factors, which account for 97% of the cumulative variance of measurements (Table 2). The factors represent composites of all the original variables, and use of five factors is judged to give the optimum synthesis of the original data. Communalities (amount of the sums of squares of the normalized data accounted for by the five factors) of all but 9 samples are high (exceeds 0.80). Four of the samples (61,128,234,236) with low communalities represent a sediment type rich in forams. When a six-factor model is used, the foram variable dominates the sixth factor. Sample 502 is from the edge of Shelikof Strait and probably represents a different sedimentary environment. The remaining samples (D24, D25, D26, D38) that have low communalities show no obvious distinguishing features and may have experienced sampling or analytical errors.

Samples for which factor 1 has the highest factor loading are shown in Figure 3. Similar maps for the other factors are Figures 4-7. The technique used in preparing these maps was to show a totally blackened circle if the particular factor is clearly dominant in a sample. If other factors are present in significant amounts, arbitrarily defined as a factor loading at least one-half as large as the highest loading value, the relative proportions of these factors are scaled as unshaded areas of the circle.

Compositions of the five factors in terms of the relative importance of the twelve original variables are given in Table 3. The values in each column indicate only a relative ranking, and negative numbers simply designate a strong disassociation of a particular variable with a particular factor. Roughly, factor one represents coarse terrigenous material, factor 2 is mud with abundant clay minerals, factor 3 is sand-size volcanic ash, factor 4 is terrigenous sand, and factor 5 is shelly sand.

Visual descriptions of several samples that were not analyzed in detail, including dart cores of semilithified to lithified bedrock, are given in Table 4.

This study was partly supported by the Bureau of Land Management through interagency agreement with the National Oceanic and Atmospheric Administration, under which a multi-year program responding to needs of petroleum development of the Alaskan continental shelf is managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office.

FIGURE CAPTIONS

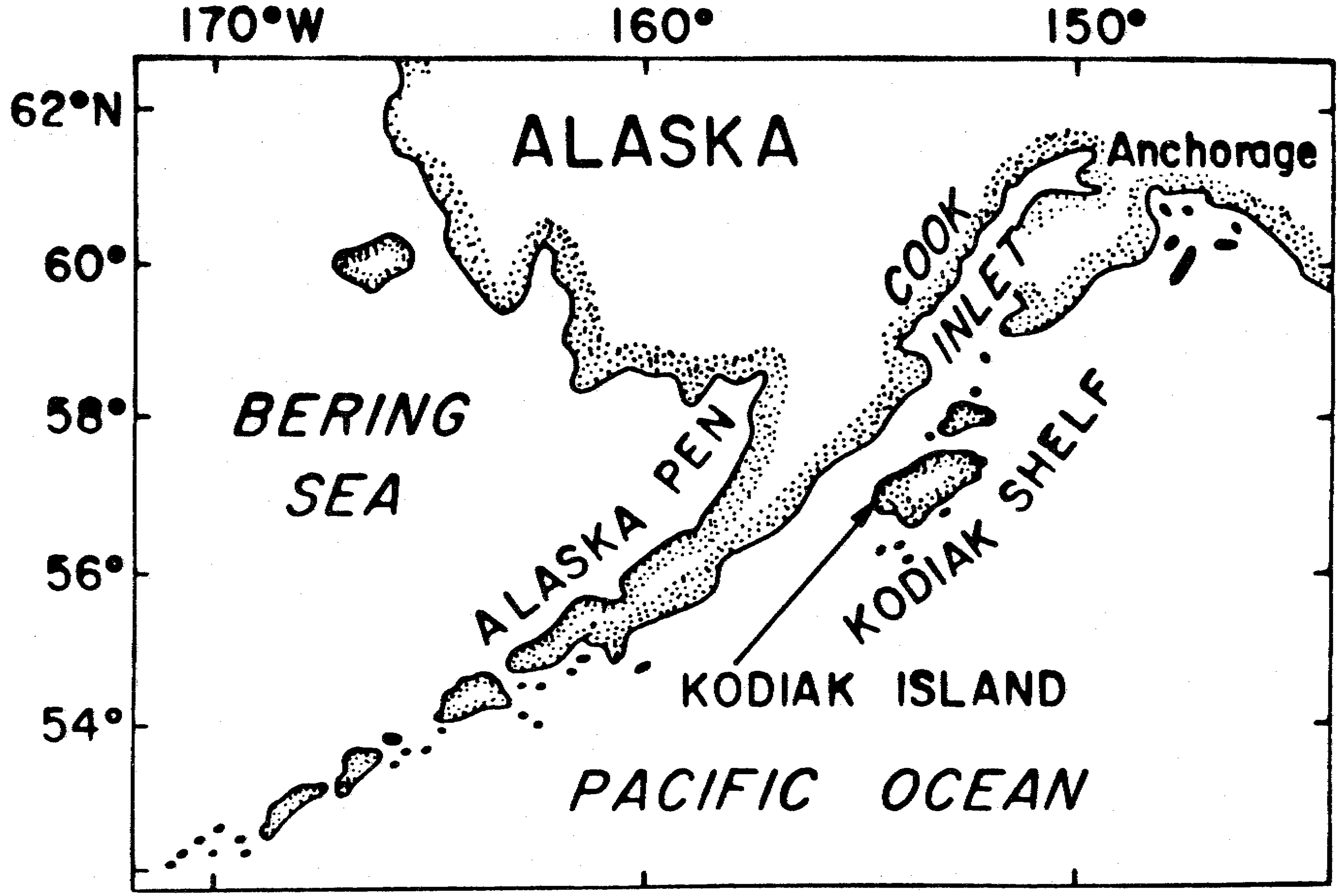

Fig. 1a - General location map of Kodiak Shelf.

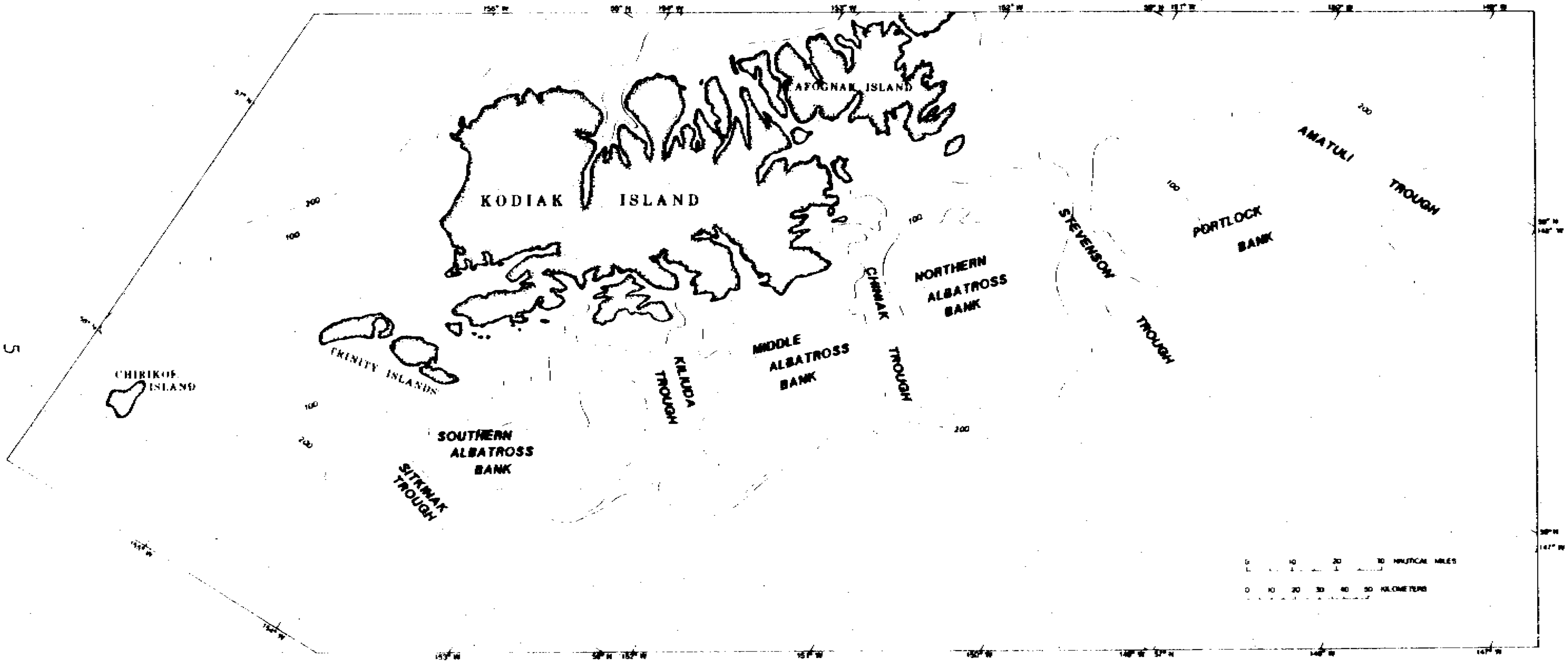

Fig. 1b - Physiographic features of Kodiak Shelf.

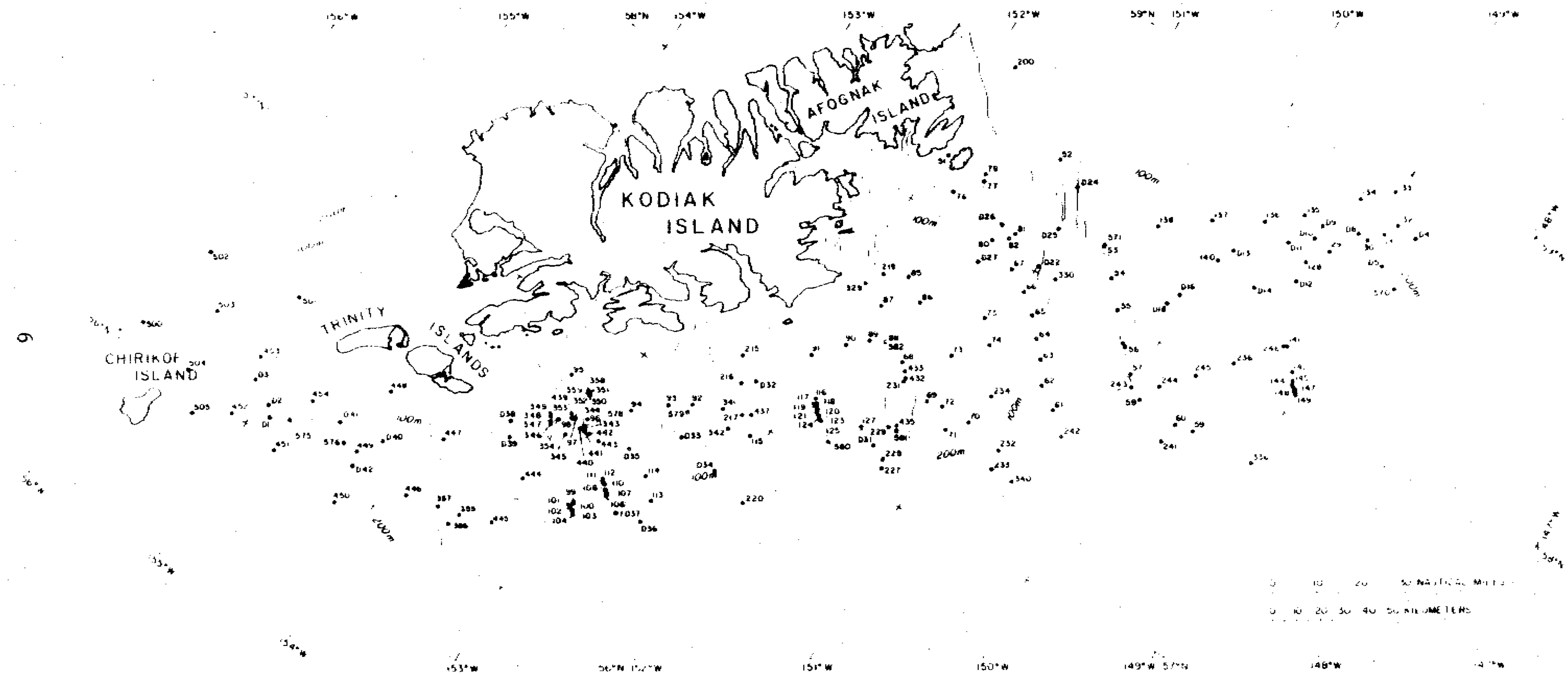

Fig. 2 - Locations of sampling stations.

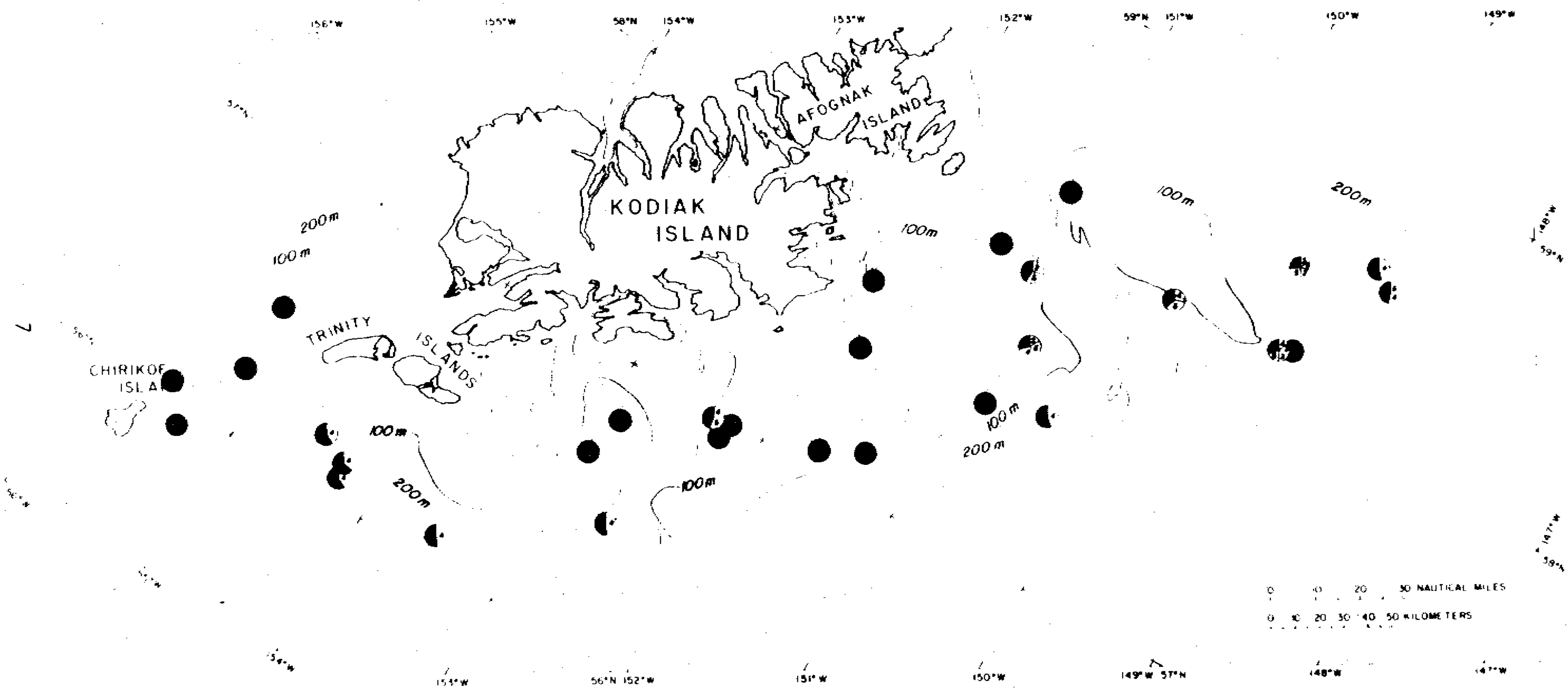

Fig. 3 - Locations of samples in which factor 1 was highest factor loading. Shaded areas of seafloor are bedrock outcrop (with thin patches of unconsolidated sediment).

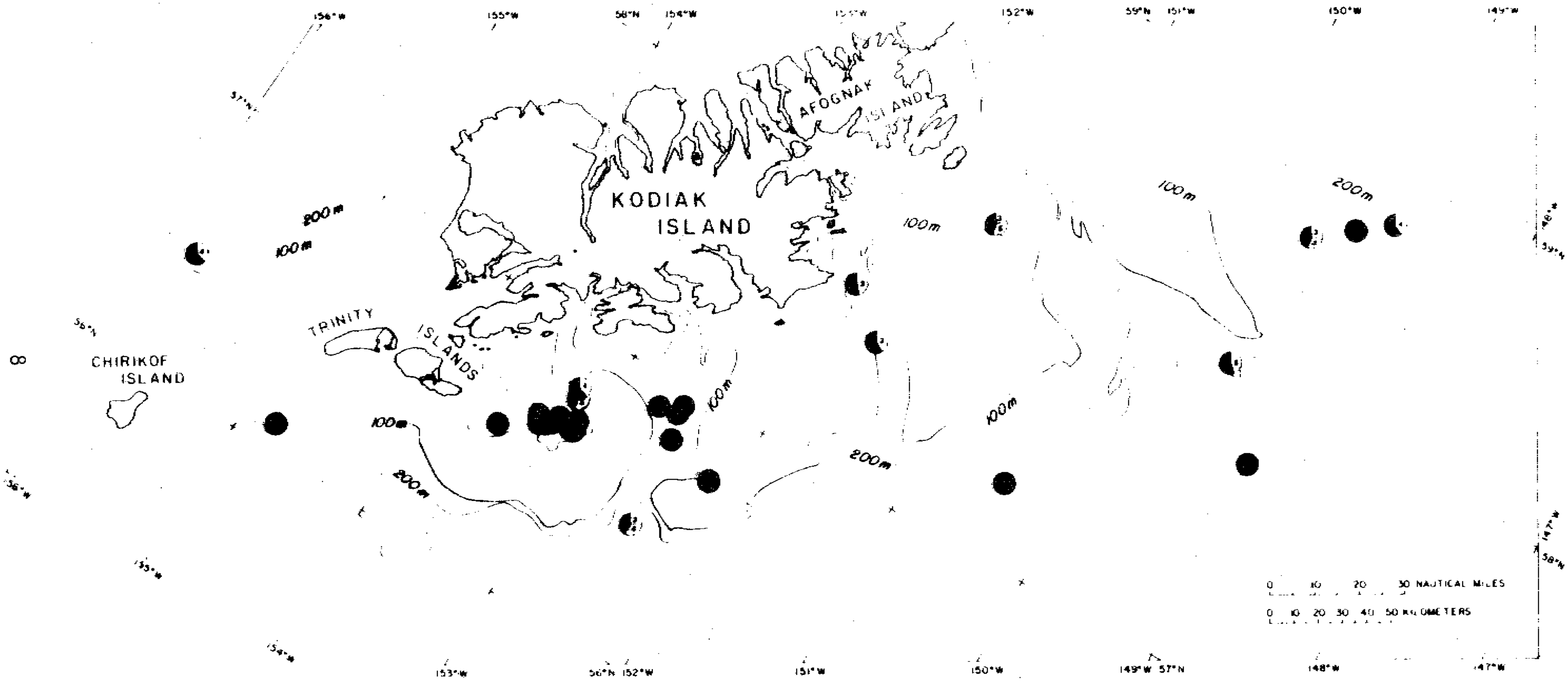

Fig. 4 - Locations of samples in which factor 2 has highest factor loading.

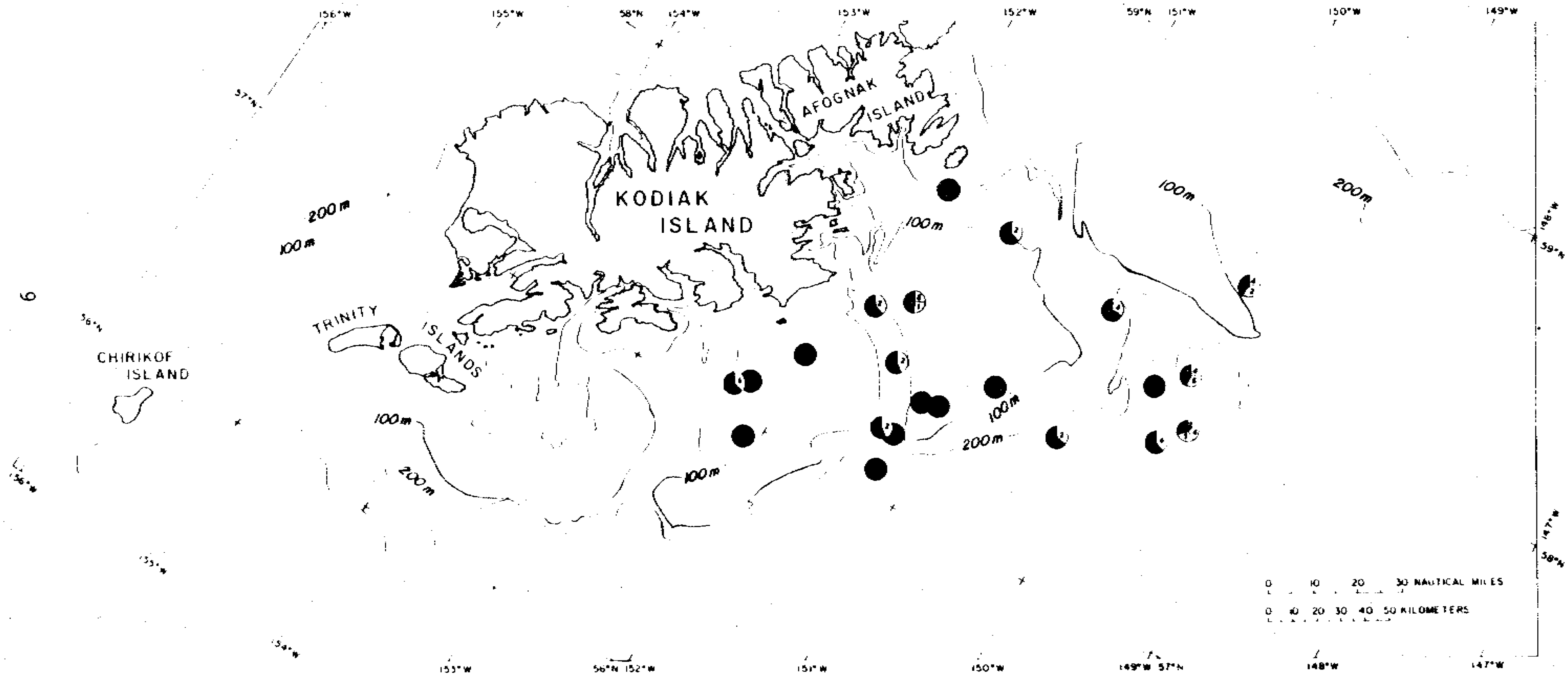

Fig. 5 - Locations of samples in which factor 3 has highest factor loading.

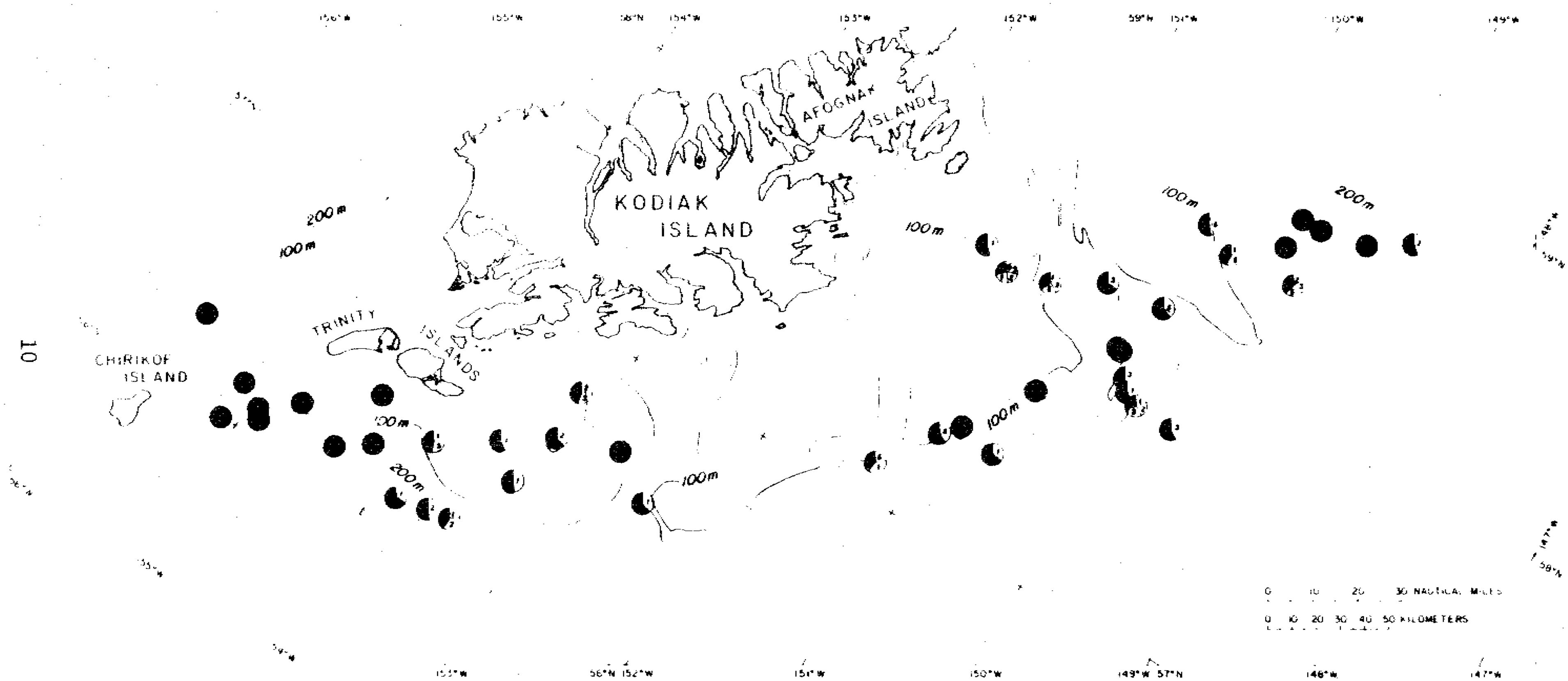

Fig. 6 - Locations of samples in which factor 4 has highest factor loading.

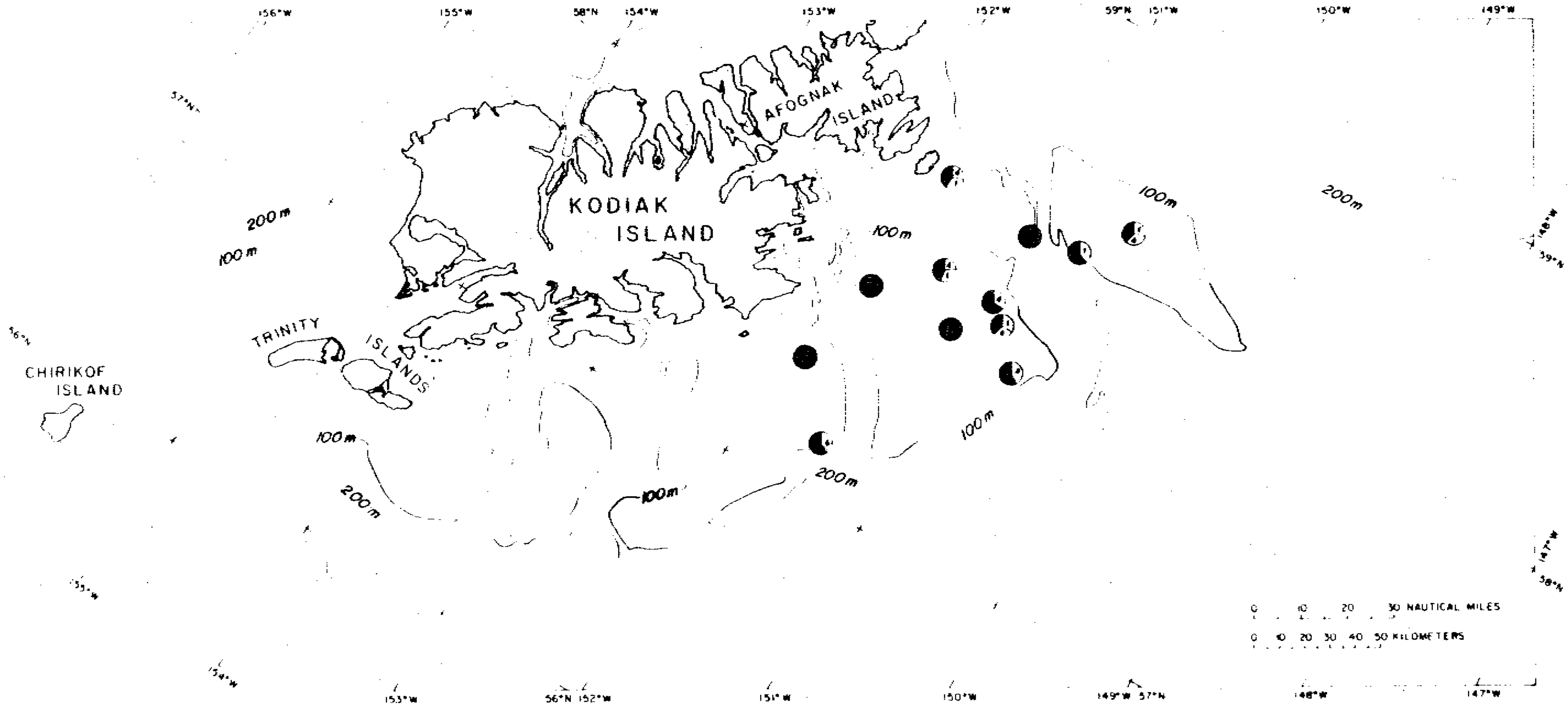

Fig. 7 - Locations of samples in which factor 5 has highest factor loading.

Table 1. Locations, textures, and compositions of sediment samples.

Sample	North Latitude	West Longitude	Water Depth (m)	Location*	Texture (weight percents) Coarse	Sand	Silt	Clay	Composition (weight percents) Terrig.	Carb.	Ash	Clay	Silic.
1	57°56.54'	150°13.56'	192	StT		98	1	1	100	tr	tr	tr	
50	59°52.50'	151°54.50'	32		58	42	tr	tr	94	6			tr
51	58°12.54'	151°55.74'	60		100				95	5			
52	58°24.42'	151°13.80'	107	StT	70	25	3	2					
53	58°12.56'	150°39.79'	86	PB	100				88	12			
54	58°73.62'	150°30.26'	175	StT	2	78	14	6	61	14	22	3	tr
55	58°01.86'	150°21.64'	184	StT		83	12	5	27	1	70	2	tr
56	57°55.56'	150°11.34'	190	StT		99	tr	1	99	tr		1	
57	57°50.94'	150°03.74'	194	StT	2	76	17	5	48	4	43	4	1
58	57°46.99'	149°55.40'	232	StT	15	56	22	7	49	tr	41	9	1
59	57°46.60'	149°29.66'	495	CS	28	56	10	6	52	1	41	6	
60	57°45.96'	149°37.41'	444	CS	2	81	10	7	56	tr	36	7	1
61	57°35.61'	150°24.46'	112	NAB	38	54	5	3	73	17	5	4	1
62	57°39.15'	150°33.49'	102	NAB	12	85	2	1	68	29	2	1	tr
63	57°43.96'	150°39.25'	90	NAB	17	79	3	1	40	58	1	1	tr
64	57°47.50'	150°45.00'	83	NAB	34	62	2	2	51	34	14	1	tr
65	57°51.50'	150°51.50'	77	NAB	32	62	3	3	47	46	5	2	tr
66	57°55.10'	150°59.30'	81	NAB	13	75	8	4	20	64	12	3	1
67	57°59.70'	151°06.40'	82	NAB	21	53	18	8	53	18	17	10	2
68	57°28.15'	151°28.35'	154	CT	1	43	46	10	5	2	86	7	tr
69	57°23.43'	151°11.44'	80	NAB	13	82	2	3	14	5	79	2	tr
70	57°24.08'	150°52.25'	96	NAB	1	97	1	1	94	1	4	1	tr
71	57°20.01'	150°59.08'	95	NAB		96	3	1	61	1	34	1	tr
72	57°24.20'	151°05.10'	92	NAB	tr	94	3	3	6	1	91	2	tr
75	57°45.80'	151°08.05'	70	NAB	10	90			13	87			
76	58°06.20'	151°46.10'	95		tr	96	1	3	12	6	80	2	tr
77	58°11.60'	151°37.00'	38		95	5			94	6			
79	58°13.23'	151°38.07'	68		36	62	tr	2	41	58	1	tr	tr
80	58°01.50'	151°21.63'	181	NAB	32	62	4	2					
81	58°05.21'	151°14.55'	143	NAB/StT		60	30	10	2	1	85	11	1

Table 1 (continued) ·

Sample	North Latitude	West Longitude	Water Depth (m)	Location*	Texture (weight percents) Coarse	Sand	Silt	Clay	Composition (weight percents) Terrig.	Carb.	Ash	Clay	Silic.
82	58°03.60'	151°15.90'	103	NAB	64	16	15	5	58	18	14	8	2
85	57°45.00'	151°44.00'	55	NAB	28	70	1	1	5	85	10		tr
86	57°41.40'	151°34.70'	61	NAB	36	61	1	2					
87	57°36.45'	151°47.60'	132	CT	4	58	31	7	3	4	80	10	3
88	57°30.00'	151°38.80'	167	CT		22	69	9	6	tr	75	17	2
89	57°28.50'	151°44.50'	70	MAB	68	24	6	2	63	11	25	1	tr
90	57°25.10'	151°51.90'	67	MAB	6	91	1	2	3	93	3	1	tr
91	57°19.29'	152°01.82'	73	MAB	5	91	2	2	3	14	84	1	tr
92	56°56.40'	152°32.90'	167	KT		6	74	20	15	tr	41	29	15
93	56°53.50'	152°41.00'	128	KT		24	62	14	12	1	38	37	12
94	56°48.15'	152°52.75'	63	SAB	87	10	2	1	83	14	1	2	tr
96	56°41.40'	153°05.90'	146	KT		3	61	36	11	tr	52	36	1
97	56°40.10'	153°10.20'	150	KT		1	60	39	5	tr	38	56	1
98	56°38.00'	153°16.00'	145	KT		1	62	37	13	tr	46	41	tr
112													
113	56°33.50'	152°27.20'	197	KT	25	70	3	2	94	2	3	1	tr
115	56°57.02'	152°06.28'	76	MAB		92	5	3	2	9	87	2	tr
127	57°11.24'	151°29.59'	69	MAB	17	25	11	7	31	54	10	5	tr
128	58°31.47'	149°21.90'	121	PB	25	45	15	15	37	36	15	11	1
130	58°42.23'	149°03.38'	145	PB		79	11	10	81		15	3	1
131	58°44.99'	148°58.18'	214	AT	3	45	25	27					
132	58°48.16	148°54.71'	236	AT	5	33	32	30	56	tr	26	15	3
134	58°49.42'	149°14.22'	206	AT	20	41	17	22					
135	58°40.39'	149°31.82'	136	PB		77	15	8	78		10	11	1
136	58°34.90'	149°45.19'	125	PB		73	17	10					
137	58°29.46'	150°05.25'	93	PB	10	72	13	5	53	42	6	9	tr
138	58°22.30'	150°24.07'	60	PB	24	70	3	3	41	51	7	1	tr
141	58°13.12'	149°11.85'	120	PB	56	26	11	7	60	13	22	5	tr
200	58°36.79'	151°50.26'	159		48	46	2	4	92	3	2	2	1
201	58°42.24'	152°17.77'	126		54	43	1	2	67	31	tr	2	tr
202	58°46.12'	152°42.85'	190		3	65	13	19	72	3	12	10	3
204	58°51.37'	152°54.13'	164		36	32	19	13	52	tr	34	12	2
205	58°58.89'	153°13.38'	118		35	47	11	7	80	2	12	5	1
215	57°11.38'	152°25.89'	115	MAB/KT	15	63	14	8					
216	57°06.00'	152°20.60'	96	MAB	1	88	7	4	6	35	56	3	tr

Table 1 (continued).

Sample	North Latitude	West Longitude	Water Depth (m)	Location*	Texture (weight percents) Coarse	Sand	Silt	Clay	Composition (weight percents) Terrig.	Carb.	Ash	Clay	Silic.
217	57°00.00'	152°13.50'	76	MAB	52	44	3	1	49	27	23	1	tr
219	57°42.65'	151°53.60'	79	CT	73	25	1	1	89	10	1		tr
227	57°05.60'	151°14.00'	358	CS		72	19	9	7	tr	87	6	tr
228	57°07.50'	151°15.40'	185	CT	33	59	5	3	67	28	2	3	tr
229	57°14.20'	151°19.90'	172	CT		55	36	9	6	1	74	17	2
232	57°22.01'	150°35.92'	262	CS	29	69	1	1	98	tr	1	1	tr
233	57°17.60'	150°34.50'	630	CS		23	55	22					
234	57°31.54'	150°49.42'	93	NAB	50	47	2	1	52	28	19	1	tr
236	58°04.20'	149°28.20'	230	StT		38	48	14	5	tr	71	23	1
241	57°41.29'	149°39.16'	606	CS	5	86	4	5	37		62	1	tr
242	57°31.40'	150°16.00'	300	CS		64	30	6	7	tr	80	12	1
243	57°48.50'	150°01.10'	190	StT	24	66	7	3	77	2	16	5	tr
244	57°51.70'	149°50.90'	257	StT	1	80	15	4	17	tr	75	7	1
245	57°57.60'	149°39.70'	135	StT	9	72	6	13	21	33	41	4	1
246	58°12.80'	149°13.40'	134	PB	32	47	13	8	35	29	23	13	tr
329	57°38.95'	151°58.03'	218	CT		36	50	14	3	tr	76	20	1
330	58°00.96'	150°50.59'	135	StT	10	78	7	5	50	28	17	5	tr
336	57°46.60'	149°02.08'	1700	CS		1	50	49	16		40	39	5
340	57°17.48'	150°24.92'	762	CS	2	23	51	24	43	2	34	21	tr
341	56°59.00'	152°21.47'	80	MAB	50	43	4	3	50	41	6	3	tr
342	56°55.77'	152°15.17'	79	MAB	59	34	4	3	66	5	26	3	tr
343	56°39.37'	153°04.72'	155	KT		5	64	31	14	1	66	15	4
344	56°39.47'	153°05.63'	160	KT		1	60	39	16	2	23	56	3
345	56°36.11'	153°10.00'	119	KT		65	23	12	69	1	17	12	1
346	56°36.22'	153°12.51'	120	KT		67	22	11					
347	56°36.76'	153°17.92'	130	KT		4	67	29	16	tr	36	44	3
348	56°37.66'	153°18.89'	143	KT		3	63	34	12		48	36	4
349	56°38.24'	153°19.80'	148	KT		1	61	38	3		53	42	2
350	56°46.20'	153°10.00'	154	KT		13	53	34	11		40	37	12
351	56°46.86'	153°11.02'	125	KT	22	32	29	17	52	tr	26	16	6
353	56°39.90'	153°11.08'	148	KT		1	61	38	6	tr	43	45	6
354	56°37.85'	153°16.05'	143	KT		1	61	38	11	3	60	21	5
355	56°08.53'	153°29.41'	314	SiT	10	45	26	19	67	2	21	10	tr
356	56°05.55'	153°31.28'	370	SiT	43	49	5	3	93	tr	3	4	tr
357	56°07.56'	153°38.46'	240	SiT		56	30	14	53	1	22	21	3

Table 1 (continued).

Sample	North Latitude	West Longitude	Water Depth (m)	Location*	Texture (weight percents) Coarse	Sand	Silt	Clay	Composition (weight percents) Terrig.	Carb.	Ash	Clay	Silic.
358	56°47.03'	153°11.70'	122	KT	2	69	16	13	54	tr	30	15	1
359	56°46.47'	153°10.59'	152	KT		49	32	19	37	tr	37	22	4
437	57°01.14'	152°10.31'	72	MAB	80	18	1	1	90	7	2	1	tr
443	56°38.56'	152°57.42'	82	SAB	71	18	7	4	89	2	5	3	1
444	56°22.91'	153°15.75'	35	SAB	39	59	1	1	96	2	1	1	
446	56°05.88'	153°51.49'	213	SiT	10	76	10	4	86		7	6	1
447	56°20.68'	153°50.84'	94	SiT	9	75	10	6	55	31	8	4	2
448	56°23.19'	154°18.80'	42	SAB		99	tr	1	100		tr	tr	tr
449	56°08.13'	154°17.33'	97	SAB	63	30	4	3	93	1	1	4	1
452	55°59.97'	155°07.08'	67	SAB	1	99			100	tr			
453	56°13.90'	155°09.84'	32	SAB	91	9	tr	tr	96	4	tr	tr	tr
454	56°12.08'	154°42.77'	89	SAB		97	1	2	97	tr	2	1	tr
501	56°29.79'	155°08.57'	30	SAB	73	26	tr	1	71	28	tr	tr	tr
502	56°27.49'	155°48.68'	180	SS		39	42	19	50	18	20	12	1
503	56°17.43'	155°32.91'	50	SAB		99	tr	1	94	6	tr	tr	
504	56°03.09'	155°30.25'	25	SAB	96	4	tr	tr	78	22		tr	
505	55°55.32'	155°18.02'	50	SAB	77	23	tr	tr	95	5	tr	tr	tr
570	58°34.4'	148°44.1'	117	PB	49	39	5	7	62	30	1	3	4
571	58°12.9'	150°39.9'	80	StT	52	46	1	1	4	92	tr	tr	4
575	56°05.9'	154°45.3'	115	SAB		10	46	44	32	12	41	2	14
576	56°08.8'	154°22.4'	134	SAB	tr	82	11	7	91	1	2	5	tr
578	56°39.5'	153°05.2'	154	KT		1	51	48	20	6	47	26	1
579	56°54.9'	152°32.6'	170	KT		2	63	35	35	12	37	15	tr
580	57°05.0'	151°38.4'	119	MAB	71	19	6	4	80	8	10	2	1
581	57°14.4'	151°19.0'	163	CT		67	25	8	2	1	92	5	0
582	57°29.7'	151°38.6'	133	CT		39	45	16	26	6	60	8	0
D1	56°03.4'	154°52.7'	113	SAB		100	tr	tr	100	tr			
D2	56°05.7'	154°55.9'	64	SAB		99	tr	1	99		tr	tr	tr
D3	56°09.1'	155°02.9'	55	SAB		100			100			tr	
D4	58°41.5'	148°45.4'	215	AT	3	49	22	26	73	3	14	9	1
D5	58°38.4'	148°53.4'	120	PB	41	46	5	9	78	10	2	3	8
D8	58°48.2'	149°08.0'	195	PB	1	23	51	25	65	5	7	15	8
D9	58°40.1'	149°23.2'	135	PB		75	15	10	69	1	23	7	1
D10	58°36.9'	149°23.2'	126	PB	3	57	21	19	29	11	39	12	8
D11	58°33.3'	149°32.6'	120	PB		79	10	11	81	4	11	2	2

Table 1 (continued).

Sample	North Latitude	West Longitude	Water Depth (m)	Location*	Texture (weight percents)				Composition (weight percents)				
					Coarse	Sand	Silt	Clay	Terrig.	Carb.	Ash	Clay	Silic.
D12	58°26.5'	149°21.8'	135	PB	9	70	12	9	45	25	18	4	7
D13	58°25.6'	149°51.0'	135	PB	15	66	17	2	45	34	13	4	3
D14	58°20.5'	149°36.2'	140	PB		58	31	11	24	9	50	14	1
D16	58°10.7'	150°01.6'	128	PB	37	52	6	5	46	36	6	3	9
D18	58°14.4'	150°51.4'	106	StT	4	93	1	2	55	27	9	2	8
D22	58°02.5'	150°59.4'	97	NAB	40	38	13	9	32	30	23	4	11
D24	58°20.3'	151°02.4'	101	StT	86	11	1	2	10	87	1	1	1
D25	58°10.4'	150°59.0'	111	NAB	27	67	3	3	20	50	5	2	22
D26	58°05.0'	151°20.8'	139	CT		55	29	16	3	47	34	13	2
D27	57°52.9'	151°22.4'	71	NAB	41	57	tr	2	40	53	3	0	5
D31	57°09.1'	151°21.6'	128	CT	64	31	3	2	69	15	11	1	4
D32	57°07.8'	152°15.2'	80	MAB		84	12	4	5	8	76	8	3
D33	56°48.7'	152°29.9'	146	KT		1	64	35	6	8	56	26	4
D34	56°46.7'	152°11.7'	102	KT		19	53	28	46	7	21	23	3
D35	56°40.6'	152°45.2'	82	SAB	tr	97	2	1	72	23	0	1	3
D36	56°28.6'	152°25.8'	338	CS		56	33	11	42	7	33	12	5
D37	56°26.9'	152°36.0'	179	KT	37	53	1	9	75	7	11	2	5
D38	56°32.4'	153°30.8'	132	KT		15	61	24	27	17	36	18	3
D39	56°29.1'	153°28.0'	88	SAB	25	58	7	10	67	24	1	5	3
D40	56°13.0'	154°11.3'	130	SiT		78	15	7	74	7	2	11	5
D41	56°11.6'	154°28.9'	91	SAB	52	41	4	3	88	5	5	2	0
D42	56°04.9'	154°14.8'	93	SAB	54	37	4	5	86	7	2	3	3

*Refer to Fig. 8. At=Amatuli Trough, PB=Portlock Bank, StT=Stevenson Trough, NAB=northern Albatross Bank, CT=Chiniak Trough, MAB=middle Albatross Bank, SAB=southern Albatross Bank, SiT=Sitkinak Trough, CS=continental slope, SS=Shelikof Strait.

Table 2. Varimax factor loadings for 5 factors used to classify and map unconsolidated seafloor sediment of Kodiak Shelf, Alaska. Factors are based on 12 textural and compositional variables. Factor-loading values listed in the columns for factors 1-5 are the proportional contributions of each factor to a given sample. Communality is the sum of squares of the 5 factor loadings for a sample, and will be unity if 5 factors account for all the information in the sample.

STA.	COMM.	1	2	3	4	5
001	0.9967	0.3287	-0.0013	0.2247	0.9015	0.1597
054	0.9874	0.2855	0.2226	0.4267	0.7709	0.2829
055	0.9973	0.1359	0.2525	0.8318	0.4467	0.1535
056	0.9967	0.3287	-0.0020	0.2238	0.9016	0.1600
057	0.9946	0.2612	0.2980	0.6222	0.6433	0.1912
058	0.9920	0.4003	0.4472	0.5558	0.5579	0.1077
059	0.9952	0.5444	0.2937	0.5664	0.5277	0.1153
060	0.9952	0.2648	0.2595	0.5537	0.7212	0.1760
061	0.7494	0.6262	0.0995	0.1631	0.5071	0.2522
062	0.9869	0.3824	0.0026	0.2731	0.7856	0.3858
063	0.9597	0.2933	-0.0078	0.2634	0.5619	0.6989
064	0.9562	0.5524	0.0500	0.3250	0.5466	0.4941
065	0.9585	0.5085	0.0502	0.2366	0.5194	0.6096
066	0.9645	0.1841	0.1053	0.3752	0.4129	0.7799
067	0.9844	0.5136	0.4011	0.3172	0.6039	0.3073
068	0.9598	0.0636	0.6032	0.7646	0.0799	0.0279
069	0.9857	0.1857	0.1659	0.8944	0.3011	0.1821
070	0.9961	0.3323	0.0102	0.2579	0.8900	0.1642
071	0.9986	0.2610	0.0736	0.5494	0.7671	0.1864
072	0.9872	0.0449	0.1652	0.9211	0.2855	0.1671
075	0.9124	0.0713	-0.0651	0.2627	0.3674	0.8361
076	0.9872	0.0699	0.1411	0.8839	0.3649	0.2189
079	0.9575	0.5127	-0.0220	0.2133	0.4536	0.6655
080	0.9789	0.6290	0.0473	0.2052	0.7095	0.1884
081	0.9951	0.0348	0.5262	0.8244	0.1656	0.1002
081	0.9951	0.0348	0.5262	0.8244	0.1656	0.1002
082	0.9874	0.9064	0.3093	0.0892	0.2222	0.1137
085	0.9156	0.2451	-0.0344	0.3586	0.1909	0.8303
086	0.8703	0.4027	0.0847	0.7407	0.0878	0.3802
087	0.9856	0.0689	0.5122	0.8260	0.1415	0.1273
088	0.8900	0.0500	0.7698	0.5425	0.0127	-0.0209
089	0.9826	0.9141	0.1418	0.2370	0.2592	0.0592
090	0.9075	0.0089	-0.0342	0.2801	0.3179	0.8525
091	0.9888	0.0703	0.1375	0.9153	0.2553	0.2492
092	0.8275	0.0546	0.8922	0.1464	0.0391	0.0706
093	0.8262	0.0440	0.8621	0.2301	0.1074	0.1287
094	0.9849	0.9588	0.0528	-0.0586	0.2397	0.0429
096	0.9548	0.0426	0.9496	0.2244	0.0098	-0.0269
097	0.8847	0.0056	0.9351	0.1011	-0.0026	0.0065
098	0.9347	0.0400	0.9503	0.1702	0.0162	-0.0291
113	0.9978	0.5625	0.0475	0.1758	0.7946	0.1297
115	0.9913	0.0388	0.1755	0.9139	0.2737	0.2209
127	0.9283	0.2858	0.1925	0.3019	0.4721	0.7039
128	0.5004	0.3932	0.3170	0.2063	0.2467	0.3768
130	0.9930	0.3289	0.2192	0.2982	0.8530	0.1428
132	0.9429	0.2948	0.7583	0.1749	0.4976	0.0523

Table 2 (continued).

STA.	COMM.	1	2	3	4	5
135	0.9891	0.3162	0.2760	0.2577	0.8500	0.1547
137	0.9434	0.2997	0.2099	0.2941	0.6172	0.5848
138	0.9419	0.4466	0.0354	0.3360	0.5529	0.5680
141	0.8416	0.8025	0.2520	0.2118	0.2615	0.1442
216	0.8213	0.0841	0.1525	0.7159	0.2769	0.4492
217	0.9614	0.7762	0.0850	0.3609	0.3271	0.3384
219	0.9858	0.9072	0.0322	-0.0059	0.3899	0.0985
227	0.9940	0.0540	0.3798	0.8823	0.2364	0.1116
228	0.9682	0.6244	0.0835	0.1834	0.6285	0.3778
229	0.9844	0.0486	0.6052	0.7539	0.1885	0.1092
232	0.9979	0.5843	0.0211	0.1479	0.7891	0.1073
234	0.6950	0.6709	0.0554	0.2887	0.2852	0.2778
236	0.9723	0.0371	0.7540	0.6253	0.0966	0.0451
241	0.9894	0.2098	0.1745	0.7796	0.5307	0.1594
242	0.9912	0.0471	0.4849	0.8352	0.2104	0.1096
243	0.9944	0.5443	0.1483	0.3092	0.7484	0.1430
244	0.9950	0.0975	0.3090	0.8584	0.3600	0.1536
245	0.9424	0.2097	0.2824	0.6330	0.4070	0.5023
246	0.5676	0.4628	0.2825	0.3141	0.2368	0.3448
329	0.9751	0.0328	0.7432	0.6455	0.0642	0.0307
330	0.8658	0.3360	0.1449	0.3974	0.6211	0.4338
336	0.9129	0.0501	0.9483	0.0903	0.0512	0.0159
340	0.9696	0.2032	0.8786	0.2114	0.3340	0.0129
341	0.9608	0.7327	0.0878	0.1653	0.3712	0.5011
342	0.9906	0.8582	0.1526	0.2872	0.3768	0.0792
343	0.9520	0.0658	0.9095	0.3457	0.0020	-0.0313
344	0.9157	0.0294	0.9532	-0.0132	0.0695	0.0350
345	0.9882	0.3133	0.4298	0.2822	0.7797	0.1338
347	0.9316	0.0493	0.9548	0.1198	0.0566	0.0032
348	0.9680	0.0451	0.9634	0.1938	0.0183	-0.0035
349	0.9493	0.0120	0.9506	0.2103	-0.0358	-0.0107
350	0.9060	0.0400	0.9310	0.1532	0.0715	0.0955
351	0.9587	0.4668	0.6968	0.2235	0.4417	0.1007
353	0.9464	0.0130	0.9631	0.1328	-0.0129	0.0275
354	0.9747	0.0454	0.9548	0.2467	-0.0060	-0.0025
355	0.9775	0.3957	0.5833	0.2146	0.6550	0.0751
356	0.9945	0.7198	0.1049	0.0890	0.6734	0.0633
357	0.9679	0.2490	0.6180	0.2968	0.6428	0.1508
358	0.9783	0.2631	0.4412	0.4510	0.6961	0.1624
359	0.9718	0.1776	0.7347	0.4005	0.4721	0.1312
443	0.9899	0.9062	0.1450	-0.0192	0.3837	0.0091
444	0.9966	0.6720	0.0255	0.1157	0.7219	0.0986
446	0.9946	0.4214	0.1608	0.2300	0.8471	0.1433
447	0.9364	0.3497	0.1763	0.2988	0.6872	0.4707
448	0.9970	0.3289	-0.0075	0.2247	0.9016	0.1596
449	0.9941	0.8565	0.1069	-0.0044	0.4978	0.0360
452	0.9968	0.3374	-0.0149	0.2243	0.8987	0.1573
453	0.9847	0.9477	0.0224	-0.0746	0.2829	-0.0180
454	0.9971	0.3295	0.0161	0.2347	0.8990	0.1579
501	0.9738	0.9222	0.0082	0.0164	0.3087	0.1666
502	0.6371	0.1370	0.6510	0.0642	0.4058	0.1602
503	0.9962	0.3142	-0.0005	0.2262	0.8959	0.2089
504	0.9797	0.9770	0.0127	-0.0676	0.1382	0.0363
505	0.9859	0.9071	0.0167	-0.0282	0.4015	0.0273
570	0.9783	0.7541	0.1896	0.0334	0.4537	0.4083

Table 2 (continued).

STA.	COMM.	1	2	3	4	5
571	0.8465	0.5057	-0.0059	0.1840	-0.0342	0.7455
575	0.8000	0.0958	0.8657	0.0896	0.1728	0.0580
576	0.9950	0.3366	0.1728	0.1855	0.8923	0.1461
578	0.9129	0.0567	0.9439	0.1172	0.0707	0.0041
579	0.8011	0.0971	0.8751	0.0468	0.1535	0.0141
580	0.9817	0.9153	0.1547	0.0294	0.3421	0.0452
581	0.9891	0.0343	0.4184	0.8796	0.1723	0.0977
582	0.9386	0.1254	0.7339	0.5537	0.2725	0.0584
D001	0.9967	0.3293	-0.0152	0.2265	0.9009	0.1587
D002	0.9970	0.3289	-0.0075	0.2247	0.9016	0.1596
D003	0.9967	0.3293	-0.0152	0.2265	0.9009	0.1587
D004	0.9523	0.3372	0.5605	0.1259	0.7049	0.1080
D005	0.9260	0.6769	0.2271	0.0448	0.5978	0.2386
D008	0.9536	0.2452	0.8037	-0.0766	0.4826	0.0934
D009	0.9955	0.3006	0.3155	0.3798	0.7982	0.1553
D010	0.8979	0.1510	0.6405	0.4270	0.4398	0.2984
D011	0.9910	0.3266	0.2242	0.2543	0.8566	0.1886
D012	0.9409	0.2856	0.3284	0.3434	0.6419	0.4706
D013	0.8904	0.3240	0.2916	0.2786	0.5988	0.5139
D014	0.9858	0.1138	0.6138	0.6206	0.4070	0.2129
D016	0.9038	0.5730	0.1934	0.1702	0.4449	0.5579
D018	0.9394	0.2493	0.0710	0.3325	0.7299	0.4785
D022	0.8166	0.5648	0.4028	0.2719	0.2331	0.4552
D024	0.6226	0.6810	-0.0004	0.0588	-0.2454	0.3085
D025	0.6019	0.2517	0.1626	0.1588	0.2624	0.6466
D026	0.6902	-0.0208	0.5739	0.2904	0.2051	0.4838
D027	0.9579	0.5413	0.0418	0.1756	0.4006	0.6869
D031	0.9769	0.8845	0.1232	0.1104	0.3681	0.1780
D032	0.9203	0.0425	0.2949	0.8189	0.2625	0.2848
D033	0.9414	0.0093	0.9510	0.1884	-0.0162	0.0329
D034	0.9789	0.1681	0.9089	0.0338	0.3441	0.0706
D035	0.9949	0.2634	0.0159	0.2581	0.8339	0.4041
D036	0.9598	0.2022	0.6394	0.4020	0.5451	0.2265
D037	0.9557	0.6567	0.1974	0.1683	0.6408	0.2157
D038	0.7172	0.0574	0.8189	0.0796	0.1613	0.1046
D039	0.9728	0.5490	0.2468	0.1199	0.6984	0.3290
D040	0.9767	0.2888	0.2853	0.1809	0.8416	0.2662
D041	0.9934	0.8020	0.0909	0.0862	0.5744	0.0677
D042	0.9889	0.8104	0.1468	0.0222	0.5406	0.1335
	% CUM. VAR	45.791	65.111	76.326	92.208	96.956

Table 3. Factor score matrix.

	1	2	3	4	5
coarse size	0.8262	-0.0345	0.0289	-0.3301	0.1309
sand size	-0.0525	-0.0958	0.4956	0.5926	0.4329
silt size	-0.0202	0.6255	0.0009	-0.0026	0.0049
clay size	-0.0188	0.5295	-0.1285	0.0573	0.0610
terrigenous	0.5182	0.0743	-0.1752	0.6814	-0.2084
clay min.	-0.0147	0.4287	-0.0677	0.0100	0.0318
volc. ash	0.0932	0.2429	0.8172	-0.1893	-0.1883
silic. micro.	0.0109	0.1785	-0.0929	-0.0074	0.2144
foram.	0.1200	0.0076	0.0325	-0.0815	0.2162
large shells	0.1388	-0.0147	0.0224	-0.1441	0.2186
crushed shells	-0.0143	-0.0032	-0.0907	-0.0866	0.7458
fine carb.	-0.0496	0.1940	-0.1245	0.0373	0.1232

Table 4. Descriptions of samples for which detailed analyses were not made

Sample	North Latitude	West Longitude	Water Depth (M)	Location	Visual Description
50	59°52.50'	151°54.50'	32		Sandy gravel
95	56°48.10'	153°21.40'	170	KT	Pebbly sand
99	56°24.50'	152°53.70'	50	SAB	Bedrock (siltstone)
100	56°24.00'	152°53.50'	50	SAB	Bedrock (siltstone)
101	56°23.20'	152°54.10'	49	SAB	Bedrock (silty, fine-grained sandstone)
102	56°23.10'	152°53.90'	45	SAB	Bedrock (siltstone)
103	56°22.70'	152°52.00	50	SAB	Bedrock (silty, fine-grained sandstone)
104	56°22.00'	152°50.90'	75	SAB	Bedrock (silty, fine-grained sandstone)
106	56°29.60'	152°43.70'	60	SAB	Bedrock (siltstone)
107	56°30.15'	152°44.10'	56	SAB	Bedrock (siltstone)
108	56°30.30'	152°44.90'	56	SAB	Bedrock (siltstone)
110	56°31.40'	152°46.70'	64	SAB	Bedrock (siltstone)
111	56°31.70'	152°47.50'	65	SAB	Bedrock (sandy siltstone)
112	56°32.00'	152°48.50'	70	SAB	Coarse sand with broken shells
114	56°37.60'	152°34.00'	160	KT	Slightly muddy sand
116	57°12.00'	151°51.10'	75	MAB	Bedrock (pebbly, sandy siltstone)
117	57°10.90'	151°50.70'	54	MAB	Bedrock (pebbly, sandy siltstone)
118	57°11.00'	151°50.00'	54	MAB	Bedrock (sandy siltstone)
119	57°10.60'	151°49.10'	56	MAB	Pebbly sand with broken shells
120	57°10.00'	151°48.40'	60	MAB	Bedrock (sandy siltstone)
121	57°09.25'	151°47.50'	70	MAB	Bedrock (sandy siltstone)
123	57°08.75'	151°46.30'	76	MAB	Bedrock (sandy siltstone)
124	57°08.50'	151°45.60'	78	MAB	Bedrock (fine sandstone)
125	57°08.00'	151°45.00'	80	MAB	Sandy silt
129	58°35.85'	149°14.91'	95	PB	Pebbly muddy sand
133	58°54.41'	149°01.95'	250	AT	Muddy sand
140	58°22.25'	149°54.26'	83	PB	Pebbly sand
142	58°08.66'	149°04.71'	114	PB	Bedrock (muddy sand)
144	58°05.92'	149°01.38'	88	PB	Bedrock (sandy siltstone)
145	58°06.59'	149°02.46'	90	PB	Bedrock (sandy siltstone)

Table 4 (continued).

147	58°05.55'	149°00.97'	88	PB	Bedrock (fine-grained sandstone)
148	58°04.96'	148°59.95'	90	PB	Bedrock (sandy siltstone)
149	58°04.64'	148°59.49'	98	PB	Bedrock (sandy siltstone)
220	56°43.80'	151°55.90'	62	MAB	Boulder
231	57°24.90'	151°23.60'	187	CT	Ash-rich mud
352	56°40.19'	153°10.88'	150	KT	Ash-rich mud
432	57°25.40'	151°23.50'	175	CT	Ash-rich mud
433	57°26.71'	151°25.26'	174	CT	Ash-rich mud
435	57°15.04'	151°17.10'	158	CT	Ash-rich mud
439	56°40.51'	153°12.30'	159	KT	Ash-rich mud
440	56°39.15'	153°06.36'	156	KT	Ash-rich mud
441	56°39.50'	153°04.62'	164	KT	Ash-rich mud
442	56°39.15'	15302.11'	135	KT	Ash-rich mud
445	56°11.17'	153°17.28'	1003	SlT	Mud
450	55°56.06'	154°14.13'	390	CS	Mud, with sand layers
451	55°58.50'	154°45.80'	371	CS	

Appendix 1. Compositional data for the various size fractions.

SAMPLE NUMBER 1

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______   __ granules   __ pebbles

Carbonate shells ______   __ cobbles   __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 98

Composition:

Terrigenous rock fragments and mineral grains 100

Carbonate megafaunal shell fragments TR

Foraminifera ______

Volcanic ash ______

Siliceous spicules and shells ______

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 1

Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals ______

Volcanic ash ______

Terrigenous mineral grains ______

Siliceous shells and spicules ______

Carbonate shells ______

SAMPLE NUMBER 50

Coarse fraction (>2 mm)

Weight percent of total sample 58

Composition:

Terrigenous rock fragments 97   X granules   X pebbles

Carbonate shells 3   __ cobbles   __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 42

Composition:

Terrigenous rock fragments and mineral grains 90

Carbonate megafaunal shell fragments 9

Foraminifera 1

Volcanic ash ______

Siliceous spicules and shells ______

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample TR

Weight percent clay (<0.0039 mm) in total sample TR

Composition:

Clay minerals 10

Volcanic ash 35

Terrigenous mineral grains 55

Siliceous shells and spicules Tr

Carbonate shells ______

SAMPLE NUMBER 51

Coarse fraction (>2 mm)

Weight percent of total sample 100

Composition:

Terrigenous rock fragments 95

Carbonate shells 5

X granules X pebbles
_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample _____

Composition:

Terrigenous rock fragments and mineral grains _____
Carbonate megafaunal shell fragments _____
Foraminifera _____
Volcanic ash _____
Siliceous spicules and shells _____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample _____
Weight percent clay (<0.0039 mm) in total sample _____

Composition:

Clay minerals _____
Volcanic ash _____
Terrigenous mineral grains _____
Siliceous shells and spicules _____
Carbonate shells _____

SAMPLE NUMBER 52

Coarse fraction (>2 mm)

Weight percent of total sample 70

Composition:

Terrigenous rock fragments 95

Carbonate shells 5

X granules X pebbles
X cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 25

Composition:

Terrigenous rock fragments and mineral grains _____
Carbonate megafaunal shell fragments _____
Foraminifera _____
Volcanic ash _____
Siliceous spicules and shells _____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 3
Weight percent clay (<0.0039 mm) in total sample 2

Composition:

Clay minerals _____
Volcanic ash _____
Terrigenous mineral grains _____
Siliceous shells and spicules _____
Carbonate shells _____

SAMPLE NUMBER 53

Coarse fraction (>2 mm)

Weight percent of total sample 100

Composition:

Terrigenous rock fragments 89 — X granules, X pebbles

Carbonate shells 11 — _ cobbles, _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments and mineral grains ____
Carbonate megafaunal shell fragments ____
Foraminifera ____
Volcanic ash ____
Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample ____
Weight percent clay (<0.0039 mm) in total sample ____

Composition:

Clay minerals ____
Volcanic ash ____
Terrigenous mineral grains ____
Siliceous shells and spicules ____
Carbonate shells ____

SAMPLE NUMBER 54

Coarse fraction (>2 mm)

Weight percent of total sample 2

Composition:

Terrigenous rock fragments 50 — X granules, _ pebbles

Carbonate shells 50 — _ cobbles, _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 78

Composition:

Terrigenous rock fragments and mineral grains 70
Carbonate megafaunal shell fragments 15
Foraminifera ____
Volcanic ash 10
Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 14
Weight percent clay (<0.0039 mm) in total sample 6

Composition:

Clay minerals 15
Volcanic ash 75
Terrigenous mineral grains 10
Siliceous shells and spicules Tr
Carbonate shells ____

SAMPLE NUMBER 55

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______

Carbonate shells ______

__ granules __ pebbles

__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 83

Composition:

Terrigenous rock fragments and mineral grains 26

Carbonate megafaunal shell fragments ______

Foraminifera 1

Volcanic ash 73

Siliceous spicules and shells ______

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 12

Weight percent clay (<0.0039 mm) in total sample 5

Composition:

Clay minerals 12

Volcanic ash 63

Terrigenous mineral grains 20

Siliceous shells and spicules Tr

Carbonate shells ______

SAMPLE NUMBER 56

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______

Carbonate shells ______

__ granules __ pebbles

__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 99

Composition:

Terrigenous rock fragments and mineral grains 100

Carbonate megafaunal shell fragments TR

Foraminifera ______

Volcanic ash ______

Siliceous spicules and shells ______

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample TR

Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 57

Volcanic ash 35

Terrigenous mineral grains 3

Siliceous shells and spicules 5

Carbonate shells Tr

SAMPLE NUMBER 57

Coarse fraction (>2 mm)

Weight percent of total sample 2

Composition:

Terrigenous rock fragments 60

Carbonate shells 40

X granules   __ pebbles   __ cobbles   __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 76

Composition:

Terrigenous rock fragments and mineral grains 56

Carbonate megafaunal shell fragments 2

Foraminifera 2

Volcanic ash 40

Siliceous spicules and shells TR

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 17

Weight percent clay (<0.0039 mm) in total sample 5

Composition:

Clay minerals 15

Volcanic ash 65

Terrigenous mineral grains 15

Siliceous shells and spicules 5

Carbonate shells ____

SAMPLE NUMBER 58

Coarse fraction (>2 mm)

Weight percent of total sample 15

Composition:

Terrigenous rock fragments 100

Carbonate shells TR

X granules   X pebbles   __ cobbles   __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 56

Composition:

Terrigenous rock fragments and mineral grains 50

Carbonate megafaunal shell fragments ____

Foraminifera TR

Volcanic ash 50

Siliceous spicules and shells TR

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 22

Weight percent clay (<0.0039 mm) in total sample 7

Composition:

Clay minerals 30

Volcanic ash 50

Terrigenous mineral grains 15

Siliceous shells and spicules 5

Carbonate shells ____

SAMPLE NUMBER 59

Coarse fraction (>2 mm)

Weight percent of total sample 28

Composition:

Terrigenous rock fragments 100 — X granules — X pebbles

Carbonate shells ____ — __ cobbles — __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 56

Composition:

Terrigenous rock fragments and mineral grains 34

Carbonate megafaunal shell fragments ____

Foraminifera 1

Volcanic ash 65

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 10

Weight percent clay (<0.0039 mm) in total sample 6

Composition:

Clay minerals 35

Volcanic ash 40

Terrigenous mineral grains 20

Siliceous shells and spicules 3

Carbonate shells 2

SAMPLE NUMBER 60

Coarse fraction (>2 mm)

Weight percent of total sample 2

Composition:

Terrigenous rock fragments 100 — X granules — __ pebbles

Carbonate shells ____ — __ cobbles — __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 81

Composition:

Terrigenous rock fragments and mineral grains 60

Carbonate megafaunal shell fragments ____

Foraminifera TR

Volcanic ash 40

Siliceous spicules and shells TR

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 10

Weight percent clay (<0.0039 mm) in total sample 7

Composition:

Clay minerals 45

Volcanic ash 40

Terrigenous mineral grains 15

Siliceous shells and spicules 10

Carbonate shells ____

SAMPLE NUMBER 61

Coarse fraction (>2 mm)

Weight percent of total sample 38

Composition:

Terrigenous rock fragments 100

Carbonate shells TR

X granules X pebbles

_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 54

Composition:

Terrigenous rock fragments and mineral grains 64

Carbonate megafaunal shell fragments 3

Foraminifera 27

Volcanic ash 5

Siliceous spicules and shells 1

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 5

Weight percent clay (<0.0039 mm) in total sample 3

Composition:

Clay minerals 45

Volcanic ash 35

Terrigenous mineral grains 8

Siliceous shells and spicules 12

Carbonate shells ____

SAMPLE NUMBER 62

Coarse fraction (>2 mm)

Weight percent of total sample 12

Composition:

Terrigenous rock fragments 16

Carbonate shells 74

X granules _ pebbles

_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 85

Composition:

Terrigenous rock fragments and mineral grains 78

Carbonate megafaunal shell fragments 20

Foraminifera 1

Volcanic ash 1

Siliceous spicules and shells TR

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 2

Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 30

Volcanic ash 28

Terrigenous mineral grains 30

Siliceous shells and spicules 9

Carbonate shells 3

SAMPLE NUMBER 63

Coarse fraction (>2 mm)

Weight percent of total sample 17

Composition:

Terrigenous rock fragments 75 — X granules — pebbles

Carbonate shells 25 — cobbles — boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 79

Composition:

Terrigenous rock fragments and mineral grains 35

Carbonate megafaunal shell fragments 63

Foraminifera 2

Volcanic ash TR

Siliceous spicules and shells TR

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 3

Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 15

Volcanic ash 35

Terrigenous mineral grains 45

Siliceous shells and spicules TR

Carbonate shells 5

SAMPLE NUMBER 64

Coarse fraction (>2 mm)

Weight percent of total sample 34

Composition:

Terrigenous rock fragments 99 — X granules — X pebbles

Carbonate shells 1 — cobbles — boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 62

Composition:

Terrigenous rock fragments and mineral grains 28

Carbonate megafaunal shell fragments 50

Foraminifera 1

Volcanic ash 21

Siliceous spicules and shells TR

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 2

Weight percent clay (<0.0039 mm) in total sample 2

Composition:

Clay minerals 30

Volcanic ash 60

Terrigenous mineral grains 5

Siliceous shells and spicules 4

Carbonate shells 1

SAMPLE NUMBER 65

Coarse fraction (>2 mm)

Weight percent of total sample 32

Composition:

Terrigenous rock fragments 95

Carbonate shells 5

X granules X pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 62

Composition:

Terrigenous rock fragments and mineral grains 26

Carbonate megafaunal shell fragments 63

Foraminifera 5

Volcanic ash 5

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 3

Weight percent clay (<0.0039 mm) in total sample 3

Composition:

Clay minerals 37

Volcanic ash 48

Terrigenous mineral grains 15

Siliceous shells and spicules Tr

Carbonate shells Tr

SAMPLE NUMBER 66

Coarse fraction (>2 mm)

Weight percent of total sample 13

Composition:

Terrigenous rock fragments 33

Carbonate shells 67

__ granules __ pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 75

Composition:

Terrigenous rock fragments and mineral grains 20

Carbonate megafaunal shell fragments 68

Foraminifera 3

Volcanic ash 8

Siliceous spicules and shells 1

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 8

Weight percent clay (<0.0039 mm) in total sample 4

Composition:

Clay minerals 25

Volcanic ash 60

Terrigenous mineral grains 6

Siliceous shells and spicules 6

Carbonate shells 3

SAMPLE NUMBER 67

Coarse fraction (>2 mm)

Weight percent of total sample 21

Composition:

Terrigenous rock fragments 70

Carbonate shells 30

X granules X pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 53

Composition:

Terrigenous rock fragments and mineral grains 70

Carbonate megafaunal shell fragments 15

Foraminifera 5

Volcanic ash 10

Siliceous spicules and shells TR

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 18

Weight percent clay (<0.0039 mm) in total sample 8

Composition:

Clay minerals 35

Volcanic ash 50

Terrigenous mineral grains 7

Siliceous shells and spicules 8

Carbonate shells ____

SAMPLE NUMBER 68

Coarse fraction (>2 mm)

Weight percent of total sample 1

Composition:

Terrigenous rock fragments ____

Carbonate shells 100

__ granules __ pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 43

Composition:

Terrigenous rock fragments and mineral grains TR

Carbonate megafaunal shell fragments TR

Foraminifera 1

Volcanic ash 98

Siliceous spicules and shells 1

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 46

Weight percent clay (<0.0039 mm) in total sample 10

Composition:

Clay minerals 12

Volcanic ash 80

Terrigenous mineral grains 8

Siliceous shells and spicules Tr

Carbonate shells Tr

SAMPLE NUMBER 69

Coarse fraction (>2 mm)

Weight percent of total sample 13

Composition:

Terrigenous rock fragments 89

Carbonate shells 11

_ granules X pebbles
_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 82

Composition:

Terrigenous rock fragments and mineral grains 3

Carbonate megafaunal shell fragments 2

Foraminifera 1

Volcanic ash 94

Siliceous spicules and shells TR

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 2

Weight percent clay (<0.0039 mm) in total sample 3

Composition:

Clay minerals 31

Volcanic ash 54

Terrigenous mineral grains 8

Siliceous shells and spicules 6

Carbonate shells 1

SAMPLE NUMBER 70

Coarse fraction (>2 mm)

Weight percent of total sample 1

Composition:

Terrigenous rock fragments ___

Carbonate shells 100

_ granules _ pebbles
_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 97

Composition:

Terrigenous rock fragments and mineral grains 97

Carbonate megafaunal shell fragments ___

Foraminifera ___

Volcanic ash 3

Siliceous spicules and shells ___

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 1

Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 26

Volcanic ash 62

Terrigenous mineral grains 5

Siliceous shells and spicules 7

Carbonate shells ___

SAMPLE NUMBER 71

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____   __ granules __ pebbles

Carbonate shells ____   __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 96

Composition:

Terrigenous rock fragments and mineral grains 64

Carbonate megafaunal shell fragments TR

Foraminifera 1

Volcanic ash 35

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 3

Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 31

Volcanic ash 60

Terrigenous mineral grains 7

Siliceous shells and spicules 2

Carbonate shells ____

SAMPLE NUMBER 72

Coarse fraction (>2 mm)

Weight percent of total sample TR

Composition:

Terrigenous rock fragments ____   __ granules __ pebbles

Carbonate shells 100   __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 94

Composition:

Terrigenous rock fragments and mineral grains 5

Carbonate megafaunal shell fragments TR

Foraminifera 1

Volcanic ash 94

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 3

Weight percent clay (<0.0039 mm) in total sample 3

Composition:

Clay minerals 35

Volcanic ash 60

Terrigenous mineral grains 5

Siliceous shells and spicules Tr

Carbonate shells ____

SAMPLE NUMBER 75

Coarse fraction (>2 mm)

Weight percent of total sample 10

Composition:

Terrigenous rock fragments 46 ___ granules ___ pebbles

Carbonate shells 54 ___ cobbles ___ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 90

Composition:

Terrigenous rock fragments and mineral grains 10

Carbonate megafaunal shell fragments 90

Foraminifera ___

Volcanic ash ___

Siliceous spicules and shells ___

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample ___

Weight percent clay (<0.0039 mm) in total sample ___

Composition:

Clay minerals ___

Volcanic ash ___

Terrigenous mineral grains ___

Siliceous shells and spicules ___

Carbonate shells ___

SAMPLE NUMBER 76

Coarse fraction (>2 mm)

Weight percent of total sample TR

Composition:

Terrigenous rock fragments ___ ___ granules ___ pebbles

Carbonate shells 100 ___ cobbles ___ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 96

Composition:

Terrigenous rock fragments and mineral grains 12

Carbonate megafaunal shell fragments 4

Foraminifera 1

Volcanic ash 83

Siliceous spicules and shells TR

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 1

Weight percent clay (<0.0039 mm) in total sample 3

Composition:

Clay minerals 36

Volcanic ash 47

Terrigenous mineral grains 5

Siliceous shells and spicules 11

Carbonate shells 1

SAMPLE NUMBER 77

Coarse fraction (>2 mm)

Weight percent of total sample 95

Composition:

Terrigenous rock fragments 95

Carbonate shells 5

X granules X pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 5

Composition:

Terrigenous rock fragments and mineral grains 80

Carbonate megafaunal shell fragments 19

Foraminifera 1

Volcanic ash ______

Siliceous spicules and shells ______

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample ______

Weight percent clay (<0.0039 mm) in total sample ______

Composition:

Clay minerals ______

Volcanic ash ______

Terrigenous mineral grains ______

Siliceous shells and spicules ______

Carbonate shells ______

SAMPLE NUMBER 79

Coarse fraction (>2 mm)

Weight percent of total sample 96

Composition:

Terrigenous rock fragments 68

Carbonate shells 32

X granules X pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 62

Composition:

Terrigenous rock fragments and mineral grains 28

Carbonate megafaunal shell fragments 70

Foraminifera 2

Volcanic ash TR

Siliceous spicules and shells ______

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample TR

Weight percent clay (<0.0039 mm) in total sample 2

Composition:

Clay minerals 20

Volcanic ash 50

Terrigenous mineral grains 30

Siliceous shells and spicules Tr

Carbonate shells ______

SAMPLE NUMBER 80

Coarse fraction (>2 mm)

Weight percent of total sample 32

Composition:

Terrigenous rock fragments 65 — X granules — X pebbles — cobbles — boulders

Carbonate shells 35

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 62

Composition:

Terrigenous rock fragments and mineral grains 85

Carbonate megafaunal shell fragments 3

Foraminifera TR

Volcanic ash 7

Siliceous spicules and shells ___

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 4

Weight percent clay (<0.0039 mm) in total sample 2

Composition:

Clay minerals ___

Volcanic ash ___

Terrigenous mineral grains ___

Siliceous shells and spicules ___

Carbonate shells ___

SAMPLE NUMBER 81

Coarse fraction (>2 mm)

Weight percent of total sample ___

Composition:

Terrigenous rock fragments ___ — granules — pebbles — cobbles — boulders

Carbonate shells ___

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 60

Composition:

Terrigenous rock fragments and mineral grains 1

Carbonate megafaunal shell fragments ___

Foraminifera TR

Volcanic ash 99

Siliceous spicules and shells TR

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 30

Weight percent clay (<0.0039 mm) in total sample 10

Composition:

Clay minerals 25

Volcanic ash 65

Terrigenous mineral grains 5

Siliceous shells and spicules 3

Carbonate shells 2

SAMPLE NUMBER 82

Coarse fraction (>2 mm)

Weight percent of total sample 64

Composition:

Terrigenous rock fragments 83

Carbonate shells 17

X granules X pebbles
_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 16

Composition:

Terrigenous rock fragments and mineral grains 30

Carbonate megafaunal shell fragments 25

Foraminifera 7

Volcanic ash 38

Siliceous spicules and shells TR

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 15

Weight percent clay (<0.0039 mm) in total sample 5

Composition:

Clay minerals 40

Volcanic ash 42

Terrigenous mineral grains 7

Siliceous shells and spicules 10

Carbonate shells 1

SAMPLE NUMBER 85

Coarse fraction (>2 mm)

Weight percent of total sample 28

Composition:

Terrigenous rock fragments 1

Carbonate shells 99

X granules _ pebbles
_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 70

Composition:

Terrigenous rock fragments and mineral grains 5

Carbonate megafaunal shell fragments 80

Foraminifera ___

Volcanic ash 15

Siliceous spicules and shells ___

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 1

Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 23

Volcanic ash 65

Terrigenous mineral grains 5

Siliceous shells and spicules 7

Carbonate shells Tr

SAMPLE NUMBER 86

Coarse fraction (>2 mm)

Weight percent of total sample 36

Composition:

Terrigenous rock fragments 4

Carbonate shells 96

X granules __ pebbles __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 61

Composition:

Terrigenous rock fragments and mineral grains 6

Carbonate megafaunal shell fragments 12

Foraminifera TR

Volcanic ash 82

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 1

Weight percent clay (<0.0039 mm) in total sample 2

Composition:

Clay minerals ____

Volcanic ash ____

Terrigenous mineral grains ____

Siliceous shells and spicules ____

Carbonate shells ____

SAMPLE NUMBER 87

Coarse fraction (>2 mm)

Weight percent of total sample 4

Composition:

Terrigenous rock fragments ____

Carbonate shells 100

__ granules __ pebbles __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 58

Composition:

Terrigenous rock fragments and mineral grains ____

Carbonate megafaunal shell fragments Tr

Foraminifera ____

Volcanic ash 100

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 31

Weight percent clay (<0.0039 mm) in total sample 7

Composition:

Clay minerals 25

Volcanic ash 60

Terrigenous mineral grains 5

Siliceous shells and spicules 10

Carbonate shells ____

SAMPLE NUMBER 88

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____

Carbonate shells ____

__ granules __ pebbles __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 22

Composition:

Terrigenous rock fragments and mineral grains ____

Carbonate megafaunal shell fragments 1

Foraminifera ____

Volcanic ash 97

Siliceous spicules and shells 2

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 69

Weight percent clay (<0.0039 mm) in total sample 9

Composition:

Clay minerals 20

Volcanic ash 70

Terrigenous mineral grains 8

Siliceous shells and spicules 2

Carbonate shells ____

SAMPLE NUMBER 89

Coarse fraction (>2 mm)

Weight percent of total sample 68

Composition:

Terrigenous rock fragments 90

Carbonate shells 10

X granules __ pebbles __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 24

Composition:

Terrigenous rock fragments and mineral grains 3

Carbonate megafaunal shell fragments 12

Foraminifera Tr

Volcanic ash 85

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 6

Weight percent clay (<0.0039 mm) in total sample 2

Composition:

Clay minerals 12

Volcanic ash 70

Terrigenous mineral grains 18

Siliceous shells and spicules Tr

Carbonate shells ____

SAMPLE NUMBER 90

Coarse fraction (>2 mm)

Weight percent of total sample 6

Composition:

Terrigenous rock fragments ____
Carbonate shells 100

__ granules __ pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 91

Composition:

Terrigenous rock fragments and mineral grains 4
Carbonate megafaunal shell fragments 95
Foraminifera Tr
Volcanic ash 1
Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 1
Weight percent clay (<0.0039 mm) in total sample 2

Composition:

Clay minerals 26
Volcanic ash 60
Terrigenous mineral grains 5
Siliceous shells and spicules 8
Carbonate shells 1

SAMPLE NUMBER 91

Coarse fraction (>2 mm)

Weight percent of total sample 5

Composition:

Terrigenous rock fragments ____
Carbonate shells 100

__ granules __ pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 91

Composition:

Terrigenous rock fragments and mineral grains 1
Carbonate megafaunal shell fragments 7
Foraminifera 1
Volcanic ash 91
Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 2
Weight percent clay (<0.0039 mm) in total sample 2

Composition:

Clay minerals 23
Volcanic ash 60
Terrigenous mineral grains 17
Siliceous shells and spicules Tr
Carbonate shells ____

SAMPLE NUMBER 92

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______ __ granules __ pebbles

Carbonate shells ______ __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 6

Composition:

Terrigenous rock fragments and mineral grains 1

Carbonate megafaunal shell fragments ______

Foraminifera 1

Volcanic ash 15

Siliceous spicules and shells 83

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 74

Weight percent clay (<0.0039 mm) in total sample 20

Composition:

Clay minerals 30

Volcanic ash 45

Terrigenous mineral grains 15

Siliceous shells and spicules 12

Carbonate shells Tr

SAMPLE NUMBER 93

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______ __ granules __ pebbles

Carbonate shells ______ __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 24

Composition:

Terrigenous rock fragments and mineral grains 10

Carbonate megafaunal shell fragments ______

Foraminifera 4

Volcanic ash 66

Siliceous spicules and shells 20

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 62

Weight percent clay (<0.0039 mm) in total sample 14

Composition:

Clay minerals 46

Volcanic ash 30

Terrigenous mineral grains 12

Siliceous shells and spicules 12

Carbonate shells Tr

SAMPLE NUMBER 94

Coarse fraction (>2 mm)

Weight percent of total sample 87

Composition:

Terrigenous rock fragments 90

Carbonate shells 10

X granules X pebbles X cobbles X boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 10

Composition:

Terrigenous rock fragments and mineral grains 53

Carbonate megafaunal shell fragments 45

Foraminifera 1

Volcanic ash 1

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 2

Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 55

Volcanic ash 33

Terrigenous mineral grains 12

Siliceous shells and spicules Tr

Carbonate shells Tr

SAMPLE NUMBER 96

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____

Carbonate shells ____

__ granules __ pebbles __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 3

Composition:

Terrigenous rock fragments and mineral grains 29

Carbonate megafaunal shell fragments 10

Foraminifera ____

Volcanic ash 30

Siliceous spicules and shells 31

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 61

Weight percent clay (<0.0039 mm) in total sample 36

Composition:

Clay minerals 35

Volcanic ash 55

Terrigenous mineral grains 10

Siliceous shells and spicules Tr

Carbonate shells ____

SAMPLE NUMBER 97

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____ __ granules __ pebbles

Carbonate shells ____ __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 1

Composition:

Terrigenous rock fragments and mineral grains 1

Carbonate megafaunal shell fragments ____

Foraminifera 3

Volcanic ash 31

Siliceous spicules and shells 65

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 60

Weight percent clay (<0.0039 mm) in total sample 39

Composition:

Clay minerals 55

Volcanic ash 40

Terrigenous mineral grains 5

Siliceous shells and spicules Tr

Carbonate shells Tr

SAMPLE NUMBER 98

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____ __ granules __ pebbles

Carbonate shells ____ __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 1

Composition:

Terrigenous rock fragments and mineral grains 1

Carbonate megafaunal shell fragments 3

Foraminifera ____

Volcanic ash 46

Siliceous spicules and shells 50

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 62

Weight percent clay (<0.0039 mm) in total sample 37

Composition:

Clay minerals 40

Volcanic ash 48

Terrigenous mineral grains 12

Siliceous shells and spicules Tr

Carbonate shells ____

SAMPLE NUMBER 113

Coarse fraction (>2 mm)

Weight percent of total sample 25

Composition:

Terrigenous rock fragments 100 — x granules, x pebbles, cobbles, boulders

Carbonate shells ____

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 70

Composition:

Terrigenous rock fragments and mineral grains 98

Carbonate megafaunal shell fragments Tr

Foraminifera 2

Volcanic ash Tr

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 3

Weight percent clay (<0.0039 mm) in total sample 2

Composition:

Clay minerals 25

Volcanic ash 60

Terrigenous mineral grains 15

Siliceous shells and spicules Tr

Carbonate shells ____

SAMPLE NUMBER 115

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____ — granules, pebbles, cobbles, boulders

Carbonate shells ____

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 92

Composition:

Terrigenous rock fragments and mineral grains 2

Carbonate megafaunal shell fragments 6

Foraminifera 2

Volcanic ash 90

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 5

Weight percent clay (<0.0039 mm) in total sample 3

Composition:

Clay minerals 19

Volcanic ash 73

Terrigenous mineral grains 6

Siliceous shells and spicules 2

Carbonate shells Tr

SAMPLE NUMBER 127

Coarse fraction (>2 mm)

Weight percent of total sample 17

Composition:

Terrigenous rock fragments 74
Carbonate shells 26

X granules X pebbles
_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 65

Composition:

Terrigenous rock fragments and mineral grains 25
Carbonate megafaunal shell fragments 73
Foraminifera 1
Volcanic ash 1
Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 11
Weight percent clay (<0.0039 mm) in total sample 7

Composition:

Clay minerals 25
Volcanic ash 55
Terrigenous mineral grains 20
Siliceous shells and spicules Tr
Carbonate shells ____

SAMPLE NUMBER 128

Coarse fraction (>2 mm)

Weight percent of total sample 25

Composition:

Terrigenous rock fragments 98
Carbonate shells 2

X granules X pebbles
_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 45

Composition:

Terrigenous rock fragments and mineral grains 5
Carbonate megafaunal shell fragments 25
Foraminifera 50
Volcanic ash 20
Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 15
Weight percent clay (<0.0039 mm) in total sample 15

Composition:

Clay minerals 35
Volcanic ash 24
Terrigenous mineral grains 35
Siliceous shells and spicules 5
Carbonate shells 1

SAMPLE NUMBER 130

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______   __ granules   __ pebbles

Carbonate shells ______   __ cobbles   __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 79

Composition:

Terrigenous rock fragments and mineral grains 99

Carbonate megafaunal shell fragments ______

Foraminifera Tr

Volcanic ash Tr

Siliceous spicules and shells 1

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 11

Weight percent clay (<0.0039 mm) in total sample 10

Composition:

Clay minerals 15

Volcanic ash 75

Terrigenous mineral grains 10

Siliceous shells and spicules Tr

Carbonate shells ______

SAMPLE NUMBER 131

Coarse fraction (>2 mm)

Weight percent of total sample 3

Composition:

Terrigenous rock fragments 100   X granules   X pebbles

Carbonate shells ______   __ cobbles   __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 45

Composition:

Terrigenous rock fragments and mineral grains 99

Carbonate megafaunal shell fragments ______

Foraminifera 1

Volcanic ash Tr

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 25

Weight percent clay (<0.0039 mm) in total sample 27

Composition:

Clay minerals ______

Volcanic ash ______

Terrigenous mineral grains ______

Siliceous shells and spicules ______

Carbonate shells ______

SAMPLE NUMBER 132

Coarse fraction (>2 mm)

Weight percent of total sample 5

Composition:

Terrigenous rock fragments 100

Carbonate shells ____

X granules __ pebbles __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 33

Composition:

Terrigenous rock fragments and mineral grains 88

Carbonate megafaunal shell fragments ____

Foraminifera 1

Volcanic ash 10

Siliceous spicules and shells 1

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 32

Weight percent clay (<0.0039 mm) in total sample 30

Composition:

Clay minerals 23

Volcanic ash 39

Terrigenous mineral grains 34

Siliceous shells and spicules 5

Carbonate shells Tr

SAMPLE NUMBER 134

Coarse fraction (>2 mm)

Weight percent of total sample 20

Composition:

Terrigenous rock fragments 100

Carbonate shells ____

X granules X pebbles __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 41

Composition:

Terrigenous rock fragments and mineral grains 94

Carbonate megafaunal shell fragments ____

Foraminifera Tr

Volcanic ash 5

Siliceous spicules and shells 1

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 17

Weight percent clay (<0.0039 mm) in total sample 22

Composition:

Clay minerals ____

Volcanic ash ____

Terrigenous mineral grains ____

Siliceous shells and spicules ____

Carbonate shells ____

SAMPLE NUMBER 135

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______ — granules — pebbles — cobbles — boulders

Carbonate shells ______

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 77

Composition:

Terrigenous rock fragments and mineral grains 100

Carbonate megafaunal shell fragments ______

Foraminifera Tr

Volcanic ash Tr

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 15

Weight percent clay (<0.0039 mm) in total sample 8

Composition:

Clay minerals 44

Volcanic ash 46

Terrigenous mineral grains 4

Siliceous shells and spicules 6

Carbonate shells ______

SAMPLE NUMBER 136

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______ — granules — pebbles — cobbles — boulders

Carbonate shells ______

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 73

Composition:

Terrigenous rock fragments and mineral grains 97

Carbonate megafaunal shell fragments ______

Foraminifera ______

Volcanic ash 3

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 17

Weight percent clay (<0.0039 mm) in total sample 10

Composition:

Clay minerals ______

Volcanic ash ______

Terrigenous mineral grains ______

Siliceous shells and spicules ______

Carbonate shells ______

SAMPLE NUMBER 137

Coarse fraction (>2 mm)

Weight percent of total sample 10

Composition:

Terrigenous rock fragments 62

Carbonate shells 38

X granules __ pebbles __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 72

Composition:

Terrigenous rock fragments and mineral grains 45

Carbonate megafaunal shell fragments 43

Foraminifera 8

Volcanic ash 4

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 13

Weight percent clay (<0.0039 mm) in total sample 5

Composition:

Clay minerals 50

Volcanic ash 20

Terrigenous mineral grains 30

Siliceous shells and spicules Tr

Carbonate shells Tr

SAMPLE NUMBER 138

Coarse fraction (>2 mm)

Weight percent of total sample 24

Composition:

Terrigenous rock fragments 3

Carbonate shells 97

__ granules x pebbles __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 70

Composition:

Terrigenous rock fragments and mineral grains 57

Carbonate megafaunal shell fragments 35

Foraminifera 2

Volcanic ash 6

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 3

Weight percent clay (<0.0039 mm) in total sample 3

Composition:

Clay minerals 10

Volcanic ash 60

Terrigenous mineral grains 30

Siliceous shells and spicules Tr

Carbonate shells ____

SAMPLE NUMBER 141

Coarse fraction (>2 mm)

Weight percent of total sample 56

Composition:

Terrigenous rock fragments 99

Carbonate shells 1

✓ granules ✗ pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 26

Composition:

Terrigenous rock fragments and mineral grains 6

Carbonate megafaunal shell fragments 3

Foraminifera 41

Volcanic ash 50

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 11

Weight percent clay (<0.0039 mm) in total sample 7

Composition:

Clay minerals 25

Volcanic ash 60

Terrigenous mineral grains 15

Siliceous shells and spicules Tr

Carbonate shells ______

SAMPLE NUMBER ______

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______

Carbonate shells ______

__ granules __ pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments and mineral grains ______

Carbonate megafaunal shell fragments ______

Foraminifera ______

Volcanic ash ______

Siliceous spicules and shells ______

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample ______

Weight percent clay (<0.0039 mm) in total sample ______

Composition:

Clay minerals ______

Volcanic ash ______

Terrigenous mineral grains ______

Siliceous shells and spicules ______

Carbonate shells ______

SAMPLE NUMBER 200

Coarse fraction (>2 mm)

Weight percent of total sample 48

Composition:

Terrigenous rock fragments 98

Carbonate shells 2

X granules X pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 46

Composition:

Terrigenous rock fragments and mineral grains 97

Carbonate megafaunal shell fragments ____

Foraminifera 3

Volcanic ash Tr

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 2

Weight percent clay (<0.0039 mm) in total sample 4

Composition:

Clay minerals 28

Volcanic ash 42

Terrigenous mineral grains 18

Siliceous shells and spicules 10

Carbonate shells 2

SAMPLE NUMBER 201

Coarse fraction (>2 mm)

Weight percent of total sample 54

Composition:

Terrigenous rock fragments 90

Carbonate shells 10

X granules X pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 43

Composition:

Terrigenous rock fragments and mineral grains 43

Carbonate megafaunal shell fragments 54

Foraminifera 3

Volcanic ash Tr

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 1

Weight percent clay (<0.0039 mm) in total sample 2

Composition:

Clay minerals 50

Volcanic ash 15

Terrigenous mineral grains 30

Siliceous shells and spicules 5

Carbonate shells ____

SAMPLE NUMBER 202

Coarse fraction (>2 mm)

Weight percent of total sample 3

Composition:

Terrigenous rock fragments 65
Carbonate shells 35

X granules __ pebbles __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 65

Composition:

Terrigenous rock fragments and mineral grains 97
Carbonate megafaunal shell fragments 1
Foraminifera 1
Volcanic ash 1
Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 13
Weight percent clay (<0.0039 mm) in total sample 19

Composition:

Clay minerals 30
Volcanic ash 38
Terrigenous mineral grains 22
Siliceous shells and spicules 9
Carbonate shells 1

SAMPLE NUMBER 204

Coarse fraction (>2 mm)

Weight percent of total sample 36

Composition:

Terrigenous rock fragments 100
Carbonate shells ____

X granules X pebbles __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 32

Composition:

Terrigenous rock fragments and mineral grains 40
Carbonate megafaunal shell fragments ____
Foraminifera 1
Volcanic ash 58
Siliceous spicules and shells 1

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 19
Weight percent clay (<0.0039 mm) in total sample 13

Composition:

Clay minerals 34
Volcanic ash 52
Terrigenous mineral grains 9
Siliceous shells and spicules 5
Carbonate shells Tr

SAMPLE NUMBER 205

Coarse fraction (>2 mm)

Weight percent of total sample 35

Composition:

Terrigenous rock fragments 95 — X granules, X pebbles, __ cobbles, __ boulders

Carbonate shells 5

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 47

Composition:

Terrigenous rock fragments and mineral grains 98

Carbonate megafaunal shell fragments Tr

Foraminifera 1

Volcanic ash 1

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 11

Weight percent clay (<0.0039 mm) in total sample 7

Composition:

Clay minerals 25

Volcanic ash 67

Terrigenous mineral grains 3

Siliceous shells and spicules 5

Carbonate shells Tr

SAMPLE NUMBER 216

Coarse fraction (>2 mm)

Weight percent of total sample 1

Composition:

Terrigenous rock fragments ____ — __ granules, __ pebbles, __ cobbles, __ boulders

Carbonate shells 100

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 98

Composition:

Terrigenous rock fragments and mineral grains 4

Carbonate megafaunal shell fragments 19

Foraminifera 15

Volcanic ash 62

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 7

Weight percent clay (<0.0039 mm) in total sample 4

Composition:

Clay minerals 30

Volcanic ash 50

Terrigenous mineral grains 12

Siliceous shells and spicules 5

Carbonate shells 3

SAMPLE NUMBER 217

Coarse fraction (>2 mm)

Weight percent of total sample 62

Composition:

Terrigenous rock fragments 91

Carbonate shells 9

X granules X pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 44

Composition:

Terrigenous rock fragments and mineral grains 3

Carbonate megafaunal shell fragments 30

Foraminifera 14

Volcanic ash 53

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 3

Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 25

Volcanic ash 50

Terrigenous mineral grains 10

Siliceous shells and spicules 7

Carbonate shells 8

SAMPLE NUMBER 219

Coarse fraction (>2 mm)

Weight percent of total sample 73

Composition:

Terrigenous rock fragments 100

Carbonate shells Tr

X granules X pebbles
X cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 25

Composition:

Terrigenous rock fragments and mineral grains 60

Carbonate megafaunal shell fragments 25

Foraminifera 14

Volcanic ash 1

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 1

Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 20

Volcanic ash 35

Terrigenous mineral grains 35

Siliceous shells and spicules 4

Carbonate shells 6

SAMPLE NUMBER 227

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____ — __ granules __ pebbles __ cobbles __ boulders

Carbonate shells ____

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 72

Composition:

Terrigenous rock fragments and mineral grains 1

Carbonate megafaunal shell fragments ____

Foraminifera Tr

Volcanic ash 99

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 19

Weight percent clay (<0.0039 mm) in total sample 9

Composition:

Clay minerals 20

Volcanic ash 60

Terrigenous mineral grains 20

Siliceous shells and spicules Tr

Carbonate shells Tr

SAMPLE NUMBER 228

Coarse fraction (>2 mm)

Weight percent of total sample 33

Composition:

Terrigenous rock fragments 86 — X granules X pebbles __ cobbles __ boulders

Carbonate shells 14

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 59

Composition:

Terrigenous rock fragments and mineral grains 63

Carbonate megafaunal shell fragments 27

Foraminifera 10

Volcanic ash Tr

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 5

Weight percent clay (<0.0039 mm) in total sample 3

Composition:

Clay minerals 40

Volcanic ash 25

Terrigenous mineral grains 30

Siliceous shells and spicules 5

Carbonate shells ____

SAMPLE NUMBER 229

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____   __ granules   __ pebbles

Carbonate shells ____   __ cobbles   __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 55

Composition:

Terrigenous rock fragments and mineral grains ____

Carbonate megafaunal shell fragments Tr

Foraminifera ____

Volcanic ash 99

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 36

Weight percent clay (<0.0039 mm) in total sample 9

Composition:

Clay minerals 35

Volcanic ash 45

Terrigenous mineral grains 15

Siliceous shells and spicules 5

Carbonate shells ____

SAMPLE NUMBER 232

Coarse fraction (>2 mm)

Weight percent of total sample 29

Composition:

Terrigenous rock fragments 100   X granules   X pebbles

Carbonate shells ____   __ cobbles   __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 69

Composition:

Terrigenous rock fragments and mineral grains 99

Carbonate megafaunal shell fragments ____

Foraminifera Tr

Volcanic ash 1

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 1

Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 55

Volcanic ash 35

Terrigenous mineral grains 7

Siliceous shells and spicules 3

Carbonate shells ____

SAMPLE NUMBER 234

Coarse fraction (>2 mm)

Weight percent of total sample 50

Composition:

Terrigenous rock fragments 85

Carbonate shells 15

X granules X pebbles __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 47

Composition:

Terrigenous rock fragments and mineral grains 20

Carbonate megafaunal shell fragments 3

Foraminifera 35

Volcanic ash 42

Siliceous spicules and shells TR

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 2

Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 24

Volcanic ash 30

Terrigenous mineral grains 40

Siliceous shells and spicules 3

Carbonate shells 3

SAMPLE NUMBER 236

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____

Carbonate shells ____

__ granules __ pebbles __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 38

Composition:

Terrigenous rock fragments and mineral grains TR

Carbonate megafaunal shell fragments ____

Foraminifera TR

Volcanic ash 100

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 48

Weight percent clay (<0.0039 mm) in total sample 14

Composition:

Clay minerals 35

Volcanic ash 55

Terrigenous mineral grains 8

Siliceous shells and spicules 2

Carbonate shells ____

SAMPLE NUMBER 241

Coarse fraction (>2 mm)

Weight percent of total sample 5

Composition:

Terrigenous rock fragments 97 — X granules — X pebbles

Carbonate shells 3 — __ cobbles — __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 86

Composition:

Terrigenous rock fragments and mineral grains 30

Carbonate megafaunal shell fragments ____

Foraminifera ____

Volcanic ash 70

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 4

Weight percent clay (<0.0039 mm) in total sample 5

Composition:

Clay minerals 14

Volcanic ash 37

Terrigenous mineral grains 47

Siliceous shells and spicules 2

Carbonate shells ____

SAMPLE NUMBER 242

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____ — __ granules — __ pebbles

Carbonate shells ____ — __ cobbles — __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 64

Composition:

Terrigenous rock fragments and mineral grains 2

Carbonate megafaunal shell fragments ____

Foraminifera Tr

Volcanic ash 98

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 30

Weight percent clay (<0.0039 mm) in total sample 6

Composition:

Clay minerals 32

Volcanic ash 51

Terrigenous mineral grains 13

Siliceous shells and spicules 4

Carbonate shells Tr

SAMPLE NUMBER 243

Coarse fraction (>2 mm)

Weight percent of total sample 24

Composition:

Terrigenous rock fragments 99

Carbonate shells 1

X granules X pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 66

Composition:

Terrigenous rock fragments and mineral grains 77
Carbonate megafaunal shell fragments 3
Foraminifera ____
Volcanic ash 20
Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 7
Weight percent clay (<0.0039 mm) in total sample 3

Composition:

Clay minerals 45
Volcanic ash 40
Terrigenous mineral grains 10
Siliceous shells and spicules 5
Carbonate shells Tr

SAMPLE NUMBER 244

Coarse fraction (>2 mm)

Weight percent of total sample 1

Composition:

Terrigenous rock fragments 100

Carbonate shells ____

X granules __ pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 80

Composition:

Terrigenous rock fragments and mineral grains 15
Carbonate megafaunal shell fragments Tr
Foraminifera ____
Volcanic ash 85
Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 15
Weight percent clay (<0.0039 mm) in total sample 4

Composition:

Clay minerals 35
Volcanic ash 45
Terrigenous mineral grains 15
Siliceous shells and spicules 5
Carbonate shells Tr

SAMPLE NUMBER 245

Coarse fraction (>2 mm)

Weight percent of total sample 9

Composition:

Terrigenous rock fragments 60

Carbonate shells 40

X granules X pebbles
_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 72

Composition:

Terrigenous rock fragments and mineral grains 20

Carbonate megafaunal shell fragments 30

Foraminifera 7

Volcanic ash 43

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 6

Weight percent clay (<0.0039 mm) in total sample 13

Composition:

Clay minerals 21

Volcanic ash 66

Terrigenous mineral grains 7

Siliceous shells and spicules 4

Carbonate shells 2

SAMPLE NUMBER 246

Coarse fraction (>2 mm)

Weight percent of total sample 32

Composition:

Terrigenous rock fragments 96

Carbonate shells 4

X granules X pebbles
_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 47

Composition:

Terrigenous rock fragments and mineral grains 5

Carbonate megafaunal shell fragments 15

Foraminifera 40

Volcanic ash 40

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 13

Weight percent clay (<0.0039 mm) in total sample 8

Composition:

Clay minerals 60

Volcanic ash 30

Terrigenous mineral grains 10

Siliceous shells and spicules Tr

Carbonate shells Tr

SAMPLE NUMBER 329

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:
Terrigenous rock fragments ____
Carbonate shells ____

__ granules __ pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 36

Composition:
Terrigenous rock fragments and mineral grains ____
Carbonate megafaunal shell fragments ____
Foraminifera Tr
Volcanic ash 100
Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 50
Weight percent clay (<0.0039 mm) in total sample 14

Composition:
Clay minerals 30
Volcanic ash 65
Terrigenous mineral grains 4
Siliceous shells and spicules 1
Carbonate shells ____

SAMPLE NUMBER 330

Coarse fraction (>2 mm)

Weight percent of total sample 10

Composition:
Terrigenous rock fragments 99
Carbonate shells 1

X granules __ pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 78

Composition:
Terrigenous rock fragments and mineral grains 47
Carbonate megafaunal shell fragments 20
Foraminifera 13
Volcanic ash 20
Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 7
Weight percent clay (<0.0039 mm) in total sample 5

Composition:
Clay minerals 40
Volcanic ash 30
Terrigenous mineral grains 30
Siliceous shells and spicules Tr
Carbonate shells ____

SAMPLE NUMBER 336

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____ — __ granules __ pebbles
Carbonate shells ____ — __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 1

Composition:

Terrigenous rock fragments and mineral grains ____
Carbonate megafaunal shell fragments ____
Foraminifera ____
Volcanic ash 2
Siliceous spicules and shells 98

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 50
Weight percent clay (<0.0039 mm) in total sample 49

Composition:

Clay minerals 38
Volcanic ash 42
Terrigenous mineral grains 15
Siliceous shells and spicules 5
Carbonate shells ____

SAMPLE NUMBER 340

Coarse fraction (>2 mm)

Weight percent of total sample 2

Composition:

Terrigenous rock fragments 100 — X granules X pebbles
Carbonate shells ____ — __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 23

Composition:

Terrigenous rock fragments and mineral grains 10
Carbonate megafaunal shell fragments ____
Foraminifera 2
Volcanic ash 87
Siliceous spicules and shells 1

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 51
Weight percent clay (<0.0039 mm) in total sample 24

Composition:

Clay minerals 28
Volcanic ash 20
Terrigenous mineral grains 50
Siliceous shells and spicules Tr
Carbonate shells 2

SAMPLE NUMBER 341

Coarse fraction (>2 mm)

Weight percent of total sample 50

Composition:

Terrigenous rock fragments 94

Carbonate shells 6

X granules X pebbles
_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 43

Composition:

Terrigenous rock fragments and mineral grains 5
Carbonate megafaunal shell fragments 73
Foraminifera 12
Volcanic ash 10
Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 4
Weight percent clay (<0.0039 mm) in total sample 3

Composition:

Clay minerals 40
Volcanic ash 42
Terrigenous mineral grains 15
Siliceous shells and spicules Tr
Carbonate shells 3

SAMPLE NUMBER 342

Coarse fraction (>2 mm)

Weight percent of total sample 59

Composition:

Terrigenous rock fragments 98

Carbonate shells 2

X granules X pebbles
_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 34

Composition:

Terrigenous rock fragments and mineral grains 20
Carbonate megafaunal shell fragments 5
Foraminifera 5
Volcanic ash 70
Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 4
Weight percent clay (<0.0039 mm) in total sample 3

Composition:

Clay minerals 45
Volcanic ash 40
Terrigenous mineral grains 10
Siliceous shells and spicules 5
Carbonate shells ____

SAMPLE NUMBER 343

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____ __ granules __ pebbles
Carbonate shells ____ __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 5

Composition:

Terrigenous rock fragments and mineral grains 50
Carbonate megafaunal shell fragments ____
Foraminifera 5
Volcanic ash 25
Siliceous spicules and shells 20

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 64
Weight percent clay (<0.0039 mm) in total sample 31

Composition:

Clay minerals 15
Volcanic ash 70
Terrigenous mineral grains 10
Siliceous shells and spicules 4
Carbonate shells 1

SAMPLE NUMBER 344

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____ __ granules __ pebbles
Carbonate shells ____ __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 1

Composition:

Terrigenous rock fragments and mineral grains 42
Carbonate megafaunal shell fragments ____
Foraminifera 3
Volcanic ash 35
Siliceous spicules and shells 20

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 60
Weight percent clay (<0.0039 mm) in total sample 39

Composition:

Clay minerals 55
Volcanic ash 25
Terrigenous mineral grains 15
Siliceous shells and spicules 3
Carbonate shells 2

SAMPLE NUMBER 345

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______ __ granules __ pebbles

Carbonate shells ______ __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 65

Composition:

Terrigenous rock fragments and mineral grains 99

Carbonate megafaunal shell fragments ______

Foraminifera 1

Volcanic ash Tr

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 23

Weight percent clay (<0.0039 mm) in total sample 12

Composition:

Clay minerals 32

Volcanic ash 50

Terrigenous mineral grains 15

Siliceous shells and spicules 2

Carbonate shells 1

SAMPLE NUMBER 346

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______ __ granules __ pebbles

Carbonate shells ______ __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 67

Composition:

Terrigenous rock fragments and mineral grains 99

Carbonate megafaunal shell fragments ______

Foraminifera Tr

Volcanic ash 1

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 22

Weight percent clay (<0.0039 mm) in total sample 11

Composition:

Clay minerals ______

Volcanic ash ______

Terrigenous mineral grains ______

Siliceous shells and spicules ______

Carbonate shells ______

SAMPLE NUMBER 347

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______ __ granules __ pebbles

Carbonate shells ______ __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 4

Composition:

Terrigenous rock fragments and mineral grains 54

Carbonate megafaunal shell fragments 4

Foraminifera ______

Volcanic ash 24

Siliceous spicules and shells 18

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 67

Weight percent clay (<0.0039 mm) in total sample 29

Composition:

Clay minerals 40

Volcanic ash 35

Terrigenous mineral grains 12

Siliceous shells and spicules 3

Carbonate shells ______

SAMPLE NUMBER 348

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______ __ granules __ pebbles

Carbonate shells ______ __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 3

Composition:

Terrigenous rock fragments and mineral grains 57

Carbonate megafaunal shell fragments ______

Foraminifera 3

Volcanic ash 40

Siliceous spicules and shells ______

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 63

Weight percent clay (<0.0039 mm) in total sample 34

Composition:

Clay minerals 35

Volcanic ash 50

Terrigenous mineral grains 10

Siliceous shells and spicules 5

Carbonate shells ______

SAMPLE NUMBER 349

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____   __ granules   __ pebbles

Carbonate shells ____   __ cobbles   __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 1

Composition:

Terrigenous rock fragments and mineral grains 2
Carbonate megafaunal shell fragments ____
Foraminifera 3
Volcanic ash 41
Siliceous spicules and shells 54

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 61
Weight percent clay (<0.0039 mm) in total sample 38

Composition:

Clay minerals 40
Volcanic ash 55
Terrigenous mineral grains 3
Siliceous shells and spicules 2
Carbonate shells ____

SAMPLE NUMBER 350

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____   __ granules   __ pebbles

Carbonate shells ____   __ cobbles   __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 13

Composition:

Terrigenous rock fragments and mineral grains 30
Carbonate megafaunal shell fragments ____
Foraminifera 3
Volcanic ash 47
Siliceous spicules and shells 20

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 53
Weight percent clay (<0.0039 mm) in total sample 34

Composition:

Clay minerals 40
Volcanic ash 40
Terrigenous mineral grains 8
Siliceous shells and spicules 12
Carbonate shells ____

SAMPLE NUMBER 351

Coarse fraction (>2 mm)

Weight percent of total sample 22

Composition:

Terrigenous rock fragments 100 — __ granules X pebbles
Carbonate shells ____ — __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 32

Composition:

Terrigenous rock fragments and mineral grains 80
Carbonate megafaunal shell fragments ____
Foraminifera Tr
Volcanic ash 20
Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 29
Weight percent clay (<0.0039 mm) in total sample 17

Composition:

Clay minerals 32
Volcanic ash 45
Terrigenous mineral grains 8
Siliceous shells and spicules 15
Carbonate shells ____

SAMPLE NUMBER 353

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____ — __ granules __ pebbles
Carbonate shells ____ — __ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 1

Composition:

Terrigenous rock fragments and mineral grains ____
Carbonate megafaunal shell fragments ____
Foraminifera 3
Volcanic ash 62
Siliceous spicules and shells 35

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 61
Weight percent clay (<0.0039 mm) in total sample 38

Composition:

Clay minerals 43
Volcanic ash 45
Terrigenous mineral grains 5
Siliceous shells and spicules 7
Carbonate shells ____

SAMPLE NUMBER 354

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____   __ granules   __ pebbles

Carbonate shells ____   __ cobbles   __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 1

Composition:

Terrigenous rock fragments and mineral grains ____
Carbonate megafaunal shell fragments Tr
Foraminifera Tr
Volcanic ash 55
Siliceous spicules and shells 45

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 61
Weight percent clay (<0.0039 mm) in total sample 38

Composition:

Clay minerals 20
Volcanic ash 62
Terrigenous mineral grains 10
Siliceous shells and spicules 5
Carbonate shells 3

SAMPLE NUMBER 355

Coarse fraction (>2 mm)

Weight percent of total sample 10

Composition:

Terrigenous rock fragments 100   X granules   X pebbles

Carbonate shells ____   __ cobbles   __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 45

Composition:

Terrigenous rock fragments and mineral grains 99
Carbonate megafaunal shell fragments Tr
Foraminifera Tr
Volcanic ash Tr
Siliceous spicules and shells 1

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 26
Weight percent clay (<0.0039 mm) in total sample 19

Composition:

Clay minerals 22
Volcanic ash 50
Terrigenous mineral grains 25
Siliceous shells and spicules Tr
Carbonate shells 3

SAMPLE NUMBER 356

Coarse fraction (>2 mm)

Weight percent of total sample 43

Composition:

Terrigenous rock fragments 100

Carbonate shells ____

X granules X pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 49

Composition:

Terrigenous rock fragments and mineral grains 100
Carbonate megafaunal shell fragments Tr
Foraminifera Tr
Volcanic ash Tr
Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 5
Weight percent clay (<0.0039 mm) in total sample 3

Composition:

Clay minerals 45
Volcanic ash 35
Terrigenous mineral grains 20
Siliceous shells and spicules Tr
Carbonate shells ____

SAMPLE NUMBER 357

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____

Carbonate shells ____

__ granules __ pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 56

Composition:

Terrigenous rock fragments and mineral grains 80
Carbonate megafaunal shell fragments Tr
Foraminifera 1
Volcanic ash 18
Siliceous spicules and shells 1

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 30
Weight percent clay (<0.0039 mm) in total sample 14

Composition:

Clay minerals 45
Volcanic ash 30
Terrigenous mineral grains 19
Siliceous shells and spicules 6
Carbonate shells ____

SAMPLE NUMBER 358

Coarse fraction (>2 mm)

Weight percent of total sample 2

Composition:

Terrigenous rock fragments 100

Carbonate shells ____

__ granules X pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 69

Composition:

Terrigenous rock fragments and mineral grains 70

Carbonate megafaunal shell fragments ____

Foraminifera Tr

Volcanic ash 30

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 16

Weight percent clay (<0.0039 mm) in total sample 13

Composition:

Clay minerals 50

Volcanic ash 40

Terrigenous mineral grains 5

Siliceous shells and spicules 5

Carbonate shells ____

SAMPLE NUMBER 359

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____

Carbonate shells ____

__ granules __ pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 49

Composition:

Terrigenous rock fragments and mineral grains 68

Carbonate megafaunal shell fragments ____

Foraminifera Tr

Volcanic ash 32

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 32

Weight percent clay (<0.0039 mm) in total sample 19

Composition:

Clay minerals 40

Volcanic ash 45

Terrigenous mineral grains 6

Siliceous shells and spicules 9

Carbonate shells ____

SAMPLE NUMBER 437

Coarse fraction (>2 mm)

Weight percent of total sample 80

Composition:

Terrigenous rock fragments 97

Carbonate shells 3

X granules X pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 18

Composition:

Terrigenous rock fragments and mineral grains 67
Carbonate megafaunal shell fragments 20
Foraminifera 5
Volcanic ash 7
Siliceous spicules and shells 1

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 1
Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 25
Volcanic ash 40
Terrigenous mineral grains 35
Siliceous shells and spicules TR
Carbonate shells TR

SAMPLE NUMBER 443

Coarse fraction (>2 mm)

Weight percent of total sample 71

Composition:

Terrigenous rock fragments 100

Carbonate shells TR

X granules X pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 18

Composition:

Terrigenous rock fragments and mineral grains 75
Carbonate megafaunal shell fragments 5
Foraminifera 4
Volcanic ash 15
Siliceous spicules and shells 1

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 7
Weight percent clay (<0.0039 mm) in total sample 4

Composition:

Clay minerals 25
Volcanic ash 29
Terrigenous mineral grains 39
Siliceous shells and spicules 4
Carbonate shells 3

SAMPLE NUMBER 444

Coarse fraction (>2 mm)

Weight percent of total sample 39

Composition:

Terrigenous rock fragments 97

Carbonate shells 3

X granules X pebbles

_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 59

Composition:

Terrigenous rock fragments and mineral grains 99

Carbonate megafaunal shell fragments 1

Foraminifera ___

Volcanic ash ___

Siliceous spicules and shells ___

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 1

Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 48

Volcanic ash 45

Terrigenous mineral grains 7

Siliceous shells and spicules ___

Carbonate shells ___

SAMPLE NUMBER 446

Coarse fraction (>2 mm)

Weight percent of total sample 10

Composition:

Terrigenous rock fragments 100

Carbonate shells ___

X granules X pebbles

_ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 76

Composition:

Terrigenous rock fragments and mineral grains 99

Carbonate megafaunal shell fragments ___

Foraminifera ___

Volcanic ash 1

Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 10

Weight percent clay (<0.0039 mm) in total sample 4

Composition:

Clay minerals 40

Volcanic ash 45

Terrigenous mineral grains 5

Siliceous shells and spicules 10

Carbonate shells ___

SAMPLE NUMBER 447

Coarse fraction (>2 mm)

Weight percent of total sample 9

Composition:

Terrigenous rock fragments 71
Carbonate shells 29

X granules __ pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 75

Composition:

Terrigenous rock fragments and mineral grains 62
Carbonate megafaunal shell fragments 25
Foraminifera 10
Volcanic ash 3
Siliceous spicules and shells Tr

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 10
Weight percent clay (<0.0039 mm) in total sample 6

Composition:

Clay minerals 25
Volcanic ash 41
Terrigenous mineral grains 20
Siliceous shells and spicules 12
Carbonate shells 2

SAMPLE NUMBER 448

Coarse fraction (>2 mm)

Weight percent of total sample ______

Composition:

Terrigenous rock fragments ______
Carbonate shells ______

__ granules __ pebbles
__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 99

Composition:

Terrigenous rock fragments and mineral grains 100
Carbonate megafaunal shell fragments ______
Foraminifera ______
Volcanic ash ______
Siliceous spicules and shells ______

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample Tr
Weight percent clay (<0.0039 mm) in total sample 1

Composition:

Clay minerals 40
Volcanic ash 45
Terrigenous mineral grains 15
Siliceous shells and spicules Tr
Carbonate shells ______

SAMPLE NUMBER 449

Coarse fraction (>2 mm)

Weight percent of total sample 63

Composition:

Terrigenous rock fragments 100

Carbonate shells Tr

X granules X pebbles _ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 30

Composition:

Terrigenous rock fragments and mineral grains 95

Carbonate megafaunal shell fragments ____

Foraminifera 3

Volcanic ash 1

Siliceous spicules and shells 1

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 4

Weight percent clay (<0.0039 mm) in total sample 3

Composition:

Clay minerals 50

Volcanic ash 15

Terrigenous mineral grains 25

Siliceous shells and spicules 10

Carbonate shells Tr

SAMPLE NUMBER 452

Coarse fraction (>2 mm)

Weight percent of total sample 1

Composition:

Terrigenous rock fragments 75

Carbonate shells 25

X granules _ pebbles _ cobbles _ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 99

Composition:

Terrigenous rock fragments and mineral grains 100

Carbonate megafaunal shell fragments ____

Foraminifera ____

Volcanic ash ____

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample ____

Weight percent clay (<0.0039 mm) in total sample ____

Composition:

Clay minerals ____

Volcanic ash ____

Terrigenous mineral grains ____

Siliceous shells and spicules ____

Carbonate shells ____

SAMPLE NUMBER 453

Coarse fraction (>2 mm)

Weight percent of total sample 91

Composition:

Terrigenous rock fragments 97

Carbonate shells 3

x granules x pebbles

x cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 9

Composition:

Terrigenous rock fragments and mineral grains 93

Carbonate megafaunal shell fragments 7

Foraminifera Tr

Volcanic ash Tr

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample Tr

Weight percent clay (<0.0039 mm) in total sample Tr

Composition:

Clay minerals 22

Volcanic ash 20

Terrigenous mineral grains 58

Siliceous shells and spicules Tr

Carbonate shells Tr

SAMPLE NUMBER 454

Coarse fraction (>2 mm)

Weight percent of total sample ____

Composition:

Terrigenous rock fragments ____

Carbonate shells ____

__ granules __ pebbles

__ cobbles __ boulders

Sand fraction (2 mm - 0.062 mm)

Weight percent of total sample 97

Composition:

Terrigenous rock fragments and mineral grains 99

Carbonate megafaunal shell fragments ____

Foraminifera ____

Volcanic ash 1

Siliceous spicules and shells ____

Fine fraction (<0.062 mm)

Weight percent silt (0.062 mm - 0.0039 mm) in total sample 1

Weight percent clay (<0.0039 mm) in total sample 2

Composition:

Clay minerals 26

Volcanic ash 49

Terrigenous mineral grains 20

Siliceous shells and spicules 3

Carbonate shells 2

Geotechnical Characteristics of Bottom Sediment in the Northern Bering Sea

by

Harold W. Olsen
Branch of Engineering Geology
U.S. Geological Survey
Box 25046, M.S. 903
Denver, CO 80225

Administrative Report to the

Outer Continental Shelf Environmental Assessment Program
National Oceanic and Atmospheric Administration

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by Harold W. Olsen
Branch of Engineering Geology
U.S. Geological Survey
Box 25046, M.S. 903
Denver, CO 80225

INTRODUCTION

Since 1976 the U.S. Geological Survey (USGS) has been acquiring geotechnical information on bottom sediment in the Northern Bering Sea. Reconnaissance level data were first obtained to provide a basis, together with geologic, geochemical, and environmental data, for identifying potential hazards to offshore resource development activities in the region. Topically oriented geotechnical studies were initiated in 1978 to clarify the importance of gas and storm wave loading as sources of bottom instability in Norton Sound.

This report presents the results of the reconnaissance geotechnical studies in the Northern Bering Sea and describes the work in progress on cores taken from gas-charged areas in central Norton Sound. The work in progress on wave-induced bottom instability in Norton Sound is being reported separately.

These geotechnical studies have been part of a broad group of USGS studies in the Northern Bering Sea aimed at identifying and evaluating those geologic conditions and processes that may be hazardous to offshore resource development activities (Thor and Nelson, 1979; Larson, Nelson, and Thor, 1980). The cruises for these studies were supported jointly by the USGS and the U.S. Bureau of Land Management (BLM) through an interagency agreement with the U.S. National Oceanic and Atmospheric Administration (NOAA) under which a multiyear program responding to the needs of petroleum development of the Alaska continental shelf is managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office.

The reconnaissance geotechnical data were obtained by USGS personnel on shipboard, in the USGS Geotechnical Laboratories in Menlo Park and Denver, and in the Geotechnical Laboratory at Cornell University. The geotechnical data on the cores from gas-charged areas in central Norton Sound are being obtained under the direction of the author of this report by the USGS Geotechnical Laboratory in Denver and the Geotechnical Laboratory at the University of Colorado in Boulder, under USGS Contract 14-08-0001-18760. University of Colorado personnel participating under this contract include Professor Robert L. Schiffman, Professor Hon-Yim Ko, Dobroslav Znidarcic, Steven A. Ketcham, and Emir J. Macari.

RECONNAISSANCE GEOTECHNICAL STUDIES IN THE NORTHERN BERING SEA

During 1976 and 1977, near-surface samples were obtained with box corers, Van Veen samplers, and a Kiel vibracorer capable of penetrating 2 m beneath the ocean floor. During 1978 additional samples were acquired with an Alpine vibratory corer system equipped to obtain 8.89 cm diameter continuous samples to a maximum depth of 6 m. The reconnaissance level geotechnical data include: (a) shipboard measurements of vibracore penetration rates; (b) laboratory measurements of specific gravity, particle-size distribution, Atterberg limits, bulk density, moisture content, strength indices (from hand vane, laboratory vane, pocket penetrometer, and unconfined compression tests); and (c) a few consolidation and triaxial tests on selected materials.

Selected aspects of this work have been reported by Clukey, Nelson, and Newby (1978); Nelson, Kvenvolden, and Clukey (1978); Nelson and others (1979); and Sangrey and others (1979). More recently a synthesis of the geotechnical information obtained to date has been prepared for publication by Olsen, Clukey and Nelson (1980) and is included as an appendix in this report. The information in the appendix shows the relation of the geotechnical data obtained to the geologic and environmental conditions in the Northern Bering Sea, and assesses the significance of these data with regard to potential hazards to offshore resource development activities in the region.

GEOTECHNICAL ANALYSES OF CORES FROM GAS-CHARGED AREAS IN CENTRAL NORTON SOUND

Approach

During 1978 the Alpine vibratory corer system was used not only to obtain samples for geologic, geochemical, and reconnaissance level geotechnical studies; replicate cores were also taken for more detailed laboratory geotechnical measurements of the bottom materials in the Yukon Delta and central regions of Norton Sound. The cores taken from the Yukon Delta region are being analyzed at Cornell University as part of a study of the potential for storm wave-induced liquefaction. The cores taken from central Norton Sound are being analyzed at the USGS Geotechnical Laboratory in Denver with the assistance of specialized geotechnical capabilities at the University of Colorado in Boulder. The work on the Yukon Delta cores is being reported separately, as noted above. The following describes the work to date on the cores from central Norton Sound.

The cores from central Norton Sound are from areas designated by Larson, Nelson, and Thor (1980) as potentially hazardous due to the thermogenic gas seep south of Nome in west-central Norton Sound, and the biogenic gas-crater fields in east-central Norton Sound (fig. 1). Figure 2 shows the location of the cores involved. Cores 78-1, 78-2, 78-3, 78-4, and 78-5 are located in the vicinity of the thermogenic gas seep, and cores 78-6, 78-8, 78-9, and 78-10 are in the gas-crater fields. Figure 2 also shows the other core locations involved in the reconnaissance geotechnical studies described above.

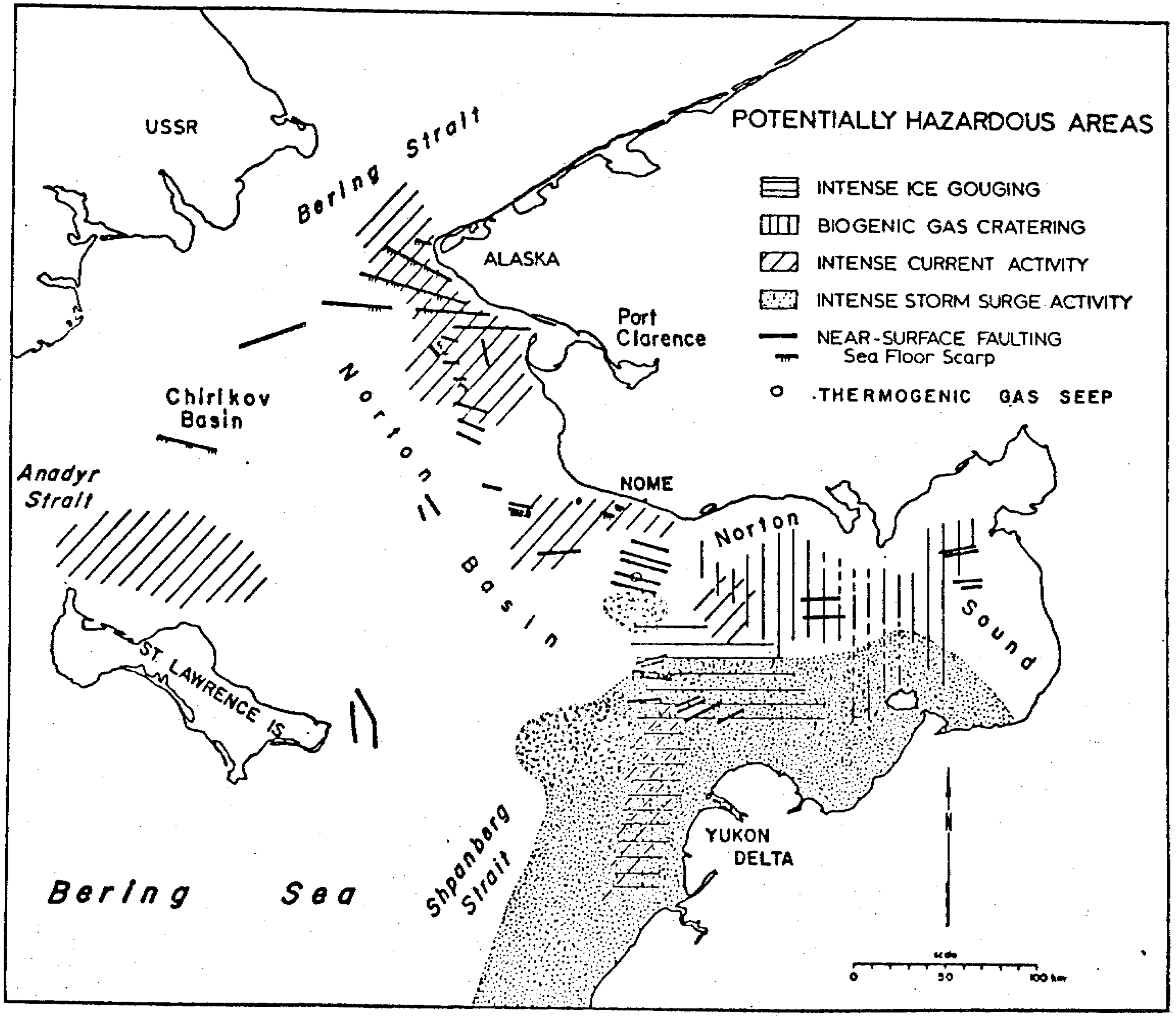


Figure 1.--Potentially hazardous areas of northern Bering Sea (from Thor and Nelson, 1971).

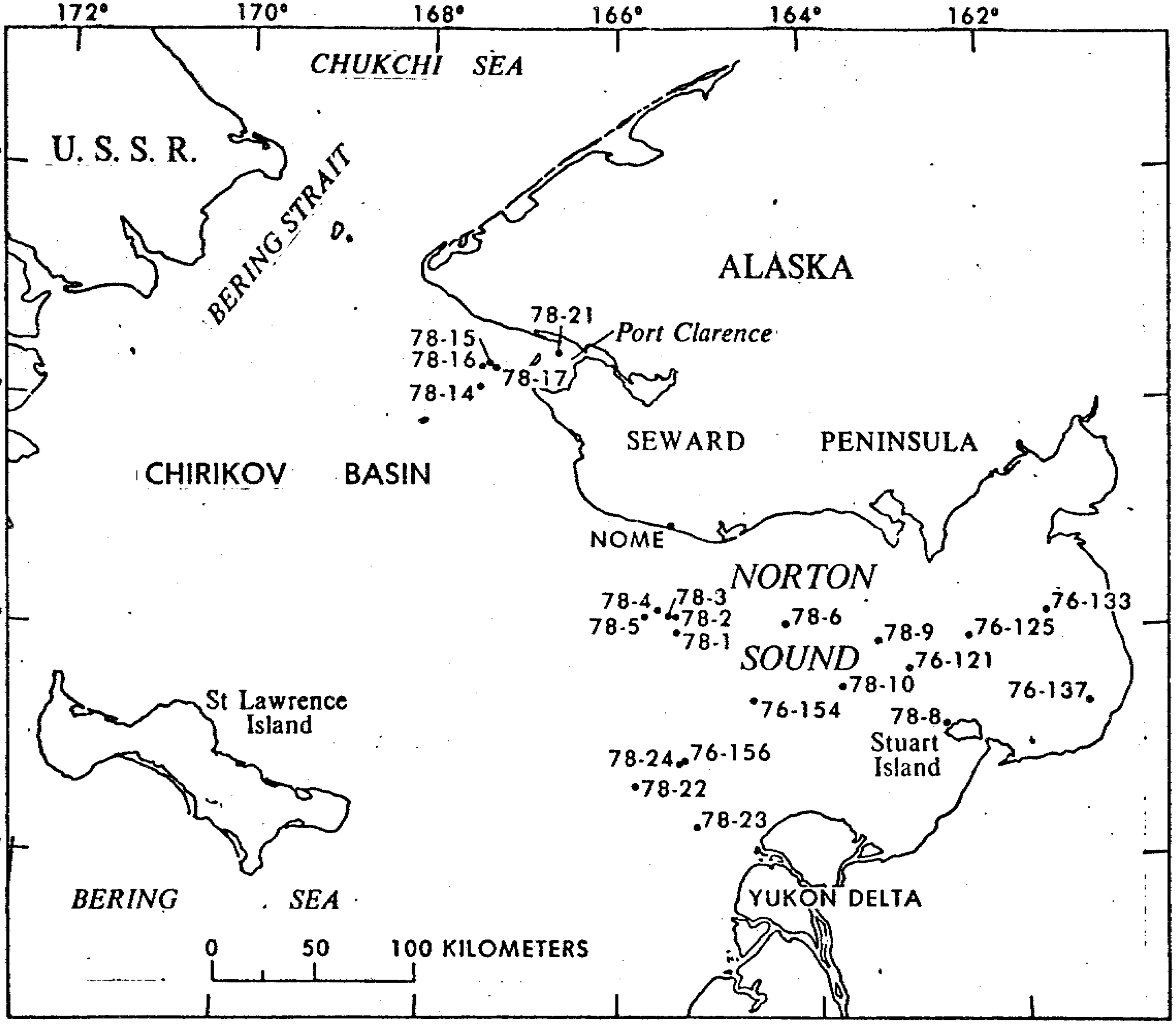


Figure 2.--Geotechnical sampling stations in the northern Bering Sea (Olsen, Clukey, and Nelson, 1980).

These cores from central Norton Sound are being used to supplement the reconnaissance geotechnical studies with more detailed and quantitative information concerning the bottom sediment in the potentially hazardous gas-charged areas. The experimental program is designed to obtain as much information as possible from the available core pertinent to quantitative assessments of the hazards in these gas-charged areas.

It needs to be recognized that such quantitative assessments will require, not only a laboratory experimental program, but also an in situ measurement program. Moreover, additional samples may be needed to expand the scope of the current laboratory experimental program. An in situ measurement program, in particular, is required to determine the magnitudes and distribution of excess pore pressures in situ, and to obtain a basis for estimating the effects of sample disturbance on laboratory test results. Current plans include the initiation of an appropriate in situ measurement program during the 1981 field season.

Experimental Program

The scope of the current experimental program includes geotechnical properties which reflect the geologic history of the materials, which govern their response to stresses imposed both by the environment and by man, and which provide a quantitative link with planned in situ measurements.

Specifically, the experimental program includes:

(a) detailed logging of the available cores (completed)

(b) consolidation-permeability measurements on selected samples from each core (in progress)

(c) shear modulus and damping measurements from resonant column tests on selected samples from each core (in progress)

(d) drained and undrained shear strength parameters from triaxial tests on selected samples from each core (not yet initiated)

(e) physical property measurements on each of the specimens used in (b) (c), and (d) above, including specific gravity, particle-size distribution, and Atterberg limits.

At the beginning of this work it was hoped that direct measurements of relative density could be obtained for each of the specimens used in parts (b), (c), and (d) above. This appeared desirable because the results of the reconnaissance geotechnical studies (Olsen, Clukey, and Nelson, 1980) suggested that relative density values would reflect the geologic history of bottom sediments in Norton Sound and provide a useful index of the magnitudes and variability of the engineering properties of the materials. Accordingly, a study was undertaken to determine whether existing laboratory experimental methods could be used to obtain direct measurements of relative density on Norton Sound materials. The negative results of this study are documented by Ketcham (1980).

Detailed Logging of Cores

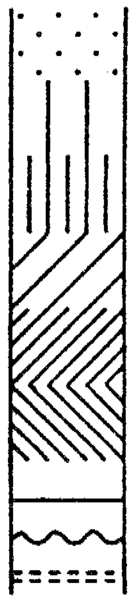
The cores available for this study were initially logged to determine their lithology, moisture content, and an index of their consolidation state (pocket penetrometer measurements of undrained shear strength). These data were then analyzed to define options for utilization of the core for consolidation-permeability, resonant column, and triaxial testing.

The logging results are presented in figures 3 through 11, and a legend for the symbols used in these figures is presented in table 1. Figures 3 through 11 are further designed to track the progress of the testing program, and the utilization of the available material. Figure 3 shows the core sections used to date for consolidation-permeability and resonant column tests on the core from station 78-1. The tests in progress on the core from station 78-4 have not yet been noted in figure 6.

The logging was conducted in a high-humidity facility to minimize evaporation of moisture from the cores during the procedure. The steps in the procedure were as follows: (a) extruding (hydraulically) a core section from the plastic cylindrical tube in which it was obtained and stored onto a heavy duty half section of a larger plastic cylindrical tube that provided a rigid holder for the core section; (b) cutting a thin section of material from the surface of the core with knives and (or) wire saws to expose the lithology; (c) photographing the core section in color; (d) visually examining and describing the lithology; (e) taking moisture content and undrained shear strength index measurements with a pocket penetrometer at representative locations along the core section; and (f) resealing the core section in cheesecloth and microcrystalline wax. Complete details concerning the logging procedures and results are being documented by Ketcham and Macari (1980).

Table 1.--Legend for detailed lithology/test program information sheets, figures 3 through 11

Lithology symbols



sand

silt

organic silt

clay

organic clay

peat

gas fracture (throughout the sample)
gas crack (not throughout the sample)
shell or rock fragments

Test program information

Column (1)--Anticipated available intact core material:

- Continuous lines show anticipated available core.
- Discontinuous lines show fractures in the anticipated available core.

Column (2)--Confirmed core material:

- Solid areas show total core material tested to date.
- Outlined areas show confirmed available core material.
- Cross-hatched areas show unusable core material.

Column (3)--Consolidometer material:

- Solid areas show consolidometer specimens tested to date.
- Outlined areas show anticipated available consolidometer specimens.
- Cross-hatched areas show unusable consolidometer specimens, or anticipated consolidometer specimens used for other purposes.

Table 1.--Legend for detailed lithology/test program information sheets, figures 3 through 11--Continued

Test program information
Column (4)--Resonant column material: - Solid areas show resonant column specimens tested to date. - Outlined areas show anticipated available resonant column specimens. - Cross-hatched areas show unusable resonant column specimens, or anticipated resonant column specimens used for other purposes.
Column (5)--Triaxial material: - Solid areas show triaxial specimens tested to date. - Outlined areas show anticipated available triaxial speciments. - Cross-hatched areas show unusable triaxial specimens, or triaxial specimens used for other purposes.

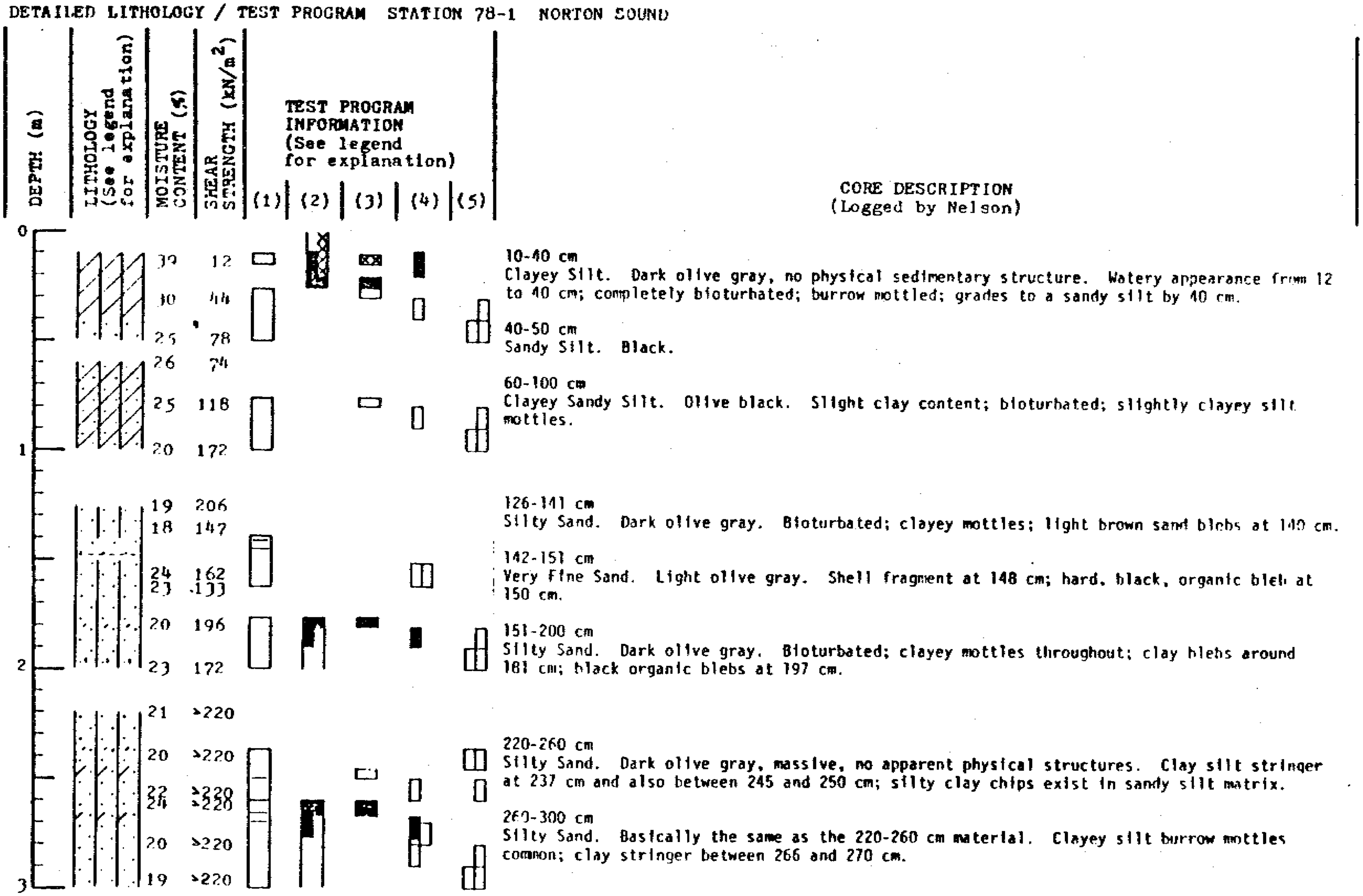


Figure 3.--Detailed lithology and test program information on the core from station 78-1.

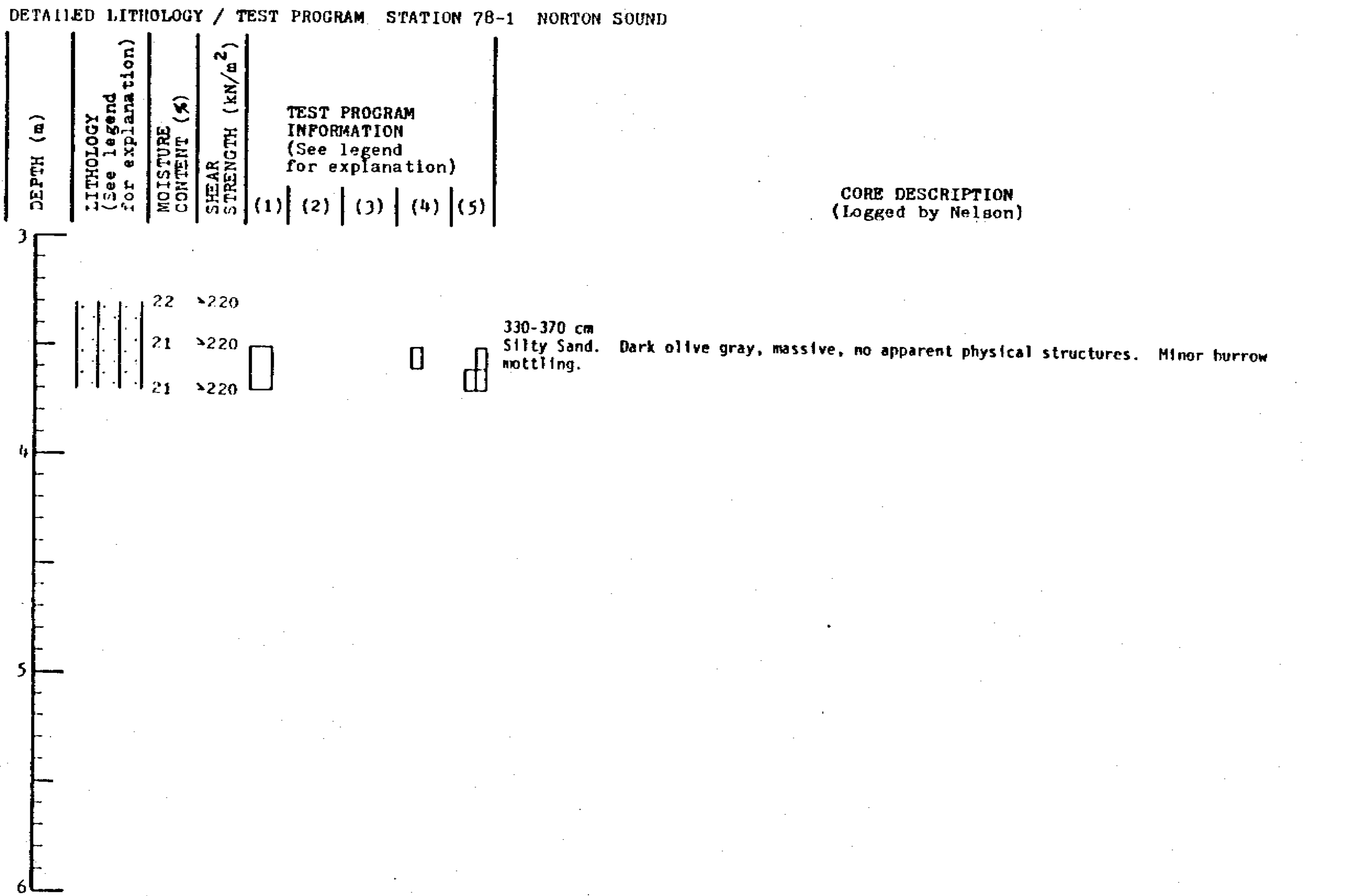
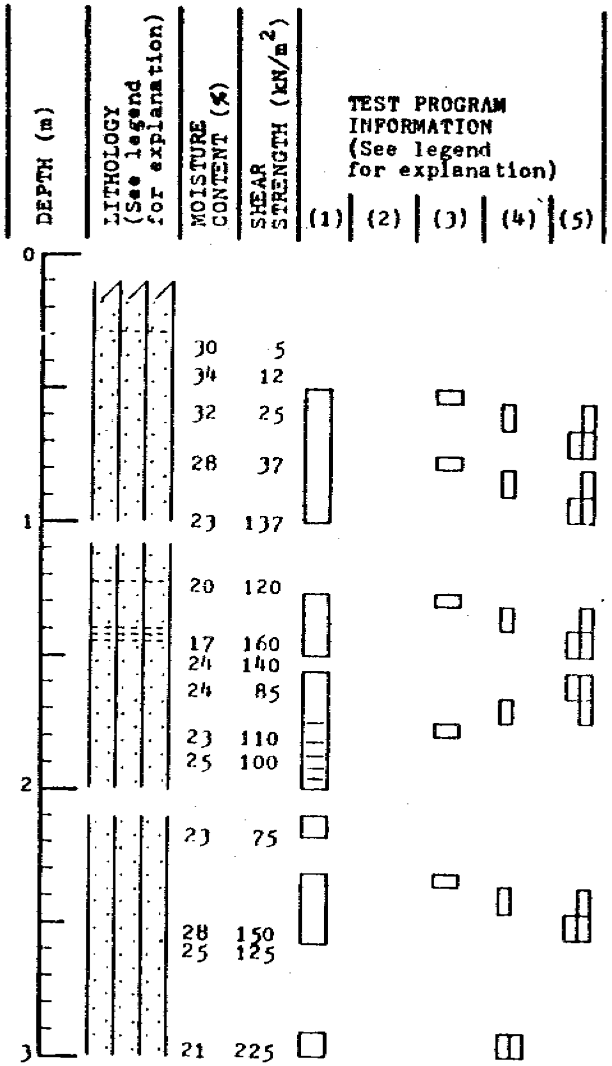


Figure 3.--Detailed lithology and test program information on the core from station 78-1--Continued.

DETAILED LITHOLOGY / TEST PROGRAM STATION 78-2 NORTON SOUND



CORE DESCRIPTION
(Logged by Nelson)

10-17 cm
Silty Clay. Watery appearance.

17-30 cm
Silty Sand. Olive gray to gray. 1 cm shell with rare associated smaller pebbles at 29 cm.

30-100 cm
Sandy Silt. Occasional clayey silt burrow mottles; watery appearance, possibly indicating a low clay content; black silt bleb exists at 80 cm; slightly cleaner sandy silt between 85 and 100 cm.

108-112 cm
Sandy Silt.

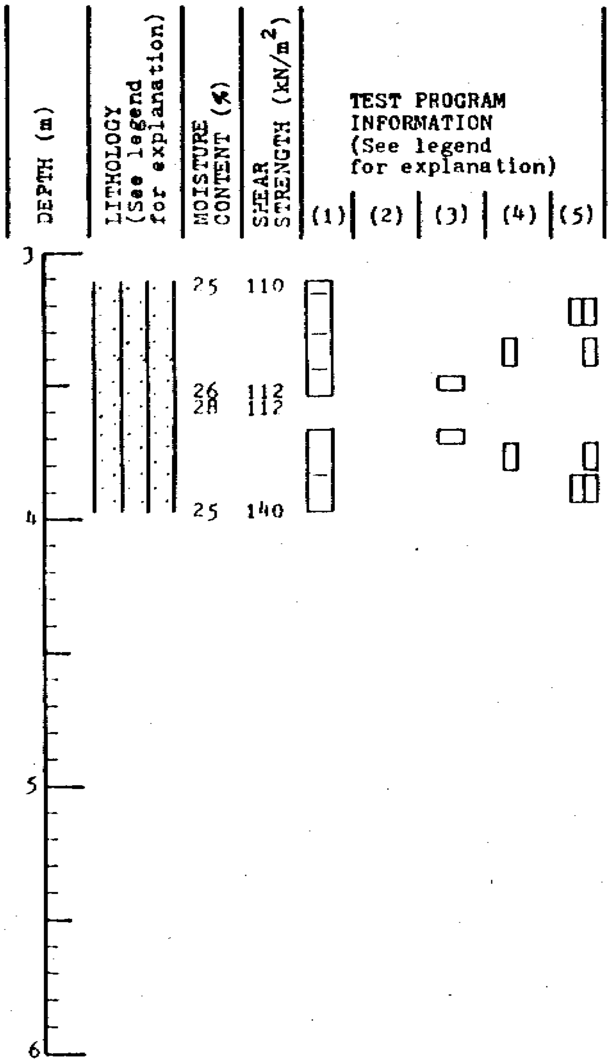
112-200 cm
Silty Very Fine Sand. Olive gray to gray, homogeneous, no apparent physical structures. Faint sandy silt burrow mottles throughout (mottles containing siltier find sand toward 200 cm); 4 cm diameter shell fragment at 122-125 cm; shell and pebble horizon between 138 and 150 cm (shells towards the top and pebbles towards the bottom); 6 cm diameter shell between 140 and 145 cm; rounded quartz pebbles between 145 and 150 cm; slight watery appearance to 140 cm.

210-217 cm
Sandy Silt.

217-300 cm
Silty Very Find Sand. Olive gray to gray, no physical sedimentary structure. Highly burrow mottled; slightly siltier between 295 and 300 cm.

Figure 4.--Detailed lithology and test program information on the core from station 78-2.

DETAILED LITHOLOGY / TEST PROGRAM STATION 78-2 NORTON SOUND

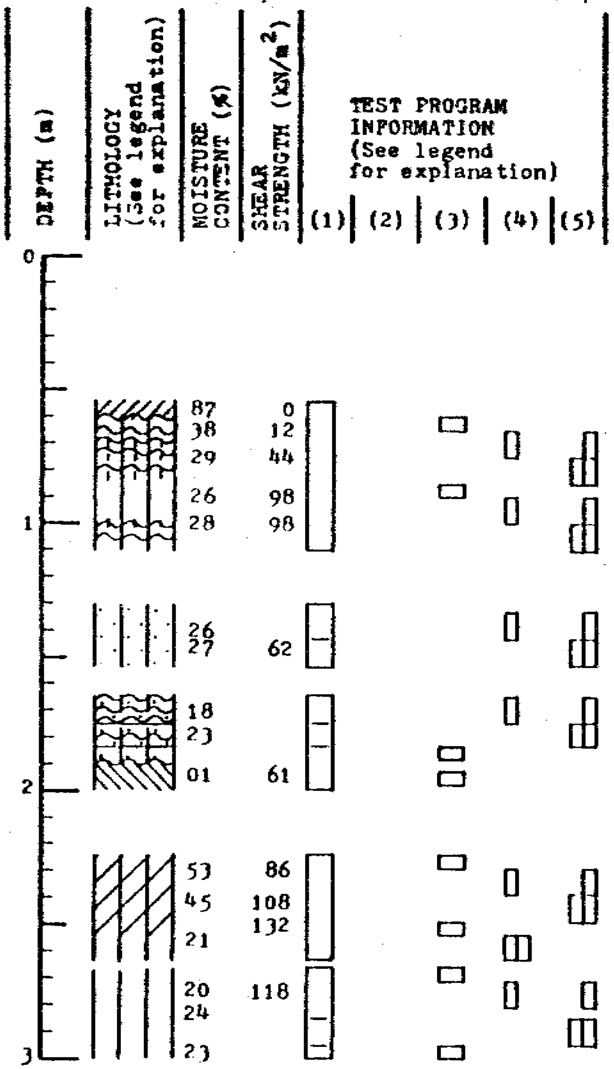


CORE DESCRIPTION
(Logged by Nelson)

310-397 cm
Silty Sand. Dark olive gray, no apparent physical structure. Mottled throughout; higher clay content between 367 and 397 cm (in burrow mottles filled with clayey sandy silt); clay bleb between 338 and 340 cm; dark organic streaks from 395 to 397.

Figure 4.--Detailed lithology and test program information on the core from station 78-2--Continued.

DETAILED LITHOLOGY / TEST PROGRAM STATION 78-3 NORTON SOUND



CORE DESCRIPTION
(Logged by Ketchom/Macari)

53-60 cm
Organic Clay. Black, very moist, very soft. Does not fragment during kneading; strong but slow HCl reaction, apparently due to low permeability.

60-110 cm
Coarse Silt. Very dark gray, fairly well graded, highly gas disturbed. Gas expansion pockets and cracks from 60 to 83 cm and from 100 to 110 cm (some cracks as wide as 2 mm); hardens with depth; decreases in clay content with depth; black organic silt lenses at 69-83 cm and 98-101 cm; small HCl reaction.

130-154 cm
Silty Sand. Very dark gray. Constant color throughout; varies slightly from fine sand at 136 cm to silty fine sand below 139 cm; very slightly mottled throughout; no reaction with HCl.

164-192 cm
Sandy Silt. Dark olive gray, highly disturbed, medium gradation. Disturbance most likely from gas; gas cracks, gas fractures, and brittle appearance throughout, but predominantly near the top; the silt is coarse silt; large and small lenses or specks of well graded, pale olive fine sand in the section; less than 1% of the particles are 1-2 mm diameter pebbles; very slight HCl reaction.

192-200 cm
Peat. Very dark brown, contains about 10% coarse silt particles in addition to the peat. Organic materials (leaves, etc.) visible to the naked eye: no reaction with HCl.

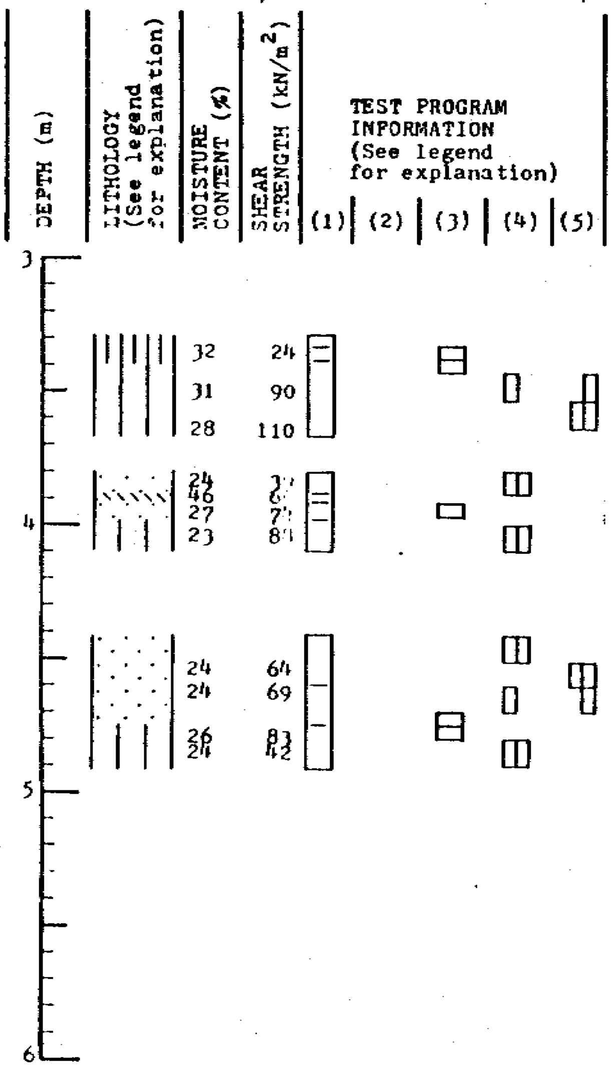
224-254 cm
Clayey Silt. Dark olive gray, very uniform. Silt particles bound together with clay: does not fragment during kneading; no reaction with HCl.

254-263 cm
Coarse Silt. Dark olive gray, stiff, uniform, medium gradation. No reaction with HCl.

267-300 cm
Coarse Silt. Basically the same material as the 254-263 cm soil. Heavily mottled with pockets; no reactions with HCl.

Figure 5.--Detailed lithology and test program information on the core from station 78-3.

DETAILED LITHOLOGY / TEST PROGRAM STATION 78-3 NORTON SOUND



CORE DESCRIPTION
(Logged by Ketcham/Macari)

329-367 cm
Coarse Silt. Basically the same material as the 254-263 cm soil. Black from 329-340 cm; organic evidence from 329-340 cm; highly disturbed from 329-340 cm (possibly from gas, slumping of the material in the tube, or sampling); brittle appearance; no reactions with HCl.

380-398 cm
Very Fine Sand. Disturbed from 380-389 cm in the same manner as the previous soil at 329-340 cm; also disturbed at 398 cm; slightly coarser than the coarse silt above it; thick peat layer with organic particles visible to the naked eye from 388-391 cm; thin peat layer (1/2 cm) at 93.5 cm; very fine sand is the background material (~75%) for the peat; no reactions with HCl.

398-410 cm
Coarse Silt. Basically the same material as the 254-263 cm soil.

441-475 cm
Very Fine Sand. Dark olive gray, uniform. Small gas pockets, especially near the bottom of the section; a few small organic silt layers throughout; no reaction with HCl.

475-492 cm
Coarse Silt. Black, uniform. Changes from a fine sand at 441-475 cm to coarse silt at 475 cm; slight watery appearance; slight evidence of gas; no reaction with HCl.

Figure 5.--Detailed lithology and test program information on the core from station 78-3--Continued.

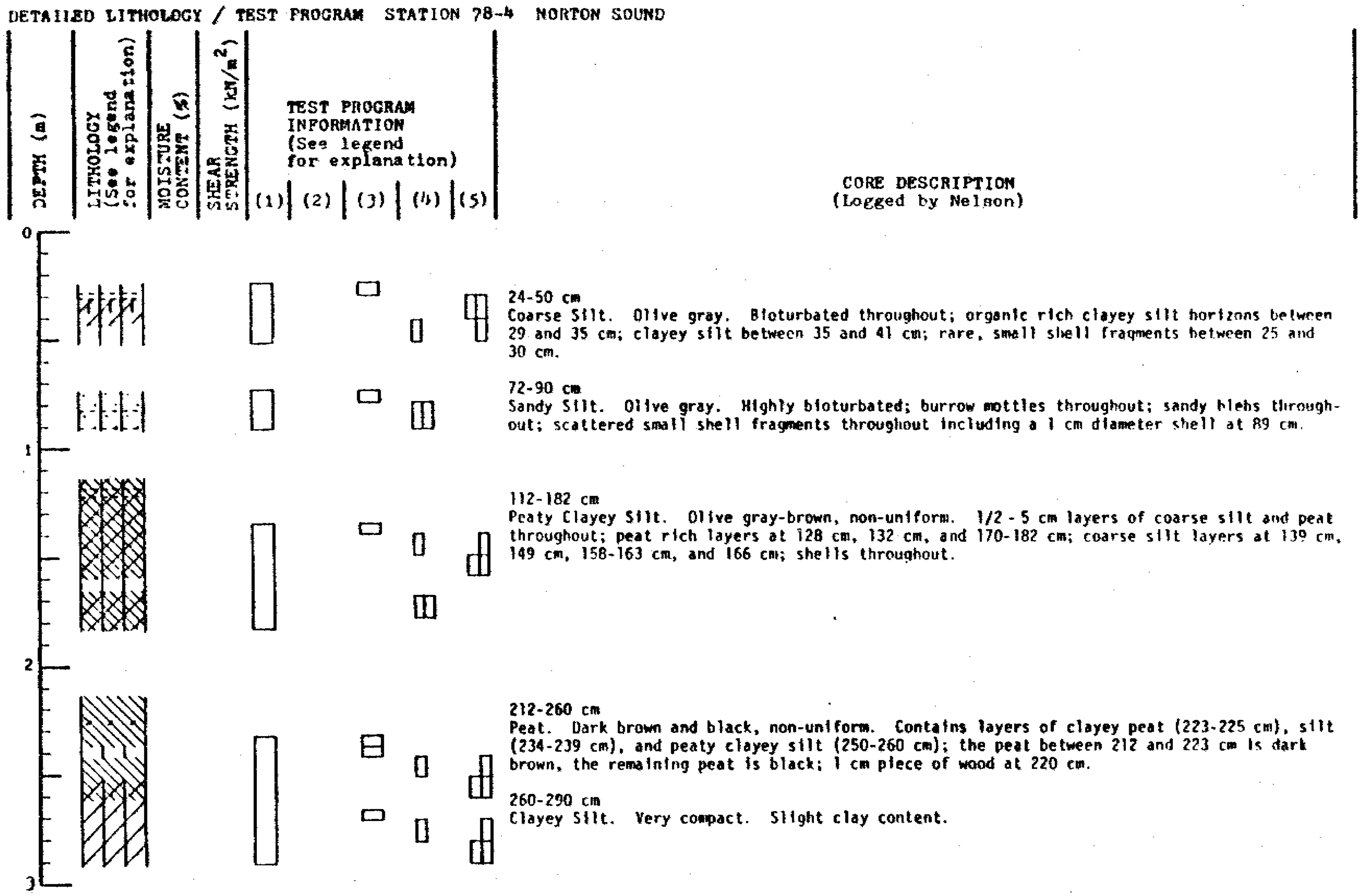


Figure 6.--Detailed lithology and test program information on the core from station 78-4.

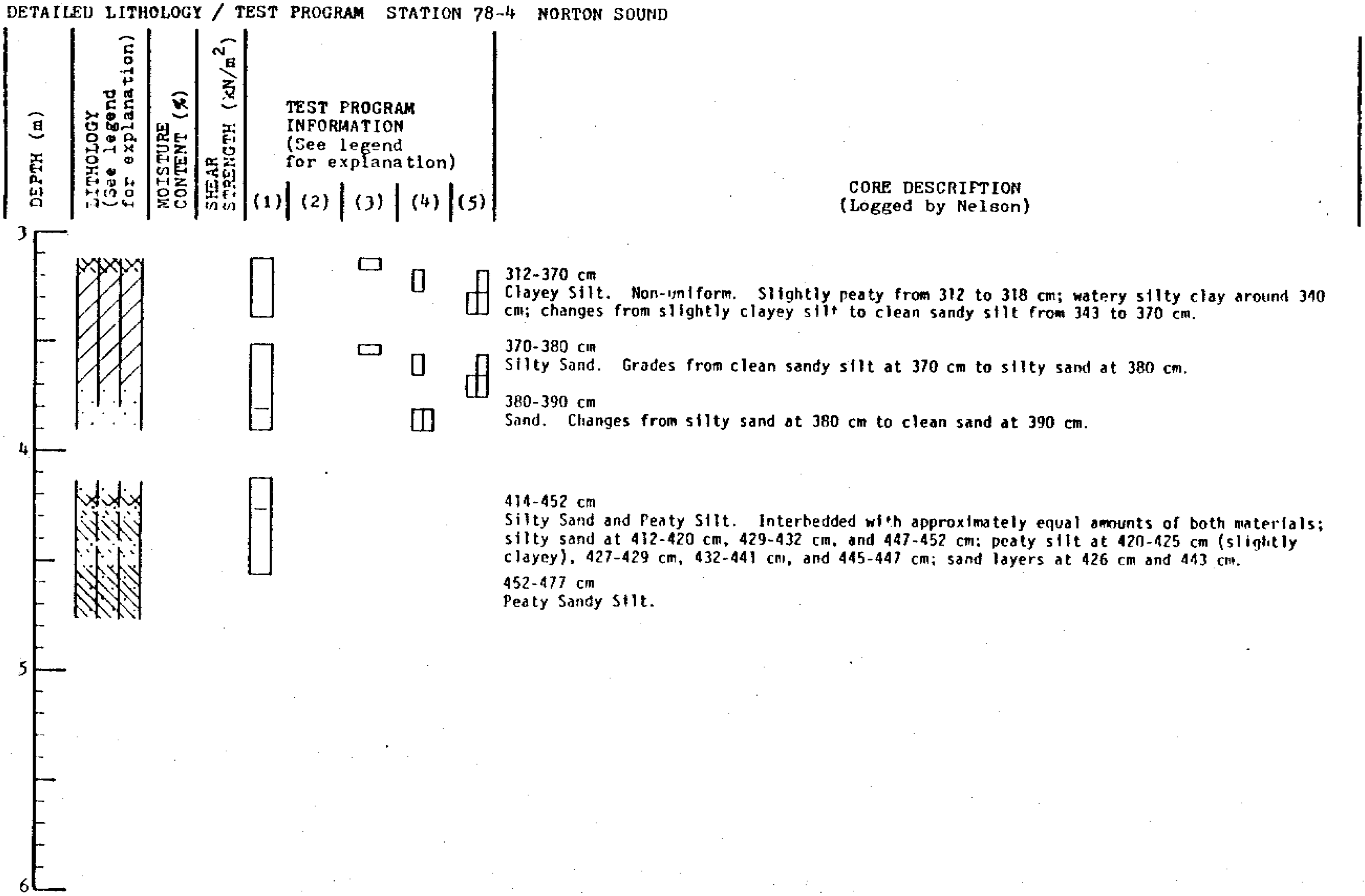


Figure 6.--Detailed lithology and test program information on the core from station 78-4--Continued.

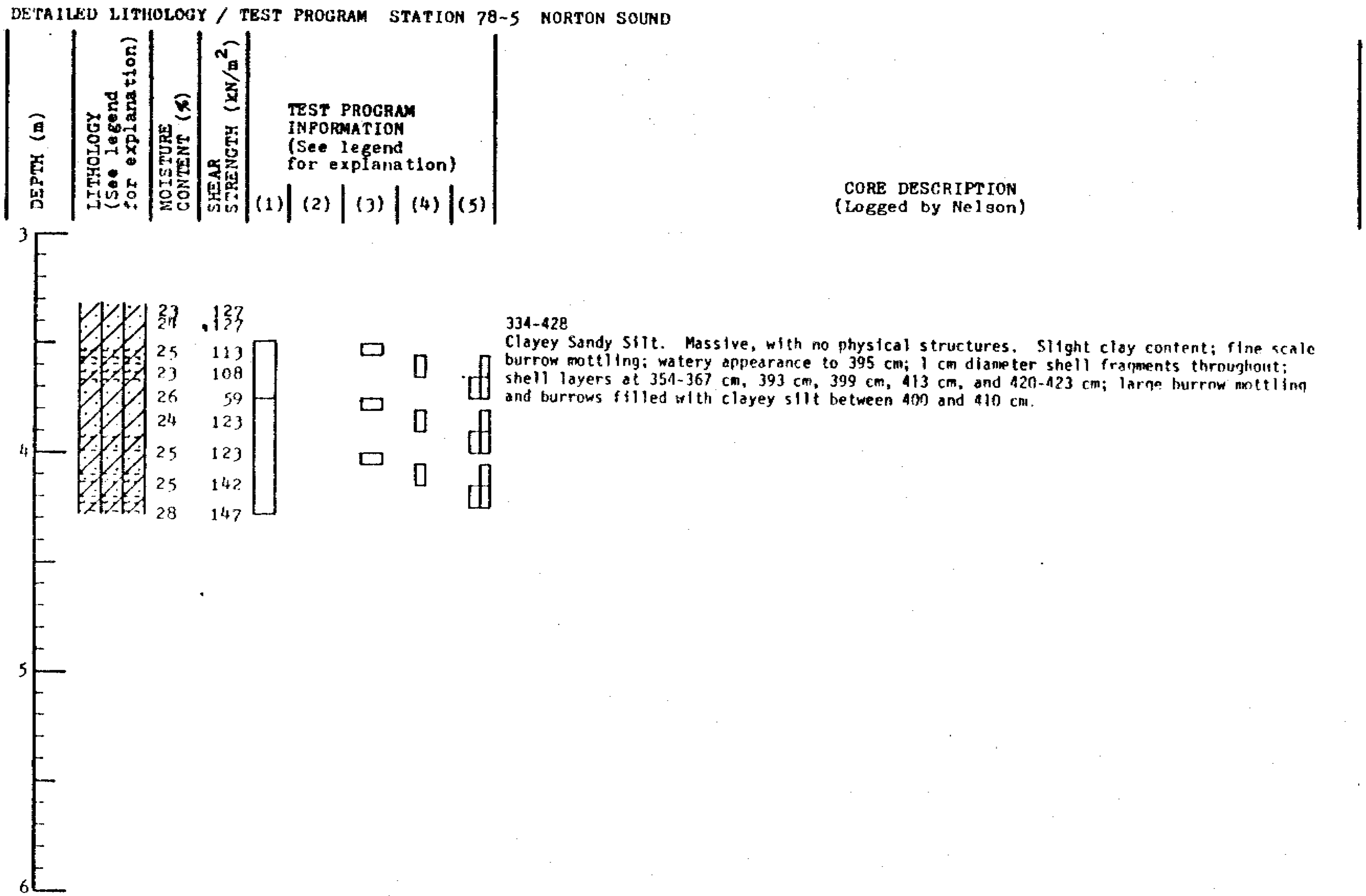


Figure 7.--Detailed lithology and test program information on the core from station 78-5.

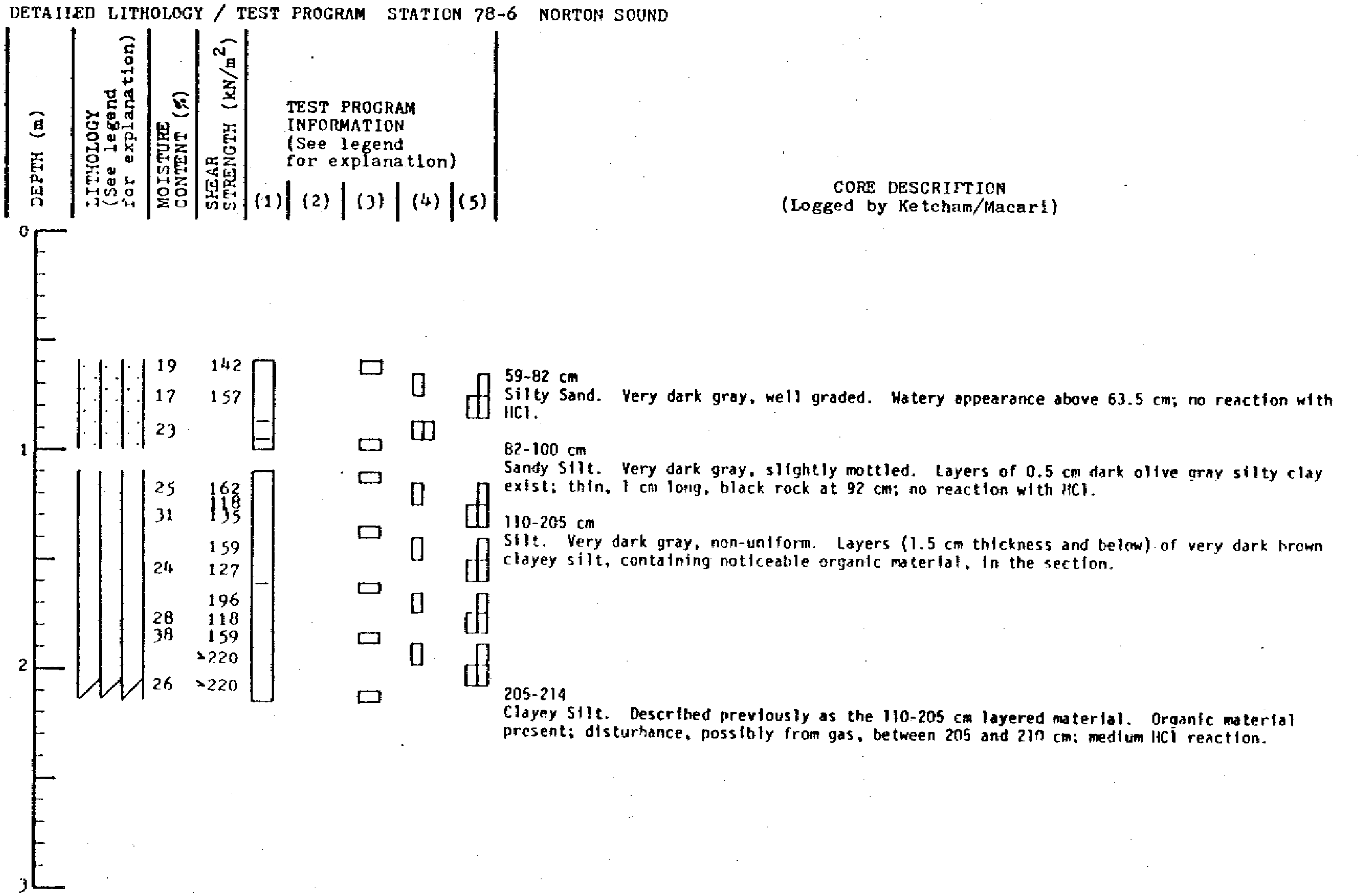
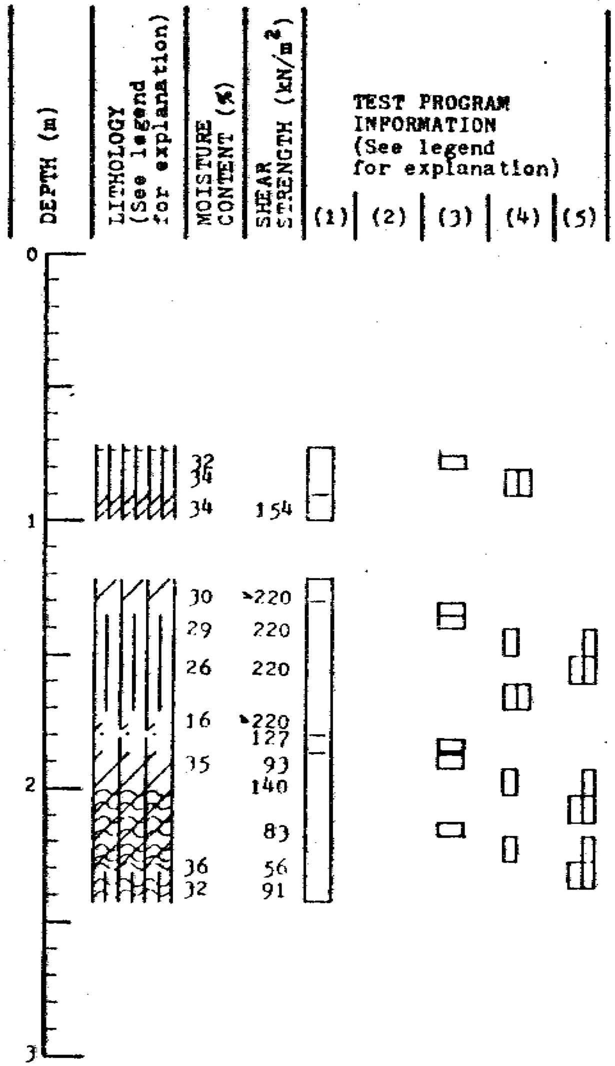


Figure 8.--Detailed lithology and test program information on the core from station 78-6.

DETAILED LITHOLOGY / TEST PROGRAM STATION 78-8 NORTON SOUND



CORE DESCRIPTION
(Logged by Ketcham/Macari)

72-90 cm
Silt. Black, non-uniform. Background for olive gray, dark gray, and very dark gray lenses and layers of clayey silts (the largest of these layers at 78 cm); quite dense throughout; shells at 73 cm; no reactions with HCl.

90-100 cm
Silty Clay. Black, non-uniform. Background for layers (less than 1 cm thick) of a black organic clay, a black and very dark gray, very fine sand, and a dark gray clayey silt; all materials have medium HCl reactions.

122-130 cm
Clayey Silt. Dark gray brown. 1 cm organic spot at 122.5 cm; very slight reaction with HCl.

130-135 cm
Silt. Very dark gray, disturbed. Strong HCl reaction.

135-172 cm
Organic Silt. Black, very dark gray, non-uniform. Background for layers of the 130-135 cm silt; organic material diminishes in content from 135 to 172 cm; organic silt varies from black at 135 cm to very dark gray at 172 cm; strong HCl reaction.

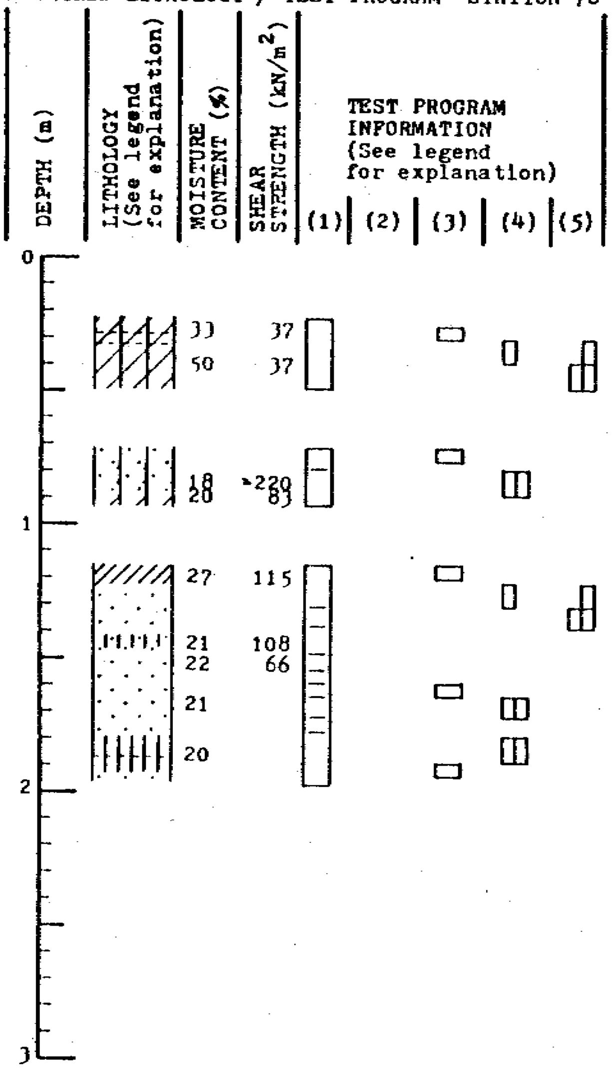
172-186 cm
Silt. Very dark gray; non-uniform. Same material as described at 130-135 cm; background for very fine, dark olive gray, sand layers at 175 and 179.5-181.5 cm, and a distinct, very dark gray, clayey silt layer at 177-179 cm; gradual change to silt from organic silt in the 172 cm region; strong HCl reaction.

186-231 cm
Clayey Silt. Very dark gray, non-uniform, disturbed. Same silt material as described at 130-135 cm; clayey silt is the background for silt and organic silt layers; gas-like disturbance increasing toward the bottom from 202 cm and into the next soil layer, consisting of horizontal 0-2 mm spaces or pockets in the soil; disturbances appear most around 230 cm, just above the next soil layer of organic silt; strong HCl reaction.

231-243 cm
Organic Silt. Basically the same material as the 135-172 cm background material. Highly gas disturbed; strong reaction with HCl.

Figure 9.--Detailed lithology and test program information on the core from station 78-8.

DETAILED LITHOLOGY / TEST PROGRAM STATION 78-9 NORTON SOUND



CORE DESCRIPTION
(Logged by Ketcham/Macari)

22-50 cm
Clayey Silt. Black. Coexists with layers of dark gray silty clay at 27-30 cm and 44-50 cm; densities of both materials are similar; shells at 33 cm in the clayey silt and at 28-29 cm in the silty clay; no reaction with HCl.

72-94 cm
Sandy Silt. Very dark gray. Contains thin layers of the 22-50 cm clayey silt at 79 and 85 cm, and a thicker layer from 90 to 94 cm; the sandy silt is much weaker than the clayey silt; no reaction with HCl.

116-124 cm
Organic Clay. Black, cohesive. Blends to a fine sand at 124 cm; medium HCl reaction.

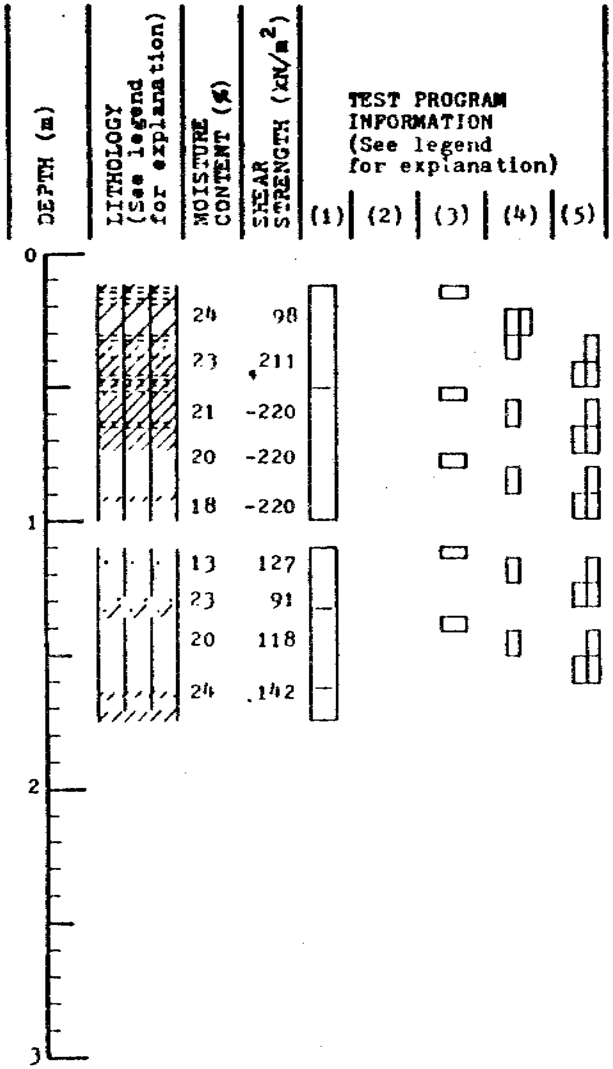
124-180 cm
Find Sand. Very dark gray, cohesionless. Background material for a thin layer of the 116-124 cm organic clay at 130 cm, and a black organic silty sand layer (medium HCl reaction) from 142 to 147 cm; relatively uniform from 147 to 180 cm; easily fractured; slight HCl reaction.

180-194 cm
Organic Silt. Black. Similar to the 116-124 cm organic clay but coarser; similar to the organic silty sand described in 124-180 cm but finer; shell fragments at 188 cm; medium HCl reaction.

194-197 cm
Fine Sand. Identical to the 124-180 cm fine sand.

Figure 10.--Detailed lithology and test program information on the core from station 78-9.

DETAILED LITHOLOGY / TEST PROGRAM STATION 78-10 NORTON SOUND



CORE DESCRIPTION
(Logged by Ketcham/Macari)

11-51 cm
Clayey Silt. Very dark gray, non-uniform. Clay content decreases toward 51 cm; background for 1 cm black organic clay layers at 20 and 36 cm; contains ~40% of the black organic clay from 37 to 51 cm; numerous shell fragments at 29-31 cm, 38 cm, and 46-51 cm; organic clay reacts slightly with HCl.

51-73 cm
Organic Clay. Black, non-uniform. Slight coarse silt background; organic clay in lenses is the predominant material between 51 and 70 cm; silt content increases to 95% from 70 to 73 cm; 1 x 1.5 cm pebble at 61 cm; shells at 63 cm.

73-100 cm
Coarse Silt. Dark gray. Background for most materials at this station; grades from a silt at 73 cm to a coarse silt at 95 cm; organic material lense at 89.5-94 cm; slight HCl reaction in the silt.

110-175 cm
Coarse Silt. Same as the 73-100 cm coarse silt. Contains many beds and lenses of other materials; olive-gray, fine sand lense at 112.5-117.5 cm; dark gray, very fine sand layer from 128 to 132 cm; dark gray clay layer from 132 to 136 cm with a thin sand lense at 134 cm; increasing amount (with increasing thickness) of black, organic clay layers below 150 cm, at 150.5 cm, 153 cm, 157.5 cm, 164.5-166 cm, and 170.5-175 cm; thin layers of silt in the coarse silt background below 150 cm; HCl reaction in the organic clay.

Figure 11.--Detailed lithology and test program information on the core from station 78-10.

Consolidation-permeability Tests

Anteus consolidometers were modified for this study to obtain consolidation parameters with both incremental loading and constant rate of strain test procedures, and to obtain rapid direct permeability measurements during the course of either consolidation test procedure. The purpose of these modifications was to have the most advanced experimental capabilities for consolidation-permeability testing available for this project.

The approach developed for constant rate of strain testing is based on the work of Smith and Wahls (1969), Wissa (1971), Znidarcic and Schiffman (1981), and also on the fundamental consolidation-permeability research in progress at the University of Colorado under a grant from the National Science Foundation (R. L. Schiffman, and Hon-Yim Ko Principal Investigators). The approach being used for rapid direct permeability measurements is that developed by Olsen (1966) which involves producing arbitrary constant flow rates through a soil specimen with a multispeed syringe pump, and measuring the hydraulic gradients induced thereby with a transducer.

Tests run to date have been conducted with the standard incremental loading procedure supplemented with direct permeability measurements after each load increment. The use of both incremental loading and constant rate of strain test procedures are planned for this program. Details concerning the equipment, procedures, and preliminary results are being documented by Ketcham and Znidarcic (1980).

The data obtained to date are presented in figures 12 through 17. These data are from specimens of the core from station 78-1, as shown in figure 3. Figures 13 and 14 show the data set for the specimen at 0.23 m depth in the core. Similarly, figures 14, 15, 16, and 17 present the data sets for specimens at core depths of 1.79 and 2.64 m, respectively.

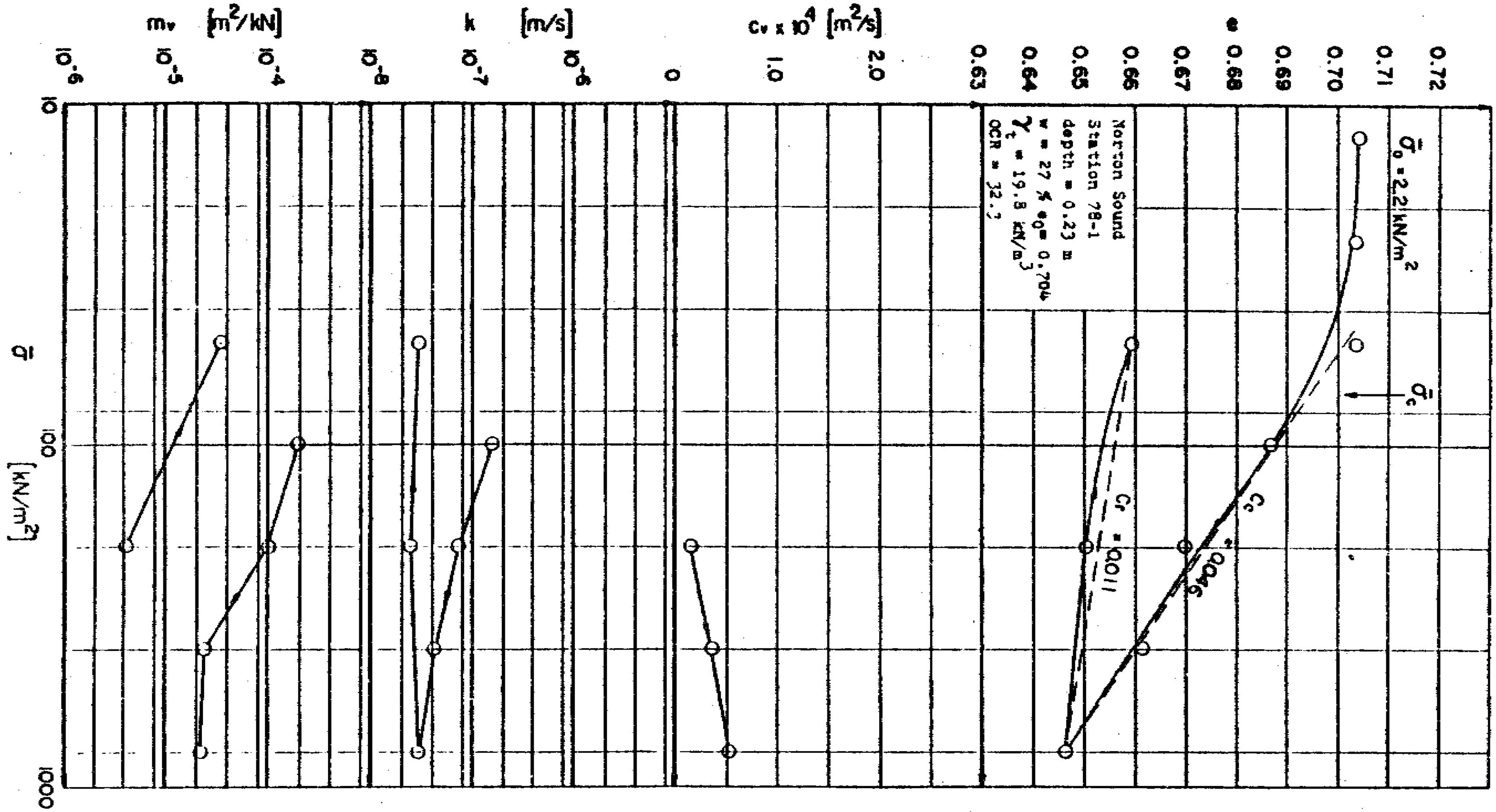


Figure 12.--Consolidation-permeability test results for 0.23 m depth at station 78-1.

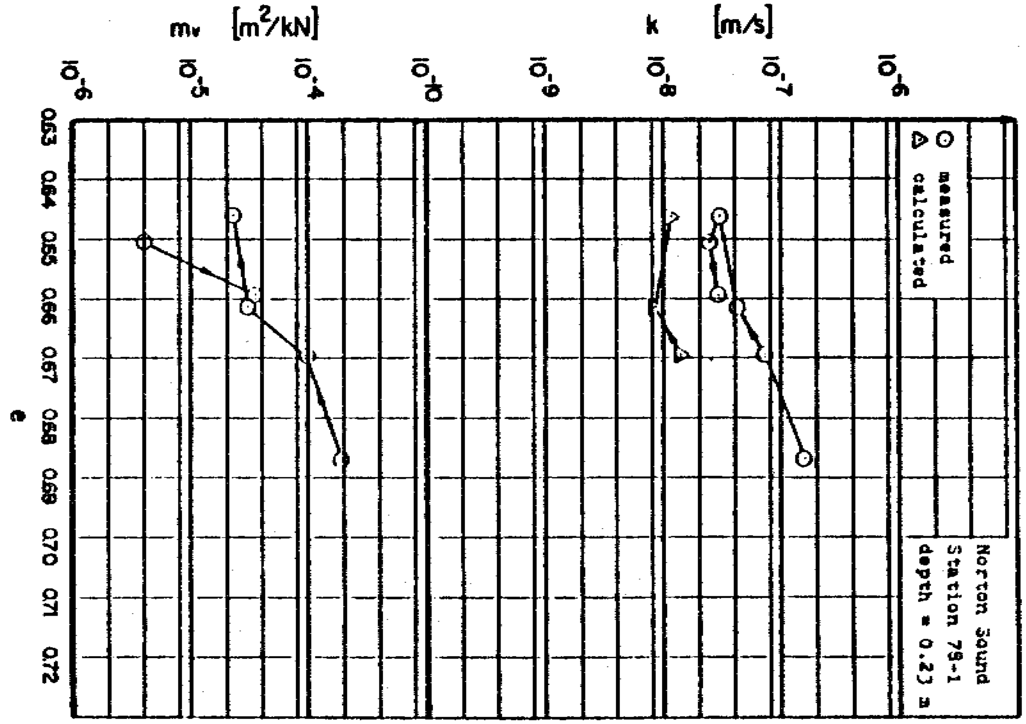


Figure 13.--Permeability, k, and compressibility, m_v, versus ratio for 0.23 m depth at station 78-1.

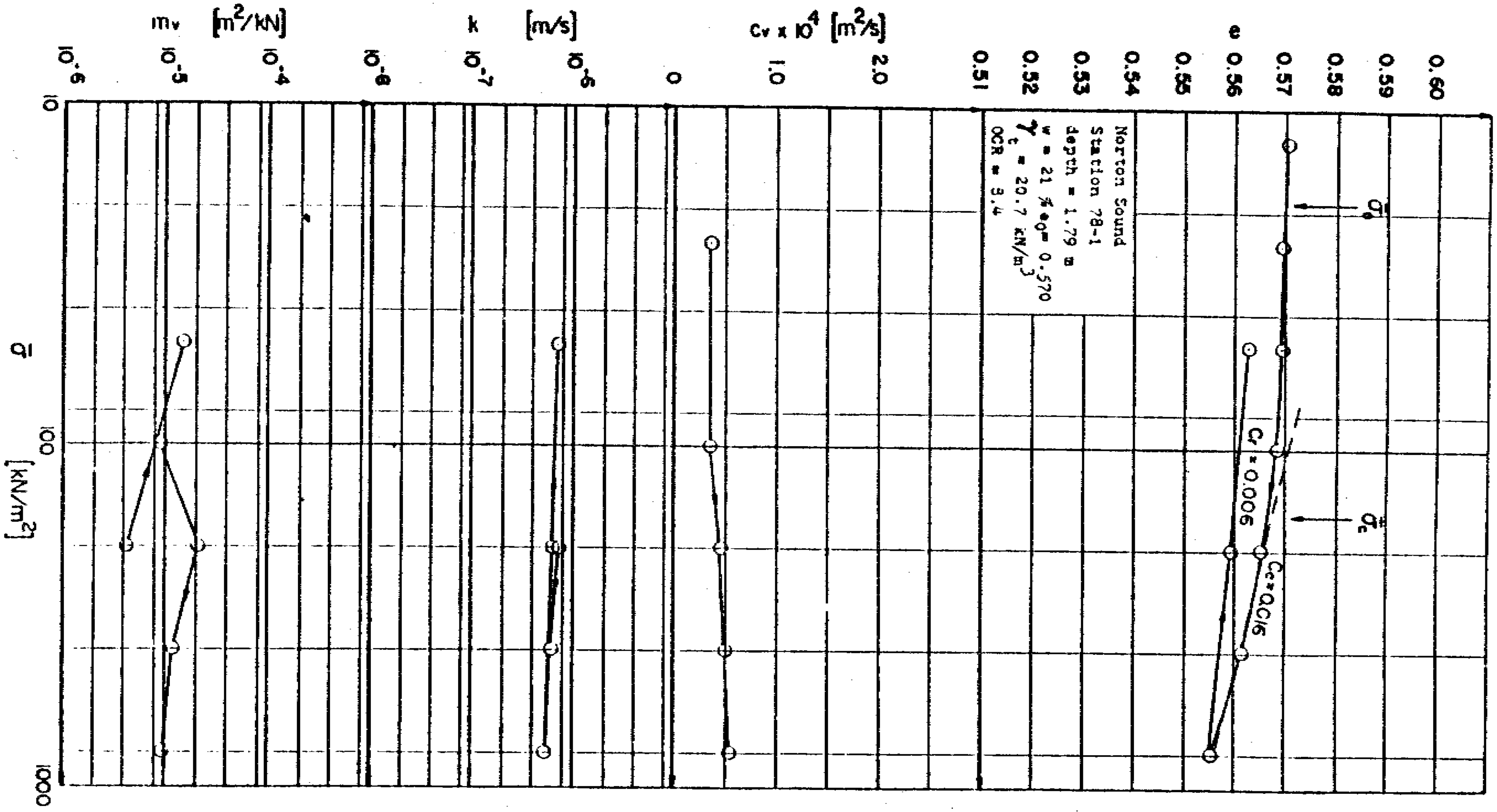


Figure 14.--Consolidation-permeability test results for 1.79 m depth at station 78-1.

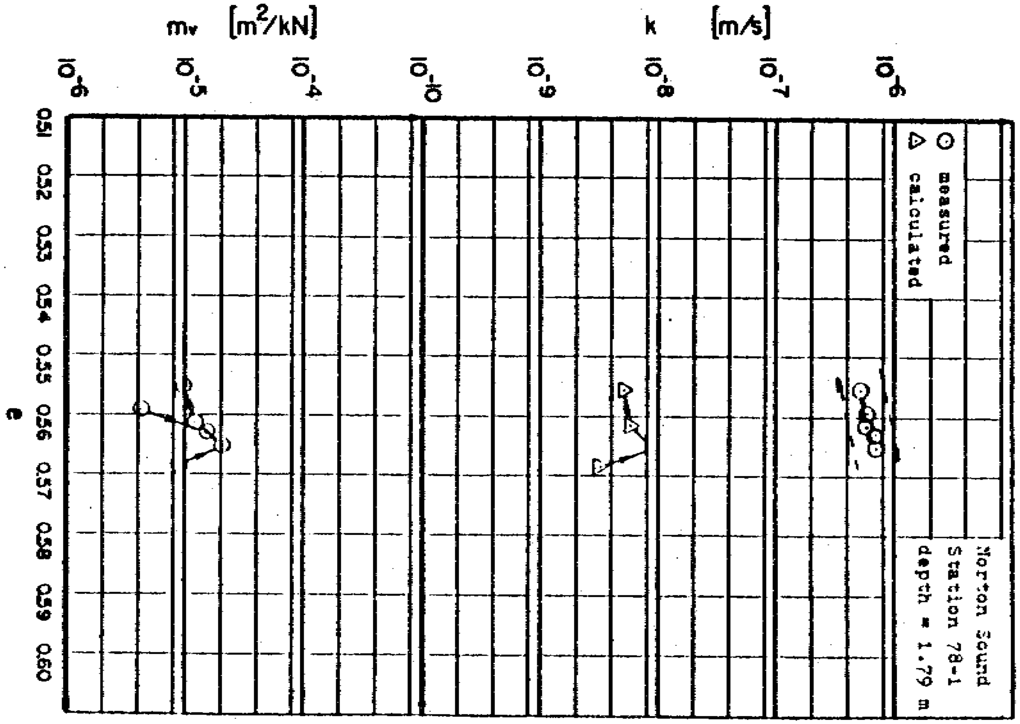


Figure 15.--Permeability, k, and compressibility, m_v, versus void ratio for 1.79 m depth at station 78-1.

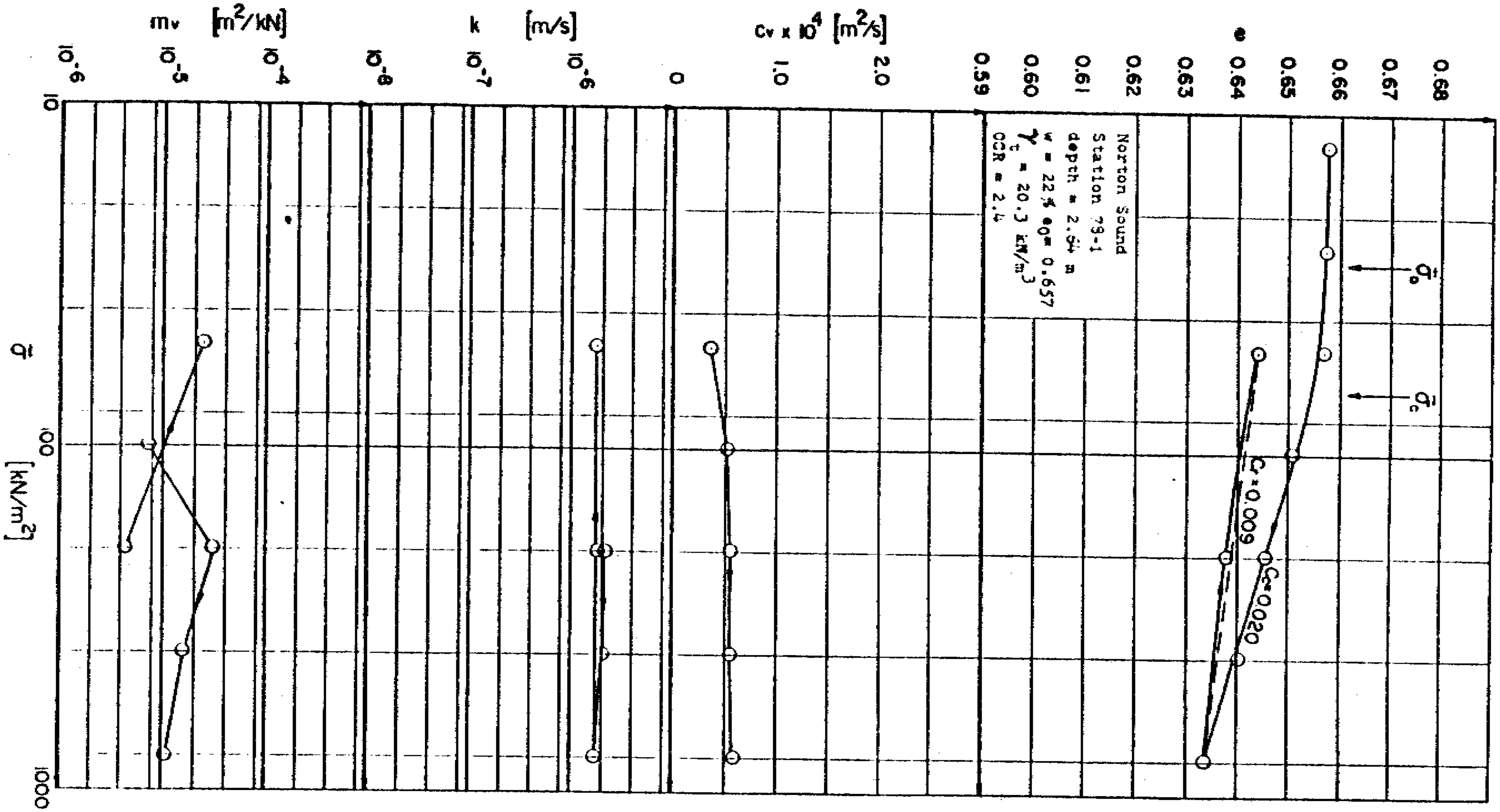


Figure 16.--Consolidation-permeability test results for 2.64 m depth at station 78-1.

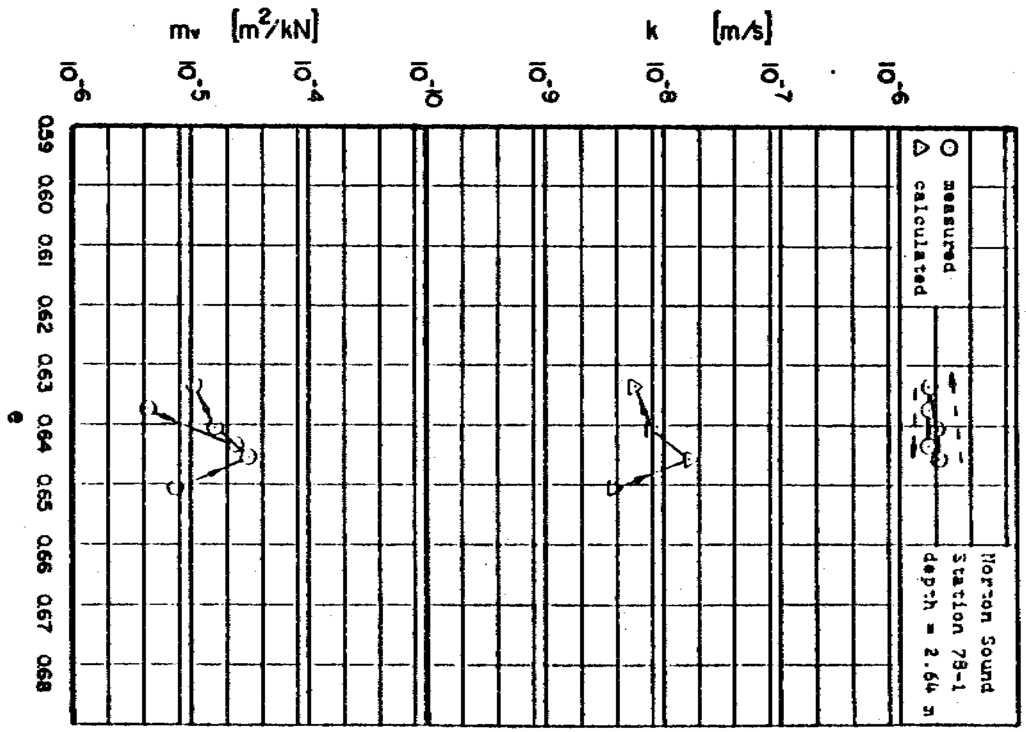


Figure 17.--Permeability, k, and compressibility, m_v, versus void ratio for 2.64 m depth at station 78-1.

The first figure for each data set presents the experimental results in the conventional format where the void ratio, e, and the coefficient of consolidation, c_v, are plotted as a function of the vertical effective stress, σ. In addition, this figure shows the measured permeability, k, after each loading increment and the compressibility, $m_v = de/d\sigma$, derived from the e-log σ relationship.

The second figure for each data set shows the permeability and the compressibility data plotted versus the void ratio, e. Also shown are permeability values, calculated from c_v values. The discrepancy between the calculated and measured permeability values reflects the limitations of existing consolidation theory for deriving permeability values from conventional consolidation tests.

The other symbols used in these figures include: σ_0 = in situ effective overburden stress; σ_c = preconsolidation stress; C_c = compression index; and C_r = rebound index. All the data are presented in SI units.

Resonant Column Tests

The resonant column equipment being used in this study was designed and built at the University of Texas at Austin under a research grant from the USGS Earthquake Program. The equipment was designed to measure dynamic shear modulus and damping ratio parameters under both torsional simple shear and resonant column modes of testing, and to define the variation of these parameters with confining stress, shear strain amplitude, and shear strain rate (Isenhower, 1979). For this study the equipment has been modified to monitor changes in the length of the sample specimen during the test procedure with proximeter gages.

Details concerning the equipment, test procedures, and preliminary results in this program are being documented by Macari (1980). The approach described therein is based largely on research at the University of Texas at Austin, under the direction of K. H. Stokoe (Isenhower, 1979; Canales, 1980), and also research with cubical testers on the dynamic behavior of soil at the University of Colorado, under the direction of Hon-Yim Ko.

The data obtained to date are presented in figures 18 through 21. Figures 18, 19, and 20 show the data on three specimens of the core from station 78-1, as shown in figure 3. Figure 21 shows the data on one specimen of the core freom station 78-4 (see fig. 6).

The data in figures 18-20 are incomplete and of marginal equality due to initial problems with the equipment and procedures (Macari, 1980). The data in figure 21 were obtained after the initial problems were solved, and hence this figure provides the best reference for explaining the steps involved in the experimental procedure.

Figure 18.--Resonant column test results for 10-20 cm depth at station 78-1.

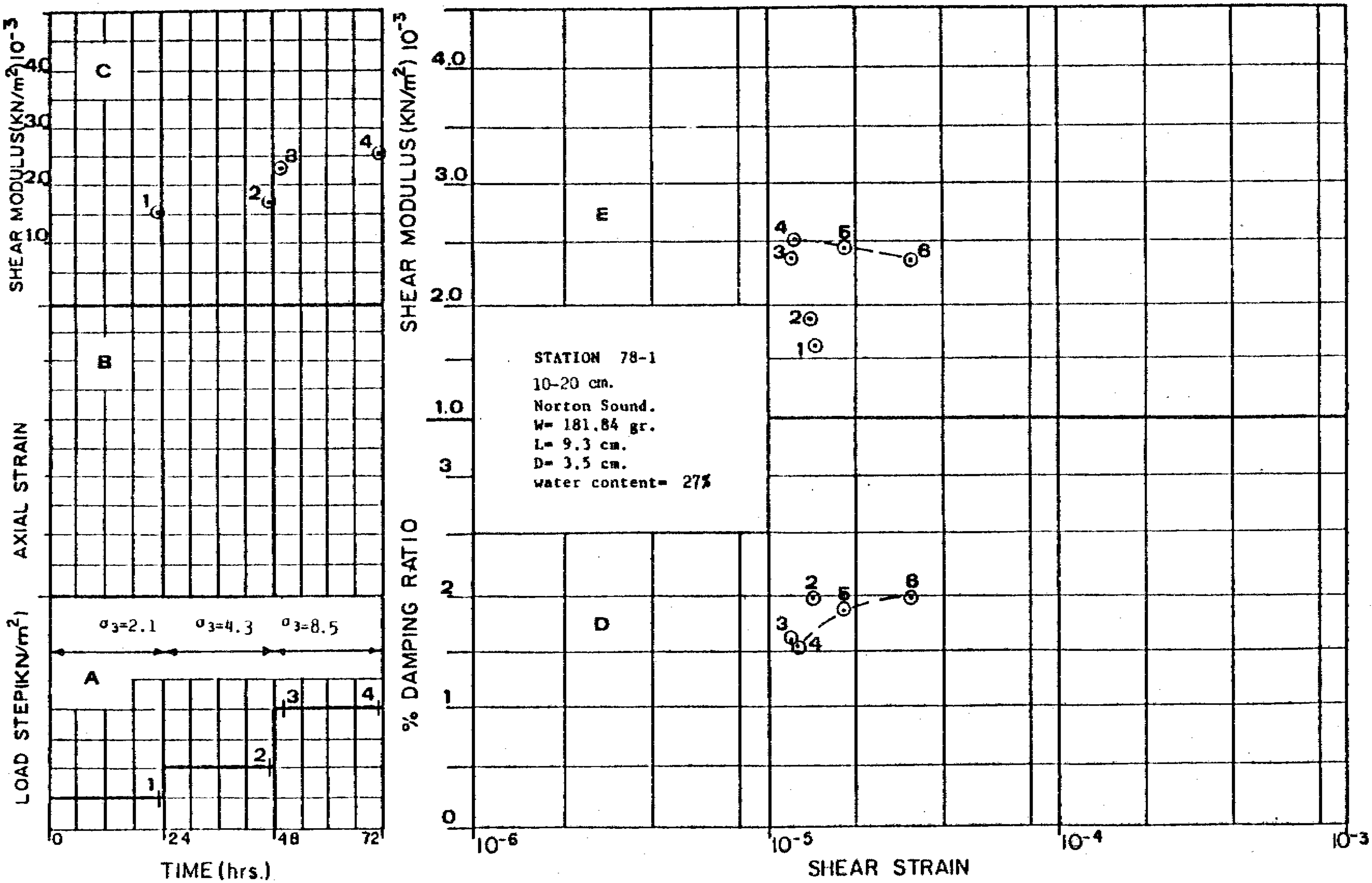


Figure 19.--Resonant column test results for 181-191 cm depth at station 78-1.

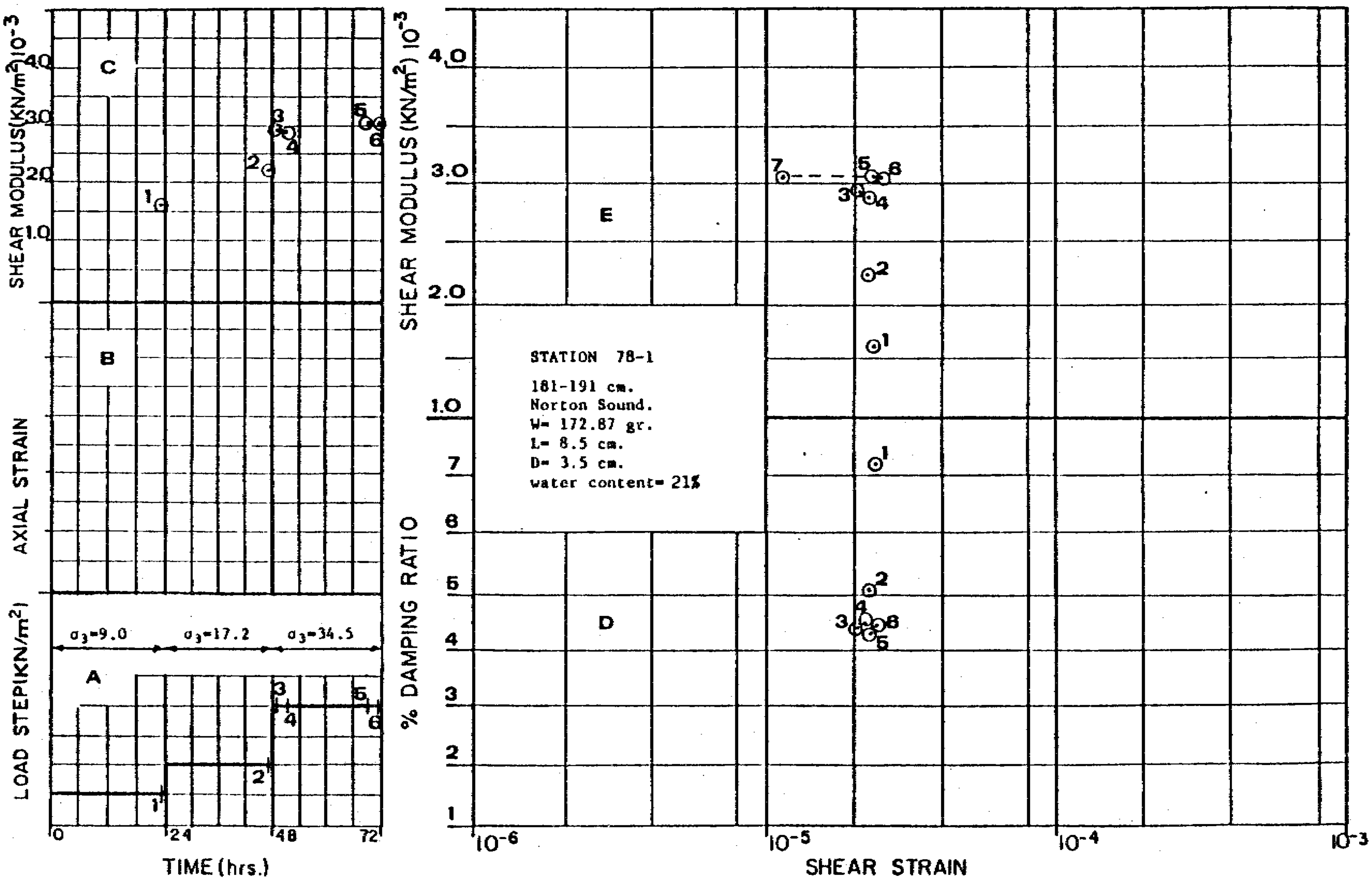


Figure 20.--Resonant column test results for 267.5-277 cm depth at station 78-1.

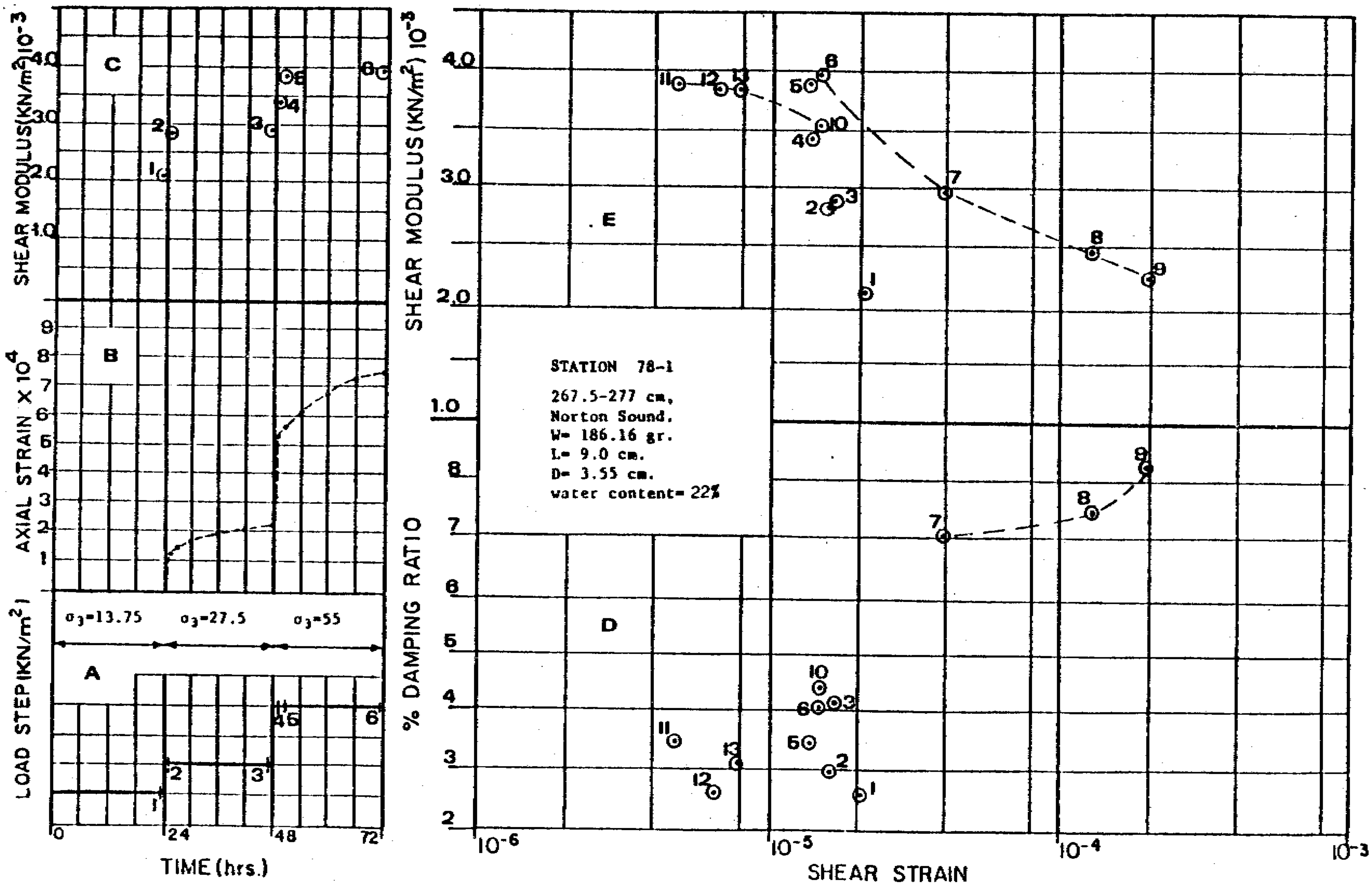
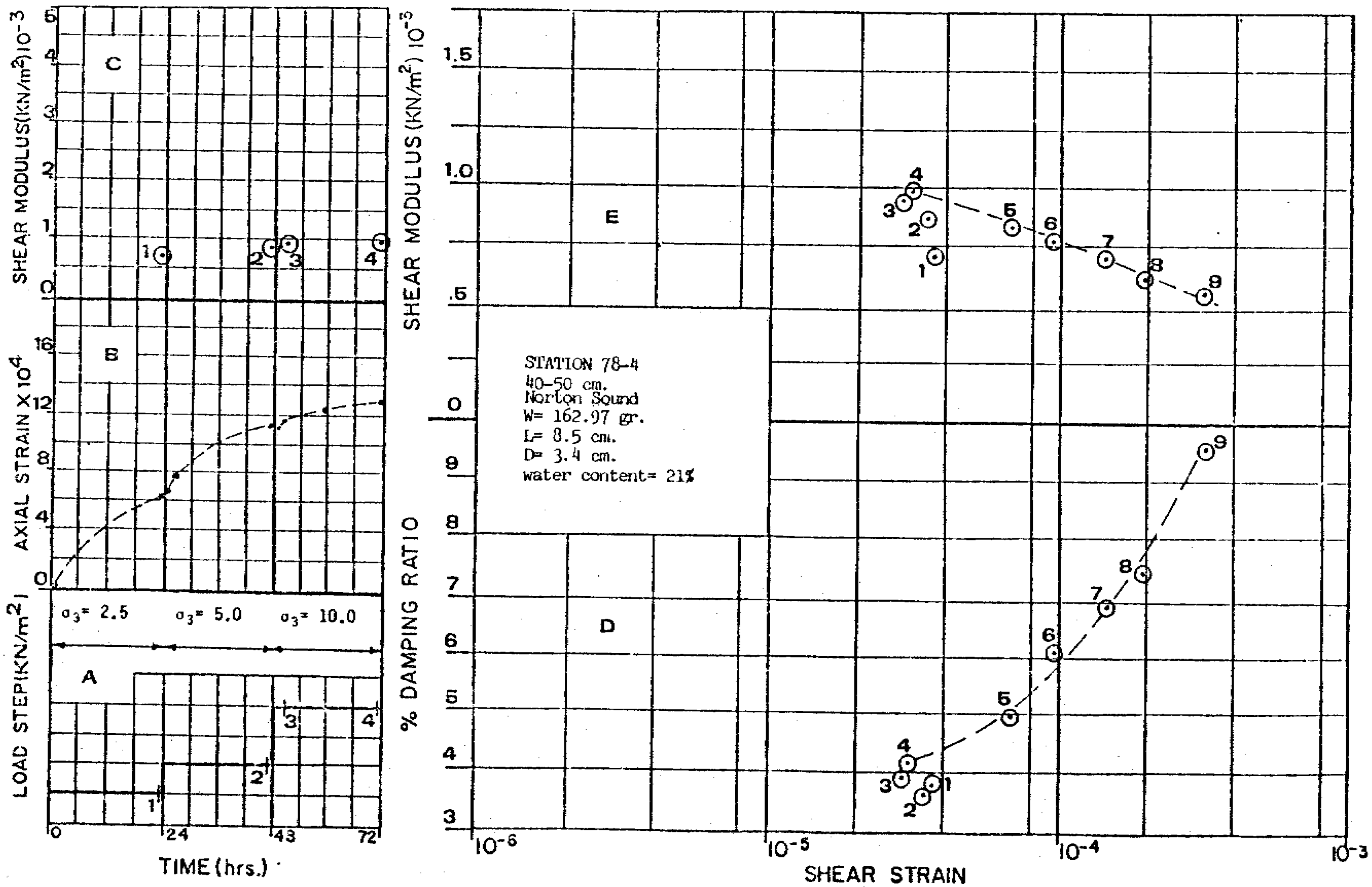


Figure 21.--Resonant column test results for 40-50 cm depth at station 78-4.



The lower left sub-figure A shows the time history of loading on each specimen, and the points in the time history where shear modulus and damping ratio measurements were made. Loads were selected below, near, and above the in situ effective stress acting on the material. The axial strain in the sample during the load history is shown in sub-figure B.

During the load history at points 1, 2, 3, and 4, shear modulus and damping ratio measurements were obtained at low shear strain amplitudes. The results for points 1, 2, 3, and 4, plotted in sub-figures C, D, and E show the variation of these parameters with consolidation load, for low strain amplitudes. Following acquisition of data point 4, and with no change in the consolidation load on the sample, the shear modulus and damping ratio were measured at successively increasing magnitudes of shear strain, points 5, 6, 7, 8, and 9. Thus, these latter points define the variation of shear modulus and damping ratio with shear strain amplitude.

Geotechnical profiles

Figures 22 and 23 illustrate the scope of geotechnical information being obtained in this experimental program for each of the cores in the gas-charged areas of central Norton Sound. The figures further show the information obtained to date on the cores from stations 78-1 and 78-4. A legend for these geotechnical profiles is provided in table 2.

These figures show results from the current experimental program together with the reconnaissance level data previously documented in the report by Olsen, Clukey, and Nelson (1980, fig. 3) that is attached as an appendix to this report. The current program will provide similar geotechnical profiles for all the available core from central Norton Sound.

The lithologies in figures 22 and 23 are those documented in figures 3 and 6, which provide more details than were presented by Olsen, Clukey, and Nelson (1980). The daca on vibracore penetration resistance, shear strength indices (pocket penetrometer data are denoted by triangles and unconfined compression data, by circles), texture, and moisture content include both the data presented by Olsen, Clukey, and Nelson (1980) and the data obtained to data in the current program. The data presented on consolidation state, permeability, and deformation modulii are derived from the test results presented in figures 12 through 21. The column for shearing resistance is provided for data from triaxial tests that have not yet been initiated.

Table 2.--Legend for geotechnical profiles

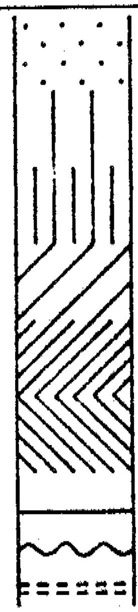
Symbols for shear strength and penetration resistance data
△ - pocket penetrometer ○ - unconfined compression — - solid line shows penetration resistance

Symbols for texture data
△ - D_{60} ○ - D_{10}

Symbol for Atterberg limits
plastic limit ├────┤ liquid limit — These data are few because the materials are generally nonplastic

△	- direct data from test results at the present effective overburden
○	- data from test results projected to the present effective overburden
⬡	- direct data from test results at the preconsolidation pressure
□	- data from test results projected to the preconsolidation pressure
▽	- data from test results projected to the initial void ratio

Symbols for lithology



sand

silt

organic silt

clay

organic clay

peat

gas fracture (throughout the sample)
gas crack (not throughout the sample)
shell or rock fragments

Figure 22.--Geotechnical profile at station 78-1.

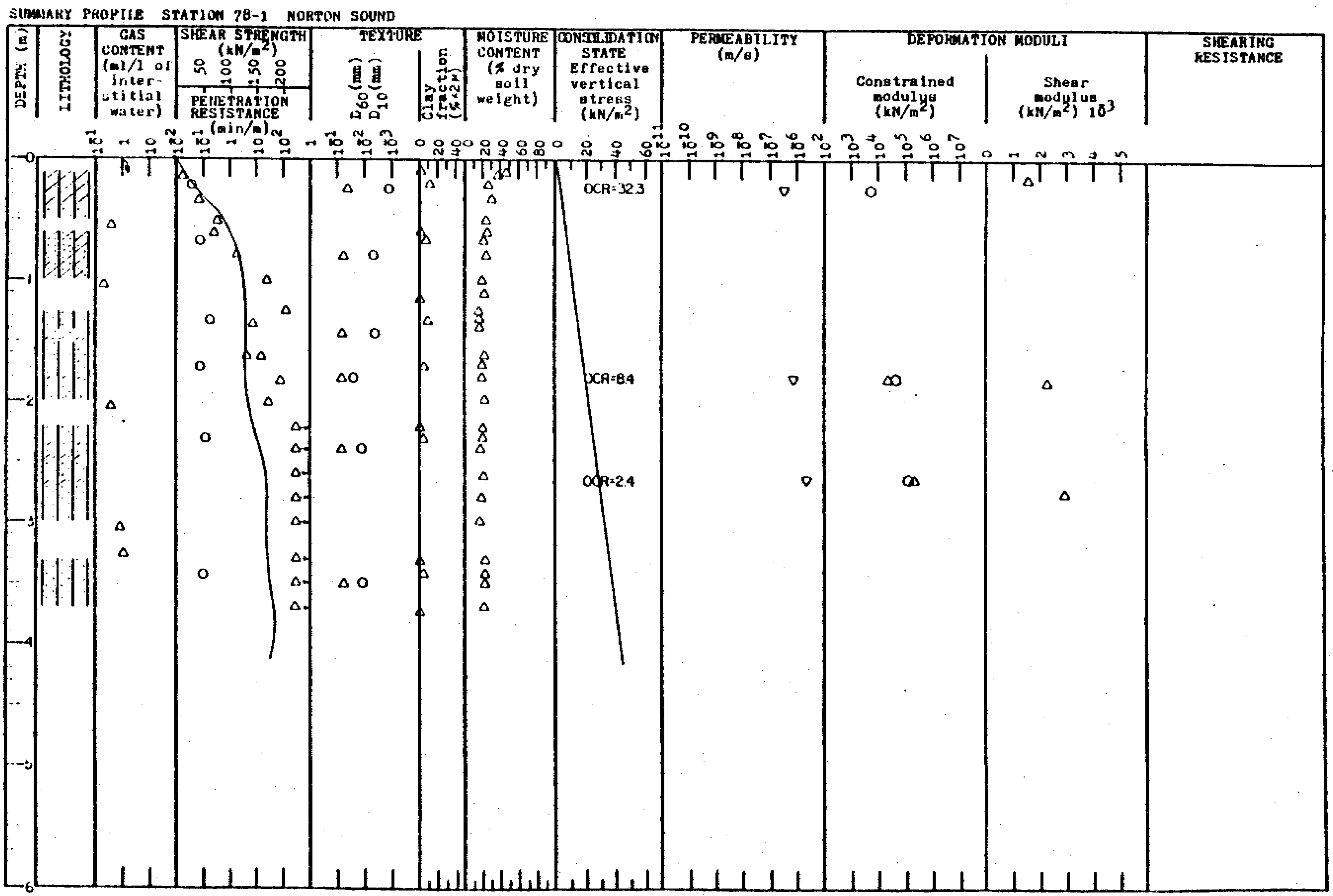
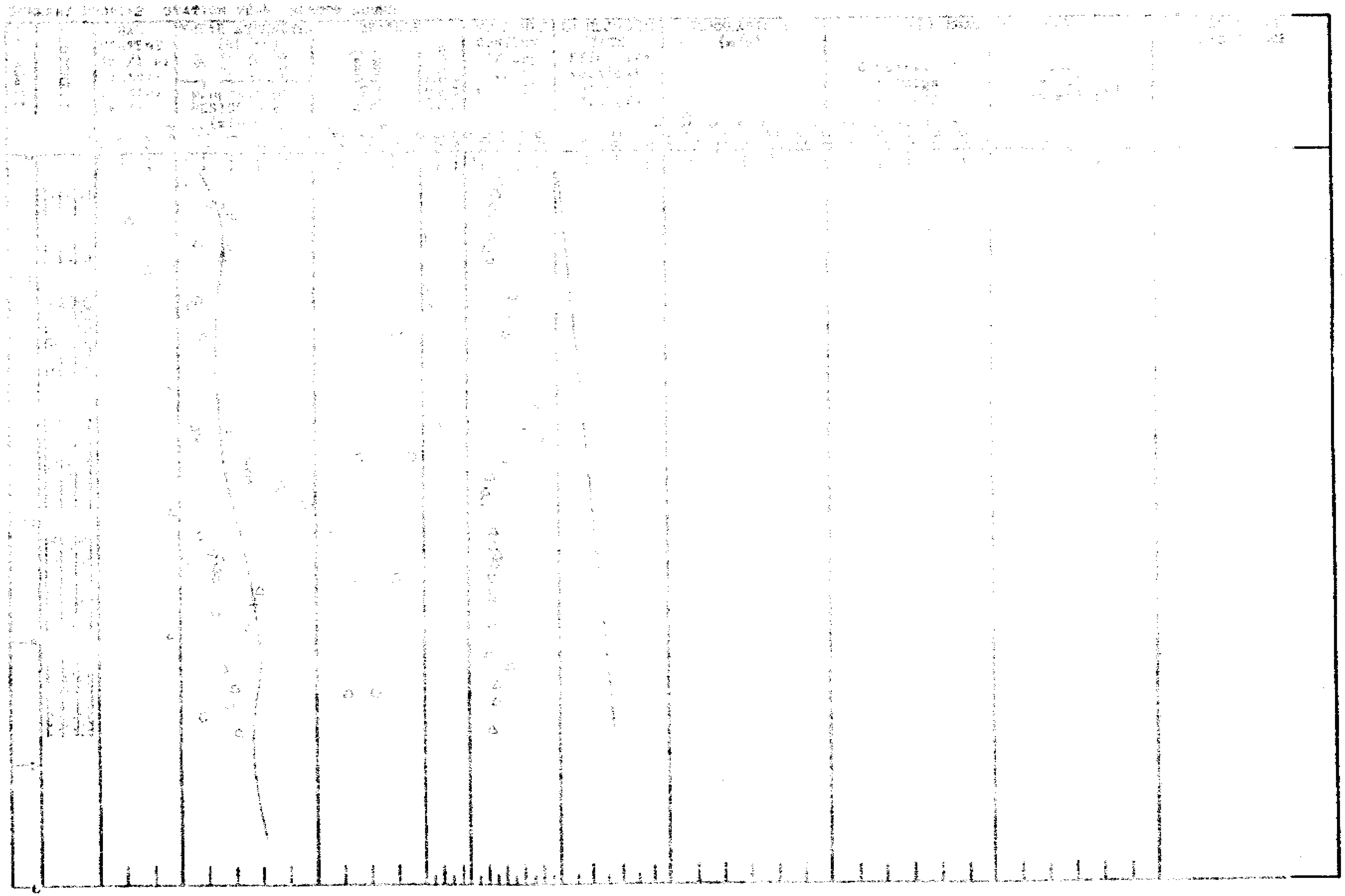


Figure 23.--Geotechnical profile at station 78-4.



More specifically, the consolidation state column shows the vertical effective stress in the profile, calculated from the average density of the core, and plotted as a continuous line. Also shown in this column are the overconsolidation ratios obtained from the consolidation test data in figures 12, 14, and 16. In the permeability column, the points plotted were interpreted from the data in figures 13, 15, and 17. The constrained modulus, a measure of resistance to volume change, is the reciprocal of the compressibility, m_v, obtained from the consolidation test, and the values plotted were interpreted from the data for m_v in figures 13, 15, and 17. The values for shear modulus, a measure of resistance to shear deformation, are derived from the data presented in figures 18 through 21.

SUMMARY AND DISCUSSION

A summary of reconnaissance level geotechnical characteristics of bottom sediment in the Northern Bering Sea, and a qualitative assessment of the implications of these characteristics with regard to potential hazards to offshore development in the region, is provided in the manuscript by Olsen, Clukey, and Nelson (1980) which is included as an appendix to this report.

A laboratory experimental program is underway to obtain more detailed and quantitative geotechnical information on existing vibracore samples from potentially hazardous gas-charged areas in central Norton Sound. The scope of this program includes research oriented consolidation-permeability, resonant column, and triaxial tests to obtain geotechnical parameters which reflect the geologic history of the materials, which govern their response to stresses imposed by the environment and by man, and which provide a link with planned in situ measurements.

Although this experimental program will contribute to the data base needed for a quantitative assessment of potential hazards to offshore development in the gas-charged areas of central Norton Sound, this objective will require, in addition, an in situ measurement program. The latter is required to determine the magnitudes and distribution of excess pore pressures in situ, and to obtain a basis for estimating the effects of sample disturbance on the laboratory test results. An expanded laboratory program may also be required, involving samples that should be taken during an in situ measurement program.

The current experimental program has not yet reached the point where a field interpretation of the data, beyond that provided by Olsen, Clukey, and Nelson (1980) is warranted. However, one result has been obtained which may be of major significance to quantitative analyses of hazards associated with in situ excess pore pressures due to storm wave loading and the occurrence of bubble phase gas in situ. The direct permeability measurements differ substantially from those calculated from standard consolidation test procedures; the data presented show discrepancies of one to two orders of magnitude. Since the permeability governs the rate of excess pore pressure dissipation and thereby influences the magnitude of excess pore pressures that control the in situ stiffness and strength of bottom sediment, it appears that quantitative hazard assessments based on conventional consolidation data may be unreliable.

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APPENDIX

Geotechnical Characteristics of Bottom Sediment in the Northern Bering Sea

By

Harold W. Olsen, Edward C. Clukey,

and C. Hans Nelson

Contents

Table

Geotechnical Characteristics of Bottom Sediment in the Northern Bering Sea

By

Harold W. Olsen[1], Edward C. Clukey[2], and

C. Hans Nelson[2]

Abstract

Yukon sediment of Holocene age, consisting dominantly of silty fine sand and sandy silt, covers the bottom of central and western Norton Sound, which is a high energy environment involving extensive ice loading, high waves, and strong bottom currents. The sediment contains significant amounts of sand in some areas and a generally minor amount of clay-size material ranging from 0 to 20 percent. Moreover, it is generally dense although loose and weak zones occur at the surface and also at depth between relatively dense layers. These characteristics, evidence of storm sand layers and scour depressions, and the results of preliminary analytical studies indicate this sediment is susceptible to liquefaction during major storms.

Substantially finer grained, weak, and highly compressible sediment of Holocene age, derived from the Yukon River and from local rivers and streams, covers eastern Norton Sound and the Port Clarence embayment, which are low energy environments with negligible ice loading, low waves, and weak bottom currents.

[1]U.S. Geological Survey, Box 25046, Mail Stop 903, Denver, Colorado 80225.

[2]U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025.

Transgressive deposits of late Pleistocene age that cover the bottom of Chirikov Basin include an inner-shelf fine sand underlain by a basal transgressive medium sand that is exposed on the north and east flanks of the basin. Geotechnical data on the latter, obtained in the sand-wave fields near Port Clarence, show the material is loose near the surface but becomes firm rapidly with depth and could not be penetrated more than about 3 m with the Alpine vibratory sampler.

Pleistocene peaty deposits underlie the Holocene and late Pleistocene deposits in both Norton Sound and Chirikov Basin and are somewhat overconsolidated, probably because of subaerial desiccation during low sea level stands in the late Pleistocene. These materials have a higher clay content than the overlying deposits and they contain substantial amounts of organic carbon and gas. The presence of gas suggests that in situ pore pressures may be high. If so, the strength of the material could be low even though the material is generally overconsolidated.

Introduction

During the last few years the U.S. Geological Survey (USGS) has been acquiring geotechnical data on bottom sediment in the Northern Bering Sea. This effort has been part of a broad group of USGS studies in this region aimed at clarifying and evaluating those geologic conditions and processes that may be hazardous to offshore resource development activities (Thor and Nelson, 1979; Larsen, Nelson, and Thor, 1980).

Previous reports concerning this geotechnical effort include the papers by Clukey, Nelson, and Newby (1978); Nelson, Kvenvolden, and Clukey (1978); Nelson et al. (1979); and Sangrey et al. (1979). These reports describe near-surface data on samples obtained during 1976 and 1977 with box corers, Soutar

Van Veen samplers, and a Kiel vibracore sampler capable of penetrating 2 m beneath the ocean floor[3]. The data also include penetration rate measurements during vibracorer sampling operations. During 1978, additional samples and penetration records were obtained with an Alpine vibratory corer system equipped to obtain 8.89 cm diameter continuous samples to a maximum depth of 6 m. All of the data obtained to date have been compiled for the Bureau of Land Management in a USGS open-file report by Larsen, B. R., et al. (1980).

The purpose of this paper is to summarize the geotechnical information obtained in the above studies in relation to the geologic and environmental conditions in the northern Bering Sea and to assess the implications of these data with regard to potential hazards to offshore resource development activities in the region.

Geologic and environmental framework

The bottom of Norton Sound consists of silty fine sand and sandy silt of Holocene age discharged from the Yukon River, except for nearshore areas where Pleistocene (>10,000 years B.P.; Hopkins, 1975) transgressive deposits remain and tidally scoured troughs where transgressive and Holocene deposits are mixed (Fig. 1; Nelson, this volume, Fig. 6). In southern Norton Sound, the Holocene sediment is interbedded with fine sand layers as much as 20 cm thick near the Yukon Delta. Pleistocene freshwater silt interbedded with peaty muds and peat layers underlies the Holocene sediment.

Most of Chirikov Basin is covered by an inner shelf fine sand deposited by the late Pleistocene shoreline transgression across this region (Fig. 1; Nelson, this volume, Fig. 6). This deposit is underlain by a basal

[3]Use of brand names in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

transgressive medium sand that is exposed on the north and east flanks of the basin. Lag gravels are exposed near the basin margins where the late Pleistocene shoreline transgression has reworked pre-Quaternary bedrock and glacial moraines and where strong modern currents have prevented subsequent deposition. Strong bottom currents and water circulation patterns have inhibited deposition of Holocene sediment from the Yukon River throughout Chirikov Basin, except for some accumulations with ice-rafted pebbles in local depressions in eastern and southern Chirikov Basin (McManus, Hopkins, and Nelson, 1977).

Prior to the deposition of the transgressive sand layers, tundra-derived peat deposits formed during several Pleistocene low sea-level stands that periodically exposed the entire northern Bering shelf until 12,000-13,000 years ago. These Pleistocene limnic peaty muds generally overlie Pleistocene glacial and alluvial deposits that are underlain by pre-Quaternary bedrock.

The Pleistocene peaty mud is a source of biogenic gas throughout the region. Seismic profiles showing acoustic anomalies associated with these materials indicate gas concentrations are of sufficient magnitude to affect sound transmission throughout Norton Sound (Holmes and Thor, this volume). The presence of shallow craters in the thin Holocene sediment in east-central Norton Sound suggests venting of biogenic gas accumulations from the underlying peaty muds. Generally low background levels of dissolved hydrocarbons in the waters of Norton Sound and high gas contents in the underlying peaty mud suggest venting is episodic, while the Holocene sediment generally acts as a seal preventing the biogenic gas from diffusing freely to the sea floor as it appears to do through the transgressive sand in Chirikov Basin (Nelson et al., 1979).

A large submarine seepage of thermogenic gas in west-central Norton Sound was discovered in 1976 (Cline and Holmes, 1977; Kvenvolden et al., 1979b). Acoustic investigations indicate the presence of bubble-phase gas associated with the sediment in the seep in an area of 50 km^2 (Nelson et al., 1978). Detailed geophysical and geochemical studies indicate that hydrocarbons and CO_2 are migrating upward along a major growth fault in the sedimentary section (Kvenvolden et al., 1979a).

Bottom sediment in the northern Bering Sea is exposed to ice loading, cyclic stress from waves, and drag from bottom currents (Table 1). Ice loading is extensive in the vicinity of the Yukon Delta (Thor and Nelson, 1979). High waves and strong bottom currents occur in central and western Norton Sound and in Chirikov Basin. Storm waves and bottom currents cause significant reworking and erosion of the sediment in Norton Sound (Larsen, Nelson, and Thor, 1979) and also cause the transport of sediment from Norton Sound to the Chukchi Sea, almost 1000 km to the northwest (Cacchione, Drake, and Weiberg, this volume; Dupré and Thompson, 1979; Nelson and Creager, 1977; Drake et al., 1980). Two areas in this study, Port Clarence and eastern Norton Sound, are protected from large waves and strong bottom currents.

Geotechnical profiles

Methods

The geotechnical profiles (Figs. 2-6) present, for each of the regions outlined in Table 1, information concerning the composition and the relative density or consolidation state of the materials. Direct evidence concerning the composition of the materials includes the data on lithology, texture, Atterberg limits, and gas content. The other data on moisture content, density, strength indices, and vibracore penetration resistance reflect the combined influences of the composition and the relative density or consolidation state. The latter can usually be inferred on a qualitative basis from the suites of information presented.

The data in Figs. 2-6 were obtained with shipboard and laboratory procedures as follows: penetration rates were derived from vibratory corer penetration rates during sampling; gas content data were obtained on shipboard from 10- to 15-cm sample tube sections using the procedures described by Kvenvolden et al. (1979a); bulk densities of tube sections were calculated from shipboard measurements of their volume and weight; visual descriptions, shear strength index measurements, and subsamples for moisture content, density, Atterberg limits, and texture analyses were obtained on shipboard from split tube sections of all cores except 78-1 through 78-5. The latter cores were preserved on shipboard and were subsequently extruded, logged, and tested in the USGS geotechnical laboratory in Denver. The Holocene-Pleistocene boundaries noted on Figs. 2-6 were derived from lithologic logging and radiocarbon dates (Nelson, this volume), and from microfaunal analyses (McDougall, this volume). Texture analyses were run with geologic (Larsen, B. R., et al., 1980), and engineering standard (American Society for Testing and Materials, 1977) sieving and sedimentation column techniques. Moisture content and density data were obtained on subsamples taken with the miniature coring device described by Clukey et al. (1978). Atterberg limits were run in accordance with ASTM Standards using the wet preparation method, D 2217 (American Society for Testing and Materials, 1977). Strength index data were obtained with laboratory vane, hand vane, pocket penetrometer, and unconfined compression test equipment. Circumstances did not generally allow these measurements to be made under controlled conditions with standardized procedures that must be employed for the data to have quantitative significance regarding shear strengths. Nevertheless, these data show differences in strength that reflect variations in the composition and the relative density or consolidation states of the materials tested. The absence of strength index data in some of the profiles is also significant in that materials, such as clean sands that do not possess any apparent cohesion, cannot be tested with the strength index test methods used in this study.

Yukon Prodelta

The three profiles in the vicinity of the Yukon Delta (Fig. 2) show mostly Holocene materials that are dominantly silty fine sand, and sandy silt with occasional thin beds of organic clayey silt having clay contents generally less than 20 percent. Gas contents vary over a wide range at station 78-22 from about 0.2 to 70 ml/l of interstitial water; the range at stations 78-23 and 78-24 is considerably less, from about 0.8 to 4.0 ml/l. The relative density of the material varies over a wide range. Moderately dense to dense zones predominate. However, loose zones, indicated by a watery appearance and very low strengths, are particularly evident at a depth of 2-3 m at station 78-22, and from the surface to a depth of about 1.5 m at station 78-24. The watery appearance of the loose zones emerged fairly rapidly after the core was split, apparently because the material densified in response to vibrations generated by the ship engines. The variations of penetration resistance with depth generally correlate with the presence of loose or dense zones. The variations in gas content with depth do not show a close association either with relative density as inferred above or with the variations in texture, density, and strength with depth.

West-central Norton Sound

The five profiles in west-central Norton Sound (Fig. 3) are located in the thermogenic (Kvenvolden et al., 1979a) gas seep acoustic anomaly (stations 78-1, 78-2, and 78-3), within a nearby biogenic (Kvenvolden et al., 1979a) gas acoustic anomaly (station 78-4), and adjacent to the biogenic gas acoustic anomaly (station 78-5). Very high gas contents occur at one location in the thermogenic anomaly (station 78-3) and in the biogenic anomaly (station 78-4). Much lower gas contents occur at stations 78-1 and 78-2 in the thermogenic anomaly and at station 78-5 adjacent to the biogenic anomaly. These profiles penetrate silty fine sand and sandy silt that are similar to the materials in the Yukon Delta region (Fig. 2) and that are probably Holocene deposits because of their lithology, texture, and consistently low moisture contents. The two profiles with very high gas contents also penetrate Pleistocene peaty muds at depths of about 3 m and 1 m at stations 78-3 and 78-4, respectively. Note that the high water contents and low densities are clearly associated with the peaty muds. The relative density of the materials varies over a wide range, which is similar to the range observed in the Yukon Delta region (Fig. 2) as indicated by watery-appearing zones and the wide variations in strength. The vibracore penetration resistance appears to correlate in general with the strength data, although not below 3 m depth at station 78-4. Low penetration resistance is associated with very high gas contents in the profile at station 78-3 and above 3 m in the profile at station 78-4. However, the increase in penetration resistance below 3 m at station 78-4, and the low penetration resistance at station 78-5 are not associated with changes in, or high values of, gas contents, respectively.

East-central Norton Sound

In east-central Norton Sound (Fig. 4) four of the five profiles (stations 78-6, 78-9, 76-121, 76-125) penetrate thin deposits of Holocene silty fine sand and sandy silt and extend into the underlying Pleistocene deposits which include freshwater peaty mud. The profile at station 78-10 appears to penetrate only the Holocene material. Compared with the west-central Norton Sound and Yukon Delta regions (Figs. 2 and 3), these profiles show similar materials with relative densities that are low near the surface, but that increase much more rapidly with depth. In fact, the Alpine vibratory corer was unable to penetrate deeper than about 3 m in this region. The rapid increase in penetration resistance with depth occurs in both Holocene and Pleistocene materials, even though their gas contents are similar to those in weaker materials at other locations such as in the station 78-5 profile in west-central Norton Sound (Fig. 3).

Eastern Norton Sound and the Port Clarence embayment

The profiles from eastern Norton Sound, near Stuart Island, and from the Port Clarence embayment (Fig. 5) penetrate materials that are generally finer grained and have relatively high moisture contents, high plasticity, low density, low strength, and low penetration resistance compared with the materials in the regions previously discussed. The characteristics of these profiles (Fig. 5) appear to be associated with their low-energy environments. Station 78-21 is located in Port Clarence, the most protected environment in the region. The materials in this profile have substantially higher water contents (90 percent) and lower strengths (10 kPa) than other materials encountered in the northern Bering Sea. The very low strengths and their uniformity with depth suggest the Holocene materials in Port Clarence may be somewhat underconsolidated; i.e., not yet in equilibrium with the weight of the material.

Sand-wave fields near Port Clarence

Four profiles in the sand-wave fields near Port Clarence in the Chirikov Basin are shown in Fig. 6. Stations 78-14 and 78-16 are located on one sand-wave crest, and the profiles penetrate medium sand that appears to be the basal transgressive deposit described by Nelson (this volume, Fig. 6). Station 78-15 is located in the adjacent sand-wave trough to the east, and penetrates the Pleistocene peaty mud that underlies the basal transgressive deposits in the region. The profile at station 78-17 is located on the adjacent sand-wave crest to the east. It penetrates the basal transgressive sand to a depth of about 1.5 m and the Pleistocene peaty mud from 1.5 to 2.2 m. The materials from 2.5 to 3.5 m are poorly to moderately sorted medium to fine sand with abundant pebbles and some silt- and clay-sized material. Below a sharp contact at 3.5 m the material appears to be glacial till consisting of a firm muddy sand with scattered pebbles.

The relative density of the basal transgressive sand is low near the surface but increases rapidly with depth, as indicated by the strength and penetration resistance data in the profiles for stations 78-14 and 78-16. The peaty mud at stations 78-15 and 78-17 is comparatively weak and has a very wide range of water contents due to the intermittent distribution and variable character of the peaty material. At station 78-17 the sand beneath the peaty mud appear to be firm and dense with a moderate to high resistance to vibracore penetration.

Consolidation and static triaxial data

Consolidation data (Fig. 7) on three box core samples of Holocene sediment show a wide range in the initial void ratio and compressibility of materials from the Yukon Delta and central regions of Norton Sound (Fig. 1; stations 76-154, 76-156). The wide range in these properties is consistent with the high variability in the strength and penetration resistance of these materials as shown in Figs. 2, 3, and 4. The compressibilities of the samples from station 76-156 may be high compared with other materials in these regions, because this station is located near vibracore station 78-24, whose profile (Fig. 2) shows a very loose and weak zone at the surface.

Triaxial data on vibracore samples of Holocene Yukon sediment from stations 78-22 and 78-23 (Fig. 8) show moderate to high static strengths with friction angles in the range of 35° to 40°. The variation in friction angle is small for the samples from station 78-22, consistent with the small variations in texture and density among the samples. The wider variation in friction angle for the samples from station 78-23 appears to be associated with variations in both the texture and density of the samples tested.

Soils that tend to contract during shear (contractive) weaken and may liquefy during cyclic loading from earthquakes and ocean waves (Sangrey, et al., 1978). The stress paths in Fig. 8 show the materials tested are generally contractive at low deviator stress levels and become dilative (tend to dilate during shear) as they approach the yield surface. Moreover, with the exception of the sample from 2.34 m depth at station 78-22, the stress paths become less contractive and more dilative at decreasing initial volumetric stress levels. This behavior pattern is normal for homogeneous material. The in situ stresses at the depths from which the samples were obtained are on the order of 10 kPa to 30 kPa. These stresses are very low compared to the initial volumetric stresses used to obtain the data in Fig. 8. Therefore, the behavior of the materials in situ should be less contractive and more dilative than that shown by the stress paths in Fig. 8.

The stress path for the sample from 2.34 m depth at station 78-22 (Fig. 8) is of particular interest in that it shows this sample is more contractive at low stress levels than any of the samples tested. This behavior is consistent with the data in Fig. 2 which shows this sample represents the loosest zone in the profiles at stations 78-22 and 78-23. Thus the data indicate that loose zones within the Holocene Yukon sediment are of the most concern with regard to strength loss and liquefaction during cyclic loading from earthquakes and ocean waves. Work in progress is aimed at defining the potential for strength loss in these materials on a more quantitative basis (Clukey, Cacchione, and Nelson, 1980).

Discussion of potential hazards

Potential hazards associated with the geotechnical characteristics of bottom sediment in the northern Bering Sea include the liquefaction of bottom sediments in response to ocean waves, earthquakes, and the upward migration of gas from thermogenic and biogenic sources; the scour and transport of bottom sediments and mobile bed forms in response to bottom currents; low strength and high compressibility of materials in low relative density and consolidation states; and gas-charged sediment.

Liquefaction is of particular concern in central and western Norton Sound because the area is exposed to strong cyclic loading from storm waves and is underlain by gas-charged material. Moreover, the susceptibility of the Holocene Yukon sediment in these regions to liquefaction is suggested by its dominantly silty fine sand and sandy silt texture and by the occurrence of relatively loose zones within it (Figs. 2, 3, 4). In addition, historic occurrences of wave-induced liquefaction are suggested by evidence of widespread storm-sand layers and scour depressions in the vicinity of the Yukon Delta (Nelson this volume; Larsen et al., 1979).

Work in progress is aimed at assessing on a quantitative basis the susceptibility of the Holocene Yukon sediment to liquefaction during storm waves. The approach involves the measurement of storm waves to define the cyclic bottom stresses induced during major storms; laboratory cyclic shear tests on Yukon Prodelta materials to determine the dynamic properties that govern the rate of pore pressure increase and associated degradation of strength during cyclic loading; and analyses of these measurements with a finite-element model that takes into account both the buildup of pore pressure induced by cyclic loading and the concomitant dissipation of pore pressure that is governed by the permeability of the material.

Preliminary analyses have been completed (Clukey et al., 1980) for a semi-infinite half-space model of the Yukon prodelta using dynamic property and permeability data estimated from the geotechnical characteristics reported in this paper together with 3-m and 6-m sinusoidal surface waves. The 3-m wave represents worst-case conditions for a storm recorded in July 1977, and the 6-m wave corresponds to a 1-percent occurrence interval for storms in September and October (Arctic Environmental Information and Data Center, 1977). The results indicate the prodelta will not liquefy in response to the 3-m storm wave even for the extreme case when zero dissipation of pore pressure is assumed. However, the results for the 6-m storm wave, presented in Fig. 9, indicate the sediment will liquefy to a depth of approximately 3.5 m. The results in Fig. 9 further indicate that the depth of liquefaction varies with storm duration but does not increase significantly for durations greater than 1 hour. This relation is suggested by the 4-m pore pressure contour, which is increasing at a very slow rate at the end of the 1-hour storm assumed in the analysis.

Materials with low strength and high compressibility are present in eastern Norton Sound and the Port Clarence embayment. Comparison of Fig. 5 with Figs. 2, 3, and 4 shows that these materials are substantially finer grained and weaker than those in central and western Norton Sound. Because eastern Norton Sound and the Port Clarence embayment are protected from strong bottom currents and large waves, deposition has taken place in a low energy environment. Also the materials have not been subjected to cyclic shear stresses associated with large waves, which have probably densified much of the sediment in other parts of the northern Bering Sea. The organic sandy clayey silt in the Port Clarence embayment is particularly weak and highly compressible because the very low strengths indicate the material may be somewhat underconsolidated.

Scour and transport of bottom sediment depend on the drag associated with bottom currents and the strength of the bottom sediment. Bottom currents are strong in central and western Norton Sound (Table 1). The bottom sediment is loose and weak at some locations in these regions (Figs. 2, 3, 4) and also in the sand waves near Port Clarence in Chirikov Basin (Fig. 6). In addition, the bottom sediment in central and western Norton Sound appear to be susceptible to liquefaction during major storms. These conditions are consistent with evidence of scour depressions in the vicinity of the Yukon Delta and also evidence for the large-scale transport and modification of sand waves near Port Clarence in the Chirikov Basin (Nelson, this volume; Larsen et al., 1979; Larsen et al., 1980).

The importance of gas in sediment depends on whether it is present in the bubble phase and whether the amount present is sufficient to cause significantly elevated pore fluid pressures. Elevated pore pressures can induce liquefaction in overlying materials, and they are associated with reductions in the strength of sediment in situ (Sangrey, 1977).

Seismic and core studies in Norton Sound suggest bubble phase gas is present in the anomaly associated with the thermogenic gas seep south of Nome and at several other locations where biogenic gas is being generated in the Pleistocene peaty mud beneath the Holocene silt (Kvenvolden et al., 1979a; Holmes and Thor this volume; Kvenvolden et al., 1980; Nelson et al., 1978; Nelson et al., 1979).

Previous work that suggests bubble phase gas may be causing elevated pore pressures in situ includes: limited data showing an association of low vibracore sample penetration resistance with very high gas contents (Nelson et al., 1978); and studies of shallow craters on the bottom of east-central Norton Sound which attribute their origin to episodic venting of biogenic gas generated in the Pleistocene peaty mud and trapped by the overlying Holocene Yukon sediment (Nelson et al., 1979).

The geotechnical profiles in this paper (Figs. 2-6) show additional data concerning the association of vibracore penetration resistance and gas contents. Low penetration resistance is associated with very high gas contents in some of the profiles (see stations 78-3, 78-4, 78-8, and 78-15), but not in general as noted in the section on geotechnical profiles above. For example, the penetration resistance at station 78-5 is about the same as that at station 78-3 even though the gas contents in the two profiles differ substantially.

However, the lack of consistent correlations between gas content and penetration resistance in all the profiles does not eliminate the possibility that gas is causing elevated pore pressures in situ. The relative density or consolidation state of the materials also influences the penetration resistance and may be masking the effects of gas. In this regard the association of the shear strength and penetration resistance data in the profiles is of interest because both measurements are influenced by the relative density or consolidation state, but only the penetration resistance is influenced by in situ elevated pore pressures. The strength data were obtained from samples on shipboard and in the laboratory where elevated pore pressures would have easily dissipated prior to the measurements.

The importance of the relative density or consolidation state of the material on penetration resistance is clearly evident in the geotechnical profiles from eastern Norton Sound and the Port Clarence embayment (Fig. 5). As noted in the discussion above very low strengths occur because these locations are not exposed to significant ice loading and waves that can densify and consolidate sediment. The penetration resistance is correspondingly low, it varies with the shear strength, and it does not appear to be influenced by variations in gas content. Similarly, in the profiles from the Yukon Delta region (Fig. 2), the penetration resistance is more closely associated with relative density, as indicated by the strength data, than with the gas content.

Hence the question remains whether significant elevated pore pressures associated with biogenic and thermogenic gas exist in the bottom sediment of the northern Bering Sea. Additional work is needed to determine the magnitudes of in situ pore pressures and their regional distribution.

Acknowledgments

The cruises for this study were supported jointly by the U.S. Geological Survey and the U.S. Bureau of Land Management through an interagency agreement with the U.S. National Oceanic and Atmospheric Administration, under which a multiyear program responding to the needs of petroleum development of the Alaska continental shelf is managed by the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Office.

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Figure Captions

8. Consolidated-undrained triaxial data on samples of Holocene Yukon silt from Alpine vibracores at stations 78-22 and 78-23 near the Yukon prodelta (see Fig. 2). ϕ' = effective friction angle. σ_1 and σ_3 are the total vertical and horizontal stresses, respectively. σ_1' and σ_3' are the effective vertical and horizontal stresses, respectively. w and γ are defined in the caption for Fig. 7. d_{50} and $<2\mu$ are the median grain size and minus 2 micron fraction, respectively. Tests run according to procedures described by Bishop and Henkel (1962). 164

9. Results of preliminary analyses of wave-induced liquefaction potential of Holocene Yukon silt near the Yukon prodelta, assuming a wave height of 6 m, a period of 10 seconds, a relative density of 54 percent, and a coefficient of permeability of 1.50×10^{-6} cm/s. U/σ = ratio of pore pressure to total overburden stress. The figure shows the variation of pore pressure ratio with time at depths below the sediment surface ranging from 0.25 m to 6 m. 165

Table 1.--Geologic and environmental framework for geotechnical studies in the northern Bering Sea

Region	Geologic units	Origin	Gas	Environmental Loading		
				Waves	Bottom currents	Ice
Yukon Prodelta.	Holocene silty fine sand and sandy silt with interbedded storm sand layers less than 20 m thick.	Yukon River. High energy deposition and redeposition.	Biogenic	High	Strong	Extensive
West-central Norton Sound.	Holocene silty fine sand and sandy silt, bioturbated, 1-2 m thick, over	Yukon River. Medium energy deposition,	Thermogenic and biogenic	Medium to strong	Medium to strong	Low
	Pleistocene freshwater peaty mud.	Freshwater deposition; tundra-derived peat; subaerial desiccation.				
East-central Norton Sound.	Holocene silty fine sand and sandy silt, bioturbated, 1-2 m thick, over	Yukon River. Medium energy deposition,	Biogenic	Medium	Medium	Low
	Pleistocene freshwater peaty mud.	Freshwater deposition; tundra-derived peat; subaerial desiccation.				
Eastern Norton Sound and Port Clarence Embayment.	Holocene sandy clayey silt, over	Yukon River and streams discharging from nearby shorelines. Low energy. deposition.	Biogenic	Low	Low	Low
	Pleistocene freshwater peaty mud and (or) glacial till.	Origin of Pleistocene peaty mud, same as above.				
Sand-wave fields near Port Clarence in Chirikov Basin	Late Pleistocene transgressive sands, over	Sand derived from pre-Quaternary bedrock and glacial moraines.	Biogenic	High	Very strong	Low
	Pleistocene freshwater peaty mud and (or) glacial till.	Origin of Pleistocene peaty mud, same as above.				

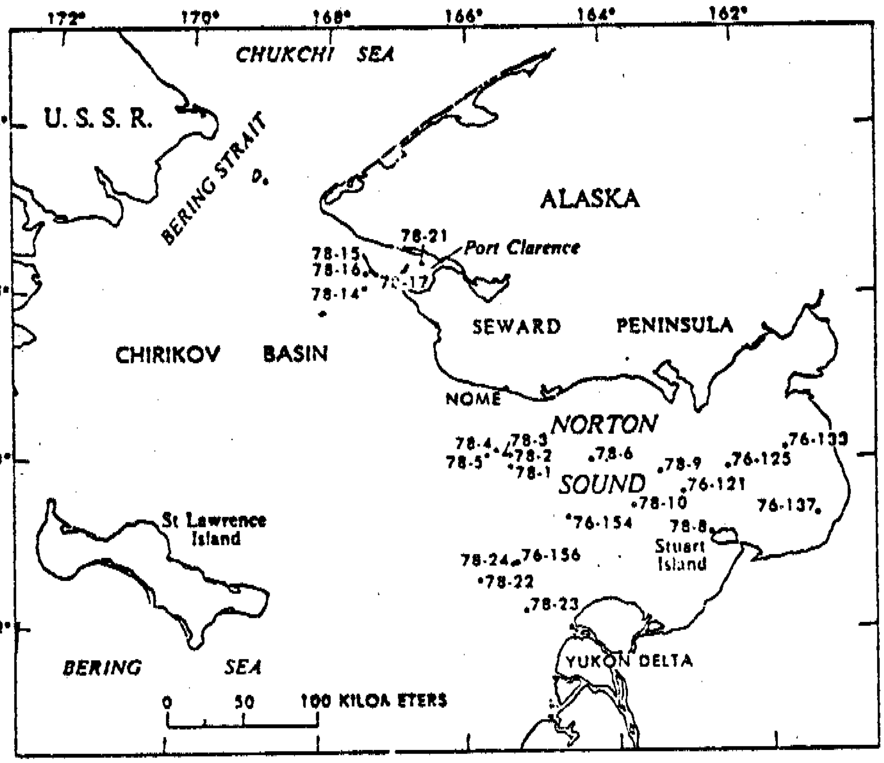


FIG. 1 - Location map of northern Bering Sea showing regions and sampling stations cited in this paper.

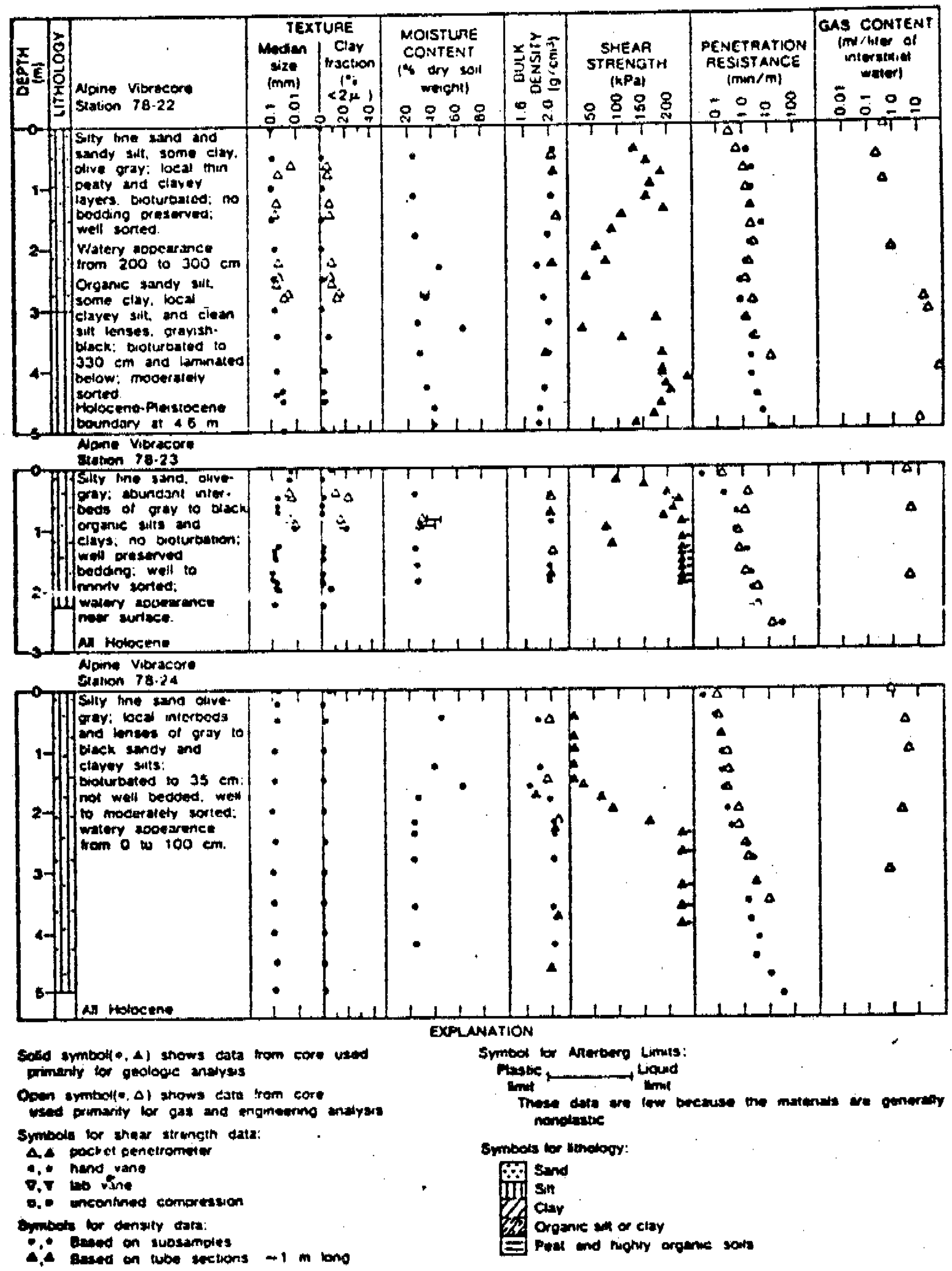


FIG. 2 - Geotechnical profiles from the Yukon Prodelta.

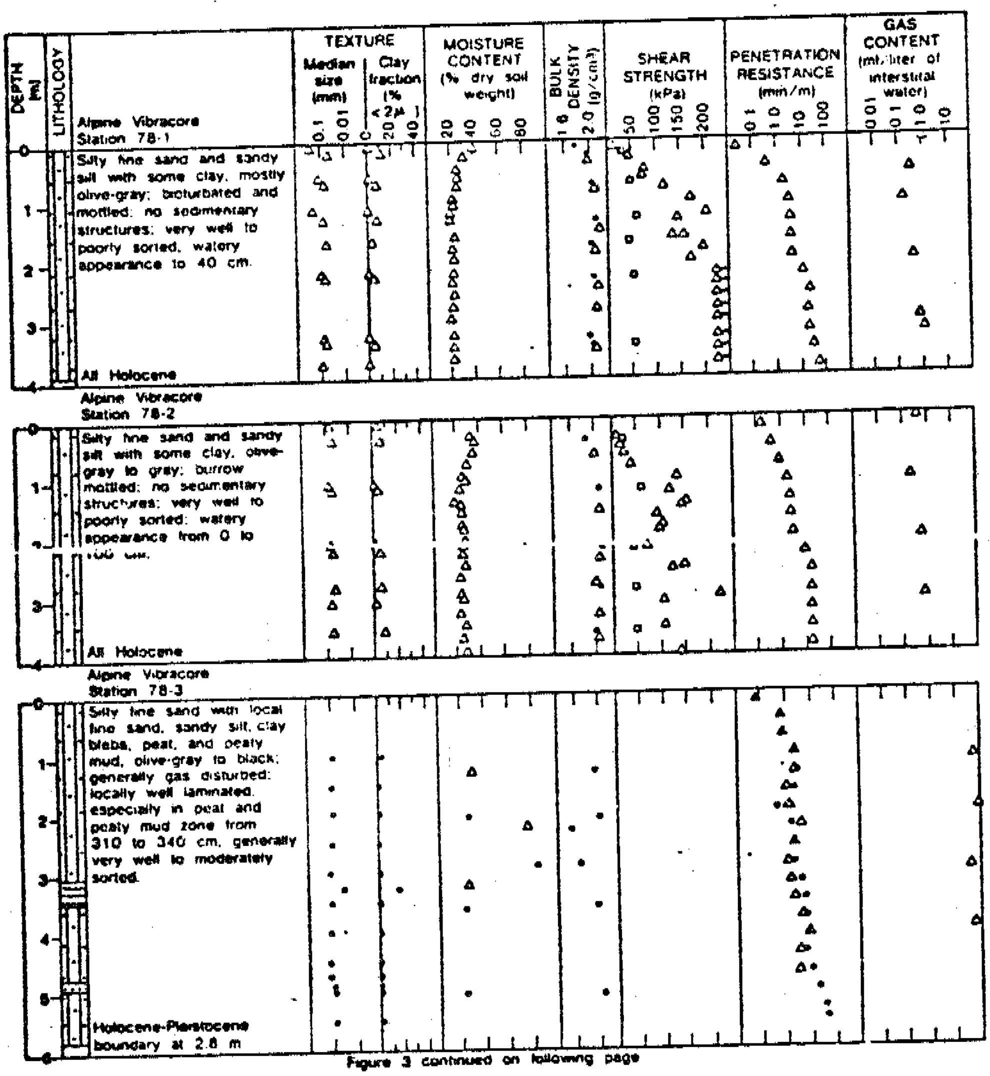


Figure 3 continued on following page

FIG. 3 - Geotechnical profiles from west-central Norton Sound. Stations 78-1, 78-2, and 78-3 are in the thermogenic gas seep acoustic anomaly south of Nome. Station 78-4 is on a nearby biogenic gas acoustic anomaly. Station 78-5 is adjacent to the biogenic gas acoustic anomaly. (Continued on the next page.)

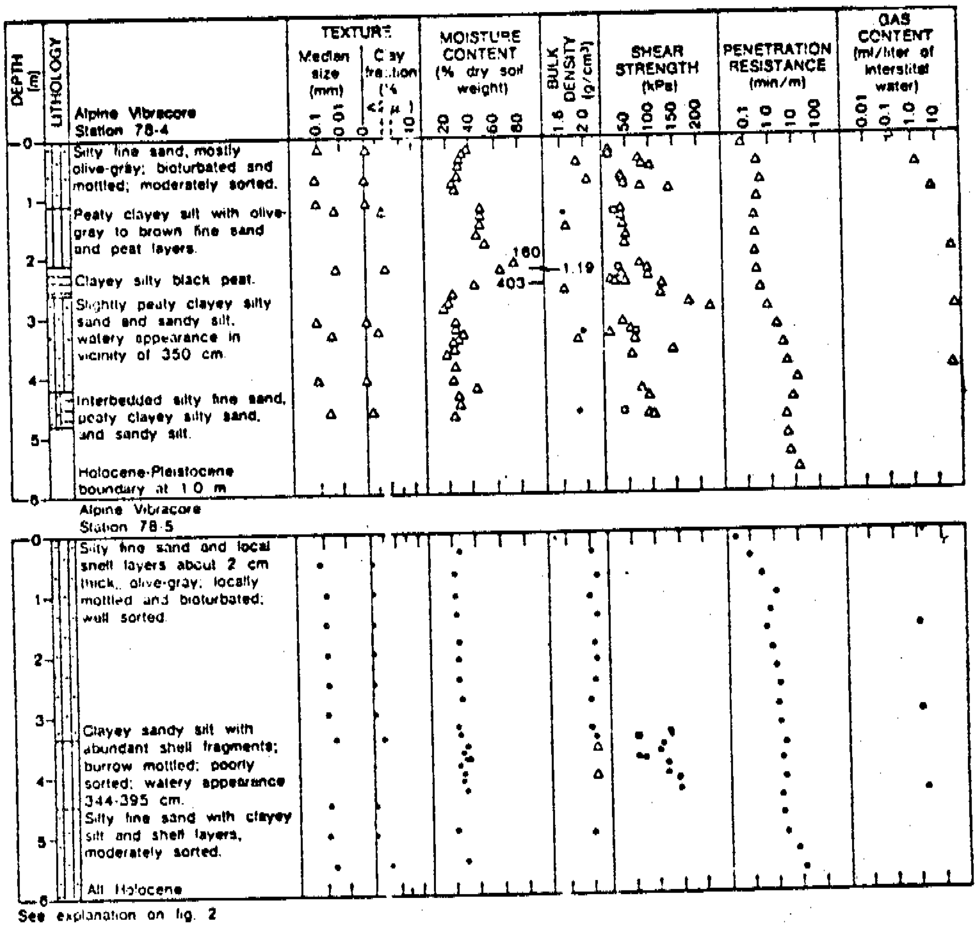


FIG. 3 - CONTINUED
Geotechnical profiles from west-central Norton Sound. Stations 78-1, 78-2, and 78-3 are in the thermogenic gas seep acoustic anomaly south of Nome. Station 78-4 is on a nearby biogenic gas acoustic anomaly. Station 78-5 is adjacent to the biogenic gas acoustic anomaly.

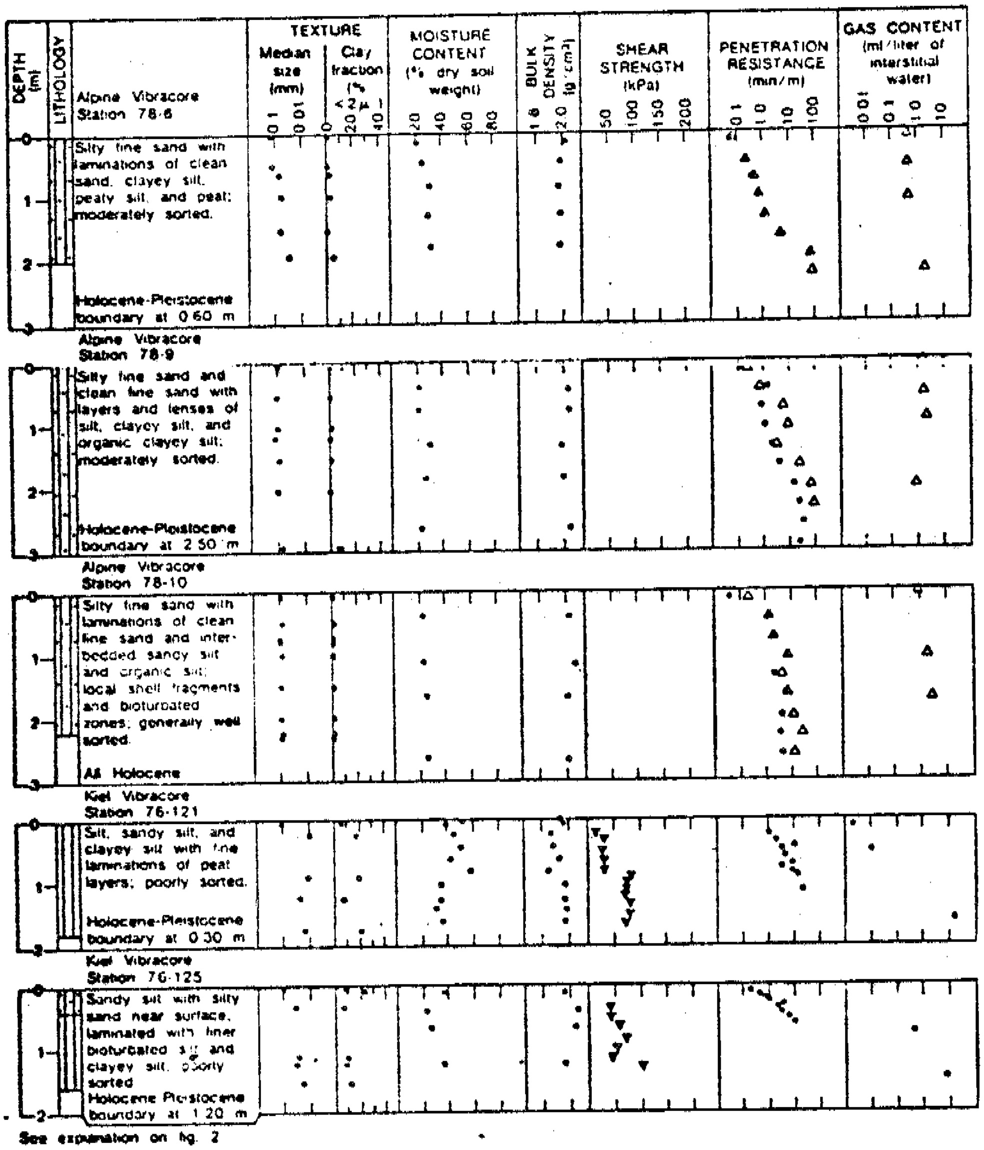


FIG. 4 - Geotechnical profiles from east-central Norton Sound where shallow gas craters are associated with thin deposits of Holocene Yukon silt overlying Pleistocene freshwater peaty mud.

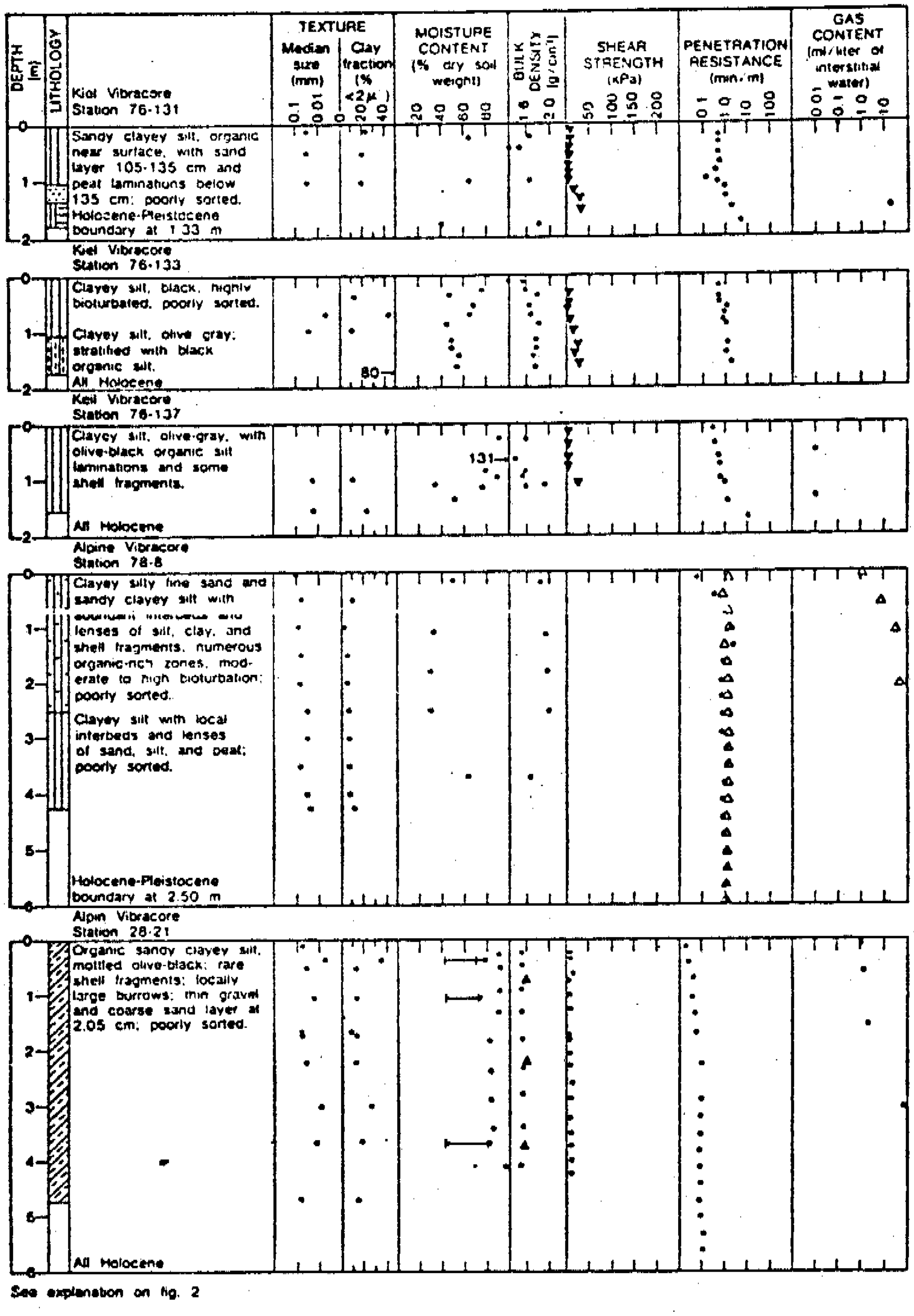


FIG. 5 - Geotechnical profiles from eastern Norton Sound, including Stuart Island (78-8), and the Port Clarence embayment (78-21).

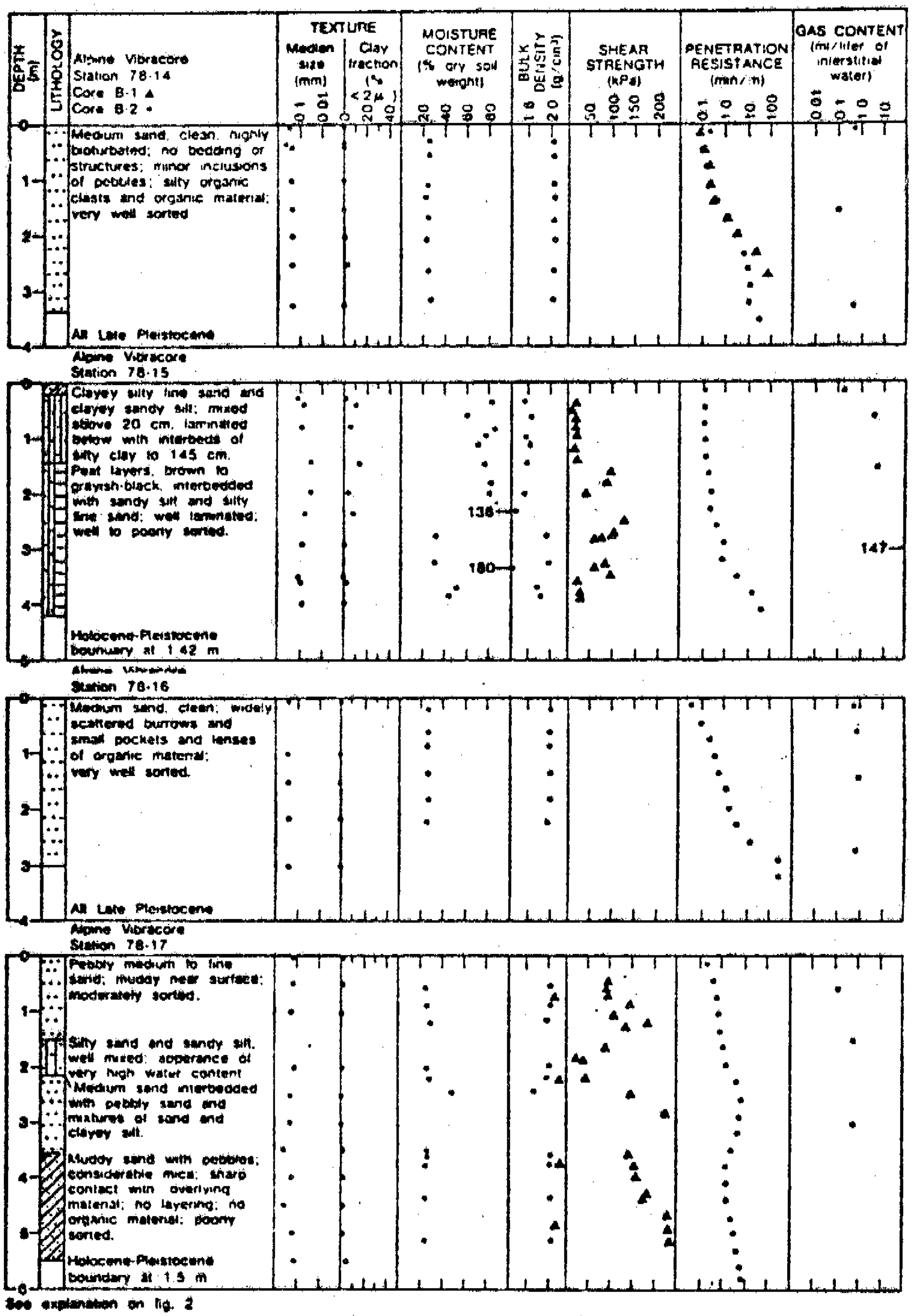


FIG. 6 - Geotechnical profiles from the sand-wave fields near Port Clarence in the Chirikov Basin. Stations 78-14 and 78-16 are located on one sand-wave crest. Station 78-17 is located on the adjacent sand-wave crest. Station 78-15 is in the trough between these sand-wave crests.

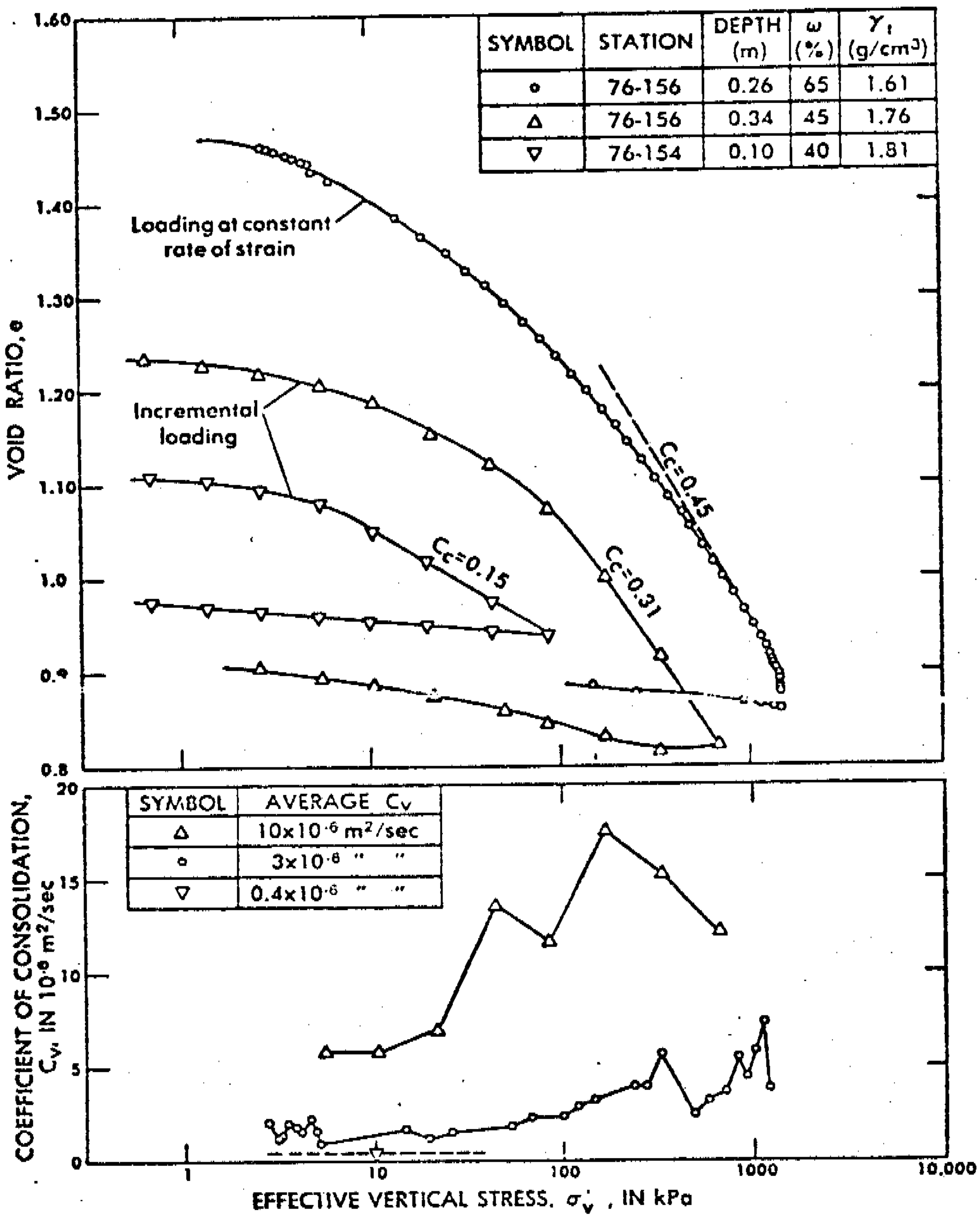
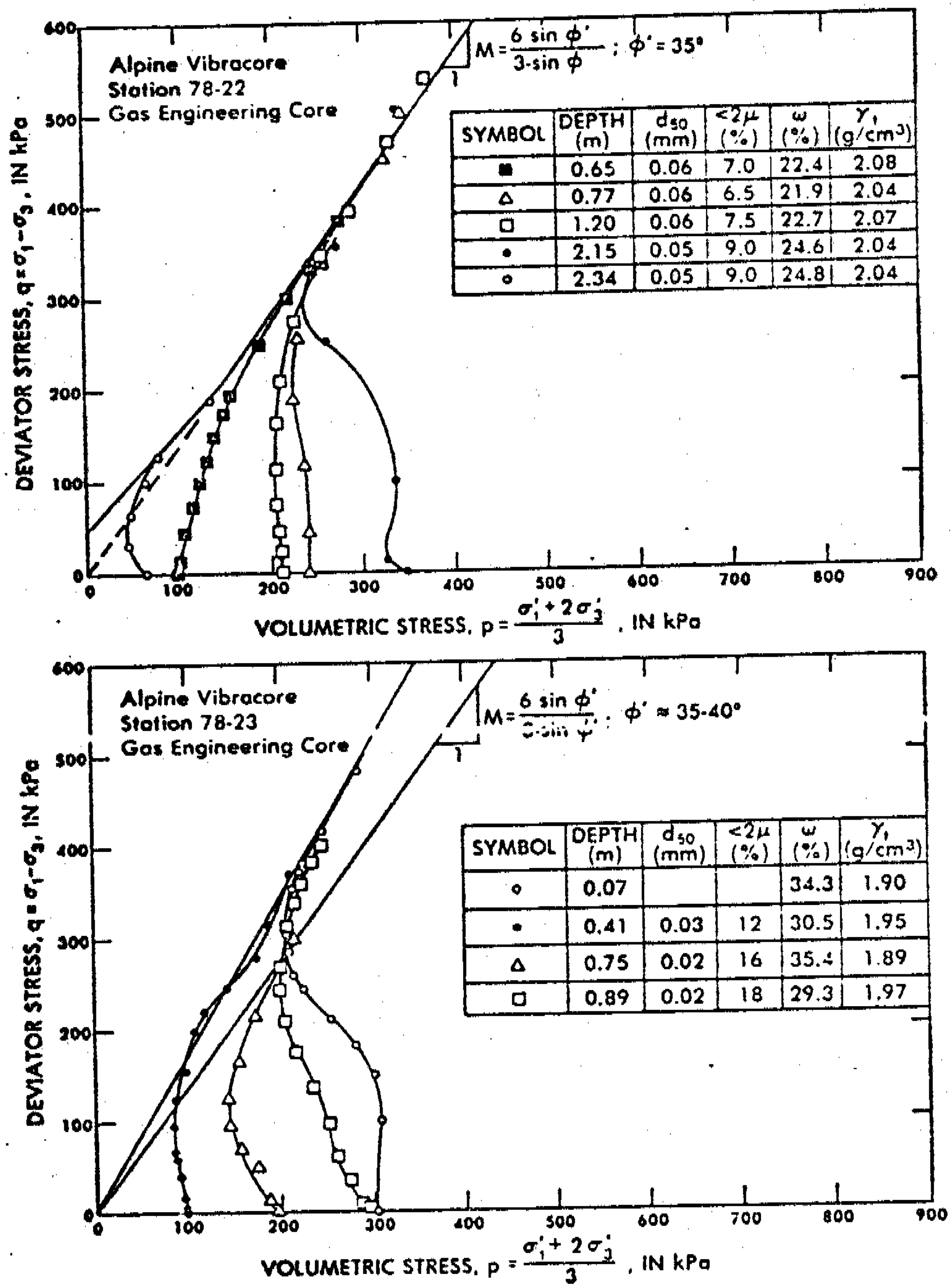


FIG. 7 - Consolidation data on samples of Holocene Yukon silt from box cores in the vicinity of the Yukon Delta and central Norton Sound. (See Figure 1.) Box core station 78-156 is adjacent to vibracore station 78-24 whose geotechnical profile is shown in Figure 2. ω = moisture content in percent dry soil weight; γ = bulk density in g/cm^3; C_V = compression index. Tests run according to procedures described by the American Society for Testing and Materials (1977) and Wissa et. al.(1971).



Station 78-22:

SYMBOL	DEPTH (m)	d_{50} (mm)	<2μ (%)	ω (%)	γ_t (g/cm³)
■	0.65	0.06	7.0	22.4	2.08
△	0.77	0.06	6.5	21.9	2.04
□	1.20	0.06	7.5	22.7	2.07
•	2.15	0.05	9.0	24.6	2.04
○	2.34	0.05	9.0	24.8	2.04

Station 78-23:

SYMBOL	DEPTH (m)	d_{50} (mm)	<2μ (%)	ω (%)	γ_t (g/cm³)
○	0.07			34.3	1.90
•	0.41	0.03	12	30.5	1.95
△	0.75	0.02	16	35.4	1.89
□	0.89	0.02	18	29.3	1.97

FIG. 8 - Consolidated-undrained triaxial data on samples of Holocene Yukon silt from Alpine vibracores at stations 78-22 and 78-23 near the Yukon prodelta (see Figure 2). ϕ' = effective friction angle. σ_1 and σ_3 are the total vertical and horizontal stresses, respectively. σ_1' and σ_3' are the effective vertical and horizontal stresses, respectively. ω and γ are defined in the caption for Figure 7. d_{50} and $<2\mu$ are the median grain size and minus 2 micron fraction, respectively. Tests run according to procedures described by Bishop and Henkel (1962).

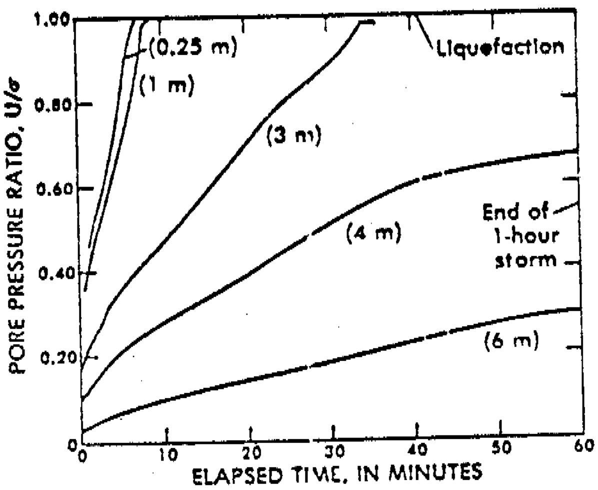


FIG. 9 - Results of preliminary analyses of wave-induced liquefaction potential of Holocene Yukon silt near the Yukon prodelta, assuming a wave height of 6 m, a period of 10 seconds, a relative density of 54 percent, and a coefficient of permeability of 1.50×10^{-6} cm/s. U/σ = ratio of pore pressure to total overburden stress. The figure shows the variation of pore pressure ratio with time at depths below the sediment surface ranging from 0.25 m to 6 m.

APPENDIX

PRELIMINARY REPORT ON STRENGTH TESTS

YUKON PRODELTA

PREPARED BY: Edward C. Clukey
U.S. Geological Survey
Menlo Park, CA 94025

INTRODUCTION

The shear strength of the Yukon prodelta sediment has been investigated under both static and dynamic loading to assess its stability for possible resource development in the Northern Bering Sea. Although the overall evaluation of the results is at this time incomplete, they provide insights into the potential response characteristics of the prodelta under climatic processes and possibly the construction of offshore facilities or artificial islands. The samples tested were taken with a vibracoring devise and as such experienced some degree of disturbance. Penetration resistance was measured with each core and helped to correlate some of the results obtained in the laboratory testing.

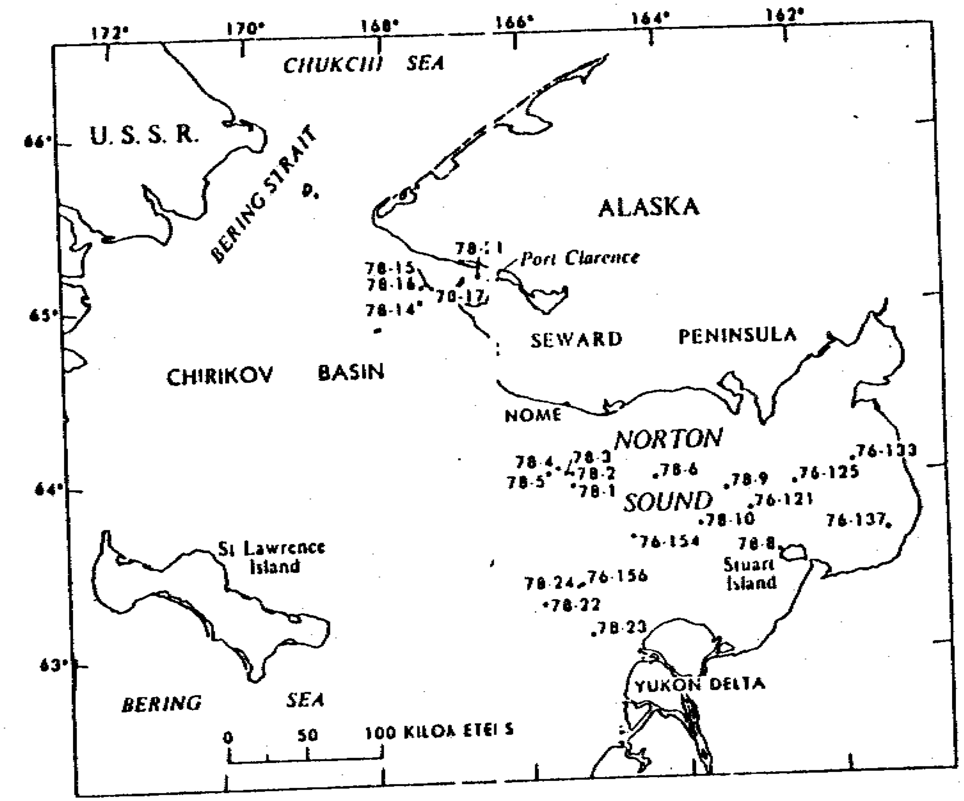
Triaxial, simple shear and direct shear tests were performed to determine static shear strength while cyclic triaxial and cyclic simple shear tests were used for dynamic strength determinations. Pore water pressures were measured directly in triaxial tests and implied from the increase in normal vertical stress necessary to maintain the sample at a constant for the simple shear tests. The direct shear test was a 'slow' or drained test and did not therefore generate excess pore water pressures.

Generally the results indicate that the sediment is highly variable with respect to position within the prodelta. The cyclic simple shear tests developed greater pore water pressures and strains than cyclic triaxial tests at the same level of loading, implying the possible significance of loading style on the response characteristics.

METHODS

Twelve triaxial tests were performed on samples from three locations, i.e., Stations 22,23,24 Figure 1. The results from Stations 22 and 23 have previously been described by Olsen and others (1980). The samples were all normally consolidated by increasing the surrounding cell pressure to a level greater than the

Fig. 1



172°
170°
168°
166°
164°
162°
66°
65°
64°
63°
CHUKCHI SEA
U. S. S. R.
BERING STRAIT
ALASKA
Port Clarence
78-15
78-16
78-14
78-17
SEWARD
PENINSULA
CHIRIKOV
BASIN
NOME
NORTON
SOUND
78-4
78-5
78-3
78-2
78-1
78-6
78-9
76-125
76-133
76-121
78-10
76-137
76-154
78-8
Stuart Island
St Lawrence Island
78-24
76-156
78-22
78-23
YUKON DELTA
BERING
SEA
0
50
100 KILOMETERS

back pressure within the sample. After the final consolidation load for each sample, the degree of saturation was measured (B coefficient). A degree of saturation of greater than 95% was considered satisfactory prior to axial loading. If 95% saturation was not obtained the cell pressure and back pressure were both increased by the same amount to further back saturate sample. The samples were then loaded at a constant rate of deformation (strain controlled). The appropriate rate of deformation was chosen to allow pore water pressure equilization throughout the sample. The vertical applied load (deviatoric stress) was measured with a proving ring while the pore water pressures were measured with a bonded strain gauge-pressure transducer which was read on voltage output in terms of strain. Pore water pressures, deformation and load were continually monitored throughout each test.

In contrast to the strain controlled tests the cyclic triaxial samples were tested under load control conditions. After consolidation a constant load was cyclically applied to the sample by mechanically adding and removing a known weight from a hanger. The load was applied until the sampler reached equilibrium conditions or failure occurred. Additional weights were added if the sample did not fail. Pore water pressures were measured with a strain-gauge bonded transducer while the vertical deflection was monitored with a linear variable differential transducer (LVDT). Both deflection and pore water pressure were continually recorded during the test with a strip chart recorder.

One cyclic triaxial test was performed on a sample resedimented prior to testing. The sample was resedimented by pluviating a slurry of sediment directly into a mold on the triaxial cell and applying a small negative pore water pressure until the sample could stand without support. The mold was then removed and the test proceeded in the usual way.

One simple shear and four cyclic simple shear tests were performed on samples taken at Station 24. The tests were performed on modified Norweigian Geotechnical Institute (NGI) equipment with circular samples surrounded by a wire-reinforced membrane. The samples were initially consolidated vertically to approximately in-situ overburden stresses ($\sim$ 50kPa). Horizontal pressures were measured by strain gauges attached to the wire reinforced membrane. A horizontal shear force was then applied to the sample. The horizontal stress and deformation as well as the adjustment in the vertical stress necessary to maintain a constant volume in the sample were monitored throughout the test. Pore pressure measurements were inferred from the change in the vertical stress. The applied horizontal shear stress was continually increased in the static test while the same horizontal shear stress was cycled continuously in the cyclic simple shear test.

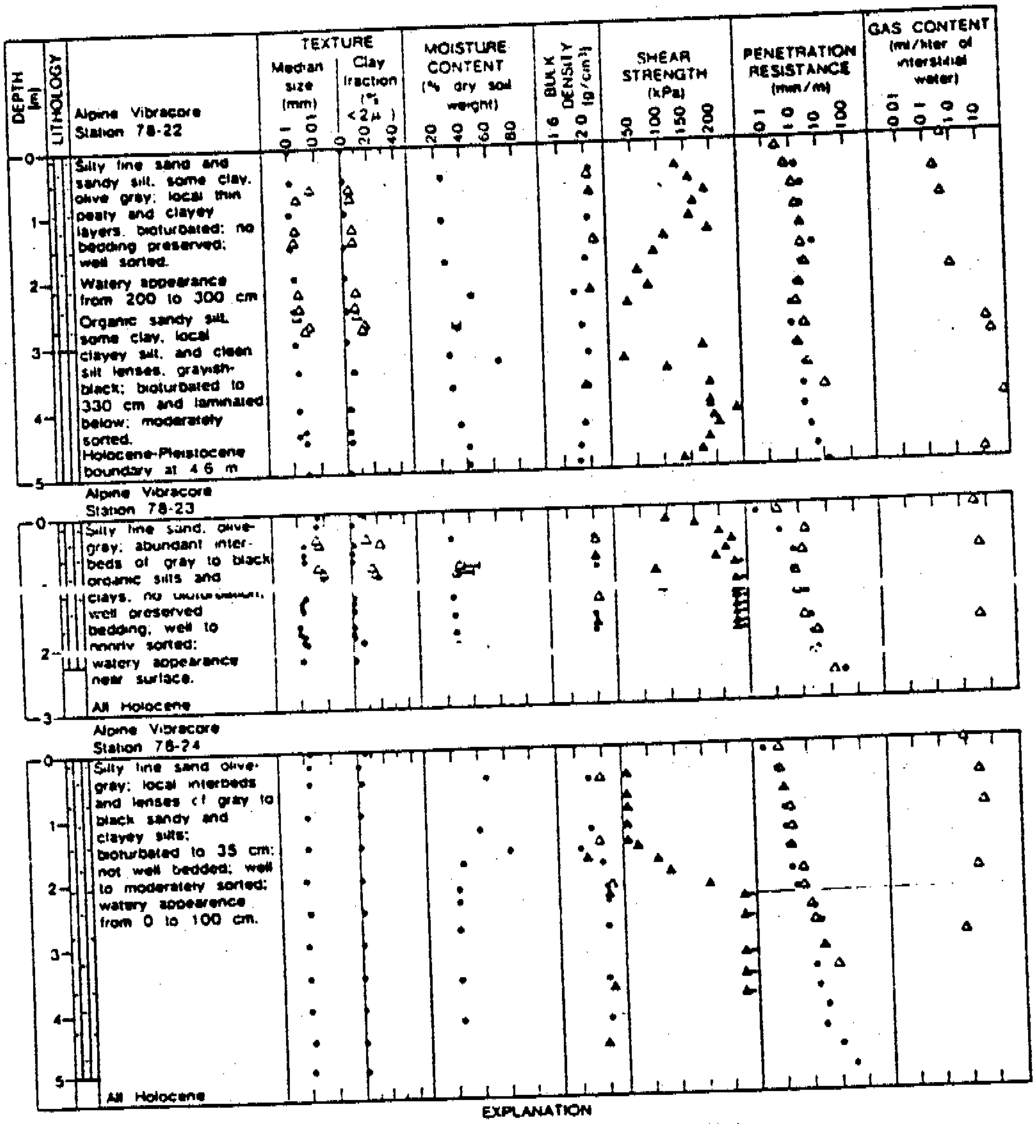
The direct shear test was performed by applying a vertical stress and shearing the sample under strain controlled conditions. Vertical and horizontal deformations were measured throughout the test.

SAMPLING TECHNIQUE

The samples were taken with a pneumatically operated vibracone powered by a compressor on board ship. The core barrel consisted of 4" standard steel pipe with a 3-1/2" inside diameter tubular plastic liner. The core barrel was driven into the sediment and then pulled out with the cover off the sea floor. Penetration rate was measured during coring with a poteniometer mounted on the vibracone. The vibracone was part of a Multi-Insitu Testing System (MITS) which has the capability of measuring core penetration in addition to vibraconing. The cone penetrometer was not used in conjuction with the vibracone in this instance.

PENETRATION RATES

The penetration rates (Fig.2) can be used to qualitatively compare the resistance to penetration at different sites or to empirically cross correlate



EXPLANATION

Solid symbol(•, ▲) shows data from core used primarily for geologic analysis

Open symbol(∘, △) shows data from core used primarily for gas and engineering analysis

Symbols for shear strength data:
- △, ▲ pocket penetrometer
- ∘, • hand vane
- ▽, ▼ lab vane
- ▫, ▪ unconfined compression

Symbols for density data:
- ∘, • Based on subsamples
- △, ▲ Based on tube sections ~1 m long

Symbol for Atterberg Limits:
Plastic limit |———| Liquid limit
These data are few because the materials are generally nonplastic

Symbols for lithology:
- Sand
- Silt
- Clay
- Organic silt or clay
- Peat and highly organic soils

Fig 2

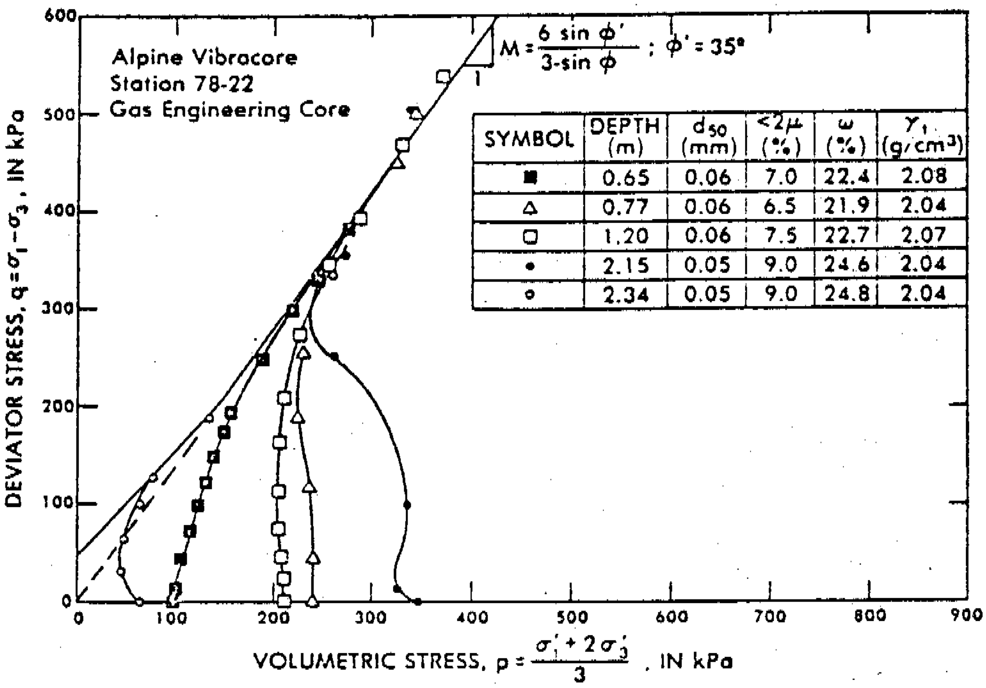
with cone penetration results, ultimately predicting either the shear strength parameters or the density state (Relative Density) of the sediment. Because cone penetration results were not obtained at each site the empirical correlations must rely on data gathered on other types of marine sediments.

DISCUSSION OF RESULTS

Laboratory Tests

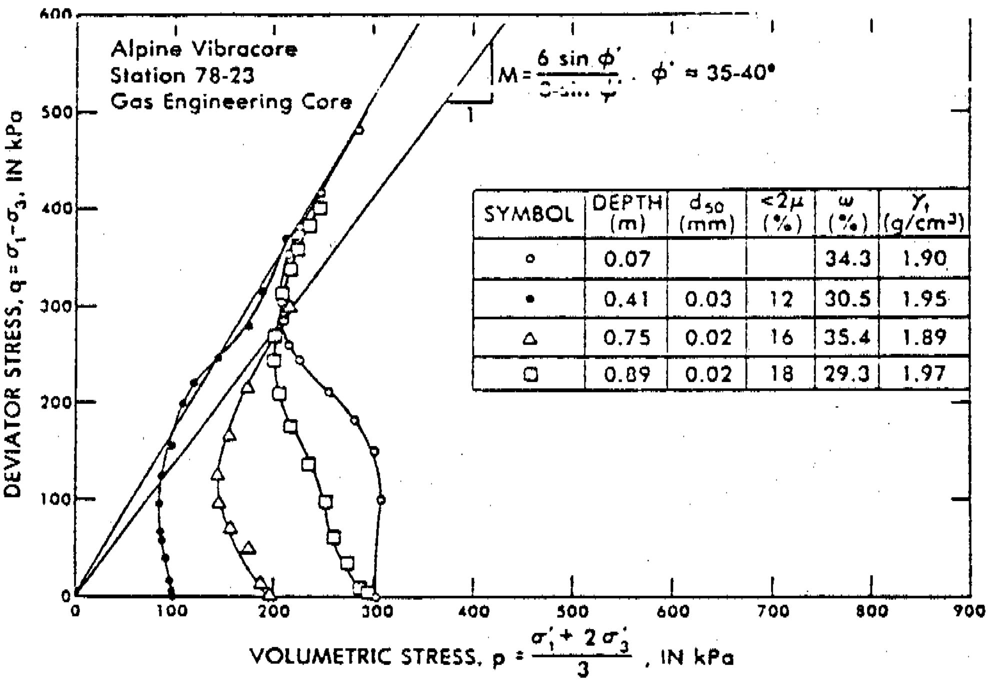
The stress paths for the triaxial tests for all three stations are illustrated in Figures 3 to 5. Tests performed at relatively low consolidation pressure (< 100kPa) appear to exhibit a dilative behavior for cores 22 and 23. This behavior is also apparent in the plots of the pore water pressure vs. the axial strain in Appendix A. The pore water pressure in these tests remains positive at small strains and then drops to negative values, indicative of a dilative response. It should be noted that the response for core 24 is significantly different than cores 22 and 23. This behavior is somewhat expected based on the vibracore penetration records and the profiles of shear strength water content and density (Fig.2).

The deviatoric stress vs. axial strain for the three cores are also illustrated in Appendix A. For the samples tested from core 22 only the samples with consolidation pressures equal to 64.0 kPa and 240 kPa reached a peak deviatoric stress at approximately 8 and 12% respectively. Although the deviatoric stress did not reach a peak value for the sample with a consolidation pressure equal to 343 kPa, a failure plane was observed prior to the final to end of the test. A similar trend was observed for the samples from cores 23 and 24 which were tested to approximately 10% strain. The final deviator stress levels at 10% strain were 1050-1750kPa, 550-650kPa and 70 to 250kPa for cores 22, 23, and 24 respectively. Other data derived from the triaxial test results are listed in Appendix B.



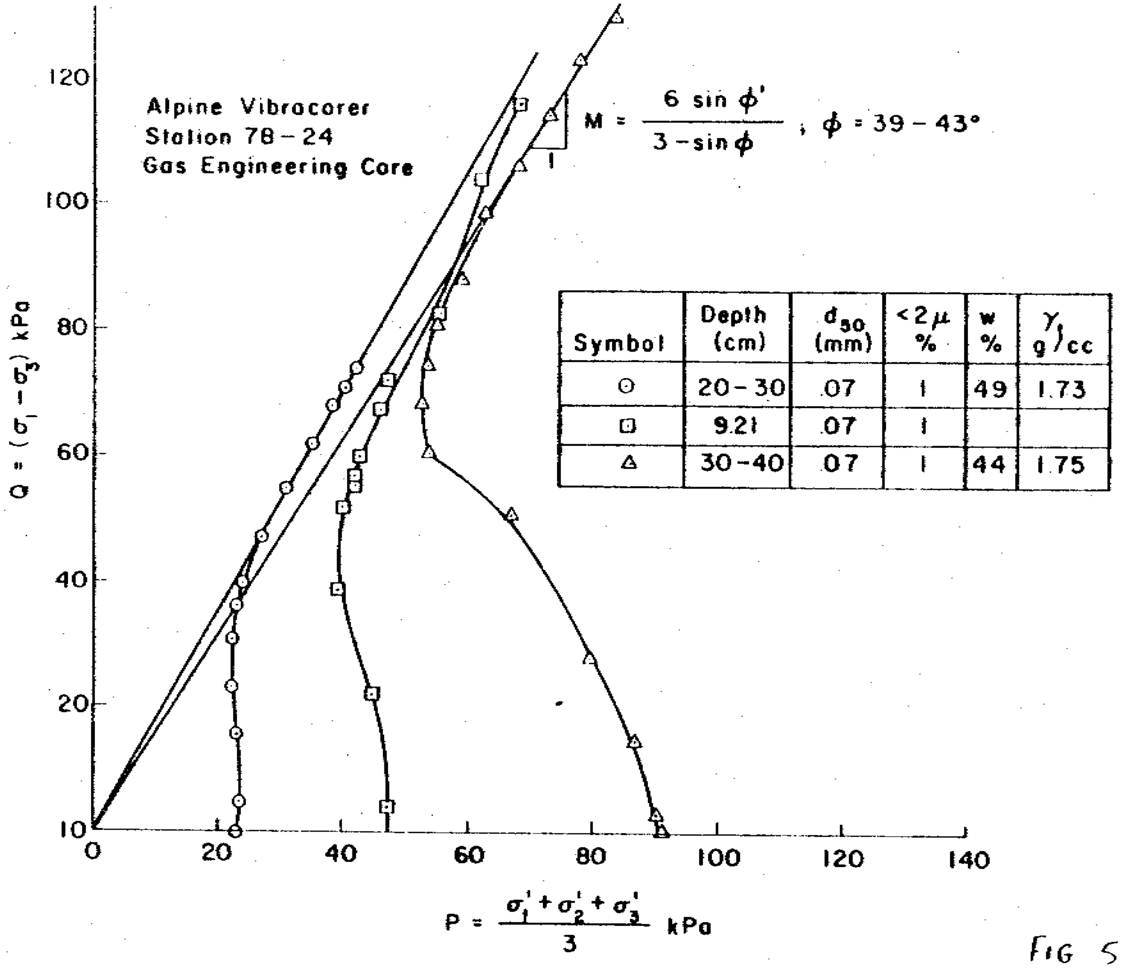
SYMBOL	DEPTH (m)	d_{50} (mm)	<2μ (%)	ω (%)	γ_t (g/cm³)
■	0.65	0.06	7.0	22.4	2.08
△	0.77	0.06	6.5	21.9	2.04
□	1.20	0.06	7.5	22.7	2.07
•	2.15	0.05	9.0	24.6	2.04
∘	2.34	0.05	9.0	24.8	2.04

FIG 3



SYMBOL	DEPTH (m)	d_{50} (mm)	<2μ (%)	ω (%)	γ_t (g/cm³)
∘	0.07			34.3	1.90
•	0.41	0.03	12	30.5	1.95
△	0.75	0.02	16	35.4	1.89
□	0.89	0.02	18	29.3	1.97

FIG4



Symbol	Depth (cm)	d_{50} (mm)	< 2 μ %	w %	γ_t g/cc
⊙	20 – 30	.07	1	49	1.73
⊡	9.21	.07	1		
△	30 – 40	.07	1	44	1.75

FIG 5

The results from the cyclic triaxial tests are summarized in Table 1. Although the maximum excess pore water pressure in many tests was a significant portion of the initial consolidation pressure, the strain level was relatively small except for the cases of the resedimented sample which reached an axial strain of 9.2% and a pore pressure ratio (μ/σ_o) of 114% and the sample from core 23 (47-59cm.) which had a final deviatoric stress of 254.6kPa (Cyclic deviatoric stress = 156.5). The initial bulk density for the resedimented sample however was 1.70g/cm^3 in contrast to the directly measured values of approximately 2.00g/cm^3 throughout core 23. It should also be noted that the strain abruptly rose to 9.2% in a relatively small number of cycles at the final cyclic deviatoric stress.

The results obtained from the cyclic simple shear tests were, however, significantly different. The samples were initially loaded vertically at 10, 24 and 50kPa. The horizontal stresses were generally low for the initial consolidation loads, indicating an overconsolidated condition, but increased significantly in all but one case with a consolidation pressure of 50kPa. This may have been the result of either a structural rearrangement within the sample and increased contact between the sample and the wire reinforced membrane.

The stress paths and the change in shear strain, shear modulus and pore water pressured vs. number of cycles are included in Appendix C. The results from the static simple shear tests are also included in Appendix C. The results suggest that significant pore water pressures and strains are generated at relatively small cyclic shear stresses. These stresses are of the relative magnitude of those possibly generated by large storm wave propagating through Northon Sound (Clukey and others, 1980).

The reasons for the large differences between the cyclic triaxial and

TABLE I

DYNAMIC SOIL ESTING RESULTS

S9-78-BS

CYCLIC TRIAXIAL TESTS

SAMPLE ID	CONSOLIDATION PRESS	HORIZ. CONSOL. PRESS	CYCLIC DEV. STRESS	MAX EXCESS PWP	NO. OF CYCLES	STRAIN %	COMMENTS
Core 22 241-256cm	196.1 kN/m^2	196.1 kN/m^2	76.0 KN/m^2	71.7 kN/m^2	63	.25	Large Strains @ EOT-Final Cycles
	196.1	196.1	156.1	145.8	375	2.14	
136-151cm	46.0	46.0	31.3	32.1	500	.29	
	46.0	46.0	76.0	34.6	670	.80	
258-270cm	98.1	98.1	50.6	36.0	431	.23	
	98.1	98.1	67.1	59.3	744	.56	
	98.1	98.1	89.1	68.2	325	.65	
	98.1	98.1	111.1	62.3	-	.89	
272-284	196.1	196.1	76.0	86.5	125	.26	
	196.1	196.1	98.2	98.2	325	.52	
	196.1	196.1	120.3	152.7	425	.88	
	196.1	196.1	133.0	165.6	450	1.28	
109-121	392.3	392.3	134.5	148.3	2211	.20	
	392.3	392.3	246.5	257.0	1537	.60	
	392.3	392.3	291.4	294.1	1038	.95	
Core 23 100-108	49.0	49.0	44.7	12.1	160	.15	Statically Loaded to Failure
	49.0	49.0	89.4	16.1	110	.19	
	49.0	49.0	134.1	20.1	510	2.2	
100-110	29.4	29.4	4.93	4.64	100	-	- Drain (Resedimented) Sample
	29.4	29.4	19.7	33.5	100	1.7	
	29.4	29.4	19.7	33.5	93	9.2	
47-59	196.1	98.1	22.4	12.1		[illegible]	
	196.1	98.1	44.8	28.2		1.01	
	196.1	98.1	67.2	32.2		1.10	
	196.1	98.1	89.6	33.0		4.70	
	196.1	98.1	118.8	24.1		8.6	
	196.1	98.1	156.5	18.4		9.4	

cyclic simple shear results have not been totally resolved. The variations in the penetration records and density and shear strength profiles suggest that the sediment may be highly variable throughout the region, although the samples taken from core 24 for the cyclic simple shear tests were in a zone or high penetration resistance and shear strength. Several additional cyclic simple shear tests on samples from cores 22 and 23 are planned to provide additional insights regarding the behavior of the sediment under different test conditions.

PENETRATION RECORDS

As previously mentioned the vibracorer was a part of a combined testing system which included a cone penetration device. Considerable work by other investigators (Schmertmann) has been done relating cone penetration results to shear strength and relative density determinations. It would therefore be possible to make some correlations between the vibracore penetration results and these parameters if empirical relationships between vibracore penetation records and cone penetrometer results were available. Unfortunatley, this data is overall, limited. However, several such comparisons have been made between vibracores and cone penetrometer results in silty sands taken for the Southwest Ocean Outfall Project for the city of San Francisco. Although these comparisons in regards to the Yukon prodelta silty sands are in no way considered conclusive, they do provide initial insights for evaluating potential in-situ strengths and providing cross correlations with regards to the laboratory results. Several observations are therefore considered appropriate.

The vibracone (Ocean Outfall Project) reached refusal when the penetration rate dropped to a range of 30 to 40 sec/ft (1.5-2.2m/min). This correlated to a range of penetrometer resistance of 80-120tsf. Based on Schmertmanns correlations with relative density, this would correspond to a very dense material with a relative density between 70-100%. Based on other comparisons at different depths and correlating similar vibracore penetration records for the Yukon prodelta, it appears that station 22 and 23 would consist of mostly medium dense to dense material, whereas station 24, particularly in the upper 2.5 meters appear to be in a much looser condition and much more susceptible to dynamic environmental loading. Future vibracores and cone penetrometer investigations planned for Norton Sound should greatly assist in improving these general observations.

CONCLUSIONS

Laboratory shear strength testing has been conducted on three cores taken from the Yukon Prodelta. These tests were directed at assessing the response of the sediment under both static and dynamic loading conditions. Although additional testing will be required to resolve unanswered questions, the results obtained indicate that the shear strength and density state of the material may be highly variable throughout the region. Sample disturbance, however, may have been partially responsible for some of the behavior. Resedimented samples may help resolve some of the problems associated with disturbance. Significantly different test results were obtained between samples tested cyclically with triaxial and simple shear devices. Although some of these differences may have resulted from tests performed on different cores, it appears that the type and direction of loading may significantly influence the results for the Yukon silty sand.

Finally, the penetration rules provided some promising insights into the potential in-situ behavior of the material. Cross correlations with cone penetrometer data will greatly enhance the applicability of the data.

REFERENCES

1. Clukey, E.C., Cacchione, D.A. and Nelson, C.H. (1980). Liquefaction potential of Yukon Prodelta, Bering Sea, Offshore Technology Conference, Proceedings, Houston, Texas, Paper 3773.

2. Olsen, H.W., Clukey, E.C. and Nelson, C.H. (1980). Geotechnical Characteristics of Bottom Sediment in the Northern Bering Sea, U.S. Geologic Survey Open-File Repore 80-979, 21 pp.

3. Schmertmann, J.H. (1978). Guidelines for Cone Penetration Test Performance and Design, Report prepared for U.S. Department of Transportation, FHWA-TS-78-209, 145 pp.

FIGURE CAPTIONS

1. Location map of northern Bering Sea showing regions and sampling stations cited in this paper.

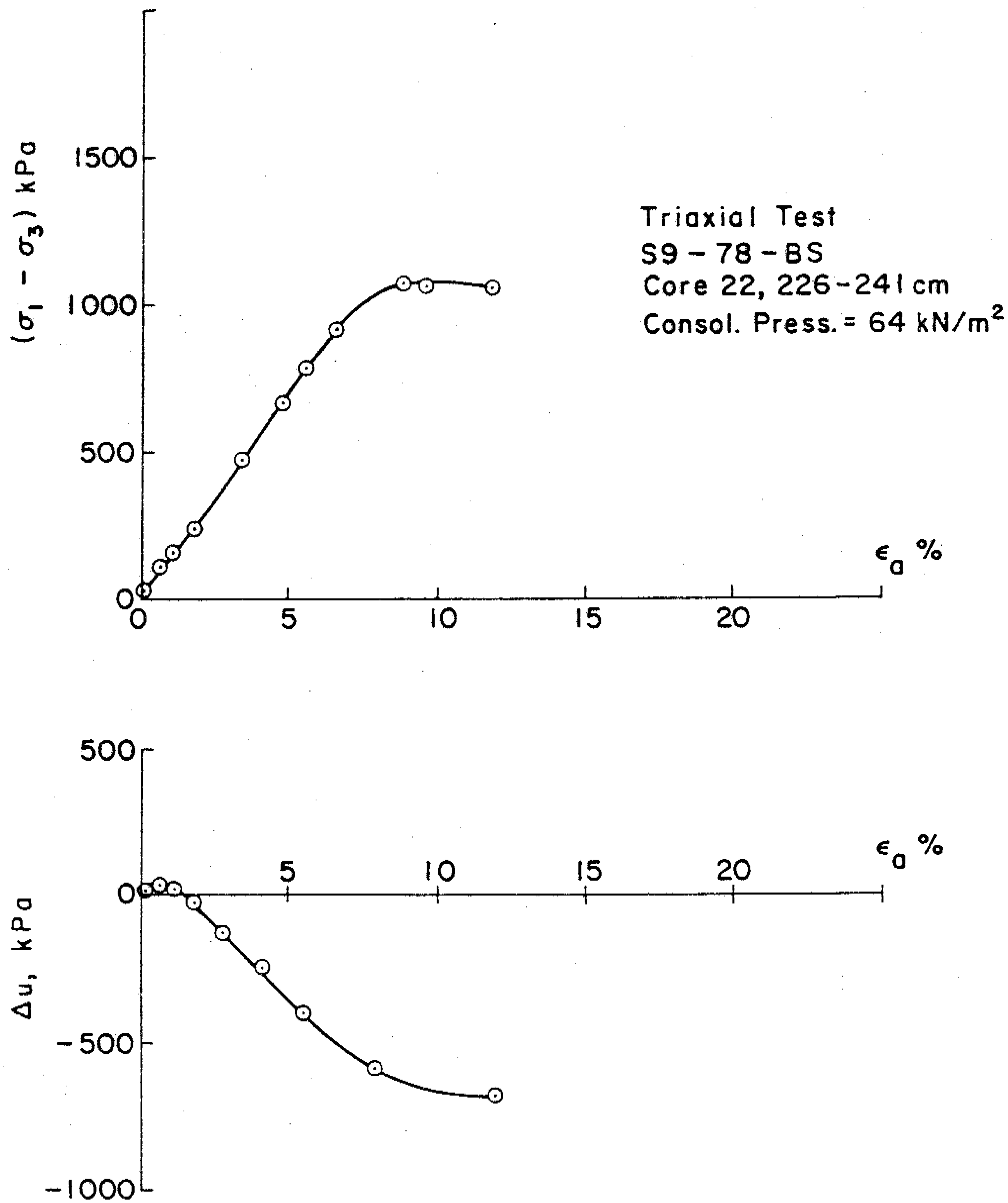
2. Geotechnical profiles from the Yukon Prodelta.

3,4, 5

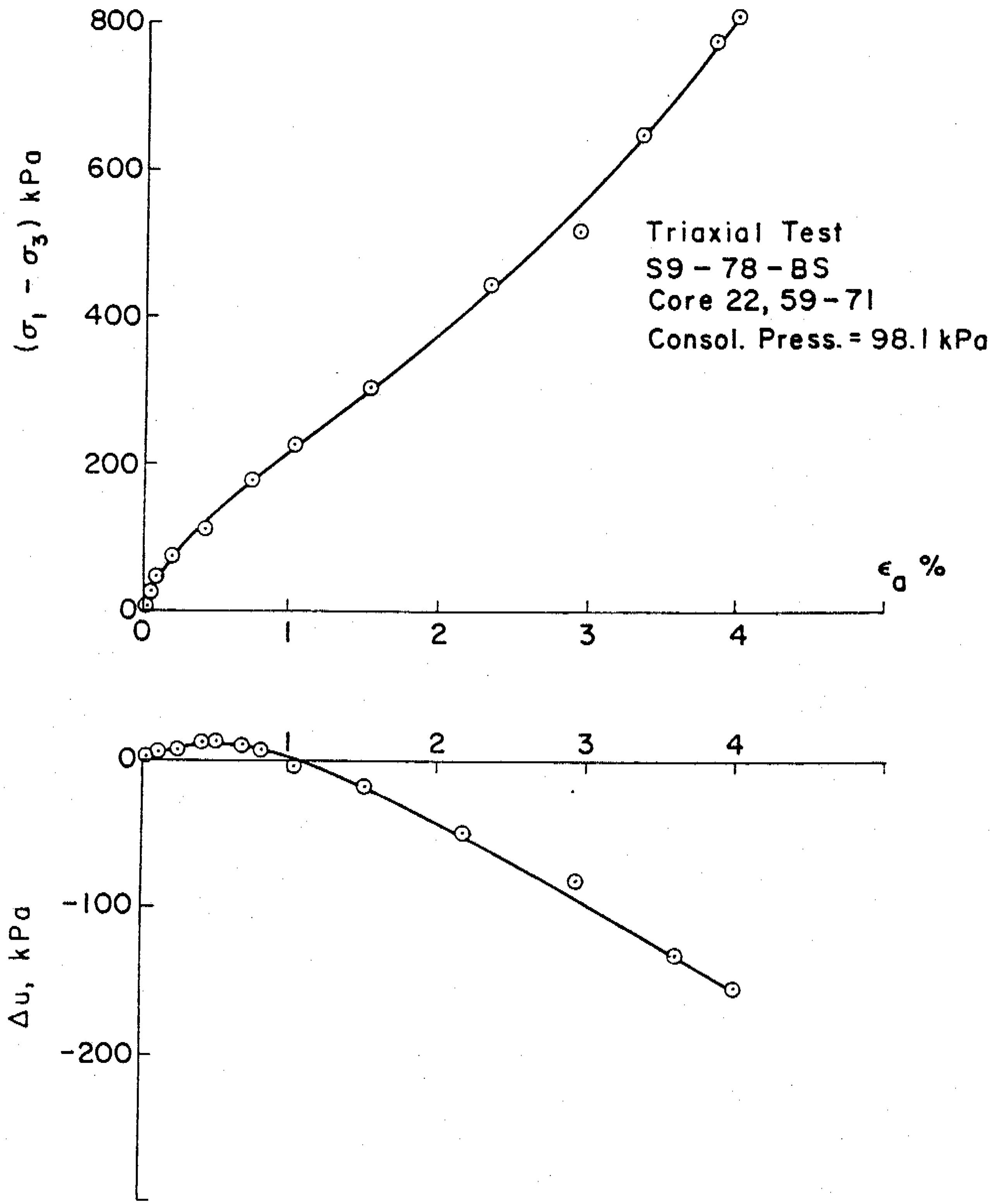
Consolidated-undrained triaxial data on samples of Holocene Yukon silt from Alpine vibracores at stations 78-22, and 78-24 near the Yukon prodelta (see Fig.2). ' = effective friction angle. $_1$ and $'_3$ are the effective vertical and horizontal stresses, respectively. and $_t$ are water content and bulk density respectively. d_{50} and 2 are the median grain size and minus 2 micron fraction, respectively. Tests run according to procedures described by Bishop and Henkel (1962).

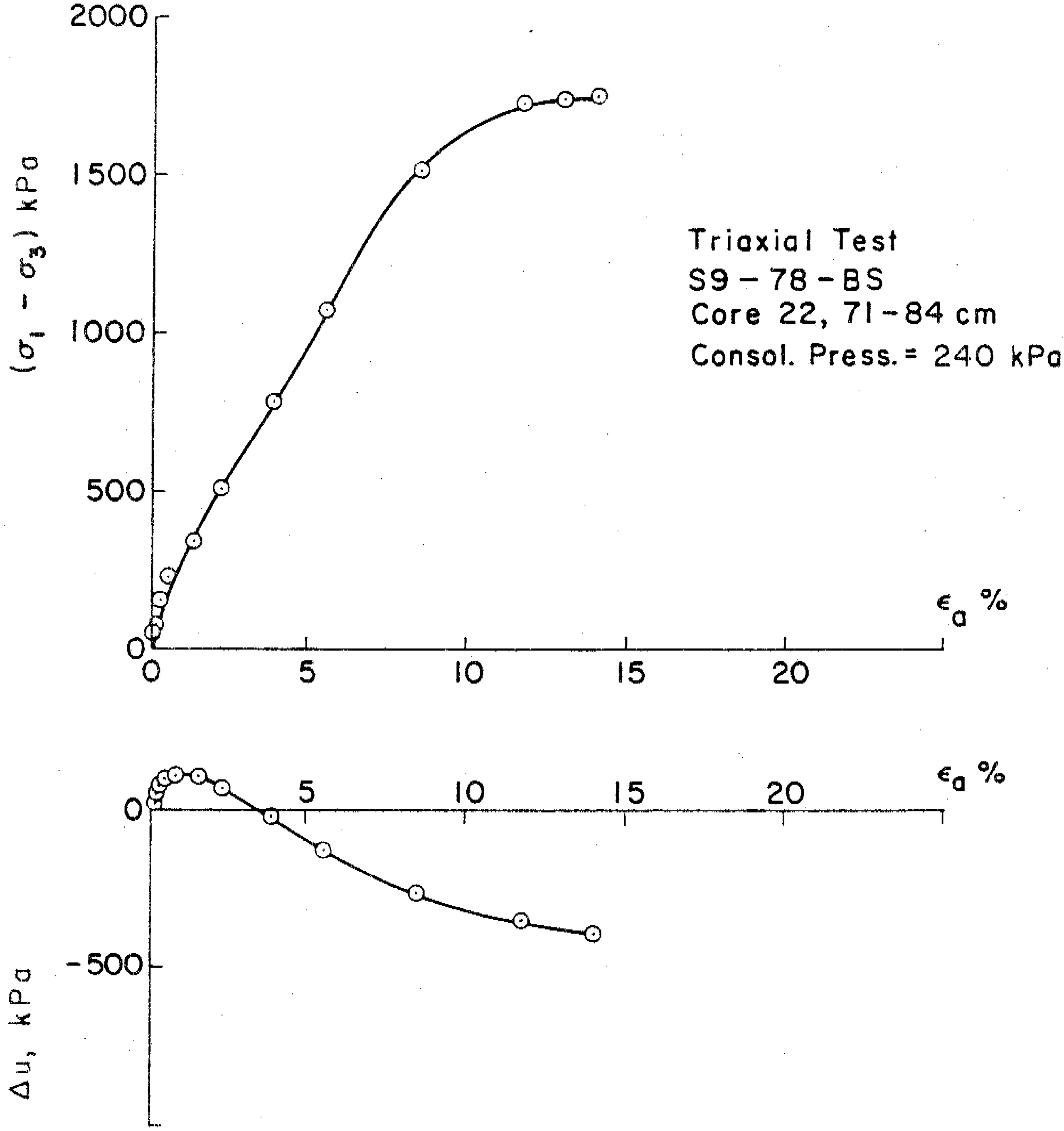
APPENDIX A

PORE WATER PRESSURE AND DEVIATORIC STRESS VS. AXIAL STRAIN

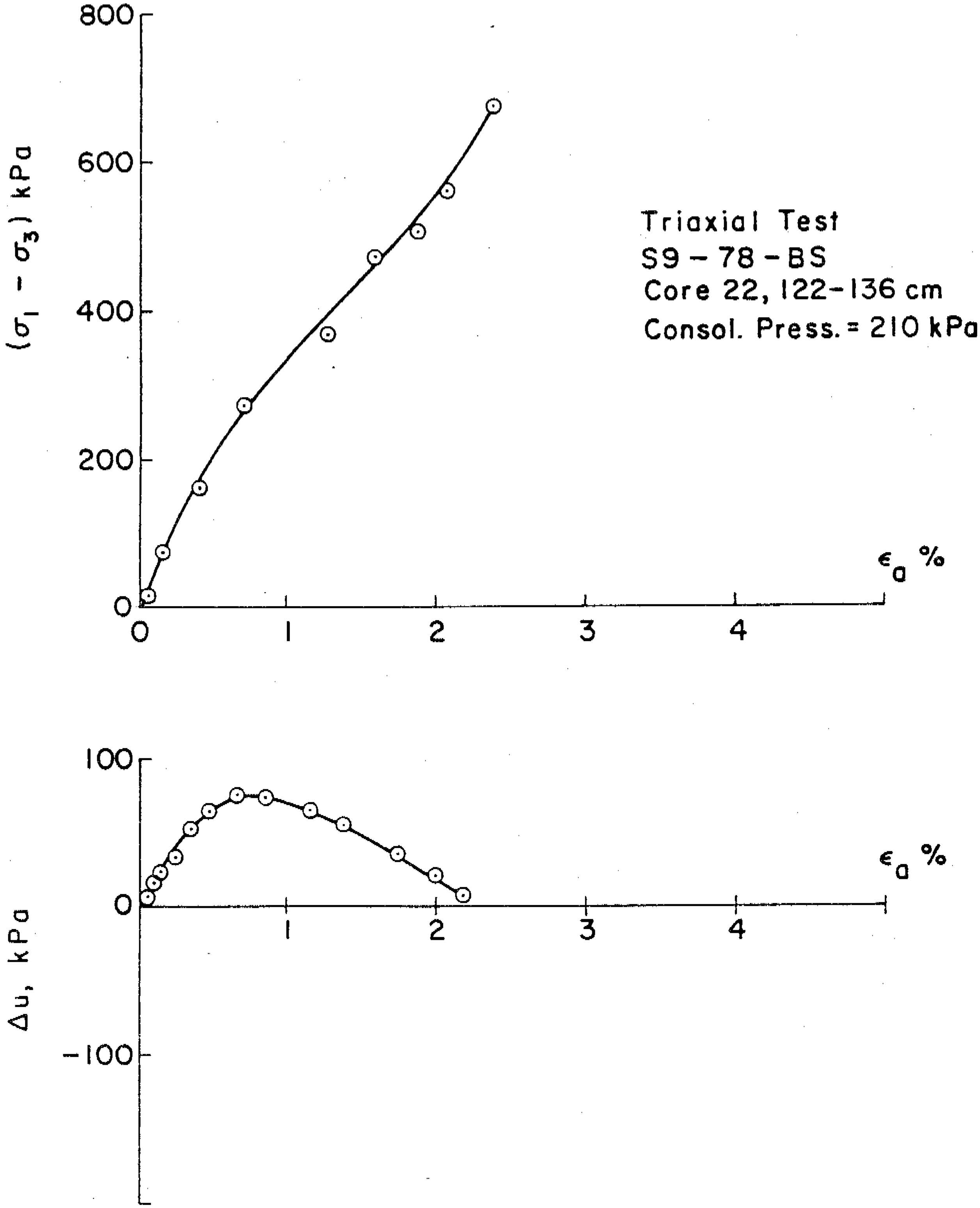


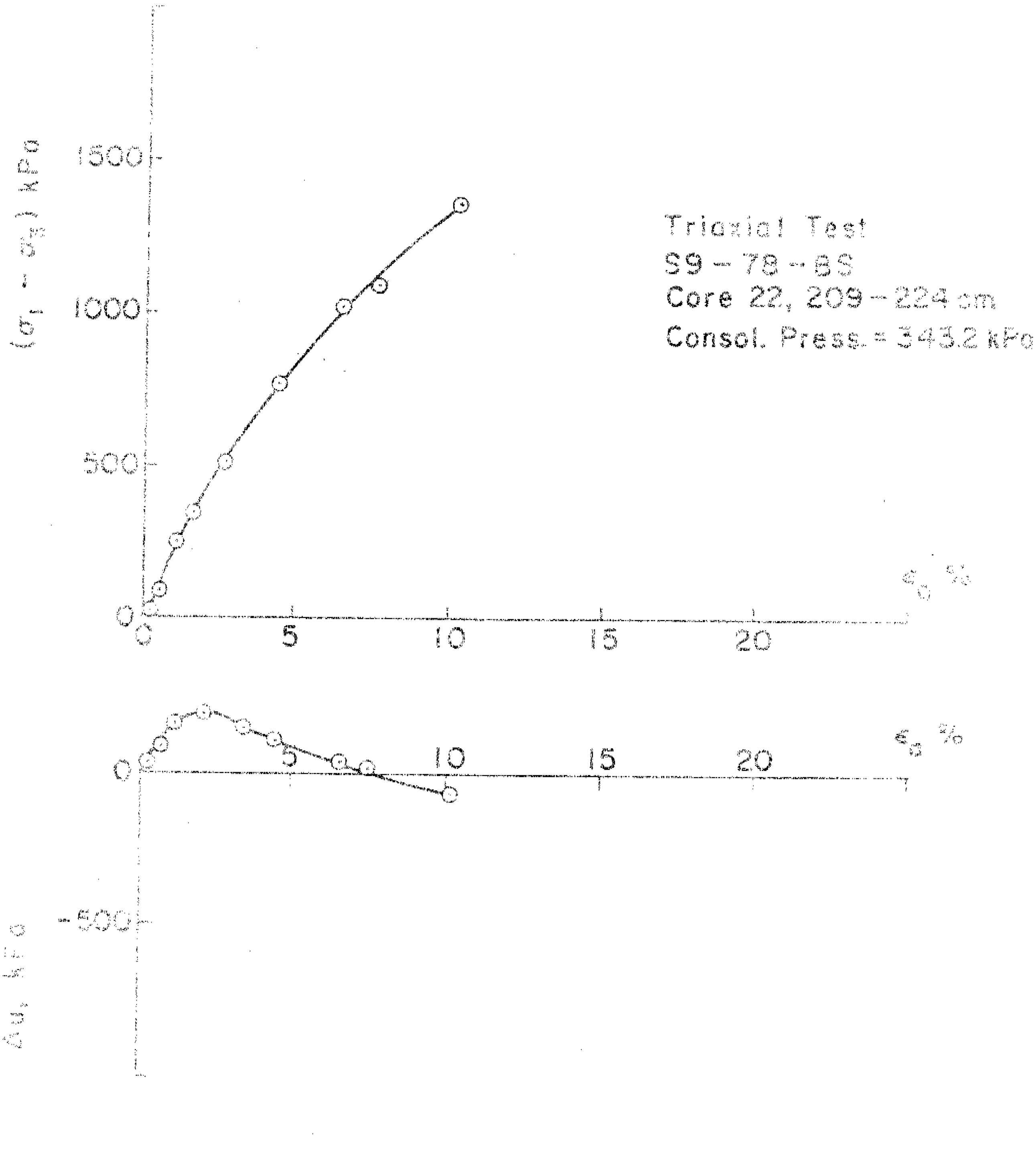
Triaxial Test
S9 - 78 - BS
Core 22, 226-241 cm
Consol. Press. = 64 kN/m²
(σ₁ - σ₃) kPa
1500
1000
500
0
0
5
10
15
20
εa %
Δu, kPa
500
0
-500
-1000
5
10
15
20
εa %

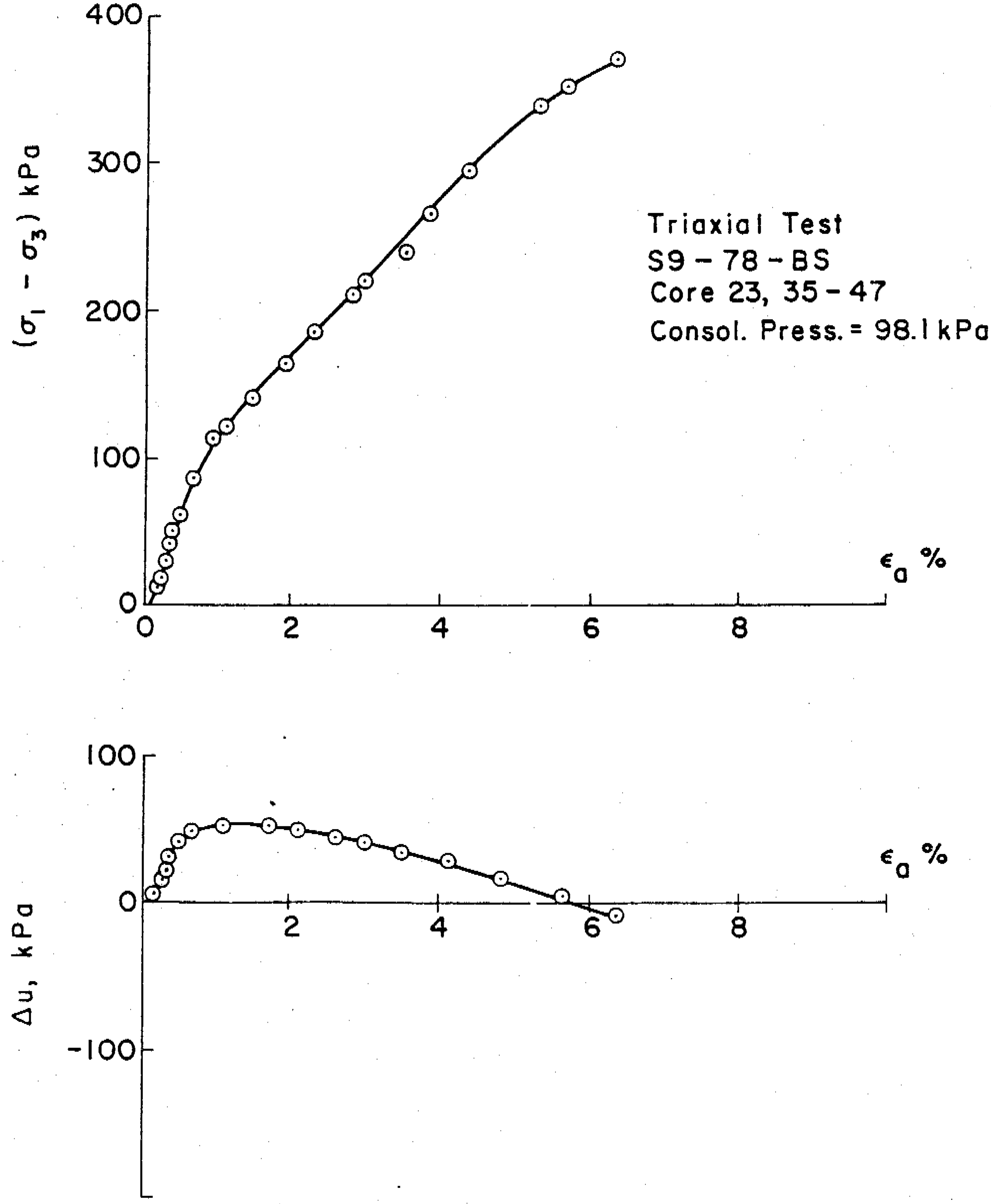

800
600
400
200
0
$(\sigma_1 - \sigma_3)$ kPa
Triaxial Test
S9 - 78 - BS
Core 22, 59 - 71
Consol. Press. = 98.1 kPa
ϵ_a %
0
1
2
3
4
0
-100
-200
Δu, kPa



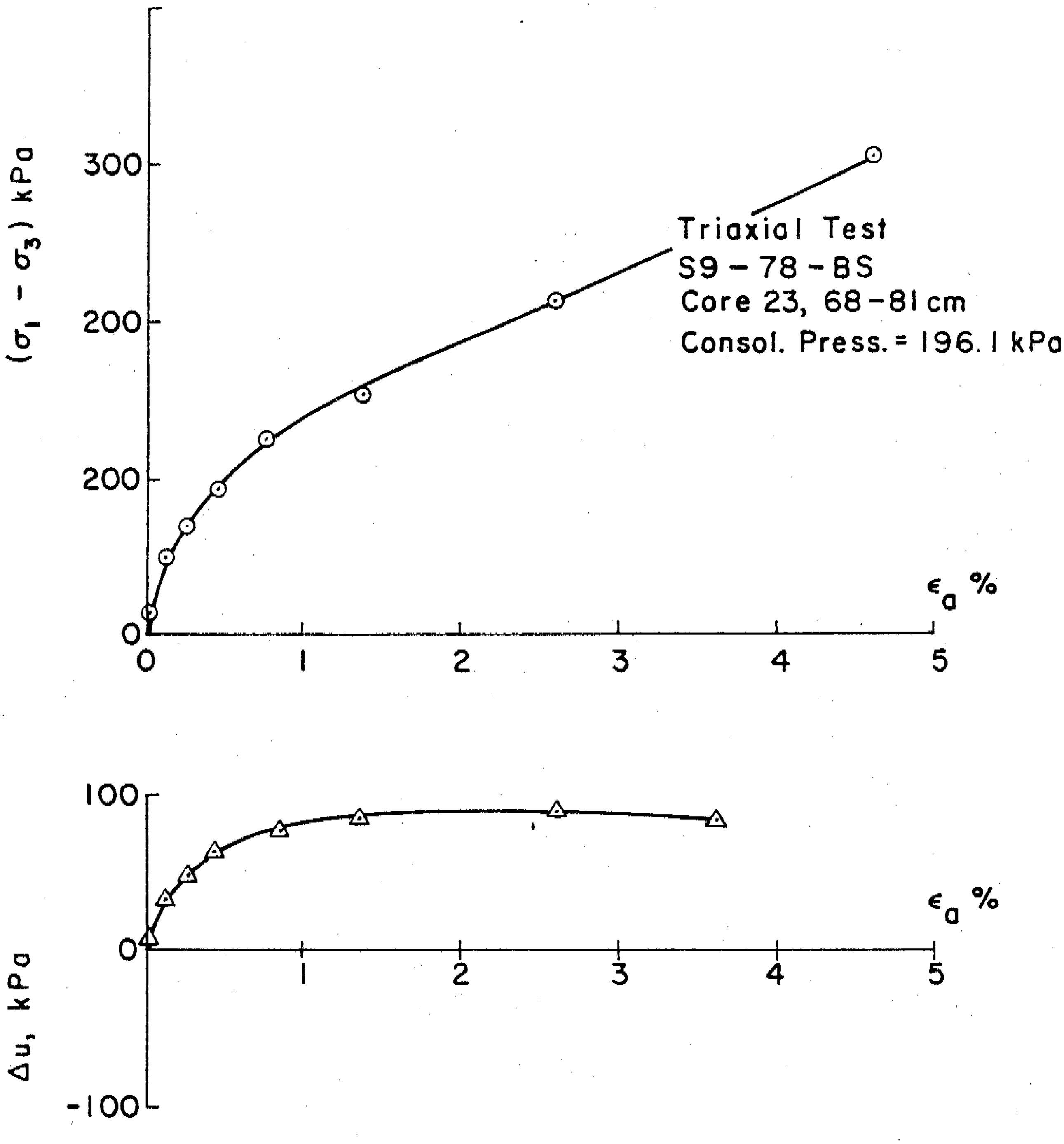
2000
1500
1000
500
0
$(\sigma_1 - \sigma_3)$ kPa
Triaxial Test
S9 – 78 – BS
Core 22, 71 – 84 cm
Consol. Press. = 240 kPa
ϵ_a %
0
5
10
15
20
ϵ_a %
-500
Δu, kPa

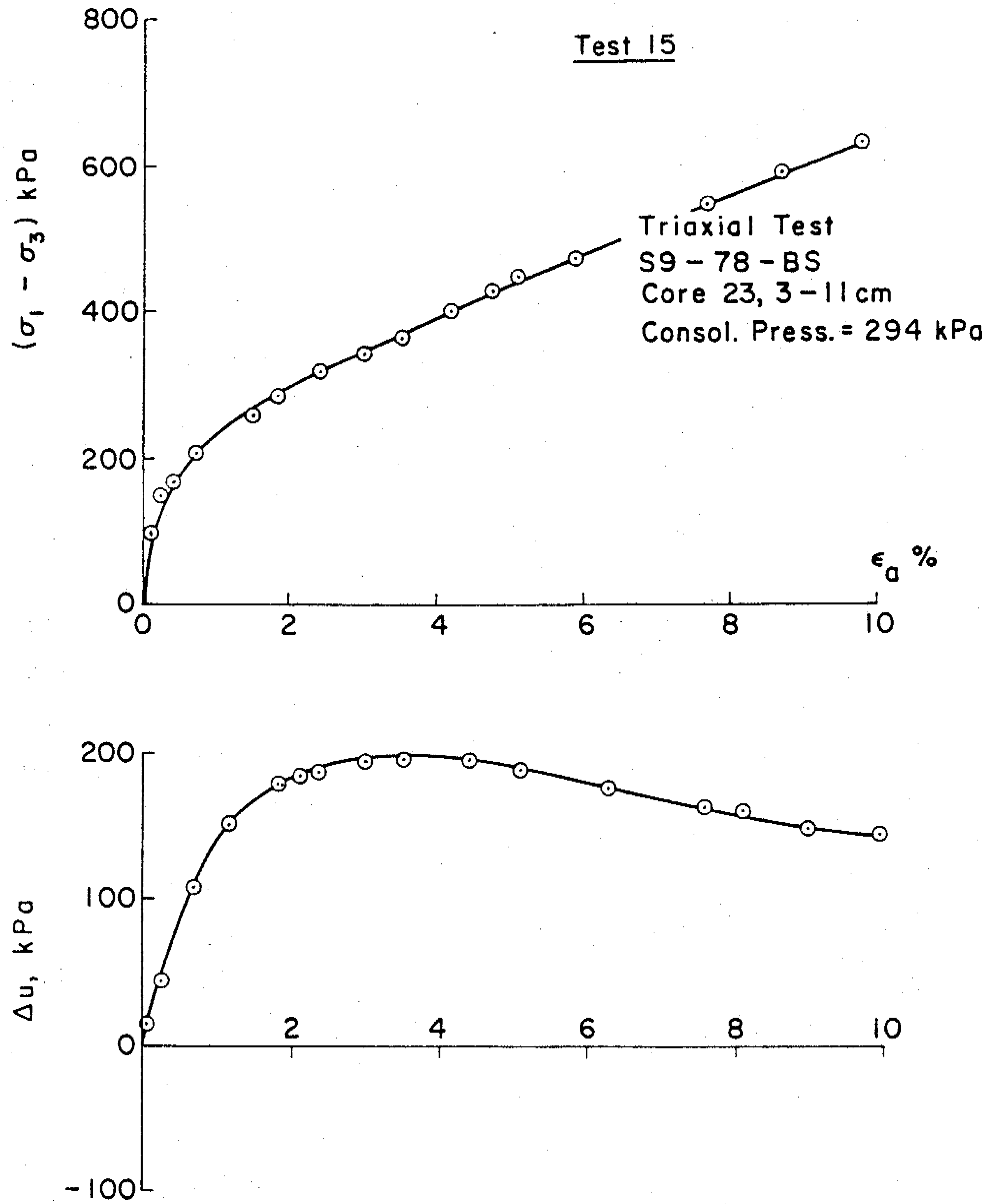

800
600
400
200
0
$(\sigma_1 - \sigma_3)$ kPa
Triaxial Test
S9 - 78 - BS
Core 22, 122-136 cm
Consol. Press. = 210 kPa
ϵ_a %
0
1
2
3
4
100
0
-100
Δu, kPa
ϵ_a %
1
2
3
4

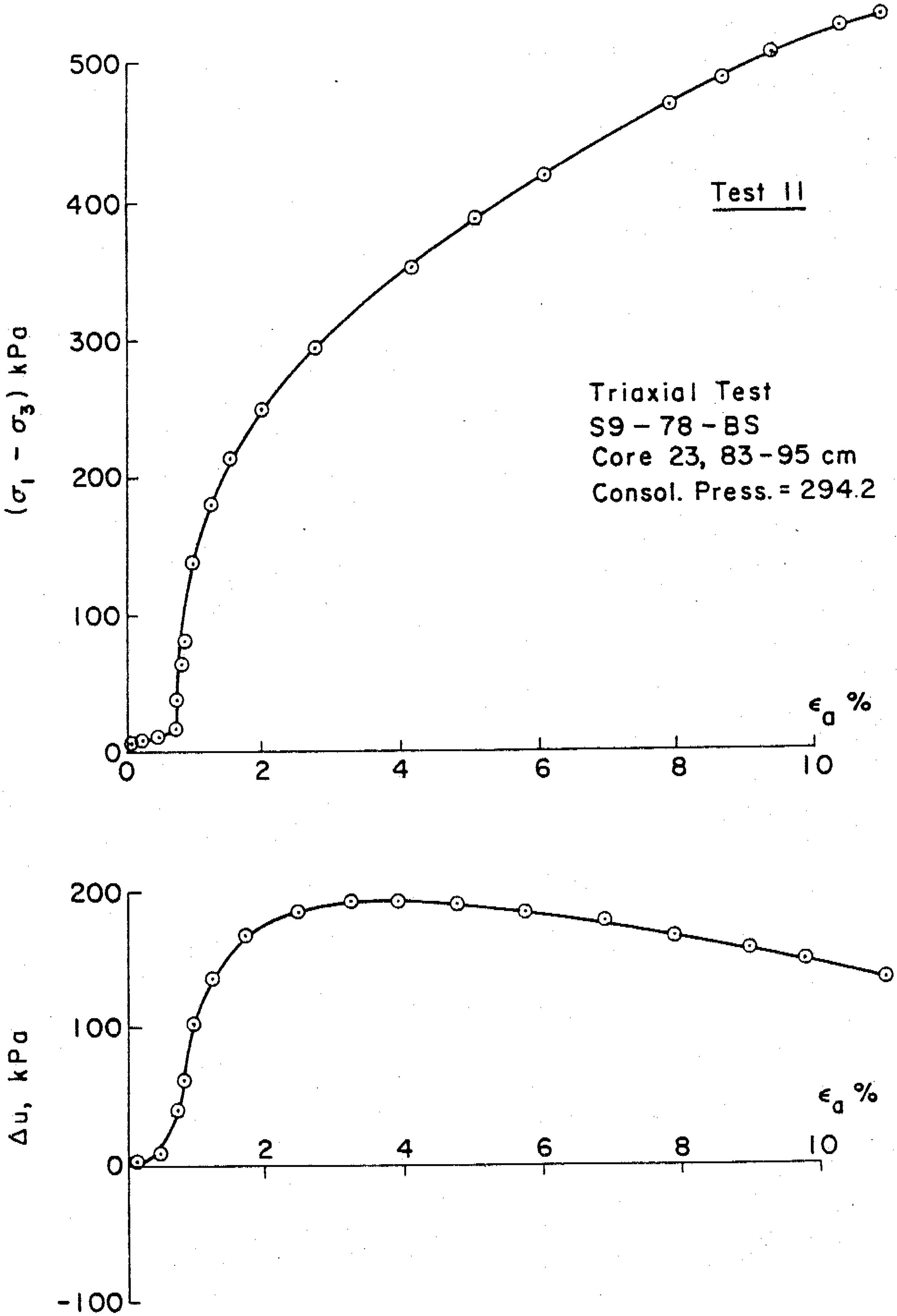

Triaxial Test
S9-78-BS
Core 22, 209-224 cm
Consol. Press. = 343.2 kPa
$(\sigma_1 - \sigma_3)$ kPa
1500
1000
500
0
0
5
10
15
20
ϵ_a %
Δu, kPa
-500



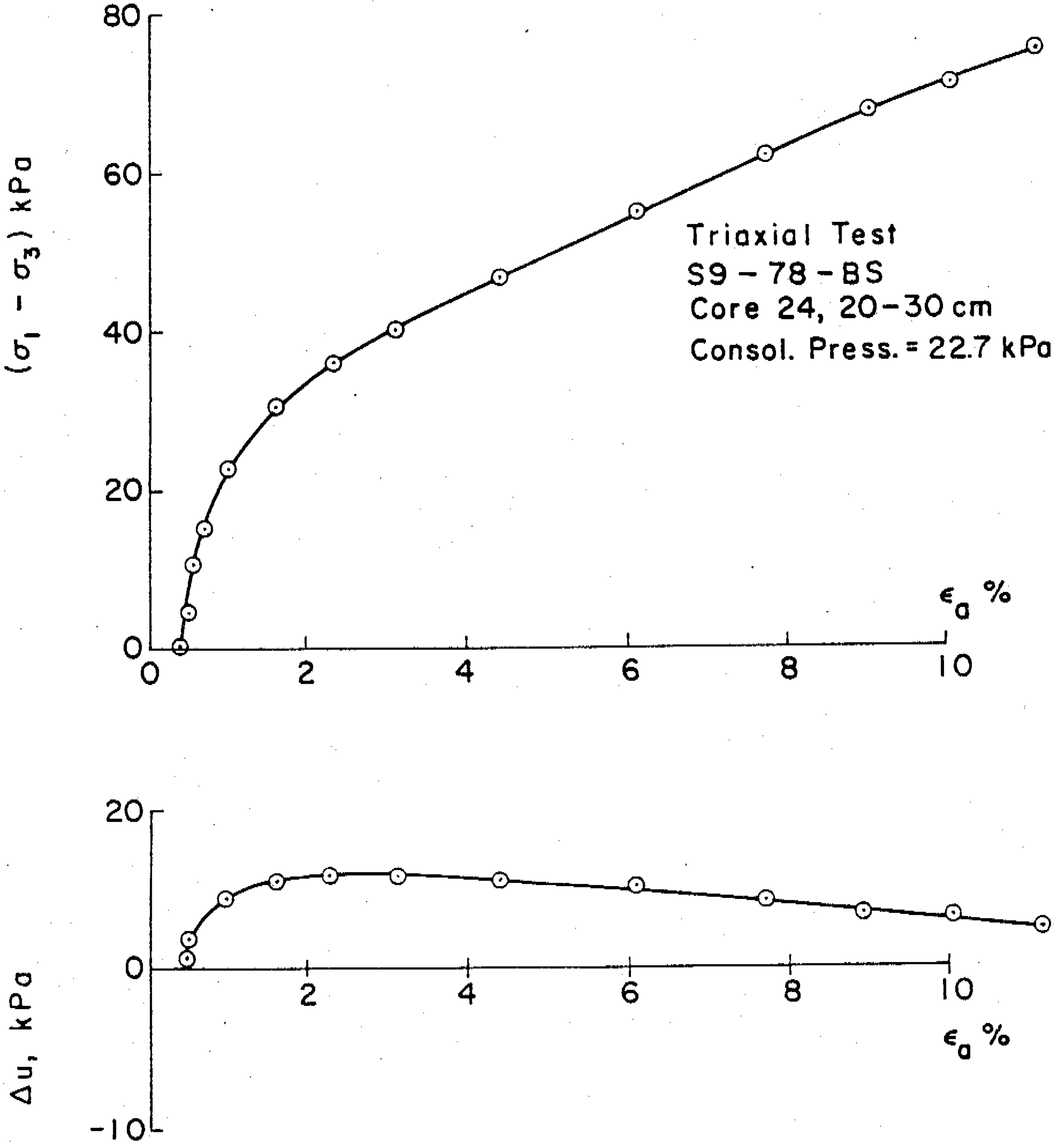
400
300
200
100
0
$(\sigma_1 - \sigma_3)$ kPa
Triaxial Test
S9 - 78 - BS
Core 23, 35 - 47
Consol. Press. = 98.1 kPa
ϵ_a %
0
2
4
6
8
100
0
-100
Δu, kPa
ϵ_a %
2
4
6
8


Triaxial Test
S9 - 78 - BS
Core 23, 68-81 cm
Consol. Press. = 196.1 kPa
$(\sigma_1 - \sigma_3)$ kPa
300
200
200
0
ϵ_a %
0
1
2
3
4
5
100
0
-100
Δu, kPa
ϵ_a %
1
2
3
4
5

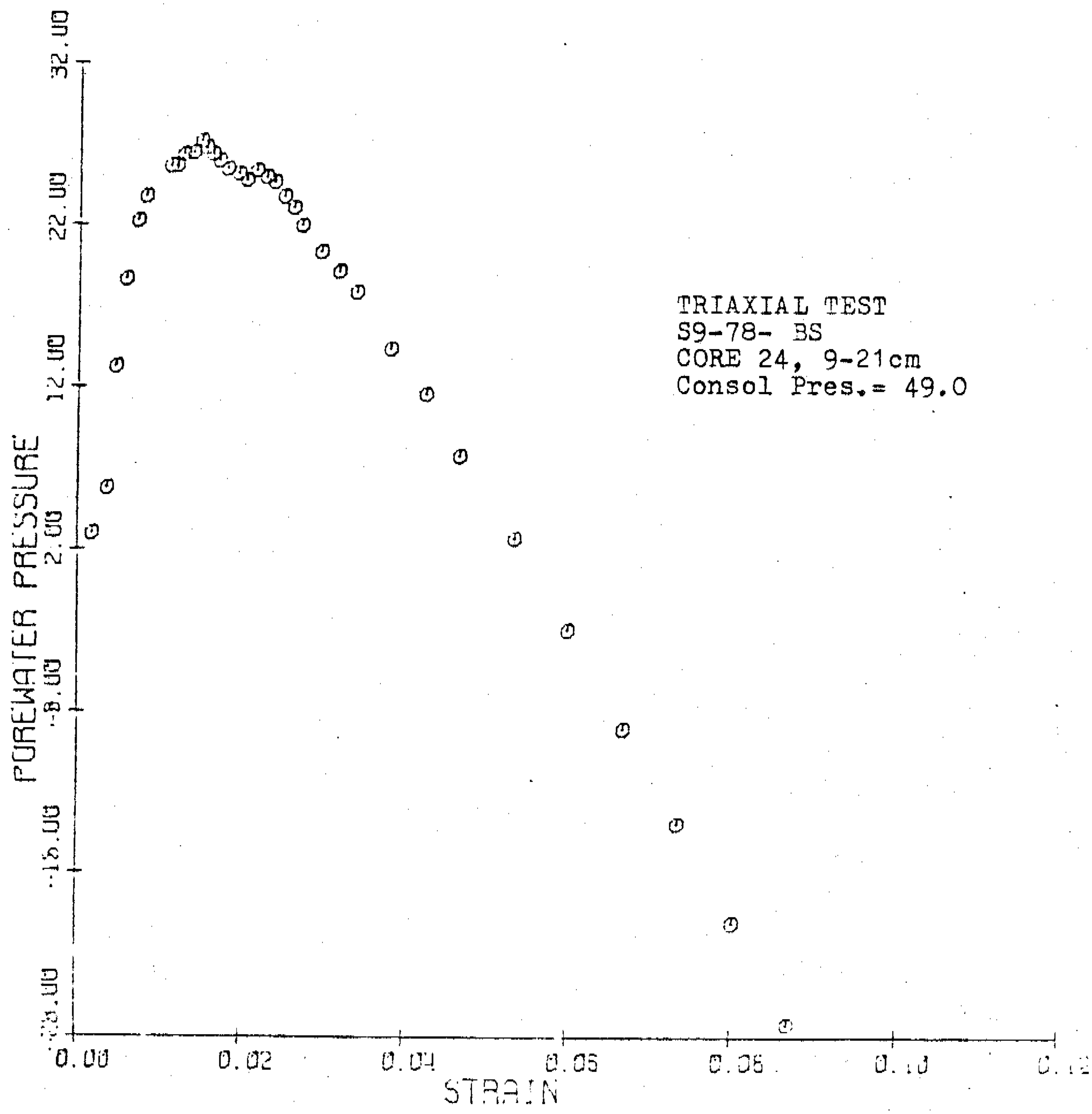

Test 15
Triaxial Test
S9 - 78 - BS
Core 23, 3 - 11 cm
Consol. Press. = 294 kPa
800
600
400
200
0
(σ1 - σ3) kPa
εa %
0
2
4
6
8
10
200
100
0
-100
Δu, kPa
2
4
6
8
10



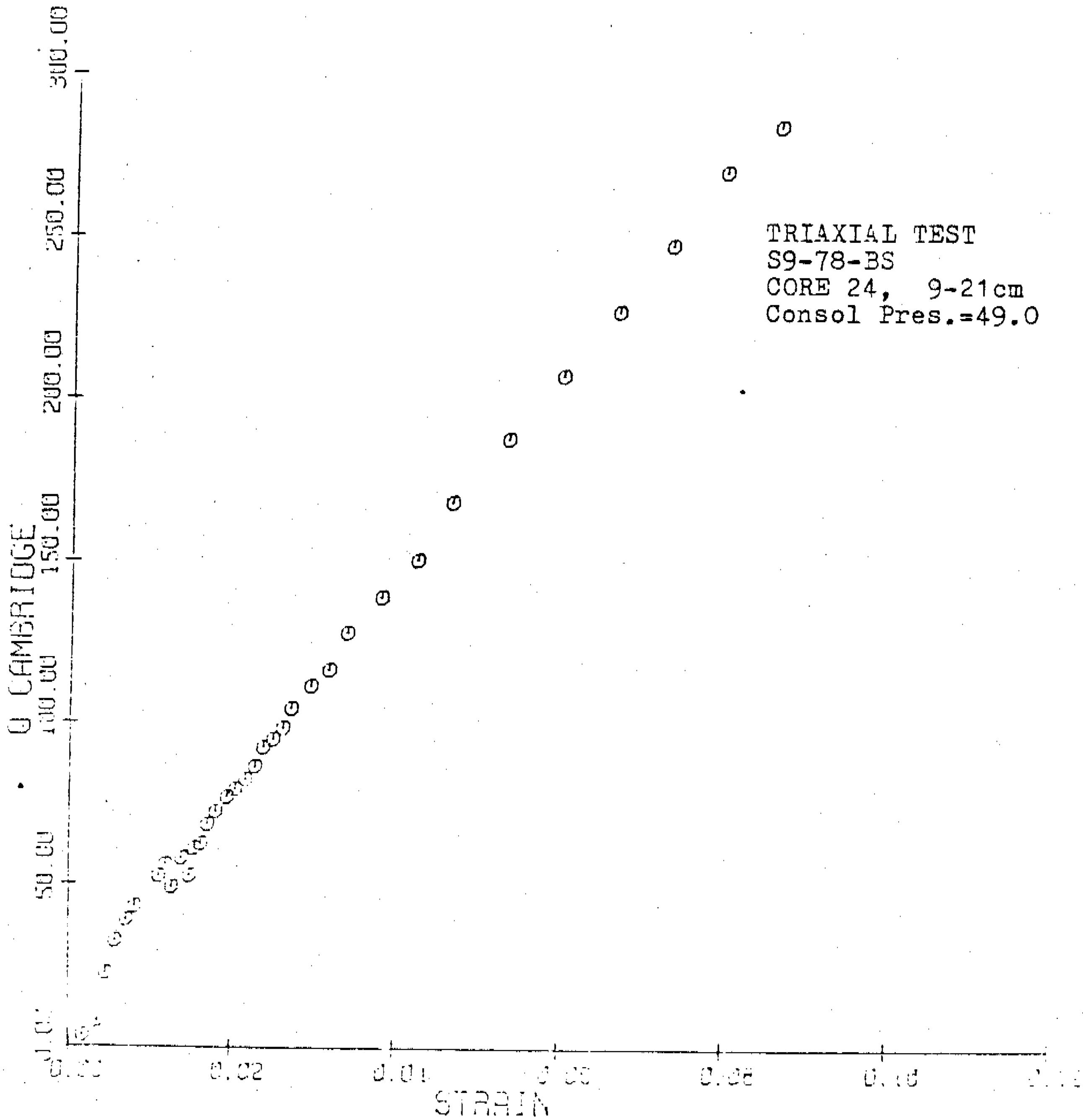
Test 11
Triaxial Test
S9 - 78 - BS
Core 23, 83-95 cm
Consol. Press. = 294.2
(σ1 - σ3) kPa
500
400
300
200
100
0
ϵa %
0
2
4
6
8
10
Δu, kPa
200
100
0
-100
ϵa %
2
4
6
8
10



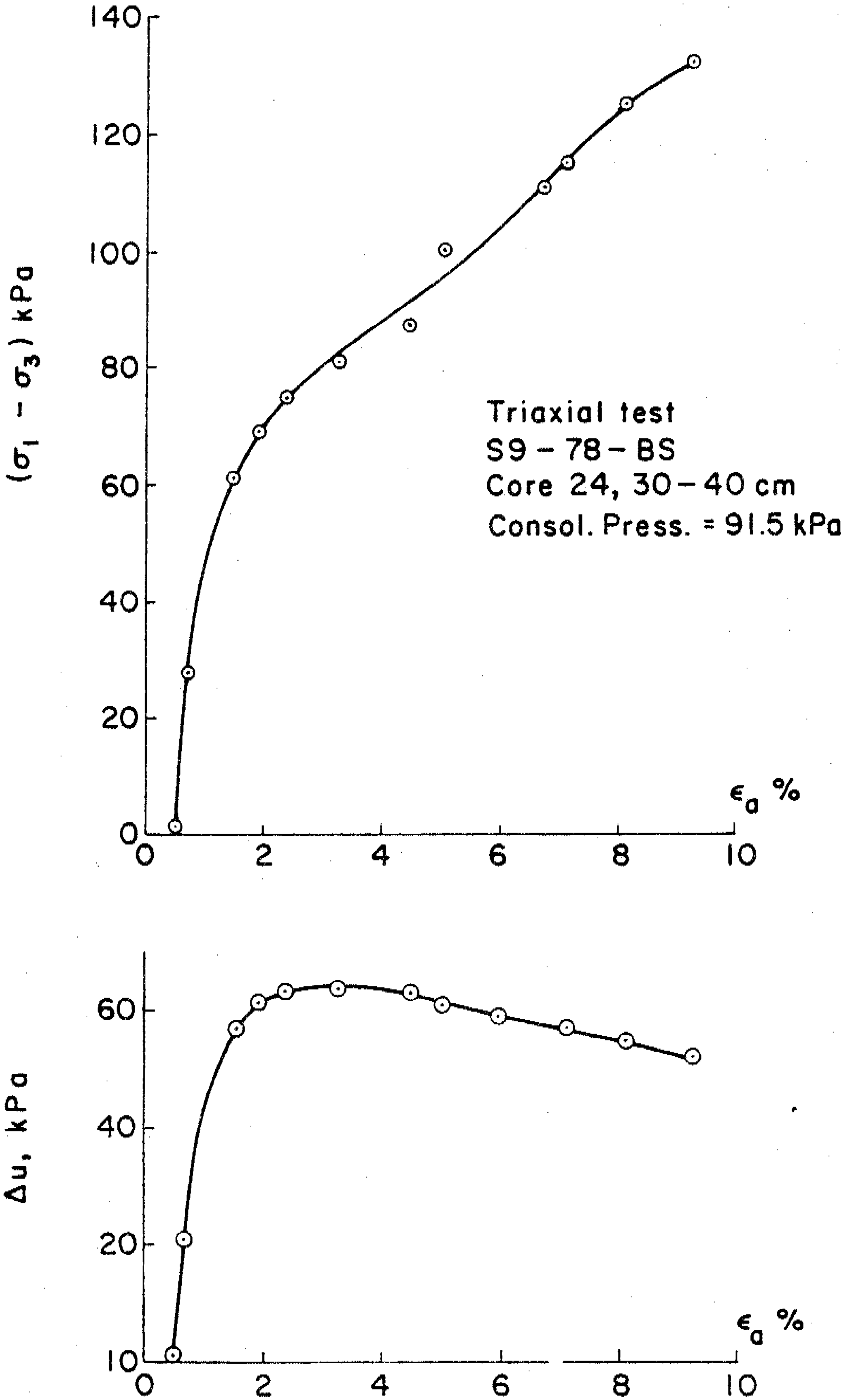
80
60
40
20
0
$(\sigma_1 - \sigma_3)$ kPa
0
2
4
6
8
10
ϵ_a %
Triaxial Test
S9 - 78 - BS
Core 24, 20-30 cm
Consol. Press. = 22.7 kPa
20
0
-10
Δu, kPa
2
4
6
8
10
ϵ_a %



TRIAXIAL TEST
S9-78- BS
CORE 24, 9-21cm
Consol Pres.= 49.0
PUREWATER PRESSURE
STRAIN



TRIAXIAL TEST
S9-78-BS
CORE 24, 9-21cm
Consol Pres.=49.0
Q CAMBRIDGE
STRAIN


140
120
100
80
60
40
20
0
$(\sigma_1 - \sigma_3)$ kPa
Triaxial test
S9 - 78 - BS
Core 24, 30 - 40 cm
Consol. Press. = 91.5 kPa
ϵ_a %
0
2
4
6
8
10
60
40
20
10
Δu, kPa
ϵ_a %
0
2
4
6
8
10

APPENDIX B

PWP - Pore Water Pressure

SIG-SIG3 - Deviatoric Stress

INVAR P - Normalized Volumetric Mean Effective Stress = $\frac{\bar{\sigma}_1 + 2\bar{\sigma}_3}{3}$

A_f - Pore Water Pressure Parameter at Failure

UNITS - SI (kPa)

S9-78-BS CORE 22

226-241 cm Consol Pres.= 64.0kPa

TRIAXIAL #	PWF KN/m²	STRAIN	SIG1-SIG3 KN/m²	STRAIN/Q
1	30.8204	.175373	32.6155	5.37698E-03
2	39.226	.363272	65.1082	5.57951E-03
3	36.4241	.688964	102.751	6.70518E-03
4	28.0186	.876863	129.545	6.76879E-03
5	14.0093	1.06476	157.314	6.76837E-03
6	-5.60371	1.40298	190.602	7.36080E-03
7	-31.9412	1.76625	241.788	7.30498E-03
8	-85.1764	2.44269	334.684	7.29849E-03
9	-123.842	2.85607	394.1	7.24706E-03
10	-165.87	3.33208	463.233	7.19309E-03
11	-209.019	3.69535	524.423	7.04651E-03
12	-247.964	4.13378	584.68	7.07016E-03
13	-311.847	4.63485	669.906	6.91865E-03
14	-349.672	5.51171	784.662	7.02431E-03
15	-395.622	5.51171	784.662	7.02431E-03
16	-441.292	5.98772	834.463	7.17554E-03
17	-498.45	6.589	906.952	7.26500E-03
18	-540.758	7.14017	958.235	7.45138E-03
19	-589.23	7.82914	1016.37	7.70301E-03
20	-639.384	8.76863	1053.21	8.32563E-03
21	-658.436	9.54528	1051.63	9.07664E-03
22	-672.446	11.8377	1051.39	.0112591

#	SIG1	SIM3	INVAR. - P	Af
1	65.5373	32.9218	43.7937	.944963
2	89.6244	24.5162	46.219	.602474
3	130.069	27.3181	61.5684	.35449
4	165.269	35.7237	78.9054	.216284
5	207.047	49.733	102.171	.089052
6	259.948	69.346	132.88	-.029400
7	337.471	95.6834	176.279	-.132104
8	483.603	148.919	260.48	-.254498
9	581.685	187.584	318.951	-.31424
10	692.846	229.612	384.023	-.35807
11	797.184	272.761	447.569	-.398568
12	896.387	311.707	506.6	-.424102
13	1045.5	375.589	598.891	-.465508
14	1198.08	413.414	674.968	-.445634
15	1244.03	459.364	720.918	-.504194
16	1339.5	505.035	783.189	-.528834
17	1469.14	562.193	864.51	-.549589
18	1562.74	604.501	923.912	-.564328
19	1669.35	652.973	991.764	-.579738
20	1756.34	703.126	1054.2	-.607081
21	1773.81	722.179	1072.72	-.626109
22	1787.57	736.188	1086.65	-.63958

~~S9-78-BS Core 22~~
59-71 cm. Consol Pres. = 98.1 kPa

AXIAL #	PWP (KN/m²)	STRAIN	SIG1-SIG3 (KN/m²)	STRAIN/Q
1	2.52167	.0299995	15.3638	1.95261E-03
2	3.64241	.05	27.5795	1.81294E-03
3	5.32353	.075	38.7413	1.93592E-03
4	5.99595	.1	45.7102	2.18769E-03
5	7.11669	.125	53.0246	2.35740E-03
6	8.12538	.175	65.2015	2.68399E-03
7	8.96594	.225	76.6692	2.93468E-03
8	9.38622	.2875	88.8109	3.23721E-03
9	10.3669	.325	99.9183	3.25266E-03
10	10.8432	.4125	112.701	3.66014E-03
11	10.8432	.4625	126.203	3.66473E-03
12	10.9272	.525	138.979	3.77754E-03
13	10.3669	.575	151.064	3.80633E-03
14	8.96594	.6875	167.544	4.10341E-03
15	7.42492	.75	178.878	4.19280E-03
16	5.60371	.825	190.174	4.33813E-03
17	4.90325	.8625	196.335	4.39300E-03
18	-.560371	1.0375	224.678	4.61772E-03
19	-7.00464	1.2125	251.194	4.82694E-03
20	-13.4489	1.4	278.958	5.01868E-03
21	-19.1927	1.5375	302.299	5.08603E-03
22	-27.7384	1.7375	334.976	5.18693E-03
23	-34.4628	1.875	331.08	5.66328E-03
24	-41.1873	2	359.754	5.55936E-03
25	-49.0325	2.175	388.838	5.59359E-03
26	-56.0371	2.3125	420.365	5.50117E-03
27	-63.8823	2.45	451.801	5.42274E-03
28	-72.0077	2.6125	482.683	5.41245E-03
29	-80.6935	2.925	514.702	5.68290E-03
30	-98.065	3.0625	577.627	5.30186E-03
31	-107.871	3.225	616.883	5.22790E-03
32	-113.475	3.35	642.08	5.21742E-03
33	-121.881	3.475	675.975	5.14072E-03
34	-130.286	3.6	707.087	5.09131E-03
35	-146.257	3.875	770.877	5.02675E-03
36	-153.822	3.9875	802.168	4.97090E-03
37	-155.503	4.0875	806.358	5.06909E-03

S9-78-BS CORE 22
122-136cm Consol Pres. =210 kPa

TRIAXIAL #	PWP	STRAIN	SIG1-SIG3	STRAIN/Q
1	7.82623	.0701164	21.7666	3.22129E-03
2	11.5022	.0841397	70.7315 (input error)	1.18956E-03
3	16.6011	.112186	43.5148	2.57811E-03
4	23.4787	.140233	59.8161	2.34440E-03
5	30.712	.182303	76.0975	2.39565E-03
6	37.471	.210349	92.3782	2.27704E-03
7	45.1787	.280466	114.034	2.45949E-03
8	51.7005	.322535	130.27	2.47591E-03
9	60.9497	.406675	162.7	2.49955E-03
10	66.8787	.476791	184.263	2.58756E-03
11	72.4519	.574954	211.152	2.72294E-03
12	74.8235	.687141	237.954	2.88770E-03
13	74.8235	.869443	275.304	3.15812E-03
14	71.859	1.00968	307.257	3.28609E-03
15	67.5901	1.16393	344.453	3.37907E-03
16	61.7798	1.27612	370.942	3.44021E-03
17	56.918	1.3883	397.37	3.49373E-03
18	48.1432	1.55658	434.217	3.58481E-03
19	38.6568	1.72486	470.935	3.66263E-03
20	25.8503	1.8651	502.327	3.71292E-03
21	21.3443	1.99131	536.371	3.71255E-03
22	14.941	2.08947	559.827	3.73235E-03
23	8.30054	2.18763	585.897	3.73382E-03
24	.711475	2.28579	611.914	3.73548E-03
25	-5.21748	2.36993	637.969	3.71481E-03

#	SIG1	SIM3	INVAR.	Af
1	225.011	203.245	210.5	.359552
2	270.3	199.569	223.146	.162618
3	237.985	194.47	208.975	.381504
4	247.408	187.592	207.531	.392514
5	256.456	180.359	205.725	.403588
6	265.978	173.6	204.393	.405626
7	279.926	165.892	203.904	.396186
8	289.64	159.37	202.794	.396873
9	312.821	150.121	204.354	.374615
10	328.455	144.192	205.613	.362952
11	349.771	138.619	209.003	.343127
12	374.202	136.248	215.566	.314445
13	411.552	136.248	228.016	.271785
14	446.469	139.212	241.631	.233872
15	487.934	143.481	258.299	.196224
16	520.233	149.291	272.939	.166548
17	551.523	154.153	286.61	.143237
18	597.145	162.928	307.667	.110874
19	643.349	172.414	329.393	.0820852
20	687.547	185.221	352.663	.0514611
21	726.098	189.727	368.517	.0397938
22	755.957	196.13	382.739	.0266886
23	788.667	202.77	398.069	.0141672
24	822.273	210.36	414.331	1.16270E-03
25	854.258	216.288	428.945	-8.17827E-03

S9-78-BS CORE 22
71-84 cm Consol PRes.= 240.3 kPa

TRIAXIAL #	PWP	STRAIN	SIG1-SIG3	STRAIN/Q
1	17.9319	.0868272	48.1753	1.80232E-03
2	31.3808	.148846	86.6616	1.71756E-03
3	48.7523	.22327	125.085	1.78495E-03
4	59.9597	.297693	147.426	2.01927E-03
5	77.8916	.483751	191.935	2.52038E-03
6	88.5387	.632597	226.784	2.78943E-03
7	93.0216	.806252	258.273	3.12170E-03
8	94.7028	1.01712	286.36	3.55188E-03
9	89.6594	1.31481	339.427	3.87362E-03
10	80.1331	1.62491	398.443	4.07815E-03
11	68.3653	1.95981	450.661	4.34875E-03
12	56.5975	2.26991	502.642	4.51596E-03
13	7.28483	3.2002	672.107	4.76144E-03
14	26.8978	3.8452	788.172	4.87863E-03
15	-81.8142	4.86232	957.209	5.07968E-03
16	-118.799	5.54453	1071.8	5.17312E-03
17	-172.314	6.53684	1231.78	5.30681E-03
18	-222.187	7.54155	1376.06	5.48054E-03
19	-264.215	9548.34	-155806	-.0612837
20	-264.215	8.54627	1508.1	5.66693E-03
21	-298.958	9.51377	1611.4	5.90405E-03
22	-352.474	11.7465	1721.99	6.82144E-03
23	-372.927	11.7465	1721.99	6.82144E-03
24	-381.333	12.9868	1734.15	7.48888E-03
25	-384.975	14.0164	1744.03	8.03675E-03
26	-320.532	2.64202	-147.089	-.0179621

#	SIG1	SIM3	INVAR. - P	Af
1	270.503	222.327	238.386	.372222
2	295.54	208.878	237.766	.362107
3	316.592	191.507	233.202	.389755
4	327.725	180.299	229.441	.406712
5	354.303	162.368	226.346	.405822
6	378.505	151.721	227.315	.39041
7	405.511	147.238	233.329	.360168
8	431.917	145.556	241.01	.330712
9	490.026	150.6	263.742	.26415
10	558.569	160.126	292.94	.201116
11	622.555	171.894	322.114	.1517
12	686.303	183.662	351.209	.1126
13	905.081	232.974	457.01	.0108388
14	1055.33	267.157	529.881	-.0341268
15	1279.28	322.073	641.143	-.0854716
16	1430.85	359.058	716.323	-.110841
17	1644.36	412.573	823.168	-.13989
18	1838.51	462.446	921.133	-.161466
19	155301	504.474	-51430.7	-1.69580E-03
20	2012.57	504.474	1007.17	-.175198
21	2150.61	539.217	1076.35	-.185527
22	2314.72	592.733	1166.73	-.20469
23	2335.18	613.186	1187.18	-.216567
24	2355.74	621.592	1199.64	-.219896
25	2369.27	625.234	1206.58	-.220738
26	413.703	560.792	511.762	2.17918

S9-78-3S CORE 22

209-224 cm Consol Pres.= 346.2 kPa

TRIAXIAL #	PWP	STRAIN	SIG1-SIG3	STRAIN/Q
1	28.0187	.375549	13.0066	.0288737
2	43.1487	.625915	36.3272	.0172299
3	94.7031	.688507	98.5403	6.98706E-03
4	139.533	.826208	186.449	4.43128E-03
5	169.793	1.03902	253.234	4.10301E-03
6	186.324	1.31442	304.065	4.32283E-03
7	189.966	1.6399	354.429	4.62687E-03
8	185.764	2.11559	429.392	4.92695E-03
9	170.914	2.67892	508.239	5.27098E-03
10	147.939	3.35491	605.651	5.53934E-03
11	108.712	4.40644	753.818	5.84550E-03
12	70.0466	5.24517	880.811	5.95494E-03
13	44.8298	6.40937	1016.62	6.30462E-03
14	21.8546	7.5235	1091.44	6.89317E-03
15	14.0093	8.65015	1197.41	7.22405E-03
16	-70.0466	10.1023	1366.16	7.39463E-03
17	-70.0466	10.1023	1366.16	7.39463E-03

#	SIG1	SIM3	INVAR. - P	Af
1	331.158	318.152	322.487	2.15418
2	339.349	303.022	315.131	1.18778
3	350.008	251.467	284.314	.961059
4	393.087	206.638	268.787	.748369
5	429.611	176.377	260.789	.6705
6	463.912	159.846	261.202	.612776
7	510.633	156.204	274.347	.535979
8	589.799	160.407	303.538	.43262
9	683.496	175.257	344.67	.336286
10	803.883	198.232	400.116	.244264
11	991.277	237.458	488.731	.144216
12	1156.93	276.124	569.727	.0795252
13	1317.96	301.341	640.213	.0440971
14	1415.76	324.316	688.13	.0200235
15	1557.59	360.18	759.316	-.0116997
16	1782.38	416.217	871.605	-.0512725
17	1782.38	416.217	871.605	-.0512725

S9-78-BS CORE 23
68-81cm Consol Pres. 193.2 kPa

TRIAXIAL #	PWP	STRAIN	SIG1-SIG3	STRAIN/Q
1	10.6721	.0375	17.4189	2.15283E-03
2	35.3365	.1375	50.0294	2.74839E-03
3	50.989	.2625	71.6914	3.66153E-03
4	65.8113	.45	93.2405	4.82623E-03
5	79.4479	.7875	125.34	6.28292E-03
6	88.9342	1.3875	156.801	8.84878E-03
7	90.7129	2.6	213.216	.0121942
8	86.3255	3.6	258.272	.0139388
9	79.4479	4.6	302.347	.0152143
10	-181.426	3.4625	-146.142	-.0236927
#	SIG1	SIM3	INVAR. - P	Af
1	199.936	182.517	188.323	.612673
2	207.882	157.852	174.529	.706316
3	213.891	142.2	166.097	.711228
4	220.618	127.378	158.458	.705824
5	239.081	113.741	155.521	.63386
6	261.056	104.255	156.522	.567178
7	315.692	102.476	173.548	.425451
8	365.135	106.863	192.954	.334243
9	416.088	113.741	214.523	.26277
10	228.473	374.615	325.901	1.24143

S9-78-BS CORE 23
3-11 cm. Consol Pres.=294.2kPa

TRIAXIAL #	PWP	STRAIN	SIG1-SIG3	STRAIN/Q
1	18.2798	.125	100.539	1.24330E-03
2	43.0881	.25	152.628	1.63797E-03
3	71.8135	.4375	183.076	2.38972E-03
4	107.59	.6875	210.609	3.26435E-03
5	151.461	1.1875	245.357	4.83988E-03
6	167.13	1.5	260.446	5.75935E-03
7	178.881	1.8125	285.977	6.33792E-03
8	186.715	2.125	289.008	7.35274E-03
9	189.326	2.375	309.235	7.68025E-03
10	194.549	3	342.407	8.76150E-03
11	194.81	3.3125	362.068	9.14884E-03
12	194.81	3.5625	366.309	9.72540E-03
13	194.549	3.875	375.443	.0103211
14	194.81	4.125	400.204	.0103073
15	193.505	4.375	413.278	.0105861
16	189.326	4.6875	428.558	.0109378
17	187.237	5.0625	445.986	.0113513
18	182.145	5.5625	463.918	.0119903
19	180.187	5.875	472.489	.0124341
20	176.008	6.3125	494.185	.0127736
21	169.088	6.9375	520.866	.0133192
22	161.907	7.625	551.734	.0138201
23	159.948	8.125	568.478	.0142926
24	154.725	8.625	588.686	.0146513
25	149.503	9.125	609.859	.0149625
26	143.235	9.75	629.891	.0154789
27	143.235	9.75	629.891	.0154789

#	SIG1	SIM3	INVAR. - P	Af
1	376.433	275.894	309.407	.181819
2	403.714	251.086	301.962	.282309
	405.437	222.361	283.386	.392261
4	397.193	186.585	256.787	.510851
5	388.07	142.713	224.499	.617309
6	387.491	127.045	213.86	.641705
7	401.27	115.293	210.619	.625508
8	396.467	107.459	203.795	.646055
9	414.082	104.848	207.926	.612242
10	442.032	99.6249	213.761	.568181
11	461.432	99.3638	220.053	.53805
12	465.673	99.3638	221.467	.53182
13	475.068	99.6249	224.773	.510185
14	499.567	99.3638	232.765	.486778
15	513.948	100.669	238.429	.468219
16	533.406	104.848	247.7	.441775
17	552.923	106.937	255.599	.419828
18	575.947	112.029	266.668	.392624
19	586.477	113.988	271.484	.381356
20	612.351	118.166	282.894	.356159
21	645.952	125.086	298.708	.324629
22	684.001	132.267	316.179	.293451
23	702.704	134.226	323.719	.281362
24	728.135	139.449	335.677	.262832
25	754.531	144.672	347.958	.245143
26	780.83	150.939	360.903	.227397
27	780.83	150.939	360.903	.227397

S9-78-BS Core 23

35-47 cm Consol Pres.= 98.1 kPa

TRIAXIAL #	PWP	STRAIN	SIG1-SIG3	STRAIN/Q
1	3.55738	.1625	3.26196	.0498166
2	5.6918	.2	12.4995	.0160006
3	9.72349	.225	18.4729	.01218
4	15.4153	.3	30.4031	9.86741E-03
5	18.3798	.3	36.9181	8.12610E-03
6	21.9372	.3125	41.2562	7.57462E-03
7	27.2732	.35	52.0935	6.71869E-03
8	32.2535	.3875	60.2104	6.43577E-03
9	37.9453	.4375	68.3126	6.40438E-03
10	41.5027	.5	76.3971	6.54475E-03
11	45.5344	.6125	87.135	7.02932E-03
12	48.0246	.7375	95.1333	7.75228E-03
13	51.9377	.9375	111.125	8.43645E-03
14	52.7677	1.1125	121.698	9.14146E-03
15	53.2421	1.45	140.066	.0103523
16	52.412	1.7125	153.073	.0111875
17	51.4634	1.925	163.424	.0117792
18	49.9218	2.1125	173.772	.0121567
19	48.6175	2.3125	184.056	.0125641
20	45.653	2.6125	199.4	.0131018
21	43.8743	2.8125	209.575	.01342
22	42.0956	3	219.735	.0136528
23	38.5382	3.3	234.853	.0140513
24	35.5738	3.5375	247.408	.0142982
25	32.3721	3.8125	262.417	.0145284
26	28.459	4.075	277.371	.0146915
27	23.2415	4.3625	292.163	.0149317
28	17.194	4.8	314.155	.0152791
29	9.48634	5.2625	335.844	.0156695
30	4.03169	5.6125	350.023	.0160347
31	-6.16612	6.3	370.434 kN/m²	.0170071

S9-78-3S CORE 23

35-47 cm.

#	SIG1	SIM3	INVAR.	Af
1	97.7696	94.5076	95.5949	1.09056
2	104.873	92.3732	96.5397	.455362
3	106.814	88.3415	94.4991	.526365
4	113.053	82.6497	92.7841	.50703
5	116.603	79.6852	91.9912	.497853
6	117.384	76.1278	89.8799	.53173
7	122.885	70.7918	88.1563	.523544
8	126.022	65.8115	85.8816	.53568
9	128.432	60.1197	82.8905	.555466
10	132.959	56.5623	82.028	.54325
11	139.666	52.5306	81.5756	.522573
12	145.174	50.0404	81.7515	.504813
13	157.252	46.1273	83.1689	.467381
14	166.996	45.2973	85.8634	.433595
15	184.889	44.8229	91.5115	.380122
16	198.726	45.653	96.6774	.342398
17	210.025	46.6016	101.076	.314908
18	221.915	48.1432	106.067	.287284
19	233.503	49.4475	110.8	.264145
20	251.812	52.412	118.879	.228951
21	263.766	54.1907	124.049	.209348
22	275.705	55.9694	129.214	.191574
23	294.38	59.5268	137.811	.164095
24	309.9	62.4912	144.961	.143706
25	328.109	65.6929	153.165	.123362
26	346.977	69.606	162.063	.102603
27	366.987	74.8235	172.211	.0795497
28	395.026	80.871	185.589	.0547308
29	424.423	88.5787	200.527	.0282463
30	444.056	94.0333	210.708	.0115184
31	474.665	104.231	227.709	-.0166457

S9-78-BS CORE 23
83-95 cm Consol Pres.=294.2 kPa

TRIAXIAL #	PWP	STRAIN	SIG1-SIG3	STRAIN/Q
1	3.20163	.125	4.89479	.0255374
2	6.04753	.25	7.60458	.0328749
3	11.3836	.5	10.2946	.048569
4	26.206	.75	19.4566	.0385473
5	35.3365	.775	38.3631	.0202017
6	43.9928	.7875	48.0829	.016378
7	-186.619	.8125	62.6541	.012968
8	53.1234	.8125	62.6541	.012968
9	64.7441	.8375	79.9178	.0104795
10	74.8233	.875	95.5413	9.15834E-03
11	89.6457	.9375	118.138	7.93566E-03
12	102.689	1	136.932	7.30292E-03
13	119.29	1.0875	156.74	6.93826E-03
14	136.484	1.225	178.037	6.88060E-03
15	147.157	1.35	193.927	6.96137E-03
16	156.643	1.5	211.333	7.09781E-03
17	169.094	1.75	230.592	7.58916E-03
18	176.801	2	248.683	8.04236E-03
19	180.359	2.125	257.427	8.25478E-03
20	184.509	2.375	272.718	8.70865E-03
21	187.118	2.5625	282.806	9.06100E-03
22	188.659	2.75	292.853	9.39038E-03
23	190.201	3	304.249	9.86035E-03
24	191.386	3.25	315.582	.0102984
25	192.098	3.55	328.784	.0107973
26	192.098	3.875	341.286	.0113541
27	191.861	4.125	350.318	.011775
28	190.438	4.5	361.949	.0124327
29	189.489	4.8125	376.315	.0127885
30	188.422	5.0625	385.666	.0131266
31	186.643	5.75	395.191	.0145499
32	184.509	5.75	407.508	.0141101
33	182.73	6.0625	417.411	.0145241
34	180.24	6.4375	427.463	.0150598
35	177.394	6.875	441.184	.0155831
36	172.295	7.375	454.452	.0162283
37	168.145	7.875	467.048	.0168612
38	164.943	8.1875	475.963	.017202
39	160.793	8.625	487.13	.0177058
40	157.473	9	498.51	.0180538
41	153.678	9.375	506.326	.0185157
42	149.647	9.8125	516.159	.0190106
43	143.599	10.375	528.558	.0196289
44	138.026	10.875	537.742	.0202235

S9-78-BS CORE 23
83-95 cm

#	SIG1	SIM3	INVAR. - F	Af
1	295.888	290.993	292.624	.65409
2	295.752	288.147	290.682	.795248
3	293.106	282.811	286.242	1.10578
4	287.445	267.989	274.474	1.34689
5	297.221	258.858	271.646	.921107
6	298.285	250.202	266.229	.914936
7	543.468	480.814	501.699	-2.97857
8	303.725	241.071	261.956	.847884
9	309.368	229.45	256.09	.810134
10	314.912	219.371	251.218	.783152
11	322.686	204.549	243.928	.758825
12	328.437	191.505	237.149	.749932
13	331.644	174.904	227.151	.761074
14	335.747	157.71	217.056	.766608
15	340.965	147.038	211.68	.758823
16	348.885	137.552	207.996	.741214
17	355.693	125.101	201.965	.733302
18	366.077	117.393	200.288	.71095
19	371.263	113.836	199.645	.700621
20	382.403	109.686	200.591	.676557
21	389.882	107.077	201.345	.661648
22	398.388	105.535	203.153	.644212
23	408.243	103.994	205.41	.625149
24	418.39	102.808	208.002	.606455
25	430.881	102.097	211.691	.584267
26	443.383	102.097	215.859	.562865
27	452.652	102.334	219.106	.547676
28	465.706	103.757	224.406	.526146
29	481.02	104.705	230.144	.503539
30	491.438	105.772	234.328	.488563
31	502.742	107.551	239.281	.472287
32	517.194	109.686	245.522	.452773
33	528.875	111.464	250.601	.437771
34	541.417	113.954	256.442	.421651
35	557.985	116.8	263.862	.402086
36	576.351	121.899	273.383	.379128
37	593.098	126.049	281.732	.360016
38	605.214	129.251	287.906	.346546
39	620.531	133.401	295.778	.330083
40	635.232	136.722	302.892	.315887
41	646.842	140.516	309.291	.303517
42	660.707	144.548	316.601	.289924
43	679.153	150.595	326.781	.271681
44	693.911	156.169	335.416	.256677

S9-78-BS   CORE 24
20-30 cm   Consol Pres.=22.7 kPa

TRIAXIAL #	PWP	STRAIN	SIG1-SIG3	STRAIN/
1	.0331268	.129988	.638927	.203447
2	4.79126E-03	.26988	1.12039	.240882
3	-.112823	.397649	1.28545	.309347
4	1.28253	.497719	5.10605	.0974764
5	3.54875	.578614	11.2981	.0512134
6	5.29091	.679001	15.7053	.0432339
7	6.57387	.775247	18.9561	.0408969
8	7.58415	.893876	21.5616	.0414568
9	8.42535	1.00322	23.4719	.0427411
10	9.10672	1.11651	25.3544	.0440361
11	9.66435	1.23728	26.7565	.0462424
12	10.1366	1.35422	28.2386	.0479562
13	10.3954	1.47505	29.3962	.0501781
14	10.8319	1.59293	30.5954	.0520643
15	11.0902	1.71458	31.7052	.0540787
16	11.2793	1.84196	32.7379	.0562637
17	11.4331	1.96208	33.451	.0586553
18	11.5289	2.08492	34.2599	.060856
19	11.677	2.2114	35.2193	.0627895
20	11.7075	2.33481	35.9467	.0649519
21	11.7075	2.45317	36.9343	.06642
22	11.7162	2.58656	37.5854	.0688181
23	11.8351	2.70504	38.3936	.0704555
24	11.8212	2.83997	39.2569	.0723432
25	11.8077	2.95681	40.0834	.0737664
26	11.7903	3.08732	40.7323	.0757954
27	11.7685	3.21357	41.484	.0774655
28	11.7249	3.34175	42.2357	.0791215
29	11.6944	3.47519	42.894	.0810181
30	11.6422	3.60121	43.5252	.0827384
31	11.5463	3.73099	44.1713	.0844665
32	11.6422	3.86158	44.9858	.0858399
33	11.5681	3.99729	45.5005	.0878516
34	11.4941	4.12521	46.3048	.0890882
35	11.3851	4.2573	46.8953	.0907832
36	11.2937	4.38683	47.6134	.0921343
37	11.2427	4.51687	48.3854	.093352
38	11.0998	4.64451	48.997	.0947917
39	10.9978	4.77565	49.6429	.0962
40	10.9146	4.90698	50.1659	.0978151
41	10.9538	5.0363	50.8616	.0990197
42	10.8406	5.16015	51.539	.100121
43	10.784	5.29023	52.0411	.101655
44	10.5966	5.42033	52.67	.102911
45	10.4659	5.54517	53.0085	.104609

S9-78-BS CORE 24

20-30 cm

46	10.3962	5.67042	53.6472	.105698
47	10.2834	5.79989	54.1346	.107138
48	10.1096	5.90257	54.718	.107872
49	10.1113	6.10262	55.0368	.110882
50	10.0355	6.17191	55.5238	.111158
51	9.87823	6.23912	56.0654	.111283
52	9.77327	6.42066	56.5613	.113517
53	9.67305	6.5419	57.1394	.11449
54	9.62512	6.66226	57.5338	.115797
55	9.3851	6.80076	58.1564	.116939
56	9.25179	6.92034	58.6962	.117901
57	9.10236	7.04424	59.1767	.119037
58	9.142	7.16858	59.789	.119898
59	9.02831	7.3012	60.32	.121041
60	8.88454	7.42652	60.8063	.122134
61	8.77998	7.54398	61.3751	.122916
62	8.64929	7.67464	62.0618	.123661
63	8.53471	7.79795	62.6192	.12453
64	8.37875	7.93245	62.9805	.125951
65	8.18359	8.03575	63.5134	.12652
66	8.03069	8.15661	64.1253	.127198
67	8.06989	8.30766	64.7637	.128276
68	7.92612	8.43593	65.3633	.129023
69	7.73401	8.55917	65.9235	.129835
70	7.57019	8.69052	66.2834	.131112
71	7.42993	8.82329	66.921	.131846
72	7.27264	8.94818	67.6178	.132335
73	7.13762	9.0758	68.1885	.133099
74	6.91107	9.20353	68.6078	.134147
75	6.77165	9.33936	69.0662	.135227
76	6.81958	9.46813	69.6764	.135848
77	6.65405	9.59913	70.2406	.136661
78	6.49808	9.73632	70.7553	.137606
79	6.35432	9.86194	71.039	.138824
80	6.1792	9.99814	71.2967	.140233
81	6.03542	10.1229	71.8497	.140889
82	5.87425	10.2567	72.4001	.141667
83	5.70827	10.3943	72.8112	.142756
84	5.67558	10.5276	73.0438	.144127
85	5.53355	10.6457	73.3268	.145182
86	5.3519	10.7762	73.6085	.1464
87	5.22948	10.9034	73.8485	.147645
88	5.02473	11.0327	74.0338	.149023
89	4.89839	11.157	74.2379	.150287
90	4.74898	5.0595	78.8802	.0641417

S9-78-BS CORE 24

20-30 cm

#	SIG1	SIM3	INVAR. - F	AF.
1	23.3046	22.6657	22.8787	.0518476
2	23.824	22.7036	23.0771	-4.27642E-03
3	24.0971	22.8116	23.2401	-.0877699
4	26.5223	21.4163	23.1103	.251179
5	30.4482	19.1501	22.9161	.314102
6	33.1132	17.4079	22.643	.336087
7	35.0811	16.125	22.4437	.346793
8	36.6763	15.1147	22.3019	.351743
9	37.7454	14.2735	22.0974	.358955
10	38.9465	13.5921	22.0436	.359176
11	39.791	13.0345	21.9533	.361196
12	40.8008	12.5622	21.9751	.358962
13	41.6997	12.3035	22.1022	.353629
14	42.4624	11.8669	22.0654	.354036
15	43.3138	11.6086	22.177	.349791
16	44.1575	11.4195	22.3322	.344533
17	44.7167	11.2658	22.4161	.341786
18	45.4299	11.1699	22.5899	.336513
19	46.2411	11.0218	22.7616	.331752
20	46.938	10.9913	22.9735	.325491
21	47.9256	10.9913	23.3027	.316983
22	48.568	10.9826	23.5111	.311722
23	49.2572	10.8637	23.6615	.308259
24	50.1345	10.8776	23.9632	.301125
25	50.9745	10.8911	24.2522	.294579
26	51.6408	10.9085	24.486	.289458
27	52.4143	10.9303	24.7583	.283688
28	53.2096	10.9739	25.0525	.277607
29	53.8984	11.0044	25.3024	.272636
30	54.5819	11.0566	25.565	.267481
31	55.3238	11.1525	25.8762	.261399
32	56.0424	11.0566	26.0519	.258797
33	56.6312	11.1307	26.2975	.254241
34	57.5095	11.2048	26.6397	.248226
35	58.209	11.3137	26.9454	.242778
36	59.0185	11.4052	27.2763	.237193
37	59.8415	11.4561	27.5846	.232357
38	60.596	11.599	27.9314	.22654
39	61.3439	11.701	28.2486	.221539
40	61.9501	11.7842	28.5061	.217571
41	62.6066	11.745	28.6989	.215366
42	63.3972	11.8582	29.0379	.210338
43	63.9559	11.9149	29.2619	.20722
44	64.7722	12.1022	29.6588	.201189
45	65.2414	12.2329	29.9024	.197439

S9-78-BS CORE 24

20-30 cm

46	65.9498	12.3026	30.185	.193789
47	66.55	12.4154	30.4603	.18996
48	67.3073	12.5892	30.8286	.184758
49	67.6243	12.5875	30.9331	.183719
50	68.1871	12.6633	31.1712	.180743
51	68.886	12.8206	31.5091	.176191
52	69.4869	12.9256	31.7793	.172791
53	70.1651	13.0258	32.0722	.169289
54	70.6076	13.0737	32.2517	.167295
55	71.4701	13.3137	32.6992	.161377
56	72.1432	13.447	33.0124	.157622
57	72.7732	13.5965	33.322	.153816
58	73.3459	13.5568	33.4865	.152904
59	73.9905	13.6705	33.7772	.149673
60	74.6205	13.8143	34.083	.146112
61	75.294	13.9188	34.3772	.143054
62	76.1113	14.0495	34.7368	.139366
63	76.7833	14.1641	35.0372	.136296
64	77.3004	14.3201	35.3136	.133037
65	78.0287	14.5152	35.6864	.128848
66	78.7935	14.6681	36.0432	.125234
67	79.3926	14.6289	36.2168	.124605
68	80.156	14.7727	36.5671	.121225
69	80.8883	14.9648	36.9393	.117318
70	81.412	15.1286	37.2231	.11421
71	82.1899	15.2689	37.5759	.111025
72	83.044	15.4262	37.9654	.107555
73	83.7497	15.5612	38.2907	.104675
74	84.3955	15.7878	38.657	.100733
75	84.9934	15.9272	38.9492	.0980458
76	85.5756	15.8792	39.1114	.097847
77	86.2853	16.0448	39.4583	.0947322
78	86.956	16.2007	39.7858	.0918388
79	87.3835	16.3445	40.0242	.0894484
80	87.8164	16.5196	40.2852	.0866688
81	88.5131	16.6634	40.6133	.0840006
82	89.2247	16.8246	40.9579	.081136
83	89.8018	16.9906	41.261	.0783982
84	90.067	17.0232	41.3712	.0777011
85	90.4921	17.1653	41.6075	.0754643
86	90.9554	17.3469	41.8831	.0727077
87	91.3179	17.4693	42.0855	.0708136
88	91.7079	17.6741	42.352	.0678708
89	92.0383	17.8004	42.5464	.0659824
90	94.83	17.9498	44.2432	.060205

S9-78-BS CORE 24
30-40 cm Consol Pres.=91.5 kPa

TRIAXIAL #	PWP	STRAIN	SIG1-SIG3	STRAIN/D
1	.790314	.501571	1.05113	.477172
2	2.72531	.527245	3.24978	.16224
3	9.24869	.629944	15.175	.0415119
4	15.5309	.426382	23.3205	.0182836
5	20.7371	.717053	28.3289	.0253118
6	27.5397	.73906	35.935	.0205666
7	33.9288	.74273	42.0581	.0176596
8	39.7433	.82067	46.9067	.0174958
9	44.4343	.802331	50.7633	.0156053
10	48.2472	.772986	53.5164	.0144439
11	50.8878	1.08017	55.211	.0195643
12	52.7689	1.15719	56.4351	.0205048
13	54.2521	1.54414	57.8503	.026692
14	56.3575	1.60741	59.8424	.0268607
15	57.7434	1.57807	61.514	.0256558
16	58.6215	1.65693	62.9938	.026305
17	59.5049	1.70736	64.3146	.026547
18	60.1767	1.94668	65.4295	.0297524
19	60.7268	1.94485	66.7986	.0291151
20	61.2167	2.3373	67.8763	.0344340
21	61.4188	1.98336	69.3987	.0285792
22	62.0811	2.37765	70.3854	[illegible]
23	62.4513	2.2071	71.7164	.0507753
24	62.6312	2.31346	72.9111	[illegible]
25	62.7581	2.48218	74.0977	[illegible]
26	62.864	2.40608	75.3071	[illegible]
27	62.9168	2.73618	76.2778	[illegible]
28	62.9063	2.77285	77.4142	[illegible]
29	62.864	2.79945	78.5632	.053633
30	62.7687	2.99934	79.5826	[illegible]
31	63.266	3.07178	80.6716	.0380776
32	63.3188	3.26251	81.6047	[illegible]
33	63.0121	3.38079	82.7581	[illegible]
34	62.9274	3.73382	83.5455	.041692
35	62.8534	3.93555	84.4939	.0465779
36	62.6629	4.02907	85.6797	.0470248
37	62.4196	4.13727	86.6848	.0477278
38	62.2292	4.51322	87.7303	.0514443
39	62.1551	4.32984	89.1464	.0485699
40	62.409	4.44629	90.3604	.0497062

S9-78-BS CORE 24
30-40 cm

41	62.1752	4.80115	91.3745	.0525436
42	61.8229	4.51506	92.6455	.0487348
43	61.7086	4.66727	93.8688	.0497212
44	61.4315	4.69111	94.9641	.0493988
45	61.2463	4.75346	95.9263	.0495533
46	60.9702	5.06248	96.9162	.0522356
47	60.5787	5.12116	98.244	.052127
48	60.748	5.06064	99.3394	.050943
49	60.7374	5.22569	100.343	.0520782
50	60.4306	5.55946	101.232	.0549181
51	60.1979	5.48886	102.405	.0535993
52	59.9334	5.54938	103.64	.0535447
53	59.653	5.74836	104.58	.054966
54	59.4478	5.7777	105.691	.0546661
55	59.0902	5.98401	106.6	.056135
56	58.7273	6.52043	107.279	.0607801
57	59.0341	6.67906	108.451	.0615859
58	58.8437	6.79276	109.482	.0620447
59	58.5263	6.70107	110.793	.0604825
60	58.0925	7.00995	111.467	.063605
61	57.8175	7.25502	112.677	.064395
62	57.5308	7.30992	113.464	.0644248
63	57.1964	7.14854	114.898	.0622161
64	56.7606	7.18705	116.05	.0619307
65	56.6855	7.28057	117.251	.062094
66	56.6442	7.44838	118.287	.0629686
67	56.3575	7.62993	119.249	.0639683
68	55.9131	7.58867	120.644	.0629[illegible]
69	55.637	7.94536	121.428	.06545[illegible]
70	55.2689	7.90777	122.627	.06440[illegible]
71	54.9483	7.87109	124.023	.0634647
72	54.5917	8.12509	124.77	.065122[illegible]
73	54.1359	8.11592	126.009	.0644076
74	54.2098	8.2663	126.804	.0651897
75	54.104	8.31489	127.843	.0650398
76	53.6174	8.60098	128.627	.0668675
77	53.2355	8.70643	129.828	.0670615
78	52.8958	8.84673	130.706	.0676842
79	52.662	9.05487	131.813	.0686948
80	52.2209	9.28961	132.705	.0700018
81	342.239	14.8747	13.0426	1.14048

S9-78-BS   CORE 24

30-40 cm

#	SIG1	SIG3	INVAR_P	A_f
~~1~~	~~91.7849~~	~~90.7337~~	~~91.0841~~	~~.751869~~
2	92.0485	88.7987	89.882	.838613
~~3~~	~~97.4504~~	~~82.2754~~	87.3337	.609467
4	99.3137	75.9932	83.7667	.665975
~~5~~	~~99.1152~~	~~70.787~~	80.2299	.732012
6	99.9193	63.9843	75.9627	.766376
~~7~~	~~99.6533~~	~~57.5953~~	71.6146	.806713
8	98.6874	51.7807	67.4163	.847285
~~9~~	~~97.8531~~	~~47.0898~~	64.0109	.875322
10	96.7933	43.2769	61.1157	.90154
~~11~~	~~95.8472~~	40.6362	59.0399	.921698
12	95.1903	38.7552	57.5669	.935037
13	95.1222	37.2719	56.5553	.937[illegible]
14	95.009	35.1666	55.114	.941735
15	~~95.2946~~	33.7806	54.2853	.938704
16	95.8963	32.9025	53.9005	.930592
17	~~96.3337~~	32.0191	53.4573	.925017
18	96.7768	31.3473	53.1571	.919719
19	97.5958	30.7972	53.0634	.909103
20	98.1836	30.3073	52.9328	.901006
21	99.504	30.1053	53.2382	.885013
22	99.8284	29.443	52.9048	.882016
~~23~~	~~100.789~~	~~29.0727~~	52.9782	.870809
24	101.804	28.8929	53.1966	.859007
25	102.864	28.7659	53.4651	.846965
26	103.967	28.6601	53.7625	.834760
~~27~~	~~104.885~~	~~28.6072~~	~~54.0331~~	.824839
28	106.032	28.6178	54.4225	.812571
29	107.223	28.6601	54.8478	.80017
30	108.338	28.7553	55.2829	.798721
31	108.93	28.2581	55.1486	.784241
32	109.89	28.2052	55.4334	.775162
33	111.27	28.512	56.098	.761401
34	112.142	28.5966	56.4451	.753211
35	113.165	28.6707	56.8353	.743081
36	114.541	28.8611	57.421	.731362
37	115.789	29.1045	57.9994	.720076
38	117.025	29.2949	58.5383	.709323
~~39~~	~~118.515~~	~~29.369~~	59.0844	.697225
40	119.475	29.115	59.2351	.690668

S9-78-BS CORE 24

30-40 cm

41	120.723	29.3488	59.807	.680443
42	122.347	29.7011	60.583	.667306
43	123.684	29.8154	61.105	.657393
44	125.057	30.0926	61.7473	.646892
45	126.204	30.2777	62.2532	.638473
46	127.47	30.5539	62.8593	.629102
47	129.189	30.9453	63.6933	.616615
48	130.115	30.776	63.8892	.61152
49	131.13	30.7866	64.2344	.605296
50	132.325	31.0934	64.8374	.596952
51	133.732	31.3262	65.4613	.587039
52	135.231	31.5907	66.1373	.578284
53	136.451	31.871	66.7311	.570405
54	137.767	32.0763	67.3065	.56247
55	139.034	32.4339	67.9673	.554315
56	140.076	32.7967	68.5564	.547426
57	140.941	32.4899	68.6403	.544339
58	142.162	32.6804	69.1743	.537475
59	143.791	32.9977	69.9289	.528247
60	144.898	33.4315	70.5872	.521164
61	146.383	33.7066	71.2655	.513127
62	147.458	33.9933	71.8147	.507030
63	149.226	34.3276	72.6271	.4978
64	150.813	34.7635	73.4467	.489105
65	152.089	34.8386	73.9222	.483455
66	153.167	34.8799	74.3089	.47887
67	154.415	35.1666	74.9162	.472604
68	156.255	35.6109	75.8254	.463457
69	157.315	35.88,	76.3631	.458189
70	158.882	36.2552	77.1307	.450708
71	160.599	36.5757	77.9168	.443049
72	161.703	36.9323	78.5224	.437538
73	163.397	37.3883	79.3912	.429619
74	164.118	37.3142	79.5821	.42751
75	165.263	37.42	80.0344	.423206
76	166.534	37.9067	80.7824	.416843
77	168.116	38.2886	81.5644	.410048
78	169.334	38.6282	82.1968	.404694
79	170.675	38.862	82.7997	[illegible]
80	172.009	39.3032	83.5383	.39351
81	446.806	433.763	438.111	-26.2402

APPENDIX C

SIMPLE SHEAR TEST RESULTS

CORE 24 200-209cm

Static Test - ADISL

Vert Stress .51 kg/cm^2

Dynamic Tests

Initial Vertical Stress .51 kg/cm^2

Cyclic Shear Stress

AD3DL	.054 kg/cm^2
AD4DL	.064 kg/cm^2
AD5DL	.074 kg/cm^2
AD6DL	.084 kg/cm^2

SYMBOLS

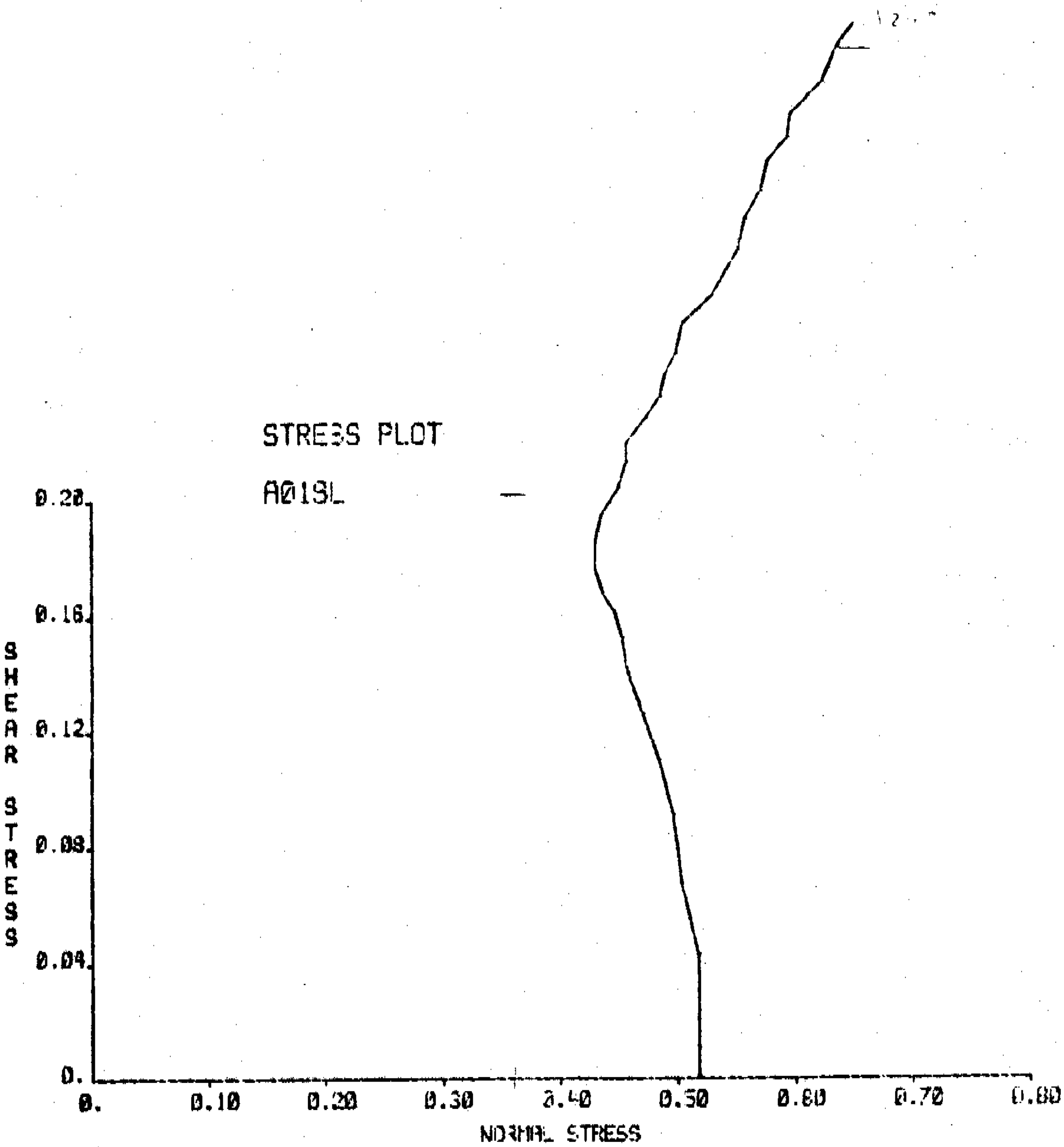
$$P = \frac{\bar{\sigma}_1 + \bar{\sigma}_3}{2}$$

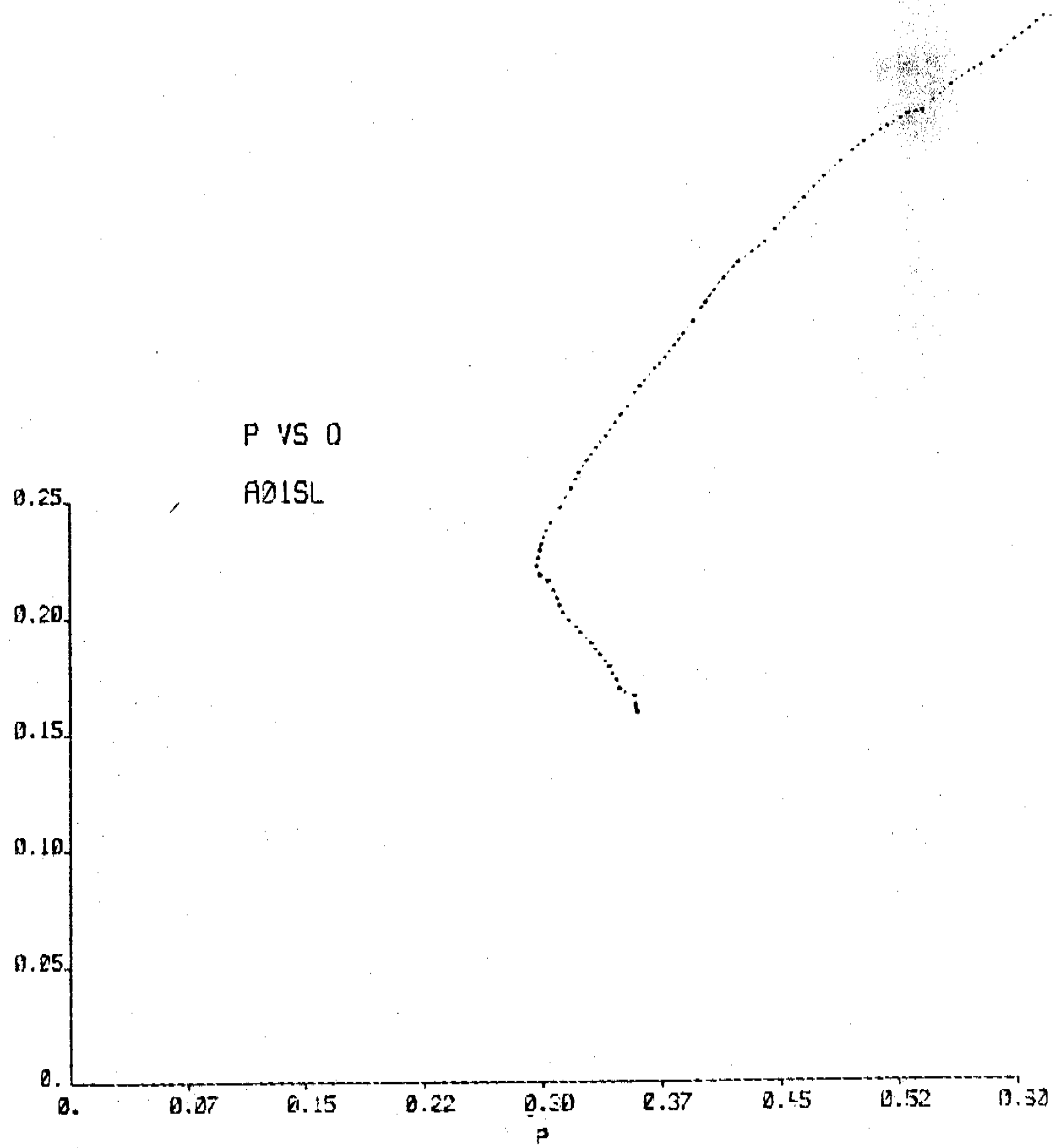
$$Q = \frac{\sigma_1 - \sigma_3}{2}$$

G = Shear Modulus

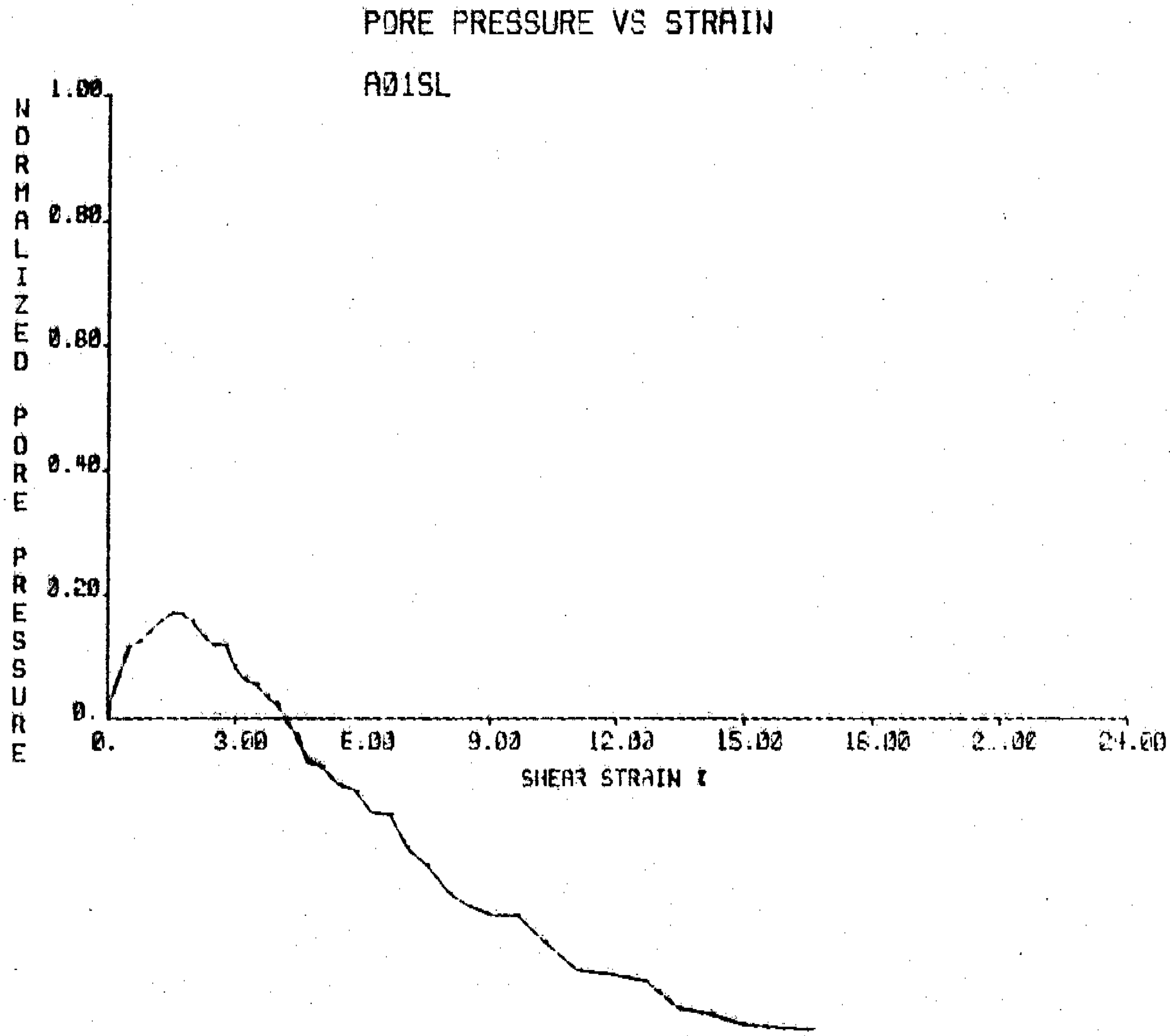
Units - English (metric) , kg/cm^2

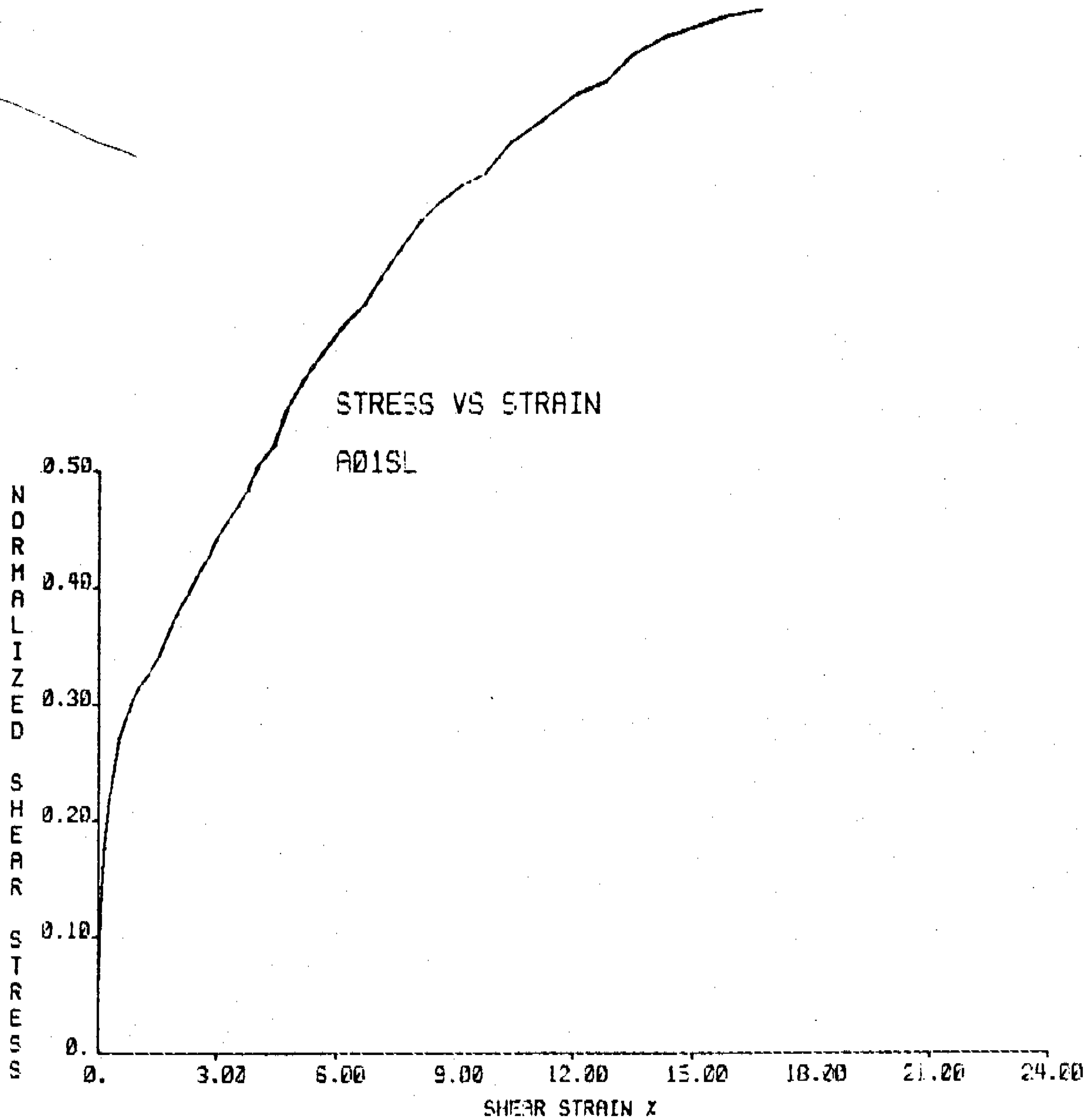
DYVIK (08) 11/11/82 2:58 PM

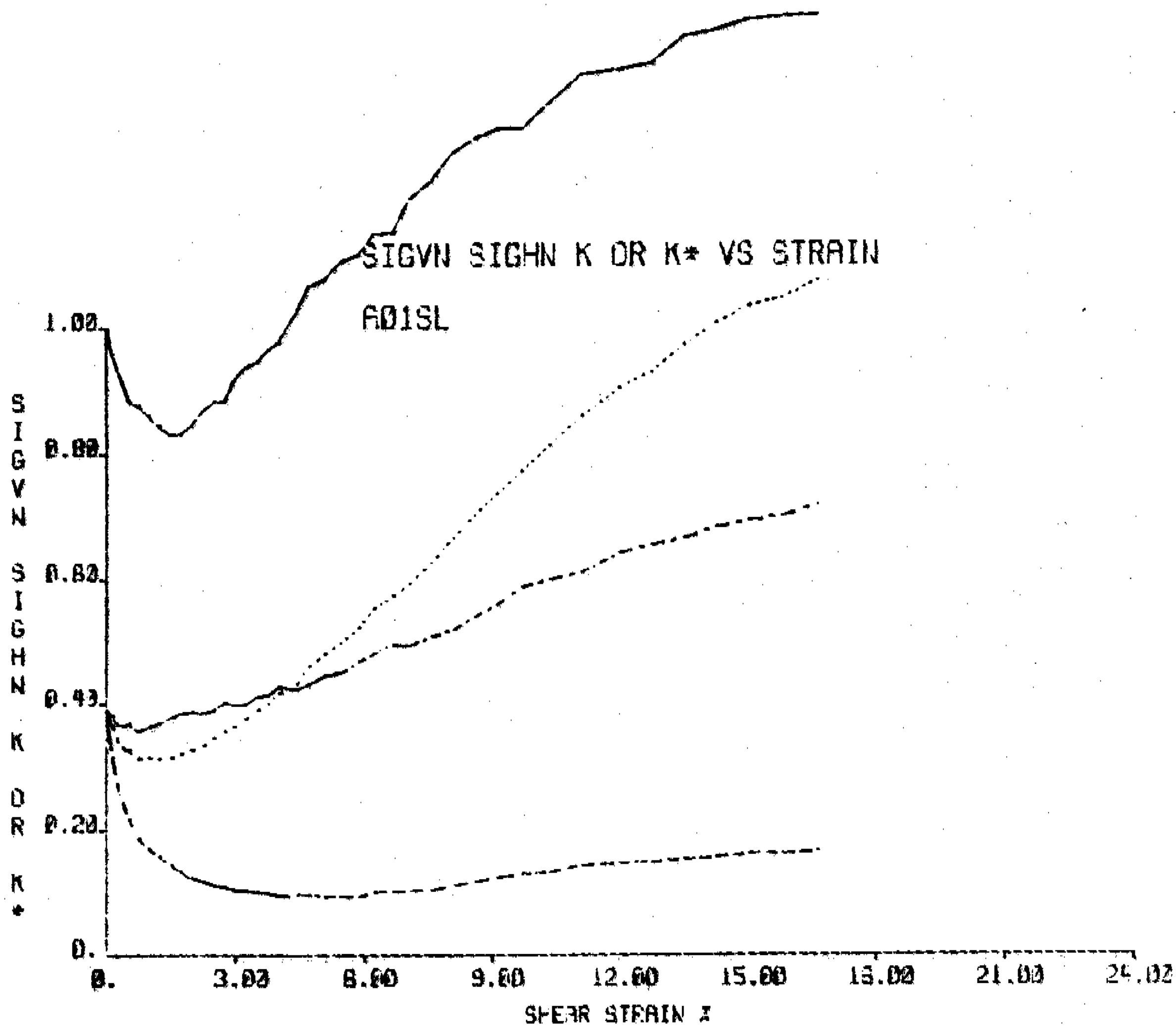


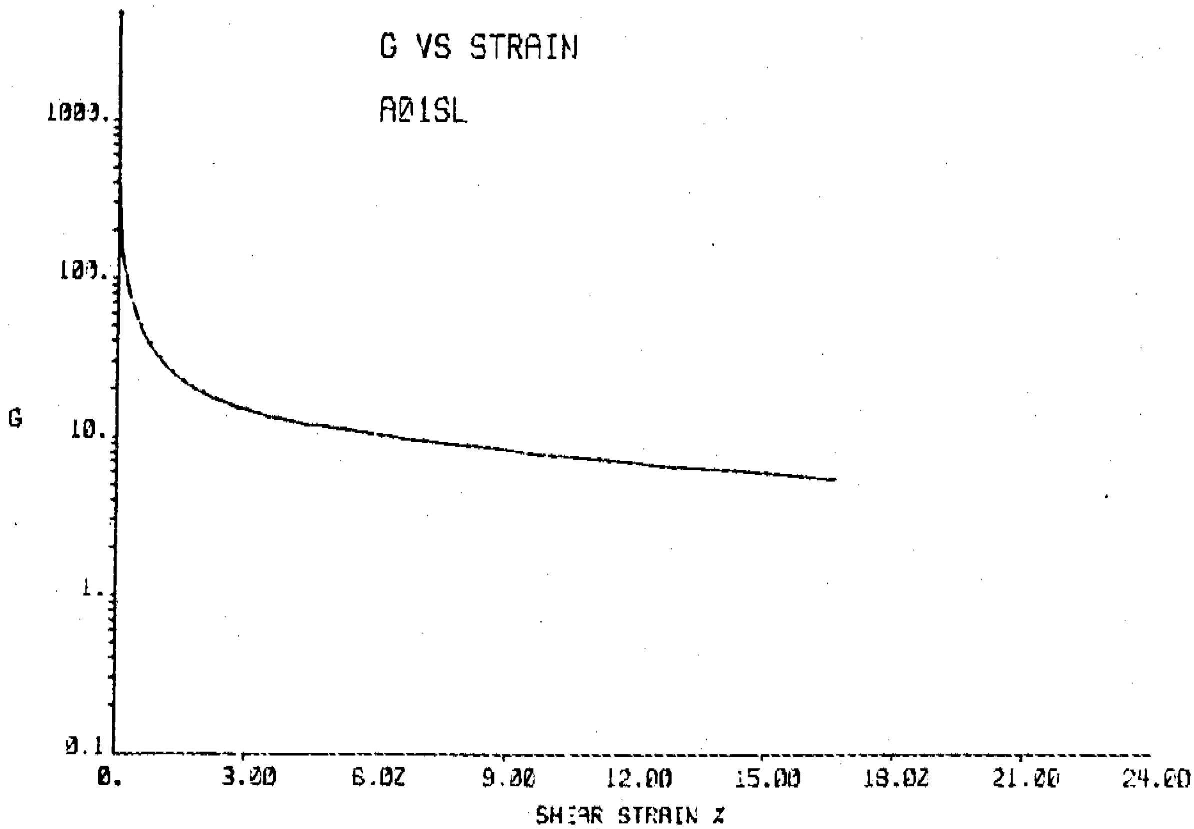

P VS Q
A01SL
0.25
0.20
0.15
Q
0.10
0.05
0.
0.
0.07
0.15
0.22
0.30
0.37
0.45
0.52
P

DYVIK (09) 11/11/82 2:58 PM

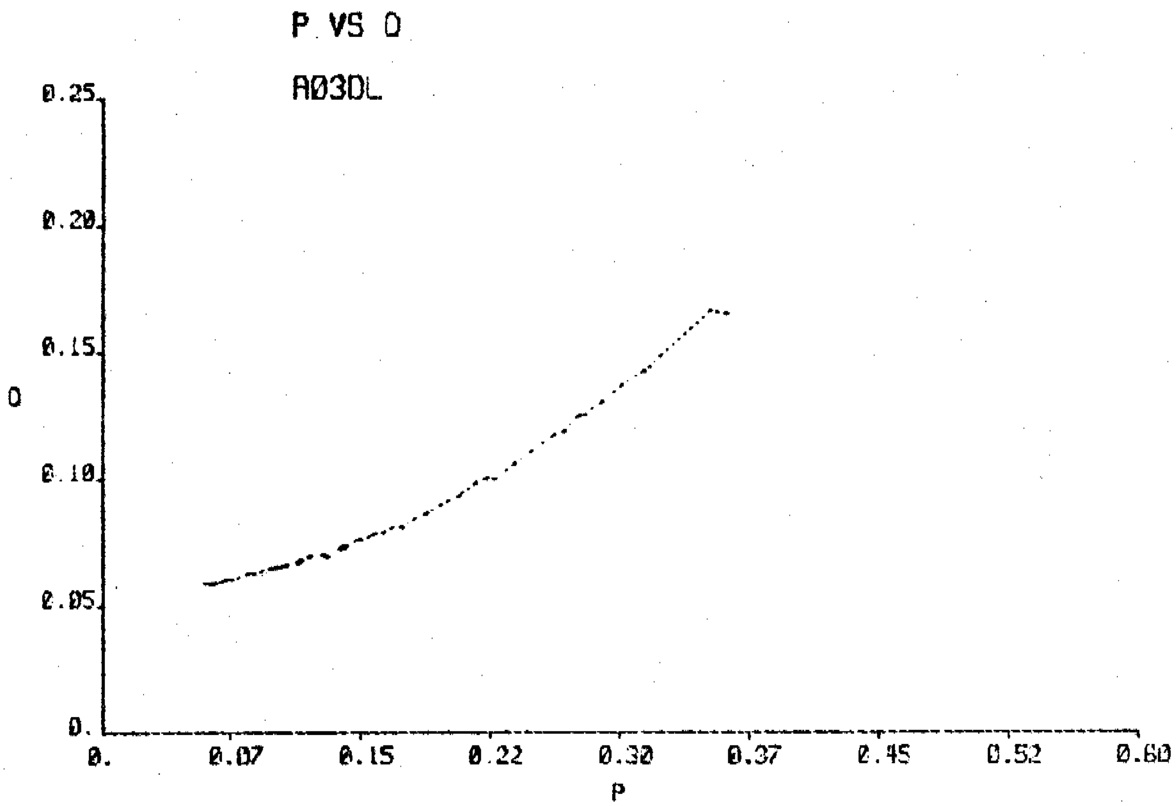


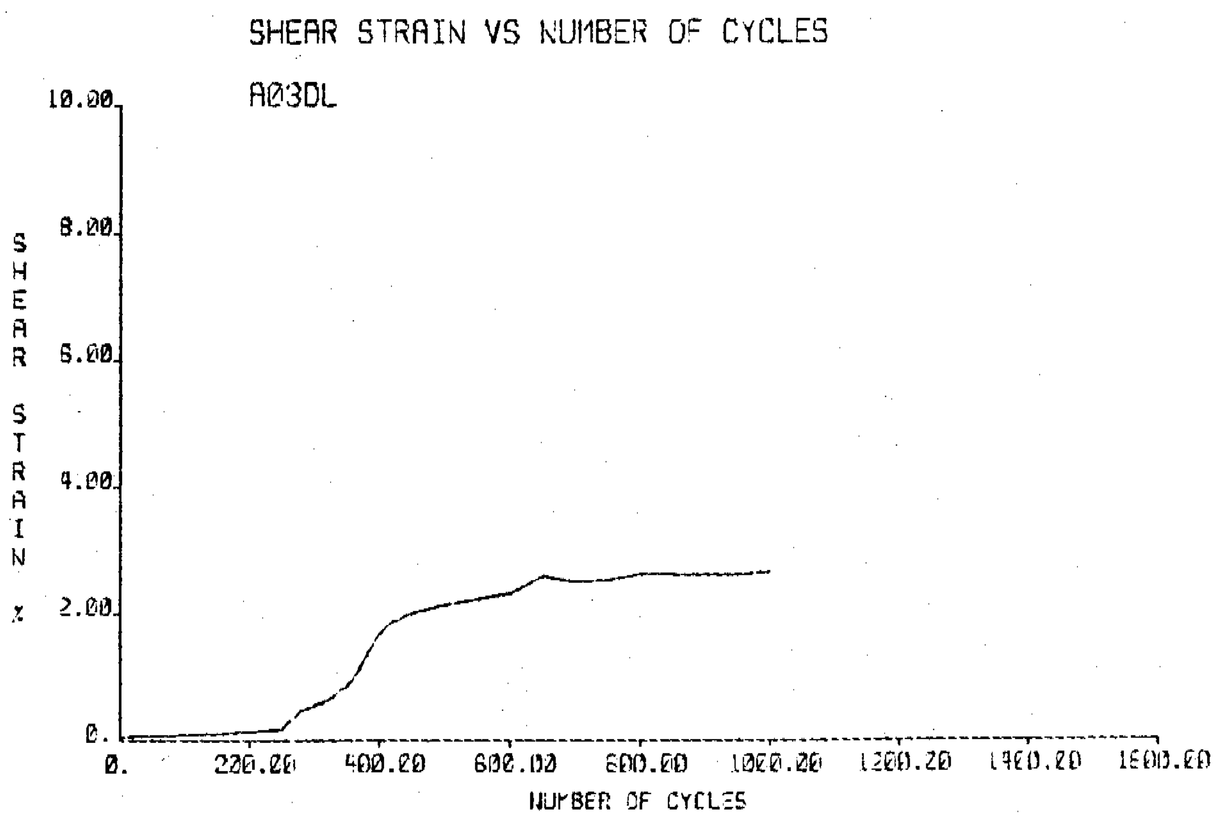

STRESS VS STRAIN
A01SL
NORMALIZED SHEAR STRESS
0.50
0.40
0.30
0.20
0.10
0.
0.
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
SHEAR STRAIN %


SIGVN SIGHN K OR K* VS STRAIN
A01SL
SIGVN SIGHN K OR K*
1.00
0.80
0.60
0.40
0.20
0.
0.
3.00
6.00
9.00
12.00
15.00
18.00
21.00
24.00
SHEAR STRAIN %

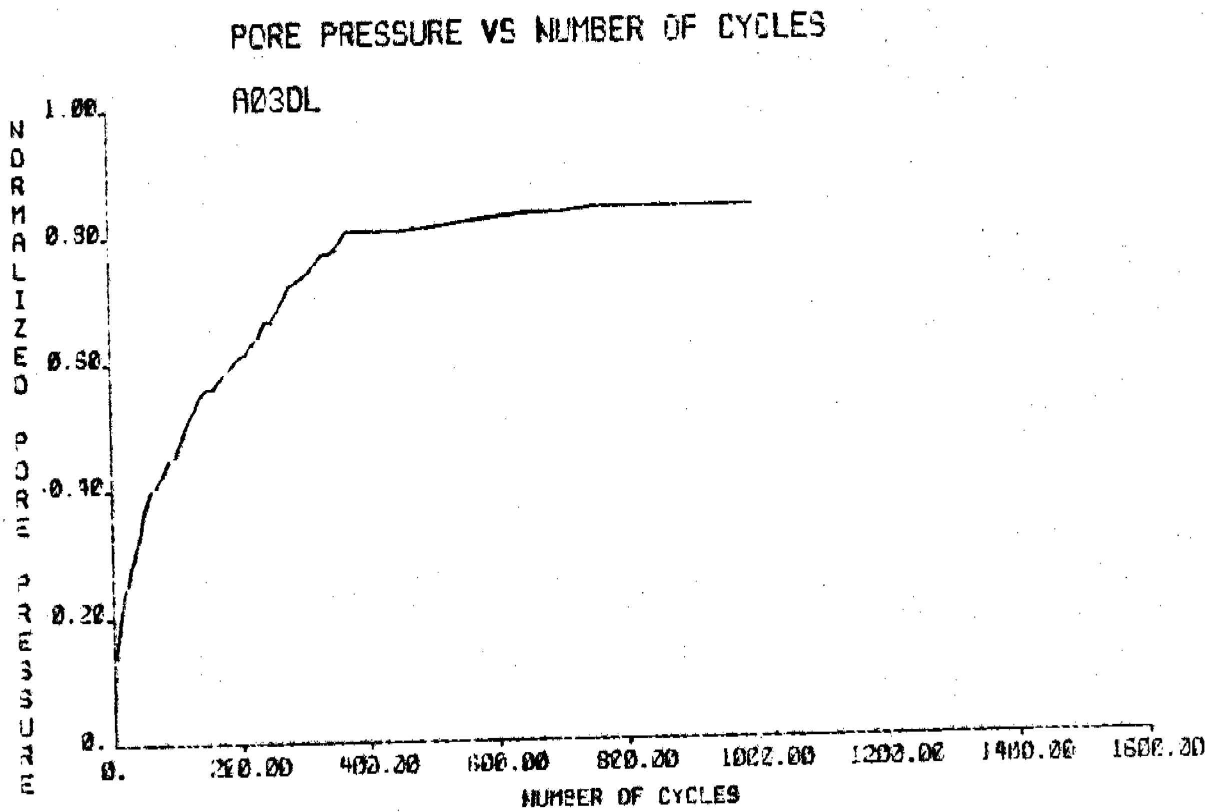

G VS STRAIN
A01SL
G
1000.
100.
10.
1.
0.1
0.
3.00
6.02
9.00
12.00
15.00
18.02
21.00
24.00
SHEAR STRAIN %

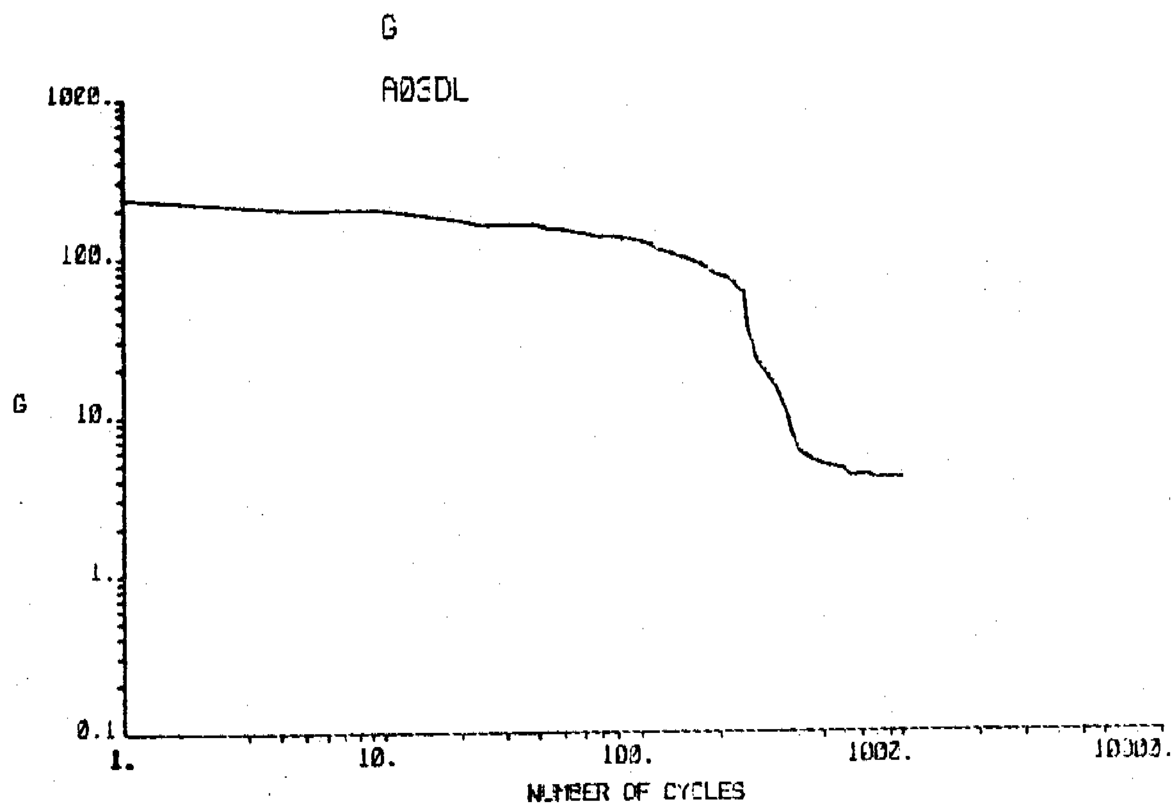
DYVIK (09) 11/11/80 3:09 PM

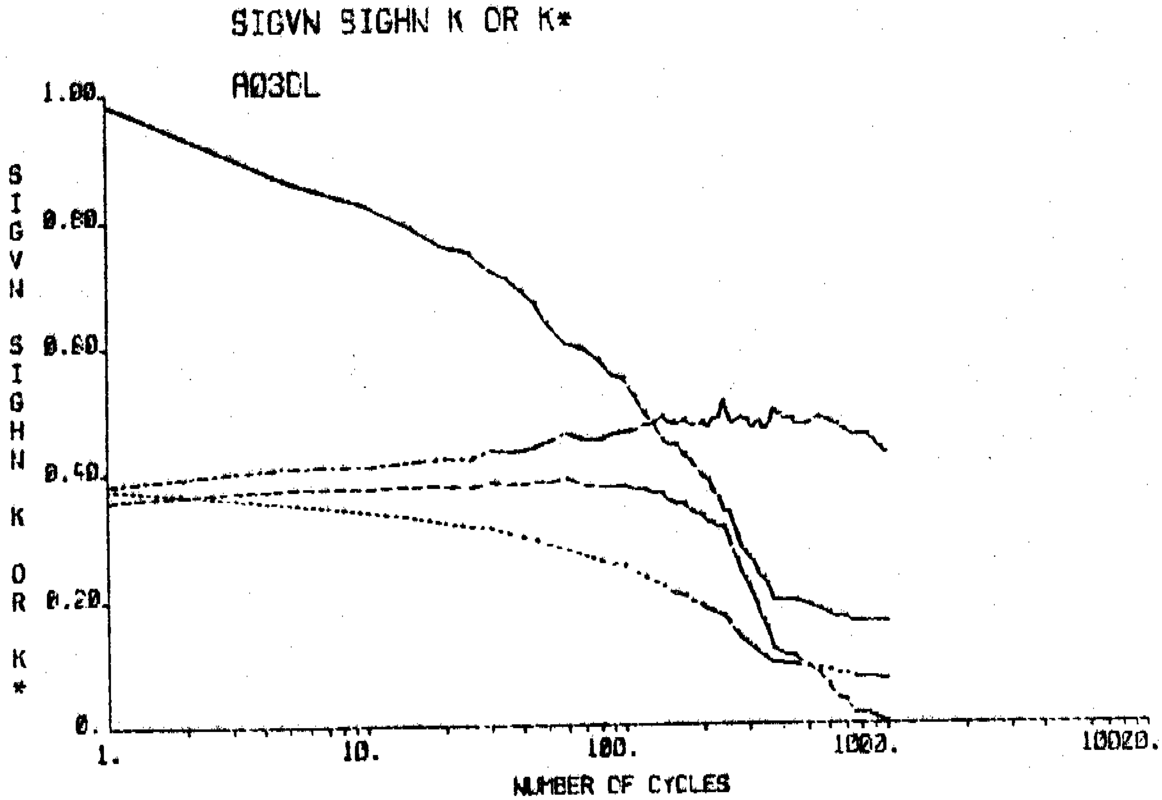



SHEAR STRAIN VS NUMBER OF CYCLES
A03DL
SHEAR STRAIN %
10.00
8.00
6.00
4.00
2.00
0.
0.
200.00
400.00
600.00
800.00
1000.00
1200.00
1400.00
1600.00
NUMBER OF CYCLES

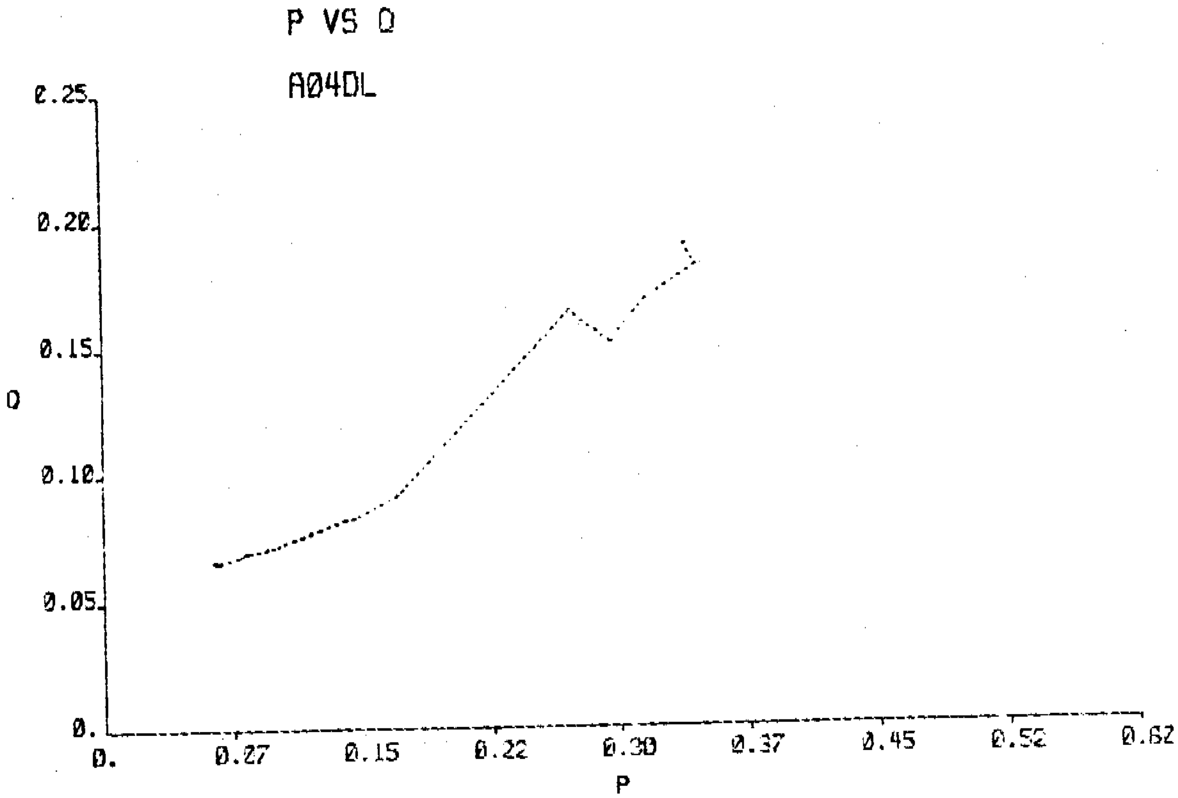
DYVIK (09) 11/11/80 3:26 PM




G
A03DL
1000.
100.
10.
1.
0.1
G
1.
10.
100.
1000.
10000.
NUMBER OF CYCLES


SIGVN SIGHN K OR K*
A03DL
1.00
0.80
0.60
0.40
0.20
0.
SIGVN SIGHN K OR K*
1.
10.
100.
1000.
10000.
NUMBER OF CYCLES

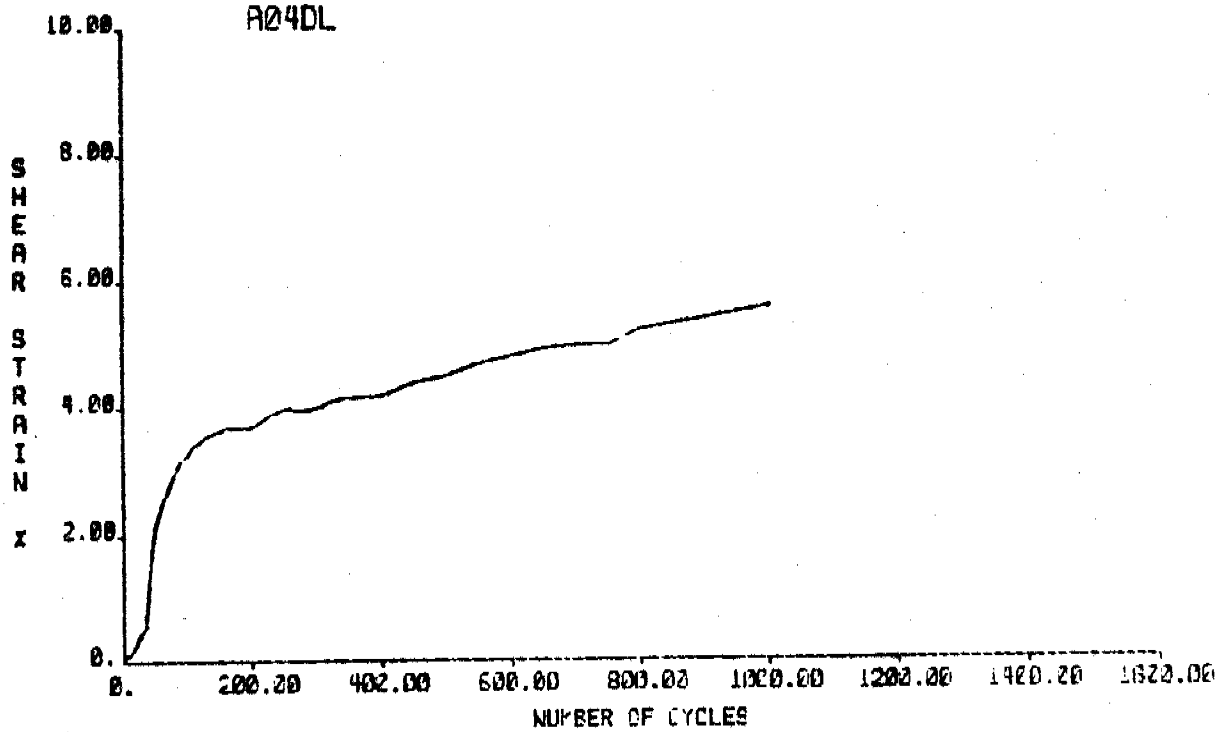
DYVIK (09) 11/11/80 3:_6 PM



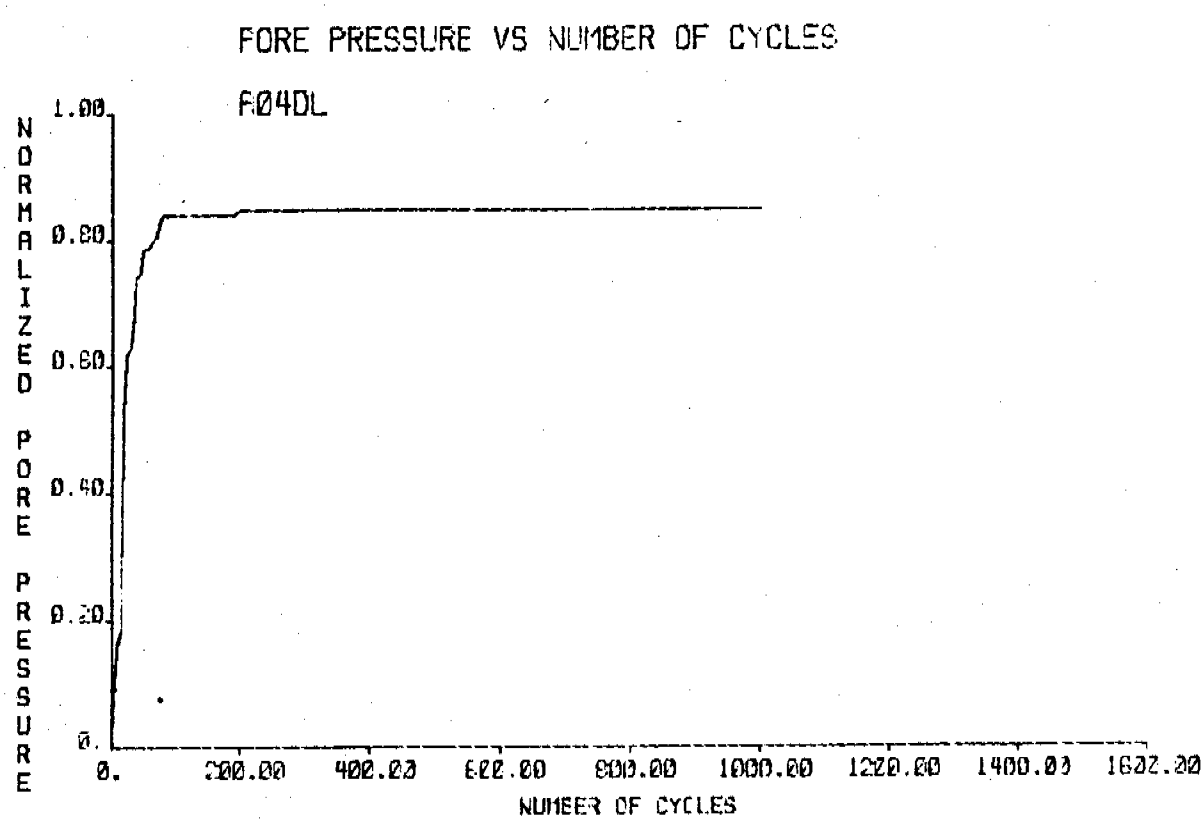
DYVIK (09) 11/11/80 3:14 PM

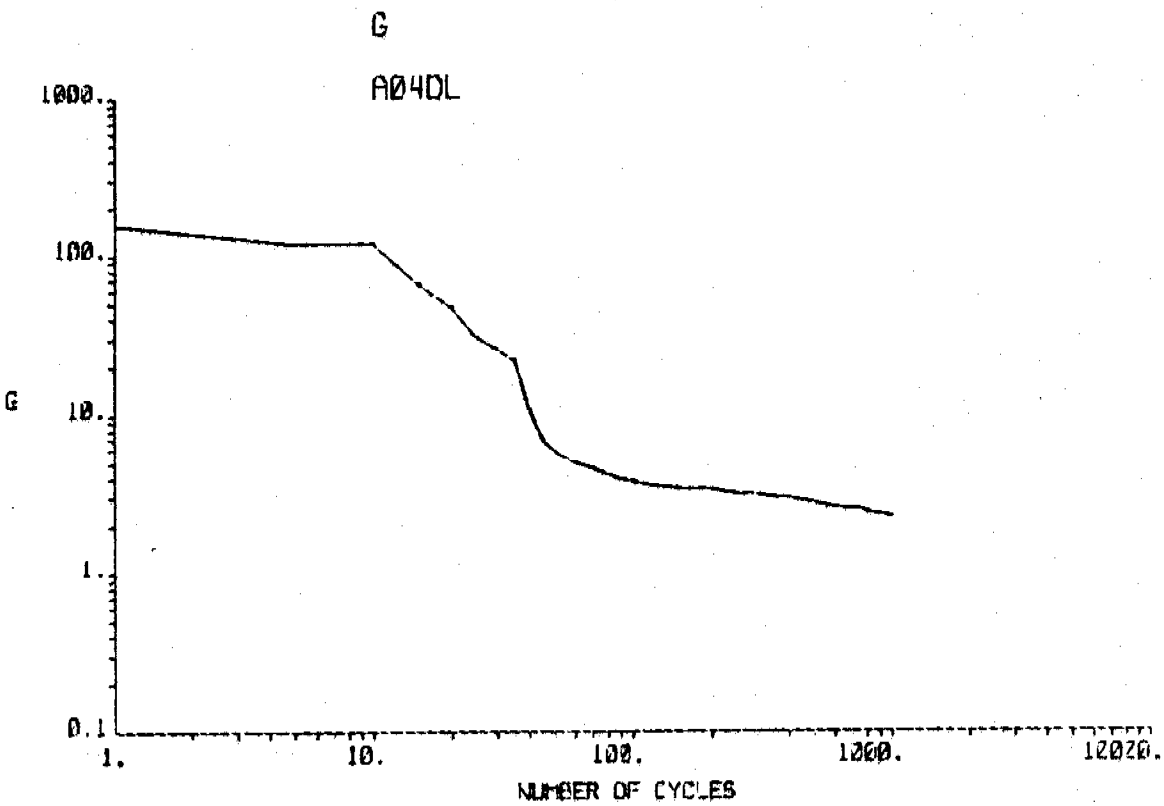
SHEAR STRAIN VS NUMBER OF CYCLES

A04DL

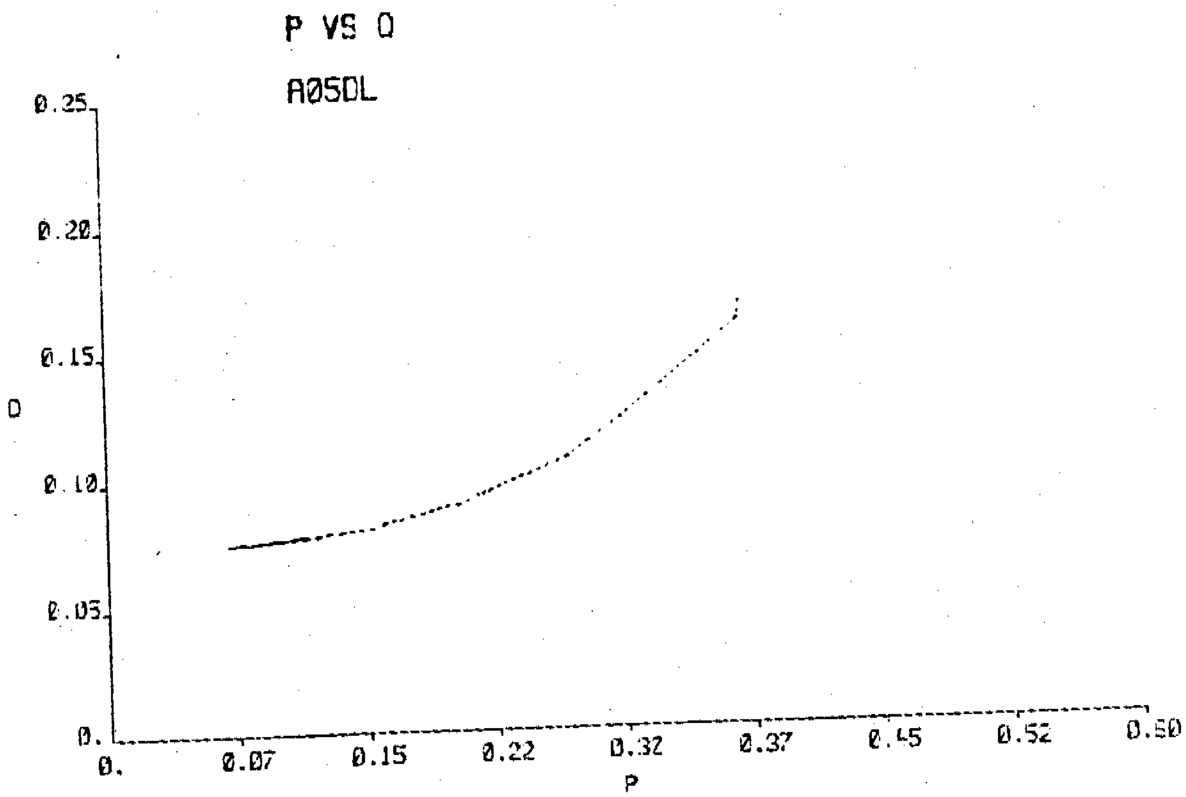


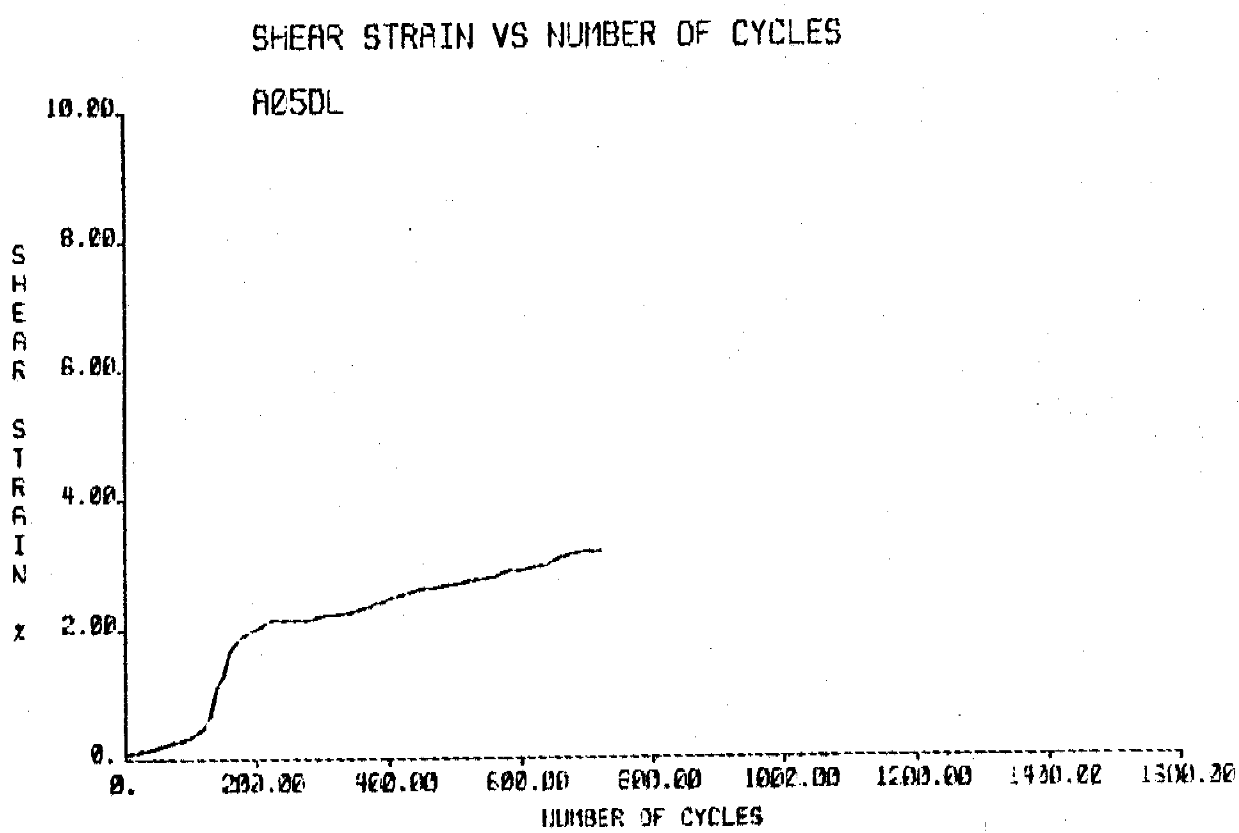
DYVIK (09) 11/11/80 3:14 PM




G
A04DL
1000.
100.
10.
1.
0.1
G
1.
10.
100.
1000.
10000.
NUMBER OF CYCLES

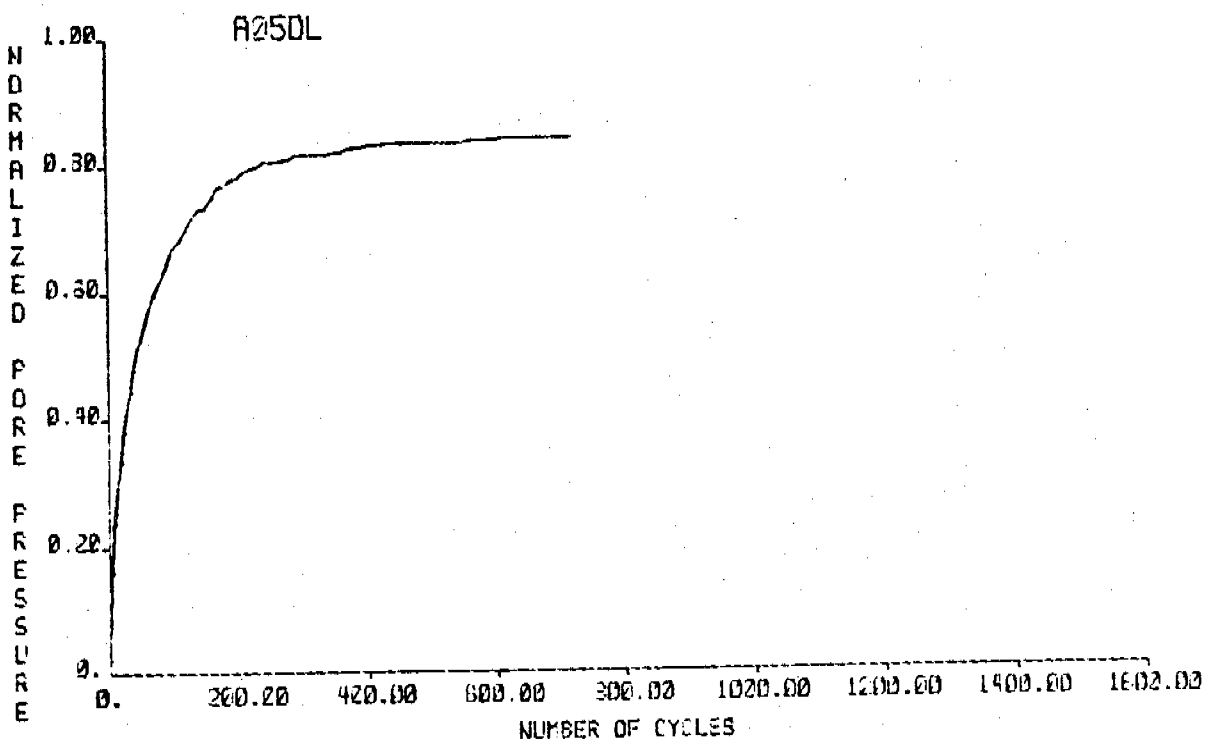
DYVIK (09) 11/11/80 3:24 PM



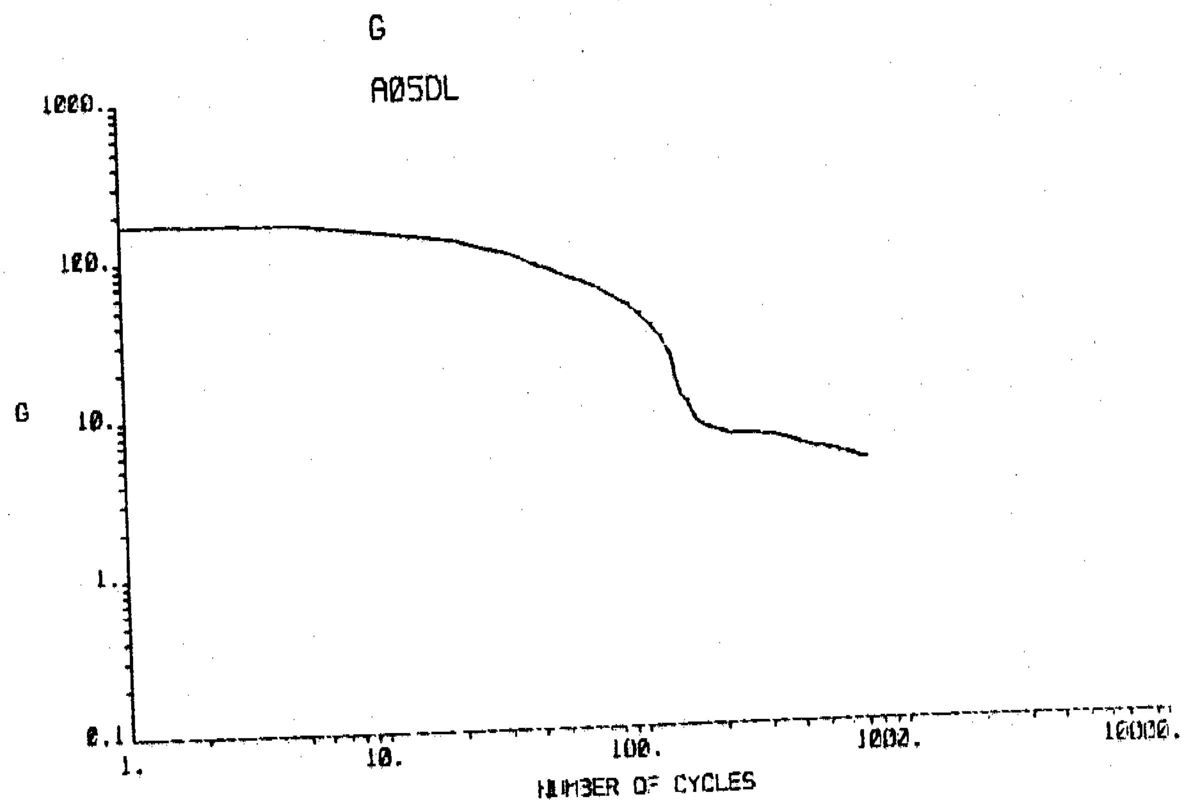

SHEAR STRAIN VS NUMBER OF CYCLES
A05DL
SHEAR STRAIN %
NUMBER OF CYCLES
10.00
8.00
6.00
4.00
2.00
0.
0.
200.00
400.00
600.00

CYVIK (29) 11/11/80 3:21 PM

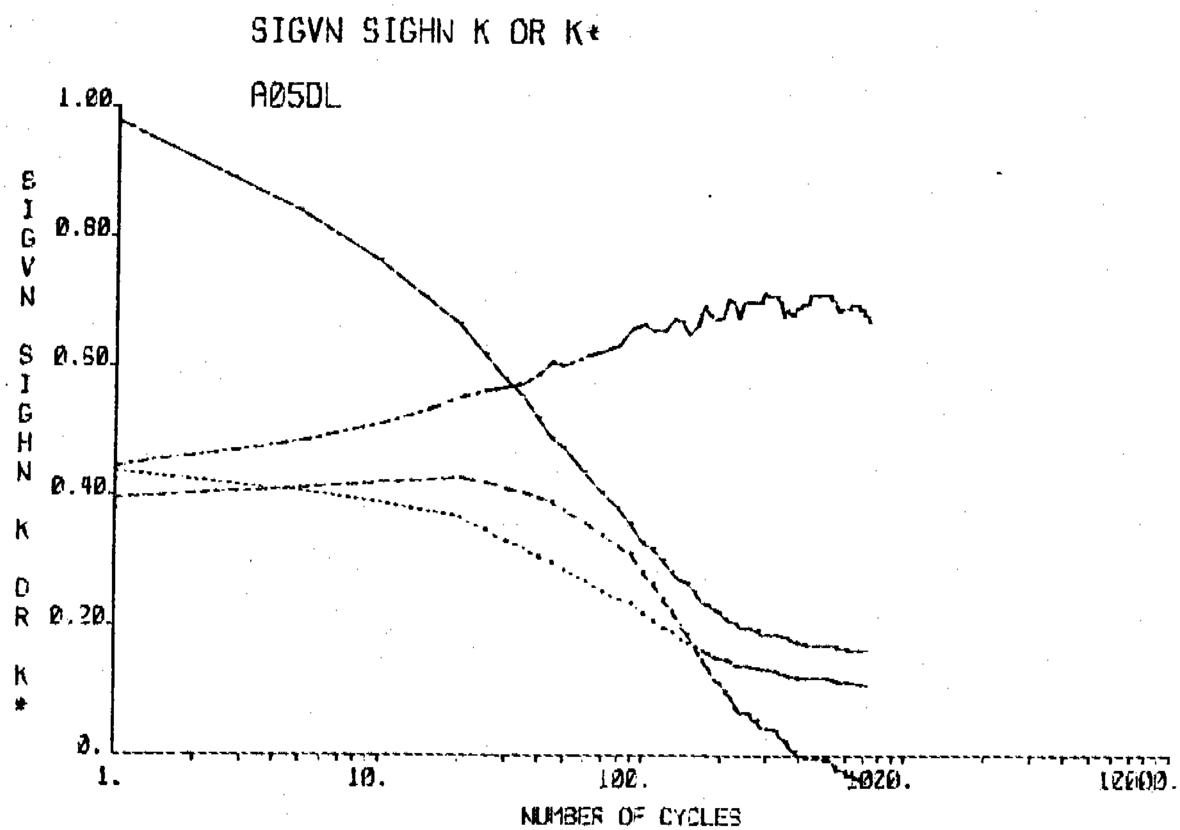
PORE PRESSURE VS NUMBER OF CYCLES

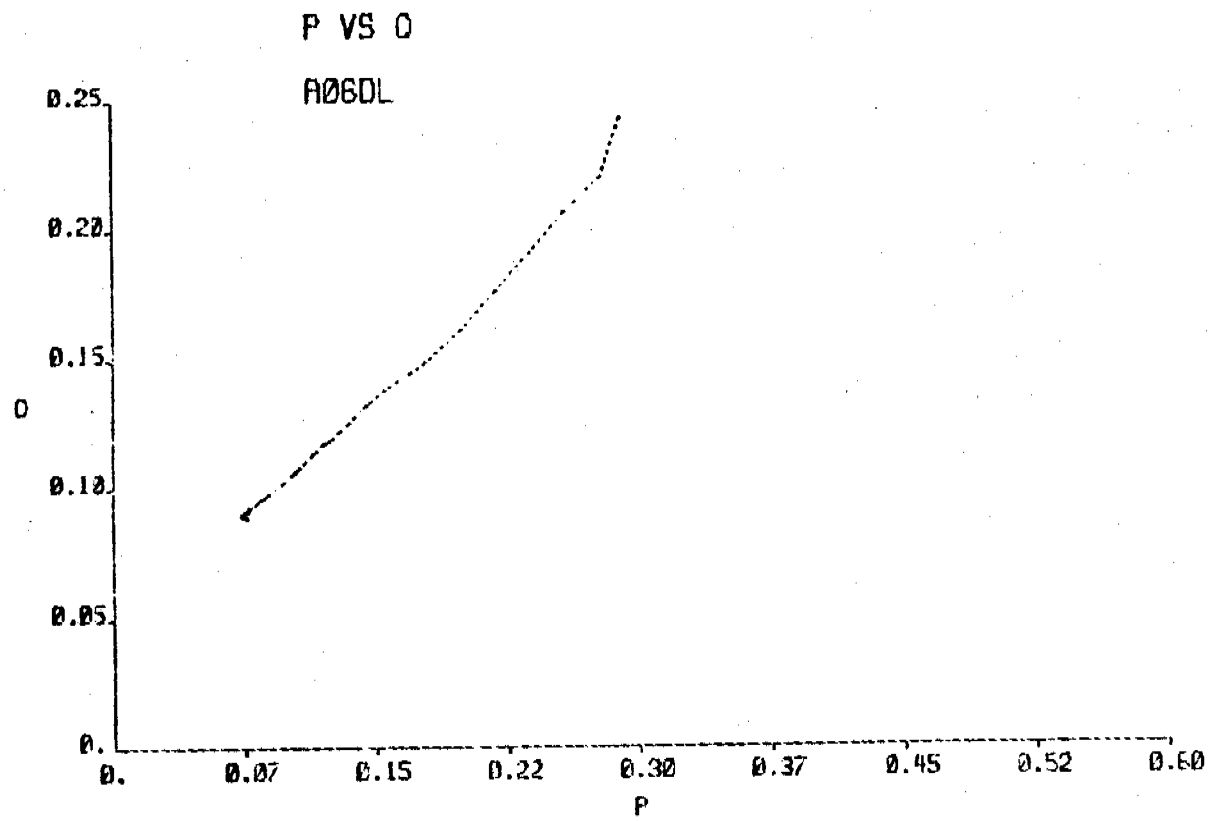


DYVIK (03) 11/11/80 3:22 PM

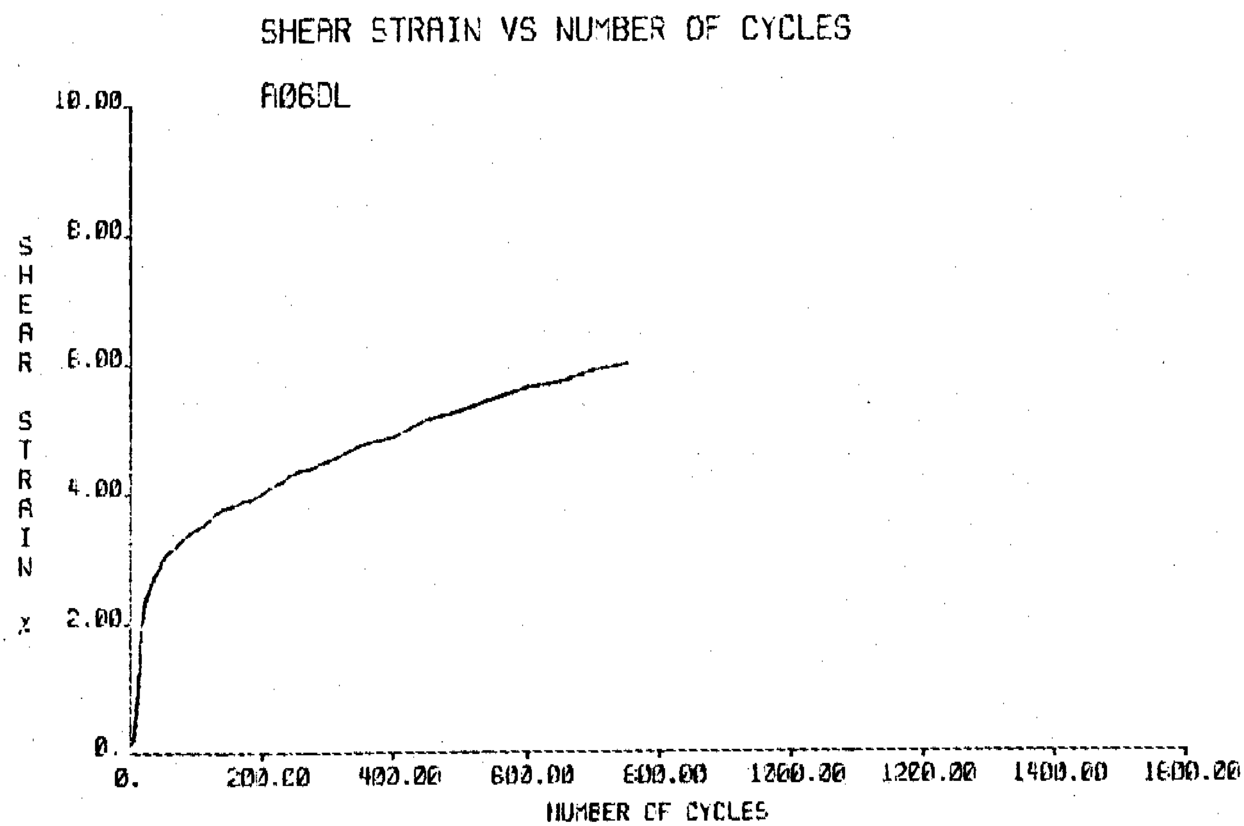


DYVIK (09) 11/11/80 3:22 PM

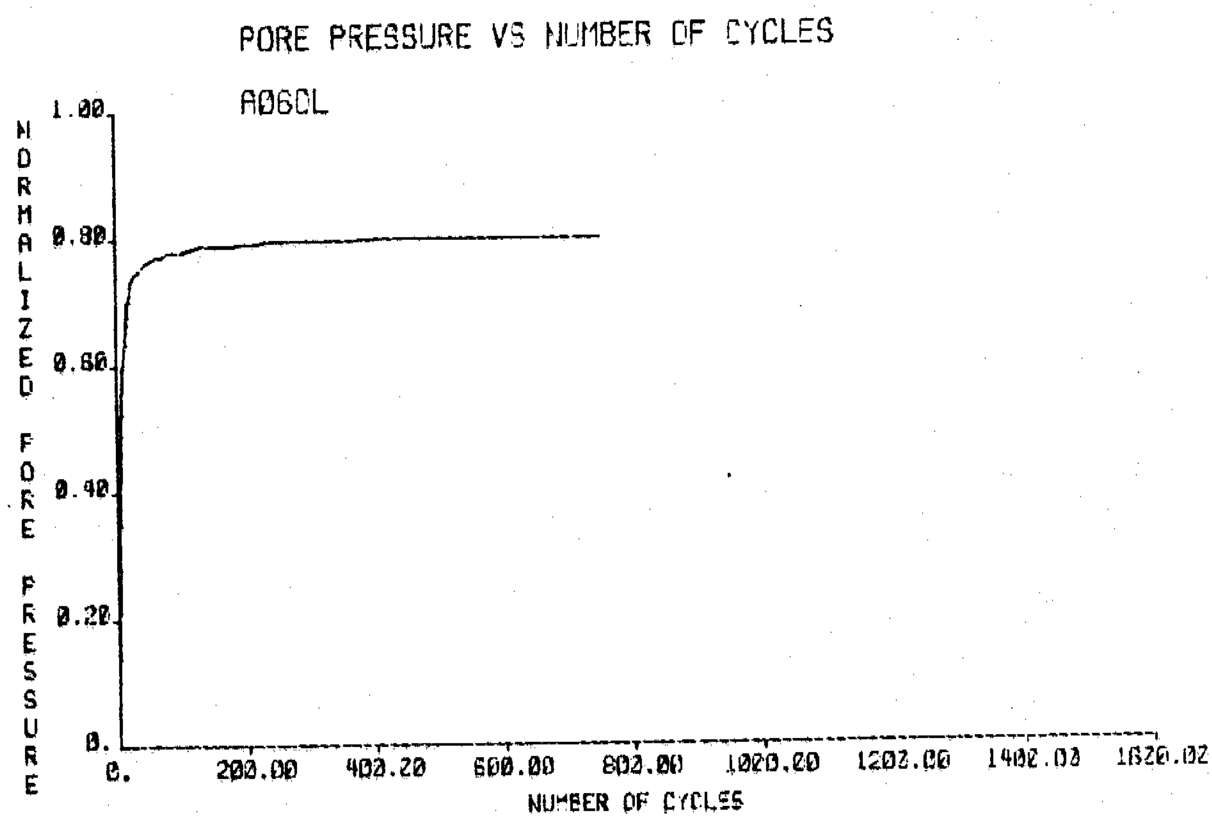



P VS Q
A06DL
0.25
0.20
0.15
Q
0.10
0.05
0.
0.
0.07
0.15
0.22
0.30
0.37
0.45
0.52
0.60
P

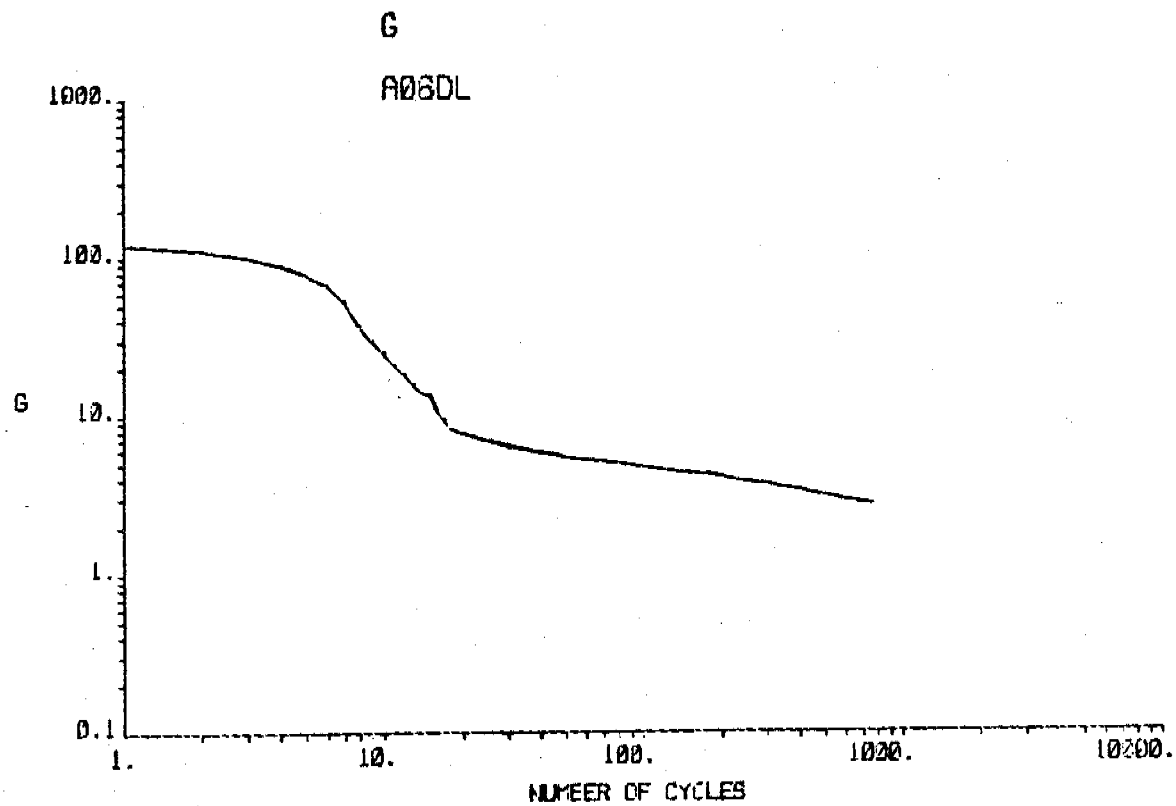
DYVIK (03) 11/11/82 3:32 PM

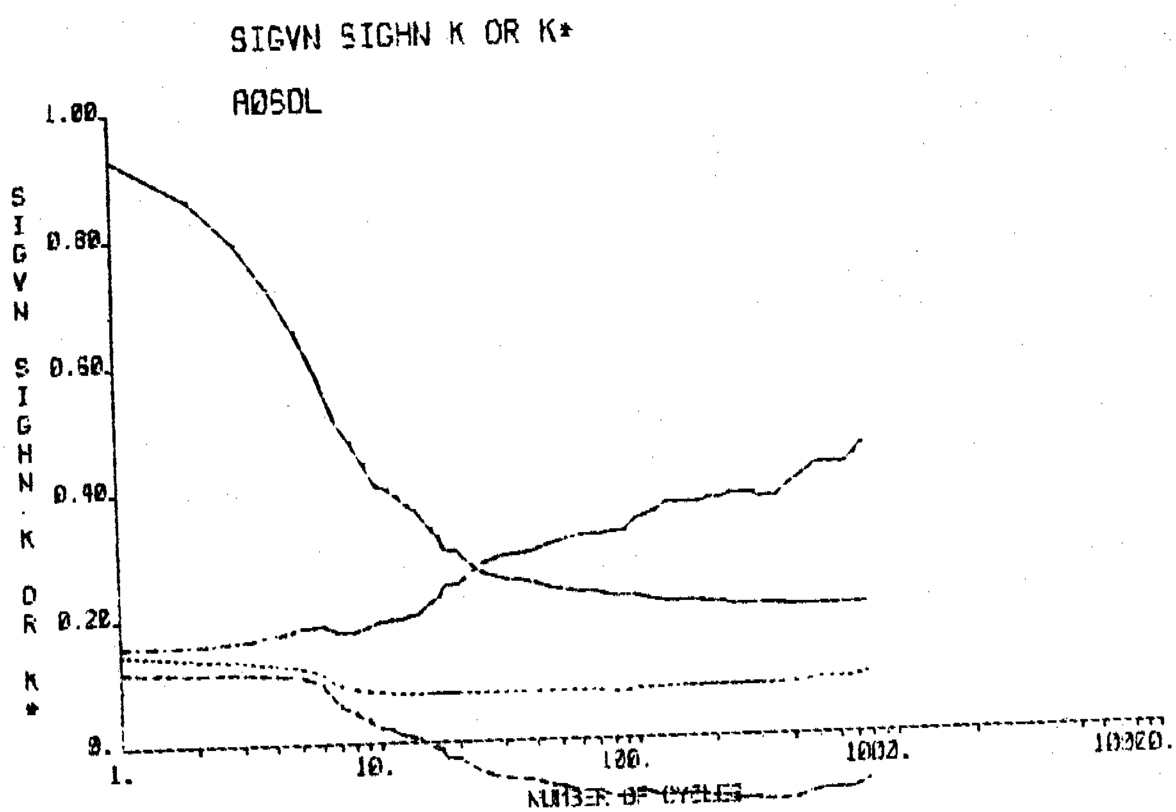


DYVIK (03) 11/11/82 3:32 PM



DYVIK (09) 11/11/80 3:34 PM




SIGVN SIGHN K OR K*
A06DL
1.00
0.80
0.60
0.40
0.20
0.
SIGVN SIGHN . K OR K*
1.
10.
100.
1000.
10000.
NUMBER OF CYCLES

APPENDIX D

DIRECT SHEAR RESULTS

DIRECT SHEAR TEST

A direct shear test was performed on a sample of marine silt from Norton Sound. The sample was consolidated under a load of 30 kN/m^2. Consolidation progressed very rapidly. One cycle of loading, forward and backward, was applied at a constant strain rate of 0.135 mm/min.

The dial gauges did not appear to function effectively on the reversed portion of the test.

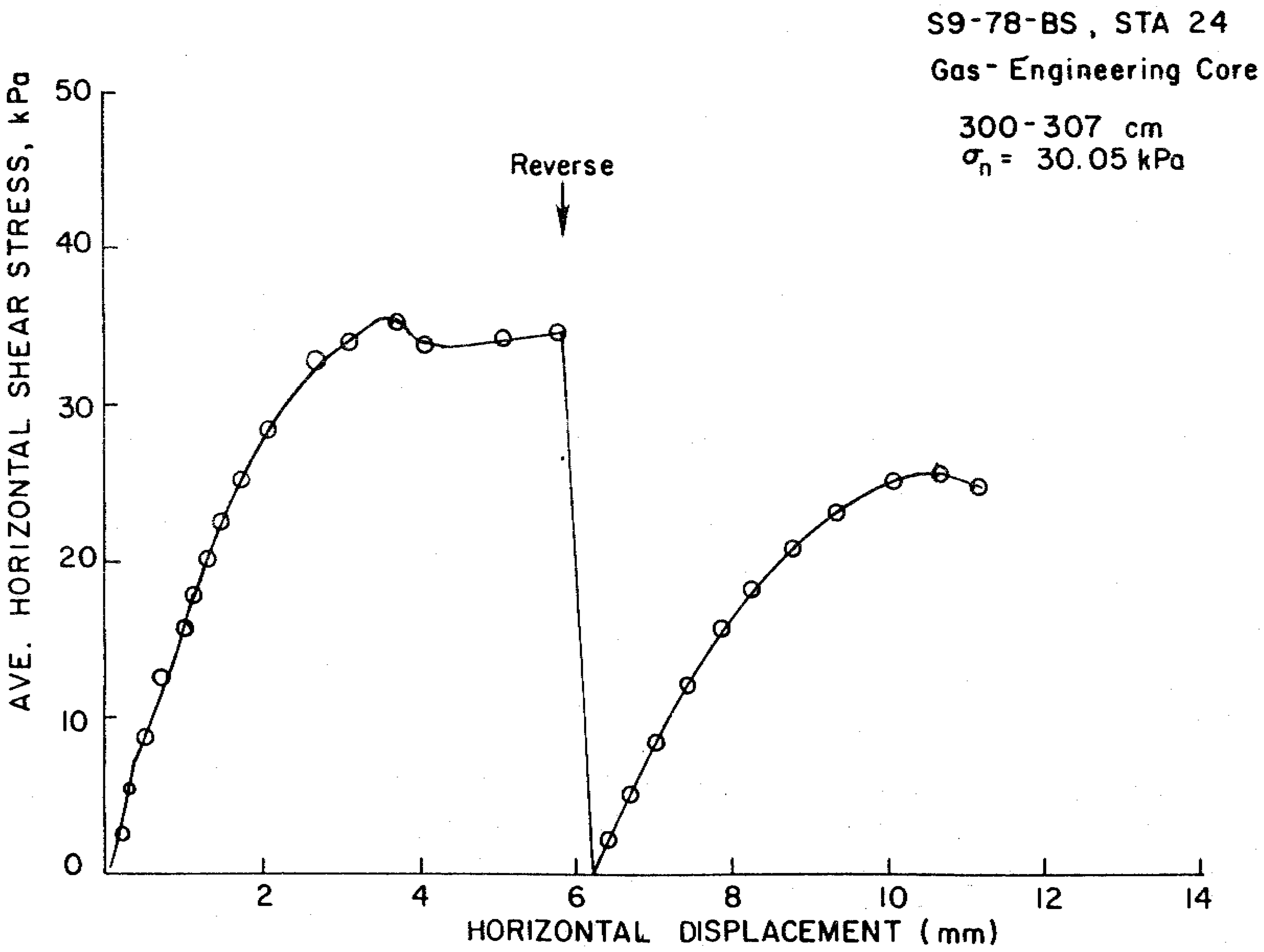
SUMMARY OF RESULTS

Maximum shear stress = 35 kN/m^2

Maximum shear stress (reverse) = 27 kN/m^2

Maximum angle of internal friction = 49°

Maximum angle of internal friction (reverse) = 41°


S9-78-BS , STA 24
Gas- Engineering Core
300-307 cm
σn = 30.05 kPa
Reverse
AVE. HORIZONTAL SHEAR STRESS, kPa
HORIZONTAL DISPLACEMENT (mm)
0
10
20
30
40
50
2
4
6
8
10
12
14

Annual Report Submitted to

National Oceanic and Atmospheric Administration

OCSEAP

by

The University of Texas Marine Science Institute

Galveston Geophysics Laboratory

700 The Strand

Galveston, Texas 77550

OFFSHORE ALASKA SEISMIC MEASUREMENT PROGRAM

Contract No. NA 79 RAC 00077

1 April 1980 to 31 March 1981

Principal Investigator from

1 April 1980 to 31 January 1981

Dr. Gary V. Latham 191-28-6294

Principal Investigator from

1 February 1981 to 31 March 1981

Dr. Cliff Frohlich 216-48-0038
Research Scientist
Marine Science Institute
The University of Texas at Austin
700 The Strand
Galveston, Texas 77550
713-765-2236

OFFSHORE ALASKA SEISMIC MEASUREMENT PROGRAM

As described in the final technical report for this program for the period 1 April 1979 to 31 March 1980, ocean bottom seismograph (OBS) research has been an active program at the University of Texas for several years. The research described in the present report is part of a larger program to determine the consequences and risks associated with offshore petroleum development in and near the western part of Alaska. This research is continuing in 1981, as we have deployed strong motion OBS units in 1980 which will be recovered by scientists working from the Miller Freeman in June 1981. We have submitted to NOAA a grant proposal to continue these programs during the period 1 April 1981 to 31 December 1981.

The format of this final technical report will be as follows: For each of the objectives stated in the original research proposal, we will summarize briefly how the objectives have been met by the research performed in the past year. Where necessary, we will refer to two appendices which describe certain aspects of this research in more detail. In particular, Appendix I is a brief history of the program and includes a summary of the research activity undertaken in 1980. Appendix I also contains a statement of the current status of our program to obtain recordings of strong, local earthquakes with a strong motion OBS. Appendix II is a summary of the high gain OBS measurements made in 1979. Appendix II will be submitted for publication in the Bulletin of the Seismological Society of America after revision.

SUMMARY OF ACHIEVEMENT OF OBJECTIVES OF PROPOSED RESEARCH

OBJECTIVE 1: "In collaboration with personnel of the University of Alaska, to locate all earthquakes detected by an ocean bottom seismic network and nearby land stations."

For OBS measurements made in 1979, a detailed analysis has been performed, and appears as Appendix II of this report. For the OBS measurements undertaken in 1980, about 50 earthquakes were recorded by the five stations that were recovered in August, 1980. Of these, nearly all were either extremely distant events, or events that were recorded only by a single OBS station. Thus it was not possible to locate any local earthquakes using the data recorded by the OBS network in 1980.

OBJECTIVE 2: "Examine patterns of seismic activity revealed by the experimental results in an attempt to delineate active fault zones. Obtain composite fault plane solutions from which slip directions and regional stresses can be inferred."

For the OBS measurements made in 1979, a discussion of the relation of the activity to the local geology appears in Appendix II of this report. Generally, the depth control of the locations was not accurate enough to determine reliable focal plane solutions. In addition, too few events occurred to determine reliable composite fault plane solutions. As noted above, no locatable events were recorded in 1980.

OBJECTIVE 3: "Examine travel times and amplitudes of primary and secondary arrivals to refine the structural model available for the region."

A discussion of the appropriate velocity models for this region appears in Appendix II. These results suggest that better results could be obtained with the land network if a different velocity model were used to locate earthquakes with the land network than the model that is presently used. In addition, these results suggest that better locations could be obtained with land network data if S-waves were routinely incorporated into the location data.

OBJECTIVE 4: "Conduct refraction experiments using land and OBS stations to obtain structural models for the region."

The NOAA ships used to deploy and recover the OBS instruments in 1979 and 1980 were not equipped to do refraction work. For this reason, the refraction work proposed could not be completed. However, Appendix II contains a brief summary of the previous refraction work in the area.

OBJECTIVE 5: "Obtain recordings of sea floor accelerations accompanying strong, local earthquakes.

As discussed in Appendix I, we have not yet recorded a strong local earthquake with the strong motion OBS program. However, the instruments recovered in 1980 all clearly operated without serious mechanical problems. In addition, one event with an acceleration of 5 cm/sec^2 was recorded by one instrument, indicating the instruments will record seismic strong motion events when they occur. Unfortunately, the character of the event that was observed indicated that it was caused by an object or animal striking the OBS instrument, and not by an earthquake. If the instruments that are presently deployed operate as successfully as the instruments recovered in 1980, it is likely that they will have recorded strong local earthquakes.

OBJECTIVE 6: "To construct six additional strong-motion stations for use on land to expand the existing NOAA/University of Alaska strong motion network."

The six string motion stations have been constructed, and will be deployed in Alaska in May of 1981. The original plan called for them to be installed in the Fall of 1980, however, it was not possible to obtain parts for the instruments in time to build and install them in 1980.

APPENDIX I: A BRIEF HISTORY OF THE WESTERN ALASKA OCEAN BOTTOM SEISMOLOGY PROGRAM AT THE UNIVERSITY OF TEXAS

The design and testing of various types of ocean bottom seismic (OBS) instruments has been a principal activity of the Marine Science Institute since its beginning in 1972. In addition, Dr. Gary Latham had been involved in testing and deploying ocean bottom seismographs in the mid 1960's while he was at Lamont, Doherty Geological Observatory.

In 1978, the Exxon Production Research Company (EPR) awarded a contract to MSI to begin developing a 3-axis digital system capable of recording strong motions of the sea floor. Members of the EPR staff undertook the task of investigating techniques for obtaining adequate ground coupling in marine sediments. Three prototype stations were installed off Kodiak, Alaska in the fall of 1978. These were recalled successfully by acoustic command after about 1 month of operation. During the following June (1979) a network of 8 strong-motion OBS stations and 11 high gain OBS stations was deployed off Kodiak Island from the NOAA ship Discoverer. Three additional stations modified for land use were installed on neighboring islands in close proximity to the offshore network. The stations of the high-gain network were recovered in August of 1979. Several of the strong-motion stations were recovered and redeployed during cruises in August and October 1979. In the October exercise, 4 strong motion stations were left on bottom and recovered in March of 1980.

Seven high-gain OBS stations were installed in June 1980 at the locations shown in Figure 1. Five of these stations were recovered in August. Two of the stations (stations 3 and 9) failed to return to the surface either by command or by the internal clock release. Approximately 50 earthquakes were recorded by the recovered stations, however, nearly all of these events were either quite distant, or else recorded by only one OBS station. For this reason, it was not possible to locate any of the events that were detected by the OBS instruments in 1980. Instead, we concentrated our efforts on continuing the analysis of the events that were recorded by the OBS stations deployed in 1979 (see Appendix II).

Three strong motion OBS stations were deployed in July 1980 at sites 3, 5, and 8 (see attached Table). These were successfully recalled by acoustic command in October 1980. Of these three stations, all three operated successfully, and would have recorded strong local events if any had occurred. In particular, the stations' recording system recorded a portion of the background ground motion every five days as planned. In addition, one of the stations recorded a brief event with a peak acceleration of about 5 cm/sec^2. This event had a duration of about one second, and much of the energy was in the 20 Hz to 30 Hz range. It is not possible that such an event is seismic in origin, and in fact the event is quite similar to what would be expected if an animal or an object struck the OBS instrument. The 20 Hz to 30 Hz vibrations are about in the range of the resonances associated with the OBS frame. The recording of this non-seismic event shows clearly that the strong-motion instruments would record earthquake activity if any did occur.

Seven additional strong motion OBS stations were installed during the October cruise at the sites shown on the attached map, with coordinates listed in the attached table. These will be recovered in June, 1981, and redeployed along with additional strong motion stations.

TABLE I

STRONG MOTION OBS DEPLOYMENT SITES

SITE NUMBER	POSITION	LORAN RATES	DEPTH FMS/METERS
#1	57 58.3N 150 28.8W	7960X 11797.21 Y 31246.36 9990Y 32072.01 Z 43068.08	86/157 meters
#2	57 41.0N 150 58.6W	7960X 11522.22 Y 31193.61 9990Y 32182.12 Z 43025.01	43/79 meters
#3	57 25.1N 151 23.0W	7960X 11300.05 Y 31143.96	94/172 meters
#4	57 08.5N 151 42.3W	7960X 11155.19 Y 31085.86 9990Y 32376.80 Z 43025.50	45/82 meters
#5	56 42.8N 152 27.0W	7960X 11034.72 Y 31025.97 9990Y 32547.29 Z 43243.99	100/183 meters
#6	56 40.1N 153 06.5W	7960X 11000.32 Y 31074.77 9990Y 32618.26 Z 43426.90	83/152 meters
#7	56 08.4N 154 03.6W	7960X 31015.08 Y 10998.16 9990Y 32839.74 Z 43852.10	84/154 meters
#8	55 47.1N 155 10.8W	7960X 11006.70 Y 31024.60 9990Z 44296.49 Y 33040.08	64/117 meters
#9	55 09.1N 158 33.8W	9990X 18546.07 Y 33586.16 Z 45587.38	104/190 meters

Table 1 (Continued)

SITE NUMBER	POSITION	LORAN RATES	DEPTH FMS/METERS
#10	54 30.7N 160 29.9W	9990X 18421.16 Y 33969.34 Z 46338.46	80/146 meters
#11	54 14.1N 163 52.4W	9990X 18237.30 Y 34479.62 Z 47549.38	53/97 meters
#12	55 49.9N 164 47.7W	9990Z 47976.48 Y 34366.37 X 18539.35	53/97 meters
#13	56 29.0N 161 48.1W	9990X 18661.33 Y 33714.30 Z 46800.64	51/93 meters

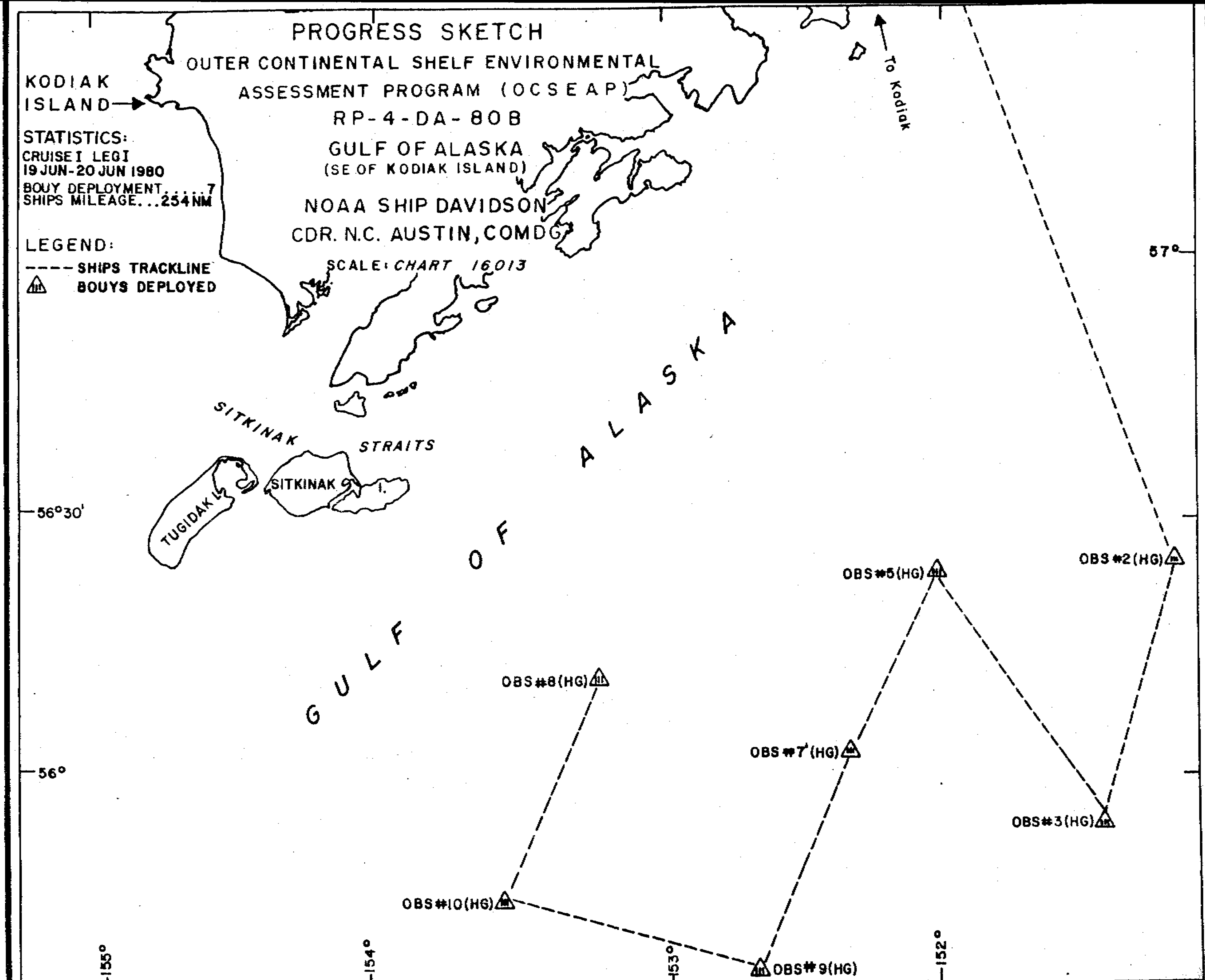

PROGRESS SKETCH
OUTER CONTINENTAL SHELF ENVIRONMENTAL
ASSESSMENT PROGRAM (OCSEAP)
RP-4-DA-80B
GULF OF ALASKA
(SE OF KODIAK ISLAND)
NOAA SHIP DAVIDSON
CDR. N.C. AUSTIN, COMDG
SCALE: CHART 16013
KODIAK ISLAND
To Kodiak
STATISTICS:
CRUISE I LEG I
19 JUN-20 JUN 1980
BOUY DEPLOYMENT.....7
SHIPS MILEAGE...254 NM
LEGEND:
SHIPS TRACKLINE
BOUYS DEPLOYED
SITKINAK STRAITS
SITKINAK I.
TUGIDAK I.
GULF OF ALASKA
OBS #2 (HG)
OBS #5 (HG)
OBS #8 (HG)
OBS #7 (HG)
OBS #3 (HG)
OBS #10 (HG)
OBS #9 (HG)
57°
56°30'
56°
155°
154°
153°
152°

FIGURE 1

APPENDIX II

EARTHQUAKE ACTIVITY AT THE CONTINENTAL SHELF, ALASKA, DETERMINED BY LAND AND OCEAN BOTTOM SEISMOGRAPH NETWORKS

Jeff Lawton[1], Cliff Frohlich[1], Hans Pulpan[2], and Gary V. Latham[3]

[1]Marine Science Institute, University of Texas, 700 The Strand, Galveston, TX 77550.

[2]Geophysical Institute, University of Alaska, Fairbanks, AK 99701.

[3]Chevron Research Lab, Houston, TX

ABSTRACT

The spatial pattern of earthquakes determined by a combined land and ocean bottom seismometer (OBS) network in the Kodiak Island shelf region differs systematically from the pattern determined by the International Seismological Center (ISC). As a part of a larger study of seismic risk on the continental shelf near Kodiak Island, we augmented the University of Alaska land network by deploying eleven recoverable OBS units south of Kodiak Island for two months in the summer of 1979. Despite a relatively short operation time and various instrument malfunctions, the combined network detected 24 locatable earthquakes in the shelf region. Because of the structural heterogeneity of this area, the earthquakes were located with a scheme which allowed different velocity models to be used for travel-time calculations of phases travelling to different stations in the network. The locations of earthquakes determined using data from both the land and OBS networks averaged about 25 kilometers south of hypocenters of the same earthquakes determined using only land network data. For these events on the continental shelf, azimuthal control of the joint land-OBS network is excellent, and thus the joint land-OBS network locations are considerably more reliable than locations determined with the land network data alone. When the locations of the combined land-OBS network are compared to 15 years of teleseismic locations reported by the ISC, the center of teleseismic activity appears to be about

20 to 30 kilometers north of the center of activity determined in our study. As suggested by studies of nuclear explosions in the Aleutians, this systematic difference between locally determined and teleseismically determined locations is probably caused by the northward dipping high velocity lithosphere subducted beneath the Aleutian arc.

INTRODUCTION

Recent hydrocarbon exploration on the Alaskan outer continental shelf provides new motivation for evaluating the occurrence and consequence of large earthquakes in these areas. Presently the shelf region off Kodiak Island is under consideration for petroleum development (See Hanley and Wade, 1981; Jones, 1980; and Fisher, 1980) and the environmental impact of such activity is receiving much attention. High seismic risk has been associated with the Kodiak region for at least 200 years (Hansen and Eckel, 1971; and Science Applications, 1980). In 1964 Kodiak Island was strongly affected by the Great Alaska earthquake, one of the largest earthquakes ever recorded. Because of the limitations of land networks (local and teleseismic) for accurate earthquake locations at convergent margin continental shelves, combined land-OBS seismic networks are necessary to obtain a better understanding of the seismicity of these areas.

As part of a larger study of the environmental consequences of petroleum development, we have utilized a land-OBS network at Kodiak Island to calibrate the existing land network and also to study the effects of the Benioff zone on teleseismic earthquake locations. In addition, a land-OBS network of strong motion accelerometers is presently in operation in the Kodiak Island area (Stienmetz et al., 1981). Data from this network are to be utilized to help understand the nature of earthquake generated ground motion in areas of potential petroleum development. The present paper, however, will not report the results of the strong motion program, but will only report the results obtained using the high land-OBS network.

Davies and House (1979) and Kelleher et al., (1974) suggest that great earthquakes associated with ruptures of extraordinary length (400 km) occur near wide, low angle seismic zones. The interface zone of the 1964 Alaska earthquake was shallow dipping (Plafker, 1972) and wide (Lahr and Page, 1972). Yakataga and Shumagin seismic gaps have been delineated, respectively, to the northeast and southwest of Kodiak Island and are potential sources of destructive earthquakes in the next twenty years (Perez and Jacobs, 1980; Lahr et al., 1980; Pulpan and Kienle, 1979; Kelleher et al., 1974; and Sykes, 1971). In view of recent destruction wrought by the 1964 earthquake (approximately $13 million in damages to Kodiak Island alone) and its related effects, and the presence of well documented seismic gaps bounding Kodiak Island, the determination of seismic risk is clearly one of the most important problems in the environmental assessment program.

The University of Alaska Geophysical Institute at Fairbanks currently operates an eleven station high gain seismic network on Kodiak Island (Pulpan and Kienle, 1979). Additionally, several three-component strong motion accelerograph units are now in operation on the island. As Kodiak generally trends northeast-southwest, the network configuration is basically linear, not an optimum condition for earthquakes occurring in the shelf region.

An offshore OBS network helps provide the necessary azimuthal coverage to allow the determination of reliable epicenters.

Although the problems in locating earthquakes in island arc areas has been studied for various different regions, the present study is the most comprehensive investigation available for earthquakes of the outer continental shelf of Kodiak Island. Systematic errors in locations of events recorded by local networks in regions near inclined seismic zones have been studied in detail by a variety of investigators (e.g. Frohlich et al., 1980; Barazangi and Isacks, 1979; Suyehiro and Sacks, 1979; Utsu, 1975; and engdahl, 1973). The presence of inclined seismic zones also produces dramatic effects on locations recorded by teleseismic stations (e.g. Huppert and Frohlich, 1981; Sleep, 1973; Davies and Julian, 1972; Jacob, 1972; Davies and McKenzie, 1969; Cleary, 1967; and Douglas, 1967).

NETWORK DESCRIPTION

The land network used in this study is a permanent installment consisting of eleven high gain, short period (peak magnification at approximately 10 Hz) seismic stations (Pulpan and Kienle, 1980). All stations record the vertical component only with the exception of station SII which also records one horizontal component. The Kodiak Island network has been in operation in its present configuration since July, 1977 (Figure 1 and Table 1). Data from each land station are telementerd by FM radio links and satellite to a central recording facility in Homer, Alaska. All data plus a time code are recorded on a Develocorder. The land network operated continuously during the experiment period with the exception of one day, July 6, when there were mechanical problems with the Develocorder (Figure 2).

The OBS network was operational in the summer of 1979, from June 23 to August 4 (Figure 2). Of the eleven OBS's deployed, only seven units produced useable data (Figure 1 and Table 1). Each OBS unit is a self contained, event triggered system which can be deployed for as long as three months (Latham et al., 1978). The OBS network is similar to the land network in that it records only vertical component signals with a peak magnification at about 15 Hz. Up to 720 events are recorded in analog form on standard magnetic tape cassettes, and then can be played back in various forms for analysis (e.g. Figure 3). All OBS components (8 Hz geophone, clock, amplifier, recording system, trigger electronics, release electronics and batteries) are housed in a 43 cm diameter spherical glass pressure vessel capable of withstanding the pressures encountered at depths exceeding 700 meters.

Eleven OBS units were deployed from the NOAA ship DISCOVERER and recovered with the NOAA ship SURVEYOR. Each unit was dropped free-fall to the ocean bottom for the duration of the experiment, and recovered when the pressure vessel was detached from its heavy metal frame, enabling a bouyant ascent. The OBS clocks were checked against the National Bureau of Standards time announcements on WWV (15 MHz) before deployment and after recovery.

METHODS

The location of earthquakes using a land network and OBS stations has produced several problems not usually encountered by land networks. To accomodate the large elevation differences (up to 5.5 kilometers) and sharp contrasts in seismic velocities across the network, a special earthquake location program was used. The program calculates travel times from the hypocenter to the seismic station, which is more accurate than calculating the travel time to sea level and then applying a station correction for the large elevation differences. Two flat layered velocity models can be specified for rays travelling to different groups of stations. This feature helps to adjust for the non-horizontal nature of the structure normal to the trench at Kodiak Island. For example, in the present study, one velocity model was used for calculating travel times of arrivals at land stations and a different model was used for calculating travel times of arrivals at OBS stations. In addition, the program employs a weighting scheme for the quality of arrival times entered. During the location process, the least squares effect of each residual is determined by the quality of each arrival time.

Seismograms and time code data reproduced from microfilm (land network) and magnetic tape (OBS network) were read carefully to determine P- and S-wave arrival times. All P-wave arrival times can be read to within about 0.1 second and S-wave arrival times, due to their characteristically emergent nature can be read to within 1.0 second. The quality of each arrival time is determined subjectively based on the clarity of phase and epicentral distance. P- and S-wave arrival times are weighted initially according to epicentral distance.

To approximate the pronounced structural variation in the Kodiak Island area, two crustal velocity models were used in the location process. The land stations use a continental-type model (Figure 4) derived from studies of regional Alaskan seismicity (Pulpan, personal communication; and Jin and Herron, 1980). The OBS stations use an offshore velocity model based on refraction studies as reported by Shor and Von Huene (1972). Lines A, B, and C (Figures 1 and 4) show the location of the refraction lines used to derive the OBS velocity model. Line A was chosen as the most appropriate velocity model due to its location on the shelf slope and its proximity to the OBS network.

Calculation of the depth of focus is the least reliable part of the earthquake location process due to the nonlinearity of the travel time function with depth. The numerical method used to find least squares solutions often has difficulty locating a unique minimum unless the trial hypocenter and depth are very close to the actual least squares optimum hypocenter. To deal with the nonlinearity problem we located each earthquake by iteratively adjusting the origin time and epicenter over a range of depths. We first located each earthquake with the depth fixed at 2 kilometers. We then increased the depth by 1 kilometer increments and found the optimum epicentral location at each depth. The depth of each earthquake was taken at that point which minimized the RMS residual error (Figure 5). This method allowed us to evaluate the depth of each earthquake in terms of its resiudal-depth curve and thereby identify as unreliable those depths from earthquakes whose RMS versus depth curves had multiple minima or extended flat portions.

RESULTS

More than 100 earthquakes were located by the combined land-OBS network during the experiment period. The majority of events occurred in the Cook Inlet region. The OBS network contributes little to the accuracy of these Cook Inlet locations and they will not be discussed further. Of the 24 earthquakes in study area, 20 were selected as well located events (Figurel). Minimum selection criteria for those events included an RMS residual of less than 0.70 second, a distance to the closest station of less than 100 kilometers, at least 4 P-phases and 1 S-phase, and a station coverage in at least three quadrants. Magnitudes for these events, determined using a coda length relationship developed for the present study, ranged from M_{OBS}=1.7 to 2.3 (Lawton, 1981, or see Appendix). $M_{OBS} \geq 2.5$ generally have signal durations greater than the record length allotted for each triggering event (70 seconds). The largest event observed within the network had a magnitude of 3.4 as determined by the University of Alaska land network.

While epicentral locations determined in this study were generally well constrained, the depth of focus for most events was not reliable. The most accurate depth determinations are those that have a well defined minimum in RMS residual error at one depth. In the residual-depth plot of Figure 5, event 11 exhibits a sharp minimum at 38 kilometers depth, whereas events 5 and 19 show considerably poorer resolution. It can be seen, however, that in all cases the residual error begins to increase substantially at depths greater than 70 kilometers. Since most of the earthquakes exhibit residual-depth curves similar to those of events 5 and 19 and therefore have poor depth control, further discussion deals with epicentral locations only, but it will be assumed that all depths are less than 70 kilometers.

Epicentral locations determined solely with land network data were compared with locations utilizing all available data collected by the combined land-OBS netowrk. In general, earthquake epicenters determined with land data moved away from the land network when OBS data were included in the location process (Figure 6). The total average displacement is approximately 25 kilometers (0.23°). It is important to note that all of the epicenters determined by the land network received poor (C-D) quality ratings (See Pulpan and Kienle, 1980). In most cases the amount of displacement depends on two factors: 1) The proximity of the event to the land network; and 2) The number of stations recording the event. Events that are well recorded and are within the land network tend to remain stationary when OBS data are included.

The pattern of earthquake locations of the land-OBS network was compared to the pattern of earthquake locations reported by the ISC between 1965 and 1978 (Figure 7). Only the most reliable ISC epicenters reported in the shelf region were considered, i.e. events recorded by 30 stations or more with at least one station within 2° of the epicenter. The ISC epicentral distribution is characterized by a northeasterly trending cluster of events occupying the shelf region north of 56.3° N lat. (average location 56.5°N; 152.9°W).

In comparison, the earthquakes located by the land-OBS network display a similar northeasterly trend, but the group is located more to the south and west (average location 56.1°N; 153.2°W). Both data sets contain only events with depths shallower than 70 kilometers. From this, the teleseismic earthquake locations appear to be on the average 25 kilometers further landward of the Aleutian trench than epicenters determined by the land-OBS network data.

In addition to earthquakes, the OBS stations also recorded about 3000 small events with impulsive onset, short duration (1 to 5 seconds) and a regular frequency content. In no case were they clearly recorded on more than one station at a time. Buskirk et al., (1980, 1981) discuss the nature of these small events in detail and conclude that they are probably biological origin. In agreement with that conclusion, we find that shallow stations (less than 1000 meters depth, in the photic zone) record far more of these small events than deeper stations (below photic zone).

DISCUSSION

The combined land-OBS network has produced the most accurate earthquake locations available for the continental shelf region near Kodiak Island. With the OBS network excellent azimuthal station coverage, not previously available with local or teleseismic land networks, was obtained for earthquakes occurring in the shelf region. Although we were not able to determine reliable depths for these events, the epicenters are well determined, as all the locations utilized at least 4 P-wave and 1 S-wave arrivals. We have attempted to account for the pronounced structural variation across the study area by employing a two model crustal structure, utilizing velocity models determined from the most recent surface wave studies and refraction profiles available in the area (Jin and Herrin, 1980; and Shor and Von Huene, 1972).

One of the original purposes of this study was to locate and delineate shallow faults through the use of accurate earthquake locations. The earthquakes that occurred near the shelf break (1000 m bathymetric contour, Figure 1) show a distinct northeast trend paralleling a major zone of faults mapped along and offshore Kodiak Island (Figure 8) reported by Hampton et al., (1979). Some of these faults offset the sea floor by as much as 10 meters and are in line with faults occurring to the northeast that were active during the 1964 Alaska earthquake. Most of the earthquakes are seaward of the most intense faulting activity. Fisher and Holmes (1980) used multichannel reflection data to show that faulting is recognizeable to a depth of 3 to 4 kilometers in the shelf region. The earthquakes in this study are believed to have depths below the deepest fault interpretation. The faults may be the shallow aseismic extensions of deeper seismically active faulting. Whether the faults continue beneath these depths though, is a matter of conjecture. The recent surface faulting and shallow seismicity are closely related in that they are both expressions of active tectonic deformation above the Aleutian Benioff zone.

The differences in location discovered between land-only epicenters and land-OBS epicenters are mainly influenced by the quality of location determined by the land network, and the proximity of the earthquake to the land network. Figure 6 consists of two classes of land-only epicenters compared with their corresponding land-OBS epicenters. Events 11 through 19 were poorly recorded by the land network (less than 5 stations included) and showed large displacements (>25 km) when OBS data were included. Conversely, events 1 through 6 were well recorded by the land network (5 stations or more) and showed smaller displacements (<25 km) when OBS data were included.

However, four events (7 through 10) were relatively well recorded by the land-only network, yet they displayed large shifts when OBS data were included in the location process. Events 7 and 8, both located at the southwest end of Kodiak Island by the land network, displayed shifts of 111 km and 147 km, respectively, with the OBS data included. The important factor here is the land-only locations did not utilize S-wave data and the land-OBS locations did. The use of S-waves helped fix the epicentral distance and origin time and produced a more reliable location in each case. Events 9 and 10 occurred well outside of the land-OBS network, and when relocated using S-wave arrival times, OBS data and the refraction based velocity model (Figure 4), displayed shifts of 32 km and 27 km, respectively. The shifts seen in events 9 and 10 are reasonable considering their locations outside of the network and inclusion of a more complete data set. The large discrepancy seen in events 7 through 10 emphasize the sensitivity of locations in the shelf region to the inclusion of S-wave arrival times and different velocity structures.

When the land-OBS epicenters are compared to the ISC epicenters it is apparent that each data defines a separate zone of activity (Figure 7). On the average, the ISC cluster is approximately 25 kilometers further landward of the Aleutian trench than the land-OBS cluster. Seismic activity in the shelf region of Kodiak Island has been a consistent and prominent feature for at least the last 26 years (Tobin and Sykes, 1966). As noted earlier, the size, shape, orientation and depth range of the two clusters are quite similar. These features in addition to the persistence of activity suggest that the two groups of activity are members of the same seismic cluster.

If the two data sets are from the same source region then the most likely explanation for the location difference is that some of the seismic phases travel within the subducted high velocity lithosphere of the Aleutian Benioff zone. Since both data sets report only shallow events, it is clear that rays travelling down dip will be affected by the slab more than those rays travelling up dip (Figure 9). Hence, for shallow events, the local network should produce more accurate earthquake locations than the teleseismic network (e.g. See Barazangi and Isacks, 1979). Studies of the nuclear explosion LONGSHOT at Amchitka Island, Alaska, show that Benioff zone structure systematically affects earthquake locations at convergent margins (Sleep, 1973; Jacob, 1972; Davies and Julian, 1972; Davies and McKenzie, 1969; and Cleary, 1967). The teleseismic epicenter of LONGSHOT (51.61°N lat and 179.22°W long, from ISC) was about 20 kilometers north of the actual explosion site (51.43°N lat and 179.18°W long). When the explosion was relocated using station corrections calculated by the joint hypocenter method, the new location was within 1 kilometer of the true epicenter (Douglas, 1967).

Three-dimensional ray tracing shows that the observed pattern of P-residuals from LONGSHOT and other Aleutian earthquakes could be explained by a descending plate with a P-wave velocity 7 to 10% higher than the surrounding mantle (Jacob, 1972; Davies and Julian, 1972; and Cleary, 1967). As a result, seismograph stations receiving down dip rays record anomalously early arrival times. Thus the European stations which are essentially due north of the Aleutian chain tend to pull the epicentral locations in that direction.

The total seismic risk of the Kodiak Island region is a composite of both the likelihood of various levels of seismic threat and the response and behavior of the system during seismic activity. The likelihood of threat is based on the seismicity rate and average earthquake locations encountered in an area. We believe that the present offshore earthquake location ability can be improved with a larger data set involving a joint land-OBS network. A larger data set will allow location improvement in several categories: 1) Refinement of the crustal structure models using travel-time inversion techniques; 2) Calculation of reliable station corrections for the land network with the joint hypocenter determination method; and 3) Relocation of earthquakes with a ray tracing program to help understand the plate effect on shallow earthquakes occurring above the Benioff zone. Finally, data from the existing land-OBS accellerometer network will help complete the seismic risk picture by enabling studies on the nature of earthquake induced ground shaking.

SUMMARY

1) 24 earthquakes occurring on the continental shelf of Kodiak Island were located using a combined land-OBS network. At the present time these are the best locations available for seismic activity on the continental shelf.

2) Locations of these 24 earthquakes determined using land network data alone, showed an average shift of 25 kilometers when OBS data were included in the location process. The average difference is due primarily to the fact that earthquakes on the continental shelf have adequate station coverage only when OBS units are used.

3) The spatial pattern of these 24 earthquakes differs from the pattern reported by ISC. The teleseismic epicenters are located 20 to 30 kilometers further landward of the Aleutian trench than epicenters determined with the combined land-OBS network.

4) The landward shift of teleseismic locations is probably due to the existence of a landward dipping slab with a seismic velocity higher than the surrounding mantle. These findings are consitent with results from an analysis of the LONGSHOT experiment.

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FIGURE CAPTIONS

Figure 1 Land and OBS (closed triangles) seismographic networks are shown with 24 earthquakes located in this study (open circles). Lines A, B, and C are refraction lines used to derive location velocity models (see Figure 4).

Figure 2 Bar graph depicting land and OBS station operation times. OBS operation was mainly hampered by tape recorder malfunctions, and large numbers of extraneous biological events. Stations are listed on vertical axis and operation times are on horizontal axis.

Figure 3 OBS seismograms from an earthquake on the continental shelf. Station 8 was closest to the event and station 4 was furthest. Compression, shear, and reflected phases are labled P, S, and R, respectively. We believe the R phases to be compressional waves reflected off the air-water interface (see Francis and Porter, 1973).

Figure 4 OBS and land network velocity models. OBS velocity model derived from refraction line A (See Figure 1). The transition from oceanic crust (right side) to a more continental type structure (left side) is characterized by an apparent expansion of section. Note the landward dipping trend exhibited by the depth to mantle ($V_p \geq 7.9$ km/sec).

FIGURE CAPTIONS (Continued)

Figure 5 Relationship of root mean square travel-time residual error versus depth for three earthquakes in the OBS network. OBS seismograms for event 11 are shown in Figure 3. Earthquakes shown are a representative sample of the earthquakes located in the land-OBS network, and are numbered as in Figure 6.

Figure 6 Comparison of epicenters located in this study (closed circles) with those located solely by the land network (open circles). The two locations of these earthquakes are connected with a line. Events 1 through 6 were well recorded by the land network and showed small displacements (< 25 km). Events 11 through 19 were poorly recorded by the land network and showed larger displacements ($\geq$ 25 km). Events 7 through 10 are anomolous in that they were well recorded by the land network, yet showed large displacements when OBS data were included.

Figure 7 Earthquakes located by the International Seismological Center during 1965-1978 (closed circles) are compared with earthquakes located in this study (open circles). Large closed circles denote ISC earthquakes with $M_b \geq 5.0$. Small closed circles represent smaller ISC events. All 30 stations with at least one station within 2° of the epicenter.

Figure 8 Offshore structure of Kodiak Island as derived from analysis of multichannel reflection data. Hatchures are on

FIGURE CAPTIONS (Continued)

the downthrown side of the seafloor faults. Note the NE-SW trend of the mapped features. Some faults offset the seafloor by as much as 10 meters and are in line with faults to the NE that were active during the Great Alaska earthquake of 1964.

Figure 9 Effect of high velocity dipping slab on shallow earthquake generated rays. A ray spending considerable time in the slab (e.g. head wave on the right) will arrive at its station anomolously early.

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Table 1

KODIAK ISLAND LAND-OBS SEISMIC NETWORK

STATION	LATITUDE(°N)	LONGITUDE(°W)	ELEVATION (Meters)
OBS 1	56.90	151.42	-928
OBS 4	55.91	151.42	-5166
OBS 5	56.19	151.74	-4424
OBS 6	56.75	152.50	-163
OBS 8	56.18	153.19	-1415
OBS 10	55.74	153.52	-1467
OBS 11	55.89	154.41	-795
CHI	55.84	155.58	250
DMB	57.09	153.96	300
KDC	57.75	152.49	13
MMC	57.33	154.64	340
PUB	57.77	155.52	280
RAI	58.10	153.16	520
SHU	58.62	152.35	34
SII	56.56	154.18	500
SKD	57.16	153.08	135
SPL	57.76	153.77	600
UGI	57.40	152.28	---

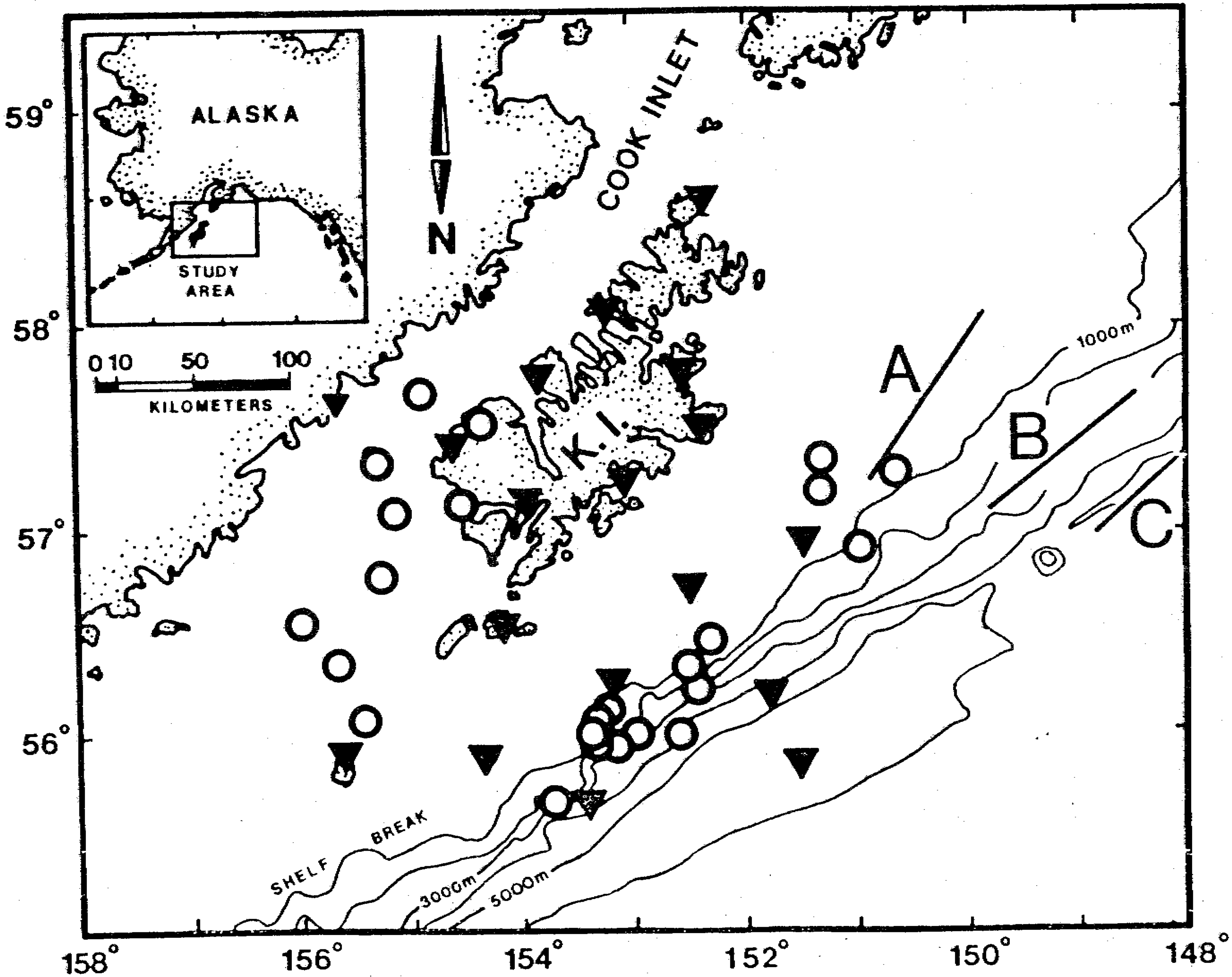
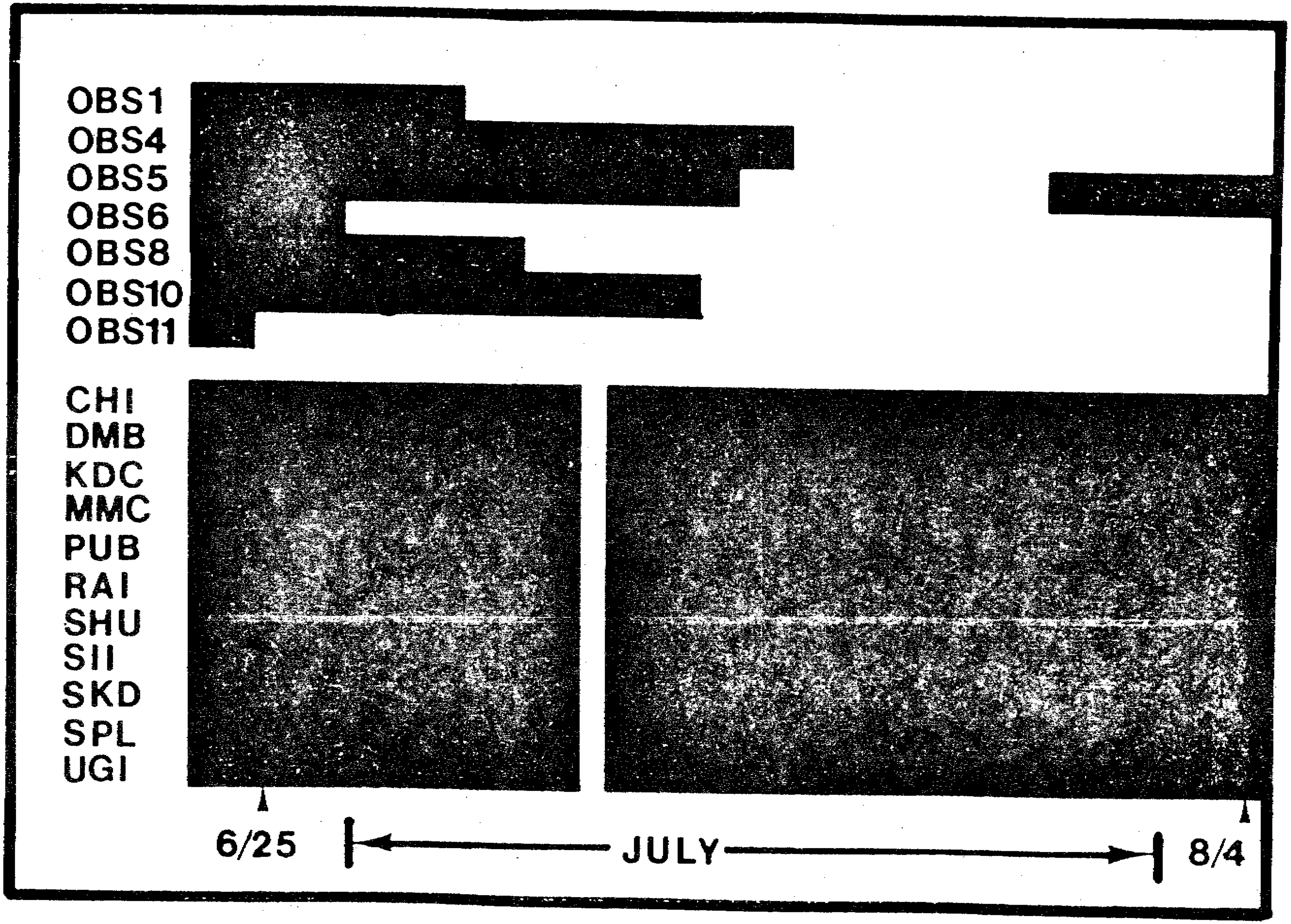

ALASKA
STUDY AREA
N
COOK INLET
K. I.
A
B
C
1000m
3000m
5000m
SHELF BREAK
0 10 50 100
KILOMETERS
59°
58°
57°
56°
158°
156°
154°
152°
150°
148°

FIGURE 1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OBS4
OBS5
OBS6
OBS8
OBS10
OBS11
CHI
DMB
KDC
MMC
PUB
RAI
SHU
SII
SKD
SPL
UGI
6/25
JULY
8/4

FIGURE 2

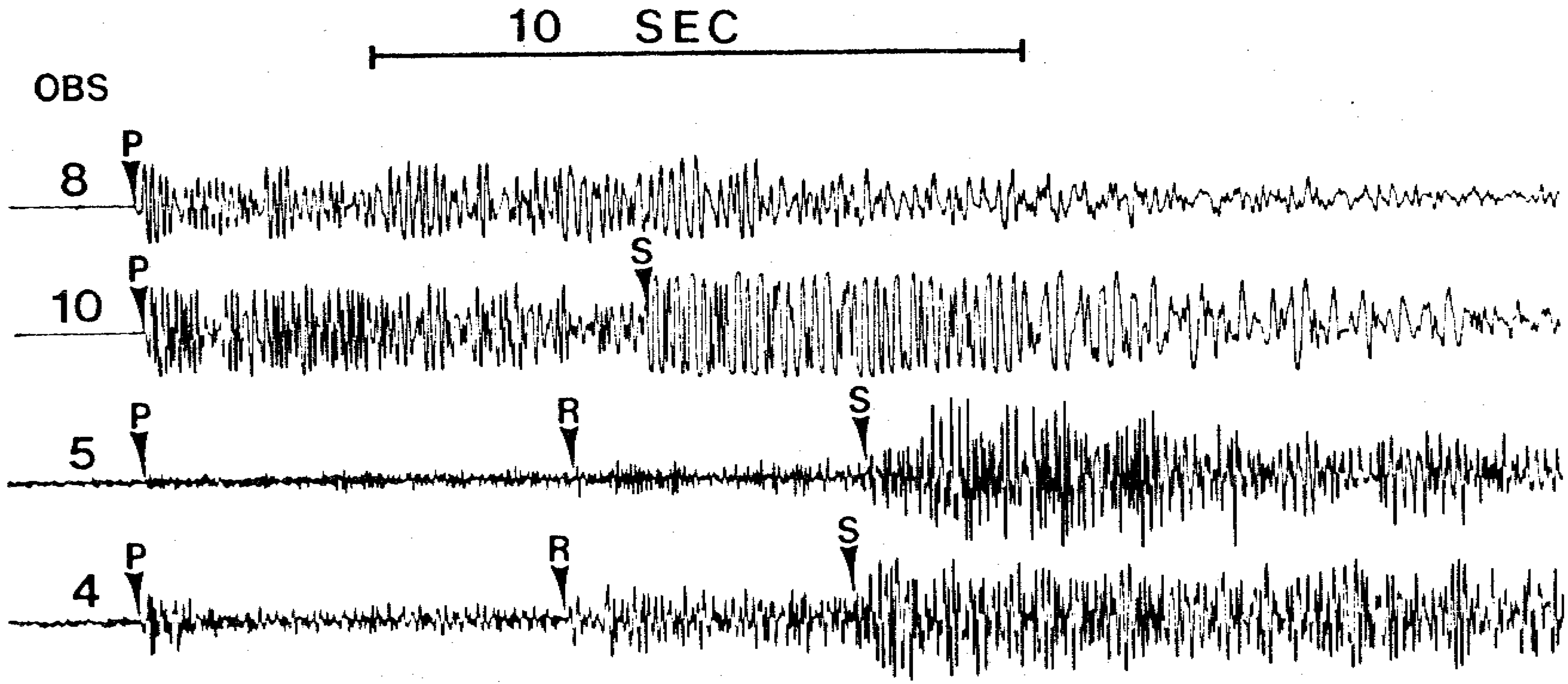
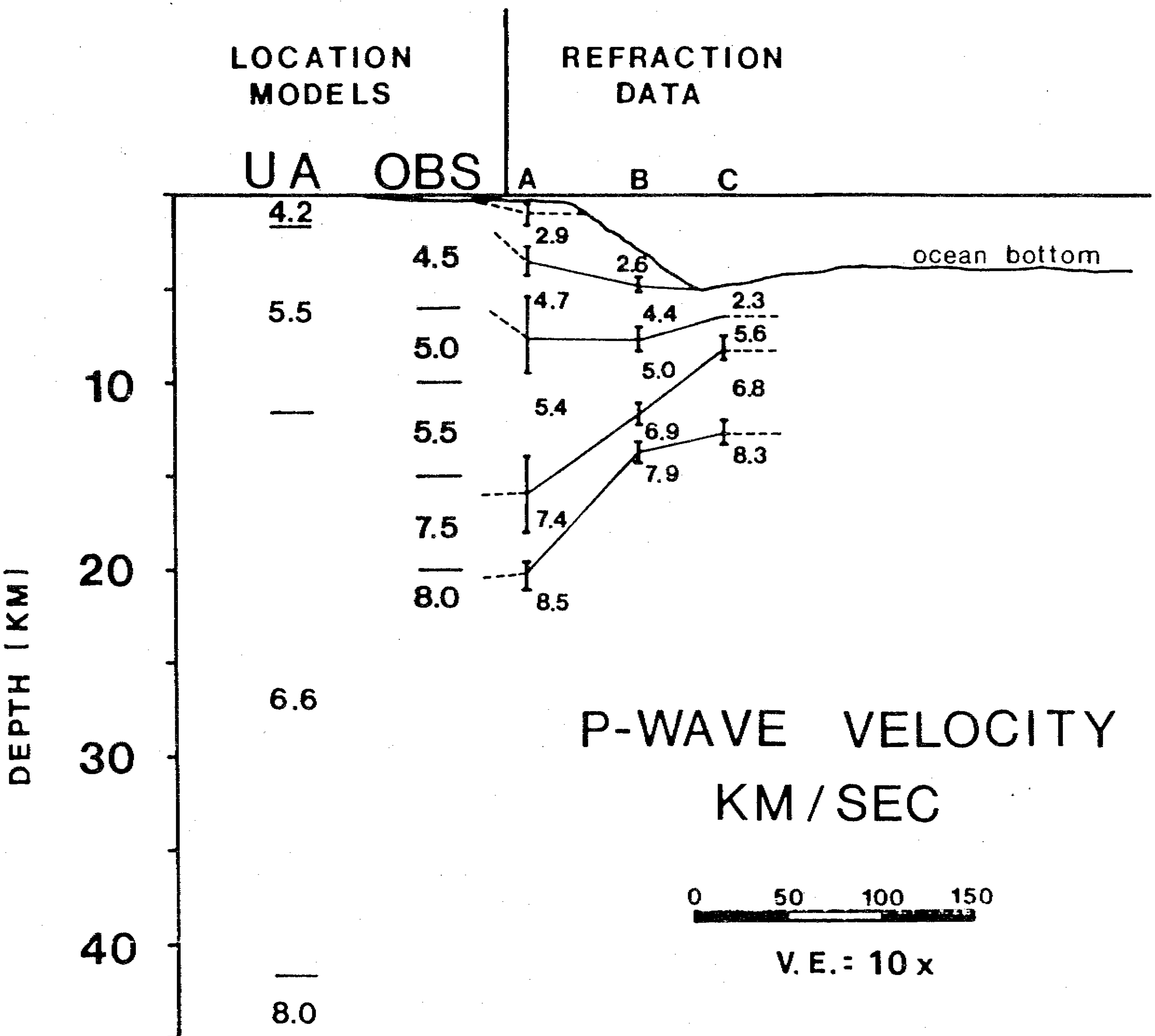


FIGURE 3



LOCATION MODELS
REFRACTION DATA
UA
OBS
A
B
C
ocean bottom
4.2
5.5
6.6
8.0
4.5
5.0
5.5
7.5
8.0
2.9
2.6
4.7
4.4
2.3
5.6
5.0
6.8
5.4
6.9
8.3
7.9
7.4
8.5
10
20
30
40
DEPTH (KM)
P-WAVE VELOCITY KM/SEC
0
50
100
150
V. E.= 10 x

FIGURE 4

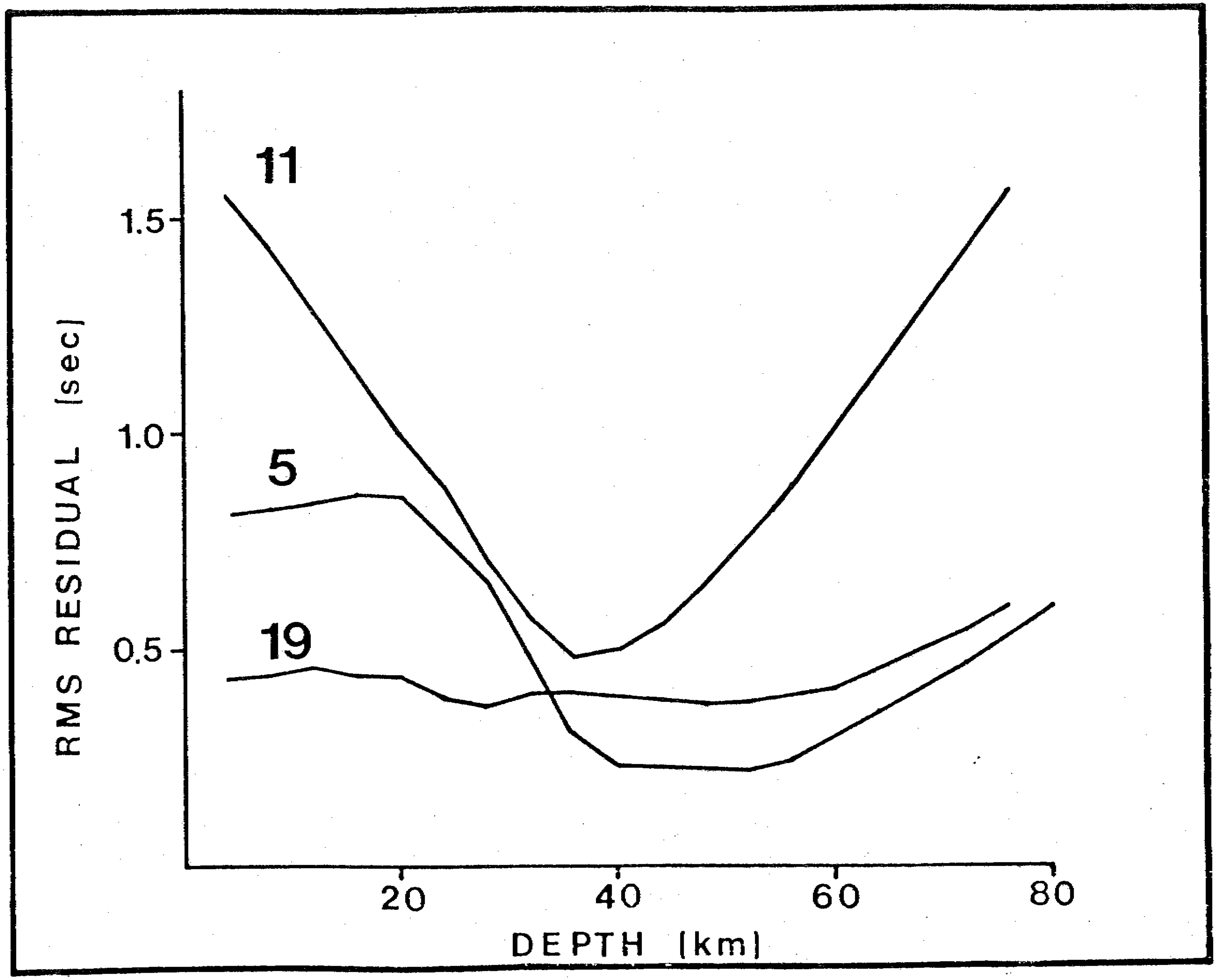
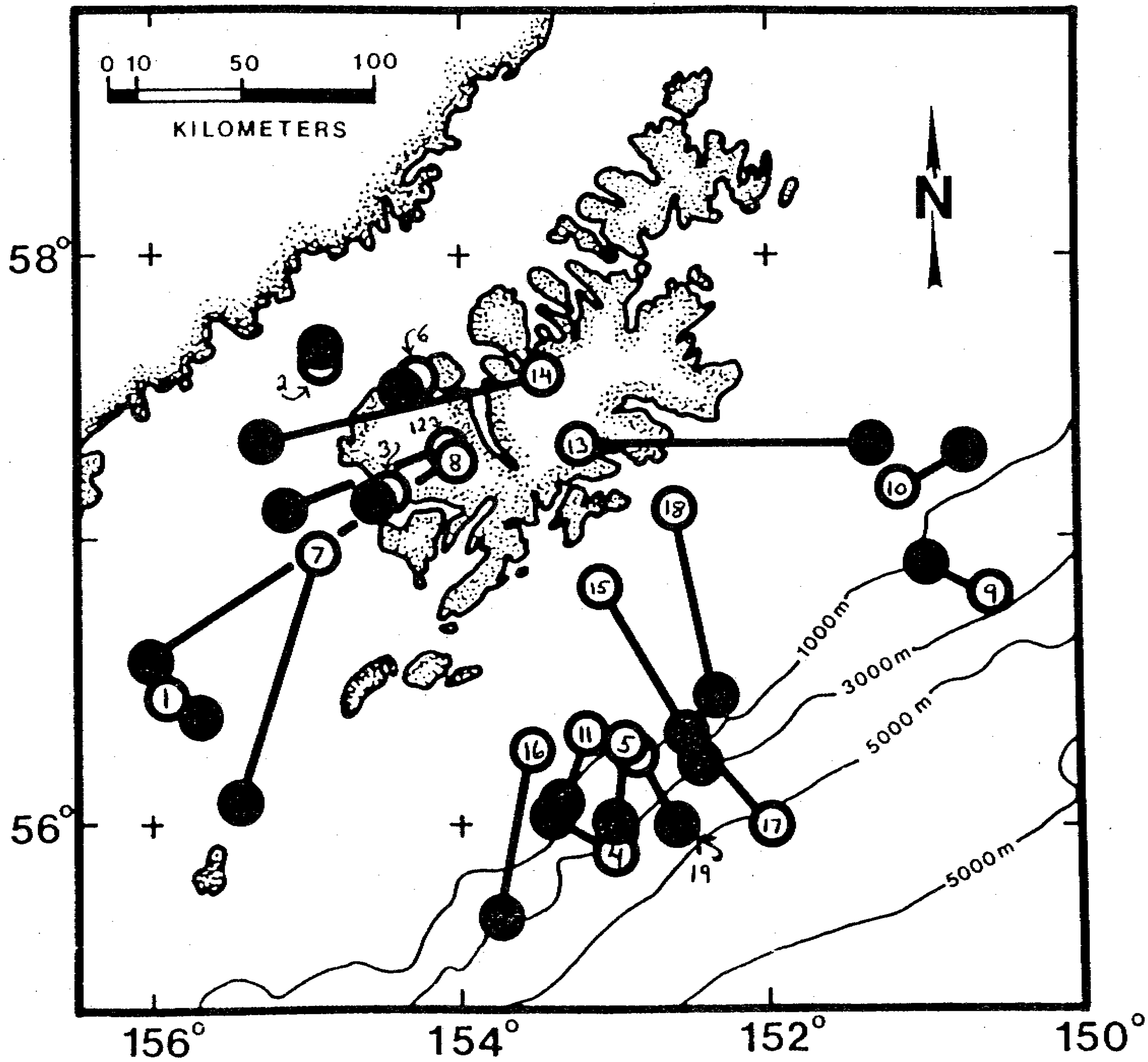


FIGURE 5


0 10 50 100
KILOMETERS
N
58°
56°
156°
154°
152°
150°
1000m
3000m
5000 m
5000m
1
2
3
4
5
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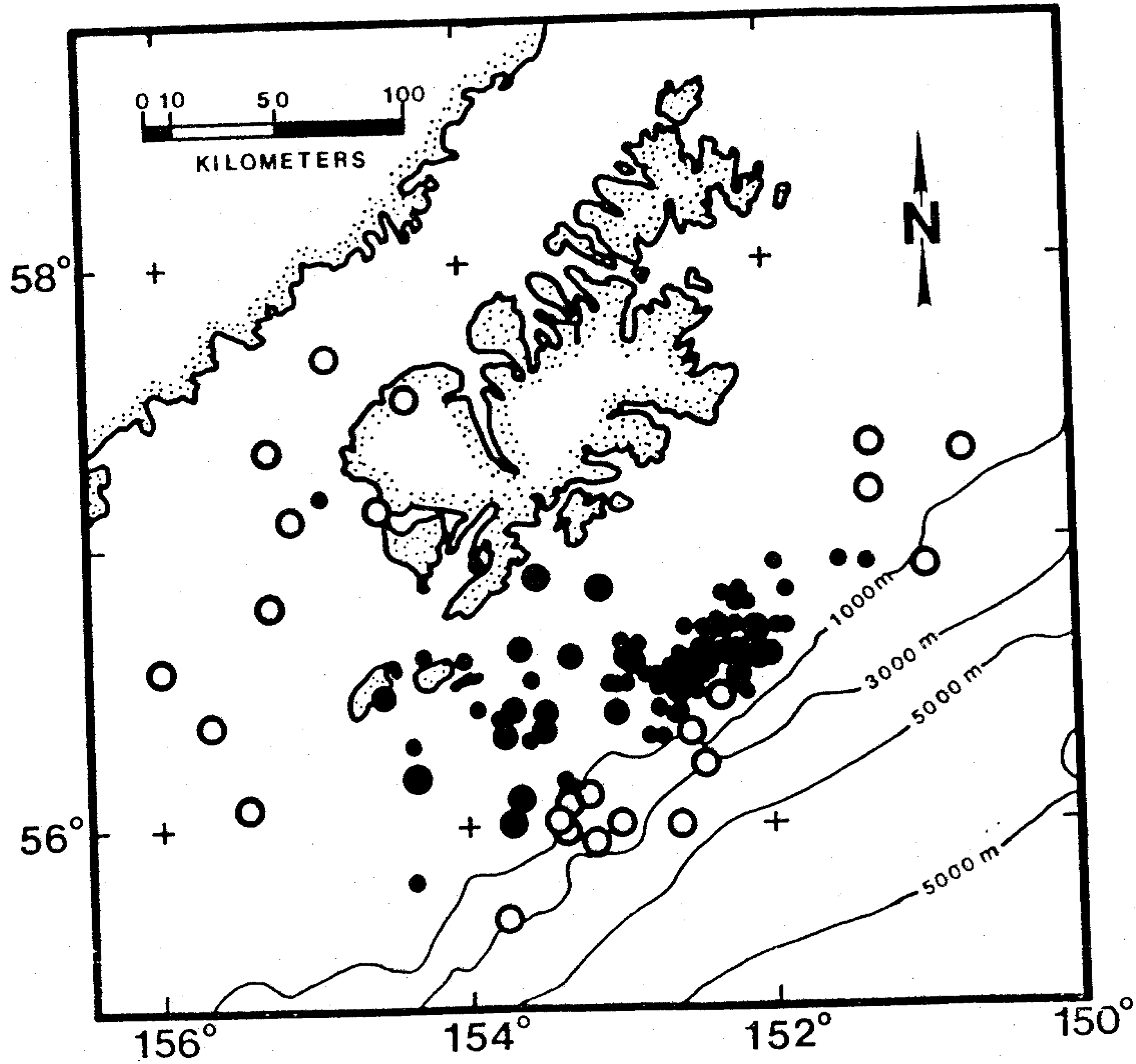
19

FIGURE 6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58°
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150°
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5000 m

FIGURE 7

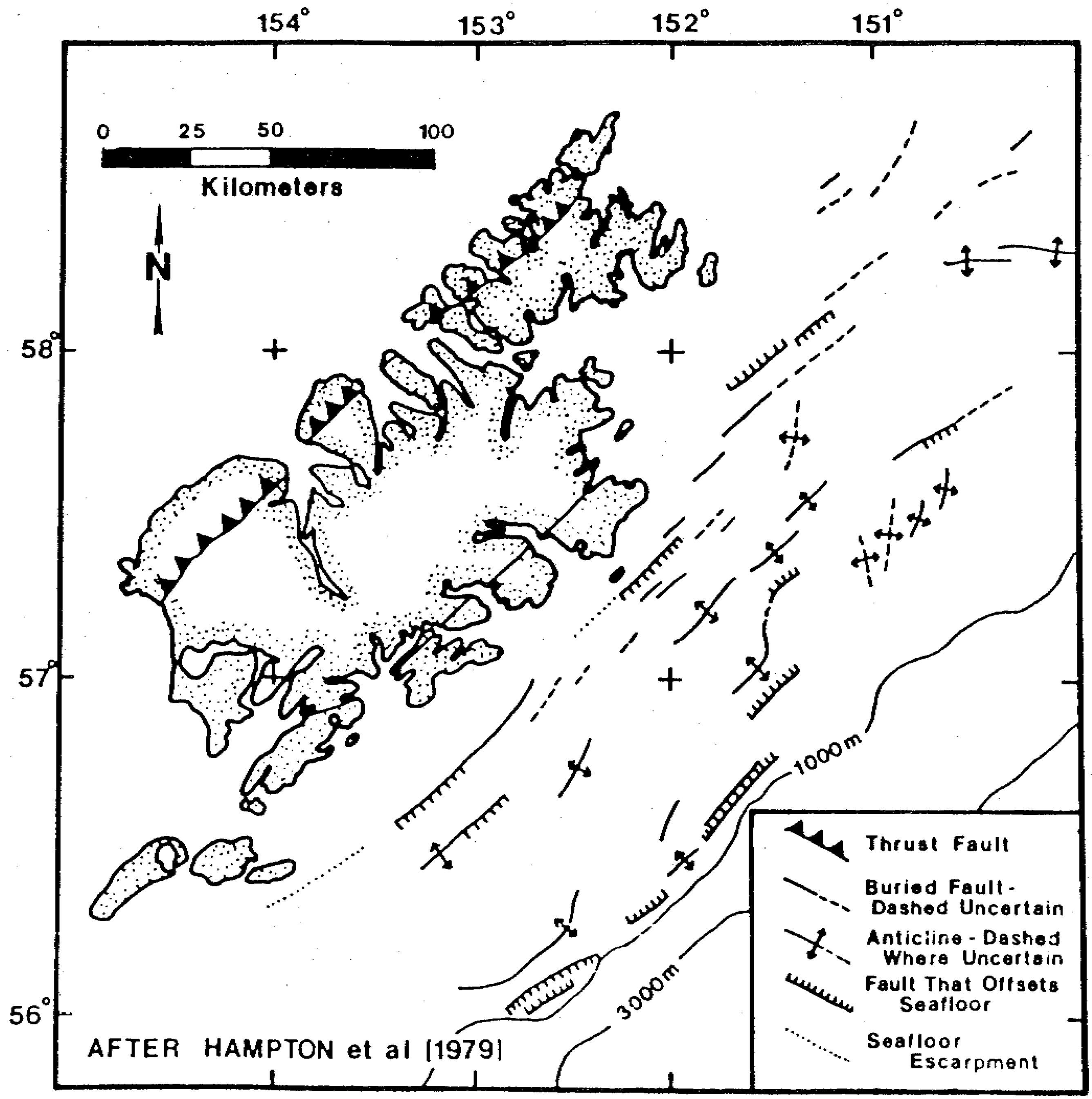

154°
153°
152°
151°
58°
57°
56°
0 25 50 100
Kilometers
N
1000m
3000m
AFTER HAMPTON et al [1979]
Thrust Fault
Buried Fault - Dashed Uncertain
Anticline - Dashed Where Uncertain
Fault That Offsets Seafloor
Seafloor Escarpment

FIGURE 8

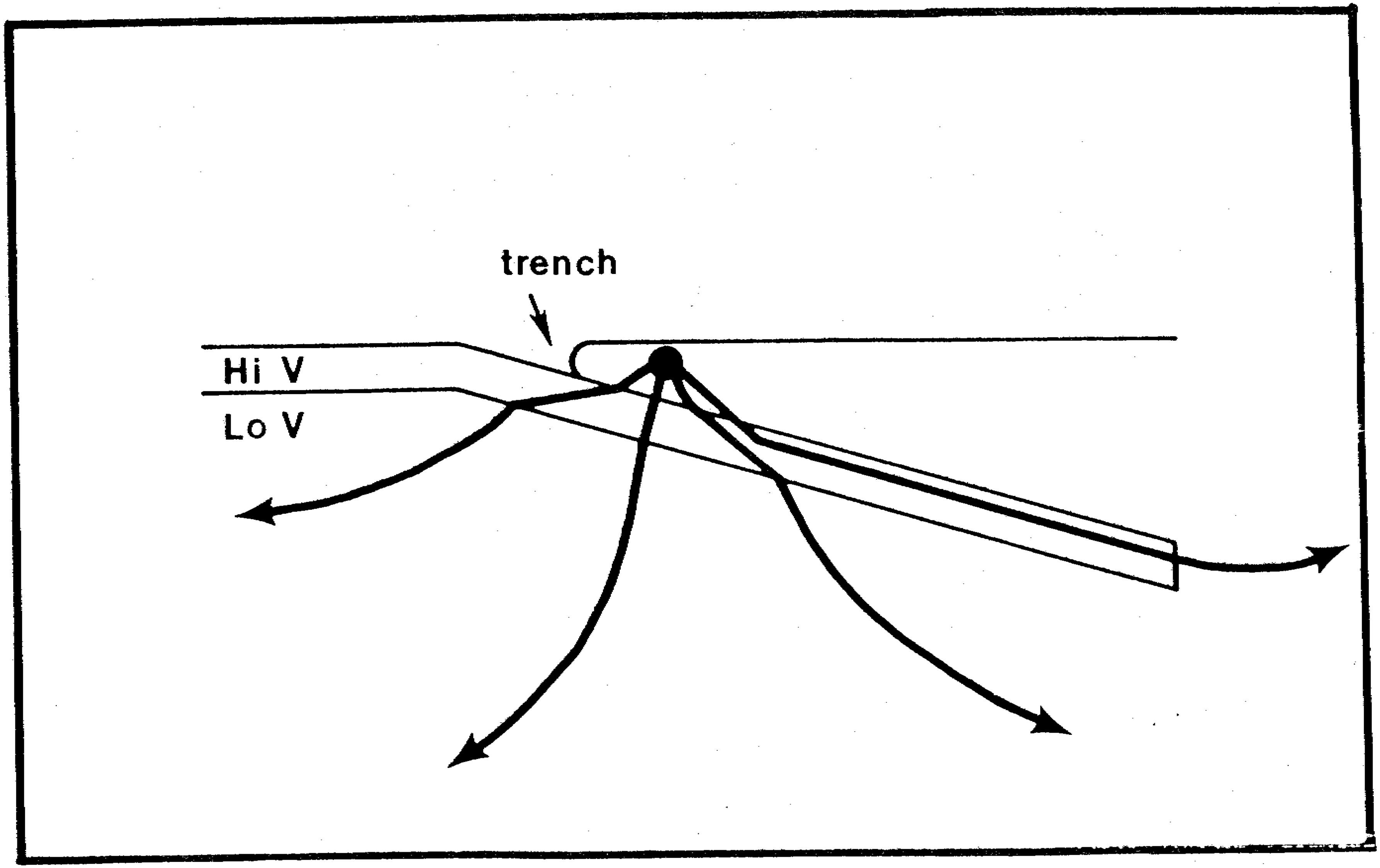


FIGURE 9

ANNUAL REPORT

Contract #03-5-022-55
Research Unit #610, #271
Reporting Annual Report
Period: Period Enging
April 1, 1981
Number of Pages: 38

BEAUFORT AND CHUKCHI SEACOAST PERMAFROST STUDIES

J. C. Rogers** and J. L. Morack*

*Geophysical Institute
University of Alaska
Fairbanks, Alaska 99701
(907) 479-7339

**Electrical Engineering Department
Michigan Technological University
Houghton, Michigan 49931
(906) 487-2513

April 1, 1981

TABLE OF CONTENTS

I. SUMMARY

Developing an understanding of the distribution and nature of permafrost beneath the ocean and barrier islands along the Alaskan Seacoast is a primary objective of this study. Marine seismic refraction equipment, the primary tool used in this study, has shown submarine permafrost to be present at relatively shallow depths to distances of at least 20 km from shore. To put these observations into perspective, the reader is referred to three principal points discussed at the Barrow Synthesis Meeting in January, 1978. Those points provide bounds on the distribution of offshore permafrost based upon the bathymetry and sea level history. (See our 1980 annual report for a listing of these points).

Some specific conclusions resulting from the current studies can be listed in addition to these general guidelines.

a. Seismic studies outside of the barrier islands have shown that the depths of ice-bonded permafrost are not simply related to their distance from shore. In the Prudhoe Bay area, shallow ice-bonded materials (within 10 m of the ocean bottom) have been mapped offshore of the islands while nearer to shore these materials are considerably deeper (up to 140 m beneath the bottom). Permafrost 80 m thick (limited by drill depth) has been observed.

b. The barrier islands are not uniformly underlain by ice-bonded permafrost. It appears to be useful to distinguish between ice-bearing and ice-bonded materials since the seismic velocities and hence mechanical properties are significantly different for these. Areas with no ice-bonding have been observed and areas with continuous ice-bonding have been observed.

c. The presence of salt brine complicates the distribution of offshore permafrost, it appears that relatively impermeable materials such as clays are a dominant factor in determining the depth to subsea permafrost.

d. Former thaw lakes and old river valleys which contribute to the variability of the upper permafrost surface can be found in subsea permafrost of land origin.

e. The seismic indications of permafrost correlate well with drilling evidence.

f. Shallow permafrost occurs under tundra portions of islands that are land remnants. Constructional islands are often not sufficiently persistent and old to be underlain by continuous bonded permafrost. Small halophytic plants that become established on these islands can be an indication that bonded materials are probably present.

g. Some areas of anomalously high velocities have been observed (velocity greater 3500 m/s). These have been postulated to be related to cold relict permafrost.

II. INTRODUCTION

A. General Nature and Scope

A particular concern to the project is the areas offshore and along the barrier islands in the Alaskan Beaufort Sea and the Chukchi Sea where subsea permafrost has been shown to exist. Mapping the distribution of offshore permafrost and determining the depth to the top of the permafrost have been given a high priority.

Seismic refraction techniques are used in the study to probe the ocean bottom along the Alaskan Northern Seacoast. Because of the nature of the geophysical tool, the primary data gathered are depths to the upper surface of the subsea permafrost. Permafrost is interpreted to be present where seismic velocities above a predetermined threshold are observed. The study will provide information relevant to task D-8 in NOAA's proposal to BLM.

B. Specific Objectives and Relevance to Problems of Petroleum Development

Using the equipment purchased by the program, data are being gathered which enable determination of the distribution and nature of offshore permafrost. The most important parameters to be determined in this study are the distribution and the depth of offshore permafrost. Another objective is compilation of the above parameters for use by other principal investigators and appropriate agencies and industries.

The Chukchi Seacoast and the Beaufort Seacoast, primarily the Prudhoe Bay area and adjacent offshore islands, are the primary focus of this study. Seismic studies to date have extended along approximately 100 km of coast around Prudhoe Bay. In addition, 27 km of lines have been run near Icy Cape in the Chukchi Sea. The truncation of permafrost beneath the ocean is of interest, particularly the shape of the frozen-nonfrozen boundary. Thus, the second major objective is the determination of the shape of the boundary.

A third major objective is determining the nature and extent of permafrost beneath the barrier islands. In this report we present the summary of all our island work to date. These results will provide valuable information for refinement and testing of thermal models as well as for determining operational methods for offshore oil and gas development.

It is possible, using the seismic technique, to extend site specific drilling information to areas remote from the drill site, by correlating seismic data at the drill site and at the remote locations. The fourth major objective, then, is to provide information to support reconnaissance drilling programs. Areas for future drilling investigations can be suggested on the basis of seismic information.

The reader is referred elsewhere for specific and detailed descriptions of the relevance of our work to problems of offshore petroleum development. These have been addressed in the synthesis documents developed by the Earth Science Study Group.

III. CURRENT STATE OF KNOWLEDGE

It is now known that the sea floor along the Arctic Coast is underlain by permafrost. Definite progress is being made toward understanding its distribution and the dynamics of its formation and destruction. Several of the problem areas needing investigation have been listed in the introduction of this report.

Hunter et al. (1978, 1981) have reported extensive permafrost beneath the Canadian Beaufort Sea. It has also been reported beneath the water of Prudhoe Bay, Alaska (Osterkamp and Harrison, 1976, 1978, 1981). Some of the physical processes involved in the degradation of relict permafrost are beginning to be understood and in addition to temperature, the porosity of the sediments and the salinity of the interstitial liquids have been shown to be important. Current data are available in the 1980 annual reports of research units 253, 255, 256, by Harrison and Osterkamp. Some details of the processes involved are also found in Harrison and Osterkamp (1976, 1981). The results reported here are in agreement with the drilling results obtained by the Joint USACRREL/USGS drilling program (R.U. 105) as reported by Sellman et al. (1976) (see also Chamberlain, et al. 1978 and Sellman et al. 1979). In our 1979 annual report a close correlation between their drilling and our geophysical results were shown. Also, our geophysical results are in general agreement with those of Osterkamp and Harrison. The depth of the permafrost upper surface is currently known along several transects made both inside and outside of the barrier islands. To date there has been little success in determining the permafrost thickness. Widespread aerial distribution and depth information remain to be determined although it is possible to make some general statements regarding offshore permafrost (see the summary section of this report) and to sketch regions of known shallow permafrost (Rogers and Morack, 1980).

IV. STUDY AREA

Figures IV-1 through IV-3 show the areas investigated during this season's study. The study was concentrated in Harrison Bay and near Icy Cape. In addition, all of the vessel tracks taken over the previous several summer field seasons are shown in Figure IV-4. Past reports by this research unit have shown some of the lines in the area covered by the latter figure in more detail.

V. SOURCES AND METHODS

A. Marine Seismic

The application of shallow refraction techniques, documented by Grant and West (1965) to the detection of subsea permafrost has been described previously (Hunter, 1974; Hunter and Hobson, 1974). The seismic refraction data taken in and near Prudhoe Bay were collected using a 40 cubic inch air gun as an acoustic source and the refracted signal was detected along a hydrophone line towed behind a 21' vessel. Some data were taken with a 10 cubic inch air gun as a source and all the data taken

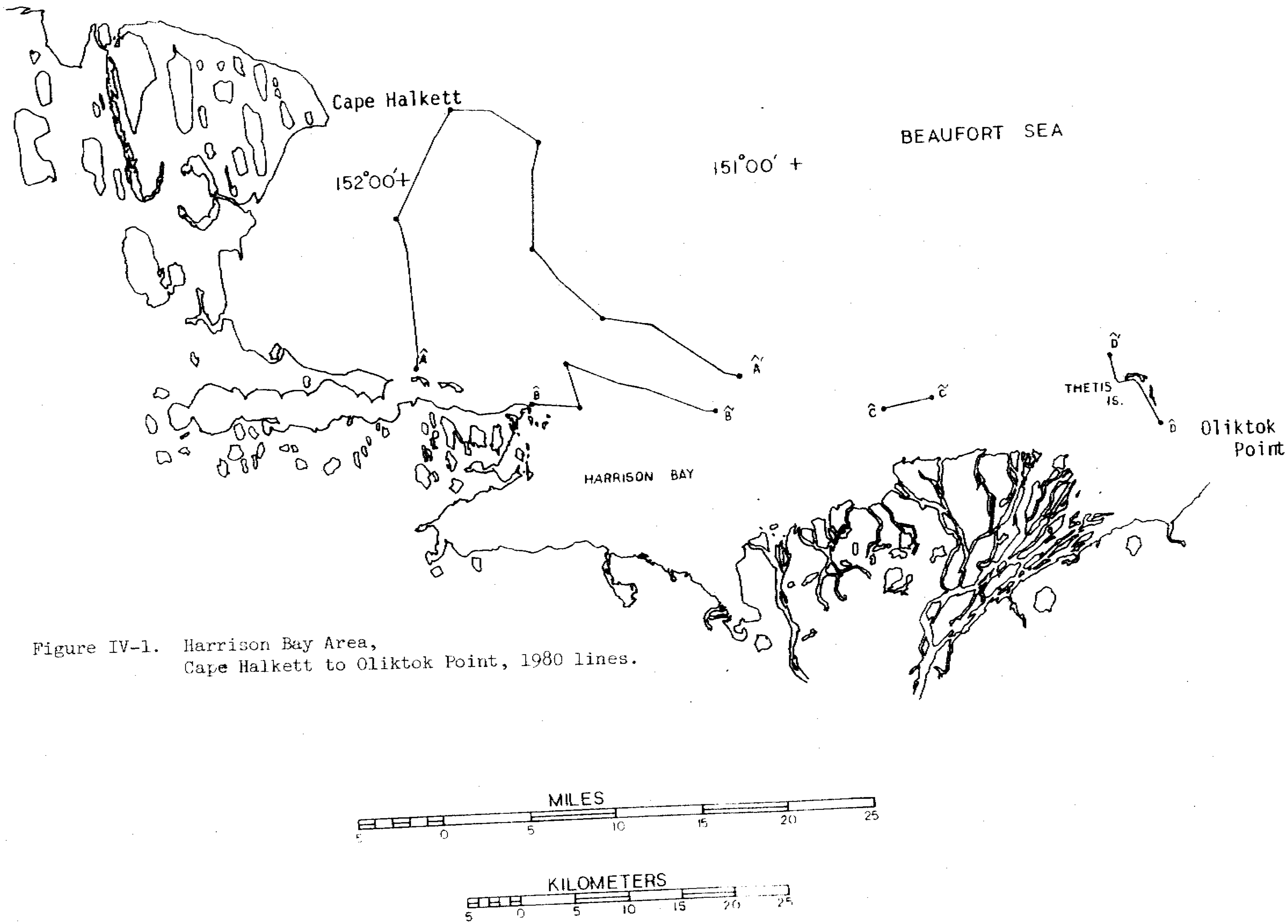


Figure IV-1. Harrison Bay Area, Cape Halkett to Oliktok Point, 1980 lines.

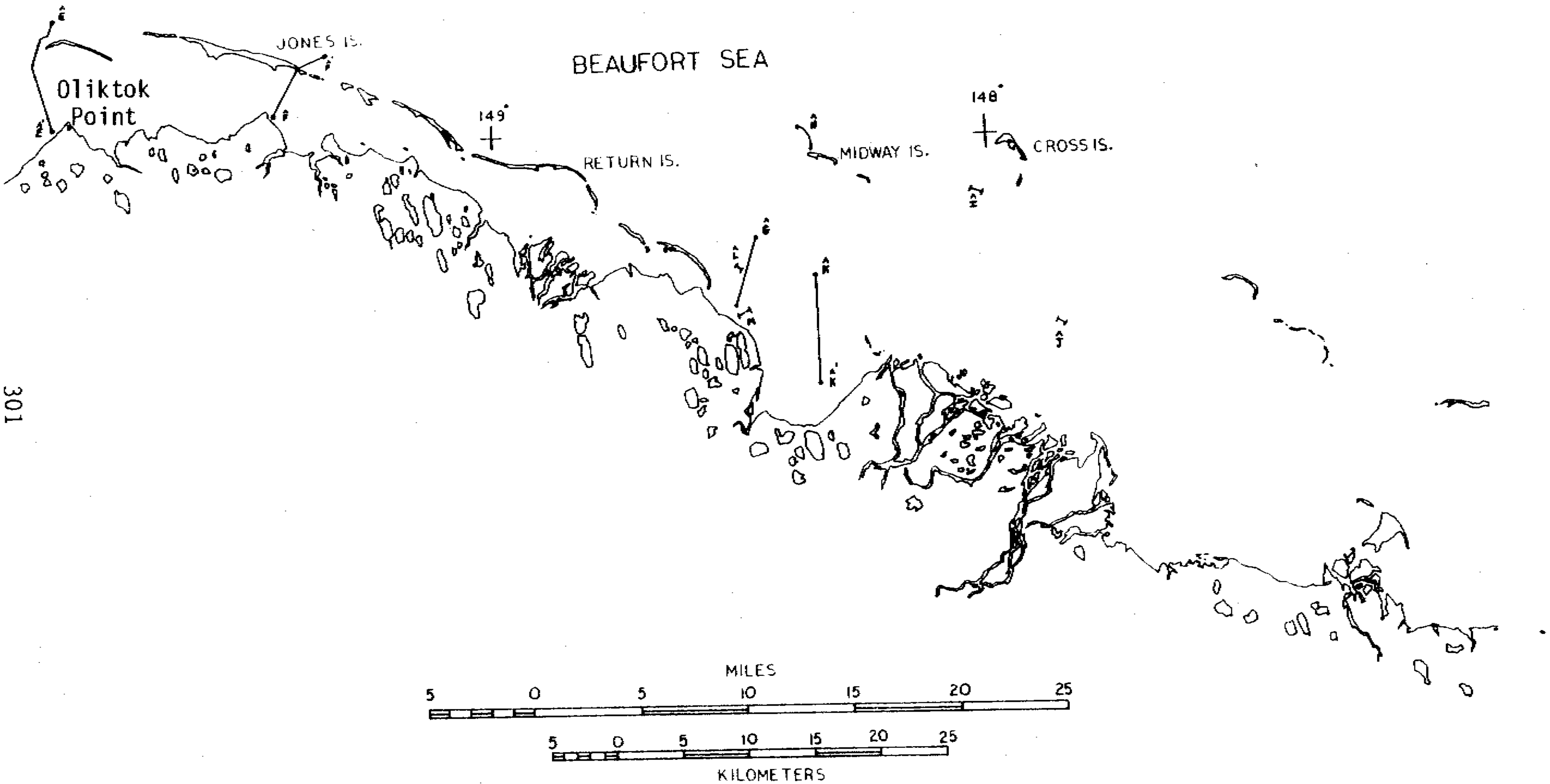


Figure IV-2. Oliktok Point to Tigvariak Island, 1980 lines.

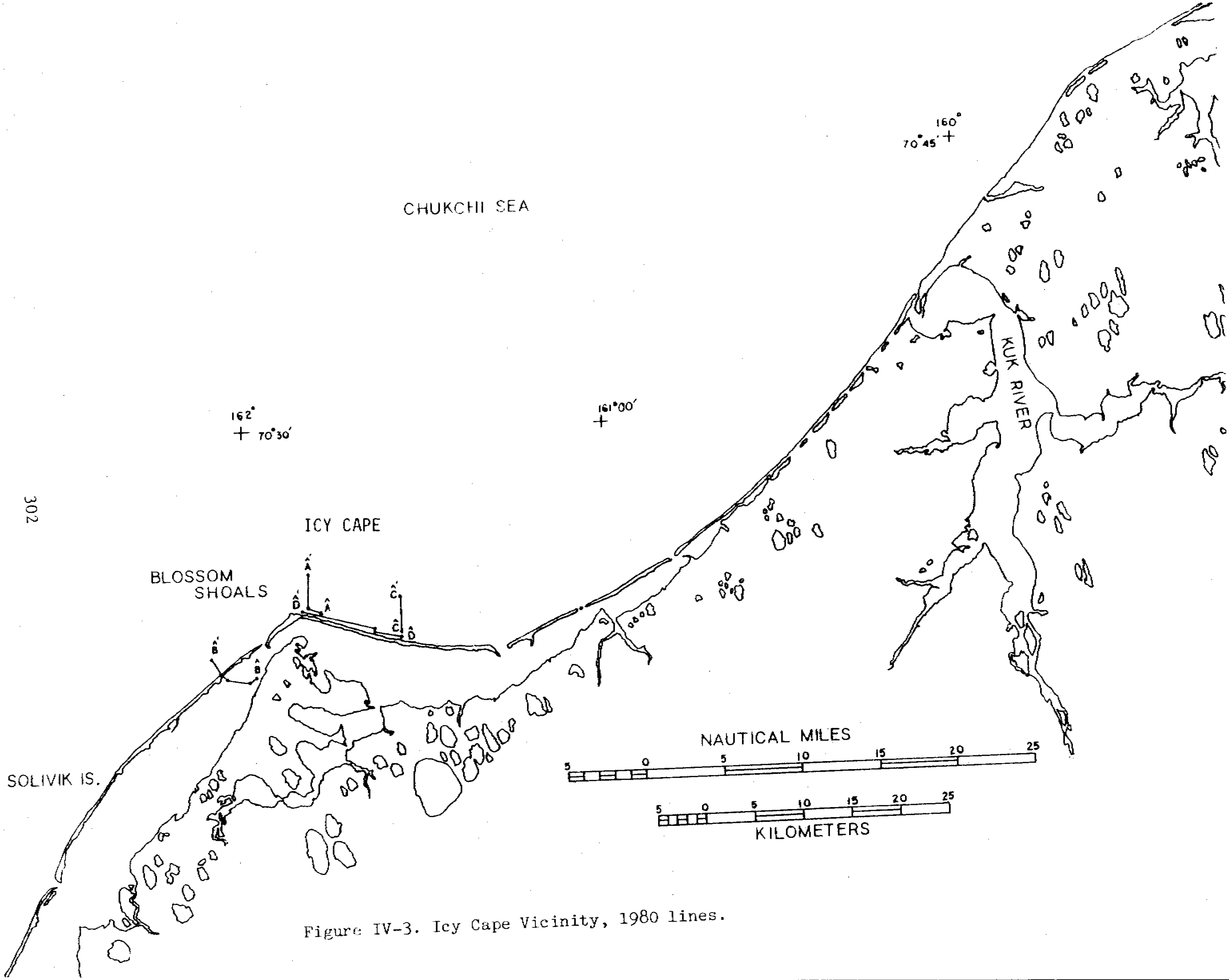


Figure IV-3. Icy Cape Vicinity, 1980 lines.

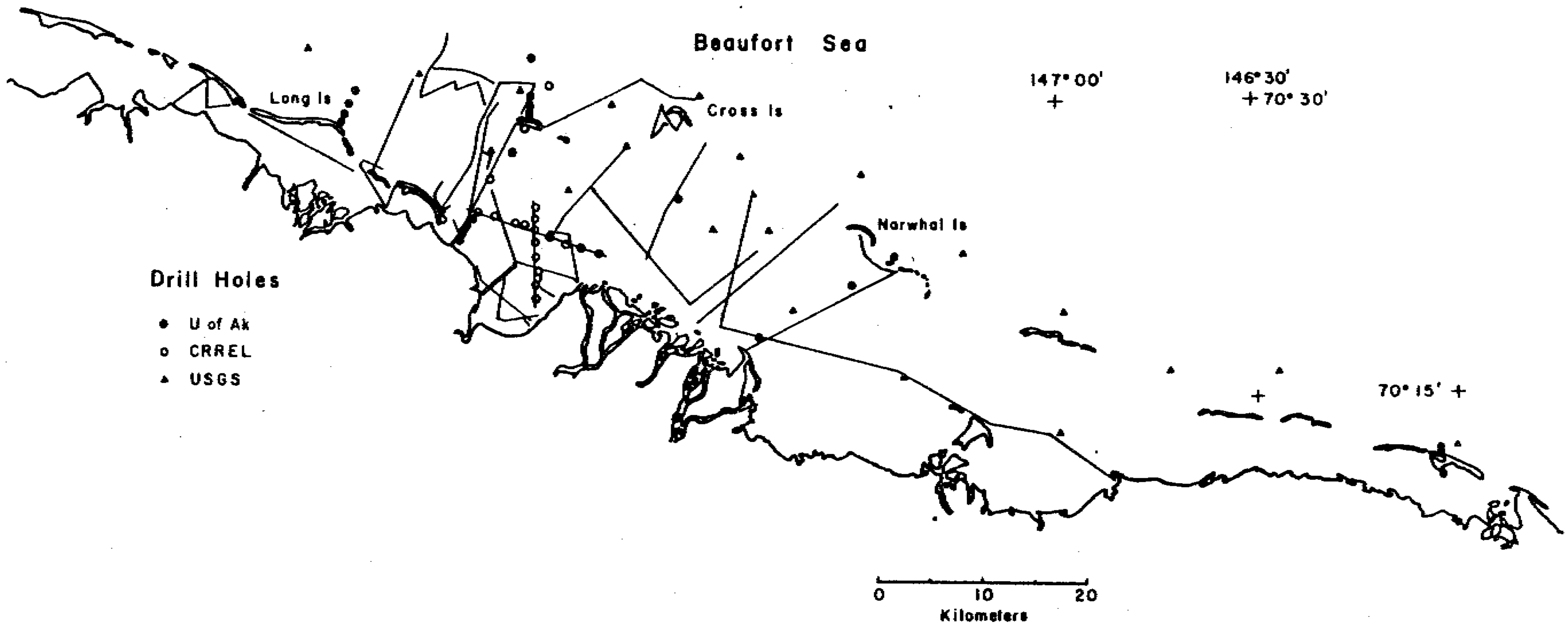


Figure IV-4. Seismic lines gathered through the 1980 field season (from our 1980 Annual Report).

during the last field season were recorded using an enhancement seismograph which allowed field evaluation of the data at the time of acquisition. These data were gathered at several points along the ship transects, scaled and reduced to time-distance plots. Over 280 of these plots were made last season along 170 km of vessel track.

Seismic velocities are calculated and used to determine whether the bottom materials are frozen. Permafrost velocities in the materials near Prudhoe Bay are typically between 2500 m/s and 3000 m/s while similar materials in the nonfrozen state typically have velocities ranging from 1600 m/s to 2000 m/s/ (Rogers et al. 1975). Significant velocity contrasts such as these, which are typical of coarse sandy materials, allow easy classification of materials into the frozen and unfrozen state. Fine grained materials, silts and clays, are more difficult to classify but do show velocity enhancement upon freezing.

Various errors exist in the data acquisition and reduction procedures. Several of these are indicated in Appendix A1 of last year's annual report. The cumulative errors in the calculated depth to permafrost are estimated to be -5% due to cable slack and -5% due to cable curvature. The random errors are estimated to be ± 8% and are judged to be additive with respect to the cable slack and curvature errors. As will be shown in the next section, we have observed a trend toward lower velocities in the bottom sediments as one proceeds from Prudhoe Bay into western Harrison Bay.

B. Island Seismic

The methods used to gather and analyse seismic data on the several islands studied were similar to those used for the marine seismic studies. The acoustic source was a ten pound sledge and a 30 m geophone string was used to give a maximum penetration depth of approximately 10 m.

VI. RESULTS

A. Chukchi Sea

Last season was our first opportunity to work in the Chukchi Sea. After some initial delays we ran lines near Icy Cape. Figure VI-1 shows the vicinity and several of the seismic lines. The lines are tabulated in Table I and given the identifiers A-A' through D-D' that are used on the location map.

In order to classify the velocities observed in this region, velocity histograms were prepared and are shown in Figure VI-2. Lines 2-1 through 2-13 show a velocity distribution that is much like our past observations near Prudhoe Bay. That is: a low velocity group (1500-1800 m/s), a medium velocity group (1900-2200 m/s), and a high velocity group (greater than 2500 m/s). Lines 3-1 through 3-48 are not so clearly divided and in both cases there are not as many observations in the high velocity group as observed in the Beaufort Sea near Prudhoe Bay.

B. Beaufort Sea

The Beaufort Sea work was concentrated in the vicinity of Harrison Bay. Figures VI-3 through VI-5 show details of the seismic lines run in the area and an overall perspective of the relative locations of all the lines. The lines are individually identified as A-A' and these identifications correspond to the tabulation of Beaufort Sea lines shown in Table I. Approximately 120 kilometers of lines were run in the area and two histograms have been prepared to indicate the distribution of observed velocities. These are shown in Figure VI-6.

Two features of the velocity distribution seen in the Harrison Bay area are significant. There is a large number of velocities observed 1500 m/s and 1800 m/s and there are only a few velocities observed that

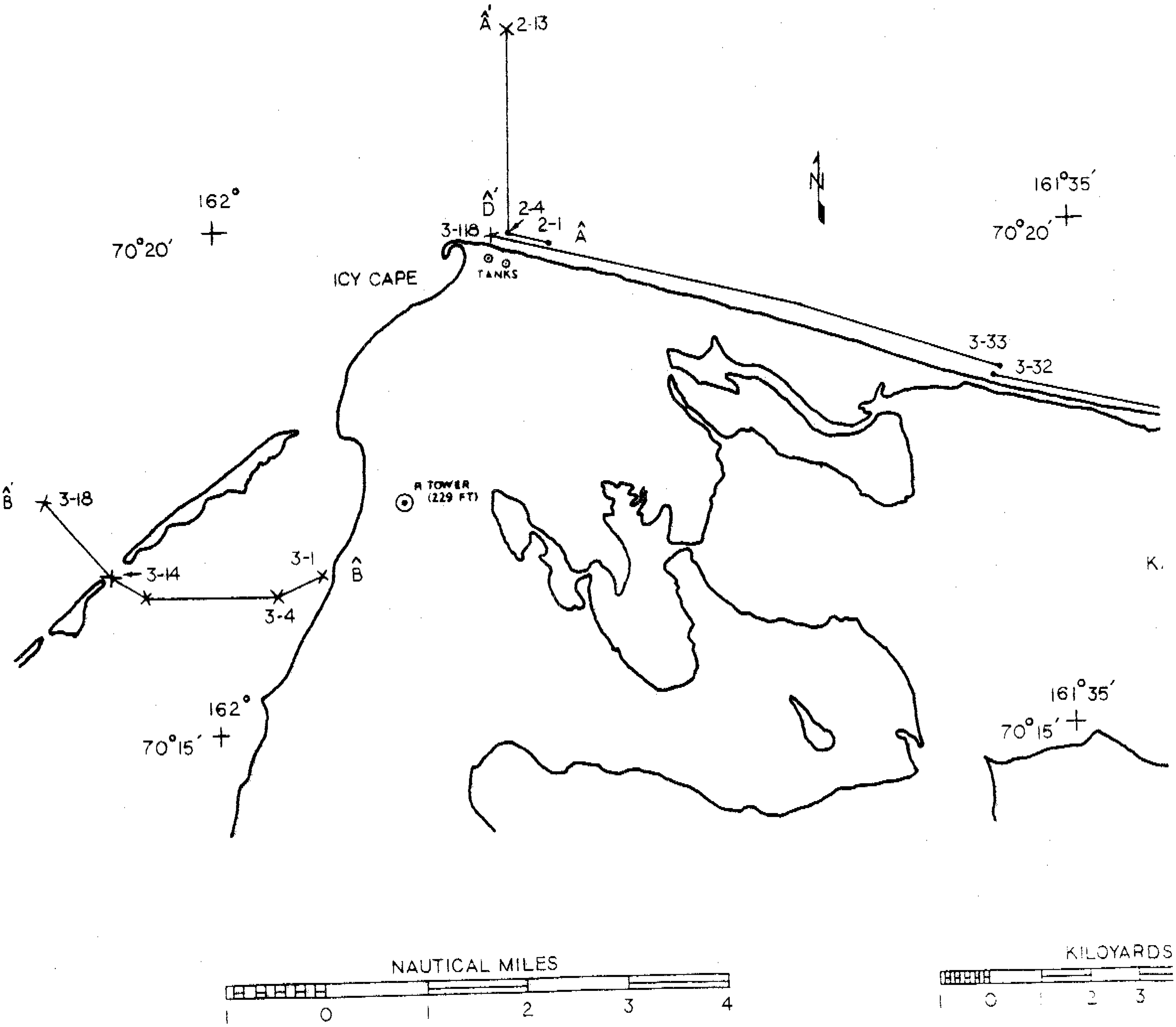


Figure VI-1a. Details of lines near Icy Cape.

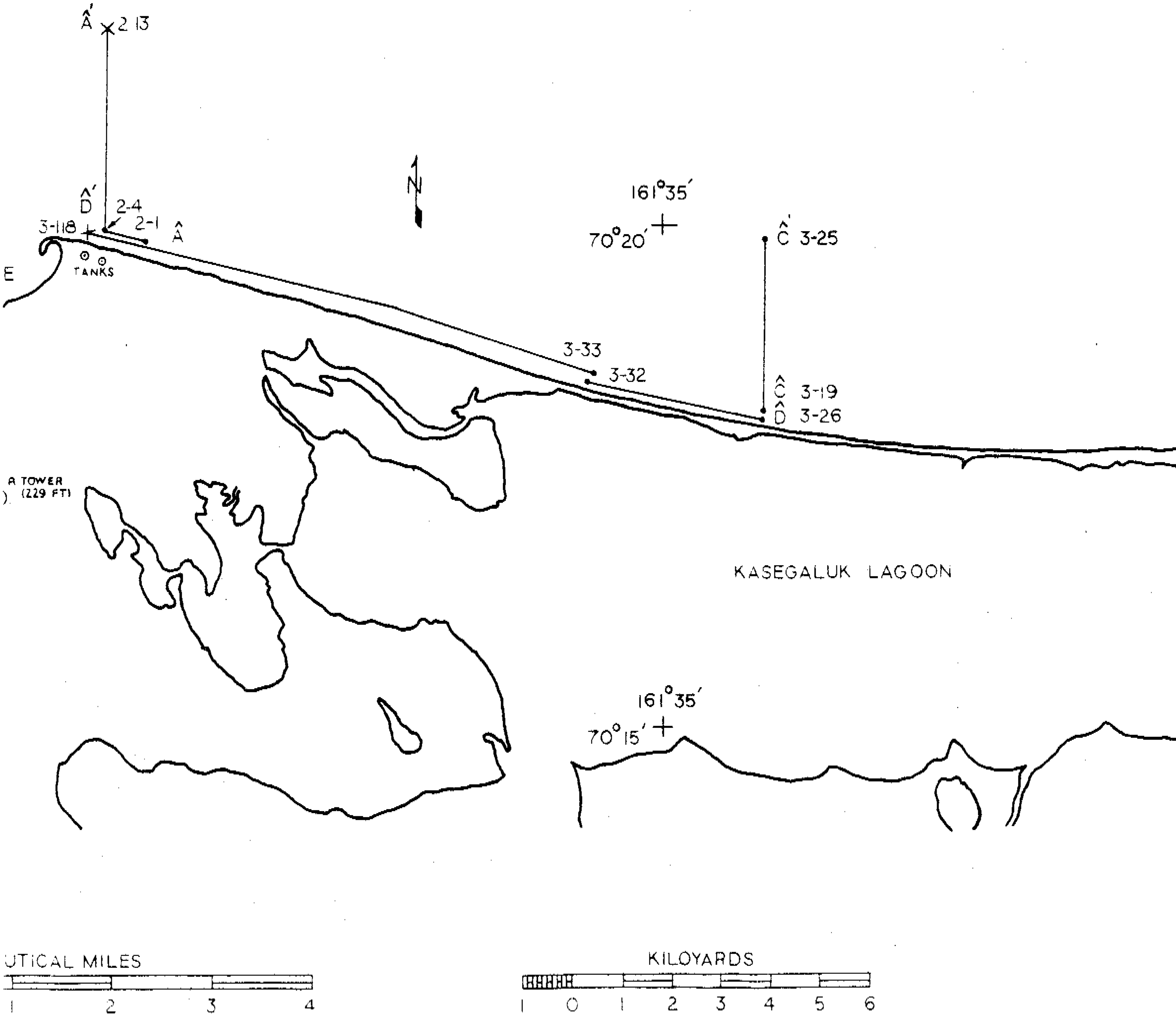


Figure VI-1b. Details of lines near Icy Cape.

Table I
1980 Field Season
Line Summary

Beaufort Sea

Line #	Description	Length, Kilometers
11-1 to 11-74 A to A'	North from Eskimo Islands then East (across Pacific Shoal) and South East	60.6
13-1 to 13-27 B to B'	East from Atigaru Pt.	23.3
13-28 to 13-36 C to C'	West to East, North of Colville River delta	6.5
17-1 to 17-17 E to E'	South to North, just to the West of Thetis Island	13.2
17-18 to 17-33 E to E'	North to South line ending at Oliktok Point	11.5
18-1 to 18-12 F to F'	North to South line ending at Milne Pt.	6.4

Chukchi Sea

Line #	Description	Length, Kilometers
2-1 to 2-13 A to A'	At Ice Cape, East to West then to North	4.7
3-1 to 3-18 B to B'	East to West, passing out of Kasegaluk Lagoon, West of Icy Cape	6.0
3-18 to 3-25 C to C'	North from house, approximately 13 kms East of Icy Cape	3.3
3-26 to 3-48 D to D'	East to West line near shore, terminating at Icy Cape	12.9
	Total	149.0 km

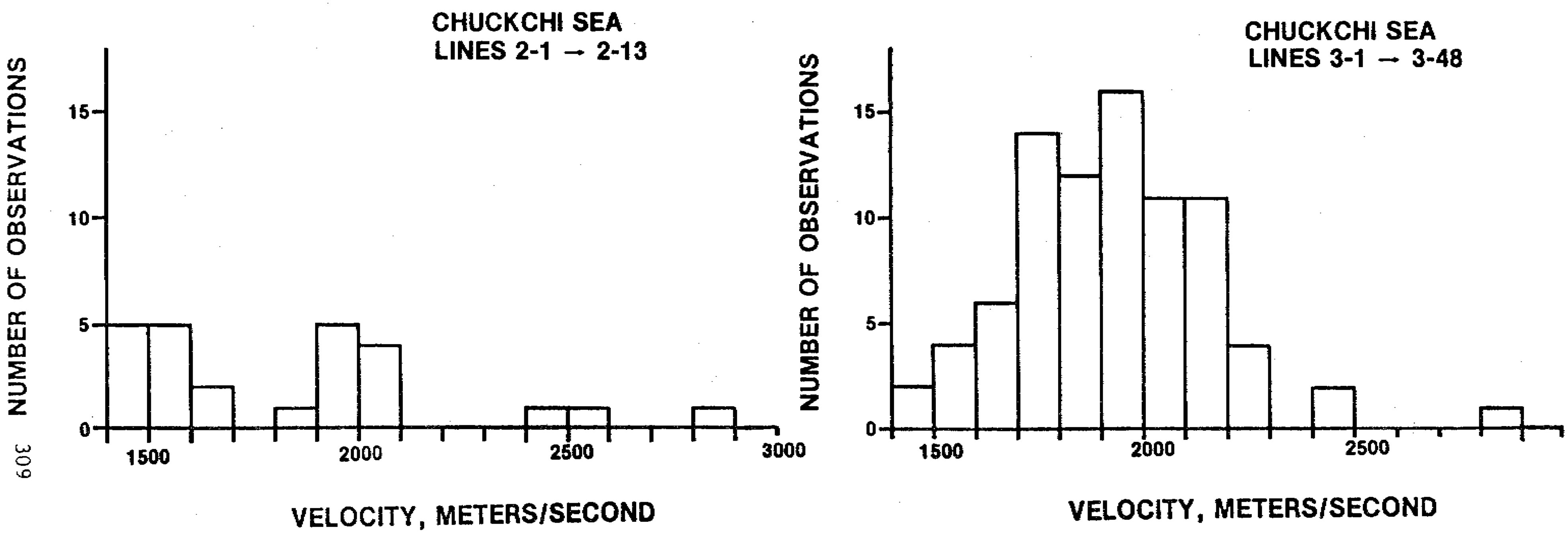


Figure VI-2. Histogram of observed velocities near Icy Cape.

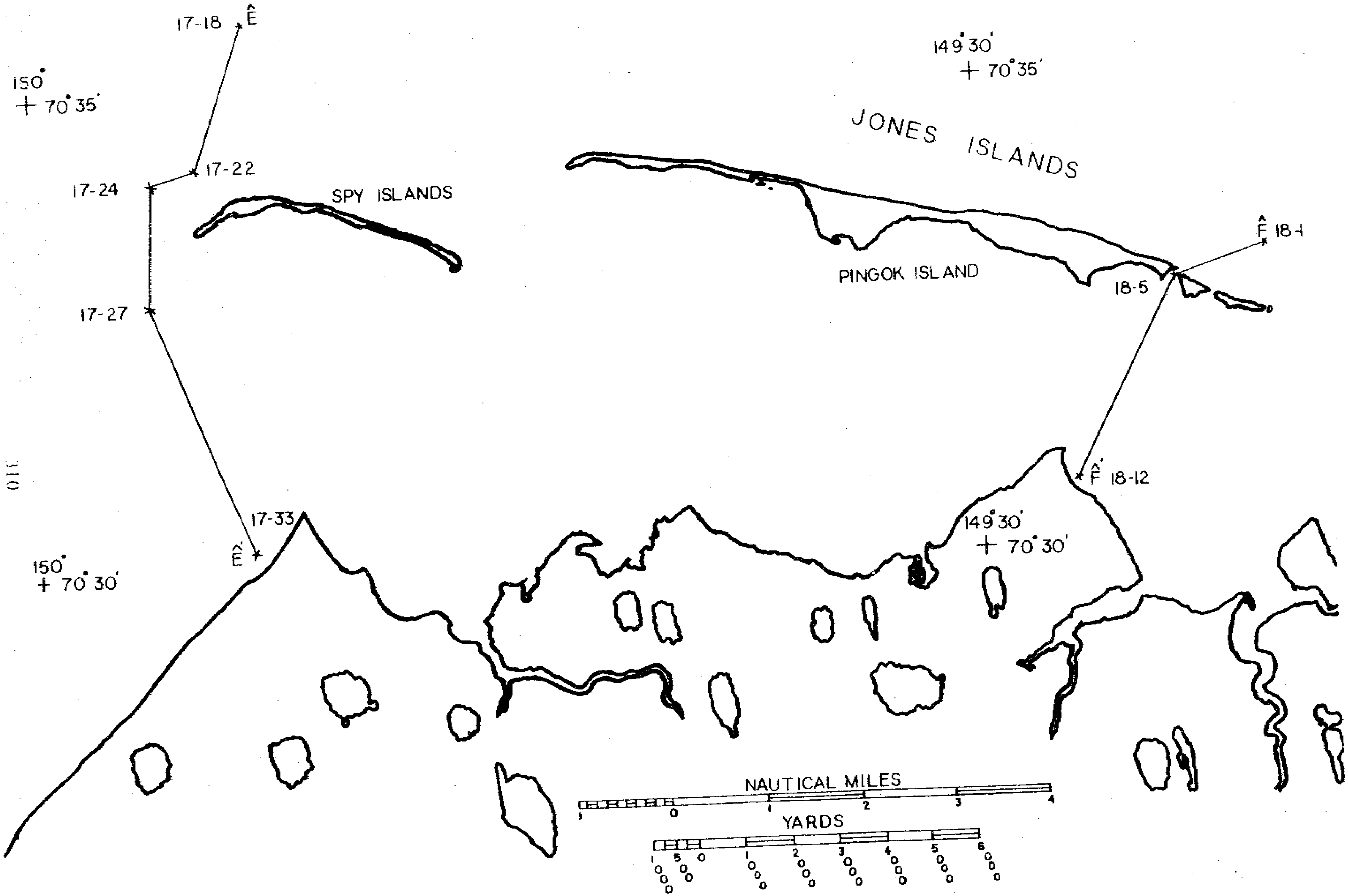


Figure VI-3. Details of seismic lines east of Harrison Bay.

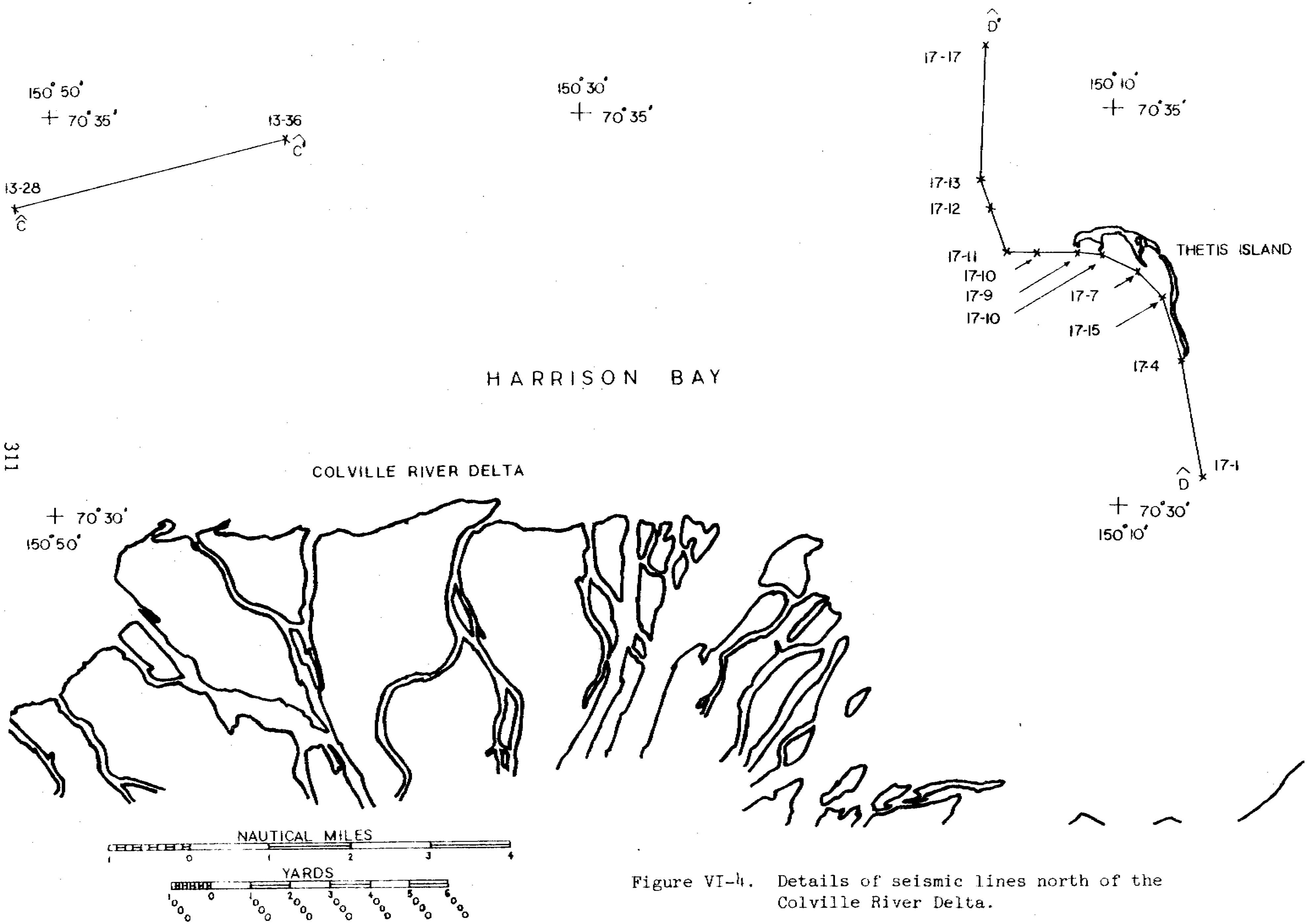
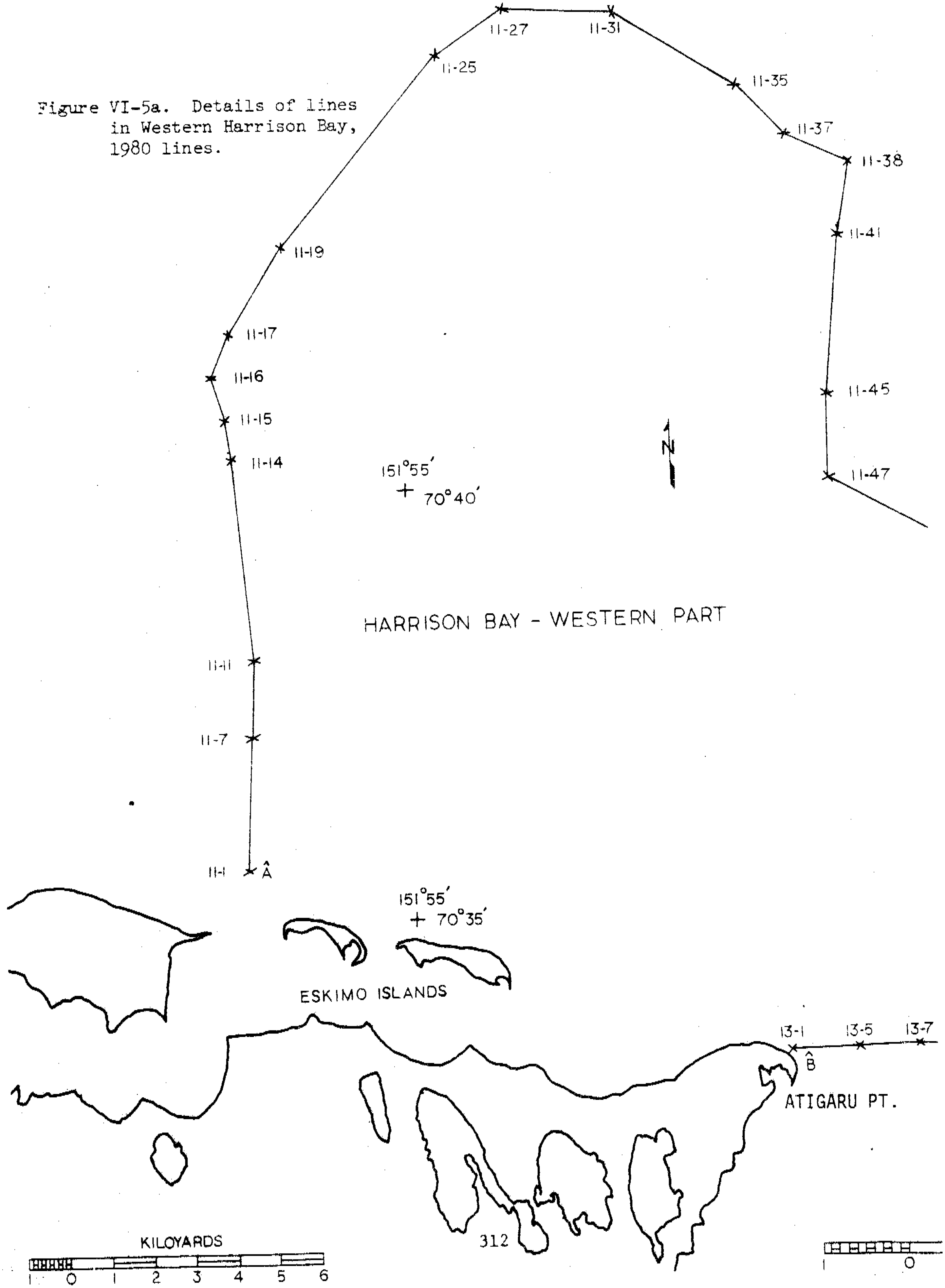


Figure VI-4. Details of seismic lines north of the Colville River Delta.

Figure VI-5a. Details of lines in Western Harrison Bay, 1980 lines.



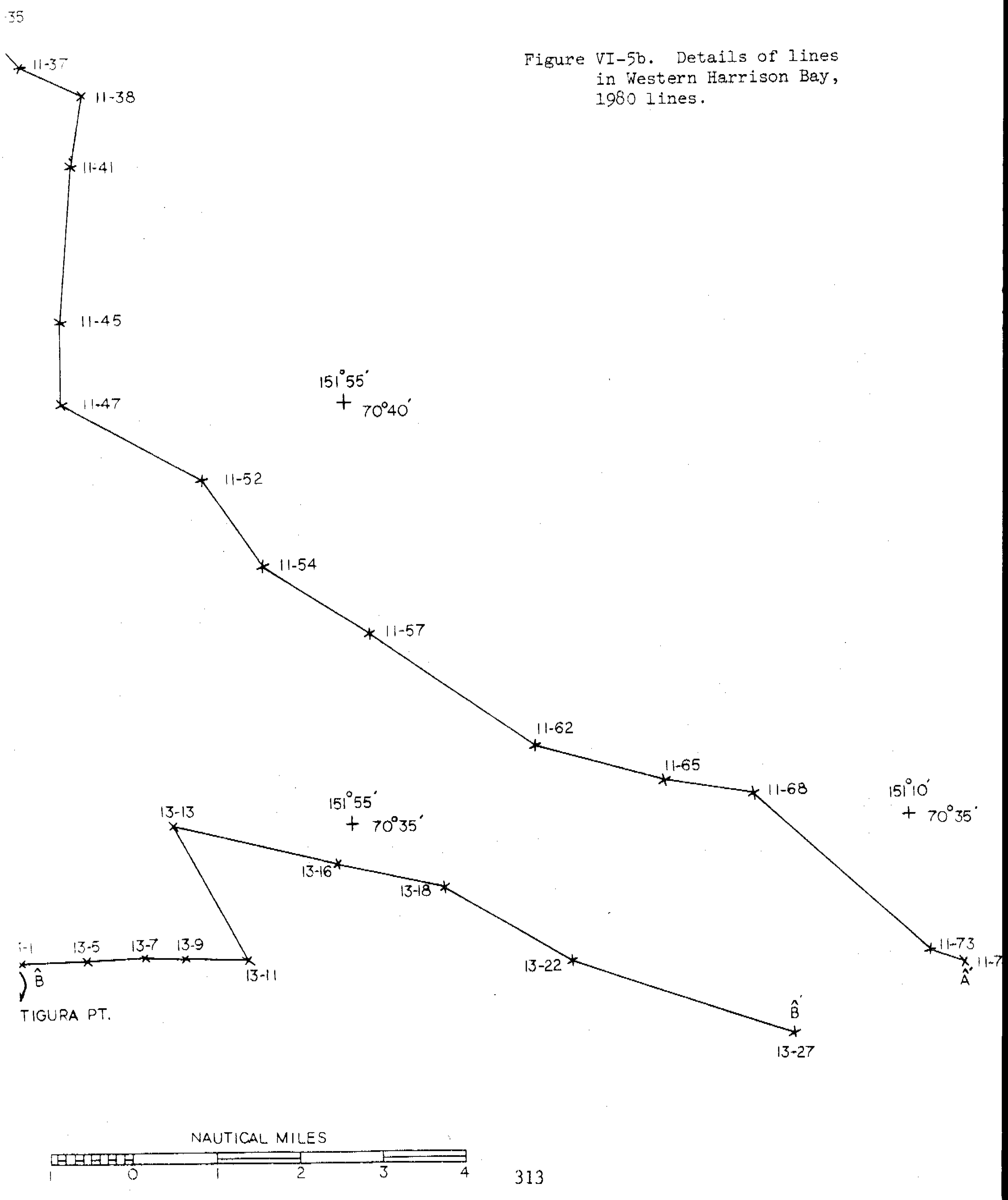


Figure VI-5b. Details of lines in Western Harrison Bay, 1980 lines.

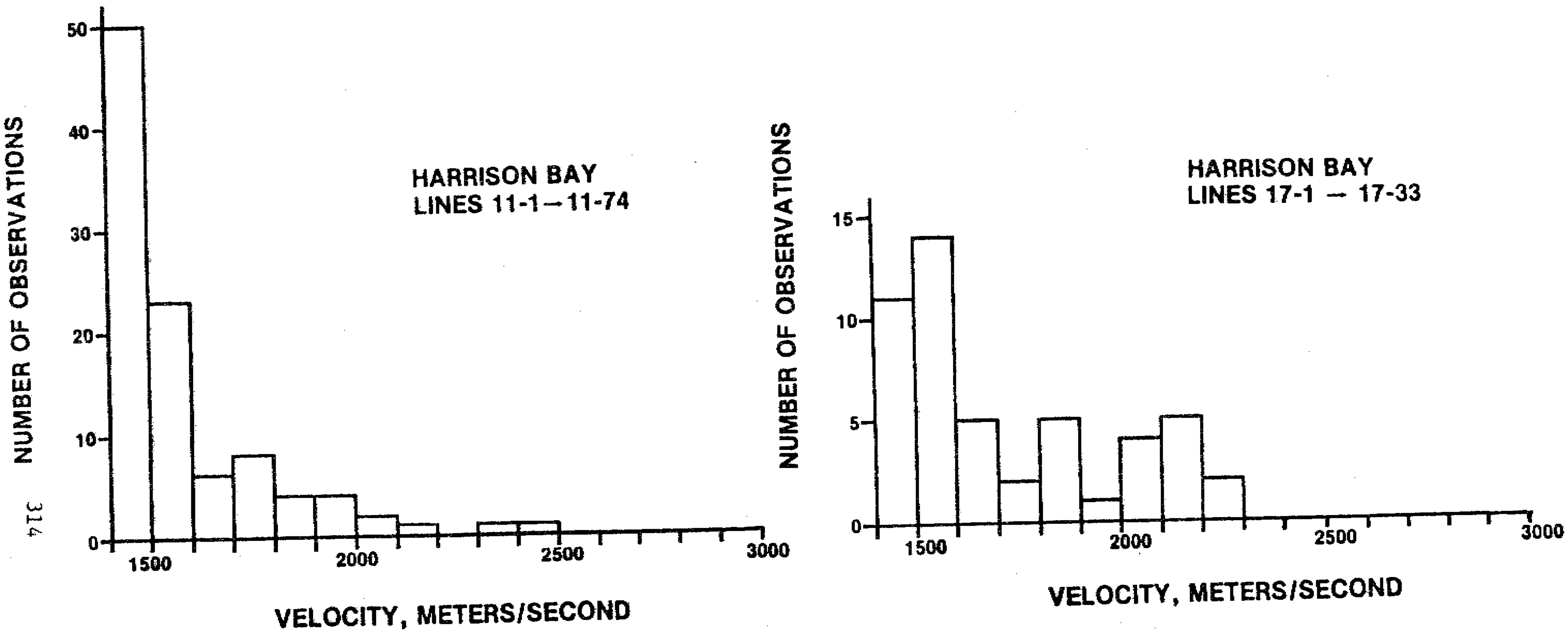


Figure VI-6. Histogram of velocities observed in the vicinity of Harrison Bay.

are near 2500 m/s. These distributions are unlike past field season results in that there is not a large group of velocities near 2000 m/s with another group of velocities above 2500 m/s. This feature is discussed further in Section VII.

Another feature of interest is the observation of refractor velocities 3337, 4315, and 4709 m/s for lines 18-3, 18-4, and 18-5. These velocities, which were not plotted on the histogram due to scale limitations, were observed near the east end of Pingok Island. To date our only other observations of such high velocities have been approximately 4 kilometers north of Reindeer Island and within a few hundred meters of shore near the ARCO west dock in Prudhoe Bay (Morack and Rogers, 1981).

C. Island Studies

Seismic refraction studies have been conducted during the past several field seasons on Jeanette Island, Karluk Island, Narwhal Island, Cross Island, Reindeer Island, Stump Island, Exxon's "Duck Island", and Sohio's "Niakuk #3 Island" which are located along the Beaufort Sea Coast near Prudhoe Bay. The experimental techniques and equipment used have been described in our earlier work (Rogers et al., 1975; Rogers and Morack; 1978; Rogers and Morack, 1979). Areas underlain by both frozen and unfrozen material were located on these islands.

VII. DISCUSSION

A. Marine Data

The principal feature of submarine permafrost that we observe is its relatively high velocity compared to nonfrozen materials. This velocity contrast is greatest for relatively coarse materials (gravelly sands). Fine-grained frozen materials have lower velocities than do the coarser frozen materials. This feature tends to broaden the frozen velocity group just as the difference in nonfrozen velocities between coarse materials and fine-grained materials tends to broaden the nonfrozen velocity group. Figure VII-1, a histogram of velocities observed in the vicinity of Prudhoe Bay, indicates three general velocity groupings. The first ($V > 2500$ m/s) we interpret to be frozen material velocities and we do not distinguish between material types. The second group (1800 m/s $< V < 2500$ m/s) we interpret to be nonfrozen materials, principally sandy gravels. The third group (1500 m/s $< V < 1800$ m/s) is associated with nonfrozen silts and silty clays, often probably with some intermixed sand.

The slope of the high velocity refractor can significantly influence the observed velocity. The effect of a ± 10 degree slope is shown in Figure VII-1 for the case of a 2800 m/s frozen refractor. A positive slope of 10° is seen to move the observed velocity out of the first group (frozen interpretation) into the second group (nonfrozen interpretation).

Figure VII-2, a histogram of observed velocities along a north-south line of drill holes reported by Sellmann and Chamberlain (1979), provides an opportunity to closely compare velocity groupings and material types. Over the 9 km length of the line eight probe holes were distributed along with two bore holes. The average penetration depth was approximately 12 m beneath the ice surface in an area where water depths were approximately

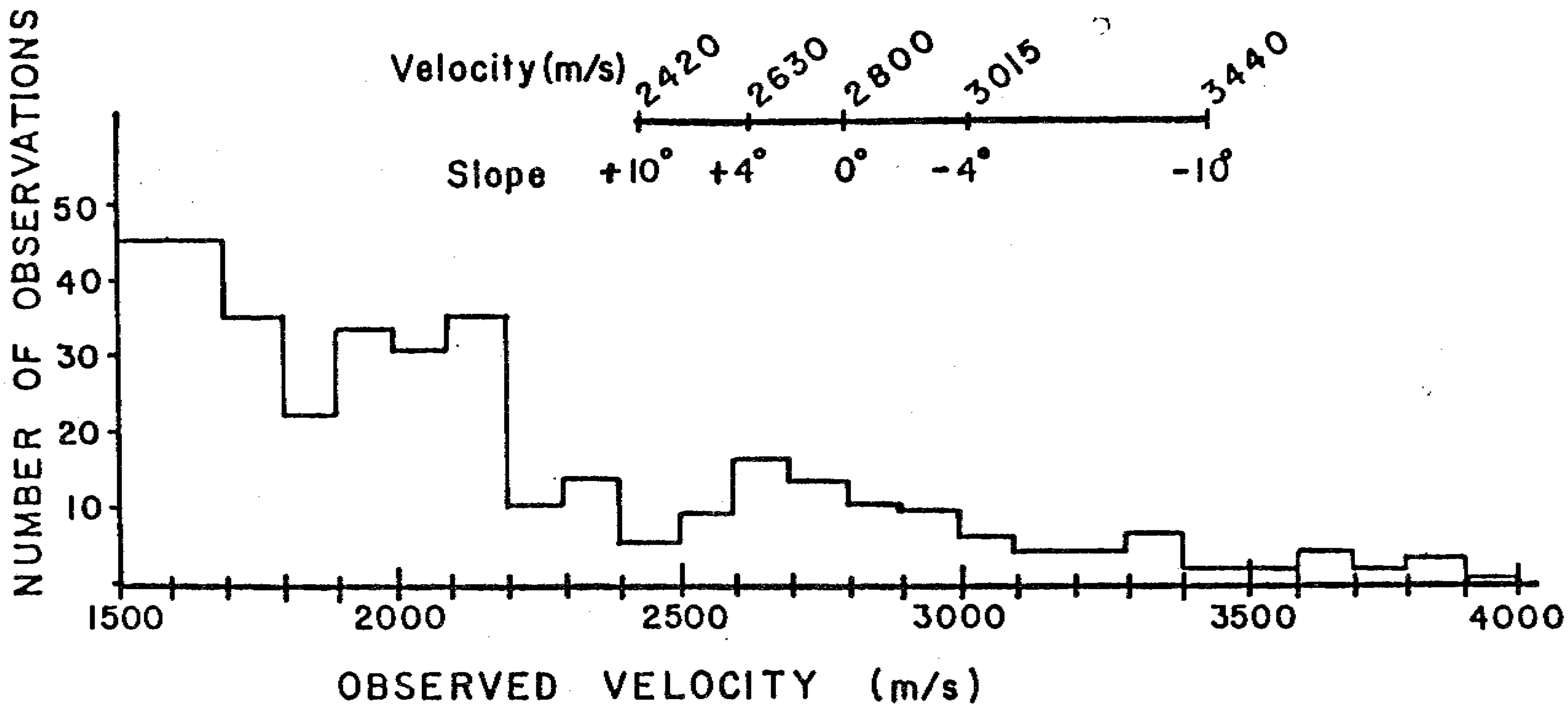


Figure VII-1. Velocities observed in the vicinity of Prudhoe Bay.

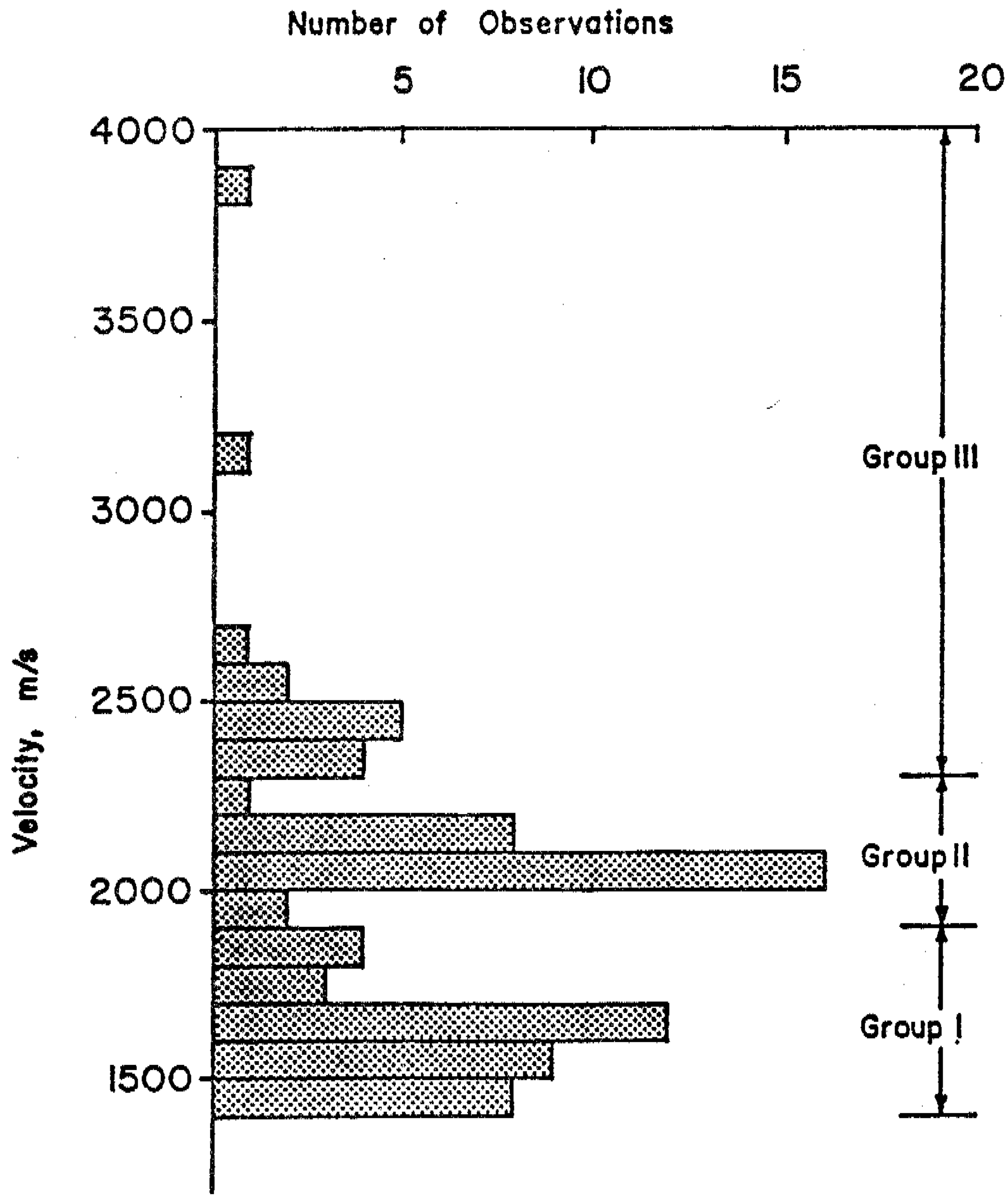


Figure VII-2. Velocities observed along N-S leg of "X" in Prudhoe Bay. Line corresponds to that reported by Sellmann and Chamberlain (1979).

one to three meters. Their classifications of the materials included gravelly sand, silty sand, clayey silt and interbedded sand and silt. By comparing our observed velocities and depths to refractors with their lithologic section along the line we have interpreted the velocity distribution as indicated in the table below.

Table II

Velocity classification of material types along Sellman and Chamberlain's Line 1" (1979) in Prudhoe Bay

Velocity Range	Material Type
1400 m/s-1900 m/s	Soft clayey silt (not frozen) Interbedded sand and silt (not frozen)
1900 m/s-2300 m/s	Gravelly sand (not frozen)
2300 m/s-2700 m/s	Gravelly sand (frozen) Silty sand (frozen)

One velocity classification not presented in the table is the velocity of frozen clayey silt and interbedded sand and silt. Presently we do not have data to indicate the range of velocities for these materials in the frozen state. We can speculate, however, that the frozen clayey silts probably have velocities in the range of the nonfrozen gravelly sands. Thus, it may not be possible to detect frozen fine-grained materials in the presence of nonfrozen coarser materials. King and Pandit (1981) have measured compressional wave velocities in sediments taken from the Canadian Beaufort Sea. They found velocities of materials at -2°C ranged from 3500 m/s for sand to 1900 m/s for clay.

It appears that our data from Harrison Bay are representative of fine-grained materials since there is a considerably larger percentage of low velocities observed in Figure VI-6 than on the histograms from the Prudhoe Bay area. These velocities below 1800 m/s we interpret to represent nonfrozen fine-grained materials. Our difficulty with these materials from the standpoint of observing permafrost is that we do not have a good idea of what their frozen velocities are. If we use the Prudhoe Bay experience (Figure VII-1), we conclude only a few observations of frozen materials were made (V > 2500 m/s). Even using the criteria developed from Figure VII-2 (frozen material velocities > 2300 m/s), we conclude few observations of frozen materials were made. However, using 1800 m/s as a representative velocity of frozen clay, we could conclude that a sizeable number of observations of frozen materials were made.

At the time of writing we do not have detailed lithologic data for Harrison Bay. Our tentative interpretation of the Harrison Bay data is that the only velocities corresponding to frozen coarse materials that were observed were: line 11-11 (about 5 km north of the Eskimo Islands on line A-a'), lines 17-21 and 17-22 (about 1 km north of Spy Island on line E-E'), line 17-30 (about 2.5 km northwest of Oliktok Point on line EE'). These correspond to observed velocities greater than 2370 m/s which would be indicative of a frozen silt with some sand.

Additional high velocities were observed near the east end of Pingok Island. Line F-F' presented three very high velocities for records 18-3 through 18-5; they were 3337, 4315 and 4709 m/s respectively. This observation supports those of Sellman which he interprets to be indicative of cold, near land, subsea permafrost. Pingok Island is clearly a land remnant and the high velocity permafrost is therefore not unexpected.

Further interpretation of our Harrison Bay data will have to wait lithologic information. Although we expect that our frozen velocity threshold could be lowered further with the knowledge of the presence of silts and clays, we are unsure whether to lower the threshold at this time.

We can put our data into perspective by comparing the results of Sellman et al. (1980).

In their September, 1980 quarterly report, Sellman et al. reported their interpretation of industry seismic data from Harrison Bay. They focused on the western part of the Bay (which would correspond to our lines A-A' and B-B'). One group of lines (1, 2, 3) ran from the shore north-northeast to approximately 5 m water depth ending roughly in all three cases within two or three kilometers of our line B-B'. (Line 1 ended approximately at line 13-27, line 2 ended approximately at 13-21 and line 3 ended approxiamtely 3 kilometers north of line 13-13). In all cases, they reported permafrost dipping from the surface on shore to approximately 200 m depth at the 5 m water depth contour. Their "average" high velocity refractor value was approximately 3.5 km/s, a value comparable to our past "frozen material" velocities in Prudhoe Bay.

We conclude from our data and Sellman's data that shallow (less than 40 m below the ocean surface) continuously bonded materials are not common, if present at all, in that portion of Harrison Bay east of Atigaru Point and north of the Colville delta. It should be noted that our data and Sellman's data nicely complement each other since our maximum penetration depth is about 40 or 50 meters and that is also about his minimum penetration depth. Thus our data are capable of resolving the depth of shallow ice-bonded materials and his data resolve deeper materials.

The area north of the Eskimo Islands and Atigaru Point was described by Sellman as anomalous in that it showed large attenuation of high frequency signals accompanied by incoherent or scattered signals. We have not identified any continuous high velocity refractor in this region. However, we did make one observation which suggests frozen material

(V_1 = 1490 m/s, V_2 = 2475m/s) with a depth to the refractor of 30 m beneath the ocean surface (water depth approximately 2.5 m). It is possible this isolated refraction event is a low velocity material with suitable slope to "present" a relatively high velocity. We have no way of determining what is the true situation at this time. We conclude that there may be isolated occurrences of shallow discontinuous permafrost in this area but there is not shallow continuous permafrost present. It is possible that the permafrost is deeper than 40 m but does not have a continuous nature suitable for identification using industry data.

Our data north and south of Thetis Island (line D-D') and the data north of the Colville delta (line C-C') do not indicate shallow continuously bonded materials. It appears that permafrost, if present in the eastern end of Harrison Bay, is deeper than 40 m unless one considers areas within a few kilometes of the islands or of the shore. We do not know whether or not there is a "rebound" of the permafrost surface at distances of several 10s of kilometers from the shore or whether the permafrost remains relatively deep. We must recall that our initial data from Prudhoe Bay suggested the permafrost surface dipped continuously to depths of 150 m as we proceeded offshore. It was not until the following season that we observed a "rebound" of the permafrost surface to depths as shallow as 7 m beneath the ocean bottom in the vicinity north of Reindeer Island.

In the Prudhoe Bay area we have reason to believe that the shallow permafrost north of Reindeer Island is the result of a clay cap that prevents salt brine from depressing the upper permafrost surface. Areas shoreward of Reindeer are believed to have had this cap removed by river action. Harrison Bay is significantly affected by the Colville River and it is likely that the submarine permafrost distribution in the area is complex due to past and present actions of the river.

Chukchi Sea: Figure VI-2, a histogram of velocities observed near Icy Cape, is significantly different from the histogram prepared for Harrison Bay and somewhat more similar to histograms from Prudhoe Bay. The refractors with velocities greater than 2500 m/s are interpreted to represent frozen materials. Lines 2-2, 2-3, and 2-4 presented refractor velocities of 2431, 2976, and 2547 m/s respectively with corresponding depths below the ocean surface of 16, 32 and 23 m. We have included line 2-2 even though the observed velocity was 2431 m/s because it was adjacent to and like lines 2-3 and 2-4. These observations were made within 100 m of shore in water depths of 3 m or less. Lines 3-33 and 3-19 also produced high velocity refractors at depths of 29 m and 27 m respectively. Since we did not observe a large percentage of low velocities ($V < 1800$ m/s) we interpret our lower velocity group to be nonfrozen sands and gravels.

One set of seismic lines was run in Kasegaluk Lagoon to the south of Icy Cape. Of the records produced, only line 3-11, with a refractor velocity of 2454 m/s, indicated the presence of possibly frozen materials. The lines that were adjacent to the barrier island (3-14 and 3-15) produced ambiguous results; no high velocity and a high velocity of 6000 m/s. We have not interpreted these results.

The work in the Chukchi Sea was somewhat restricted and it is desirable to obtain records on Blossom Shoals, at other locations in Kasegaluk Lagoon (principally to the east of Icy Cape), offshore of the barrier islands to the east of the Cape and on the barrier islands.

B. Island Data

The fact that ice-bonded permafrost exists beneath several islands in the Beaufort Sea has been determined from seismic data taken during the past several summers and confirmed by shallow probing and drill holes.

The presence of permafrost beneath these islands will be an important consideration in their anticipated uses for offshore resource development.

It is possible that specific information on the distribution and depth of permafrost beneath the offshore islands will help in understanding the complicated physical processes which are causing the islands to slowly migrate. A more detailed understanding of these processes coupled with the permafrost information will also be needed before the complete geological history of the area can be determined.

The area between the Colville River in the west and the Canning River to the east contains several chains of barrier islands, and it is this area where most of the data has been taken. Some additional data has been taken near Point Barrow.

The research of Skackleton and Updyke (1973) suggests that the world sea level fell to a minimum level during the late Wisconsin period about 18,000 years ago. During this period of low sea level, permafrost was formed under much of the present continental shelf in the Beaufort Sea.

As the sea level rose due to glacial melting, a set of distinctly Arctic processes began to erode the coastline along the Beaufort Sea. Ice-rich Pleistocene sediments subject to localized thawing were effected by thermokarst collapse. As the excessive ground ice was melted, it led to a collapse of the material and thaw lakes were formed. These thaw lakes grew and were overrun by the receding coastline, forming a highly crenulated shoreline. Along the coast, where the bluffs were composed of ice-rich sediments, a combination of thermal and wave erosion led to a slow disintegration of the coastline. These processes continue today and are eroding the coastline an average of approximately 1.5 meters a year in the Beaufort Sea (Hopkins and Hartz, 1978).

As the coastline receded, areas which were higher were left as islands. These high tundra remnants are formed of Pleistocene sediments having frozen cores. In some cases, areas of thick peat accumulation have slowed the erosion processes since these materials are resistant to wave attack. Examples of this kind of island are Flaxman, Tigvariak, Pingok, and Cottle Islands. These islands are still covered by tundra vegetation and are underlain by relict permafrost. Thermal and wave action are even today eroding away the shoreline of these islands.

Many of the islands, which were initially high tundra remnants, have been eroded by the processes discussed earlier over a long enough period that the fine sediments have been washed away, leaving only accumulations of sand and gravel. These erosional remnants are not static, but are migrating generally westward and landward due to a complicated process involving wave motion, currents, winds and ice rafting. Examples of such constructional islands where seismic data has been taken are Cross (1977, 1978), Narwhal (1980), Jeanette (1980), Karluk (1980), Stump (1978), and Reindeer Islands (1977). These islands are the most interesting from a scientific standpoint since the processes involved are not completely understood. The details of the data collected on these islands can be found in past annual reports as indicated above.

The seismic reconnaissance on the several barrier islands listed above indicates that they are no longer all completely underlain by bonded permafrost. Indeed, Jeanette and Karluk Islands appear to be rapidly migrating and are free of bonded permafrost. Cross, Narwhal and Reindeer Islands are partially underlain by bonded permafrost. Cross, Narwhal and Reindeer Islands are partially underlain by bonded permafrost and Stump Island, which is very near shore, is entirely underlain by bonded permafrost. Additional permafrost data coupled with a better understanding of coastal recession and island migration may complete our understanding of the dynamics of these barrier islands.

A few islands have been formed as depositional shoals from rivers. They are formed of fine-grained sediments. Gull island and Duck Island are probably such features. These islands and others have been enlarged, raised, and possibly stabilized by the addition of gravel. They have served as drilling pads and there will undoubtedly be many more such islands used for that purpose in the future. We have taken seismic data on two such islands, Exxon's "Duck Island" and Sohio's "Niakuk #3". These islands are not initially underlain by shallow ice-bonded permafrost as they are formed, and it is intended that the seismic data taken already will serve as baseline data for future measurement.

VIII. CONCLUSIONS

Several conclusions can be summarized at this time.

Harrison Bay Vicinity:

(1) Harrison Bay shallow materials (less than 40 m below the ocean surface) appear to be finer grained on the average than those of the Prudhoe Bay area.

(2) Keeping in mind the somewhat limited coverage of our data, it appears that the upper permafrost surface in Harrison Bay is generally below 40 m where it is present.

(3) Shallow permafrost (depths less than 40 m) has been interpreted locally in the eastern end of Harrison Bay. Typically this has been less than a few kilometers from shore or from barrier islands.

(4) Given our experience in Prudhoe Bay, we cannot rule out shallow continuous ice-bonded permafrost in regions not covered by our seismic lines.

(5) The Colville River is likely to significantly affect the depths to and distribution of permafrost in the vicinity of Harrison Bay.

Icy Cape Vicinity:

(1) The velocity distributions we obtained were typical of frozen and nonfrozen sands and gravels.

(2) Ice-bonded materials have been interpreted at several locations along the immediate coastline near Icy Cape (principally within a few hundred meters of shore in water depths equal to or less than 5 meters).

(3) Our data coverage is quite limited, we are not able to put forth a general interpretation for the area.

Island Studies

(1) Seismic reconnaissance on six barrier islands indicates that they are not all underlain by continuous bonded permafrost, but that some are free of ice-bonded permafrost. This fact is dependent upon the history of the islands, the size of any particular island, its migration rate and soil types. We have observed continuous bonded materials beneath Stump Island along its entire length. In contrast, no high velocity refractors have been observed on Reindeer Island. Jet drilling on the island indicates a highly variable material beneath this island, some frozen and some not frozen. We have observed high velocity refractors on portions of Cross Island and Narwhal Island but none on Jeanette or Karluk Island. Thus, the islands seem to be highly variable with regard to their permafrost conditions. It is clear that islands which are former land remnants, Cottle and Flaxman for example, are underlain by continuous bonded materials.

(2) Several island sites have been studied where seismic velocity data and drilling data seem not to agree; drilling evidence indicated frozen material, but refraction velocities were not high. Our conclusion is that ice-bearing materials should be distinguished from ice-bonded materials. The distinction between ice bearing and ice-bonded is important from the standpoint of material properties. For example, an ice-bonded material may have a high resistance to shear stress, but the same material when not ice-bonded may have little shear resistance. An important parameter affecting offshore permafrost is temperature; in contrast to permafrost on land it is relatively warm and consequently more thermally fragile. This fact coupled with the presence of salt water accounts for some of its local variability.

IX. NEEDS FOR FURTHER STUDY

There are significant gaps in our Harrison Bay data. Although we do not expect to increase the density of the coverage, there are at least two areas that should be investigated. These are the shoal off Cape Halkett which is known to be the site of a somewhat recent island and the mouth of the Kogru River embayment. Reimnitz et al. (1977) reported continuous, well-defined reflectors accompanied by irregular reflectors in the embayment.

Our past work in the Icy Cape region identified ice-bonded materials and these investigations need to be extended. The extension should include investigation of Blossom Shoals, the barrier islands and offshore of the barrier islands. This additional work will provide a more complete picture of the subsea permafrost distribution in the Chukchi Sea.

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ANNUAL REPORT

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OPERATION OF AN ALASKAN FACILITY FOR APPLICATIONS OF REMOTE-SENSING DATA TO OCS STUDIES

William J. Stringer
Albert E. Belon
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99701

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OPERATION OF AN ALASKAN FACILITY

FOR APPLICATIONS OF REMOTE-SENSING DATA TO OCS STUDIES

1980/81 Annual Report

Principal Investigator: William J. Stringer
Principal Investigator: Albert E. Belon
Affiliation: Geophysical Institute, University of Alaska
Contract: NOAA #03-5-022-55
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I - SUMMARY OF OBJECTIVES

The primary objective of the project is to assemble available remote-sensing data of the Alaskan outer continental shelf and to assist OCS investigators in the analysis and interpretation of these data to provide a comprehensive assessment of the development and decay of fast ice, coastal geomorphology and ecology, sediment plumes and offshore suspended sediment patterns along the Alaskan coast from Yakutat to Demarcation Bay. An additional objective of increasing importance is to provide the Bureau of Land Management with timely environmental analyses based on archived remote sensing data. The need for these analyses are often discovered during synthesis meetings as required to fill "data gaps." Hence the analyses must be performed in an expeditious fashion in order for the "gap" to be filled in time for preparation of an Environmental Impact Statement by BLM.

Five complementary approaches are used to achieve this objective. They are: 1) the operation of a remote-sensing data library which acquires, catalogs and disseminates satellite and aircraft remote-sensing data; 2) the operation and maintenance of remote-sensing data processing facilities; 3) the development of photographic and computer techniques for processing remote sensing data; 4) consultation and assistance to OCS investigators in data processing and interpretation; and 5) by participating in synthesis meetings, and maintaining close liaison with the various OCS offices.

While in the past, this project has acted primarily in a support role for other OCS projects, this year it has also performed a number of disciplinary projects which rely largely on quick access to and analysis of archived remote sensing imagery.

Still acting in its traditional role, this research unit has provided remote sensing data to 11 disciplinary OCS projects, of which seven, RU 205, 530, 250, 88, 289, 519 and 265 are using remote sensing data extensively. In addition, the availability of near-real-time data (NOAA, DMSP satellite and in some cases Landsat) provides a continuous monitoring of environmental conditions along the Alaskan continental shelf for research and logistical support of the OCSEAP program.

II - INTRODUCTION

A. General Nature and Scope of Study

The outer continental shelf of Alaska is so vast and so varied that conventional techniques, by themselves, are unlikely to provide the detailed and comprehensive assessment of its environmental characteristics which is required before the development of its resources is allowed to proceed during the next few years. The utilization of remote-sensing techniques, in conjunction with conventional techniques, provides a solution to this dilemma for many disciplinary investigations. Basically the approach involves the combined analysis of ground-based (or sea-based), aircraft and satellite data by a technique known as multistage sampling. In this technique, detailed data acquired over relatively small areas by ground surveys or sea cruises are correlated with aerial and space photographs of the same areas. Then the satellite data, which extend over a much larger area and provide repetitive coverage, are used to extrapolate and update the results of the three-way correlations to the entire satellite photograph. Thus, maximum advantage is taken of the synoptic and repetitive view of the satellite to minimize the coverage and frequency of data which have to be obtained by conventional means.

B. Specific Objectives

The principal objective of the project is to make remote-sensing data, processing facilities and interpretation techniques available to the OCS investigators so that the promising applications and cost effectiveness of remote-sensing techniques can be incorporated in their disciplinary investigations. The specific objectives of the project are: 1) the acquisition, cataloging and dissemination of existing remote-sensing data obtained by aircraft and satellites over the Alaskan outer continental shelf, 2) the operation and maintenance of University of Alaska facilities for the photographic, optical and digital processing of remote-sensing data, 3) the development of photographic, optical and computer techniques for processing remote-sensing data for OCS purposes, 4) the active interaction of the project with OCS users of remote-sensing data, including consultation and assistance in disciplinary applications, data processing and data interpretation, and 5) the performance of specific studies required to fill data gaps identified by the OCSEAP program which can be made using archived remotely-sensed data.

C. Relevance to Problems of Petroleum Development

The acquisition of remote-sensing data, especially satellite data, has proved to be a cost-effective method of monitoring the environment on a synoptic scale. Meteorological satellites have been used for over a decade to study weather patterns and as an aid to weather forecasting. The earth resources satellite program, initiated in 1972, offers a similar promise to provide, at a higher ground resolution, synoptic information and eventually forecasts of environmental conditions which are vital to petroleum development on the continental shelf. For instance the morphology and dynamics of sea-ice which are relevant to navigation and construction of offshore structures, the patterns of sediment transport and sea-surface circulation which will aid to forecast trajectories of potential oil spills and impact on fisheries, the nature of ecosystems in the near-shore regions which can be changed by human activity, are among the critical development-related environmental parameters which can be studied, in conjunction with appropriate field measurements, and eventually routinely monitored by remote-sensing.

III - CURRENT STATE OF KNOWLEDGE

The utilization of remote-sensing techniques in environmental surveys and resource inventories has made great strides during the last few years with the development of advanced instruments carried by aircraft and satellites. The early meteorological satellites had a ground resolution of a few miles and a broad-band spectral response which made them well-suited to meteorological studies and forecasting but inadequate for environmental surveys. The ground resolution of the sensors has been gradually much improved over the years and thermal sensors were added for cloud and sea temperature measurements, but generally the relatively low ground and spectral resolution of the meteorological satellites is a limitation for environmental surveys.

The initiation of a series of Earth Resources Technology Satellites (now renamed Landsat) in July 1972 was intended to fill the need for synoptic and repetitive surveys of environmental conditions on the land and the near-shore sea. With a ground resolution of about 80 meters and sensitivity in four visible spectral bands, Landsat-1 and 2, have fulfilled that promise beyond all expectations. Landsat 3 was launched on March 5, 1978 and is acquiring MSS data in all four spectral bands as well as RBV data which provides higher ground resolution (40 meters) than either of the first two satellites. Unfortunately the thermal spectral band on Landsat 3 never worked properly and very little useful data was acquired from it.

The development of techniques for analyzing and interpreting Landsat have proceeded at an even more rapid pace than the satellite hardware. While in 1972 much of the Landsat data interpretation was done by visual photointerpretation, the last four years have seen major developments in photographic, optical and, in particular, digital techniques for processing and interpreting the Landsat data. Some of these techniques, applicable to OCS studies, will be discussed in section V and VI of this report.

Through the impetus provided by the national commitment to satellite observations of the earth, the aircraft remote-sensing program has also made great strides in the last few years. While in the early 1960's airborne platforms were mostly used for aerial photography, the late 1960's saw the development of advanced multispectral scanners, thermal scanners, side-looking radars and microwave radiometers, partly for the testing of future satellite hardware and partly because the airborne observations serve for middle-altitude observations between ground and satellite measurements as part of the multistage sampling technique. Two philosophies are apparent in the airborne remote-sensing program: the first, exemplified by the NASA program as well as several universities and industrial agencies, involves relatively large aircraft and sophisticated instrumentation which produce vast quantities of data usually applied to intensive, non-repetitive surveys of relatively small areas. The second approach uses airborne remote-sensing in a truly supporting role for ground-based or satellite measurements. The aircraft are smaller and the instrumentation usually consists of proven, simpler instruments such as aerial cameras, single-band thermal scanners, and single wavelength side-looking radars which usually generate data only in photographic format. The costs of data acquisition and data processing, while they are not small, are sufficiently low that the approach is often used for repetitive surveys of relatively large areas. In our opinion the second approach fulfills best the needs of the NOAA/OCSEAP program and we have been working very closely with the NOAA Arctic Project Office toward the implementation of such a remote-sensing program.

IV - STUDY AREA

The study area for the project includes the entire continental shelf of Alaska, except for the southeastern Alaska panhandle. This area includes the Beaufort, Chukchi and Bering Seas and the Gulf of Alaska shelves and coastal zone. Temporal coverage is year-round, although the data coverage from November 1 to February 15 is limited owing to the very low solar illumination prevailing at high latitudes during winter.

V - SOURCES, METHODS AND RATIONALE OF DATA COLLECTION

A remote-sensing data library and processing facility was established in 1972 on the Fairbanks campus of the University of Alaska as a result of a NASA-funded program entitled "An interdisciplinary feasibility study of the applications of ERTS-1 data to a survey of the Alaskan environment". This experimental program, which covered ten environmental disciplines and involved eight research institutes and academic departments of the University, terminated in 1974, but the facility which it established proved to be so useful to the statewide university and government agencies that it has continued to operate on a minimal basis with partial funding from a NASA grant and a USGS/EROS contract. In view of the large potential demand of the OCS program on these facilities, a proposal was submitted to NOAA in March 1975 for partial funding of the facility for OCS purposes. This proposal resulted in a contract from NOAA on June 12, 1975, and the work performed since that time is the basis for the present report.

As a result of the NASA-funded program, the remote-sensing data library had total cloud-free and repetitive coverage of Alaska by the ERTS - now renamed Landsat - satellite from the date of launch (July 29, 1972) to May 1974 (about 30,000 data products), 60 rolls of imagery acquired by NASA aircraft (NP3 and U-2) some of which includes coverage of the Beaufort Sea, Cook Inlet and Prince William Sound, and substantial facilities for photographic, optical and digital processing of these data. Through a NOAA-funded pilot project, which studied applications of NOAA satellite data in meteorology, hydrology, and oceanography, the remote-sensing data library also had nearly complete coverage of Alaska by the NOAA satellites since February 1974.

A. Remote-Sensing Data Acquired for the OCS Program

1) Landsat data

At the initiation of the project we performed searches of the EROS Data Center (EDC) data bank for Landsat and aircraft remote-sensing data obtained over the four areas of interest to the OCSEAP program. From the several thousand scenes so identified, we selected the scenes which we did not have in our files and which had satisfactory quality and 30% or less cloud cover. As a result of this search 566 Landsat scenes (2830 data products) were ordered from the EROS Data Center in the following data formats:

-70mm positive transparencies of multispectral scanner (MSS) spectral bands 4, 5 and 7
-70mm negative transparencies of MSS spectral band 5
-9-1/2 inch print of MSS spectral band 6

During the first four years of the project, 2,806 additional cloud free scenes were acquired by the satellite and purchased from EDC.

After March 31, 1977, the EDC price for Landsat products having increased by an average of 166%, we reduced our routine purchase of selected Landsat scenes to two formats:

-70mm positive transparency of MSS, spectral band 5
-9 1/2 inch print of MSS, spectral band 7

Other formats are ordered on a case-by-case basis and at the request of individual OCS investigators. During the past year, 465 scenes were added to our files.

2) NOAA satellite data

With the termination of a NOAA pilot project, sponsored by NOAA/NESS, in October 1975, our acquisition of NOAA satellite scenes stopped after having accumulated 1320 images since February 1974. Following an interim arrangement with the National Weather Service, which turned out to be inconvenient for both parties, funding was provided by OCSEAP, starting on 1 February 1976, to purchase NOAA satellite imagery directly from the NOAA/NESS Satellite Data Acquisition Facility at Fairbanks. Under this purchase order we are receiving two NOAA scenes daily from the Bering Sea pass of the satellite (covering the Beaufort, Chukchi and Bering Seas) and one scene daily from the interior Alaska pass (covering the Gulf of Alaska) in both the visible and infrared spectral bands (6 images daily except in winter) for a total of 997 images received during the reporting period.

In addition we have made arrangements with the NOAA/NESS facility to save digital tapes of the thermal infrared data, upon request and for the cost of tape replacement, for scenes which are especially cloud-free or of high interest to OCS investigators. These tapes allow the precise mapping of sea-surface temperatures at locations and at times of special interest to OCS investigators.

3) USGS/OCS aircraft remote-sensing data

In November 1975, we started receiving the remote-sensing data acquired by USGS aircraft, under a NOAA/OCS contract, along the Alaskan arctic coast since July 1975.

These data consist of six 250 ft. rolls of black and white aerial photography and 42 strips of side-looking radar imagery. This program terminated in December 1975.

4) NASA aircraft remote-sensing data

Over the last few years the NASA Earth Resources Aircraft Program has flown several missions over preselected test sites within Alaska. The program is directed primarily at testing a variety of remote-sensing instruments and techniques and to support NASA-sponsored investigations. However, black and white and color-infrared aerial photography were obtained on most missions and in particular during the May 1967, July 1972, June 1974, and October 1976 missions which include flights over portions of the Alaskan coast and coastal waters. We have acquired copies of these data from NASA.

The U-2 imagery of the Beaufort Sea obtained in June 1974 is of particular interest to OCS investigators because it was obtained during the sea-ice break-up period, it covers a large area (20x20 mi.) in a single frame with good ground resolution (10 ft.), and nearly concurrent Landsat data are available. Similarly, the U-2 imagery of the northern Gulf of Alaska and Prince Williams Sound, acquired in October 1976, is of excellent quality.

During June 1977, the U-2 aircraft once again acquired photography over Alaska. New flight lines, mostly in the Prudhoe Bay area, using a 6" and 12" focal length lens were flown and copies of the data are included in our files.

In 1978 several state and federal agencies combined efforts to obtain high altitude aerial photographic coverage of the whole State of Alaska. This imagery is being acquired by NASA over a three-year period which commenced in summer 1978. Approximately sixty percent of the state was satisfactorily covered in the first two years' efforts. Two cameras are being used with focal length lenses of 6" and 12" resulting in black and white coverage at 1:120K scale and color infrared coverage at 1:60,000 scale. Coastal areas covered include Point Hope to Cape Espenberg, Kodiak Island, most of the Beaufort coast, all of Southeast Alaska, and most of the coastal areas from Seldovia to Glacier Bay. All of this imagery is in our files and available to OCSEAP investigators for use at the library or copies may be ordered for their individual use.

5) NOS aircraft remote-sensing data

In spring 1976 we learned that the National Ocean Survey's (NOS) Buffalo aircraft was scheduled to obtain aerial photographic coverage of Shelikof Strait during summer 1976. Knowing that this area is frequently covered by clouds, we requested NOS to acquire aerial photography of other areas of the Alaskan coastal zone on a non-interference basis with their primary mission. NOS agreed to do so for the cost of the raw film. As a result 1316 frames of color aerial photography were acquired, covering the entire coast from the Yukon delta to Cape Lisburne and several isolated areas in the Gulf of Alaska.

During July 1977 the NOS aircraft flew additional flight lines on the Chukchi and Beaufort coasts extending our coverage eastward to the mouth of the Kogu River, in Harrison Bay. This medium scale photography is of excellent quality and has been used heavily by OCS investigators.

6) Army aircraft remote-sensing data

With the termination of the USGS/OCS remote-sensing data acquisition program in December 1975, an important need developed for all-weather remote-sensing coverage of the Beaufort and Chukchi coasts during critical periods (end of winter and end of summer). We worked closely with the OCSEAP Arctic Project Office and with a major user (Dr. Cannon, RU #99) in investigating various options culminating in a contractual arrangement with the U. S. Army remote-sensing group at Ft. Huachuca, Arizona.

Under this contract an Army Mohawk aircraft equipped with an all-weather side-looking radar (SLAR) flew two missions in Alaska in May and August 1976 resulting in complete SLAR coverage (51 flights) of the Beaufort and Chukchi shelves during the critical periods. These data have been heavily used, particularly by OCSEAP RU #88 (Weeks) and RU #99 (Cannon). An April 1977 SLAR mission was flown which resulted in spring sea-ice coverage of the Chukchi and Beaufort coastlines as far east as Camden Bay. During the 1978-79 ice season four flights were made along the Beaufort coast. Additionally, NASA/Lewis Research Center flew several SLAR flights in the Bering and Beaufort Seas in March 1979 and these data are on file in our library.

During this reporting period arrangements were made by NOAA/BLM and USA/CRREL to obtain SLAR missions along the Beaufort and Bering coasts on a regular basis. The imagery is obtained by an Army Mohawk OV-1B and to-date data has been received for the Beaufort area on February 13 and the Bering Sea on February 20, 1980. The film is copied in the Geophysical Institute photo lab, transparencies made as well as several copies of prints for distribution. The original imagery is then returned to the Army and a copy is retained in our file.

7) Near-real-time satellite imagery

Near-real-time satellite imagery is now available to OCS investigators through the Remote-Sensing Library. Air Force weather satellite imagery (DMSP) is received at Elmendorf Air Force Base near Anchorage and shipped on a regular basis to the Geophysical Institute. Also, Landsat quick-look data from selected scenes is received from Canadian sources two or three days after acquisition. These new data products are made possible through a State-funded project to evaluate the utility of near-real-time satellite imagery to Alaskan problems. OCS has made extensive use of these data, primarily to determine sea-ice conditions.

8) Preparation and distribution of remote-sensing data catalogs

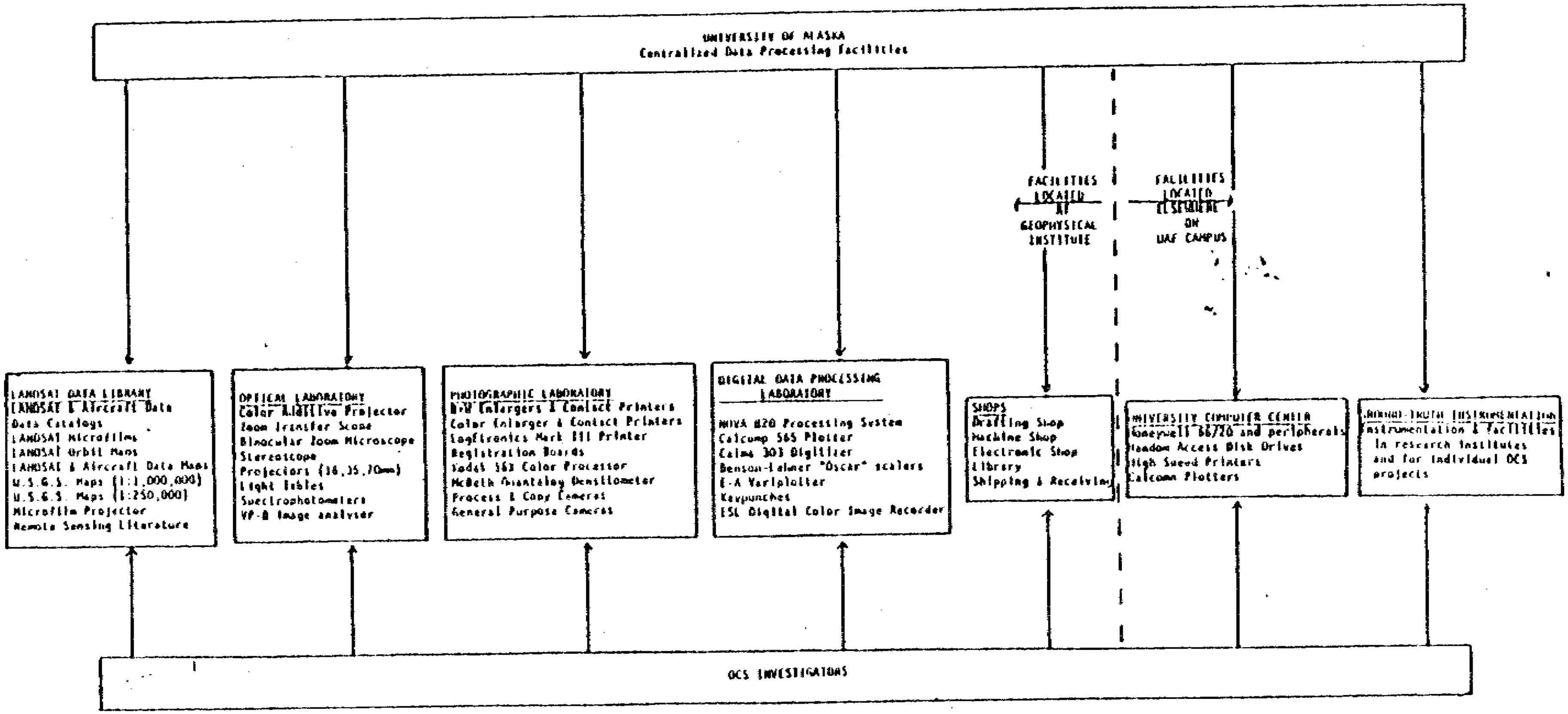
All the remote-sensing data available in our files for the Alaskan continental shelf have been indexed and plotted on maps. Catalogs summarizing the availability of these data and providing instructions for selecting and ordering data have been prepared and distributed to all OCS investigators as appendices to the series of Arctic Project Bulletins (Nos. 6, 9, 10, 12, 14, 17, 22 and 28). In addition we have developed a file of catalogs and photo indices of aerial photography obtained by federal, state and industrial agencies in Alaska, and we attempt to stay informed on plans for future aircraft photographic missions.

B. Remote-Sensing Data Processing Facilities and Techniques

The facilities and equipment commonly used for remote-sensing data processing are listed in Figure 1. Most of this equipment is not devoted exclusively to remote-sensing data processing but arrangements have been made to support the needs of the OCS investigators on a time-share and work-order basis, and to take into account the needs of the OCS program in any planned modifications or expansions.

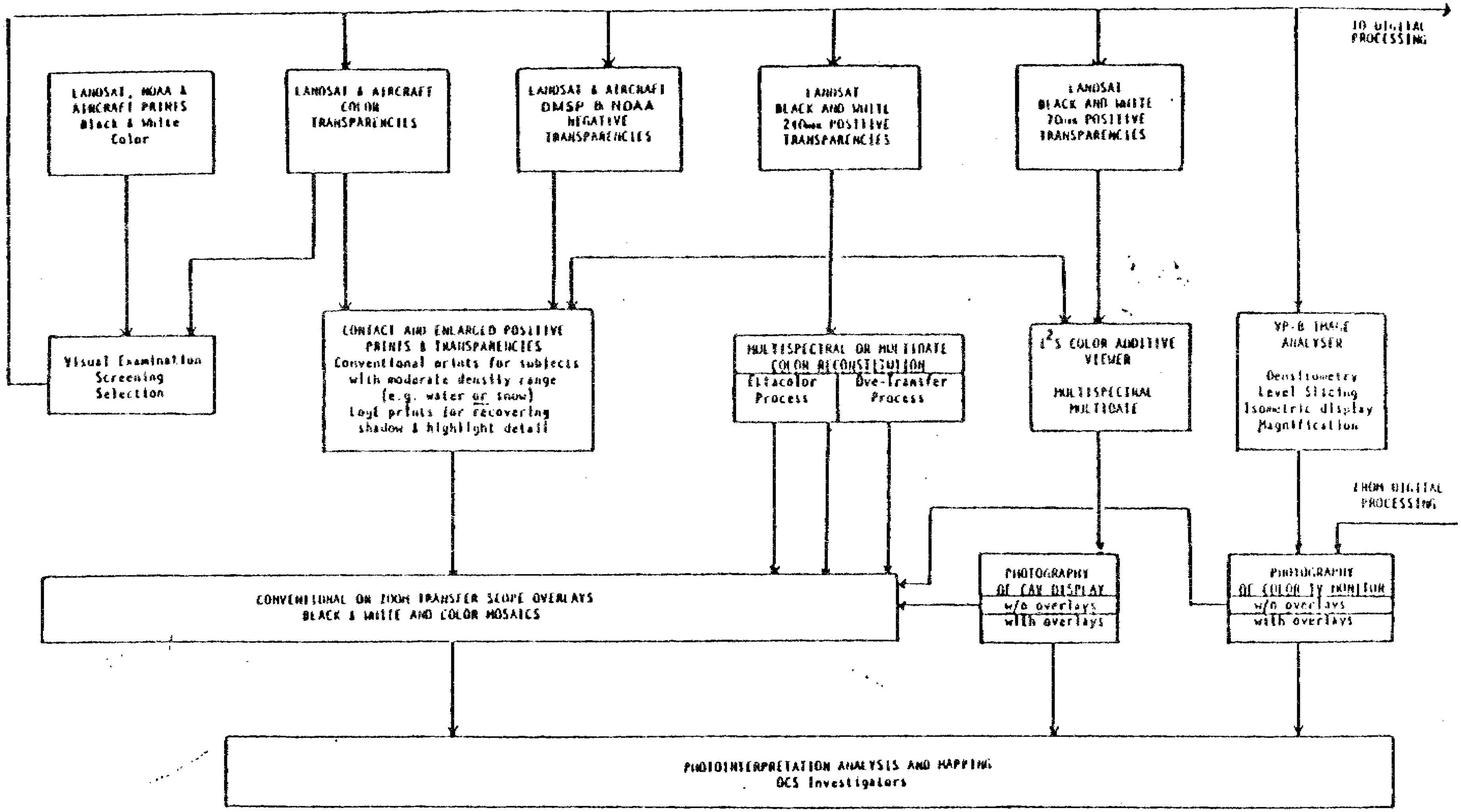
The optical and photographic processing techniques developed for the remote-sensing program are described in the flow diagram of Figure 2.

Photographic processing probably needs no further explanation. The full range photographic laboratory of the Geophysical Institute is well adapted to the generation of custom, as distinct from production run, photographic products. However, the available equipment limits photographic enlargements to 16x20" maximum size from 8x10" originals. Electronically dodged prints or transparencies are produced by contact printing only.



Centralized Data Processing Facilities

Figure 1



Optical and Photographic Processing

Figure 2

Optical processing revolves around the use of specialized equipment such as the multiformat photo-interpretation station, the zoom transfer scope, the color additive viewer and the VP-8 image analyzer in addition to conventional light tables, stereoscopes and a binocular zoom magnifier.

Multiformat Photo Interpretation Station - Analysis of aerial imagery in roll form is a cumbersome task and is likely to damage the original material even with careful handling if one uses ordinary reel holders and a light table. With stereo coverage, it is impossible to achieve stereo viewing with the frames appearing on the roll format unless one uses the photo interpretation machine. It can accommodate either 5-inch or 9-inch film formats and the film transport adjusts to permit stereo viewing with varying amounts of forward lap between frames. The viewing turret includes zoom binoculars with up to 5X magnification.

Zoom Transfer Scope - The time-consuming process of transferring information from images to maps is made considerably easier by the use of the zoom transfer scope. This table-top instrument allows the operator to view simultaneously both an image and a map of the same area. Simple controls allow the matching of differences in scales (up to 14X) and provide other optical corrections so that the image and the map appear superimposed. In particular a unique one-directional stretch capability (up to 2X) allows the matching of computer print-out "images" to a map or photograph.

Color Additive Viewer/projector/tracer - This instrument is primarily intended for the false-color recomposition of Landsat images from 70mm black and white transparencies and tracing information contained on these images at scales of 1:1,000,000 and 1:500,000. However it has proved to be very useful also for superimposing and color-coding Landsat images acquired on different dates and looking for change or movement and for viewing any other enlarged image on 70mm film format.

VP-8 Image Analysis System - The VP-8 image analysis system provides an electronic means of quantizing information contained in a photograph when the sought information can be expressed in terms of density ranges. It consists of:

- -a light table having uniform brightness and a working surface of 15x22 inches
- -a vidicon camera which transforms the photographic (transmittance) data to electrical signals
- -an electronic image analyser which quantizes and formats the vidicon signals
- -a CRT oscilloscope
- -a color television monitor as an output device

The capabilities of the VP-8 image analysis system include:

-density level slicing. This feature allows lines of uniform density on the input image to be displayed as contours. These contours form the boundaries of density bands which are displayed as up to 8 color bands on the color television monitor. The base density levels and the density range of the bands are individually as well as collectively variable. An example and illustration of the density slicing technique applied to coastal sedimentation studies was provided in the OCSEAP Arctic Project Bulletin No. 7, Appendix C, "Environmental Assessment of Resource Development in the Alaskan Coastal Zone based on Landsat Imagery" by A. E. Belon, et al, University of Alaska.

-single scan line display. Any single horizontal scan line of the vidicon camera can be selected for display on the CRT oscilloscope by positioning a horizontal cross-hair on the image. This display of a single scan line is effectively a microdensitometer trace.

-digital read-out of point densities, selected by adjustable cursors or of total area of the image having a given (color-coded) density range. For instance the VP-8 image analysis system is well adapted to the area measurement of sea-ice, newly refrozen ice, and open water in any area of the Beaufort Sea imaged by Landsat.

-3-D display. This mode of operation allows a three-dimensional presentation where the X and Y coordinates of the original image are displayed in isometric projection and intensity information is shown as a vertical deflection. Subtle features of the image which are often lost on level-sliced displays, become obvious in 3-D displays.

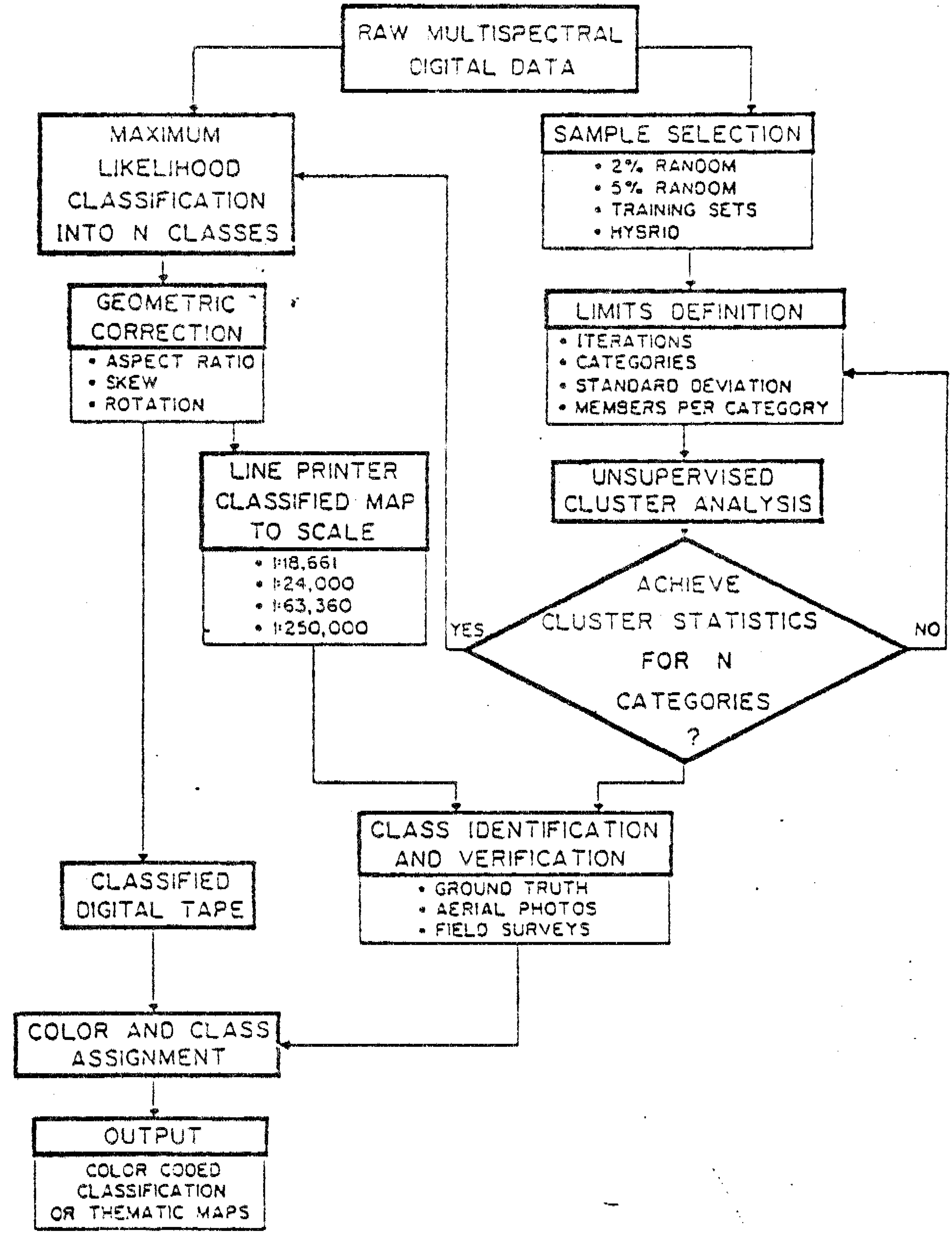
-5X magnification. This feature allows the expansion of a small part of the image on the 3-D display to full screen size.

The digital data processing equipment available to the OCS investigators include the main University computer, a Honeywell model 66/20 with 1 M bytes of core memory, which has a remote time-share terminal at the Geophysical Institute, a NOVA 820 data preprocessing computer as well as conventional line printers, plotters and digitizers. Most remote-sensing imagery in digital format is reformatted, classified or otherwise processed on offline computing systems. An overall flow diagram of digital processing of Landsat imagery is illustrated in figure 3 and discussed later in this report. Once the digital data have been processed, they are displayed on line printer maps or the digital image film recorder.

Digital Color Image Recorder - It often is necessary to reconstitute an image from the processed digital data in order to convey information in the most suitable form to the human mind. Also, if one deals with multi-spectral data it is impossible to convey the density of information required without the use of color. A digital image recorder with the capability of reconstituting color products was procured and installed in 1976 using State of Alaska funds appropriated to the University of Alaska Geophysical Institute. Basically it is a rotating-drum film recorder which produces four simultaneous standard images on film up to 8x10" in size. Density resolution is 255 levels of gray, and spatial resolution is 500 lines per inch. Recording rate is 1.5 lines per second. Any combination of the four negatives so produced can be registered and printed with suitable filters to produce a reconstituted color negative which can be processed and enlarged photographically.

Remote-Sensing Data Interpretation Techniques - The basic techniques for remote-sensing data reduction and interpretation are described in flow diagram format in figure 2 (optical and photographic data processing) and figure 3 (digital data processing). The techniques for visual photointerpretation, as applied to sea-ice mapping; for density slicing, as applied to sea-surface suspended sediment mapping and transport; and for digital data processing, as applied to ecosystem thematic mapping, are described in the OCSEAP Arctic Project Bulletin No. 7, in particular its Appendix C "Environmental Assessment of Resource Development in the Alaskan Coastal Zone based on Landsat Imagery" by A. E. Belon, J. M. Miller and W. J. Stringer.

Variations of these techniques offer considerable promise of effective applications to OCS studies, but are too numerous and varied to be discussed in detail here. Usually they are developed in cooperation with individual OCS investigators for application to a specific project. Therefore we refer to the reports of other OCS investigators for detailed descriptions of applications of remote-sensing data to disciplinary studies.



FLOW CHART FOR GENERATING ECOSYSTEM MAPS

Figure 3 Digital Processing of Landsat Imagery

Flow chart of the unsupervised classification algorithms used for generating ecosystem maps of the Alaskan coastal zone from Landsat digital imagery.

C. Consultation and Assistance to OCS Investigators

This activity may be subdivided into two parts: general assistance to all OCS investigators provided through the Arctic Project Bulletins, program planning and negotiations and meetings/workshops; and individual assistance through consultation, training sessions on the use of remote-sensing data and equipment, and cooperative data analyses.

1. General Assistance

In order to familiarize OCS investigators with the available remote-sensing data, processing equipment, and interpretation techniques, we prepared seven substantial reports which were included as appendices to the OCSEAP Arctic Project Bulletins Nos. 6, 7, 9, 10, 12, 14, 17, 22 and 28 and distributed to all OCS investigators active in studies of the Beaufort, Chukchi and Bering Seas and the Gulf of Alaska.

The appendix to Arctic Project Bulletin No. 6 described the operation of the remote-sensing data library, provided catalogs of Landsat and aircraft data available in our files and provided instructions to OCS investigators on the selection and ordering of these data.

The appendix to Arctic Project Bulletin No. 7 described the facilities and techniques available for analyzing remote-sensing data and included a scientific report in which these facilities and techniques were used to analyse and interpret remote-sensing data in three representative investigations of the Alaskan continental shelf: sea-surface circulation and sediment transport in the Alaskan coastal waters, studies of sea-ice morphology and dynamics in the near-shore Beaufort Sea, and mapping of terrestrial ecosystems along the Alaskan coastal zone.

The appendix to Arctic Project Bulletin No. 9 provided a cumulative catalog of all available OCS remote-sensing data including Landsat and NOAA satellite data, USGS/OCS aircraft data and NASA aircraft data.

Arctic Project Bulletin No. 10 provided a catalog of the SLAR (Side-looking radar) imagery obtained by the Army Mohawk remote-sensing aircraft in May 1976.

The Appendix to Arctic Project Bulletin No. 12 provided an updated catalog of satellite and aircraft remote-sensing data acquired since the issuance of the cumulative catalog of Bulletin No. 9.

Arctic Project Bulletin No. 14 provided a catalog of the SLAR imagery obtained in May 1977 by the Army-Mohawk aircraft.

Arctic Project Special Bulletin No. 17 provided an updated catalog of satellite and aircraft remote sensing data acquired through the spring and summer field season of 1977.

Arctic Project Special Bulletin No. 22 provided an updated catalog of Landsat and NOAA imagery acquired through the spring and summer field season of 1978.

Arctic Project Special Bulletin No. 28 provided an updated catalog of Landsat and NOAA imagery as well as Side-Looking Airborne Radar and high-altitude aerial photography acquired through winter 1978 and all of 1979.

Additionally, several other special reports and projects have been performed:

Special Report on Monthly Landsat Coverage, July, 1980, provided to OCSEAP investigators maps showing total and cumulative monthly Landsat coverage in Alaska on a path and row basis. (See Appendix B)

During the summer, 1980, Beaufort Sea field season, this RU provided near-real-time satellite imagery to OCSEAP investigators working in the Prudhoe-Harrison Bay area. NOAA, DMSP and Landsat imagery was obtained, enlarged if necessary and transported to Prudhoe Bay within 12 hours of acquisition. Following this effort, a special report was prepared and distributed to OCSEAP investigators detailing the imagery available for that period. (See Appendix C)

Although the existing remote-sensing data base is very useful in supporting OCS disciplinary projects, there is also a vital need for an airborne remote-sensing data acquisition program dedicated to OCS purposes. To this end we have worked very closely with the NOAA Arctic Project Office in attempting to implement such a program. We participated in several meetings at the Geophysical Institute and one at Barrow in an attempt to set the USGS/OCS airborne remote-sensing data acquisition program on the right course, and took over responsibility for cataloguing, reproducing and disseminating these data. When this program failed and was terminated in January 1976, we studied alternatives and recommended several options to NOAA, one of which was a contractual arrangement with the U. S. Army remote-sensing squadron at Ft. Huachuca, Arizona. This recommendation was implemented, and two missions of the Army Mohawk remote-sensing aircraft were conducted in May and August 1976, resulting in high quality SLAR imagery of the Beaufort, Chukchi and Gulf of Alaska shelves at critical period. Another mission was conducted in April 1977. In parallel with these activities we have negotiated with NASA for the acquisition of high altitude (U-2, 65,000 ft.) aerial photography of the entire Alaskan coastal zone. This program was approved NASA at no cost (so far) to NOAA/OCSEAP. The first attempt to acquire the requested data, in June 1975, failed because of prevailing heavy cloud cover during the 3 weeks the U-2 aircraft was in Alaska. A second attempt, unfortunately delayed until October 1976, was partically successful and acquired high quality aerial photography of the Gulf of Alaska and Prince Williams Sound. Due to excessive cloud cover very little usable U-2 imagery was acquired from the June 1977 mission; however, two flight lines in the Prudhoe Bay area were of good quality. We also participated in successful negotiations with the National Ocean Survey for acquisition of color aerial photography of the Bering and Chukchi Sea coasts during a previously scheduled mission of their Buffalo aircraft to Alaska in summer 1976. Excellent medium altitude photography was acquired from the Yukon delta to Cape Lisburne, as well as isolated areas of the Gulf of Alaska coast. In summer 1977 NOS again flew several flight lines, extending from Cape Sabine on the Chukchi Sea coast to Cape Halkett on the Beaufort Sea. This imagery is of excellent quality and is archived here for OCS investigators' use.

While the OCSEAP Arctic Project Office and our project have been fairly successful in negotiating remote-sensing data acquisition by other agencies on an irregular basis, such arrangements are not wholly satisfactory on a long-term basis because the type and format of the data vary from one mission to another and the frequency of data acquisition is insufficient to provide timely observations and good statistical information on coastal zone conditions and processes. For this reason we worked with the Arctic Project Office on a plan which would utilize a Naval Arctic Research Laboratory (NARL) C-117 aircraft, remote-sensing equipment available from several sources, and local processing of the data to provide more frequent and more relevant data on a consistent format.

OCSEAP agreed with this plan and contracted with NARL for the airborne data acquisition program and with our project (RU 267) for the processing of the data. The Cold Regions Research Laboratories (CRREL) provided a Motorola side-looking radar and a laser profilometer, as well as a qualified engineer, to NARL, and we located and secured four aerial cameras for installation in the aircraft which was subsequently modified and committed to a remote-sensing program by NARL. Our project also acquired wide-film processing and printing equipment and constructed a photographic laboratory for processing of the data acquired by the NARL aircraft. Unfortunately, the NARL data acquisition program failed after acquiring very little SLAR data, and it was terminated by OCSEAP in the spring of 1978.

The most recent attempt to acquire SLAR data on regular basis is based on a contract, through CRREL, to the local (Ft. Wainwright) Army Mohawk squadron which obtained well-equipped, new model, remote-sensing Mohawk aircraft in early 1978. A trial mission was flown at our request in September 1978 as a training army mission. The resultant SLAR data of the Beaufort Sea coast proved to be of sufficiently good quality that formal arrangements were made for identical flight lines to be flown on a monthly basis during winter 1978/79. Good quality SLAR data have been received for December 1978, January, February and March 1979, and February 1980. They provide for the first time excellent coverage of Beaufort sea-ice morphology and dynamics during the important mid-winter period when other remote-sensing data are not available owing to the absence of daylight.

2. Individual Assistance

Individual assistance to OCS investigators involves consultations on the applicability of remote-sensing data to specific studies, data selection and ordering, preparation and supervision of work orders for custom photographic products and data processing, training in the use of remote-sensing data processing equipment and techniques, development of data analysis plans and sometimes participation in or performance of data analysis and interpretation.

This individual assistance has stabilized over the past year as requests become more site specific and detailed in nature. OCS investigators utilized our facilities during the past year, most of them for several hours, and some of them repeatedly. In addition, numerous contacts occurred by mail or telephone correspondence. Therefore, it is not possible to describe in detail these individual activities but their scope is illustrated by listing the user projects: RU's numbers 562, 526, 265, 205, 530, 460, 250, 88, 537, 230, 196, 289, 529, 87, 248, 519, 253. Of these about twelve are using remote sensing data routinely and seven of them (RU no. 205, 530, 250, 88, 289, 519, and 265) almost exclusively. The principal applications are sea-ice morphology and dynamics, coastal geomorphology and geologic hazards, sea-surface circulation and sedimentation, sea-mammals habitat and herd habitat mapping. A partial list of users and their needs is included as Appendix A of this report.

3. Cooperative projects

This research unit has been collaborating with RU 529 (Naidu) to quantitatively associate oceanic suspended sediment loads with reflectance levels measured by Landsat in the Beaufort Sea lease areas. This study has required the simultaneous acquisition of Landsat imagery and suspended sediment samples. Limited success was achieved during the 1980 field season when samples representing the lower limit of Landsat detectability were obtained. Plans call for additional efforts this summer to obtain additional suspended sediment samples during periods with higher sediment loads than sampled this past summer.

4. Special Studies

During this past year this research unit has responded to special OCSEAP needs in the following areas:

a. Norton Sound ice motions

In order to better understand ice motions in Norton Sound and the adjacent Bering Sea, an extensive analysis of floe trajectories was undertaken. The floe trajectories were reported in a special report to OCSEAP (Appendix D) and have been analyzed to date in two papers, the preliminary drafts of which appear as appendicies E and F.

b. Summertime ice coverage in the Harrison Bay/ Prudhoe Bay lease areas

As a result of the Sale 71 Synthesis Meeting, it was determined that a data gap existed in terms of knowledge of ice extent and concentration in the Harrison Bay/Prudhoe Bay area during summer. A short, intensive study has been undertaken to correct this lack of knowledge. The draft report is attached as Appendix G.

c. This research unit, along with the Arctic Project Office, compiled a review paper describing studies of oil in ice which have been funded by OCSEAP. This paper is attached as Appendix H.

VI - RESULTS

The results of the project so far can be separated into two categories: the operational results (establishment of a remote-sensing data facility) and the research results (disciplinary applications of remote-sensing data to OCS studies).

A. Establishment of a Remote-sensing Facility for OCS Studies

The principal result of the project, as specified in the work statement of the contract, is that there now exists at the University of Alaska an operational facility for applications of remote-sensing data to OCS studies. This facility and its functions have been described in detail in the previous section of the report. Briefly it consists of:

1) A remote-sensing data library which routinely acquires catalogs and disseminates information on Landsat and NOAA satellite imagery and aircraft imagery of the Alaskan continental shelf.

2) A remote-sensing data processing laboratory which provides specialized instrumentation for the photographic reproduction and optical or digital analysis of remote-sensing data of various types and formats.

3) A team of specialists that generates and develops techniques of remote-sensing data analysis and interpretation which appear to be particularly well-suited for OCS studies.

4) A staff that is continually available to OCS investigators for consultation and assistance in searching for, processing and interpreting remote-sensing data for their disciplinary investigations.

As a result of the establishment of the remote-sensing facility established by our project, about OCS projects are routinely using remote-sensing data, of them almost exclusively, and many more OCS investigators are occasional users of remote-sensing data.

B. Disciplinary Results of the Applications of Remote-Sensing Data to OCS Studies

In general, the results of applications of remote-sensing data to OCS studies will be contained in the annual reports of the individual projects and need not be repeated here. However as part of our function to develop techniques of remote-sensing data analysis and interpretation, we did prepare a scientific report entitled "Environmental Assessment of Resource Development in the Alaskan Coastal Zone based on Landsat Imagery" which illustrates the applications of Landsat data to three important aspects of the OCSEAP program: studies of sea-surface circulation and sediment transport in Alaskan coastal waters, studies of sea-ice morphology and dynamics in the near-shore Beaufort Sea, and mapping of terrestrial ecosystems in the Alaskan coastal zone. This report was presented at the NASA Earth Resources Symposium, Houston, Texas, June 1975 where it was acclaimed as one of the best presentations. It was also distributed to OCS investigators as part of Arctic Project Bulletin No. 7 and is now out of print due to heavy demand in spite of the fact that 250 copies were made.

A report produced by RU's 267 and 258, was released in September 1978 by the OCSEAP Arctic Project Office. The report incorporates part of the RU 267 annual report for 1977 and an article by RU's 267 and 258 in Arctic Project Bulletin No. 20 to illustrate, by means of historical Landsat imagery and sea ice morphology maps, the seasonal sequence of sea ice and sea-surface conditions from fall freeze-up to summer breakup in the 1979 Beaufort lease sale area.

8. In addition to these results, specific disciplinary results have been achieved and are reported in the reports attached as Appendicies D, E, F and G.

C. Results of Cooperative Investigations

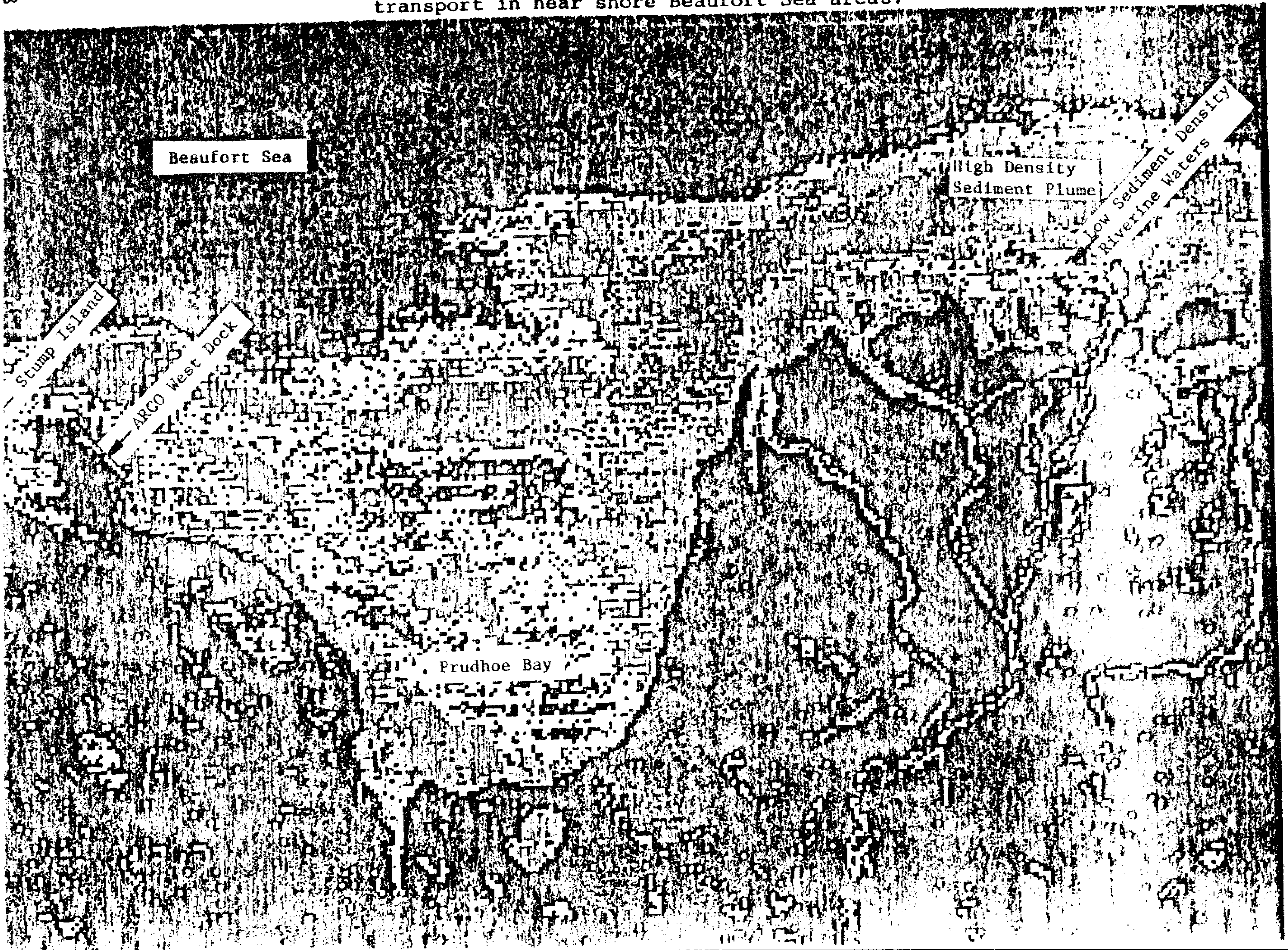
1. Beaufort Coast Sediment Transport

Landsat scenes of the Beaufort Sea coastal area have long been known to show great amounts of sediment transport. Naidu (RU 529) has pointed out that summertime Landsat scenes show mid-summer coastal suspended sediment arises from wave action on exposed headlands and shoals. Previously it was thought that coastal rivers were the sources of suspended material during this time as well as in spring when they are known to provide transport for great amounts of material. In fact, summertime scenes showed plumes of relatively clear water eminating from the mouths of coastal rivers into turbid coastal waters.

The Landsat data alone is only qualitative--showing sources and transport vectors of turbid water. During this past year a joint effort was initiated between this research unit and RU 529 to quantify the levels of suspended sediment observed on the Landsat scenes. This effort had two aspects: first, this research unit investigated methods of assigning quantitative grey level values to the observed sediment plumes, and second, RU 529 prepared to obtain sediment samples simultaneously with satellite overpasses.

The first effort was carried out with some degree of success. In order to assess the technique deemed most likely to produce useful results, Landsat scene 2915-20483 was digitally processed by means of an IDIMS image interpretation system. Figure C.1 shows the portion of this scene containing

FIGURE C.1. Processed Landsat image showing sediment transport in near shore Beaufort Sea areas.



Prudhoe Bay. On this figure, continuous grey levels appearing on the Landsat image have been dividied into discrete step density levels. This process clearly delineates the patterns of suspended sediment density and would allow quantitative assessments of volumes to be made when on-site measurements are available.

In addition to aiding quantitative analyses, this process shows more clearly the sources and distribution patterns of suspended sediment than an unprocessed Landsat image. For instance, on figure C.1 suspended sediment can clearly be seen to arise from the Sagavanirktok River prodelta and not from the river channels. Further, the sediment plume can be seen traveling to the west in response to wind-driven currents. Another source of suspended sediment can be seen on the exposed, western side of Prudhoe Bay and continuing even beyond to the eastern side of the ARCO west dock. Another interesting feature is the zone of relatively unturbid water on the lee side of the west dock.

The second phase of this joint effort was to collect sediment samples in the study area simultaneously with Landsat imagery in the study area during the summer of 1979. Unfortunately, clouds prevented the acquisition of the required imagery.

During the summer, 1980, field season, suspended sediment samples were obtained on August 23, in several locations in the Prudhoe/Harrison Bay area by RU 529 (Naidu). These sediment loads have been compared with reflectance levels measured on nearly simultaneous Landsat imagery. The data suggest that the suspended sediment load measured represents the lower limit of detectability of suspended sediment on Landsat imagery.

OCSEAP experience to date suggests that the large suspended sediment plumes observed on satellite imagery actually result from resuspension of sediment from river deltas during storms. This being the case, the required samples must be obtained during or just after coastal storms (along with the additional requirement that simultaneous cloud-free Landsat imagery will be available.)

The probability of obtaining simultaneous suspended sediment measurements in the value range required and cloud-free Landsat imagery in any one year is relatively small. However, the value to OCSEAP of such data is sufficiently great that additional efforts will be made this summer to acquire the needed sediment samples.

2. Sea Ice Mapping Activities

This research unit has taken over the files and some follow-up activities of RU 258 (Near Shore Ice Morphology). These activities have included:

a) Coordinating preparation of the section of the Bering Sea Synthesis effort dealing with sea ice. Because our remote sensing activities have played such a large part in Bering Sea ice studies, we have performed the role of coordinating this effort. In addition, we have prepared a chapter for this section, dealing with Bering Sea near shore ice conditions.

b) Coordinating preparation of materials to be used by RU 516 (Vigdorchik) in preparing computer-generated ice maps of the Beaufort Coastal areas. RU 516 is using computer mapping techniques to compile site-specific information concerning hazardous conditions in the Beaufort Lease Sale areas arising from a wide variety of causes. One of the chief sources of hazards arises from sea ice activity. This research unit has supplied RU 516 with maps derived from Landsat images at 1:500,000 scale showing the locations of leads, fast ice, ridges and polynyes. The results of this work have been reported in the current annual report of RU 516.

3. Synthesis activities

This research unit participated in three synthesis efforts this contract year and as a result of each meeting has identified one or more areas requiring short-term, high-intensity analysis effort required to fill "data gaps".

Norton Sound As a result of this synthesis meeting attention was drawn to ice movement in and from Norton Sound and the implications of this movement on the transport of pollutants. As a result an extensive analysis of ice floe trajectories has been performed and is reported here in Appendicies D, E and F.

Sale 71 As a result of this synthesis meeting a "data gap" in terms of summertime ice extent was discovered. In order to supply the missing information, the report included here as Appendix G was prepared.

St. George Basin As a result of this synthesis meeting, it was determined that very little knowledge was at hand regarding the frequency of pack ice in the potential sale area. A study is under way to supply this missing information.

VII & VIII - DISCUSSION AND CONCLUSIONS

The principal objective of the contract, as specified in its work statement, has been achieved: a facility for applications of remote-sensing data to outer continental shelf studies has been established at the University of Alaska and is now fully operational. In addition, as described below, the research unit has taken on the additional duty of performing short-term studies utilizing remote sensing data to information needed to fill "data gaps".

The remote-sensing data library has acquired all available cloud-free remote-sensing imagery of the Alaskan continental shelf, catalogued it and provided information on its availability to all OCS investigators through the series of Arctic Project Bulletins.

Existing instrumentation for analyzing remote-sensing data has been consolidated into a data processing laboratory and techniques for its use have been developed with particular emphasis on the needs of the OCSEAP program. New instrumentation is being acquired and new analytical techniques are continually being developed from this contract and other funding sources.

The staff of the project is interacting with a number of OCS investigators, providing consultation and assistance in all aspects of remote-sensing applications from data searches and ordering to advanced analyses of the data in photographic and digital format. We have also worked very closely with the OCSEAP Arctic Project Office in designing an interim remote-sensing data acquisition program using contract and aircraft missions by other agencies.

At this time about fourteen OCS projects are using remote-sensing data and processing facilities routinely, some of them almost exclusively of other research activities, and many more OCS investigators are occasional users of remote-sensing data. As the focus of OCSEAP changes from synoptic studies to the leasing process, requests have become more detailed and site specific. Studies of processes and potential impacts on individual areas rely heavily on historical remote sensing data and detailed interpretations on a case by case basis. It is important to collect and archive available coverage as well as assist in the acquisition of more detailed imagery of key areas.

This past year we have found that as synthesis meetings are held and the deadlines for Environmental Impact Statements approach, the need for short-term specific topic studies arises. Some of these needs can be filled through analysis of our archived remotely-sensed data. This research unit has been performing studies of this nature and anticipates the need for additional studies of this nature in the coming year.

It is clear from the foregoing discussions and from consultations with OCS investigators, regarding their study plans for the next year, that there will be a continuing need for the research support thtat our project provides. We intend to submit a continuation proposal to NOAA for this purpose.

APPENDIX A: Remote Sensing Facility Use Activity During This Past Year

I. Activity by OCSEAP investigators

1) RU 596 (Overland/Pease) through Lyn McNutt, performed an extensive data search for Landsat imagery showing polynya occurrence and growth in Norton Sound and the northern Bering Sea. These data have been subsequently analyzed and the results reported to OCSEAP.

2) RU 205 (Reimnitz, et al) queried concerning the availability of summertime color Landsat imagery showing "dirty ice," and late fall imagery showing recently-formed ice being advected away from coastal areas during storm conditions. Several images were sent to the investigators to be examined. The matter of interest here is to test a hypothesis that considerable transport of near shore sediment takes place through incorporation of resuspended sediment into newly-forming near shore ice in the fall and the subsequent transport of the "dirty ice."

3) RU 460 (LGL) Alan Springer looked through NOAA imagery to find thermal imagery representative of various along-shore current regimes. Several interesting examples were chosen for further study. Some of these were examined on the VP-8 image analyzer. However, the results appeared too ambiguous to use for purposes of illustration. For that reason, an effort is currently underway to obtain digital tapes of the satellite scenes chosen in order to digitally enhance the features of interest.

4) RU 248 (Fay) through Brendan Kelly used custom enlargement of DMSP imagery as a navigational aid while aboard the Coast Guard Cutter Polar Star conducting research on sea mammals in the Gulf of Anadyr and the Bering Sea. Before leaving on another field trip, Frank Fay was provided current-day NOAA and DMSP imagery for use as a navigational aid in the Bering Sea.

5) RU 248 (Shapiro) through Teri McClung used the remote sensing facility equipment (light tables, projectors, film splicers, to edit a film that research unit is preparing on ice movement in the Barrow area.

6) RU 567 (Prichard) was provided satellite imagery of Norton Sound for those times when they were placing satellite position buoys on the ice there. Early in the ice year this research unit and project management were provided current satellite imagery and interpretation of ice conditions concerning when to initiate deployment of buoys. Ron Reimer of this research unit performed a data search of NOAA imagery for January and February, 1977, and selected representative examples to accompany field observations he had made.

7) RU 250 (Shapiro) examined the files to obtain stratified examples of NOAA imagery, Landsat imagery, side-looking airborne radar and aerial photography of ice condtions in the Beaufort and Bering seas.

8) RU 289 (Royer) through Kristina Ahlnaes continued as in previous years to make weekly examinations of NOAA and DMSP thermal imagery in order to select examples for enhancement and further analysis.

9) RU 529 (Naidu) ordered imagery of the Oliktok Point area and coordinated his suspended sediment sampling program with Landsat overpasses.

10) RU 88 (Kovacs) examined the browse files to find the latest NOAA, DMSP, Landsat and aerial imagery of ice conditions in the various OCSEAP study areas.

11) RU 530 (Cannon) has continued to examine Landsat imagery of the Prudhoe Bay vicinity as it becomes available in order to identify data which may be useful to delineate geomorphic units or illustrate geological processes that help explain the recent geologic history of the lease areas.

12) RU 251 (Kienle) examined recently acquired imagery of the Alaska Peninsula for imagery complementing his geologic hazards studies.

II. Activity By Related BLM Studies

Project Whales. Arnold Hansen, performing sea ice analyses for Project Whales, spent several days browsing through Chukchi Sea imagery and obtained photographic prints of DMSP imagery.

III. Activity By OCSEAP Personnel

Rich Wright, Juneau Project Office, requested a data search and copies of Landsat imagery showing re-suspended turbidity in the region of the Yukon Delta.

IV. Activity By Related Agencies

1) Doug Woodby, Institute of Environmental Studies-Seattle, came into the library to browse through imagery of the Chukchi-Beaufort Sea area after having inquired about its availability previously. He took with him a list of the suitable imagery for his purposes.

2) Arthur Grantz, U.S.G.S.- Menlo Park, called to ask for our assistance in monitoring ice conditions in the Chukchi Sea to aid in navigation on their cruise to "Katie's Floeberg."

3) John Rezek, Department of Transportation, visited and asked our assistance in obtaining current imagery of the Bering Straits, Chukchi Sea and Beaufort Sea. The Coast Guard icebreaker Polar Sea made a trial cruise from Nome to Barrow and, if conditions had permitted, would have gone over to Prudhoe Bay. We obtained several enhanced NOAA images which showed existing open leads and continued to obtain imagery and forwarded it to Barrow so they could assess ice conditions before proceeding to Prudhoe Bay. Unfortunately many problems, mechanical as well as ice, arose and the ship became icebound on the return trip and spent several months in the ice waiting for conditions to improve. Arctec Inc., consultants overseeing the whole operation, ordered imagery of the Feb. 15 - March 15 time period to verify ice conditions and for inclusion in their report of the trip.

4) Bud Lehnhausen, U.S.Fish & Wildlife Service-Anchorage, browsed through our files searching for satellite images showing ice conditions over a span of several season for the Icy Cape area. After looking through all of it he ordered several representative images.

5) Cal Fifield, Bureau of Land Management-Anchorage, called to query for any aerial photography along the Beaufort coast in the Flaxman Island Quad which would give the location of offshore islands in relation to the coast.

V. Activity By Private Industry

1) John Kreider, Shell Development Co.-Houston, called and asked that we monitor imagery of the Bering Straits for a certain time period and send him the imagery as it becomes available.

2) George Ross, Shell Oil Company-Houston, placed a large order for Landsat imagery of the Chukchi coastal areas.

3) Brian Thomas, Gulf Research and Development, Houston, asked for a search of Landsat imagery of "Katie's Floeberg." A search was made and Xerox copies of the imagery were sent to him along with ordering information.

4) John Harper, Woodward Clyde Consultants, queried about the availability of aerial photography of the Chukchi and Beaufort seas. He later visited the facility and browsed through the imagery and placed an order for several frmes of photography.

5) Terrance Ralston, EXXON Production Research Co., browsed through our files and ordered many aerial photographs and Landsat images of the Beaufort lease area.

6) Mark Perry, Nortac-Anchorage, asked for a selection of Landsat imagery that showed the overflows on the Sagavanirktok River. Several were chosen and sent to him.

7) Ray Finucane, EXXON, was the senior engineer working on construction of the EXXON Ice Island off Prudhoe Bay and called from Houston to order several enlargements of aerial photography of the island obtained in 1979.

8) Mary Throw, Shell Development Company, called to ask for a search for Landsat imagery in the Cape Halkett area and an order was placed for several images for her which showed the ice movement and characteristics in that area.

SPECIAL REPORT ON MONTHLY LANDSAT COVERAGE

The Geophysical Institute at the University of Alaska has maintained a Landsat image archive since the launch of Landsat 1 during June, 1972. Through a series of contracts and projects, an effort has been made to obtain and archive at least one black-and-white print of each Alaskan Landsat scene sufficiently cloud-free so that some interpretation of surface conditions would be possible. Over the years several checks against the USGS Landsat data base in Sioux Falls have been made to determine the completeness of the Fairbanks archives. Any data gaps discovered were filled. However, on several occasions it was found that the Fairbanks archives contained images which had not been entered in the Sioux Falls archives.

Many times at the beginning of a particular scientific study, depending in large part on the availability of satellite imagery, an initial search is made of available imagery in the proposed study area or conversely a search is made for an area with sufficient imagery to support the proposed plan of work.

We have, from time to time, published catalogs of available imagery in various forms. However, it occurred to us recently that no cumulative catalog had been made in terms of total number of images available for a given location, or total number per location per calendar month. This publication results from an effort to remove that deficiency.

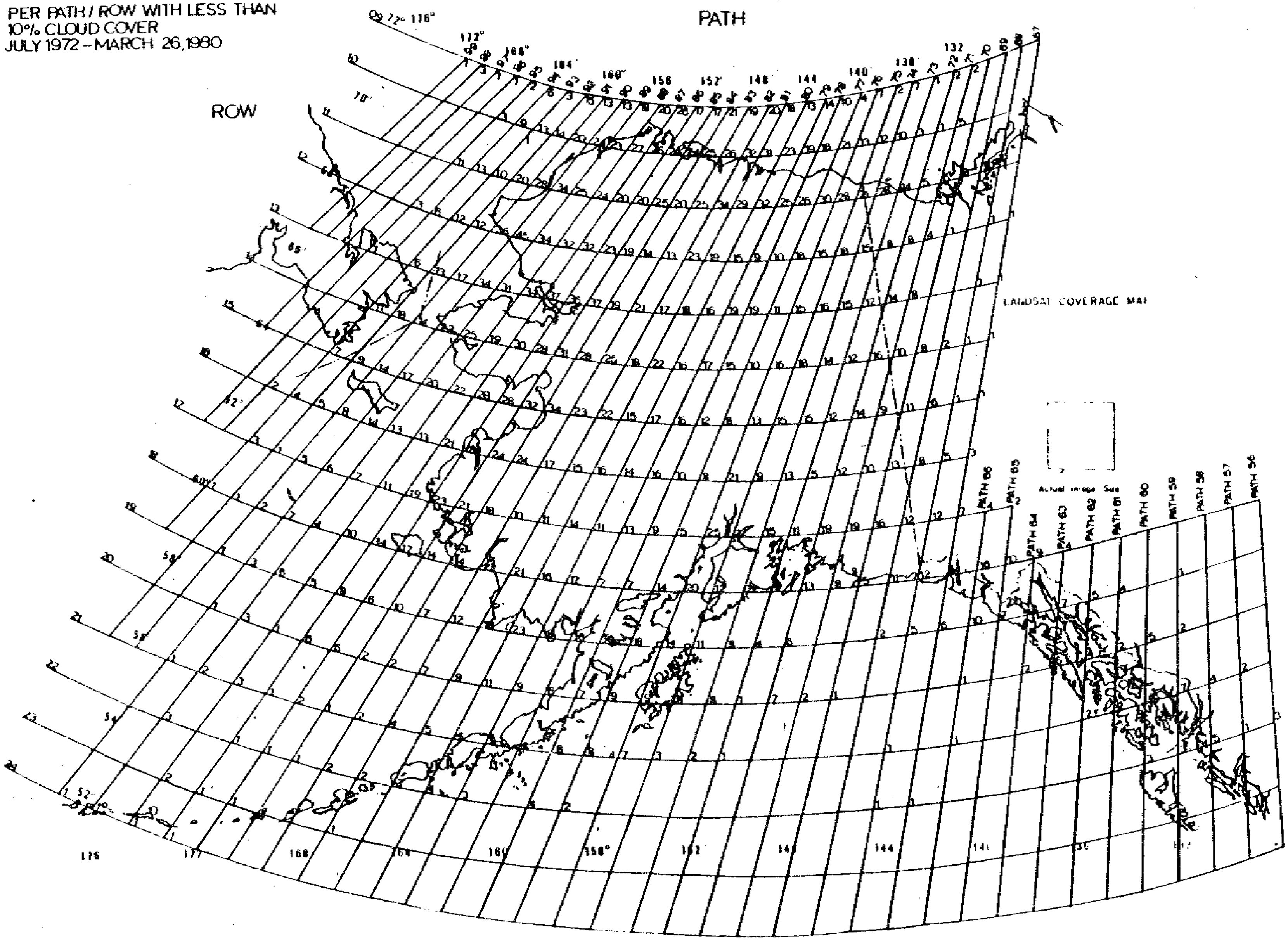
The following pages of this report consist of thirteen maps of Alaska showing the number of images available in terms of satellite path and row location. The first map represents the cumulative total images available and the following twelve maps break this total down in terms of calendar month. Hence we see that on path 85, row 15 there have been 32 images archived for central eastern Norton Sound. Of these, none were recorded in December or January but 4 were recorded in February and 8 in March and 4 in April, etc.

While using this catalog it should be borne in mind that the actual image size is sufficiently large to cover three row locations so that the actual data density is considerably greater than might appear at first glance.

In the instance that a particular location is of great interest, a special data inventory for that area should be undertaken. However, this catalog should give the Landsat user a reasonably accurate representation of the quantity of imagery currently available for a given area.

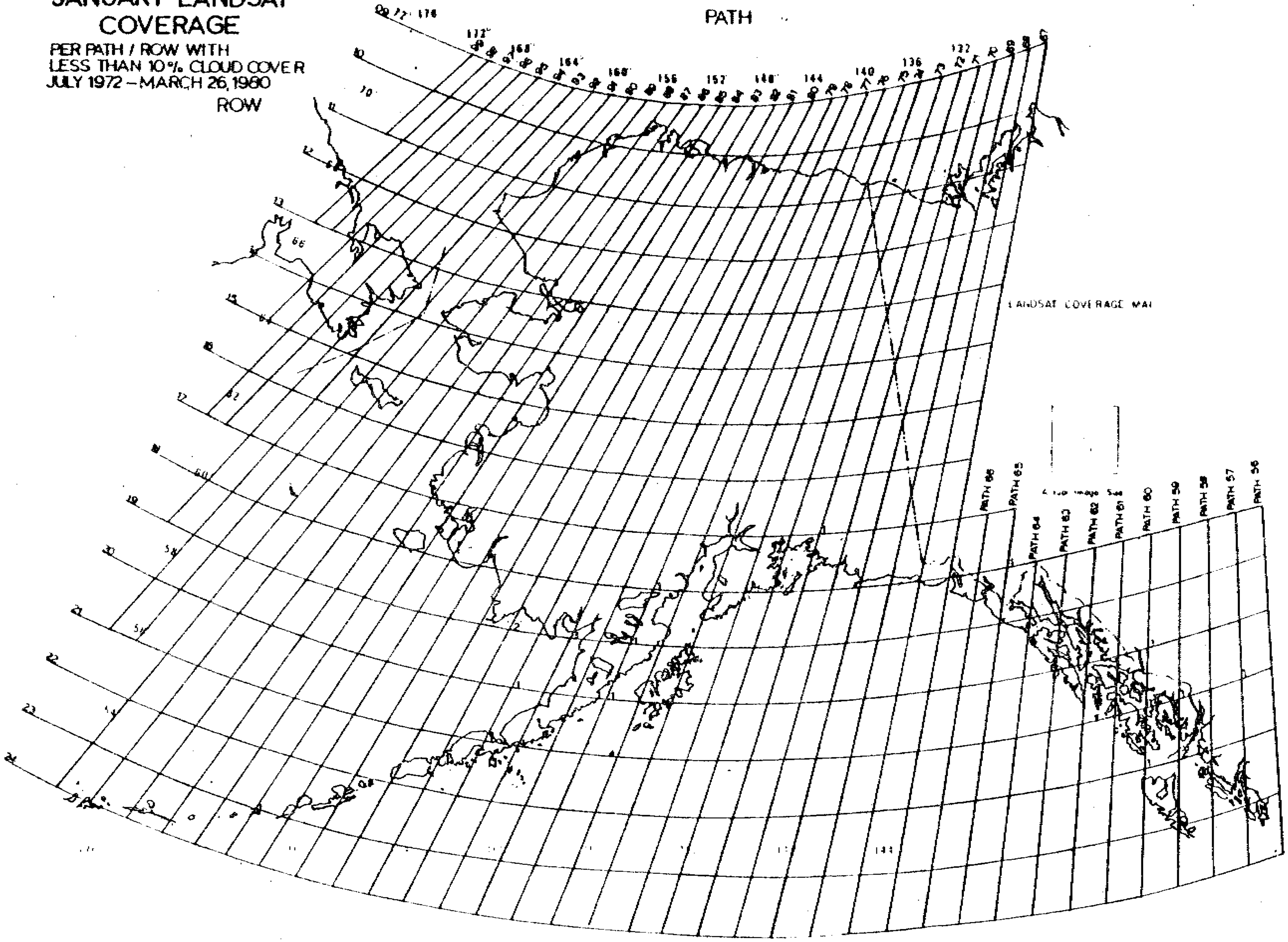
TOTAL LANDSAT COVERAGE

PER PATH / ROW WITH LESS THAN
10% CLOUD COVER
JULY 1972 – MARCH 26,1980



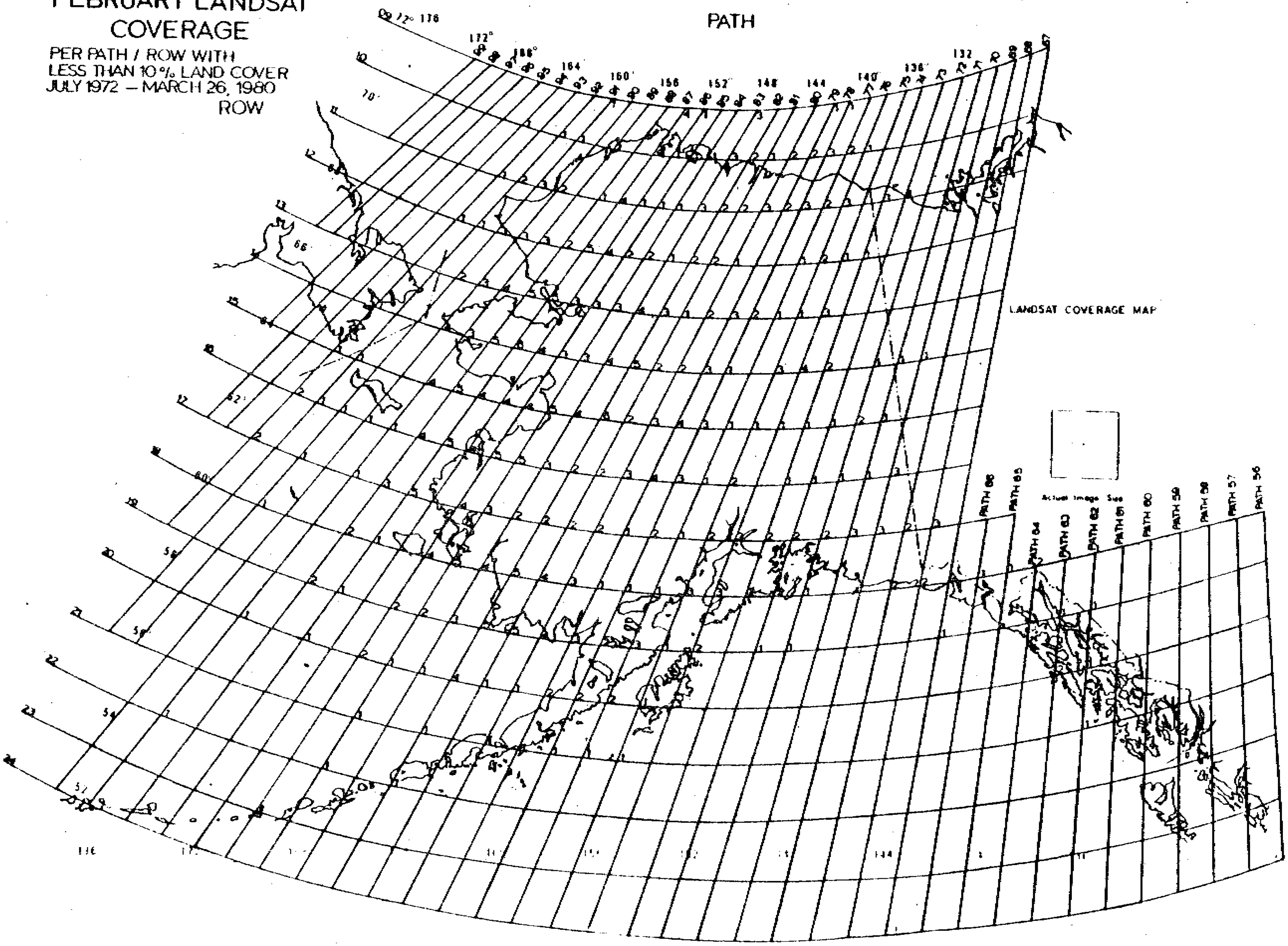
JANUARY LANDSAT COVERAGE

PER PATH / ROW WITH
LESS THAN 10% CLOUD COVER
JULY 1972 – MARCH 26, 1980



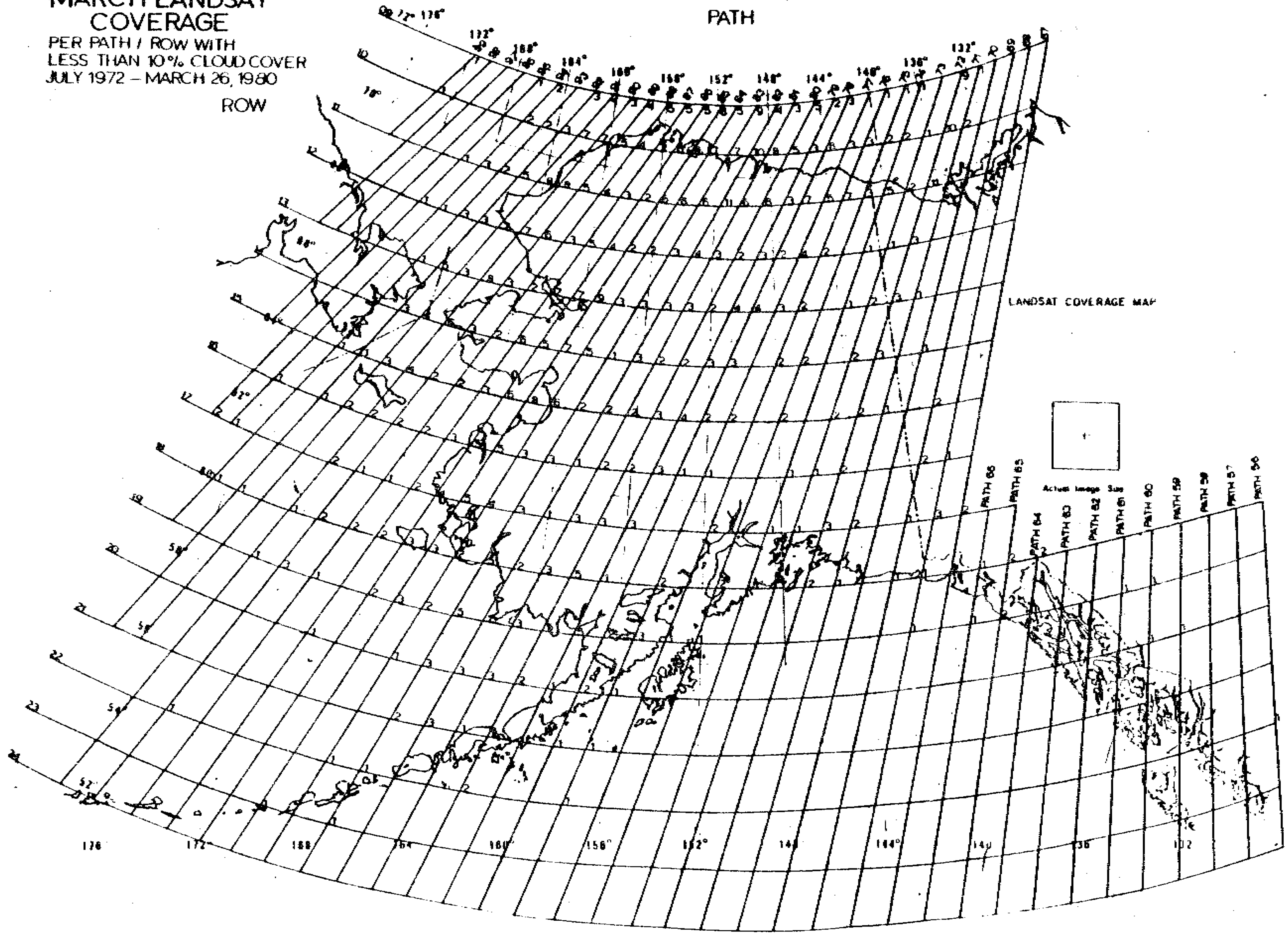
FEBRUARY LANDSAT COVERAGE

PER PATH / ROW WITH LESS THAN 10% LAND COVER
JULY 1972 – MARCH 26, 1980



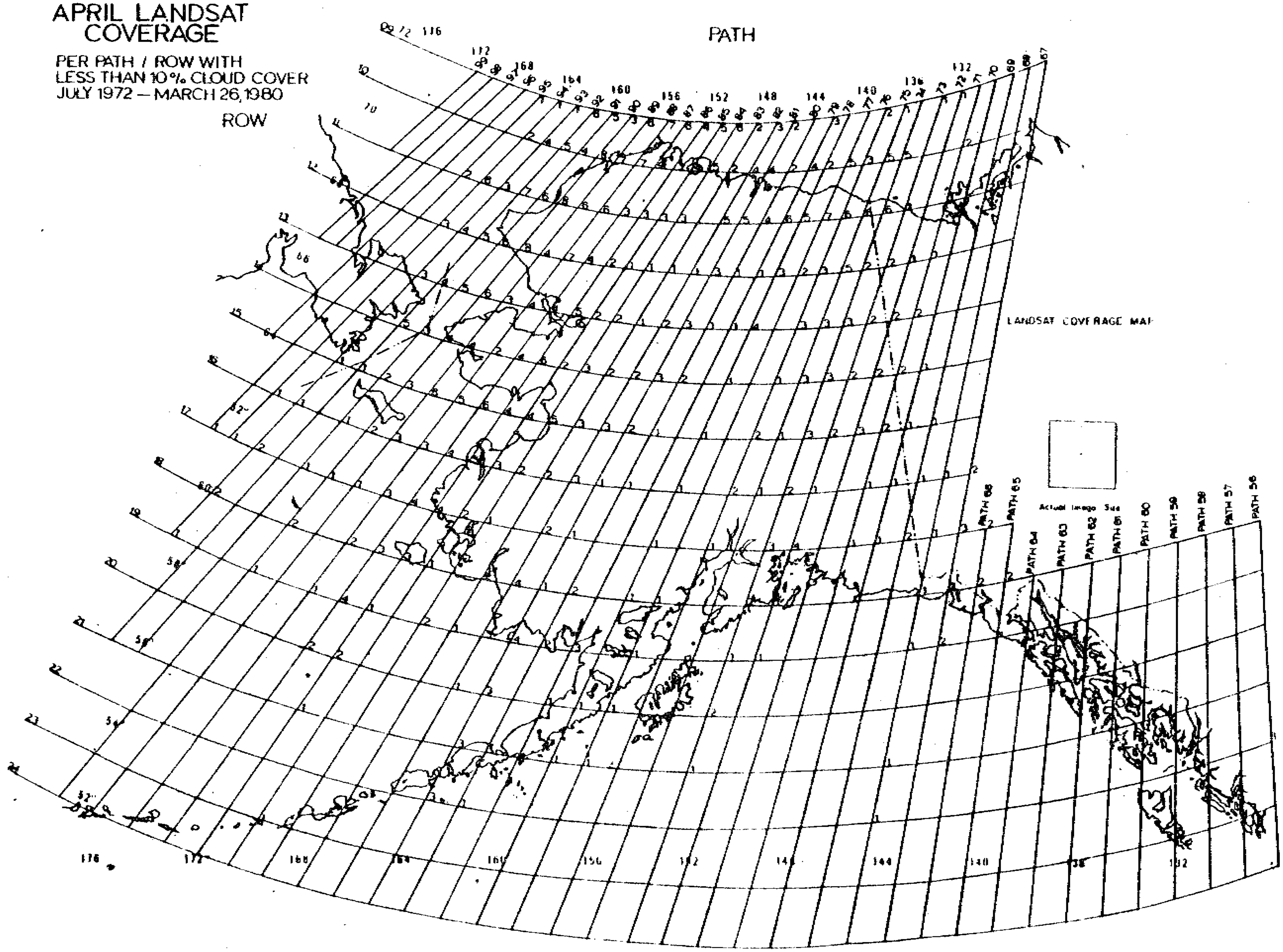
MARCH LANDSAT COVERAGE

PER PATH / ROW WITH LESS THAN 10% CLOUD COVER
JULY 1972 – MARCH 26, 1980



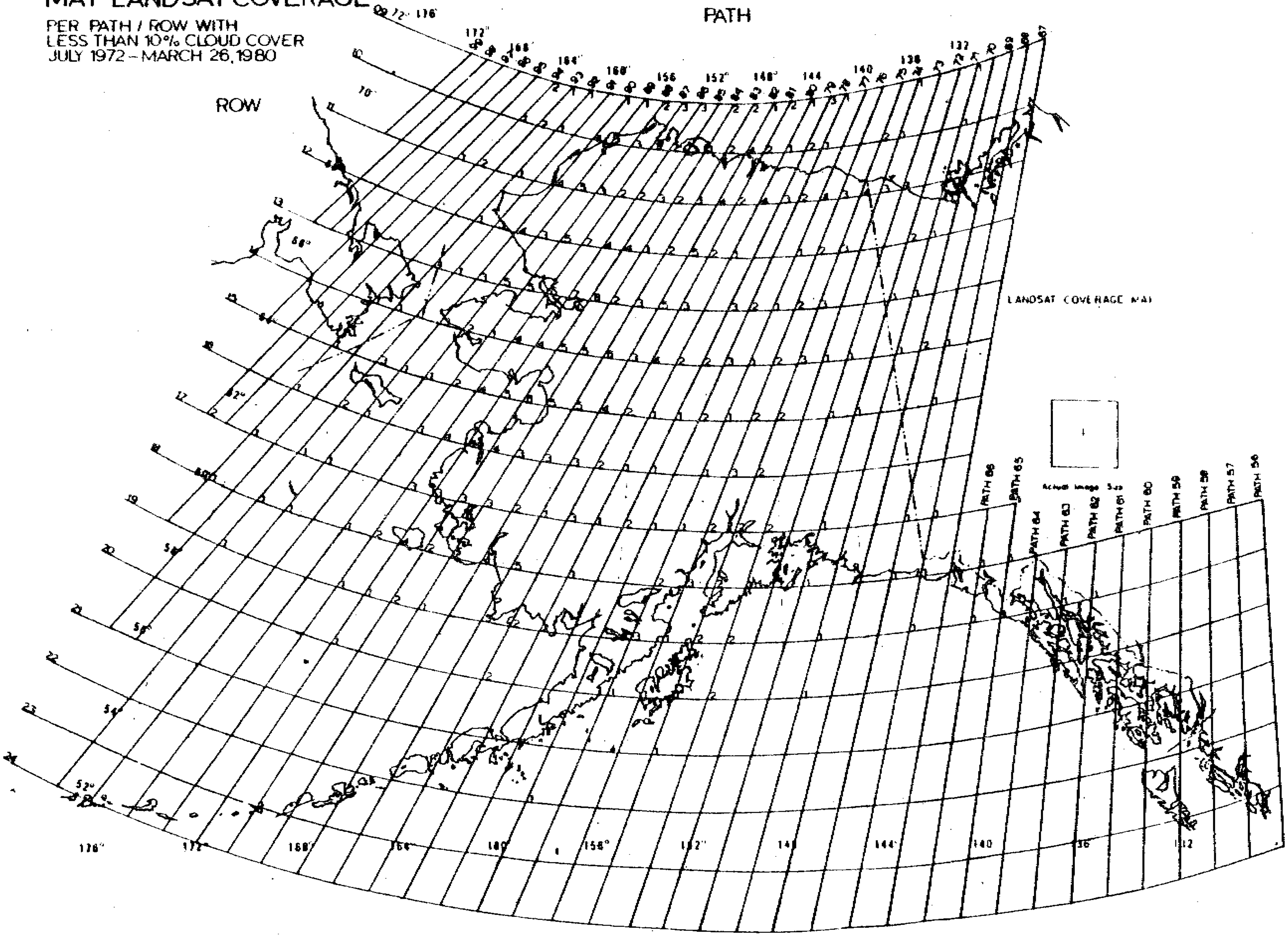
APRIL LANDSAT COVERAGE

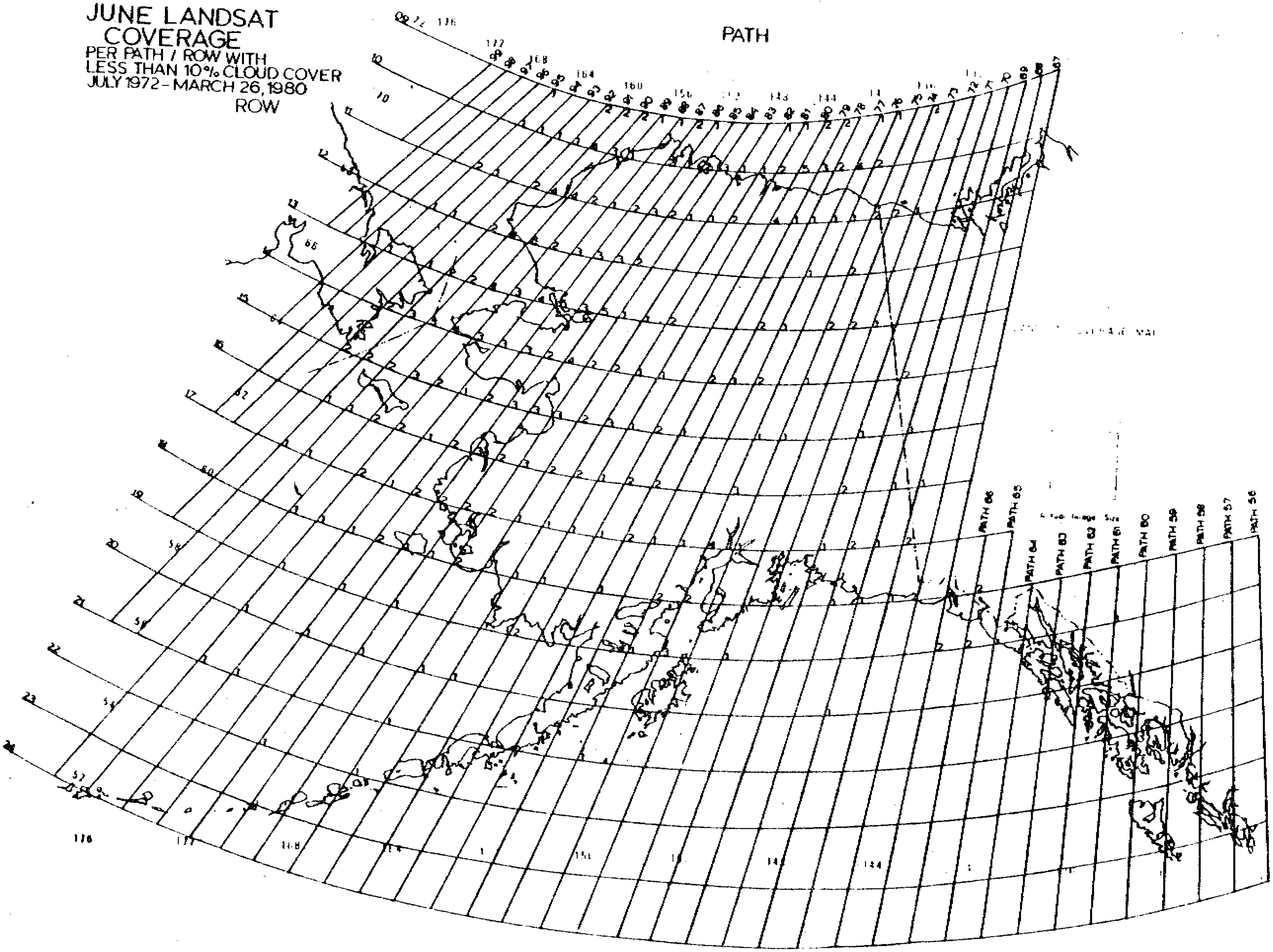
PER PATH / ROW WITH
LESS THAN 10% CLOUD COVER
JULY 1972 — MARCH 26, 1980



MAY LANDSAT COVERAGE

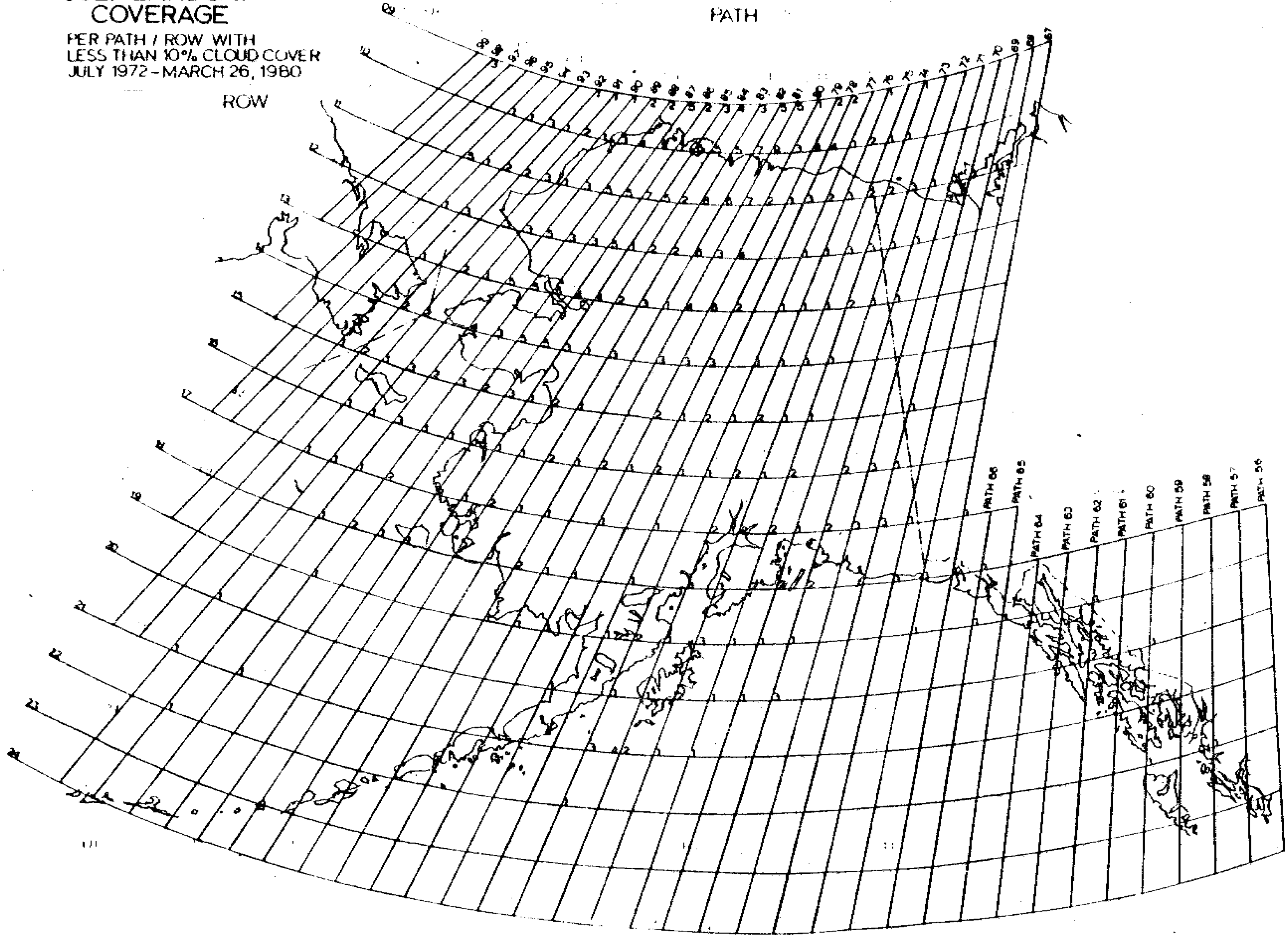
PER PATH / ROW WITH
LESS THAN 10% CLOUD COVER
JULY 1972 – MARCH 26, 1980




JUNE LANDSAT COVERAGE
PER PATH / ROW WITH LESS THAN 10% CLOUD COVER
JULY 1972 - MARCH 26, 1980
PATH
ROW
PATH 66
PATH 65
PATH 64
PATH 63
PATH 62
PATH 61
PATH 60
PATH 59
PATH 58
PATH 57
PATH 56

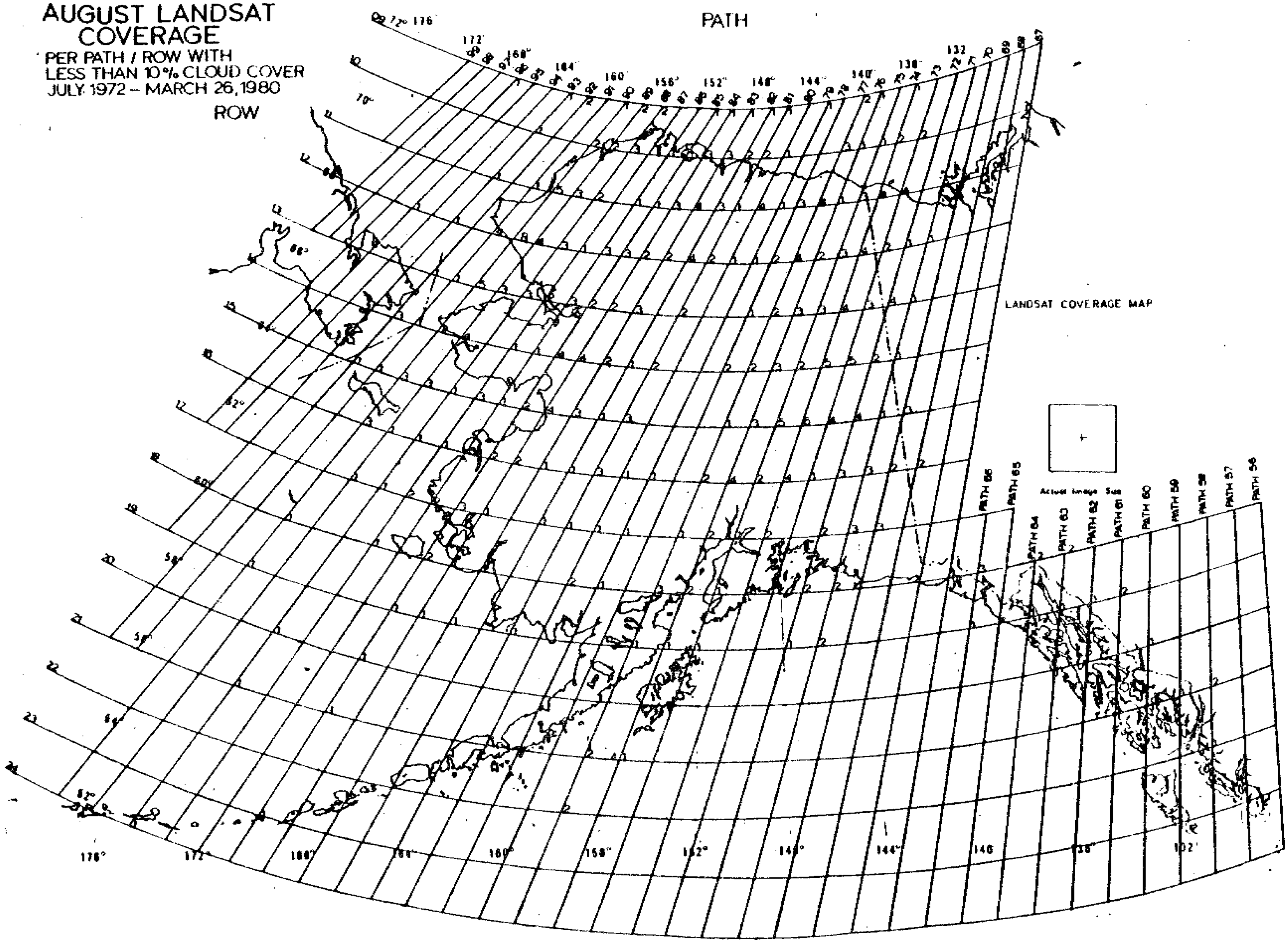
JULY LANDSAT COVERAGE

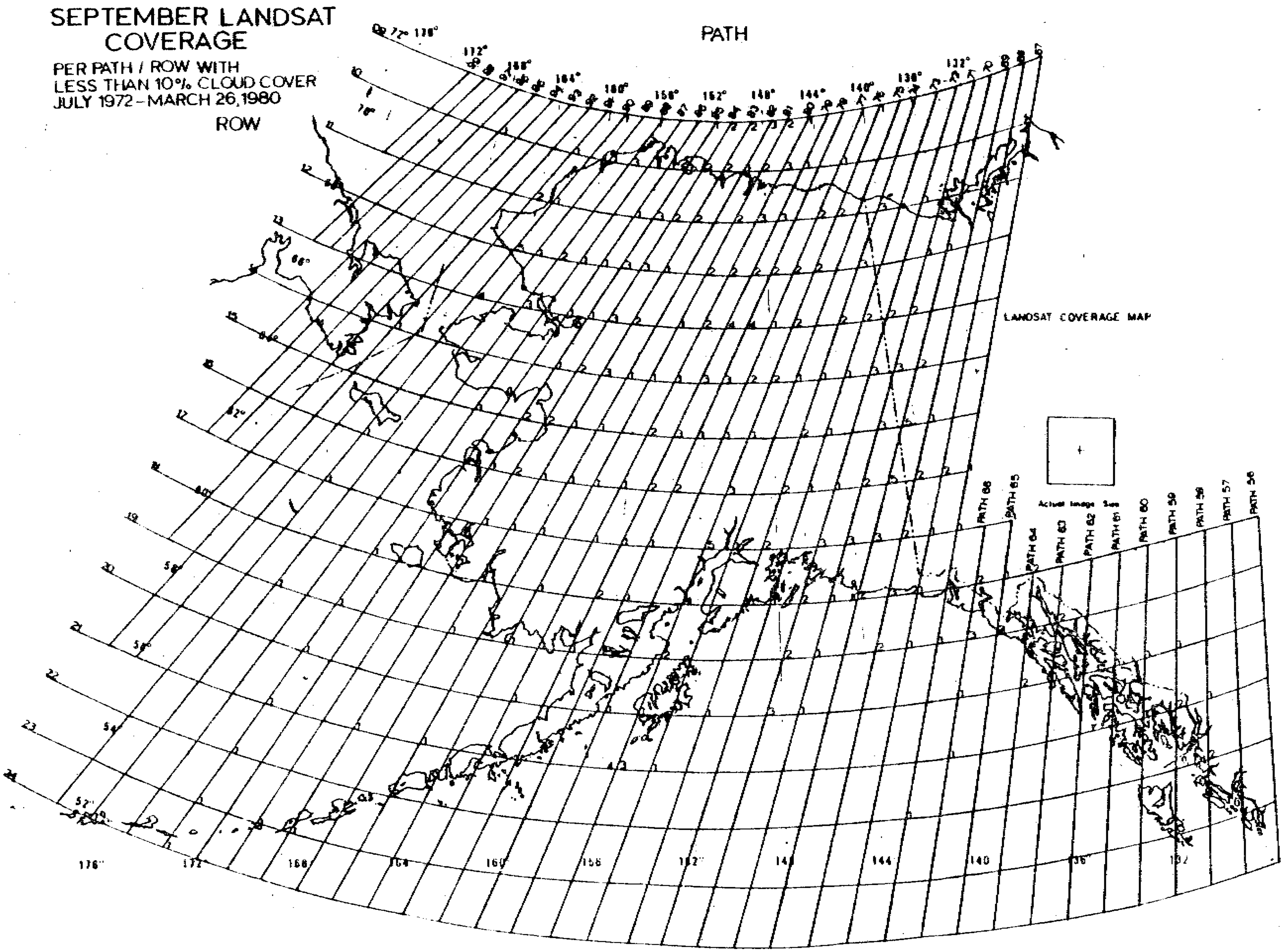
PER PATH / ROW WITH
LESS THAN 10% CLOUD COVER
JULY 1972 - MARCH 26, 1980



AUGUST LANDSAT COVERAGE

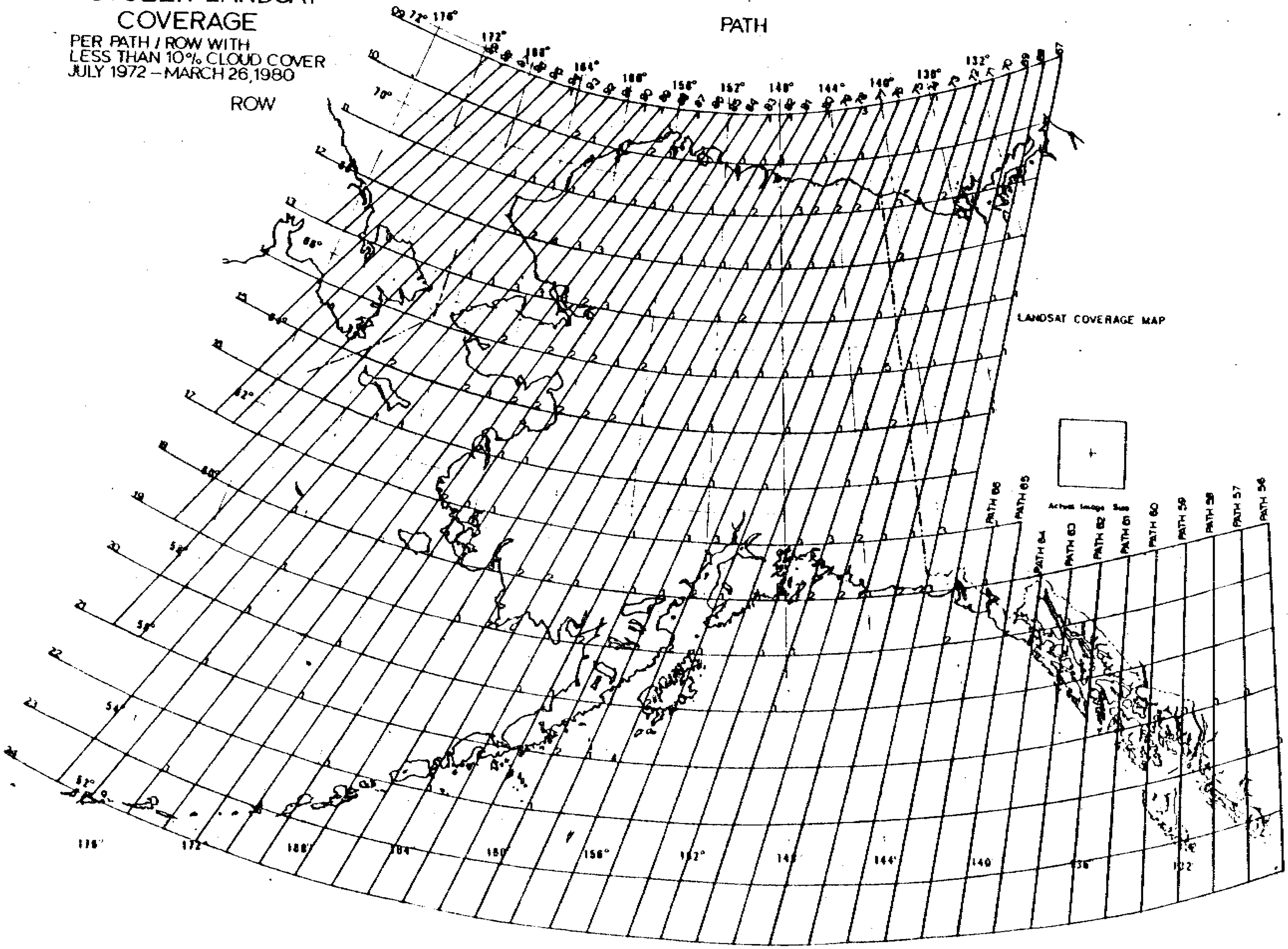
PER PATH / ROW WITH LESS THAN 10% CLOUD COVER
JULY 1972 – MARCH 26, 1980




SEPTEMBER LANDSAT COVERAGE
PER PATH / ROW WITH LESS THAN 10% CLOUD COVER JULY 1972 - MARCH 26, 1980
ROW
PATH
LANDSAT COVERAGE MAP
Actual Image Size
PATH 66
PATH 65
PATH 64
PATH 63
PATH 62
PATH 61
PATH 60
PATH 59
PATH 58
PATH 57
PATH 56

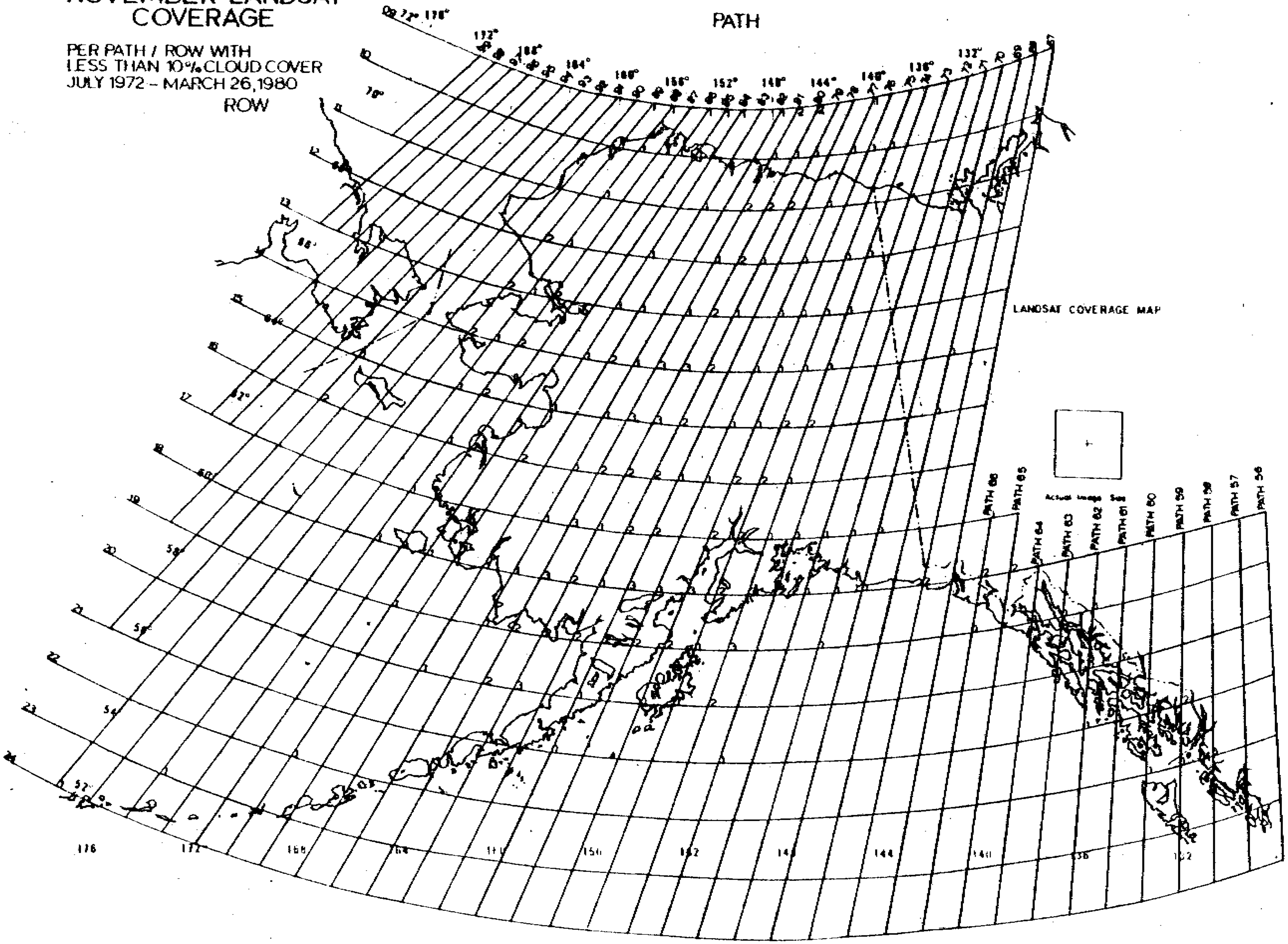
OCTOBER LANDSAT COVERAGE

PER PATH / ROW WITH LESS THAN 10% CLOUD COVER JULY 1972 – MARCH 26,1980



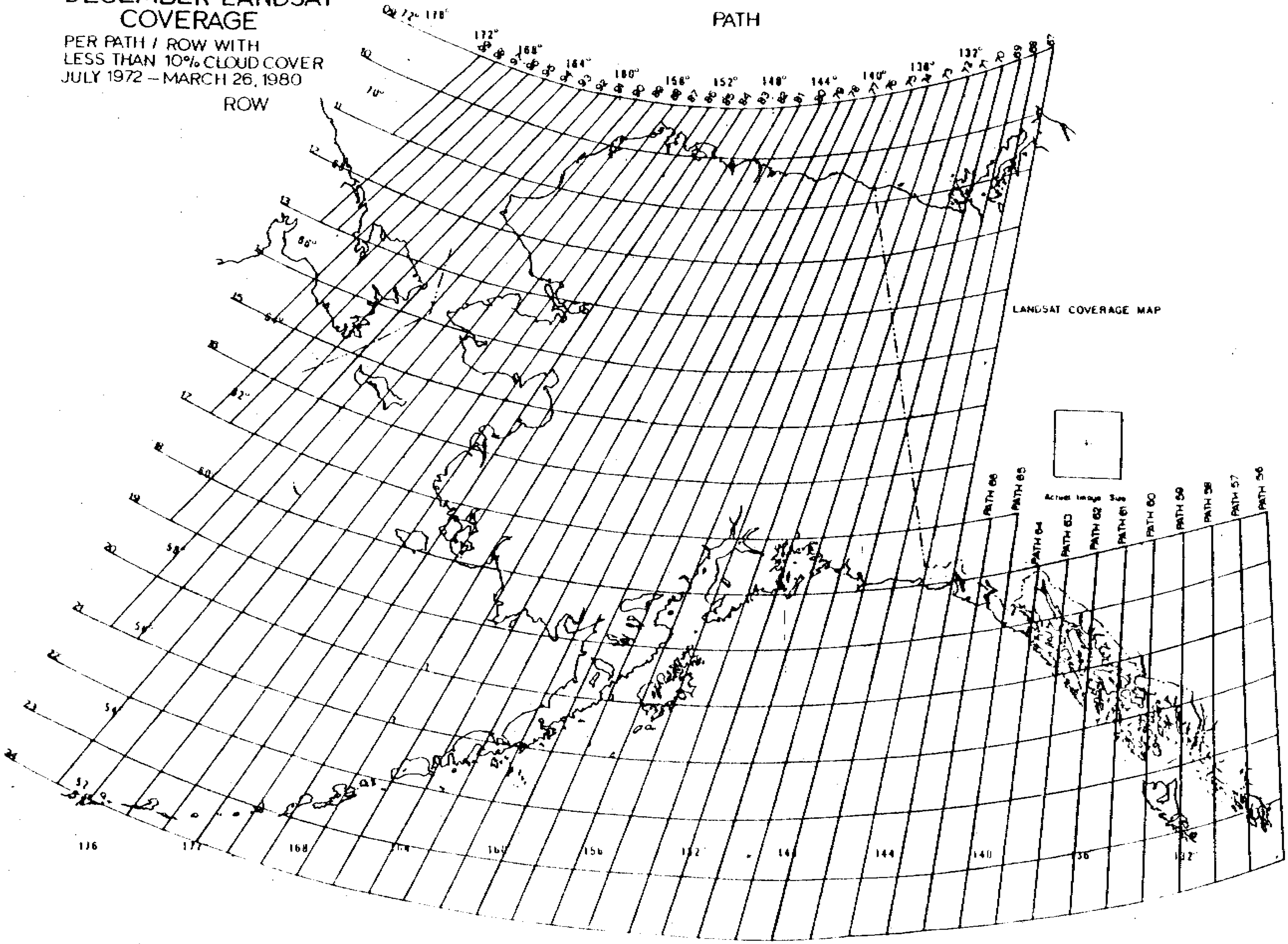
NOVEMBER LANDSAT COVERAGE

PER PATH / ROW WITH
LESS THAN 10% CLOUD COVER
JULY 1972 – MARCH 26, 1980



DECEMBER LANDSAT COVERAGE

PER PATH / ROW WITH LESS THAN 10% CLOUD COVER JULY 1972 – MARCH 26, 1980



BEAUFORT SEA SATELLITE IMAGERY AVAILABLE FOR SUMMER, 1980 STUDIES

BY

WILLIAM J. STRINGER

OCSEAP RU 267

GEOPHYSICAL INSTITUTE

UNIVERSITY OF ALASKA

FAIRBANKS, ALASKA

NOVEMBER, 1980

OCSEAP Research Unit 267

Satellite Imagery Available for Summer, 1980 Studies

Last summer, we acquired satellite imagery from both Landsat and large field of view weather satellites. The weather satellite images are currently on hand, while the Landsat data is only now arriving in a format which will allow useful duplication for scientific studies. This report lists the data which will soon be available and gives a short description of the various satellite formats and utilities.

Landsat:

Last summer there were two Landsat vehicles providing data for us: Landsat 2 with a working multi-spectral scanner system (MSS) and Landsat 3 with an operational return-beam vidicon system (RBV) and occasionally, an MSS. Each satellite requires 18 days to repeat a particular orbit and the two satellites are situated nine days apart. However, overlap is sufficiently great that a given location on the ground is imaged on three successive days as the satellite path moves westward (about 50 km/day at Beaufort Sea latitudes.)

The MSS system produces the image most people associate with Landsat. Images are produced in four wavelength bands and are generated by a series of line scans across the earth's surfact by photometers. The RBV system is essentially a television camera with a broad band spectral response. While the RBV data is not available in single spectral band format, the picture elements are 1/4 the size of the MSS picture elements so that detection of smaller objects should be more possible than with the MSS system. (Each image is actually made up of four parts, labeled starting on the upper right hand corner, A,B,C, and D.) However, the brightness range on the RBV image is so large that it is impossible to simultaneously show details of ice and land. In fact, in order to even show the coast, ice details are lost. Generally, the ice is so overexposed that nearly all ice appears uniformly white. This can be corrected by special photographic processing of retrospective imagery which arrives approximately two to three months after the "quick-look" image is obtained. The effect of this "over-exposure" is that all ice is well-identified, but thickness and structure information is lost.

The "quick-look" imagery was obtained by the Canadian ground station at Price Albert and after photographic prints were made, sent to us by using commercial phone lines and facsimile machines. However, we were not always able to keep an archival copy of these relatively poor images. Instead, often the only copy we had was sent to Deadhorse to help various research units. Because of this, even to have a complete set of images we have had to wait until they became available through regular channels. They are just now becoming available.

Large Field Imagery:

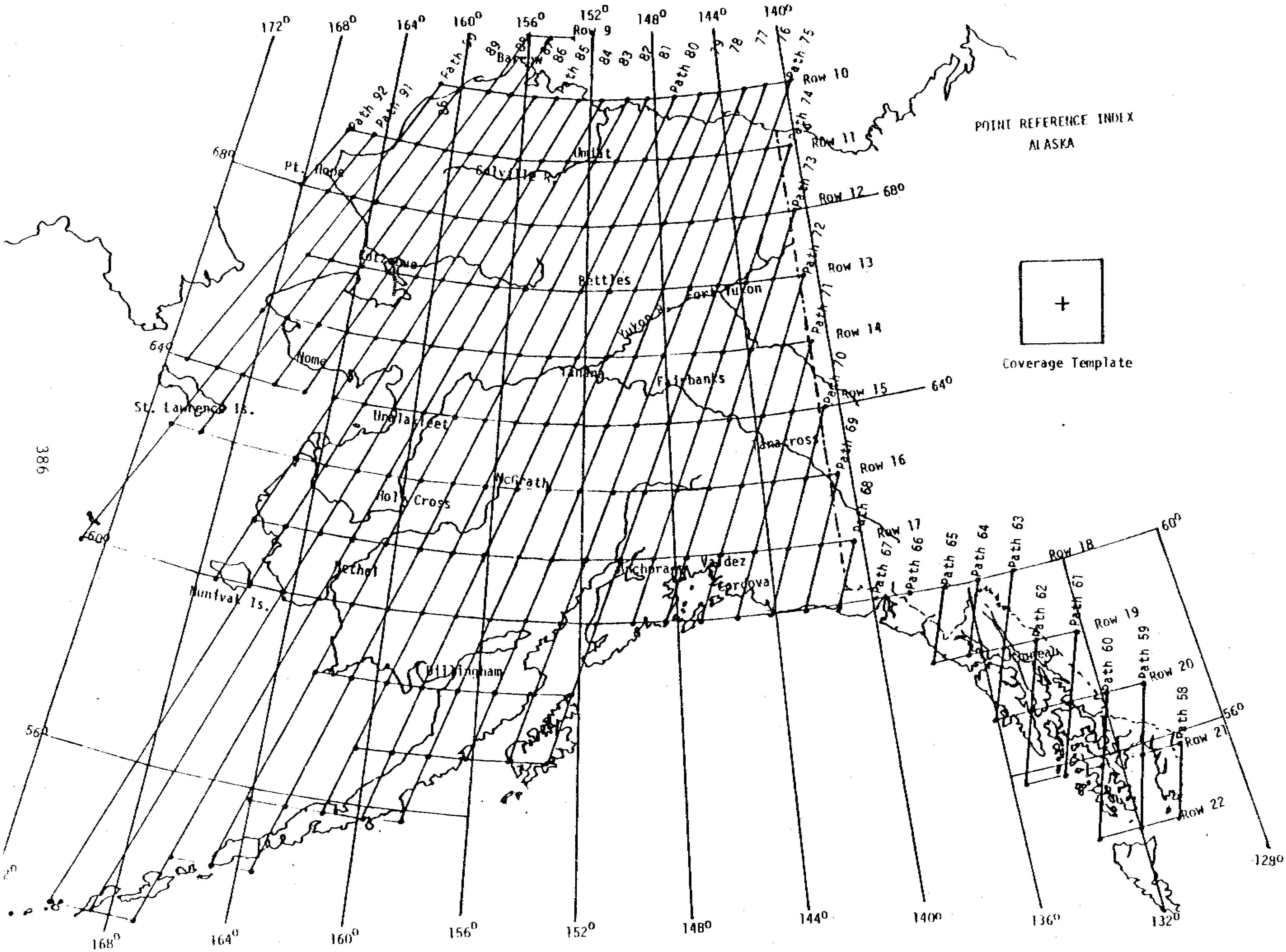
Military and civilian weather satellite imagery is available at approximately 1:10,000,000 scale. This can be enlarged to approximately 1:2,000,000 scale, but since the resolution elements are approximately 400 m square (as opposed to 80 m for Landsat MSS) considerable "graininess" is encountered and details are often obscured. These images are normally obtained daily. They are archived in the form of transparencies. Occasionally, high quality images were enlarged and several copies printed. Copies were sent to various investigators at Deadhorse. Some additional enlargements are still on hand. These are available on a first come, first served basis.

Assistance:

Research Unit 267 maintains a library of satellite images containing all the material described above as soon as it is available. We will be more than happy to conduct data searches, order retrospective imagery or special photographic processing for you.. Our phone number is (907) 479-7487. Mrs. Katie Martz carries out this function. In addition, please feel free to contact me concerning special processing (for instance, computer analysis) of remote sensing data.

The following pages contain a catalog of satellite imagery of the Beaufort Sea coast. Although we do not have all this imagery on hand yet, we believe that this is a complete list of what will soon be available.

The catalog is preceeded by a map showing the location of the Landsat image path and row system. Please note the "coverage template" on the right hand side of this map. This template shows the extent of a single Landsat image. Note that in the Beaufort Sea area a given location has a chance of being imaged on three successive days.


POINT REFERENCE INDEX
ALASKA
Coverage Template
Row 9
Row 10
Row 11
Row 12
Row 13
Row 14
Row 15
Row 16
Row 17
Row 18
Row 19
Row 20
Row 21
Row 22
Path 92
Path 91
Path 80
Path 75
Path 74
Path 73
Path 72
Path 71
Path 70
Path 69
Path 68
Path 67
Path 66
Path 65
Path 64
Path 63
Path 62
Path 61
Path 60
Path 59
Path 58
Pt. Hope
Colville R.
Bettles
Fort Yukon
Yukon R.
Nome
Tanana
Fairbanks
St. Lawrence Is.
Unalakleet
Tanacross
McGrath
Holy Cross
Bethel
Nunivak Is.
Anchorage
Valdez
Cordova
Juneau
172°
168°
164°
160°
156°
152°
148°
144°
140°
136°
132°
128°
68°
64°
60°
56°

DATE	LANDSAT IMAGERY			LARGE FIELD IMAGES						REMARKS
	SCENE ID	MSS	RBV	NOAA			DMSP			
		Path/Row	Path/Row	Pass	IR	Visual	Pass	IR	Visual	
June 1				4853	x	x				
June 2				4849	x	x				Mackenzie Bay visible
				4850	x	x				
							4849		x	
June 3				4863	x	x				
				4864	x	x				
							4864		x	
June 4				4877	x	x				
				4878	x	x				
June 5				4892	x	x				
				4893	x	x				
							4892		x	
June 6				4906	x	x				
				4907	x	x				
June 7				4920	x	x				
				4921	x	x				
							4921		x	
June 8				4934	x	x				
				4935	x	x				mostly clear
							4935		x	
June 9				4948	x	x				
				4949	x	x				partly clear
				4950	x	x				
							4949		x	
June 10				4963	x	x				partly clear
				4964	x	x				partly clear
June 11				4977	x	x				
				4978	x	x				
							4977		x	
							4970		x	
June 12				4991	x	x				Mackenzie Bay partly clear
				4992	x	x				coastline partly clear
							4992		x	
June 13				5005	x	x				
				5006	x	x				Mackenzie Bay partly clear
							5295		x	

DATE	LANDSAT IMAGERY			LARGE FIELD IMAGES						REMARKS
	SCENE ID	MSS	RBV	NOAA			DMSP			
		Path/Row	Path/Row	Pass	IR	Visual	Pass	IR	Visual	
June 14				5020	x	x				
				5021	x	x				
June 15				5034	x	x				clear
				5035	x	x				clear
June 16				5048	x	x				partly clear
				5049	x	x				Barrow to Flaxman clear
June 17				5062	x	x				small amount visible
				5063	x	x				Barrow, Mackenzie clear
June 18				5077	x	x				clear
June 19				5091		x				
				5092	x	x				partly clear
June 20				5105	x	x				
				5106	x	x				
June 21				5119	x	x				
				5120	x	x				
				5127		x				
							5120		x	
June 22				5133	x	x				
				5134	x	x				
				5135	x	x				
June 23				5148	x	x				
				5149	x	x				
June 24				5162	x	x				
				5163	x	x				
June 25				5176	x	x				
				5177	x	x				Barrow to Mackenzie Bay clear
June 26				5190	x	x				
				5191	x	x				Barrow to Mackenzie Bay/ mostly clear
June 27				5205	x	x				Barrow to Mackenzie Bay/ Mostly clear
June 28				5219	x	x				
				5220	x	x				
							5508		x	
June 29				5233	x	x				Mackenzie Bay clear
				5234	x	x				to Mackenzie, mostly clear
June 30				5247	x	x				Mackenzie Bay, partly clear
				5248	x	x				partly clear

DATE	LANDSAT IMAGERY SCENE ID	MSS Path/Row	RBV Path/Row	LARGE FIELD IMAGES NOAA Pass	NOAA IR	NOAA Visual	DMSP Pass	DMSP IR	DMSP Visual	REMARKS
July 1	30849 210819		82/9C							cloudy
	30849 210822		82/9D							cloudy
	30849 210831		82/10A							scattered clouds
	30849 210835		82/10B							scattered clouds
	30849 210844		82/10C							scattered clouds
				5261	x	x				
				5262	x	x				Barrow to Mackenzie clear
							5263		x	
	21987 20231	73/8								scattered clouds
	21987 20233	73/9								scattered clouds
	21987 20235	73/10								clear
July 2	30850 211426		83/10C							cloudy
	30850 211429		83/10D							cloudy
	21988 20292	74/9								clear
	21988 20294	74/10								clear
	21988 20301	74/11								clear
	21988 04502	145/234*								scattered clouds
	21988 04504	145/235*								clear
	21988 04511	145/236*								clear
				5275	x					
				5276	x	x				Mackenzie Bay mostly clear
				5277	x	x				
July 3	21989 20344	75/8								clear
	21989 20350	75/9								cloudy
	21989 20353	75/10								cloudy
				5290	x	x				partly clear
				5291	x	x				partly clear

(*)denotes northbound night pass

DATE	LANDSAT IMAGERY			LARGE FIELD IMAGES						REMARKS
	SCENE ID	MSS	RBV	NOAA			DMSP			
		Path/Row	Path/Row	Pass	IR	Visual	Pass	IR	Visual	
July 4	21990 05021	147/235*								cloudy
	21990 05024	147/236*								cloudy
	21990 20402	76/8								clear
	21990 20405	76/9								scattered clouds
	21990 20411	76/10								scattered clouds
				5304	x	x				
				5305	x	x				
July 5	21991 20461	77/8								clear
	21991 20463	77/9								cloudy
	21991 20470	77/10								scattered clouds
	30853 213109		86/9D							cloudy
				5319	x	x				mostly cloudy
				5320	x	x				
July 6	21992 20515	78/8								cloudy
	21992 20522	78/9								cloudy
	21993 20583	78/10								clear
				5332	x	x				
				5333	x	x				mostly cloudy
				5334	x	x				
July 7	21993 20574	79/8								cloudy
	21993 20580	79/9								cloudy
	21993 20583	79/10								clear
				5347	x	x				
				5348	x	x				
July 8	21994 21032	80/8								cloudy
	21994 21041	80/10								cloudy
				5361	x	x				
				5362	x	x				partly clear

(*) denotes northbound night pass

DATE	LANDSAT IMAGERY SCENE ID	MSS Path/Row	RBV Path/Row	LARGE FIELD IMAGES NOAA Pass	IR	Visual	DMSP Pass	IR	Visual	REMARKS
July 9				5375	x	x				
				5376	x	x				Mostly clear
July 10	21996 21150	82/8								cloudy
	21996 21152	82/9								cloudy
	21996 21155	82/10								cloudy
				5390	x	x				
				5391	x	x				partly clear
July 11	21997 21211	83/9								scattered clouds
	21997 21213	83/10								scattered clouds
				5404	x	x				
				5405	x	x				
							5692		x	
July 12	30860 202703		75/8A							cloudy
	30860 202706		75/8B							clear
	30860 202715		75/8C							cloudy
	30860 202719		75/8D							clear
	30860 202731		75/9B							clear
	30860 202744		75/9D							scattered clouds
				5418	x	x				
				5419	x	x				
July 13				5432	x	x				
				5433	x	x				
July 14				5447	x	x				
							5447		x	
July 15										
	22001 21434	87/8								cloudy
				5460	x	x				
				5461	x	x				
				5462	x	x				

DATE	LANDSAT IMAGERY			LARGE FIELD IMAGES						REMARKS
	SCENE ID	MSS	RBV	NOAA			DMSP			
		Path/Row	Path/Row	Pass	IR/Visual		Pass	IR/Visual		
July 16	30864 205031		79/9A							cloudy
	30864 205031		79/9B							cloudy
	30864 205052		79/10A							scattered clouds
	30864 205056		79/10B							clear
	30864 205428		79/18D							scattered clouds
	30864 205437		79/19A							cloudy
				5475	x	x				partly clear
				5476	x	x				partly clear
July 17	30865 205609		80/9A							cloudy
	30865 205613		80/9B							clear
	30865 205622		80/9C							clear
	30865 205625		80/9D							clear
	30865 205634		80/10A							scattered clouds
	30865 205638		80/10B							clear
				5489	x	x				partly clear
				5490	x	x				partly clear
							5778		x	
July 18	30866 20121	81/10								scattered clouds
	30866 210206		81/10B							scattered clouds
	30866 210215		81/10C							scattered clouds
	30866 210219		81/10D							scattered clouds
				5504	x	x				
				5505	x	x				
July 19	30867 210810		82/10C							scattered clouds
	30867 210813		82/10D							scattered clouds
	30867 210822		82/11A							scattered clouds
	30867 210826		82/11B							scattered clouds
	30867 210835		82/11C							clear
	30867 210838		82/11D							clear

DATE	LANDSAT IMAGERY SCENE ID	MSS Path/Row	RBV Path/Row	LARGE FIELD IMAGES NOAA Pass	NOAA IR	NOAA Visual	DMSP Pass	DMSP IR	DMSP Visual	REMARKS
June 19				5518	x	x				
				5519	x	x				
July 20				5532	x	x				
				5533	x	x				
July 21	30869 211858		84/9D							cloudy
	30869 211910		84/10B							cloudy
	22007 20350	75/8								scattered clouds
	22007 20352	75/9								clear
	22007 20355	75/10								scattered clouds
	22007 20361	75/11								scattered clouds
				5547	x	x				
July 22	22008 05021	147/234*								scattered clouds
	22008 05023	147/235*								scattered clouds
	22008 05030	147/236*								scattered clouds
				5561	x	x				
July 23	22010 20530	78/10								cloudy
	22010 20533.	78/11								clear
	30871 213018		86/9C							cloudy
	30871 213022		86/9D							scattered clouds
	30871 213031		86/10A							cloudy
	30871 213034		86/10B							clear
	22010 05134	149/234*								cloudy
	22010 05140	149/235*								scattered clouds
	22010 05143	149/236*								cloudy
				5575	x	x				
July 24				5589	x	x				
July 25				5603	x	x				
				5604	x	x				
July 26				5617	x	x				
				5618	x	x				
							5909		x	
July 27	22013 21093	81/8								scattered clouds
	22013 21095	81/9								scattered clouds
				5632	x	x				

(*)denotes northbound night pass

DATE	LANDSAT IMAGERY SCENE ID	MSS Path/Row	RBV Path/Row	LARGE FIELD IMAGES NOAA Pass	NOAA IR	NOAA Visual	DMSP Pass	DMSP IR	DMSP Visual	REMARKS
July 28				5646	x	x				
				5647		x				
July 29	22015 21212	83/9								cloudy
				5660	x	x				
				5661	x	x				
July 30	22016 21264	84/8								clear
	22016 21271	84/9								scattered clouds
				5675	x	x				
July 31	22017 21323	85/8								scattered clouds
	22017 21325	85/9								cloudy
	22017 21332	85/10								cloudy
				5689	x	x				
August 1	22018 21381	86/8								scattered clouds
	22018 21390	86/10								cloudy
	22018 21393	86/11								clear
				5703	x	x				
August 2	22019 21440	87/8								cloudy
	22019 21442	87/9								cloudy
	22019 21445	87/10								cloudy
				5717	x	x				partly clear
				5718	x	x				
August 3	30882 204939		79/9D							cloudy
				5731	x	x				
				5732	x	x				
August 4				5745	x	x				
				5746	x	x				
August 5	30884 250059		81/9C							scattered clouds
	30884 210111		81/10A							scattered clouds
	30884 210115		81/10B							scattered clouds
				5759	x	x				
				5760	x	x				
							6048		x	
August 6				5773	x	x				
				5774	x	x				

DATE	LANDSAT IMAGERY			LARGE FIELD IMAGES						REMARKS
	SCENE ID	MSS	RBV	NOAA			DMSP			
		Path/Row	Path/Row	Pass	IR/Visual		Pass	IR/Visual		
August 7	22024 04511	145/235*								clear
				5788	x	x				
				5789	x	x				
							5559		x	
August 8	22025 04563	146/234*								scattered clouds
	22025 04570	146/235*								scattered clouds
				5803	x	x				
August 9				5817	x	x				
August 10				5831	x	x				
August 11				5845	x	x				
				5846	x	x				
August 12				5859	x	x				
				5860	x	x				
August 13	22030 21040	80/8								cloudy
	22030 05255	151/236*								scattered clouds
				5873	x	x				
				5874	x	x				
August 14				5887	x	x				
				5888	x	x				
August 15	22032 21153	82/8								scattered clouds
	22032 21155	82/9								cloudy
	22032 21162	82/10								cloudy
	22032 05372	153/235*								cloudy
				5901	x	x				
				5902	x	x				
				5903		x				
August 16	22033 21211	83/8								cloudy
	22033 21213	83/9								cloudy
				5916	x	x				
				5917	x	x				
							5902		x	
August 17				5930	x	x				
				5931	x	x				
August 18				5945	x	x				
		(*)denotes northbound night pass								

DATE	LANDSAT IMAGERY SCENE ID	MSS Path/Row	RBV Path/Row	LARGE FIELD IMAGES NOAA Pass	NOAA IR	NOAA Visual	DMSP Pass	DMSP IR	DMSP Visual	REMARKS
August 19	30898 20375	77/10								clear/partial
	22036 21382	86/8								cloudy
	22036 21385	86/9								cloudy
	22036 21391	86/10								scattered clouds
	22036 21394	86/11								scattered clouds
				5959	x	x				
				5960	x	x				
August 20	30899 20432	78/10								clear/partial
				5973	x	x				partly clear
				5974	x	x				
							5944		x	
							5973		x	
August 21	30900 204841		79/9C							cloudy
	30900 204844		79/9D							scattered clouds
	30900 20490	79/10								clear
	30900 204853		79/10A							cloudy
	30900 204857		79/10B							cloudy
	30900 204906		79/10C							cloudy
	30900 204909		79/10D							scattered clouds
				5987	x	x				
				5988	x	x				
							5987		x	
August 22	30901 245427		80/9C							scattered clouds
	30901 205430		80/9D							clear
	30901 21544	80/10								cloudy
	30901 205433		80/10A							scattered clouds
	30901 205443		80/10B							scattered clouds
	30901 205352		80/10C							scattered clouds
	30901 205455		80/10D							scattered clouds
				6001	x	x				
				6002	x	x				
							6001		x	
August 23	30902 21003	81/10								clear
	30902 210011		81/9C							clear
	30902 210014		81/9D							clear
	30902 210023		81/10A							scattered clouds

DATE	LANDSAT IMAGERY SCENE ID	MSS Path/Row	RBV Path/Row	LARGE FIELD IMAGES NOAA Pass	NOAA IR	NOAA Visual	DMSP Pass	DMSP IR	DMSP Visual	REMARKS
August 23	30902 210027		81/10B							scattered clouds
	30902 210039		81/10D							scattered clouds
				6015	x	x				
				6016	x	x				partly clear
							6015		x	
August 24				6030	x	x				
August 25				6044	x	x				
				6045	x	x				
August 26				6058	x	x				
				6059	x	x				
							6058		x	
August 27				6073	x	x				
August 28				6087	x	x				
August 29				6101	x	x				
				6102	x	x				
August 30				6115	x	x				
				6116	x	x				
September 1				6143	x	x				
				6144	x	x				
September 2				6157	x	x				
				6158	x	x				
September 3				6172	x	x				partly cloudy
				6173	x	x				partly cloudy
September 4				6186	x	x				Mackenzie Bay partly clear
				6187	x	x				
September 5				6201	x	x				
September 6				6215	x	x				
September 7				6229	x	x				
				6230	x	x				
September 8				6243	x	x				
				6244	x	x				
September 9				6257	x	x				

DATE	LANDSAT IMAGERY SCENE ID	MSS Path/Row	RBV Path/Row	LARGE FIELD IMAGES NOAA Pass	NOAA IR	NOAA Visual	DMSP Pass	DMSP IR	DMSP Visual	REMARKS
September 10				6271	x	x				
				6272	x	x				
September 11				6286	x	x				
				6287	x	x				
September 12				6301	x	x				
September 13				6314	x	x				
				6315	x	x				
September 14				6329	x	x				
September 15				6343	x	x				
				6344	x	x				
September 16				6357	x	x				
September 17				6371	x	x				
				6372	x	x				
September 18				6385	x	x				
				6386	x	x				
September 19				6399	x	x				
				6400	x	x				
	22067 21095	81/8								cloudy
	22067 21102	81/9								partly cloudy
September 20	22068 21160	82/9								clear
				6414	x	x				
				6415	x	x				
September 21	22069 21212	83/8								cloudy
	22069 21215	83/9								clear
	22069 21221	83/10								cloudy
				6427		x				
				6428	x	x				
				6429	x	x				
September 22				6442	x	x				
				6443	x	x				
September 23				6457	x	x				
September 24				6471	x	x				
September 25	30935 20422	78/10								clear/partial
				6485	x	x				
				6486	x	x				
September 26				6499	x	x				
				6500	x	x				

DATE	LANDSAT IMAGERY			LARGE FIELD IMAGES						REMARKS
	SCENE ID	MSS	RBV	NOAA			DMSP			
		Path/Row	Path/Row	Pass	IR/Visual		Pass	IR/Visual		
September 27				6513	x	x				
				6514	x	x				
September 28				6527	x	x				
				6528	x	x				
September 29				6541	x	x				
				6542	x	x				
September 30				6556	x	x				
				6557	x	x				

ICE DISPLACEMENT VECTORS

MEASURED IN NORTON SOUND AND

THE ADJACENT BERING SEA

1973 - 1979

BY

W. J. STRINGER AND R. D. HENZLER

GEOPHYSICAL INSTITUTE

UNIVERSITY OF ALASKA

FAIRBANKS, ALASKA

MARCH, 1981

PREPARED FOR NOAA-OCSEAP

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ABSTRACT

Twenty maps showing displacements of identifiable ice floes within Norton Sound and the adjacent Bering Sea are presented. These maps document ice motion during thirty-one 24-hour periods and six 18-day periods between 1973 and 1979. On several occasions individual floes could be tracked for two successive observation periods, making 48-hour and 36-day observation periods.

Three general modes of ice behavior within Norton Sound were observed: (in order of occurrence) outbound ice, inbound ice and gyre. Not only was the outbound ice mode observed most frequently, but the velocities during those periods appeared to be higher than during the inbound mode. Hence, the general trend is for a net transport of ice within Norton Sound to take place out of its entrance and into the Bering Sea.

A high degree of variability was observed: outbound ice velocities range as high as 30 km/day and inbound velocities over 10 km/day were measured. Two dramatic reversals within 48 hours took place with net velocity changes well over 10 km/day.

Often an abrupt transition between the Bering Sea and Norton Sound regimes is observed at the entrance to the sound, giving the appearance that the Bering Sea regime dominates the interaction between the two systems.

Introduction

This report has been prepared in order to aid in assessment of environmental impact occurring as a result of offshore petroleum development within Norton Sound, Alaska. Because spilled oil can become associated with ice in a variety of ways (Stringer and Weller, 1980) there is considerable interest in the residence time and trajectory of ice within, into and from Norton Sound. This report consists of a compendium of ice floe trajectories measured on Landsat images of the Norton Sound vicinity between 1973 and 1980 to aid in this assessment.

Landsat is a polar-orbiting satellite with an orbit determined to provide a 10% overlap between adjacent images at the equator. As a consequence of converging orbit paths with increasing latitude, the overlap at Norton Sound is sufficiently large that a given location on the earth's surface can be imaged on three successive days. Hence it is at least theoretically possible that trajectories representing up to 72 hours' motion may be measured.

Each Landsat repeats a given orbit every eighteen days, allowing the possibility of following ice floes over periods of that duration. During periods when two Landsats are operating, their orbit schedules are arranged such that a floe position could be measured every nine days.

Obviously the determination of floe trajectories depends not only on acquisition of largely cloud-free imagery, but also the ability to recognize particular floes from one image to the next. While this latter requirement does not impose many restrictions from one day to the next, it can be quite difficult to recognize particular floes on images eighteen days apart---even if one attempts to find the pieces of floes which have obviously broken up.

II. Estimated Errors of Measurement

The displacements reported here were measured by sequentially projecting successive Landsat multi-spectral (MSS) images on a transparent screen so that individual pieces of ice could be tracted. (The device used is called a "color-additive viewer" and is manufactured by I^2S, Inc.) The Landsat images were projected to 1:500,000 scale from 70 mm positive transparencies. Registration of images was provided by superimposing geographical features on the sequential Landsat images. Colvocoresses and McEwen (1973) have shown that the random distortions on a Landsat MSS image have an rms value on the order of 200 m. This is the average error to be expected from the instrumentation. However, the results reported here were based on a visual best fit of two projected images. At the scale used, 1:500,000, 1 km is 2 mm. Some transparencies appeared to superimpose uniformly over the whole Landsat image to well within 1 mm (500 m) while others would show appearent displacements of geographical features of 2 km on one side of a pair of images made to coincide on the opposite side. In these latter cases, a best average fit was obtained. Since the geographical features used are located on three sides of Norton Sound, this technique tended to minimize the errors in the center of the area of observation. The errors resulting from this latter systematic effect are estimated to be on the order of 1 km. Even though this latter errors would be systematic, it would not be easy to describe and correct. For instance, the averaging technique would probably result in displacement errors in a circular pattern with its center at some point within Norton Sound. Because of the difficulty of describing this systematic error, it should be considered a random error, or uncertainty.

This discussion has shown that the largest uncertainty in displacement values is on the order of 1 km and is made up of several components However, the consistency between adjacent displacements achieved on the maps presented here seem to indicate that random errors of measurements were at least less than or equal to 500 m.

III. Measured Ice Displacements

The following 20 figures display ice floe displacements measured within Norton Sound between 1973 and 1979. These maps are arranged with eighteen-day displacements (if any) measured for each year, followed by one-day displacements for that year. In cases where particular floes could be tracked for two consecutive intervals, their displacement vectors are joined. Eighteen-day displacements are labeled in terms of interval data while single day displacements are coded by thickness of the displacement vector with successively later days denoted by thicker vectors.

1973 Ice Displacements

Eighteen-day displacements were measured for three successive eighteen-day Landsat cycles between March 21 and May 13. Although no single floes were monitored over this entire period, several were monitored for two successive cycles. This is the longest period that ice motion could be monitored by means of observations of specific floes.

One day displacement maps for 1973 show motions for:

1) 18-19 March (37 displacements)

   19-20 March (46 displacements)

   20-21 March (69 displacements)

2) 7-8 April (86 displacements)

   8-9 April (32 displacements)

3) 24-25 April (79 displacements)

   25-26 April (133 displacements)

   26-27 April (48 displacements)

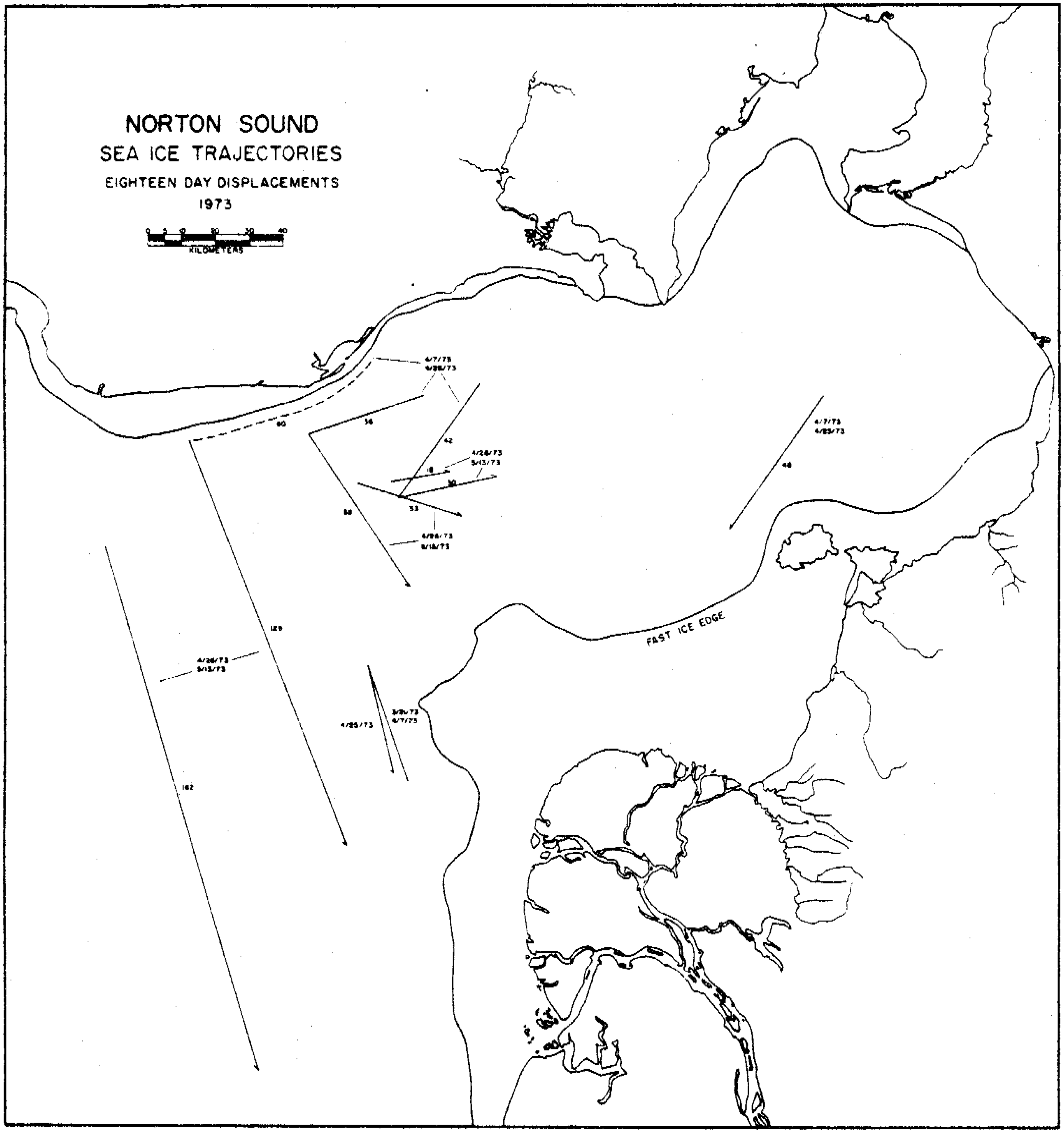


Figure 1 The data shown here span the period March 21 to May 13, 1973. Some ice motions seen here were not measured on any other occasions. Note the floe just off the Yukon Delta which originally moved north and then south. This long-time northward motion appears to be somewhat unusual for this time of year. Between April 26 and May 13 ice within Norton Sound not only remains but moves slightly to the inside of the sound. This is the only observation this far inside Norton Sound at dates this late in the year and may represent the motion of ice remaining in northern Norton Sound after other ice has been removed.

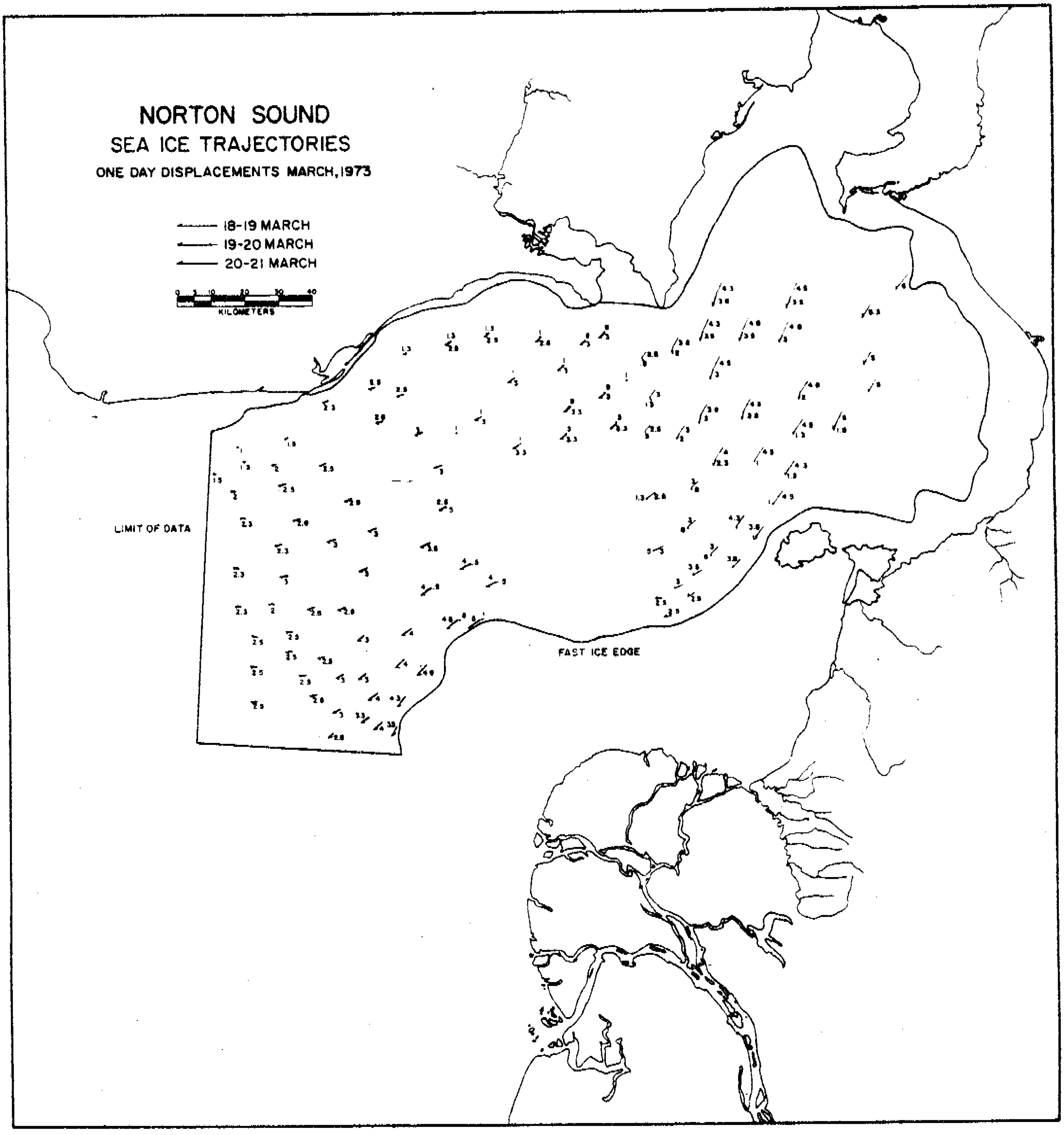


Figure 2 This map, derived from data obtained between March 18 and 21, 1973, shows a rather uniform displacement field throughout Norton Sound. The ice is generally outbound from the sound at rates between 1 and 5 km/day. Note that ice velocities are generally greater at the eastern end of the sound. This is possibly because the ice is thinner in that region and compaction as well as displacement can take place. It is interesting to observe that ice leaving Norton Sound appears to turn slightly northward.

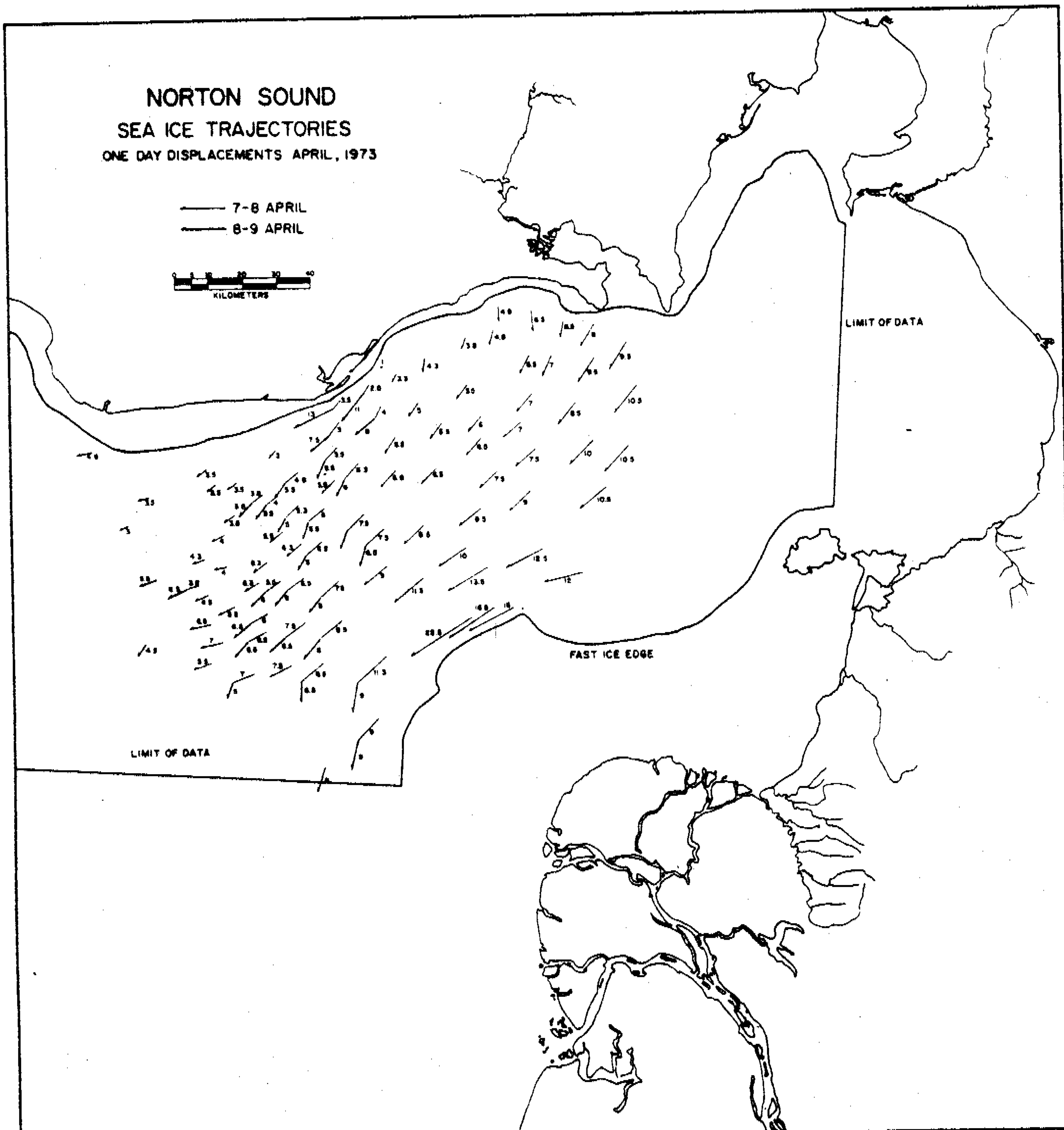


Figure 3 This map exhibits displacements measured between April 7 and 9 1973, in central and western Norton Sound. Ice motions on both days were outbound from the sound at speeds ranging from 3 to 22 km/day. The greatest speeds were observed just seaward of the fast ice edge located on the Yukon prodelta. There is a general decrease of displacement from east to west which is thought to result at least in part from compaction of the relatively thin ice in the eastern portion of the sound.

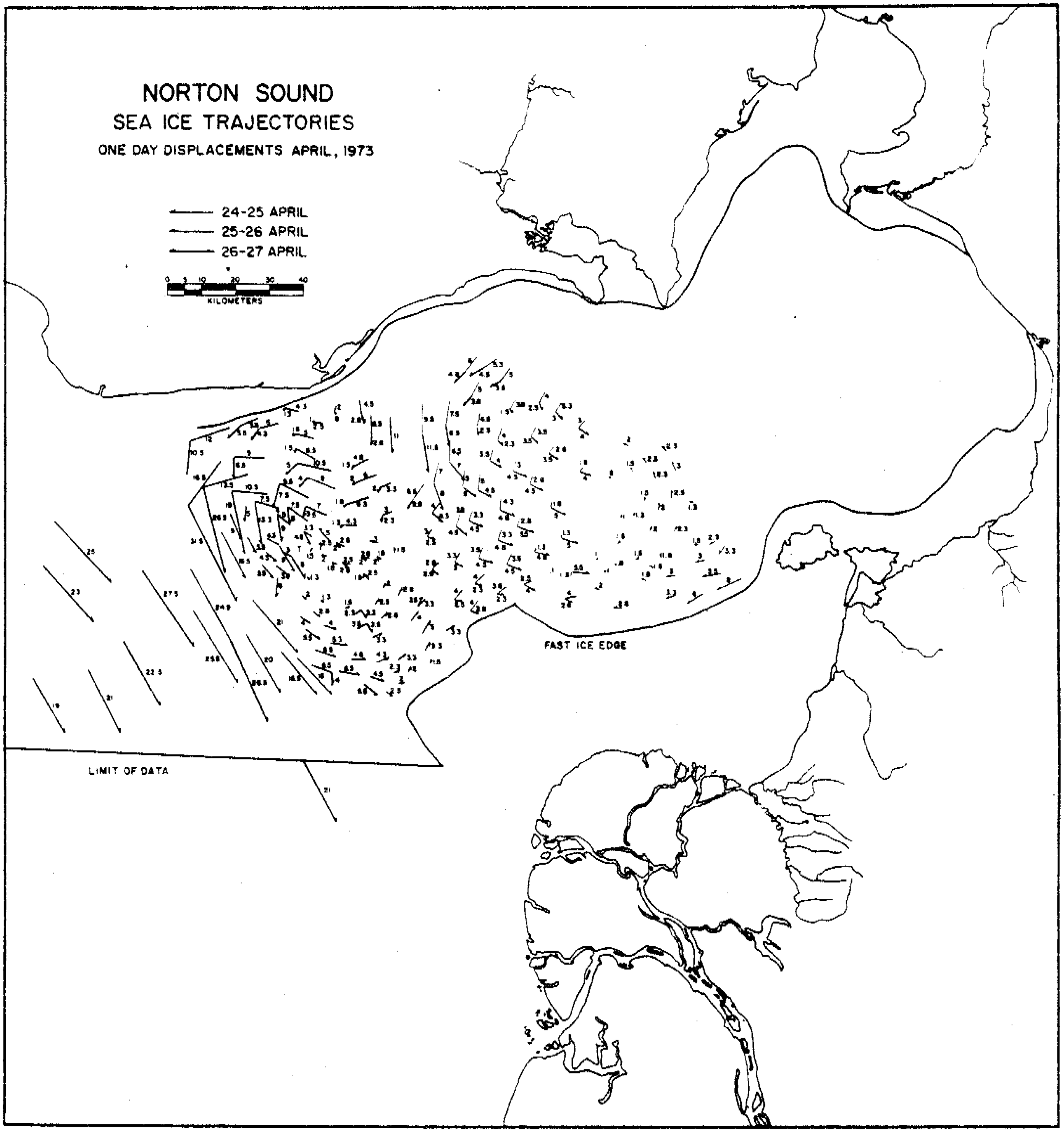


Figure 4 Shown here are Norton Sound ice displacements observed between April 24 and 27, 1973. During this period the ice appears to be participating in two counterclockwise (looking down) gyres. At the same time, the ice in the adjacent Bering Sea is streaming past the entrance to Norton Sound on a nearly due south heading at speeds ranging up to 27 km/day One piece of Norton Sound ice which has entered this stream from the top of the western gyre has a displacement of 31 km in one day.

1974 Ice Displacements

Eighteen-day displacements were measured for the period April 2 to April 21.

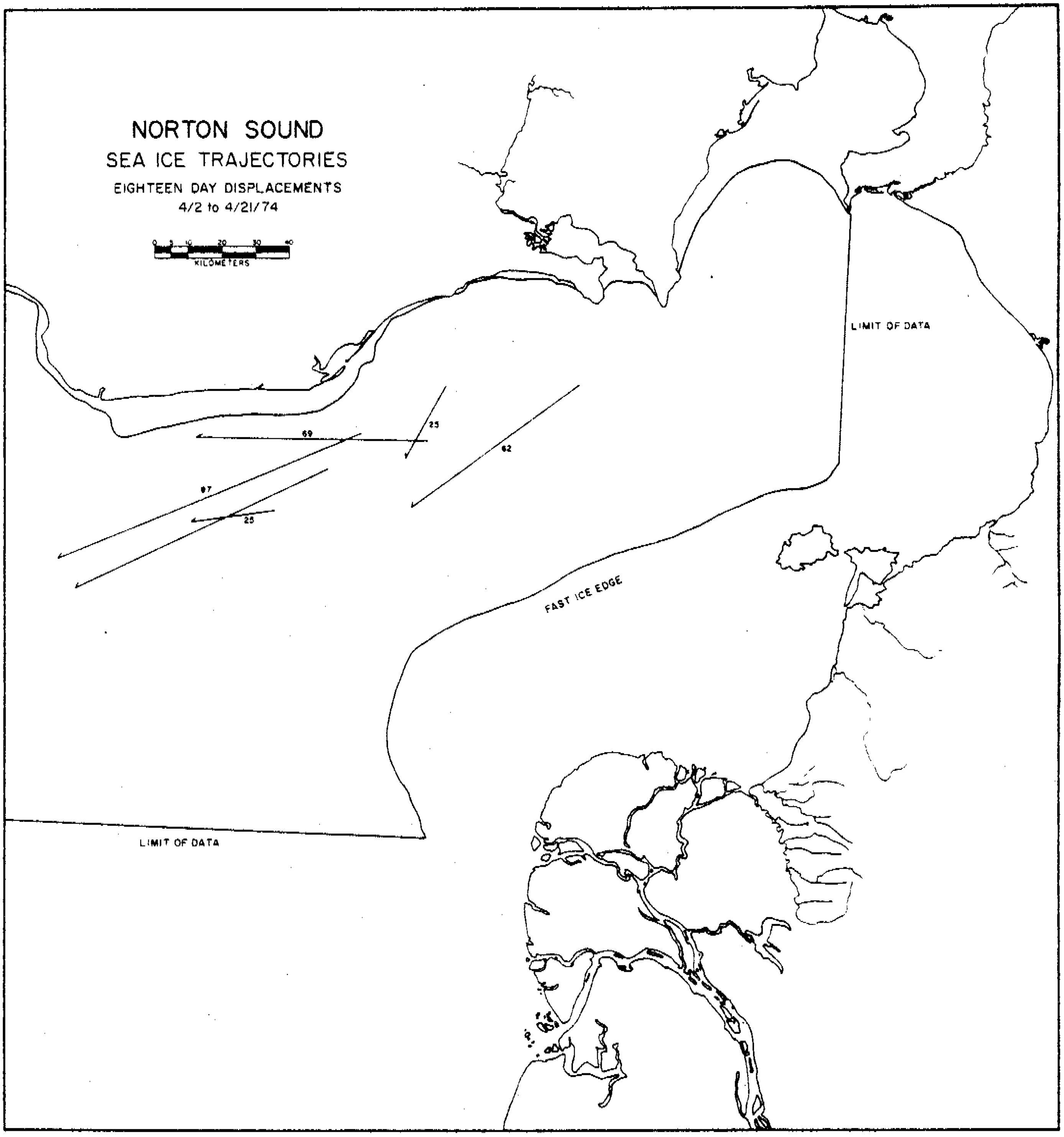
One-day displacements were measured for:

1) 8-9 February (39 displacements)

2) 14-15 March (42 displacements)

15-16 March (63 displacements)

3) 1-2 April (31 displacements)



<u>Figure 5</u> Eighteen-day displacements in 1974 were only measured between April 2 and 21. Note that these displacements do not form a uniform vector field as do the one-day displacements. Speeds of nearby floes vary significantly and tracks of floes cross. This behavior suggests that during the 18-day interval general behavioral patterns took place resulting in the displacement pattern seen here. Note that the largest displacement shown here, 97 km, corresponds to a daily speed of 5.4 km/day---not inconsistent with the range of daily displacements observed.

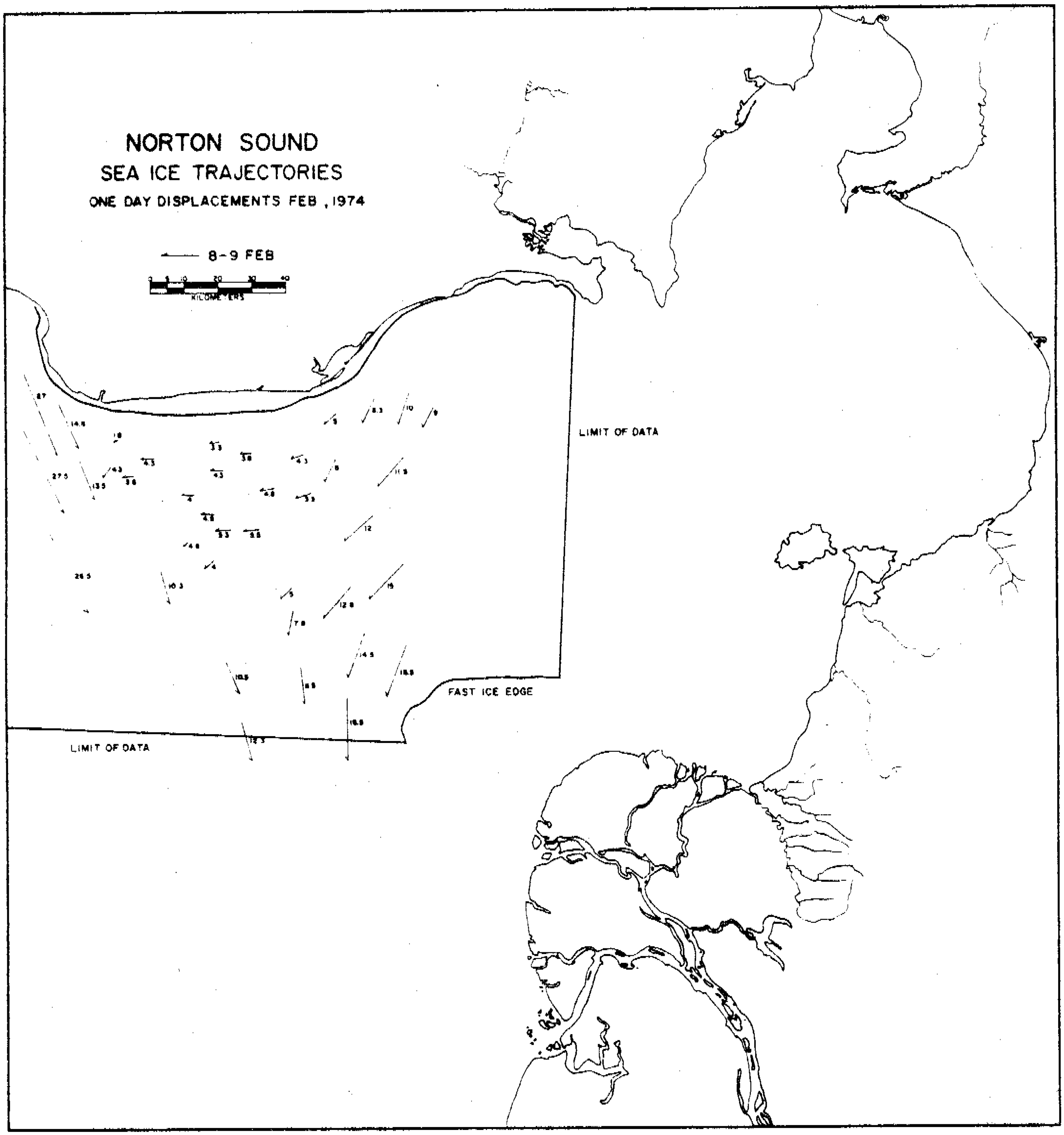


Figure 6 This map shows ice floe displacements in western Norton Sound measured between February 8 and 9, 1974. Although not forming a uniform vector field, ice is generally flowing out from Norton Sound. As is often the case when ice is outbound, the highest speeds are found just seaward of the fast ice boundary off the Yukon prodelta. Here these speeds are in the 16-18 km/day range. Bering Sea ice is moving past the entrance to Norton Sound at speeds on the order of 27 km/day.

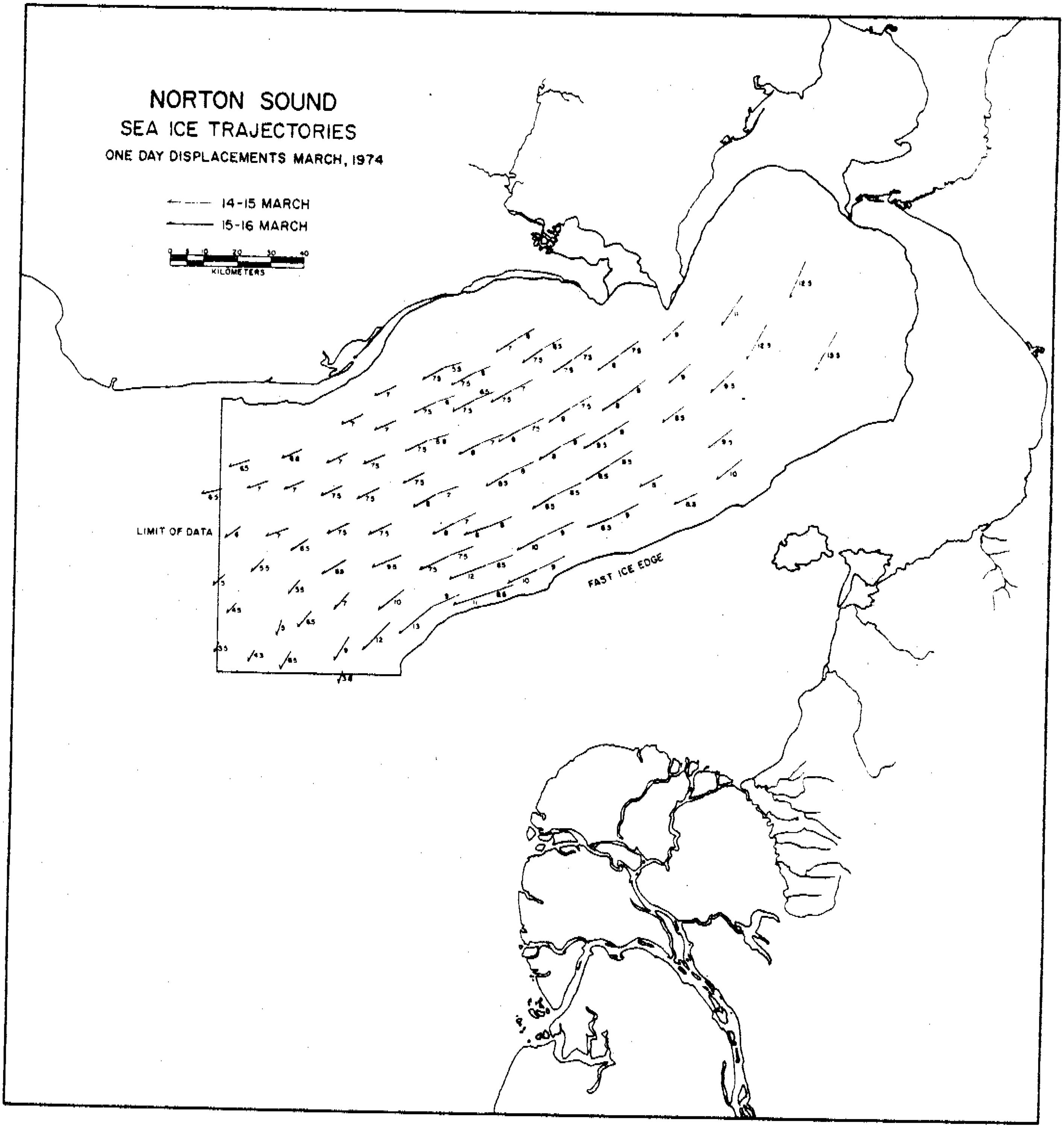


Figure 7 This map was derived from Landsat images obtained between March 14 and 16, 1974. Two-day displacements were measured for some floes in central Norton Sound. The generally constant values found for these floes from one day to the next suggest that the conditions mapped here were constant over the two-day period. Note that higher speeds are measured as the eastern end and southern side of the sound as is often the case when the ice displacements form a uniform vector field. Note also that displacements are smallest where the ice is turning to join the ice in the Bering Sea.

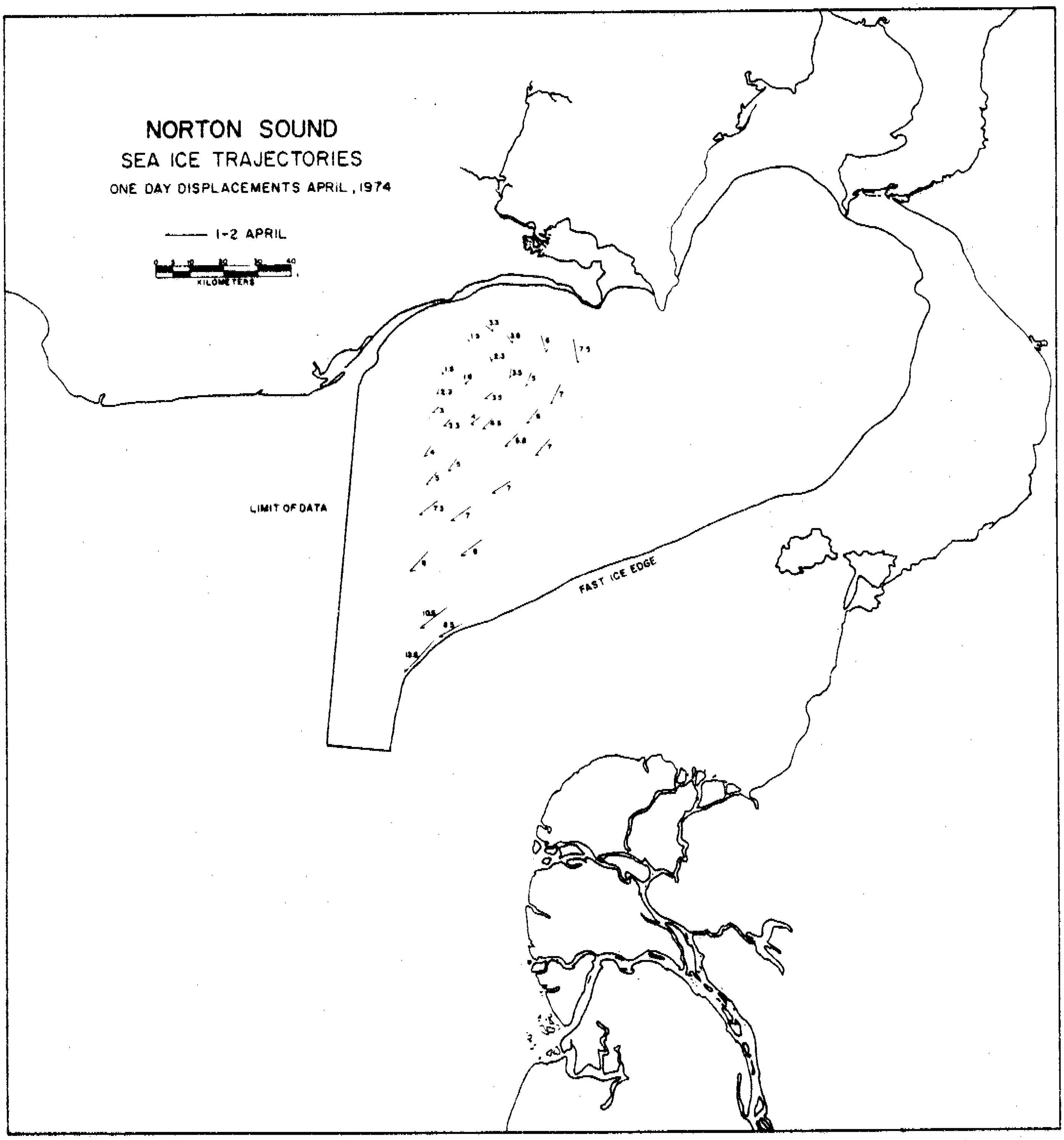


Figure 8 This map shows ice floe displacements measured between April 1 and 2, 1974. Although not many displacements were measured at least part of the general pattern seen on other maps is seen here again: The largest displacements are measured just seaward of the fast ice edge located on the Yukon River prodelta. Here these displacements are as great as 13 km/day.

1975 Ice Displacements

Eighteen-day displacements were measured for the period May 13 to May 31.

One-day displacements were measured for:

7-8 April (32 displacements)

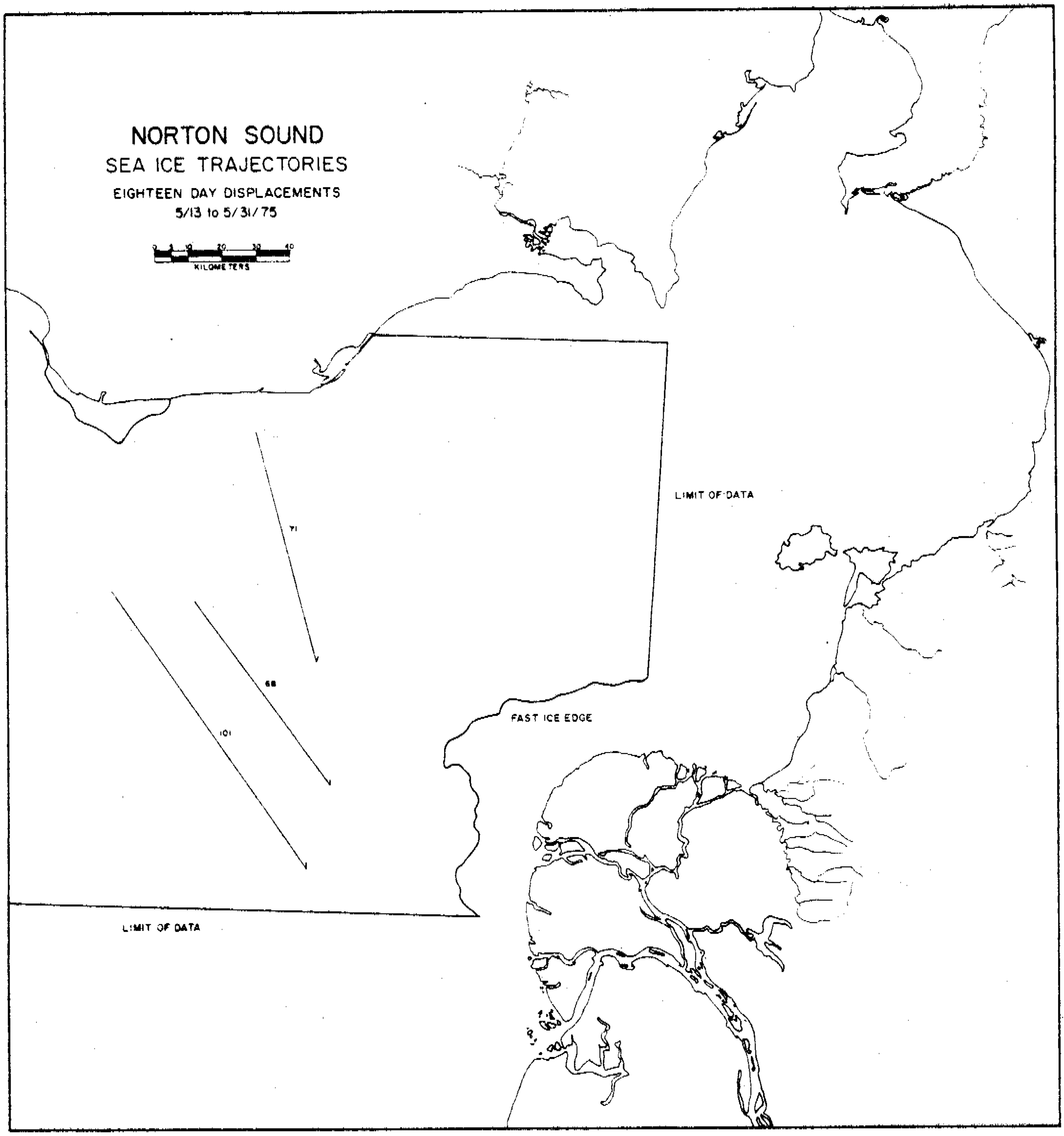


Figure 9 This map shows 18-day displacements measured between May 13 and May 31, 1975. The displacements shown here are generally outside Norton Sound and do not yield much information about motions of Norton Sound ice. However, they do show that ice can be southbound at these late dates, showing that the generally held concept that Bering Sea ice becomes northbound at this time of the year is not universally true.

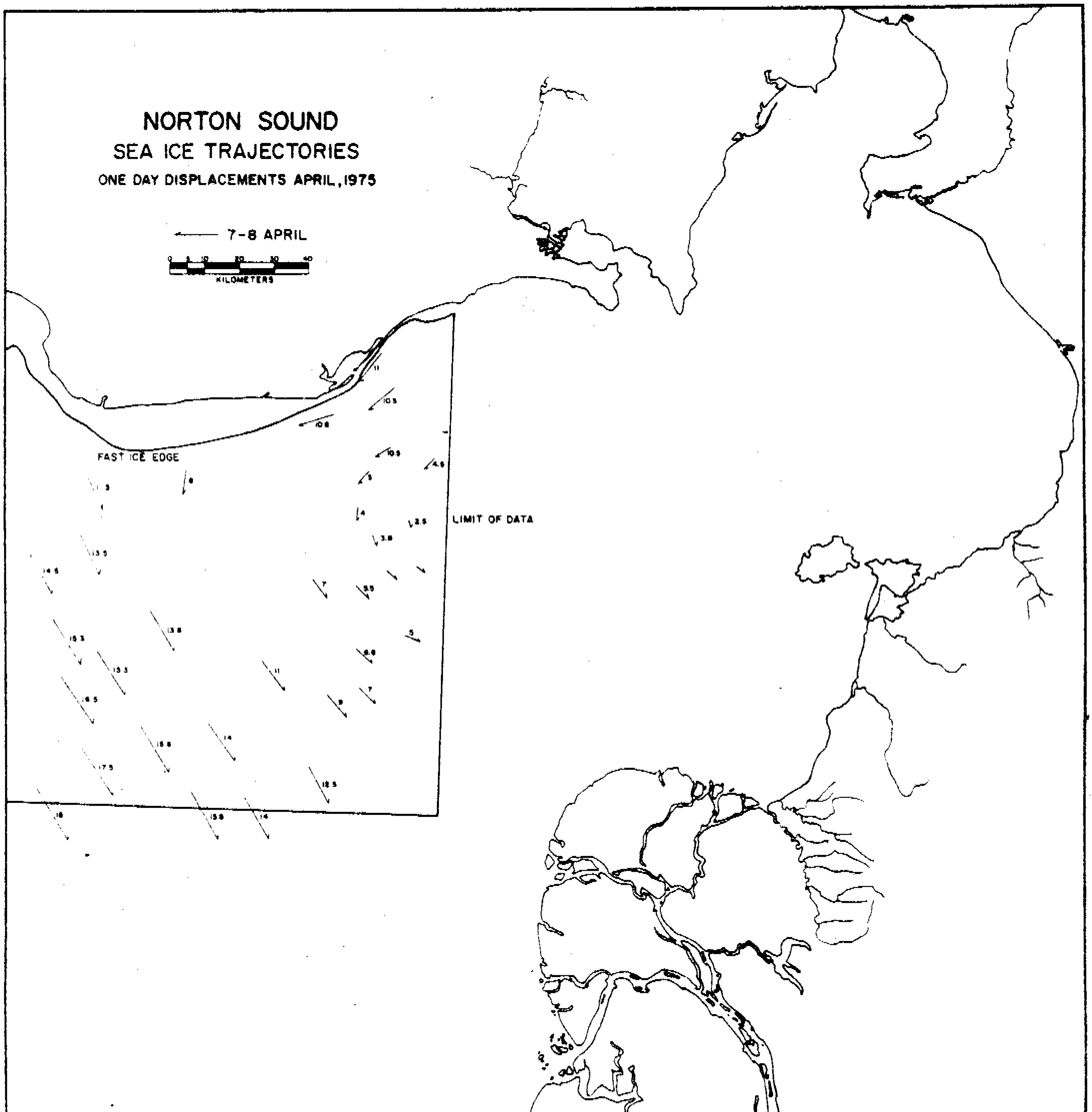


Figure 10 This map shows floe displacements in western Norton Sound and the adjacent Bering Sea. There is fairly strong evidence of a counterclockwise gyre of ice in Norton Sound. Bering Sea ice is moving past the entrance to Norton Sound with a heading azimuth nearly due south. The Bering Sea displacements are as great as 18 km/day. One has the impression that the Norton Sound gyre is driven by the Bering Sea ice moving past the entrance to the sound.

1976 Ice Displacements

No eighteen-day displacements were measured for this year.

One-day displacements were measured for:

1) 25-26 February (67 displacements)

2) 12-13 March (62 displacements)

   13-14 March (45 displacements)

   14-15 March (25 displacements)

3) 29-30 March (19 displacements)

   30-31 March (32 displacements)

4) 17-18 April (58 displacements)

   18-19 April (78 displacements)

   19-20 April (40 displacements)

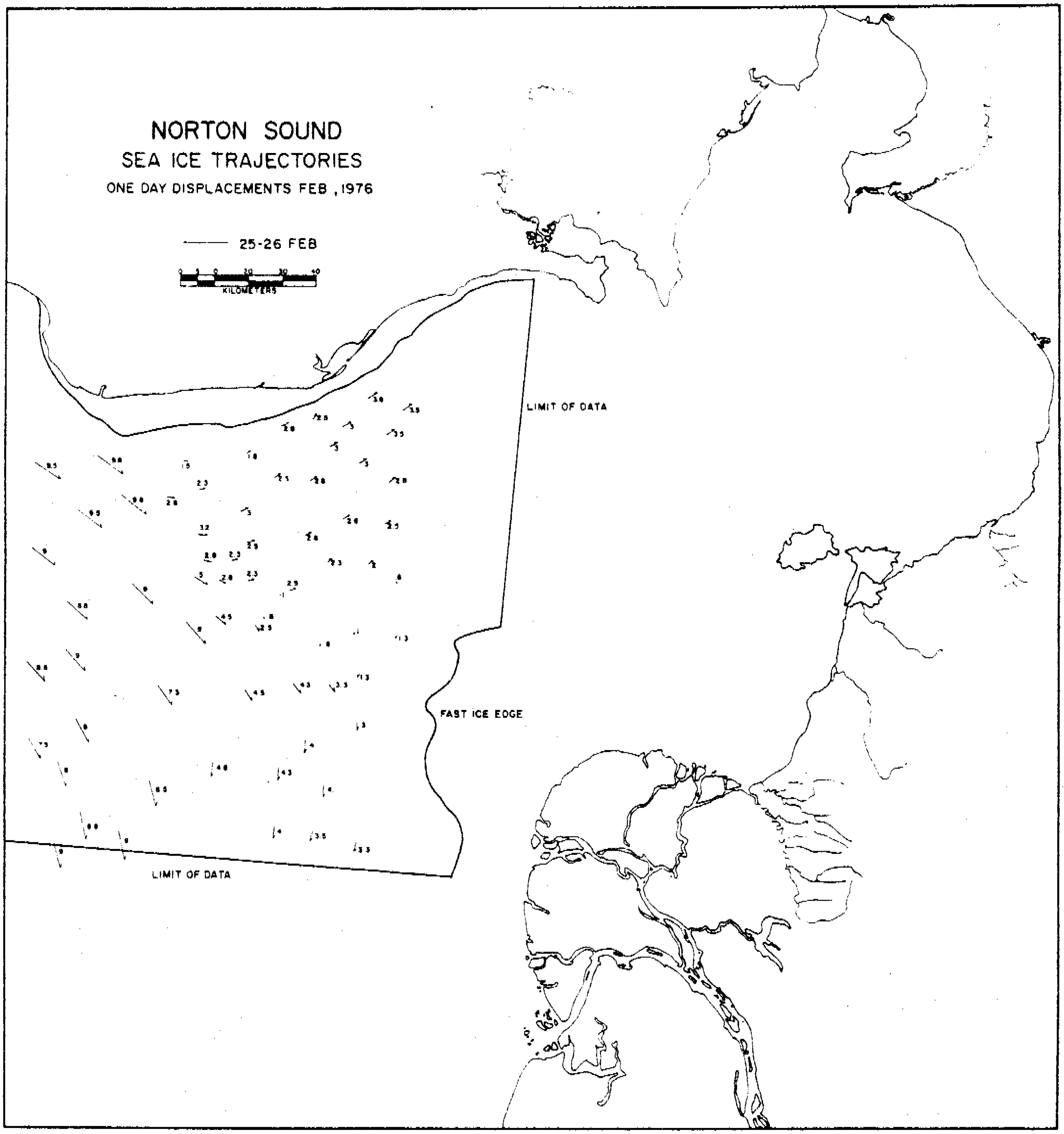


Figure 11 This map shows ice displacements in Norton Sound and the adjacent Bering Sea between Feb. 25 and 26, 1976. Here ice is generally being advected into Norton Sound and no gyre is taking place. Note that the Bering Sea ice heading angle is changing as it moves past the entrance to Norton Sound. This gives a greater impression of ice actually being pushed into Norton Sound than in the cases where the gyre was formed. In those cases the Bering Sea ice appeared to be merely moving past the entrance on a more or less constant heading.

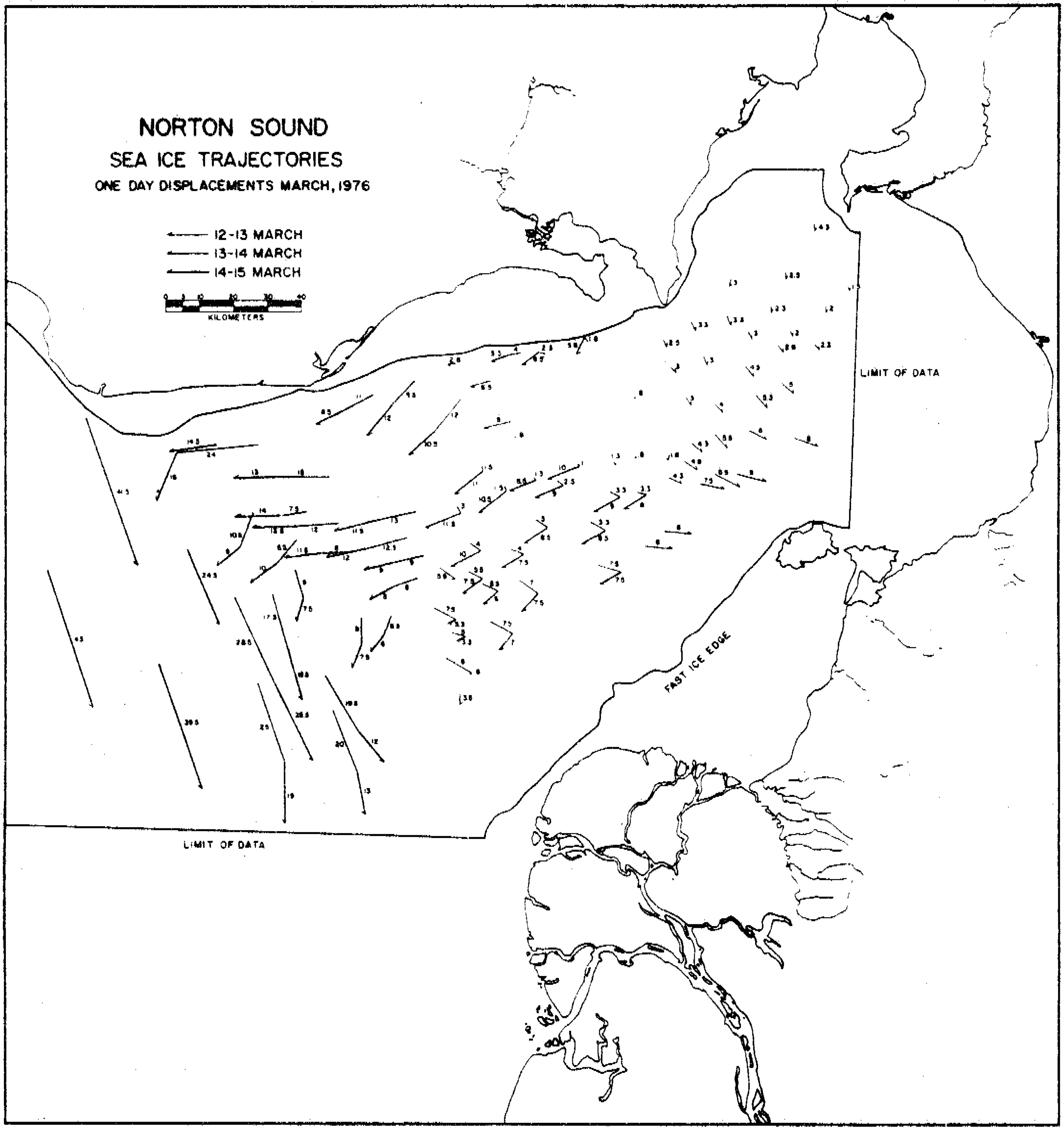


Figure 12 This map shows ice floe trajectories obtained between March 12 and 15, 1976. The situation shown appears somewhat confused: Apparently, between the 12th and 13th, ice in the eastern end of the sound was moving inward and the ice in the far eastern end was participating in a counterclockwise gyre. On the two subsequent days, ice within Norton Sound was outbound. It is interesting to note that between the first and second days some floes actually reversed the general inbound/outbound direction of their motion, traveling over 7 km each day in nearly opposite directions. Bering Sea ice was monitored only between the second and fourth days. The displacements measured were as great as 43 km/day. Note the abrupt transition between Norton Sound and Bering Sea displacements, both in terms of heading angles and displacements.

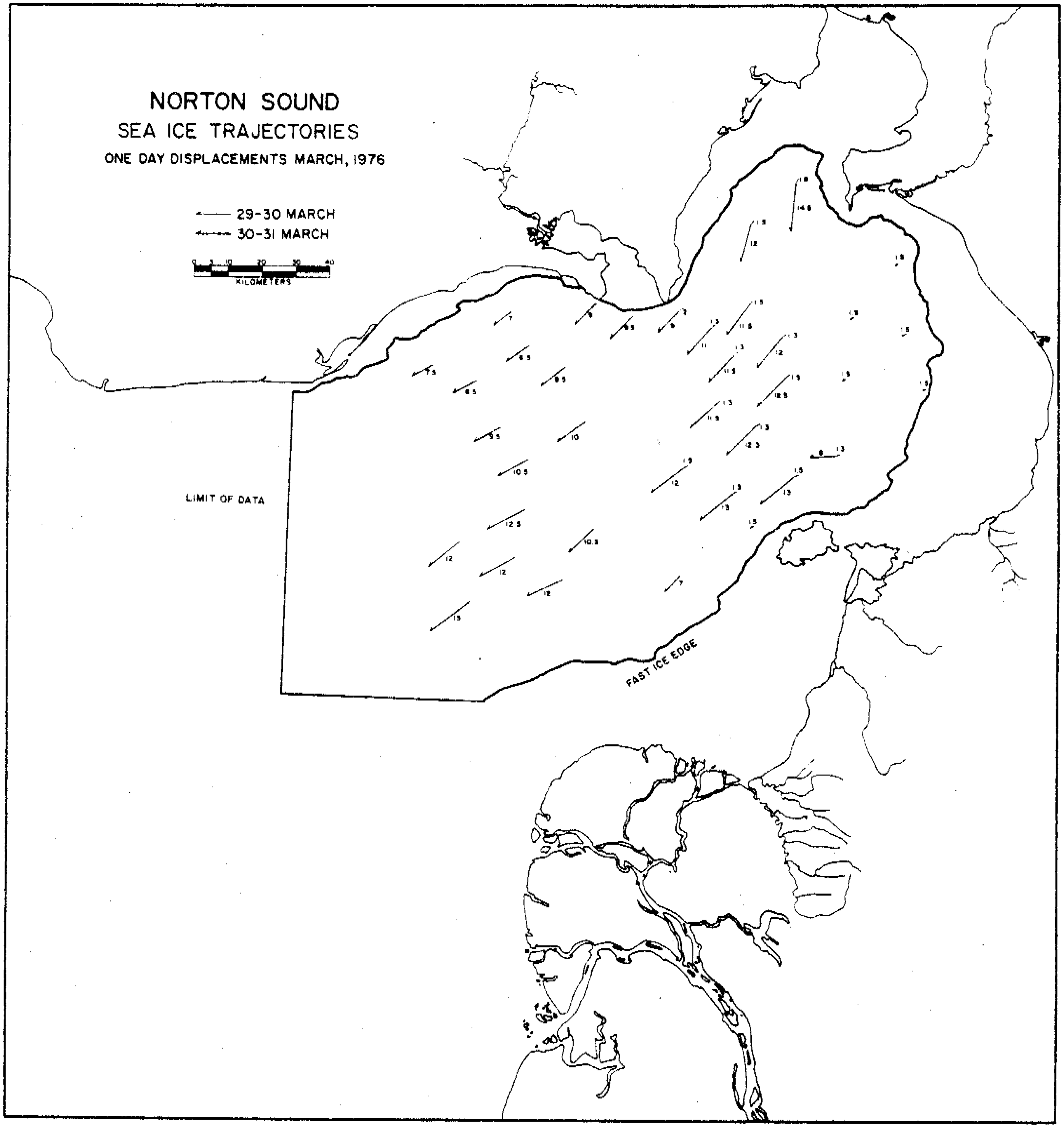


Figure 13 This map shows Norton Sound ice floe trajectories observed between March 29 and 31, 1976. In this case there was a considerable difference in displacements between the first and second days (on the order of a factor of ten) again showing the considerable degree of variation possible from one day to the next. However, in both cases, ice motions are generally outbound. On the second day displacements as great as 15 km were observed. Again as in other cases of general outbound ice motion the highest speeds were observed in the vicinity of the fast ice located off the Yukon River prodelta.

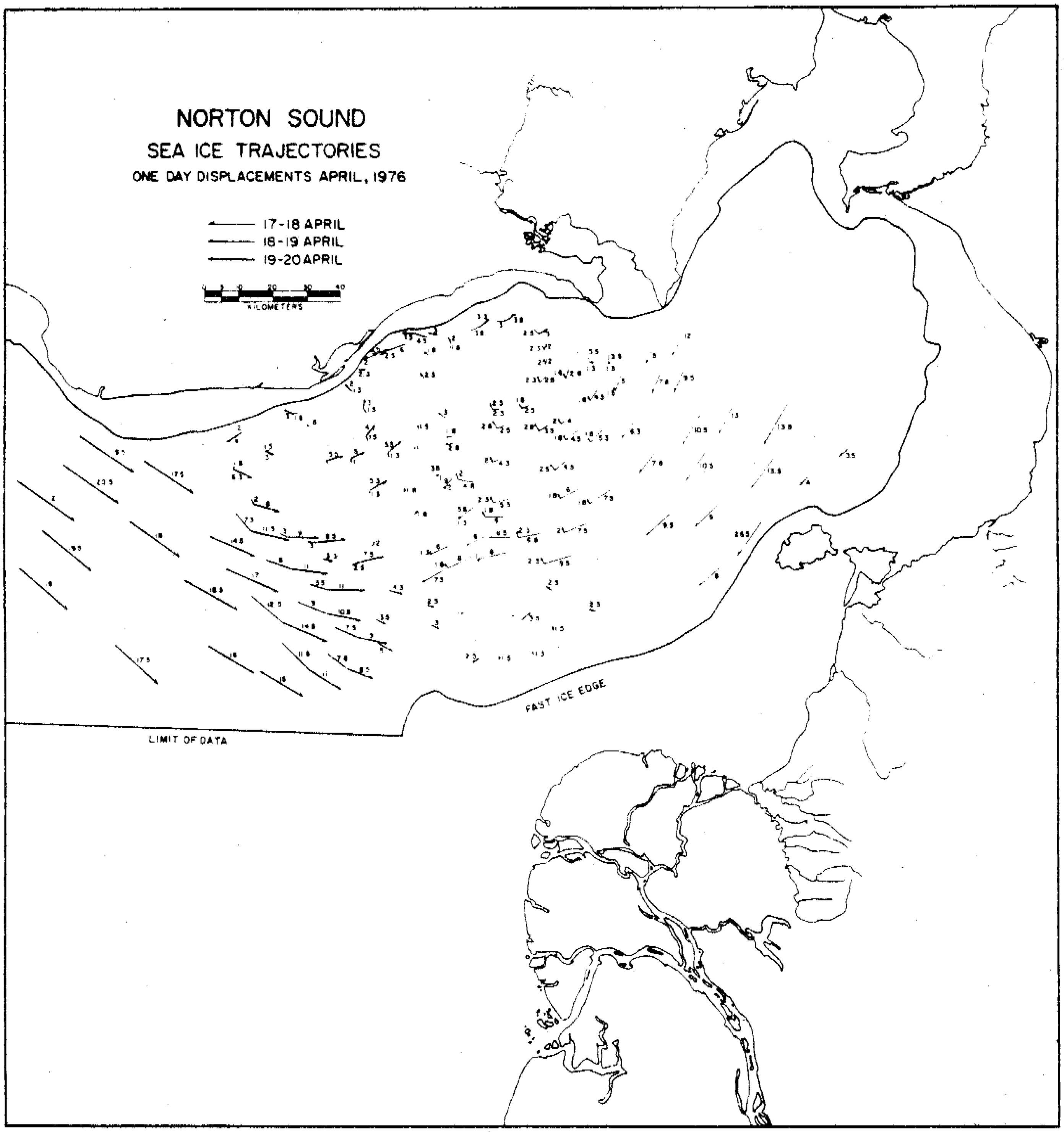


Figure 14 This map shows ice displacements observed between April 17 and 20, 1976. The ice motions seen here appear to illustrate a transition from ice following an outbound behavioral mode to an inbound mode. On the first pair of days ice in eastern end of Norton Sound was monitored. At that time the ice appeared to be flowing uniformly from Norton Sound. On the second day many floes appear to undertake an abrupt 90° turn to the north and undergo a small displacement in that direction. Most third day displacements observed within Norton Sound are directly into the sound. Bering Sea floe displacements are rather interesting. The ice appears to be driven into Norton Sound, being slowed down considerably in the process. Hence this occasion appears to show a direct confrontation between the Norton Sound and Bering Sea ice regimes.

1977 Ice Displacements

Eighteen-day displacements were measured for the period April 14 to May 2.

One-day displacements were measured for the periods:

1) 24-25 March (41 displacements)

   25-26 March (58 displacements)

2) 13-14 April (49 displacements)

   14-15 April (36 displacements)

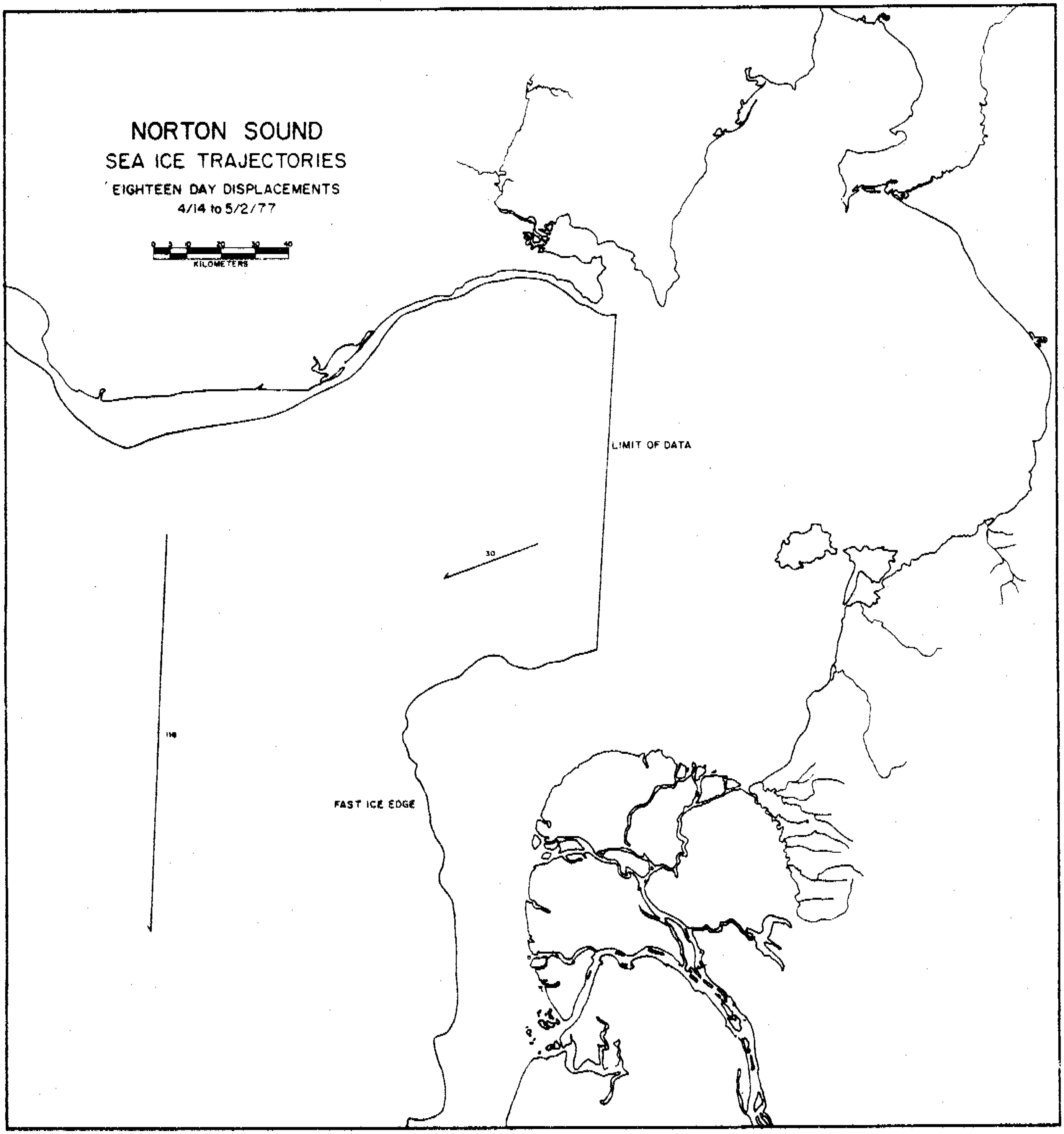


Figure 15 This map shows ice displacements measured between April 14 and May 2, 1977. Only two displacements were measured; one in Norton Sound, the other in the adjacent Bering Sea. The Norton Sound displacement corresponds to an average daily motion of less than 2 km/day and shows that Norton Sound ice can be rather stagnant at this time. Even the Bering Sea displacement measured during this time is rather small; an average of 6.5 km/day to the southwest.

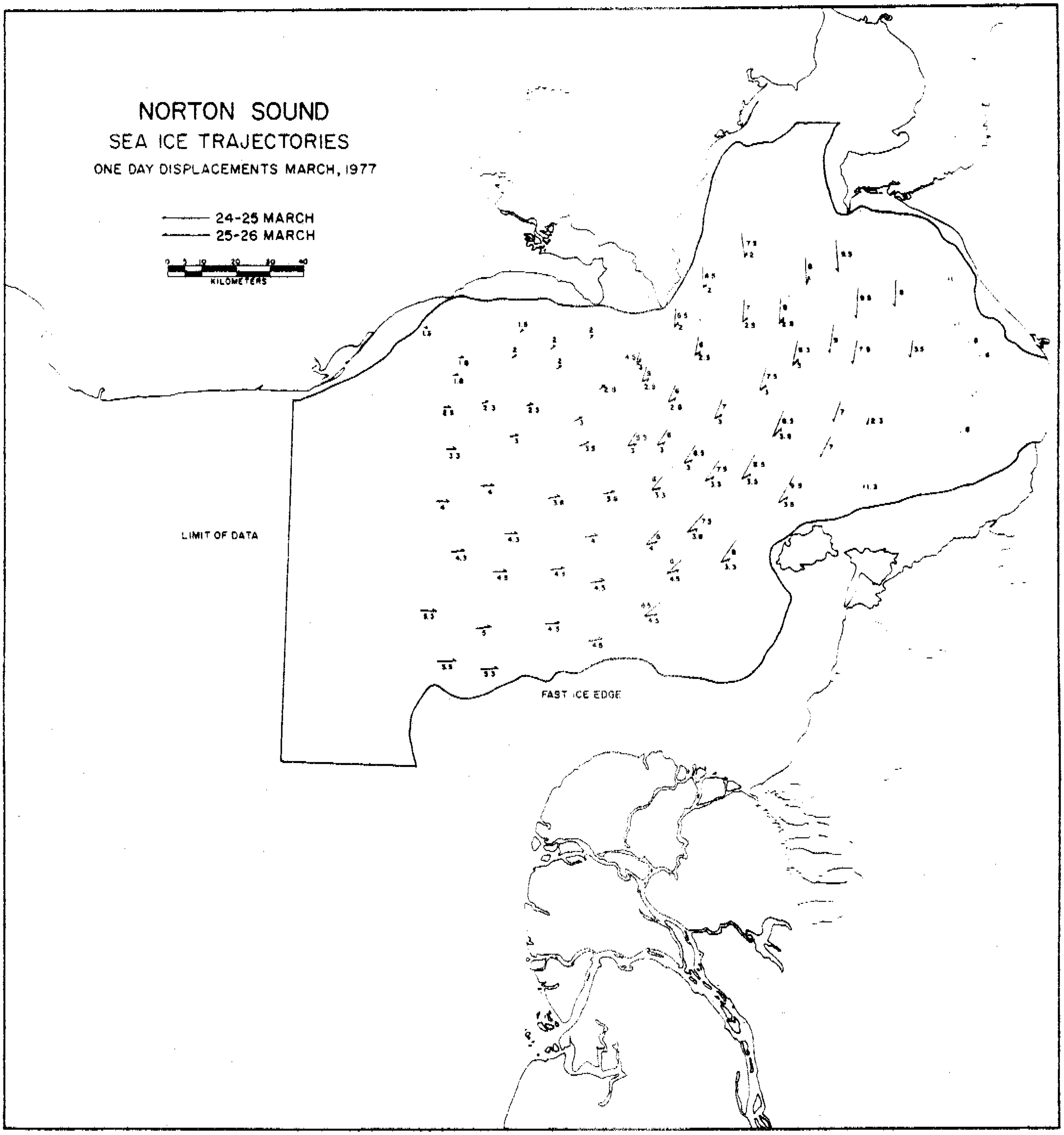


Figure 16 This map shows Norton Sound displacements measured between March 24 and 26, 1977. The motions shown here illustrate clearly the abrupt transition possible between the outbound and inbound modes of Norton Sound pack ice: on the first day, outbound ice motions on the order of 7–9 km were measured, while on the second day inbound ice displacements on the order of 3–5 km were measured. Floes monitored for two consecutive one-day intervals made an almost complete reversal from one day to the next. Note that just as the outbound velocities are greatest along the southern boundary of the Norton Sound pack ice, so are the inbound velocities there the greatest among those observed.

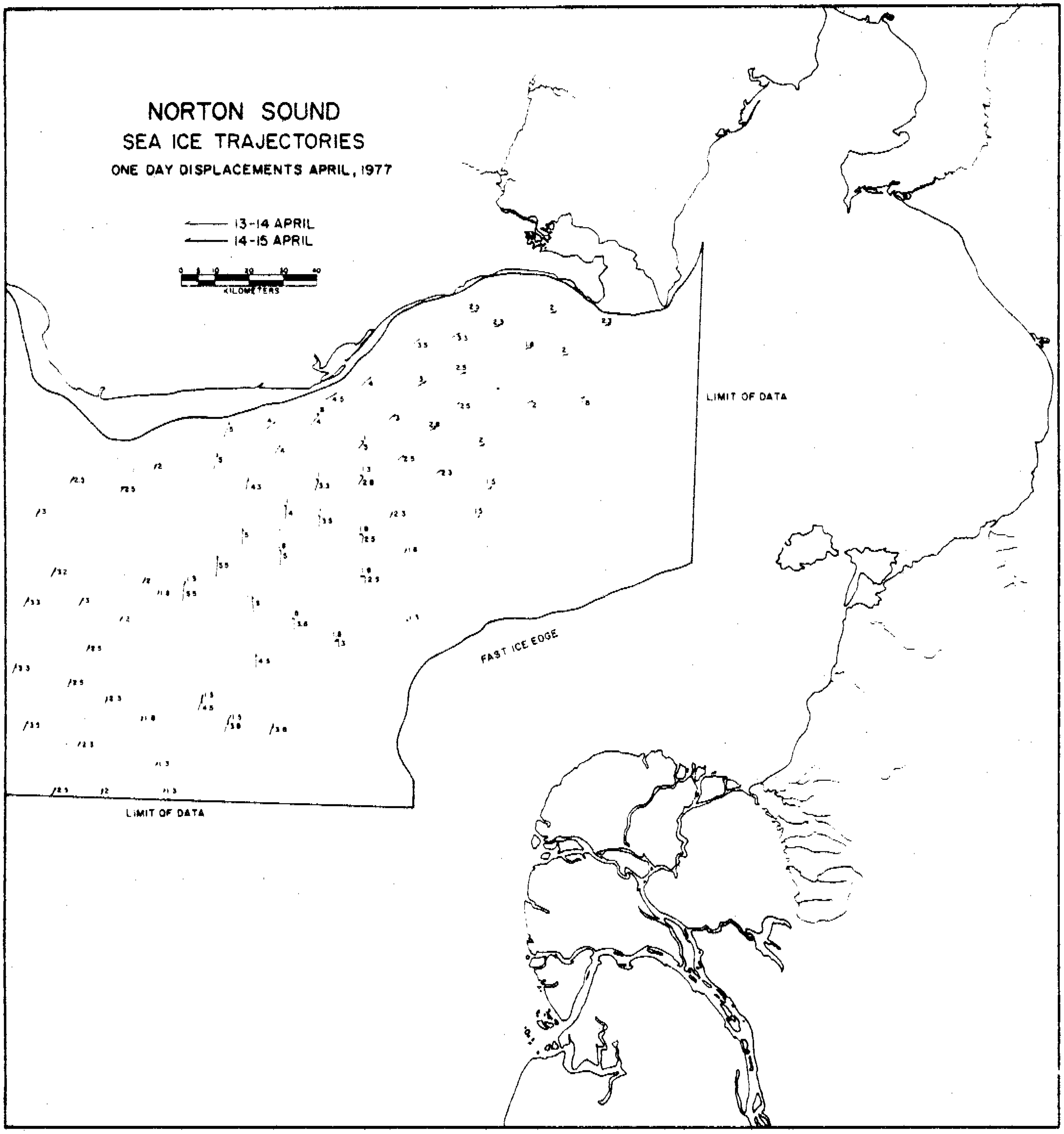


Figure 17 This map shows Norton Sound ice displacements measured between April 13 and 15, 1977. On the first day the ice motions were clearly inbound, with the greatest velocities measured along the northern boundary of the sound. Displacements measured for the second day continued to be inbound in the entrance to the sound, but showed signs of an abrupt halt farther toward the central region of the sound. It is interesting to observe that Bering Sea ice appears to be driven into Norton Sound in this case from the southwest.

1978 Ice Displacements

No eighteen-day displacements were measured for this year.

One-day displacements were measured for:

1-2 March (25 displacements)

2-3 March (59 displacements)

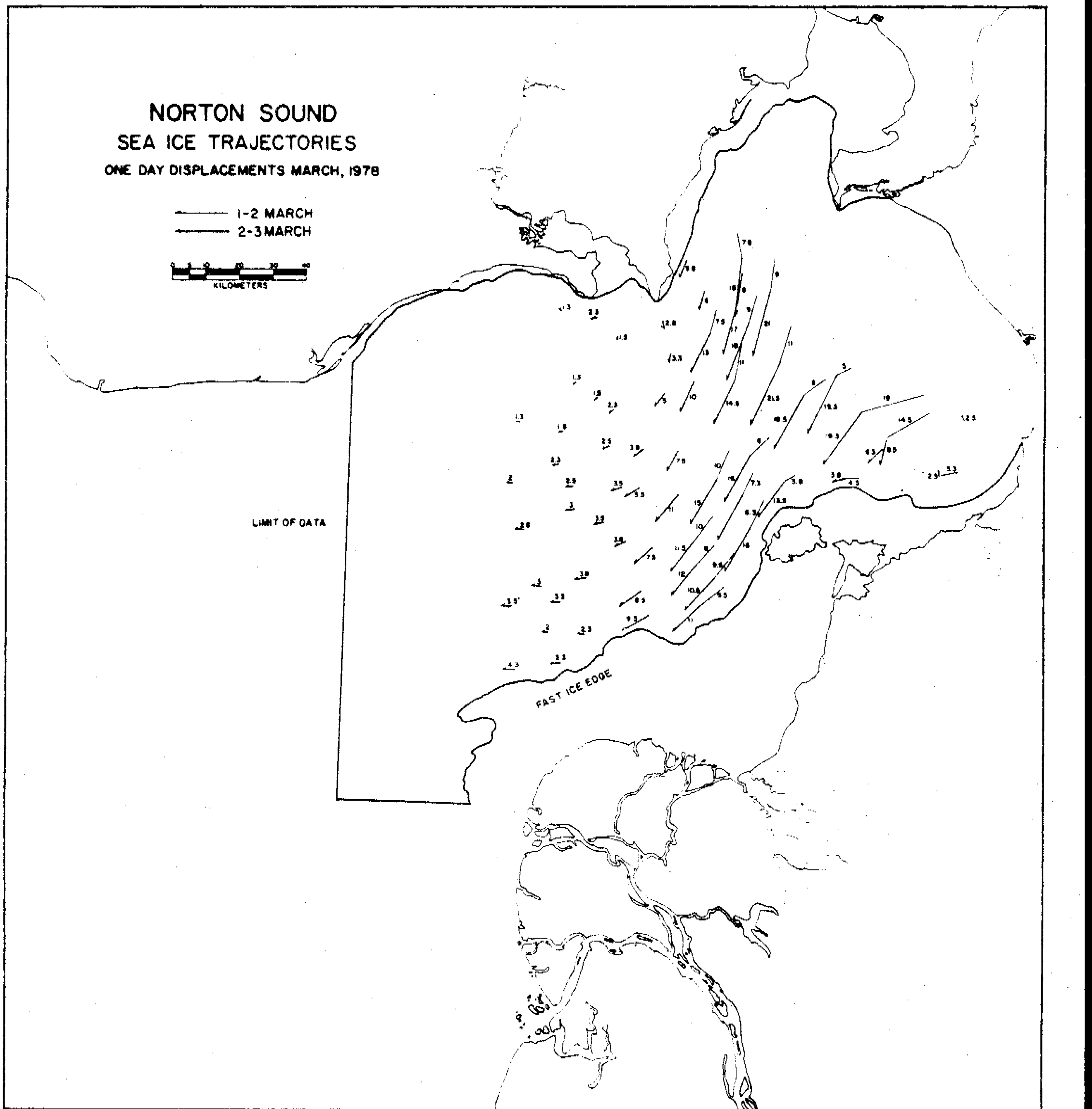


Figure 18 This map shows Norton Sound ice displacements measured between March 1 and March 3, 1978. Here a large variation in displacements can be seen from the eastern portion of the sound to the central region. Although the ice motions are generally outbound, a small gyre exists in the north central portion of the vector field. The ice in the eastern portion of this map is quite thin and is subject to compaction mechanisms including minor ridging and rafting.

1979 Ice Displacements

No eighteen-day displacements were measured for this year.

One-day displacements were measured for:

1) 15-16 February (35 displacements)

16-17 February (47 displacements)

2) 24-25 February (17 displacements)

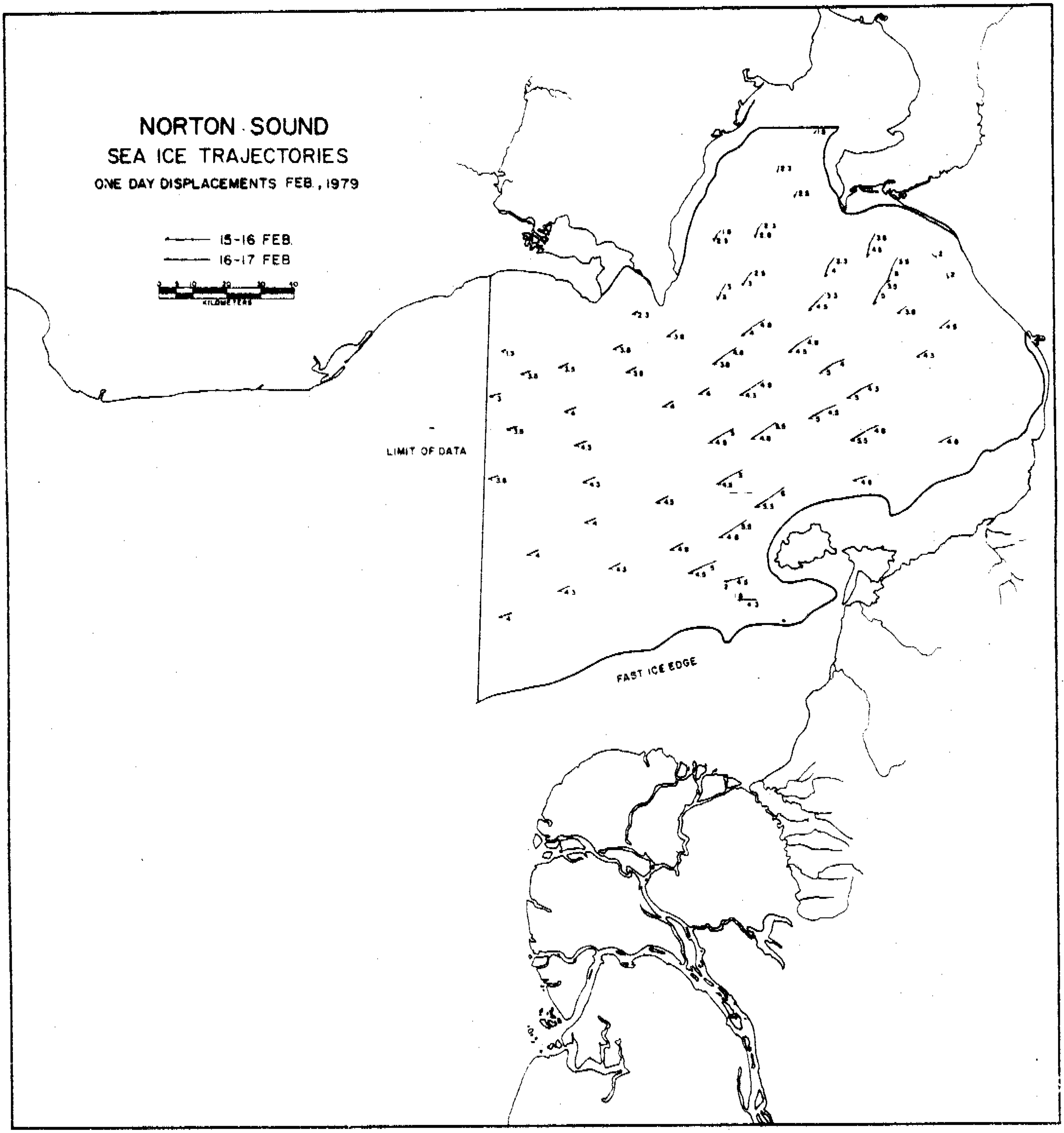


Figure 19 This map shows Norton Sound ice trajectories between Feb. 15 and 17, 1979. The floes imaged all three days show considerable uniformity in displacement from one day to the next. Again, the most southerly displacements appear to be the largest.

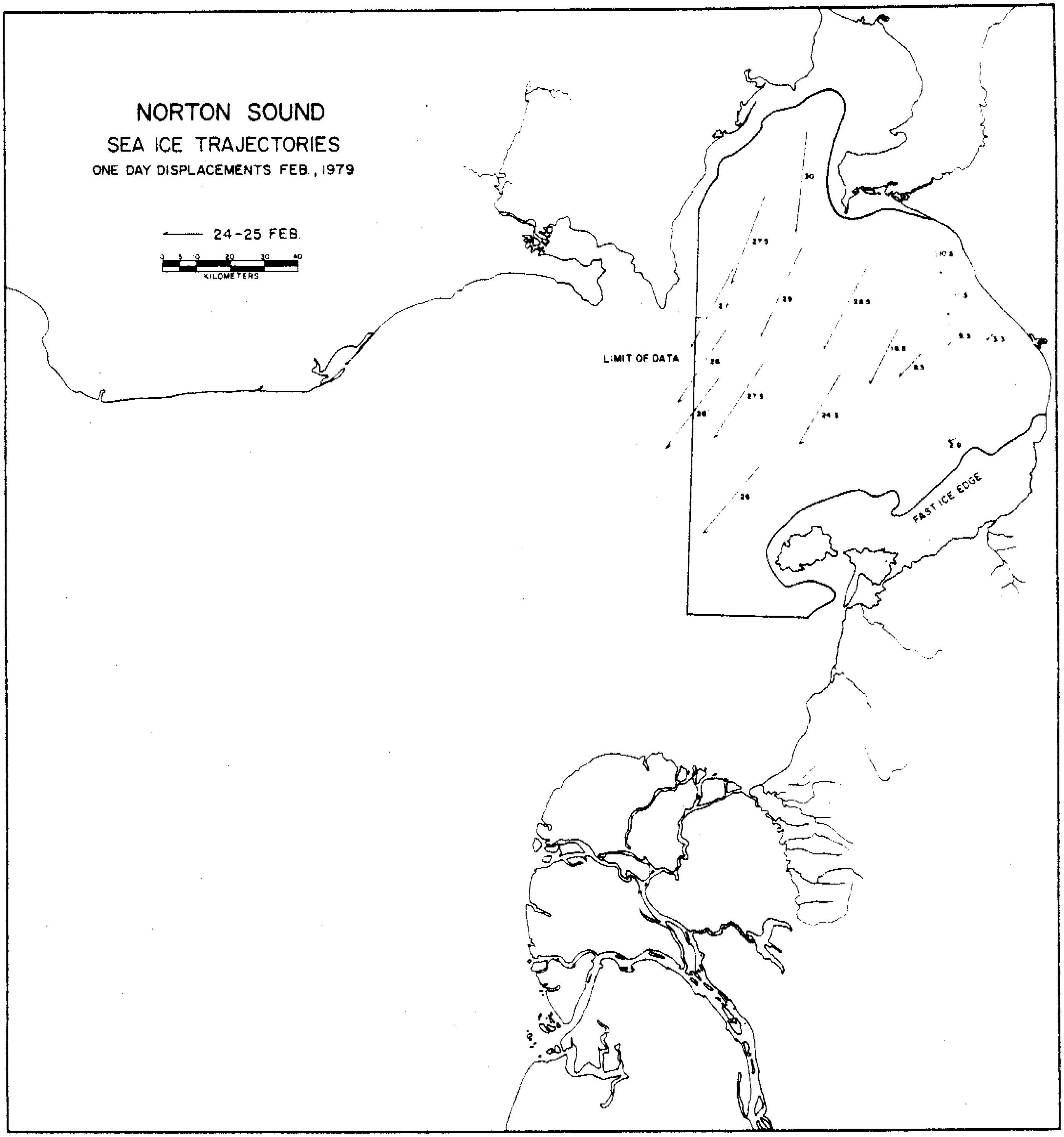


Figure 20 This map shows Norton Sound ice displacements measured between Feb. 24 and 25, 1979. The displacements observed here are among the largest seen in Norton Sound and range up to 30 km/day (30 km/sec). Again, uniform outbound ice motion is shown.

Influence of Cloudiness on Selection of Data

Obviously satellite imagery dependent on the visible portion of the spectrum will not be available during cloudy periods. This selection effect raises the question of the general applicability of data derived by this means. It can be argued that cloudiness is associated with barometric low pressure systems and therefore ice conditions during lows are not monitored.

In order to test this hypothesis, a running pressure chart for Nome was analyzed for those periods when sea ice trajectories were measured. The events were divided into four categories of barometric pressure variation at Nome on the north side of Norton Sound:

1) Relative high
2) Pressure increasing from relative low
3) Relative low
4) Pressure decreasing from relative high

The results of this analysis are shown on Table 1 (Page 33)

In terms of pressure variations at Nome, the Landsat observations seem to be nearly evenly distributed. While this analysis by no means shows that cloudiness is not associated with unique meterological effects influencing ice motion, it does show that in terms of barometric pressure variations the data is not highly skewed in terms of any particular pressure situation. Perhaps a better parameter with which to gauge the influence of cloudiness on ice motion would be the geostrophic wind. This would require a much more detailed analysis which may be possible in the future.

Sense of Barometric Pressure Variation

Observation Period	Relative High	High going Low	Relative Low	Low going High
3/18-21/73		x		
4/7-9/73			x	
4/24-27/73		x		
2/8-9/74			x	
3/14-16/74		x		
4/1-2/74			x	
4/7-8/75				x
2/25-26/76	x			
3/12-15/76	x			
3/29-31/76			x	
4/17-26/77				x
4/13-15/77	x			
3/1-3/78	x			
2/15-16/79		x		
2/24-25/79				x
Totals	4	4	4	3

Table 1. Categorization of Norton Sound ice movement observations in terms of sense of barometric pressure variation at Nome.

OBSERVATIONS

The main purpose of this report is to display the ice displacement maps and discuss the uncertainties involved in measurements and data availability. Detailed discussions will follow. However, several general observations can be made at this time:

1. Ice within Norton Sound behaves, in general, according to three behavorial modes: ice outbound, ice inbound and ice gyre.

2. The outbound mode appears most frequently, supporting the generally-held thought that ice formed in Norton Sound is fed into the Bering Sea.

3. The inbound mode can correspond to both northbound <u>or</u> southbound Bering Sea ice.

4. The displacements observed during the inbound mode are generally smaller than those of the outbound mode, further supporting the thought that the net ice motion is outbound.

5. Bering Sea ice often moves past the entrance of Norton Sound at speeds 3 to 4 times greater than the simultaneous Norton Sound ice motion speeds. In the cases that this phenomenon coincides with outbound modes, the Norton Sound ice accelerates upon joining the stream of Bering Sea ice. The line marking the location of this acceleration runs roughly across the entrance to Norton Sound.

6. For periods as long as 36 days, ice within northern Norton Sound can remain relatively motionless. (See the 1973 18-day displacements).

7. Often, in the case of outbound modes, the greater ice speeds near the entrance to the sound are measured on the south side, just off the Yukon River prodelta.

8. Across the length of the sound the greatest displacements are found at the eastern end.

9. Ice motions within Norton Sound can easily reverse from one day to the next.

CONCLUSIONS

1. Ice behavior in Norton Sound should not be considered to be a simple extension of the motion in the adjacent Bering Sea. Although at times the outbound mode appears to be coupled with southbound Bering Sea ice, the inbound mode can also occur when Bering Sea ice is southbound. Furthermore, Norton Sound ice seldom flows directly into the Bering Sea. Often the Norton Sound ice appears to be held back by the stream of Bering Sea ice flowing past the entrance to Norton Sound. It would be more correct to consider the Norton Sound and Bering Sea ice regimes as coupled systems with the Bering Sea as dominating the relationship.

2. The movement of ice from and within Norton Sound is highly variable. Outbound displacements of 10-15 km/day are not unusual, but probably represent the high end of the spectrum of velocities. On the other end of the velocity spectrum, ice has been shown to linger up to 36 days near the entrance to the sound. Displacement reversals can take place from one day to the next and besides the inbound and outbound modes, even gyres of ice floes are possible. Taken together these observations indicate that although the general motion of ice is toward the entrance, a great deal of loitering and mixing can take place. This conclusion is particularly important when considering the trajectory of an oil spill associated with the Norton Sound ice pack.

ACKNOWLEDGEMENTS

This work was supported by the Bureau of Land Management through an interagency agreement with the National Oceanic and Atmospheric Administration, under which a multi-year program responding to an environmental assessment of petroleum development on the Alaskan Continental Shelf is being performed. Specifically, Contract 03-5-022-55, Research Unit 267, supported the work described here.

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2. Colvocoresses, Alden P., and Robert B. McEwen, EROS Cartographic Progress. Photogrammetric Engineering, Volume XXXIX, No. 12, p. 1303-1309, December, 1973.

Ice Motion in Western Norton Sound

William J. Stringer
Geophysical Institute, University of Alaska
Fairbanks, Alaska 99701

Abstract

Analysis of one-day ice floe displacement fields in western Norton Sound, Alaska, has yielded a statistical model for long-term ice floe drift. The model describes ice motions as being normally distributed with average velocities ranging from 2.8 to 4.5 km/day westward, toward the entrance at locations across the sound and with standard deviations of 5 to 7 km/day.

The long-term drifts projected are compared with observed long-term drifts and found compatible. These results indicate that although pack ice within Norton Sound is generally moving westward (toward the entrance), a high degree of variability also exists such that even after a period as long as twenty days, a 7% probability remains of a net motion away from the entrance of the sound.

The net westward drift of ice within Norton Sound is linked to persistent westward winds observed in eastern Norton Sound. However, interaction with Bering Sea ice at the entrance to the sound is suggested to contribute to the high degree of variability of ice motions observed.

Introduction

Norton Sound is a relatively shallow arm of the Bering Sea, located in western Alaska just north of the Yukon River delta and forming the southern side of the Seward Peninsula. The sound is roughly rectangular, with sides parallel to the cardinal directions. The western face of the sound is approximately 150 km wide and is open to the Bering Sea. The sound extends approximately 250 km to the east from this entrance.

Annual sea ice is found here between October and late May. Satellite imagery available over the last decade has often shown an opening polynya on the eastern end of Norton Sound. This has generally been taken to indicate that ice within Norton Sound normally moves westward in a somewhat systematic manner (Stringer, 1980).

The detailed motion of ice within Norton Sound is of interest in determining the thermodynamic ice budget for the sound and also for projecting the trajectory of spilled oil associated with the ice.

This paper reports an attempt to determine the representative values for motion of ice in western Norton Sound based on ice floe displacements taken from Landsat images and to associate the motions observed with causal relationships.

Background

Stringer and Henzler (1981) have published a series of twenty maps of sea ice displacements in Norton Sound. The displacements were mapped by back projecting Landsat images from successive days onto a translucent screen and drawing the daily displacement vectors for identifiable floes. Owing to increasing overlap of Landsat imagery with latitude, locations in the Norton Sound region are imaged on three consecutive days with the result that displacement vectors for two successive 24-hour periods can be mapped. These maps show displacement vectors for 485 individual floes measured over thirty-one 24-hour intervals, from which fifteen 48-hour observation intervals were possible. Also, six 18-day intervals mapped yielded two occasions of consecutive 36-day observations. A representative portion of one of these maps has been reproduced here as Figure 1. Shown are ice trajectories measured in Norton Sound between March 12 and 16, 1976. The displacements of individual floes are indicated by vectors whose width signifies the particular 24-hour interval and whose length in kilometers is indicated by adjacent numbers. The extent of fast ice shown on this map is normal for this time of year (Stringer, 1980).

The random error of measurement of these floe displacements has been estimated at ± 1 km. This estimate has been discussed in some detail by Stringer and Henzler (1981) and refers to an article by Colvocovesses and McEwen (1973) for estimates of errors in position measurements made from Landsat imagery.

Obviously Landsat observations of sea ice require nearly cloudless conditions. This requirement raises the question of whether cloudiness is associated with ice-forcing mechanisms different from clear sky conditions. Specifically, one might expect that cloudiness occurs during barometric lows and that data during these times is excluded.

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For the data set used here, Stringer and Henzler (1981) have examined the dates of available imagery against barometric pressure variations measured at Nome, on the north side of Norton Sound, and found that the dates Landsat imagery was acquired were evenly distributed in terms of four pressure categories: relative low, relative high, low increasing toward high and high decreasing toward low. While this analysis does not entirely rule out the possibility of data availability preselecting the observations, it does show that the various barometric conditions are adequately represented.

In further support of these data two additional arguments can be made. As will be shown, a very wide range of ice movement conditions were monitored, indicating at least that cloudless conditions are not strongly correlated with any single mode of ice motion. In addition, a considerable effort was made to correlate the ice motions observed and barometric pressure patterns. No simple relationship could be found. These arguments suggest that even if Landsat imagery obtained during a particular barometric condition is excluded from the data set, the result may not be significantly altered.

Analysis

The purpose of this work was to describe average ice motion in western Norton Sound. Analysis of the modal behavior of Norton Sound ice (Stringer, 1981a) shows that the most frequent behavior for ice in western Norton Sound is to flow westward out of the sound (50% occurrence). The next most frequent behavior is for ice to move inward

(30%). Finally, on 20% of all occasions the ice moved in a circular gyre. Hence most displacement vectors in that region are largely either parallel or anti-parallel to the axis of the sound. Even in the case of a gyre, the displacements at the top and bottom of the gyre are in these directions.

In order to describe the bulk average motion of ice within western Norton Sound, representative values for the axial components of floe displacements were obtained for the northern, central and southern regions of the sound. This was possible on twenty-two of the occasions when 24-hour observations were possible. Table 1 gives the means, extremes and standard deviations obtained:

	North	Central	South
$\overline{v}$	+ 3.5 km/day	+ 2.8 km/day	+ 4.5 km/day
extremes	- 4 to + 13 km/day	- 7 to + 11 km/day	- 9 to +17 km/day
σ	+ 5.0 km/day	+ 5.0 km/day	+ 7.1 km/day

(positive values correspond to outbound velocities)

Table 1. Ice drift parameters for Western Norton Sound

These values all indicate an average motion of ice from Norton Sound. Yet, in all cases the standard deviation is sufficiently large that inbound displacements should be considered highly possible, because the while outbound displacements dominate, inbound displacements are also frequent and large. And, although the average displacement is positive, the standard deviation includes possible negative values.

These values, however, are based on averages of one-day displacements. What we might wish is a projection of likely ice motion over a period of several days. This would be an expanding envelope centered on the mean drift with the standard deviation defining the width of the envelope.

Generally one would anticipate that if the displacements observed were random events, the envelope would be described by the equation

$$E(km) = n(\overline{v}) \pm \sigma\sqrt{n} \qquad (1)$$

However, the ice motions are not entirely random. On those occasions when 2-day observations were possible, modal persistence at the entrance to Norton Sound was three times greater (Stringer, 1981b) than would be anticipated by random ordering of events. Hence some significance must be placed on the possiblity of persistance. A formulation of equation 1, taking persistence into account is given by:

$$E(km) = n(\overline{v}) \pm \sqrt{n_p}\,\sigma\,\sqrt{n} \qquad (2)$$

This relationship describes an envelope based on the assumption that on the average the ice behavorial mode functioning on the first day will persist for n_p days. Note that for $n_p = 1$ equation 2 reduces to equation 1 and that for $n = n_p$, $E = n_p v \pm n_p\sigma$ which reflects the persistence of the variation $\pm\sigma$ for n_p days. The equation follows directly from assuming random walk increments of length $n_p\sigma$ in the well-known derivation of equation 1.

We do not have real direct data upon which to base a value of n_p. However, if we adopt the reasonable assumption that ice motions are largely associated with weather systems, we can establish a value of $n_p = 3$ by noting that pressure variations at Nome change slope on intervals ranging between two to five days.

The precise value of n_p is not extremely critical since it represents a correction to an estimate of deviation from the mean. Furthermore the magnitude of the correction varies as $(n_p)^{1/2}$ and quickly becomes rather insensitive to n_p.

Using this relationship, the envelopes of expected drift were calculated for the three locations across the entrance to Norton Sound. Figure 2 shows the result of assuming this relationship to operate over a period up to 20 days at the northern location. The average drift is shown by a solid line and the 3-day persistence envelope by the dot-dashed line. For comparison, the envelope obtained by assuming one day persistence is given by the dashed line.

Figure 3 shows the distribution of floe locations to be expected after twenty days' drift for an initial location in central Norton Sound, assuming the distribution of drifts will be normal. The peak of the distribution is located at the mean drift displacement from the initial location. The probability that after 20 days ice will be located between any two given distances from the initial point is given by the area under the curve between those two points. These values can be obtained from tables of normal distribution in terms of the values of $T = \frac{X}{\sigma}$ given here along the horizontal axis of the distribution. An additional horizontal axis has been drawn giving distances from the point of origin.

From this distribution it can be seen that although positive (westward) drifts of ice are most likely, even after twenty days there is a finite (approximately 7%) chance that ice in central Norton Sound may have drifted farther into the sound rather than out.

Figure 4 shows a map of Norton Sound where the 1σ and 1.5σ envelopes assuming 3-day persistence have been used to project the probable 20-day drift of ice originating in west central Norton Sound. Indicated are a line along which the hypothetical floes originated, the average location of the ice after 20 days' drift and the 1σ and 1.5σ portions of the 20-day drift envelope.

The 1σ portion of the 20-day envelope has a 68% probability of containing ice starting along the line of origin while the 1.5σ envelope includes the next 19% of all cases as well. Hence there is an 87% probability that ice originating along the line indicated will be within the total envelope shown after 20 days' drift.

Discussion

A. Comparison of long-term drift projections with observed long-term drifts.

The results presented so far are based on analysis and extension of 24-hour ice drift values. As stated earlier, it was possible to measure 18-day displacements in a few instances. Several of these displacements are located in western Norton Sound and are useful to compare with the values obtained here.

The chief purpose of this discussion is to reconcile the observed 18-day drift patterns with the projection based on one-day observations.

Several floes were tracked across northwestern Norton Sound between April 7 and 26, 1973. These floes traveled between 60 and 30 km westward, their average corresponding to somewhat less than the average drift but still within the 1σ envelope for 18 days. During the next 18-day period one of these floes and two others in central Norton Sound experienced a net drift between 18 and 30 km back into Norton Sound. This would seem to be an unusual event and will be discussed in detail later.

Between April 2 and 21, 1974, five floes had a net displacement between 15 and 97 km toward the entrance of the sound. All but one of these would fall within the 1σ envelope and that lowest value would fall within the 1.5σ envelope.

Finally between April 14 and May 2, 1977 a 30 km westward displacement was observed in central western Norton Sound, one which would correspond to the 1σ envelope.

First, it would appear obvious that the 18-day observations tend to be acquired during relatively quiet periods. During active periods, ice would be transported from western Norton Sound into the Bering Sea and be advected away. Furthermore, in order for 18-day displacements to be measured, the same floe must be identified on occasions eighteen days apart. In general this would be expected to be most likely during relatively quiet periods. Hence, one would expect the 18-day displacements to tend to lie on the short displacement side of the average displacement position. These conjectures are supported by the data.

However, on one occasion floes were actually observed to move inward over an 18-day period. During the 7-year surveillance period there were approximately 35 opportunities to monitor 18-day displacements in western Norton Sound. Only on six occasions could floes actually be tracked and on one of these the negative displacements occurred. (The 29 missed opportunities presumably occurred because of large displacements and mechanical destruction of floes.) The negative displacement case corresponds to approximately 3% of possible observations. The 30 km negative displacement would place the trajectory into the wing of the probability distribution beyond the 2σ envelope. This wing contains 2% of the expected events. Thus this observation, while extreme, agrees statistically with the ice drift distribution and the number of possible events.

The extreme negative 18-day displacement event was observed in May, later than any of the 24-hour displacement events used to generate the probability distribution. Inspection of Landsat images shows that in some years there is a tendency for late season ice to remain in northern and central Norton Sound. These arguments suggest that although the extreme negative values observed in May might be statistically acceptable, the application of the motion statistics generated here should be terminated at a date roughly coincident with the end of the spectrum of dates used to generate the displacement distribution, May 1.

The earliest data used in this analysis was obtained in early February and it would appear that a similar argument could be made that the range of validity in this direction should not be extended earlier than this date. However, in late spring no new ice is forming and several general climatological processes in the northern Bering Sea region appear to be changing at this time. On the other hand, winter observations are limited by availability of light, and on the basis of meterological satellite imagery obtained in the thermal infrared there is evidence to suspect that ice and meteorological conditions have been roughly similar at least since mid-December. For that reason it would appear reasonable to consider the mid-winter validity of the ice drift distribution to diminish toward earlier dates rather than to terminate abruptly.

B. Comparison of results with other analyses.

Although the results obtained here indicate a net westward (outbound) movement of ice in western Norton Sound, the high variability of ice velocities measured and specifically the inbound displacements indicate the likelihood that more than one displacement mechanism is operating. In other analyses of the ice displacements studied here, Stringer (1981a, 1981b) has examined the model behavior of Norton Sound ice and the interaction of Norton Sound ice at its entrance and the adjacent Bering Sea ice. The first study showed that the outbound mode dominates in the eastern, central and western sectors of the sound, but the other modes (inbound and gyre) increase in frequency as the entrance is approached. The second study examines a direct relationship between the observed heading azimuth of Bering Sea ice adjacent to the entrance to Norton Sound and the ice movement mode operating in the entrance sector.

The dominance of the outbound ice motion mode indicates a mechanism operating to push the ice westward. Its greatest occurrence frequency in the easternmost sector indicates that either this mechanism is more prevalent in the eastern sector or that it is overriddent at times in the western (entrance) sector by other processes, or both. The discovery of a direct relationship between Bering Sea ice motion and Norton Sound ice mode suggests that at least the forcing mechanism can operate in a less hindered fashion in the eastern sector and that ice motion in the entrance sector is modified by interaction with Bering Sea ice. Since forces can be transmitted several hundred kilometers through pack ice, the question of whether the forcing mechanism varies throughout the length of the sound is not particularly important here.

C. Forcing mechanism for Norton Sound ice movement.

The net outbound motion of Norton Sound ice combined with the dominant frequency of occurrence by the outbound ice motion mode suggests a persistent westward forcing mechanism for Norton Sound ice. In the modal analysis of Norton Sound ice motions, Stringer (1981a), based on an extensive analysis by Brower et al. (1977) of Alaskan climatological conditions, cites several statistical criteria suggesting that winds in eastern Norton Sound are strong and persistently toward the west. These westward winds are taken to be the forcing mechanism responsible for the net westward transport of Norton Sound ice.

Conclusions:

1. Between January and May, ice in Norton Sound undergoes a net westward displacement of roughly 3.5 km/day. Drift rates along

the sides are slightly greater than the drift rates in central Norton Sound.

2. Although the net drift is westward, large variations in drift can occur to the extent that even after 20 days, a net negative drift has a probability of around 7%.

3. The net westward drift appears to be associated with strong and persistent westward winds measured in eastern Norton Sound.

4. The variability of ice motions in the entrance sector to Norton Sound is associated with interactions between Norton Sound ice and pack ice in the adjacent Bering Sea.

5. The picture of Norton Sound ice being driven westward by winds in eastern Norton Sound and throttled by interaction with Bering Sea ice appears to explain the net westward motion but a high degree of motion variability was observed.

Acknowledgements

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This work was supported by the Bureau of Land Management through an interagency agreemnt with the National Oceanic and Atmospheric Administration, under which a multi-year program responding to an environmental assessment of petroleum development on the Alaskan Continental Shelf is being performed. Specifically, Contract 03-5-022-55, Task 10, Research Unit 267 supported the work described here.

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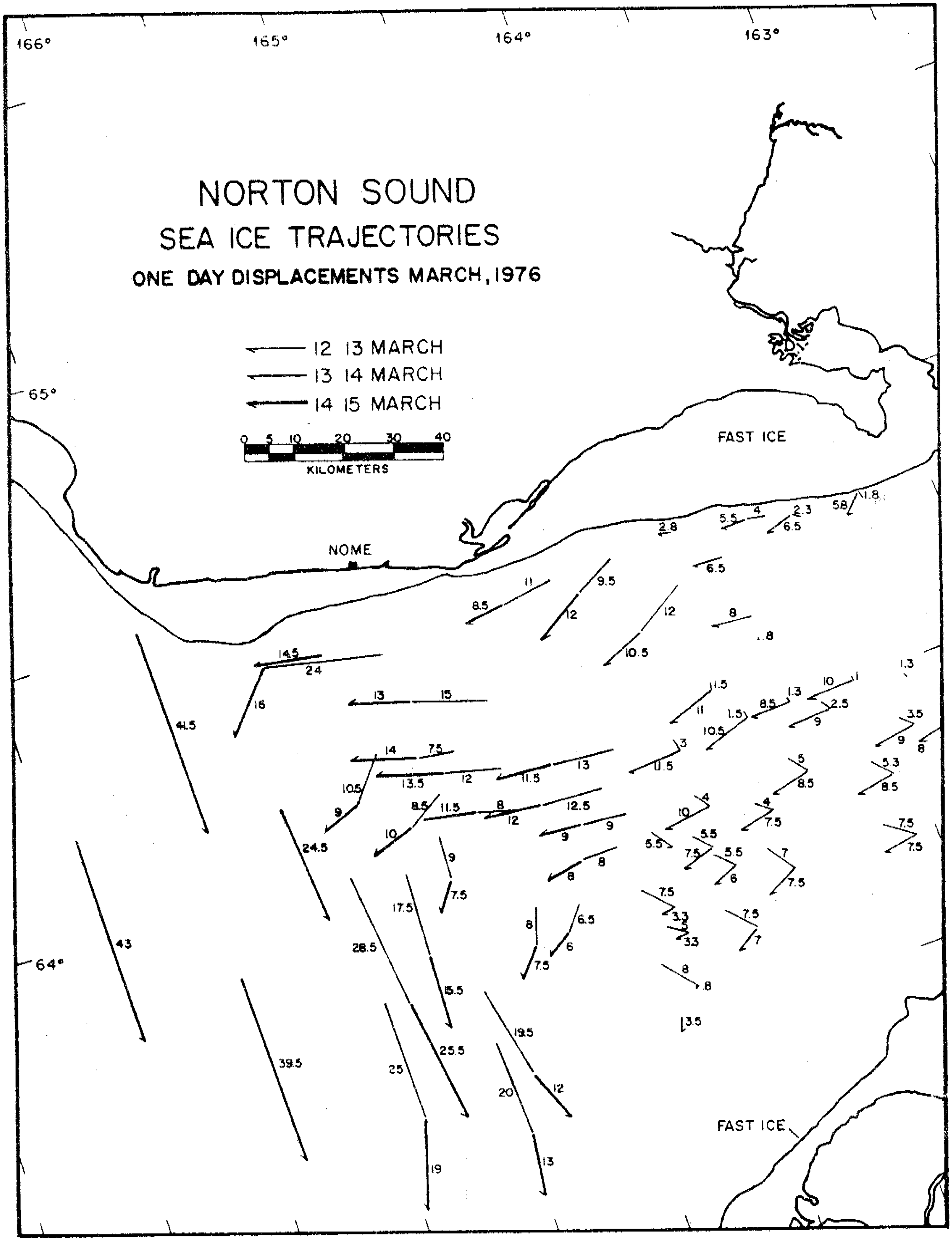
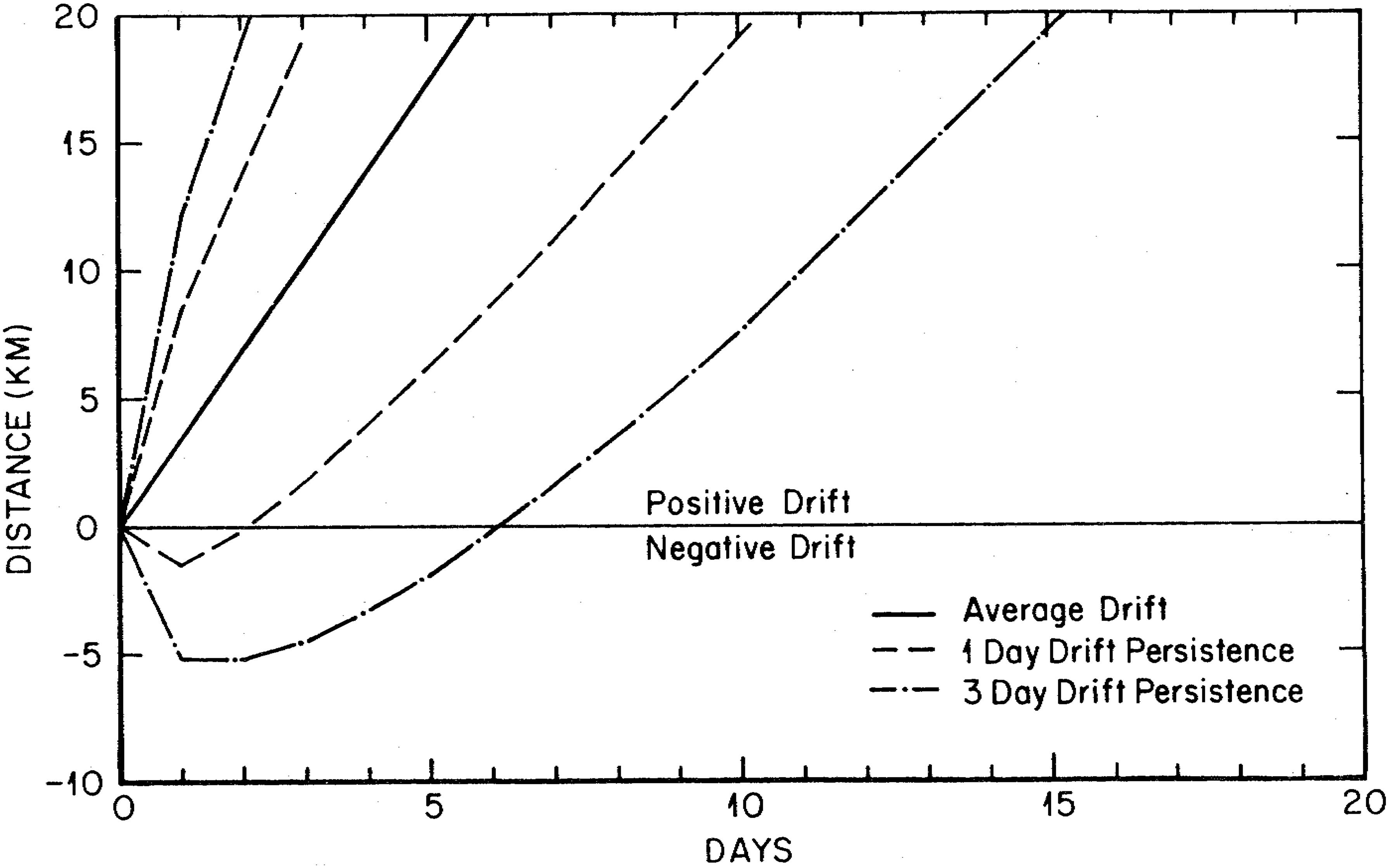
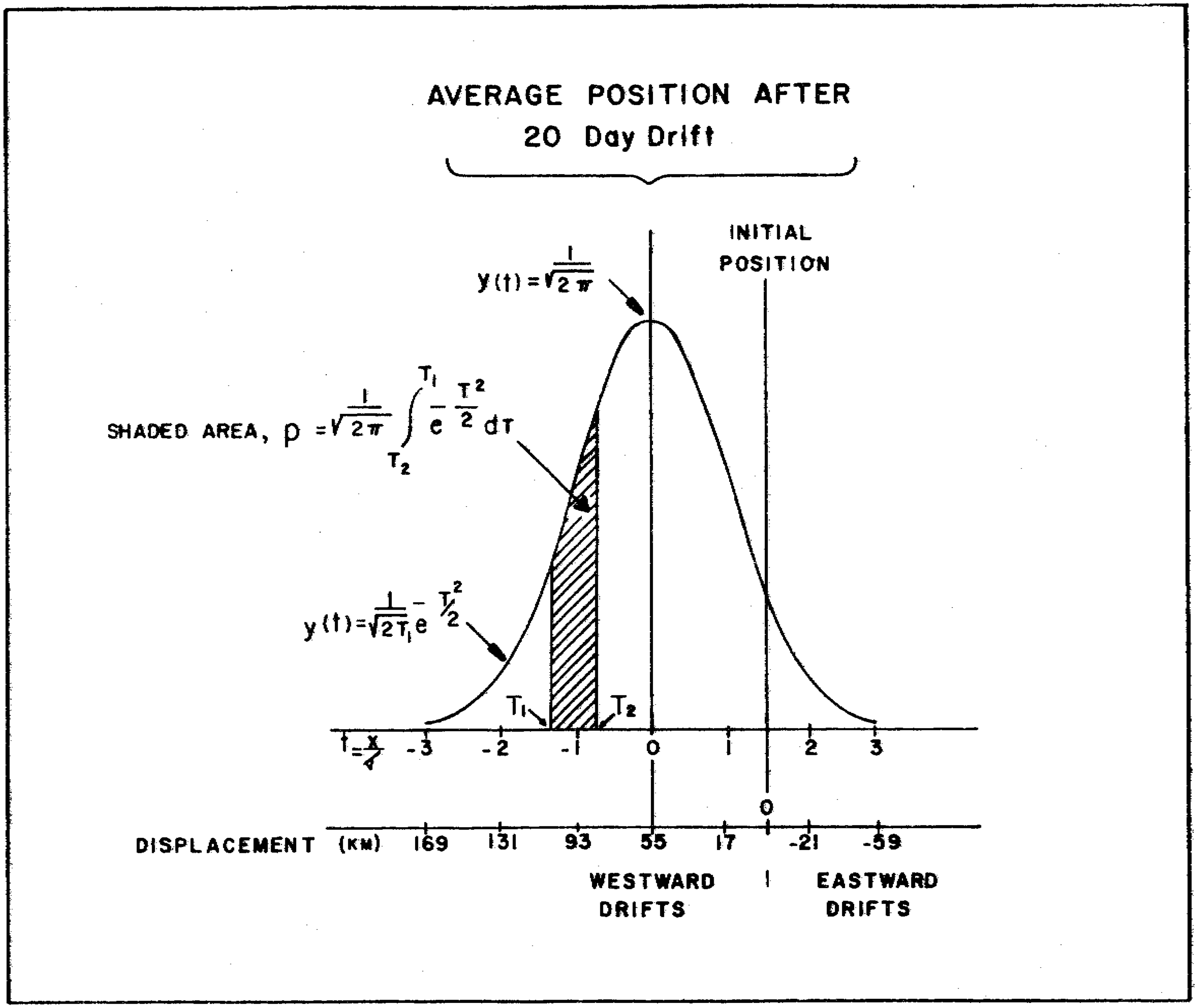
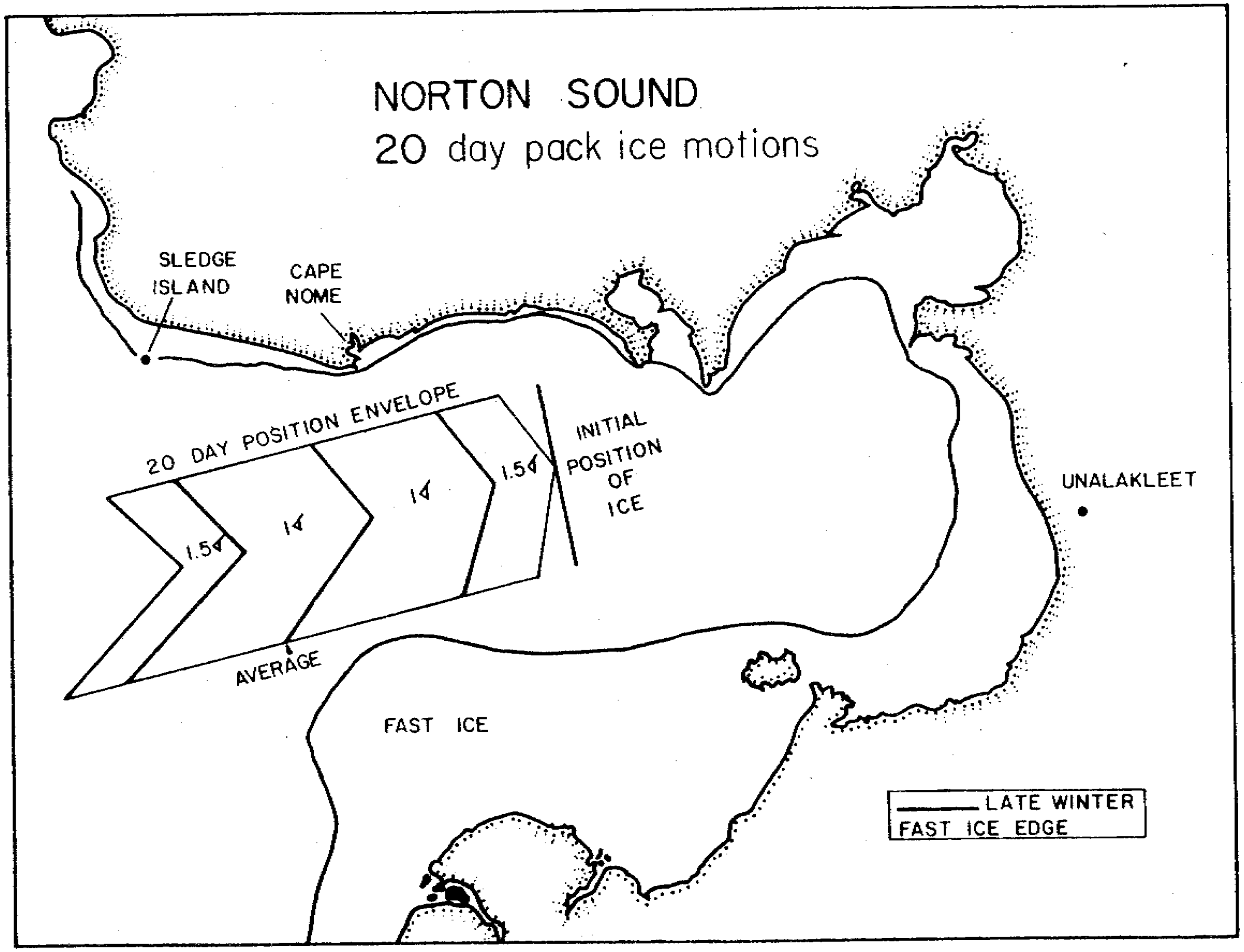


NORTON SOUND
SEA ICE TRAJECTORIES
ONE DAY DISPLACEMENTS MARCH, 1976
12 13 MARCH
13 14 MARCH
14 15 MARCH
0 5 10 20 30 40
KILOMETERS
166°
165°
164°
163°
65°
64°
NOME
FAST ICE
FAST ICE

ICE DRIFT IN NORTHERN NORTON SOUND




AVERAGE POSITION AFTER
20 Day Drift
INITIAL
POSITION
y(t) = 1/√2π
SHADED AREA, ρ = 1/√2π ∫ from T2 to T1 e^(−T²/2) dT
y(t) = 1/√2π e^(−T²/2)
T1
T2
t = x/σ
-3
-2
-1
0
1
2
3
0
DISPLACEMENT (KM)
169
131
93
55
17
-21
-59
WESTWARD
DRIFTS
EASTWARD
DRIFTS


NORTON SOUND
20 day pack ice motions
SLEDGE ISLAND
CAPE NOME
20 DAY POSITION ENVELOPE
INITIAL POSITION OF ICE
1.5√
1√
1√
1.5√
AVERAGE
UNALAKLEET
FAST ICE
LATE WINTER FAST ICE EDGE

Interaction of Bering Sea and Norton Sound pack Ice

William J. Stringer

Geophysical Institute University of Alaska
Fairbanks, Alaska 99701

Abstract

The interaction of Bering Sea and Norton Sound pack ice has been examined in terms of the influence of Bering Sea ice motions on the behavior of Norton Sound ice in the entrance sector of Norton Sound. A direct relationship has been found between the azimuthal heading angle, α, of Bering Sea pack ice and the behavioral mode of pack ice in the entrance sector of the sound.

The data suggest that for heading angles between 20° and 150° Bering Sea ice is driven into Norton Sound and for heading angles between 170° through 360° to 20° ice within Norton Sound leaves the sound. A transitional gyre mode was observed for heading angles between the values of α producing these modes: 150° through 170°. Although not observed, based on the geometry of the entrance to Norton Sound and symmetry, a second gyre mode is postulated for heading angles between 0° and 20° as a second transitional mode between inbound and outbound Norton Sound ice modes.

I. Introduction and Background

Norton Sound is an east-west oriented embayment of the Bering Sea located just south of Seward Peninsula, Alaska. The sound is roughly rectangular, approximately 250 km by 150 km in length and width. The sound and adjacent Bering Sea are covered with annual ice from approximately late October through mid-May. The motion of ice from Norton Sound is of interest scientifically because of its contribution to the overall ice budget of the Bering Sea and in terms of the ice budget of Norton Sound itself. Also, because of possible offshore petroleum development within Norton Sound, the motion of Norton Sound ice is of interest from the standpoint of possible transport of pollutants.

Stringer and Henzler (1981) have published a series of maps showing displacements of ice floes within and adjacent to Norton Sound. These maps were compiled by projecting Landsat images from successive days on a translucent screen and constructing daily displacement vectors for floes which could be identified from one day to next. Owing to increasing overlap of Landsat imagery with latitude, locations in the Norton Sound region could be imaged up to three successive days, resulting in the possibility two consecutive displacements measured for each flow.

In an analysis based on these maps, Stringer (1981a) has shown that the motion of ice within Norton Sound is characterized by an average westward drift. However, in an analysis of characteristic ice movement modes, Stringer (1981b) has shown that the westward drift mode is much more prevalent in eastern and central Norton

Sound than in the western (entrance) sector. It was suggested that the strong persistent westward winds observed in eastern Norton Sound (Brower, et al. 1977) were responsible for the general westward movement of Norton Sound ice, but that Bering Sea ice motions were possibly responsible for the greater role of other behavioral modes at the entrance to the sound.

This paper examines the nature of the interaction of Bering Sea ice with Norton Sound ice and defines a quantitative relationship between the vector azimuth of Bering Sea pack ice motion and the mode of ice behavior at the entrance to Norton Sound. These results should be useful in further understanding the factors influencing the rate of ice exiting Norton Sound and may apply generally in similar geographic configurations elsewhere.

Analysis

Of the thirty-one 24-hour intervals mapped by Stringer and Henzler (1981), fifteen showed not only the entrance portion of Norton Sound but the adjacent Bering Sea as well. Figure 1 shows a representative portion of one of these maps. Obviously space considerations preclude publishing all these maps here.

Examination of the data showed Norton Sound ice behavior at the entrance to Norton Sound could be divided into three modes of interaction (Stringer 1981b).

1. THE OUTBOUND MODE: Norton Sound ice flows into the Bering Sea. (50% occurrence)
2. THE INBOUND MODE: Bering Sea ice flows into Norton Sound. (30% occurrence)

3. THE GYRE MODE: Norton Sound ice circles in gyres while Bering Sea ice moves past the entrance to the sound. (20% occurrence)

In addition, three general behavioral modes of Bering Sea ice were observed:

1. NORTH-TO-SOUTH MODE: Bering Sea ice moves past the entrance to Norton Sound at speeds ranging from 12 km/day to 40 km/day. (60% occurrence)
2. WESTWARD MODE: Bering Sea ice moves generally westward at speeds ranging between 3 and 7 km/day. (26% occurrence)
3. SOUTH-TO-NORTH MODE: Bering Sea ice is northbound. Velocities observed were 2 to 3 km/day. (13% occurrence)

There was not a strict one-to-one correlation between Norton Sound and Bering Sea modes. The highest correlation was between westward moving Bering Sea ice and the outbound Norton Sound mode. The association here is obvious. Norton Sound faces west. Outbound ice is traveling westward when it leaves the sound. Therefore one would expect the outbound Norton Sound mode to be observed when Bering Sea ice is moving westward.

However, when Bering Sea ice motion was from north to south all three Norton Sound modes were observed. During the two days when Bering Sea ice movement was from south to north, the inbound mode was observed.

Hence the interaction is not strictly linked to the displacement mode of either Norton Sound or the adjacent Bering Sea. However, a relationship can be found by tabulating the interactions observed in terms of increasing heading angle, α, of Bering Sea ice measured at the entrance to Norton Sound.

Case	α(±2°)	Date	Norton Sound Ice Behavior
A	32°	13-14/4/77	Ice moves into Norton Sound from SSW
B	32°	14-15/4/77	Ice moves into Norton Sound from SSW
C	142°	18-19/4/76	Ice moves into Norton Sound from NW
D	142°	19-20/4/76	Ice moves into Norton Sound from NW
E	150°	25-26/2/76	Ice moves into Norton Sound from NW
F	166°	25-26/4/73	Gyre formed at entrance to Norton Sound
G	166°	26-27/4/73	Gyre formed at entrance to Norton Sound
H	170°	7- 8/4/75	Gyre formed at entrance to Norton Sound
I	174°	8- 9/2/75	Ice exits Norton Sound, turns to south
J	175°	13-14/3/76	Ice exits Norton Sound, turns to south
K	175°	14-15/3/76	Ice exits Norton Sound, turns to south
L	216°	8- 9/4/73	Ice exits Norton Sound, turns SSW
M	216°	15-16/3/74	Ice exits Norton Sound, turns southwest
N	248°	7- 8/4/73	Ice exits Norton Sound, continues WSW
O	303°	20-21/3/73	Ice exits Norton Sound, turns northwest

Table 1. Ice behavior at entrance to Norton Sound related to Bering Sea pack ice heading angle.

These data can be grouped in the following way:

Bering Sea Ice Heading Angle	Norton Sound Mode
$32° \leq \alpha \leq 150°$	Inbound
$166° \leq \alpha \leq 170°$	Gyre
$174° \leq \alpha \leq 303°$	Outbound

Table 2. Grouped Bering Sea head angles and corresponding Norton Sound ice motion modes.

Discussion. It is tempting to generalize the relationship between observed heading angle and Norton Sound ice mode to account for all possible heading angles. In order to do this some guess must be made about the heading angle of transition between inbound and gyre modes and gyre and outbound modes. These angles are fairly well defined by the existing data and it would not be far from correct to select the transition angle as the mean between the observed heading angles in both cases.

It is somewhat more difficult to determine the transition heading angle between the outbound and inbound modes. Obviously this angle lies between 303° and 32° and is likely determined largely by the geometry of the entrance to Norton Sound. Examination of this geometry suggests that this angle is probably in the vicinity of 20°. Since the gyre mode observed appears to be a transition phenomena between inbound and outbound modes at heading angles around 165°, it is tempting to postulate the existance of a gyre mode for heading angles in the vicinity of 0-20°.

Conclusions. Based on the previous discussion it appears reasonable to extend the range of heading angles in Table 2 to include all possible heading angles. This results in a model relating the observed mode of Norton Sound ice behavior and Bering Sea pack ice motion at the entrance to Norton Sound. Figures 2 through 4 illustrate this model.

The model presented here merely relates the mode of ice movement in the entrance sector of Norton Sound and the direction of Bering Sea ice motions. It does not explain the driving mechanisms involved in the ice motions observed. However, the results do indicate that the two ice systems involved are coupled and the Bering Sea system appears to dominate the relationship.

It would appear from the data presented that the mode of ice behavior at the entrance to Norton Sound is determined by the heading angle of the adjacent Bering Sea ice. This is consistent with earlier results (Stringer, 1980) suggesting that although eastern and central Norton Sound ice appeared to be driven westward by dominant westward winds, Bering Sea ice behavior determines to a very large extent the flow of ice from Norton Sound into the Bering Sea. The reason for this could be simply that longer fetches are available for accumulation of wind stress on the Bering Sea ice than on the Norton Sound ice and that therefore Bering Sea forces are larger.

Acknowledgements

This work benefited greatly from many helpful discussions with Gary Hulford of the NOAA National Environmental Satellite Service, Anchorage, Alaska.

This work was supported by the Bureau of Land Management through an interagency agreement with the National Oceanic and Atmospheric Administration, under which a multi-year program responding to an environmental assessment of petroleum development on the Alaskan Continental Shelf is being performed. Specifically, Contract 03-5-033-55, Task 10, Research Unit 267 supported the work described here.

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Stringer, W. J., 1981b: Modal Behavior of Norton Sound Pack Ice, submitted to Arctic.

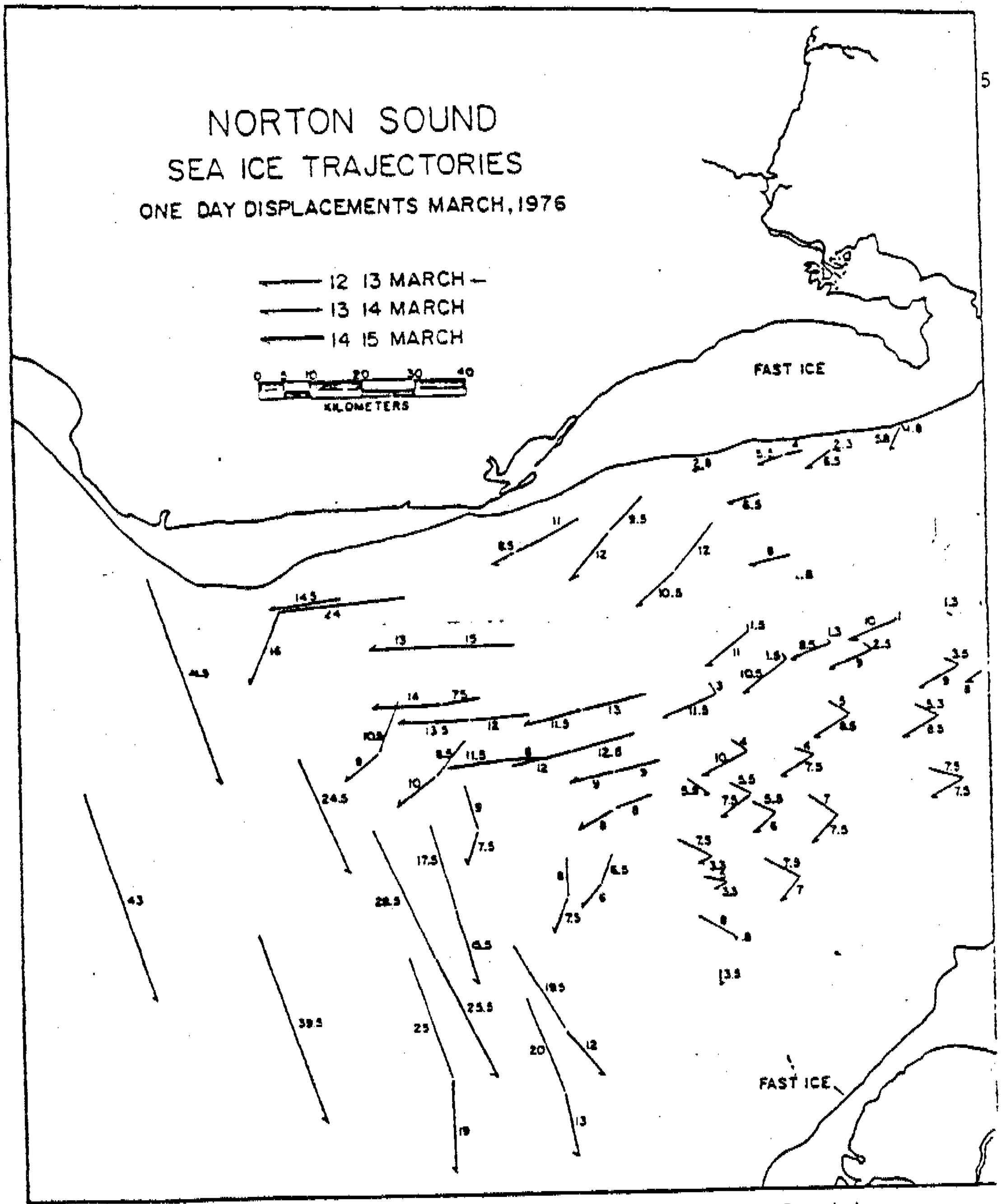
Figure Captions

Figure 1. Shown here is a portion of the map of Norton Sound ice displacements for 12-15 March, 1976, from Stringer and Henzler (1981). Although displacements were observed for these one-day periods over the area covered by this map, a specific location was only imaged on three consecutive occasions, resulting in a maximum of two consecutive displacements being observed. Displacements in kilometers are given adjacent to specific floe vectors. Reference to Table 1 will show that this map was used for the observations of interaction between Bering Sea and Norton Sound pack ice. On both occasions, the heading angle of Bering Sea ice was 175° and Norton Sound ice turned southward upon exiting the sound.

Figure 2. This map represents the relationship between heading angle, α, of Bering Sea ice and the outbound mode of Norton Sound ice. Although the drawing shows Bering Sea ice directed southward, the range of α producing the outbound mode is indicated on the drawing left, and includes values of α from 170° through 360° to 20°. Also shown is the range of values of α, postulated to create a second gyre mode not observed here.

Figure 3. This map represents the relationship between heading angle, α, of Bering Sea ice and the gyre mode of Norton Sound ice. This appears to be a transitional mode between values of α which would either result in Bering Sea ice being driven into Norton Sound or allowing ice to exit the sound.

Figure 4. The map represents the relationship between heading angle, α, of Bering Sea ice and the inbound mode of Norton Sound ice. Also shown here is the range of α, from 0° to 20°, postulated to produce a second gyre mode as a transition between inbound and outbound Norton Sound modes.



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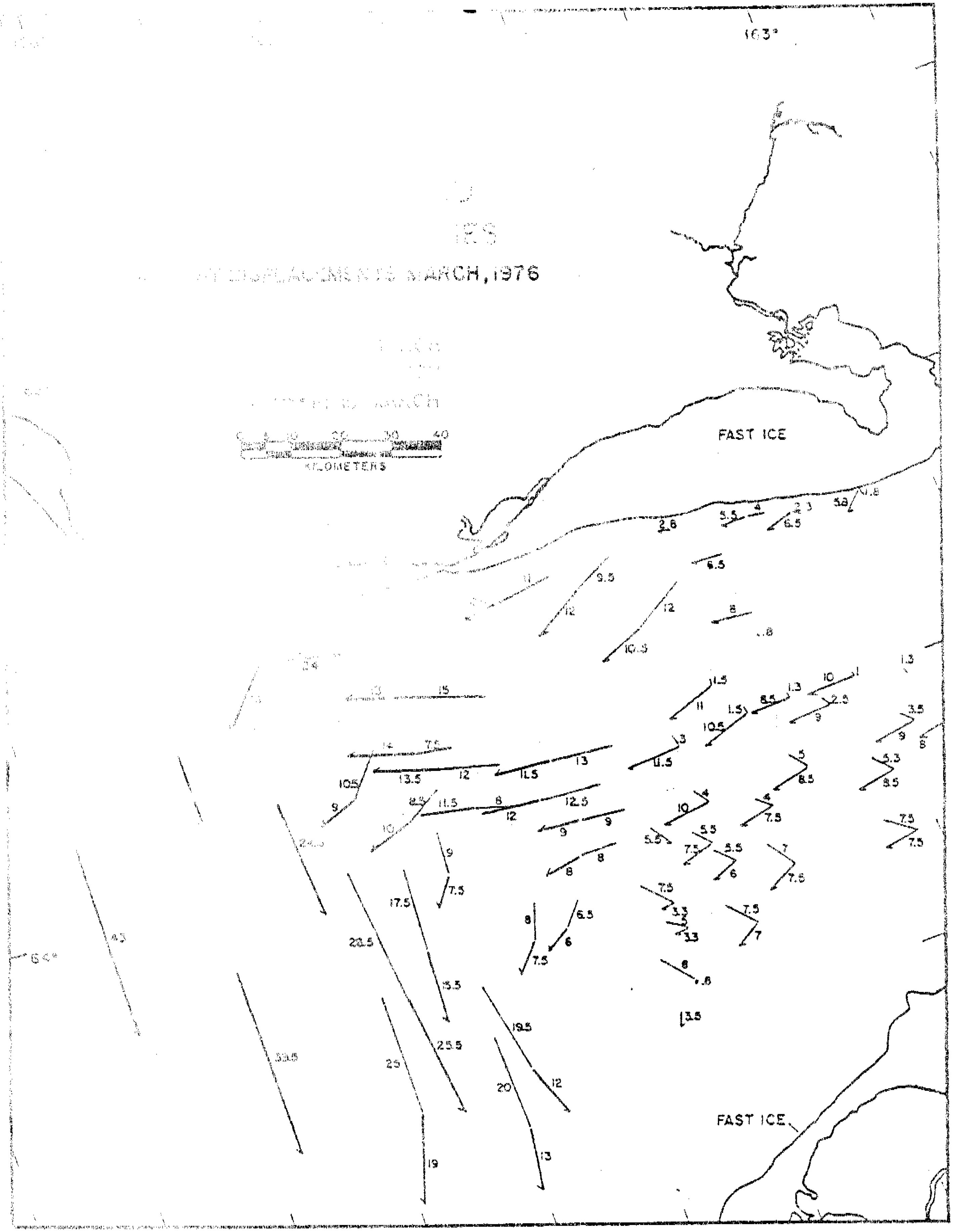

163°
MARCH, 1976
KILOMETERS
FAST ICE
64°
FAST ICE

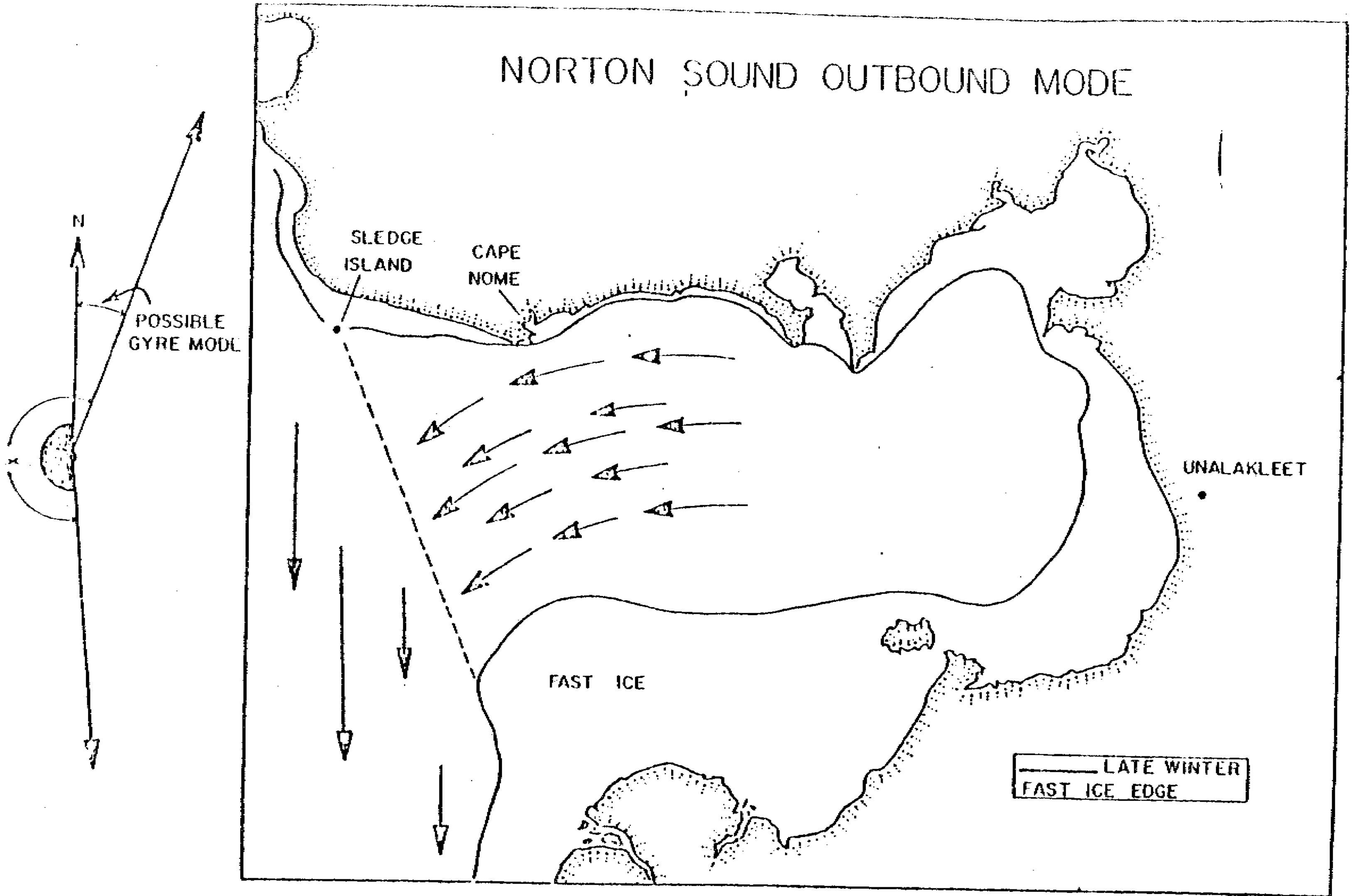
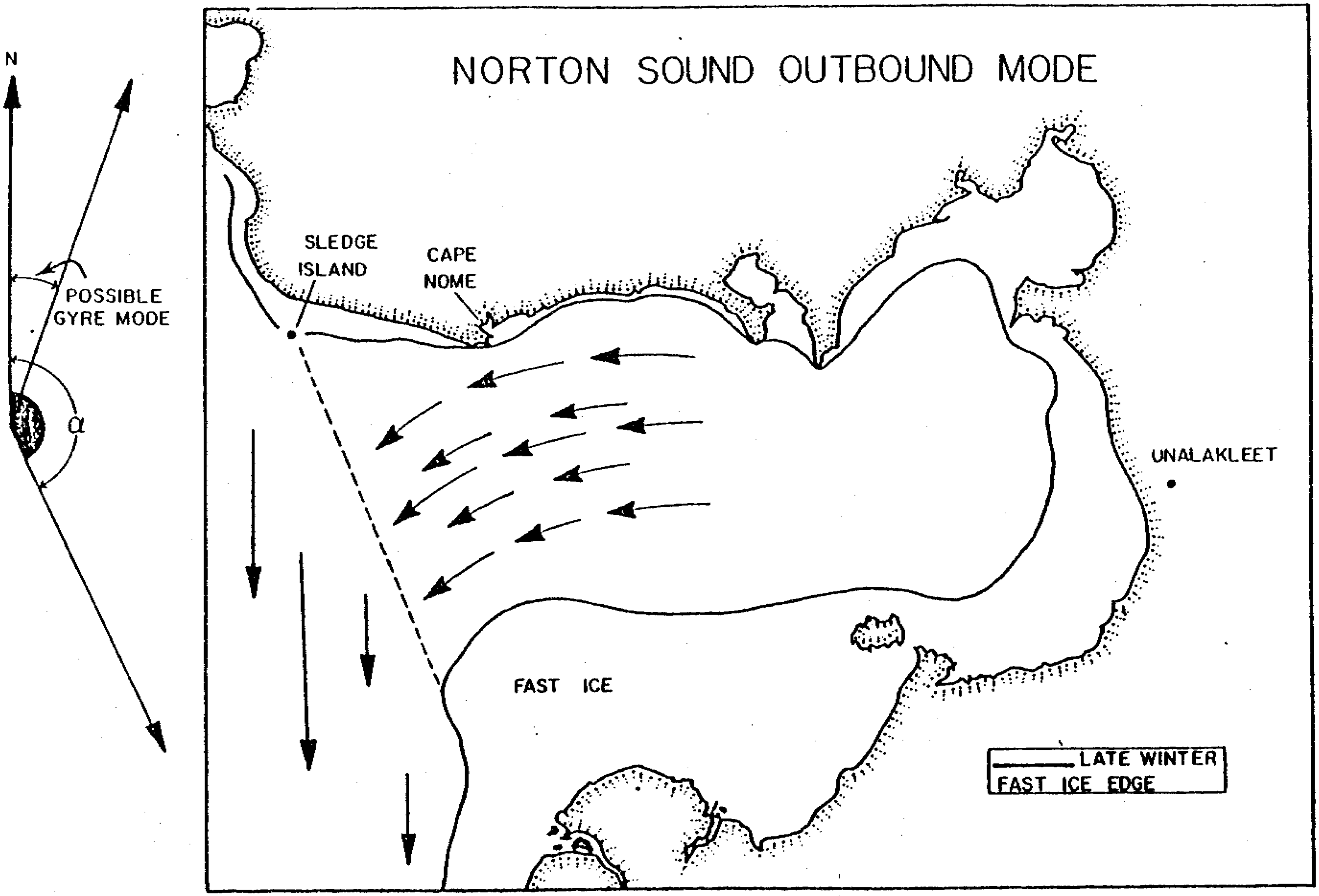


Figure 2. This map represents the relationship between heading angle, α, of Bering Sea ice and the outbound mode of Norton Sound ice. Although the drawing shows Bering Sea ice directed southward, the range of α producing the outbound mode is indicated on the drawing left, and includes values of α from 170° through 360° to 20°. Also shown is the range of values of α, postulated to create a second gyre mode not observed here.


N
POSSIBLE
GYRE MODE
α
NORTON SOUND OUTBOUND MODE
SLEDGE
ISLAND
CAPE
NOME
UNALAKLEET
FAST ICE
LATE WINTER
FAST ICE EDGE

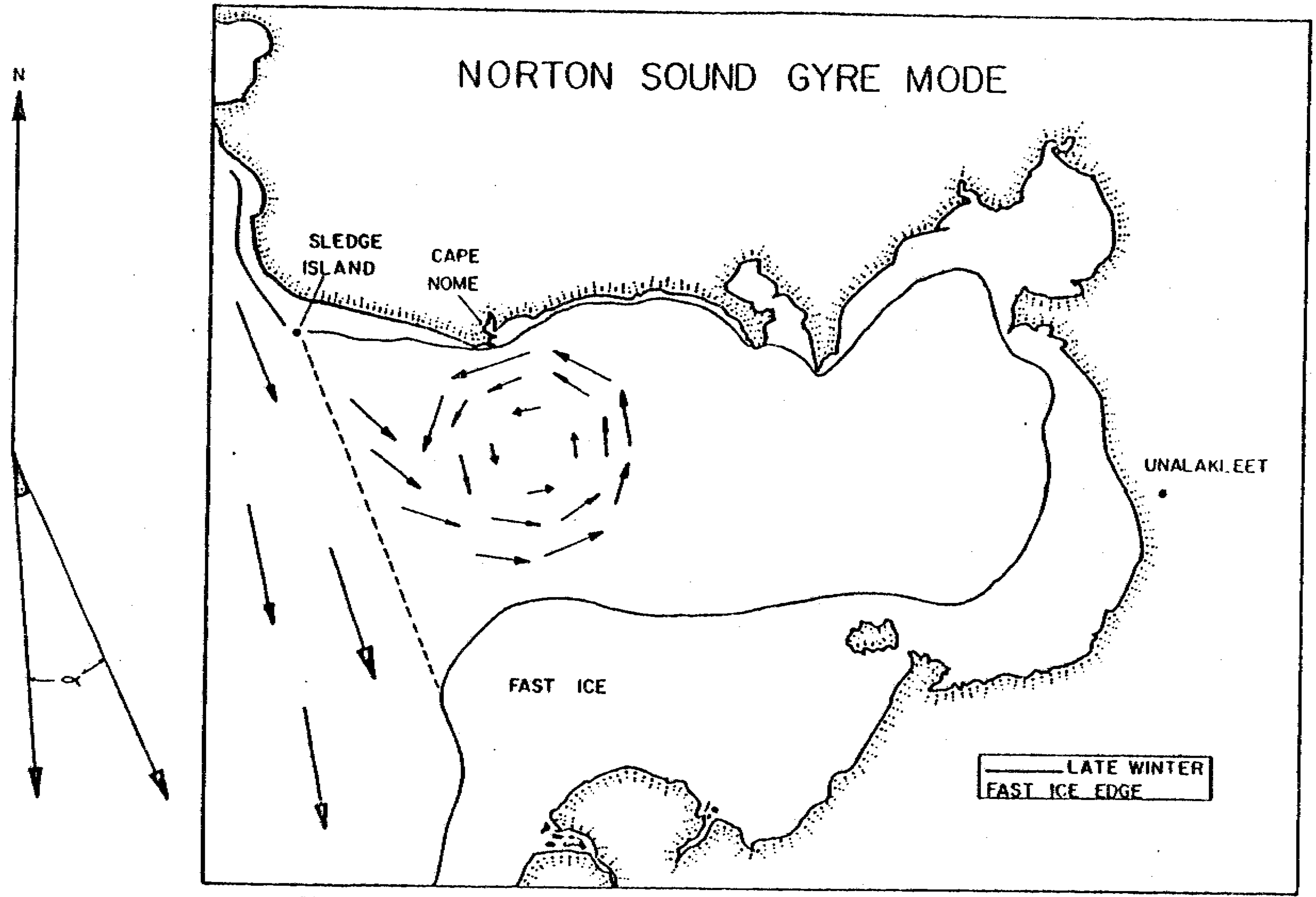
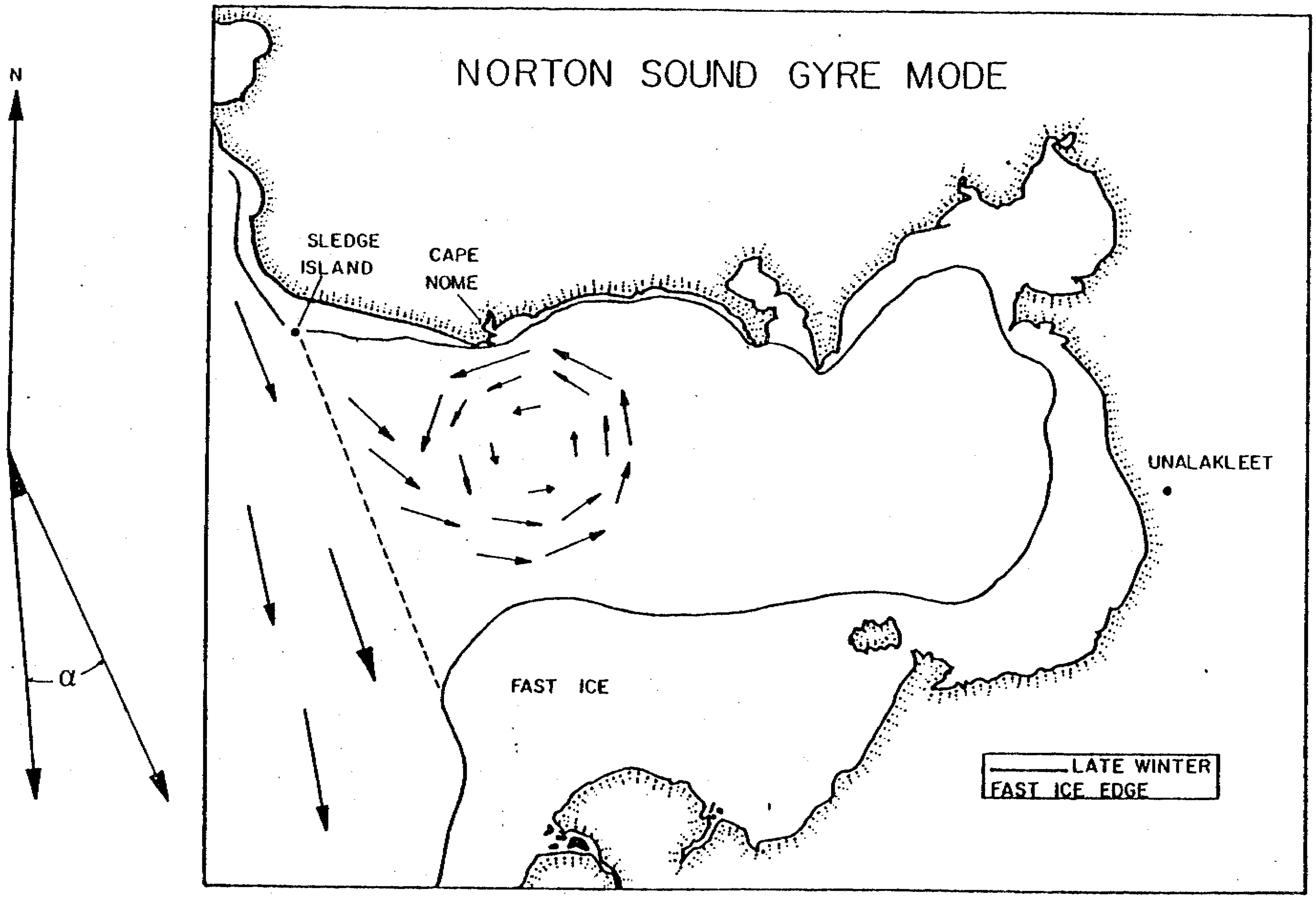


Figure 3. This map represents the relationship between heading angle, α, of Bering Sea ice and the gyre mode of Norton Sound ice. This appears to be a transitional mode between values of α which would either result in Bering Sea ice being driven into Norton Sound or allowing ice to exit the sound.


NORTON SOUND GYRE MODE
N
α
SLEDGE ISLAND
CAPE NOME
UNALAKLEET
FAST ICE
LATE WINTER FAST ICE EDGE

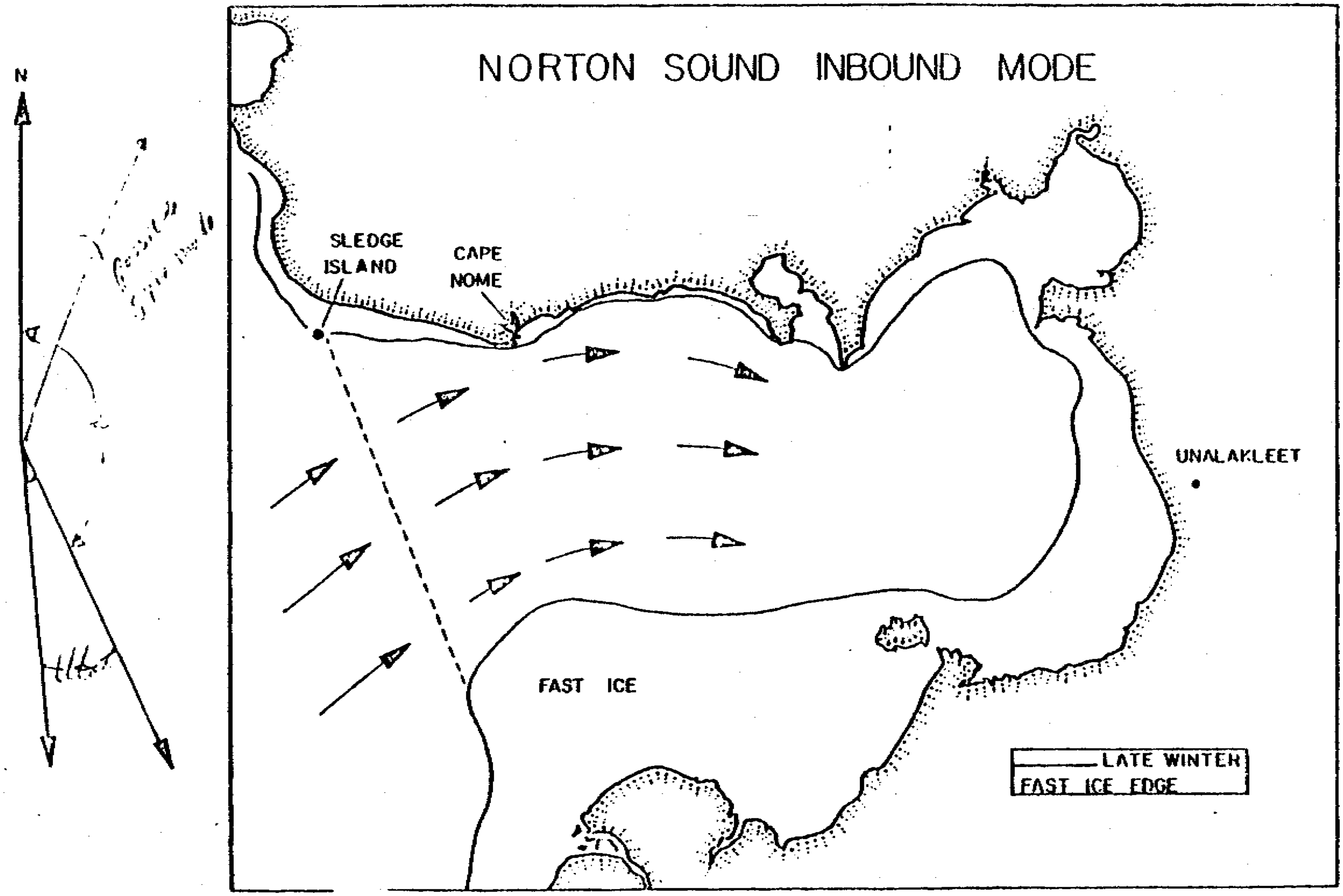
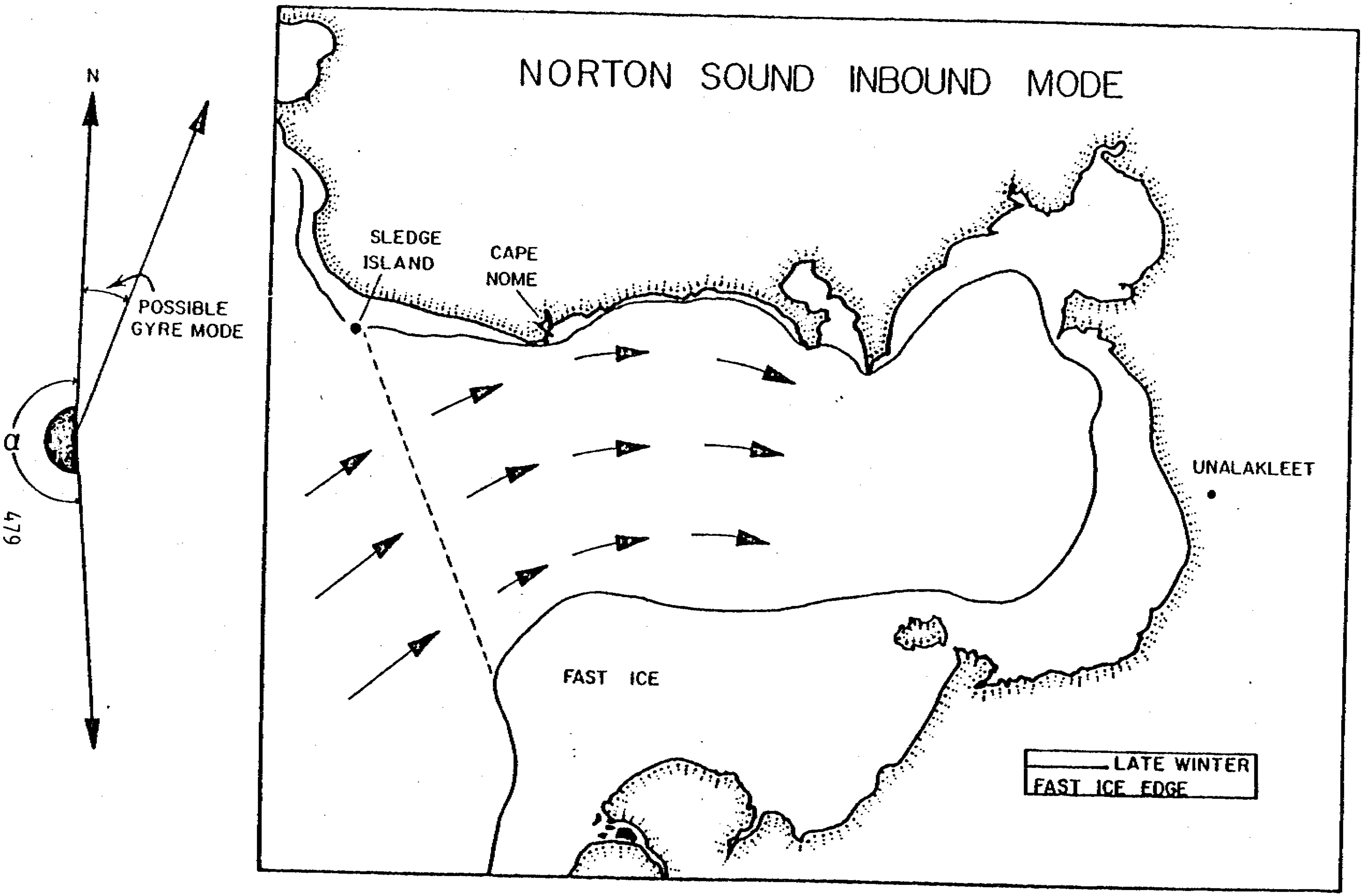


Figure 4. The map represents the relationship between heading angle, α, of Bering Sea ice and the inbound mode of Norton Sound ice. Also shown here is the range of α, from 0° to 20°, postulated to produce a second gyre mode as a transition between inbound and outbound Norton Sound modes.


NORTON SOUND INBOUND MODE
N
POSSIBLE
GYRE MODE
α
SLEDGE
ISLAND
CAPE
NOME
UNALAKLEET
FAST ICE
LATE WINTER
FAST ICE EDGE

SUMMERTIME ICE CONCENTRATION IN THE PRUDHOE BAY / HARRISON BAY REGION

BY

WILLIAM J. STRINGER

GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS, ALASKA

SCIENTIFIC REPORT
SUPPORTED BY
NOAA-OCS

CONTRACT NO. 03-5-022-55, TASK NO. 10

RU 267

MAY 21, 1981

This report resulted from a need to fill "data gaps" in OCSEAP studies discovered at the Sale 71 Synthesis meeting. The desired product was some characterization of summertime ice conditions in the Prudhoe/Harrison Bay region. The enclosed maps were generated by means of analysis of all existing Landsat imagery for the area in question (1972 through present) using a scaling grid with 12.5 km cells.

In order to achieve the characterization, it was determined to attempt to establish the dominant ice condition for the time periods chosen rather than the average floe concentrations. Hence the zones defined on the following maps are defined in terms of ice cover observed on fraction of occasions. This is not as simple to accomplish as determining floe concentrations and is subject to some interpretation. However, the results are probably more meaningful to studies of possible oil spill trajectories.

On the following pages the dates when Landsat imagery was available for this study are listed, along with the total number of observations for each time period. This is followed by six maps of characteristic ice concentration for bi-monthly periods between June 15 and September 15.

DATE	June 15-30	July 1-15	July 16-31	Aug. 1-15	Aug. 16-31	Sept. 1-15
1972						
July 25			x			
August 12				x		
1973						
July 2-3		x				
August 24					x	
September 11-12						x
1974						
June 26	x					
July 14, 15, 16		x	x			
August 2				x		
September 6, 8						x
1975						
June 30	x					
July 18, 19, 20			x			
September 9						x
September 12						x
1976						
July 13, 14		x				
July 30, August 1			x	x		
August 17				x		
September 5						x
1977						
June 22	x					
July 6, 7, 8, 9,		x				
July 13, 15		x				
July 24, 25, 27			x			
July 31, August 1, 2			x	x		
August 14				x		
September 2						x

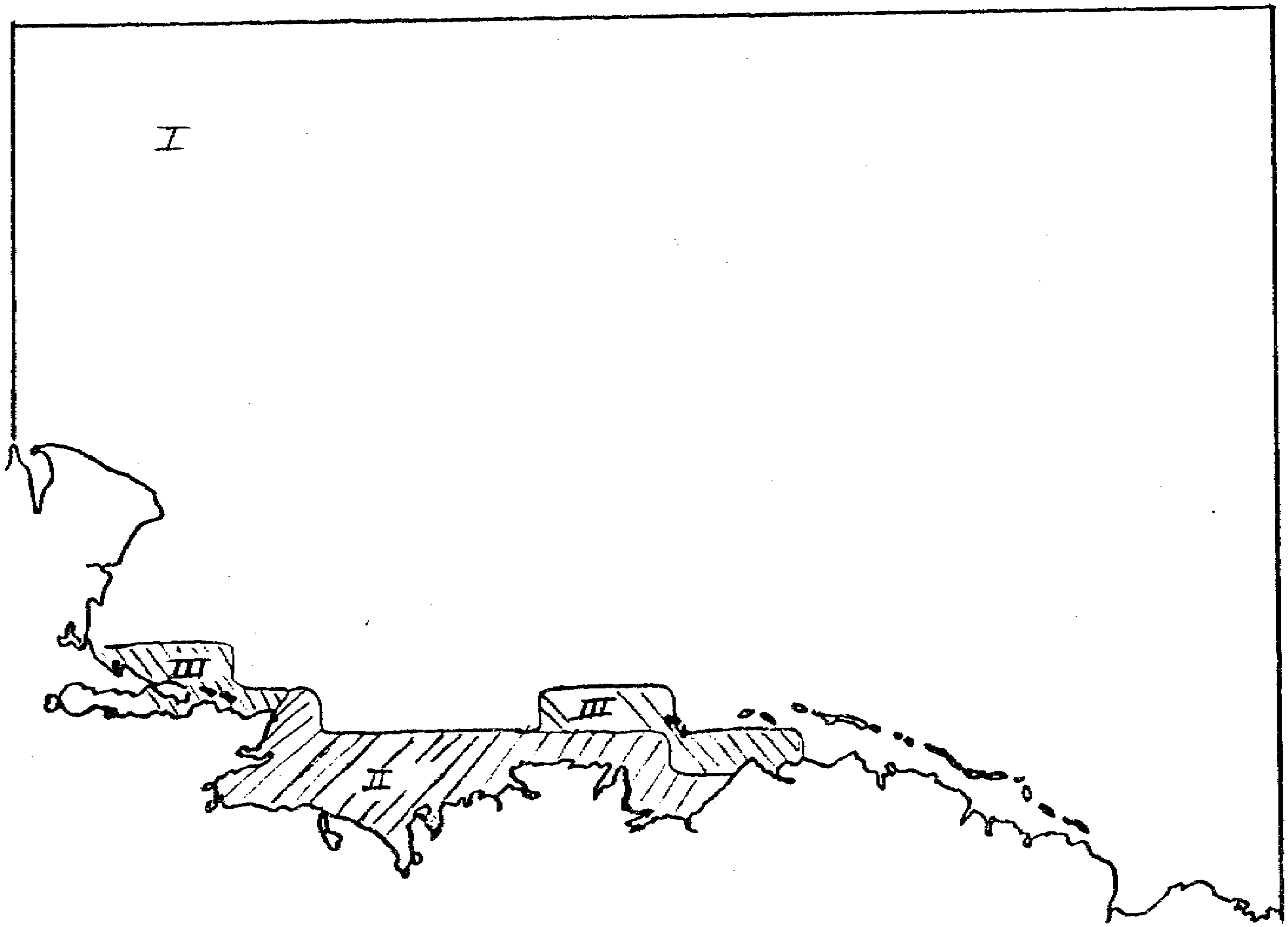
DATE	June 15-30	July 1-15	July 16-31	Aug. 1-15	Aug. 16-31	Sept. 1-1
1978						
June 25-26	x					
July 11, 12, 13		x				
July 20			x			
August 16, 18					x	
September 3, 4						x
1979						
July 14, 15, 16, 17		x	x			
1980						
June 24	x					
August 23					x	
TOTAL	5	7	8	6	3	7

June 15-30

I. characterized by > 90% ice cover on 50% or more of observed occasions

II. characterized by zero ice cover on 50% or more of observed occasions

III. characterized by variable floe concentration

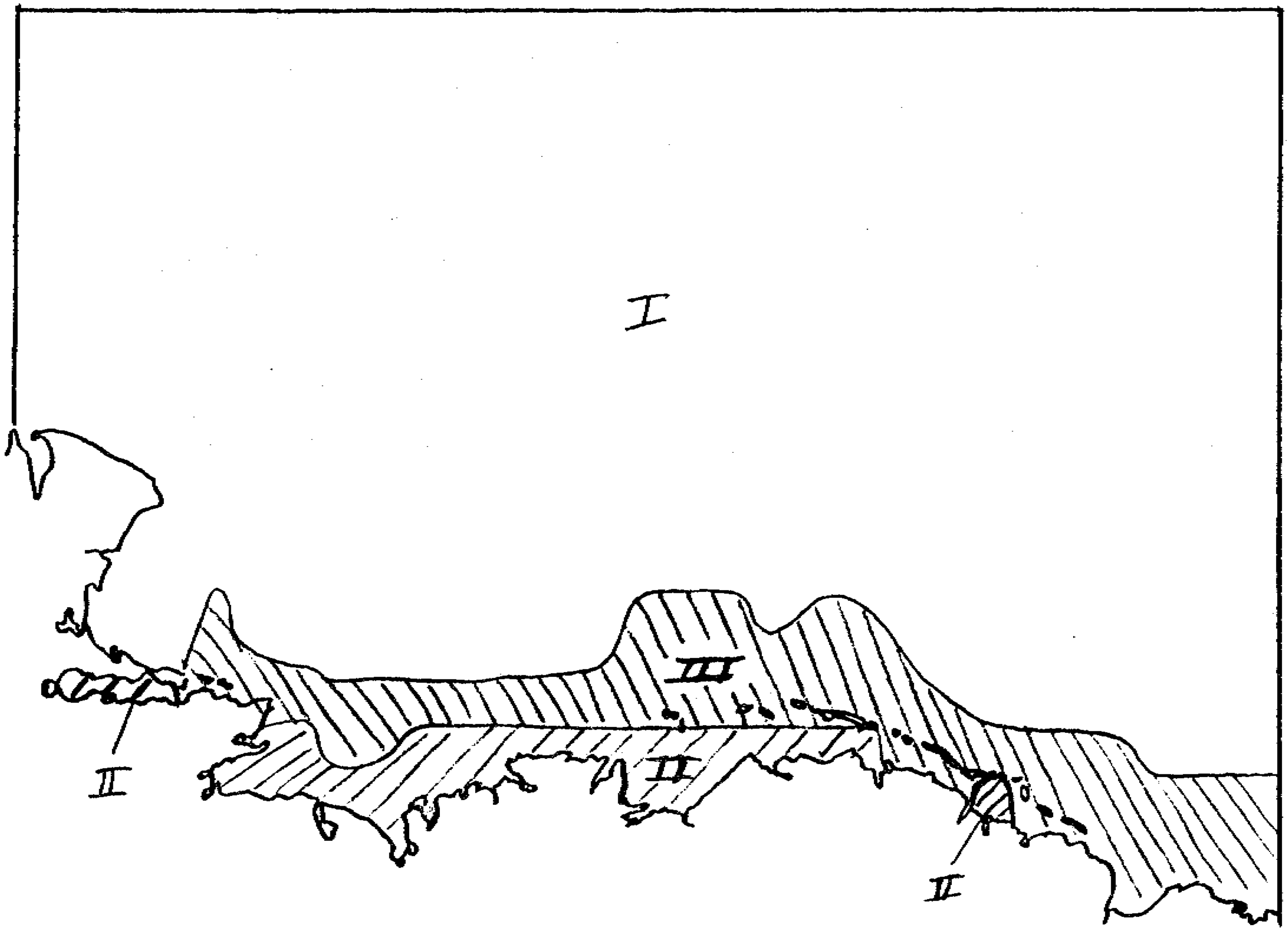


484

I. Characterized by > 90% cover on 50% or more of observed occasions

II. Characterized by zero ice cover on 50% or more of observed occasions

III. Characterized by variable floe concentration



July 16-31

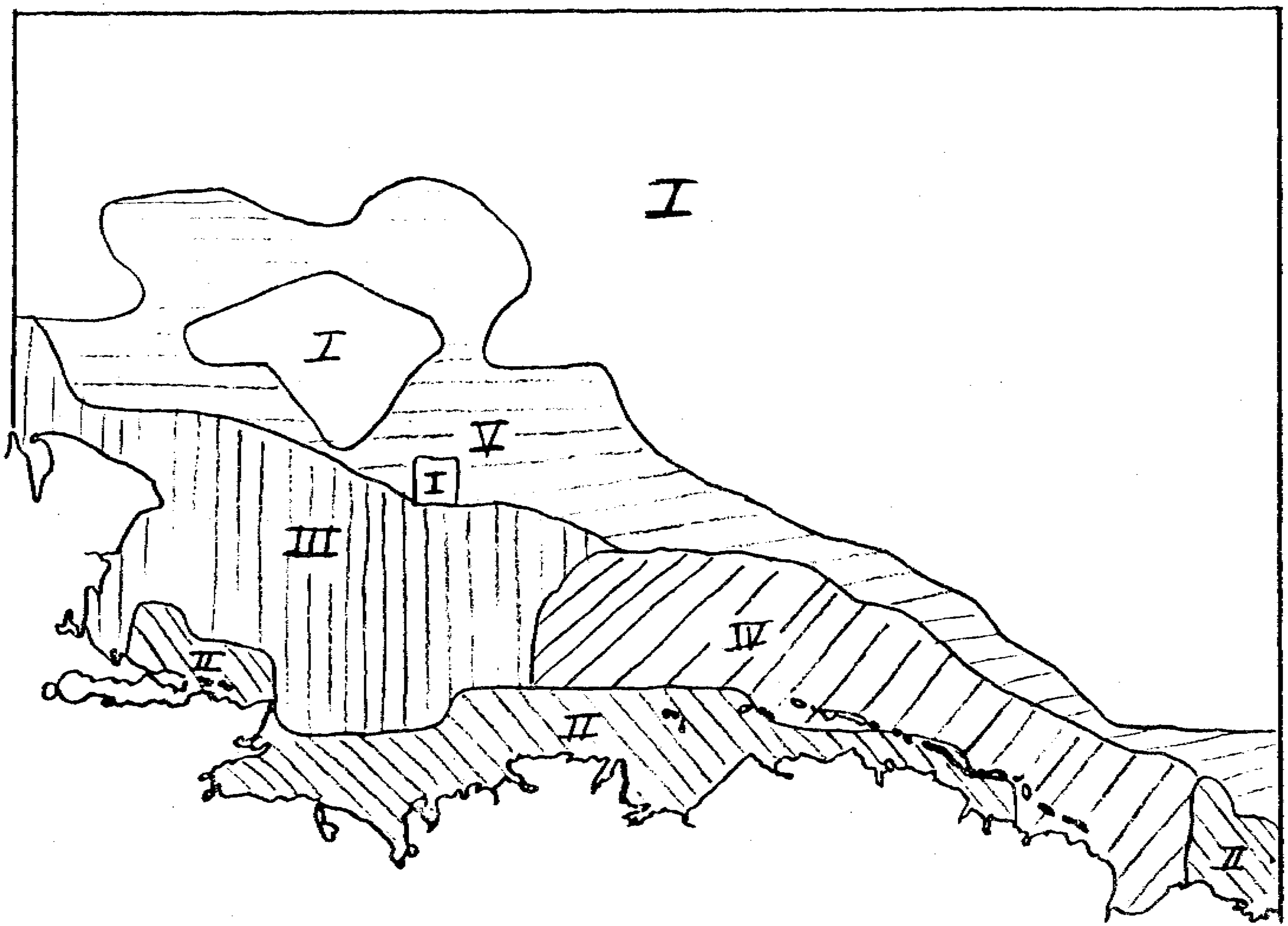
I. Characterized by > 90% ice cover on 50% or more of observed occasions

I. Characterized by zero ice cover on 50% or more of observed occasions

I, Characterized by variable ice conditions generally less than 50% concentration.

I characterized by 0-50% ice cover on 50% or more of observed occasions

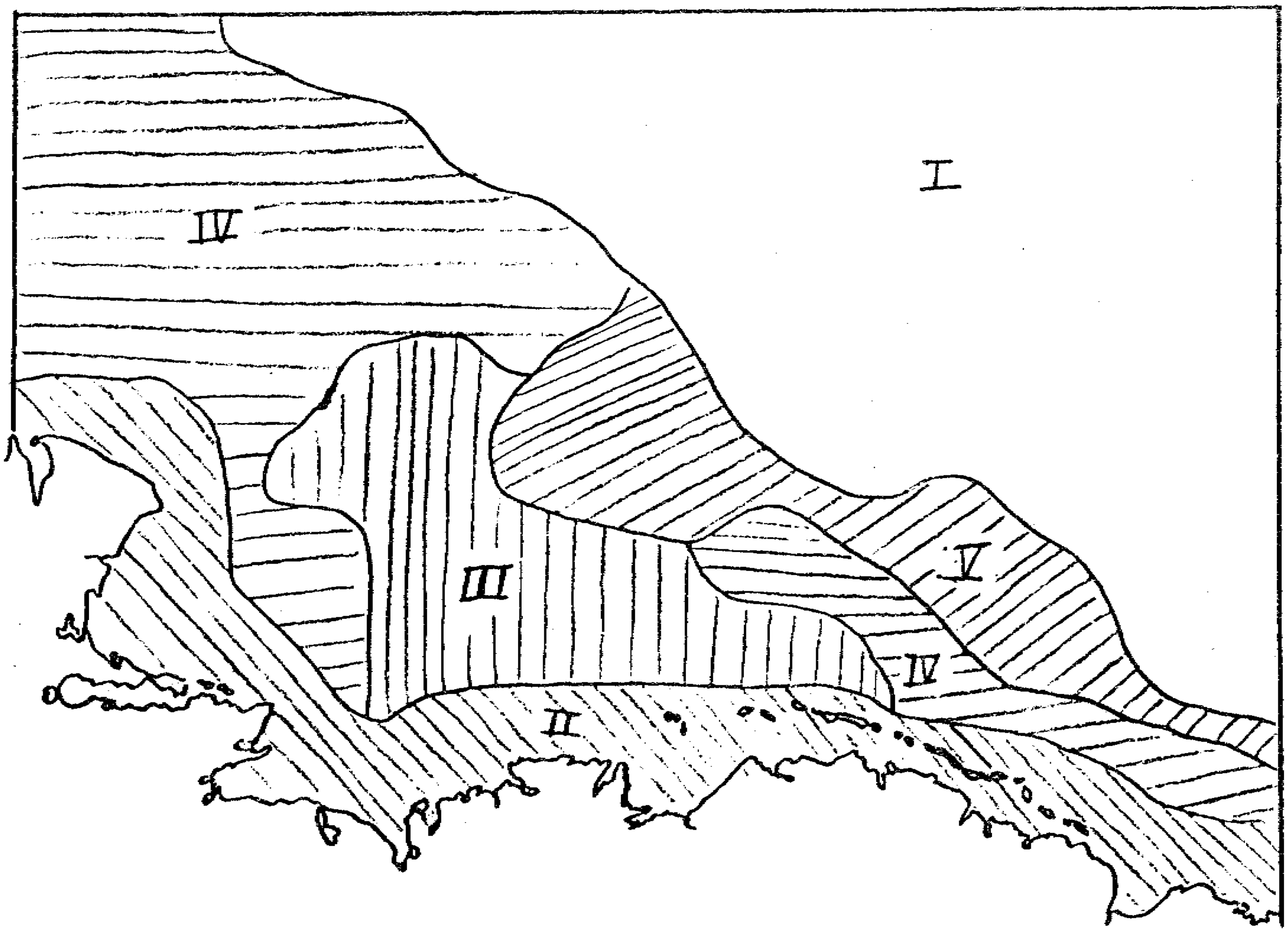
: characterized by 50-90% ice cover on 50% or more of observed occasions



486

August 1-15

I. Characterized by >90% ice cover on 50% or more of observed occasions
II. Characterized by zero ice cover on 50% or more of observed occasions
III. Characterized by variable ice cover generally less than 50% concentration
IV. Characterized by 0-50% ice cover on 50% or more of observed occasions
V. Characterized by 50-90% ice cover on 50% or more of observed occasions



August 15–31

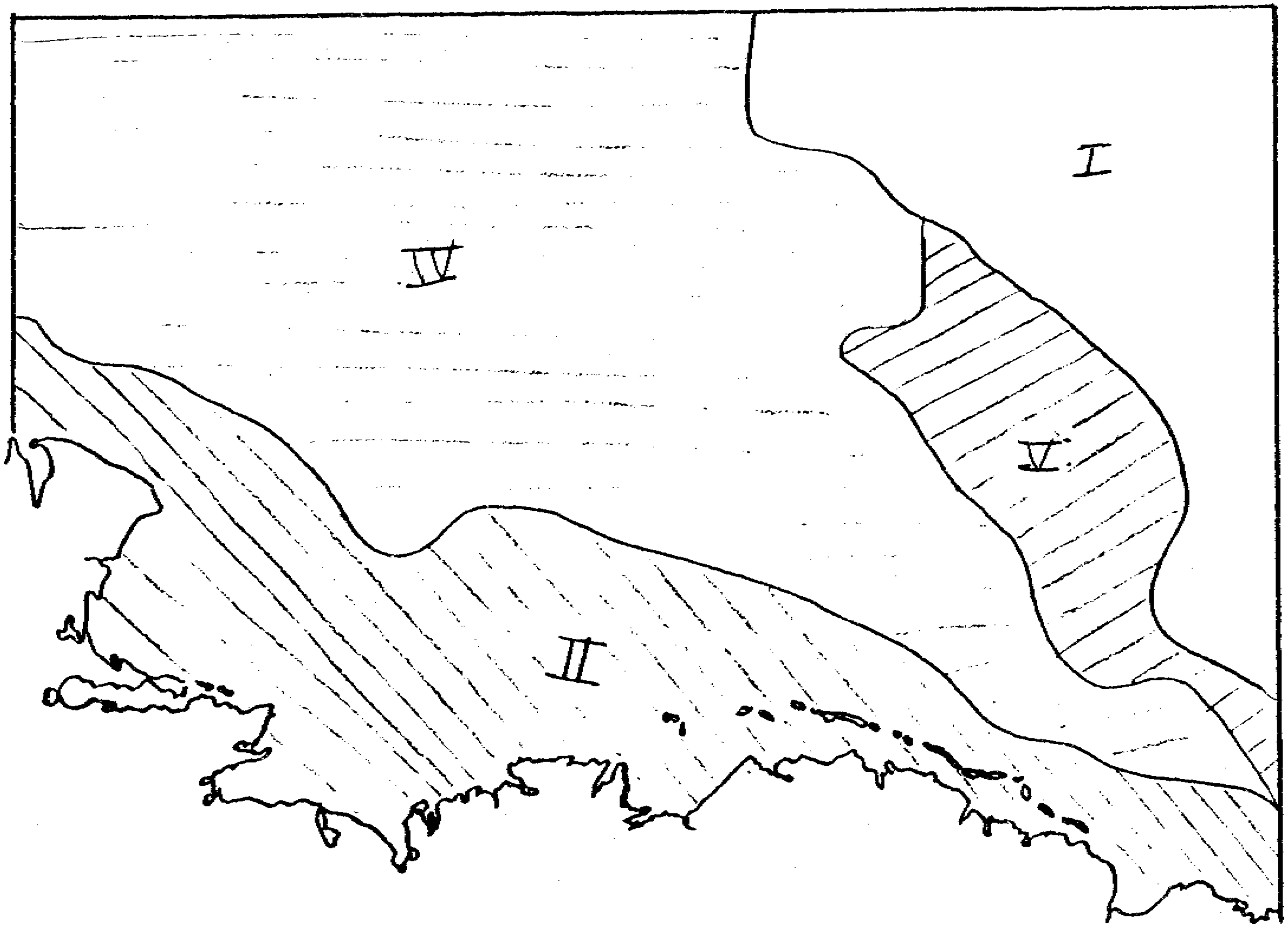
I. Characterized by >90% ice cover on 50% or more of observed occasions

II. Characterized by zero ice cover on 50% or more of observed occasions

III. does not occur

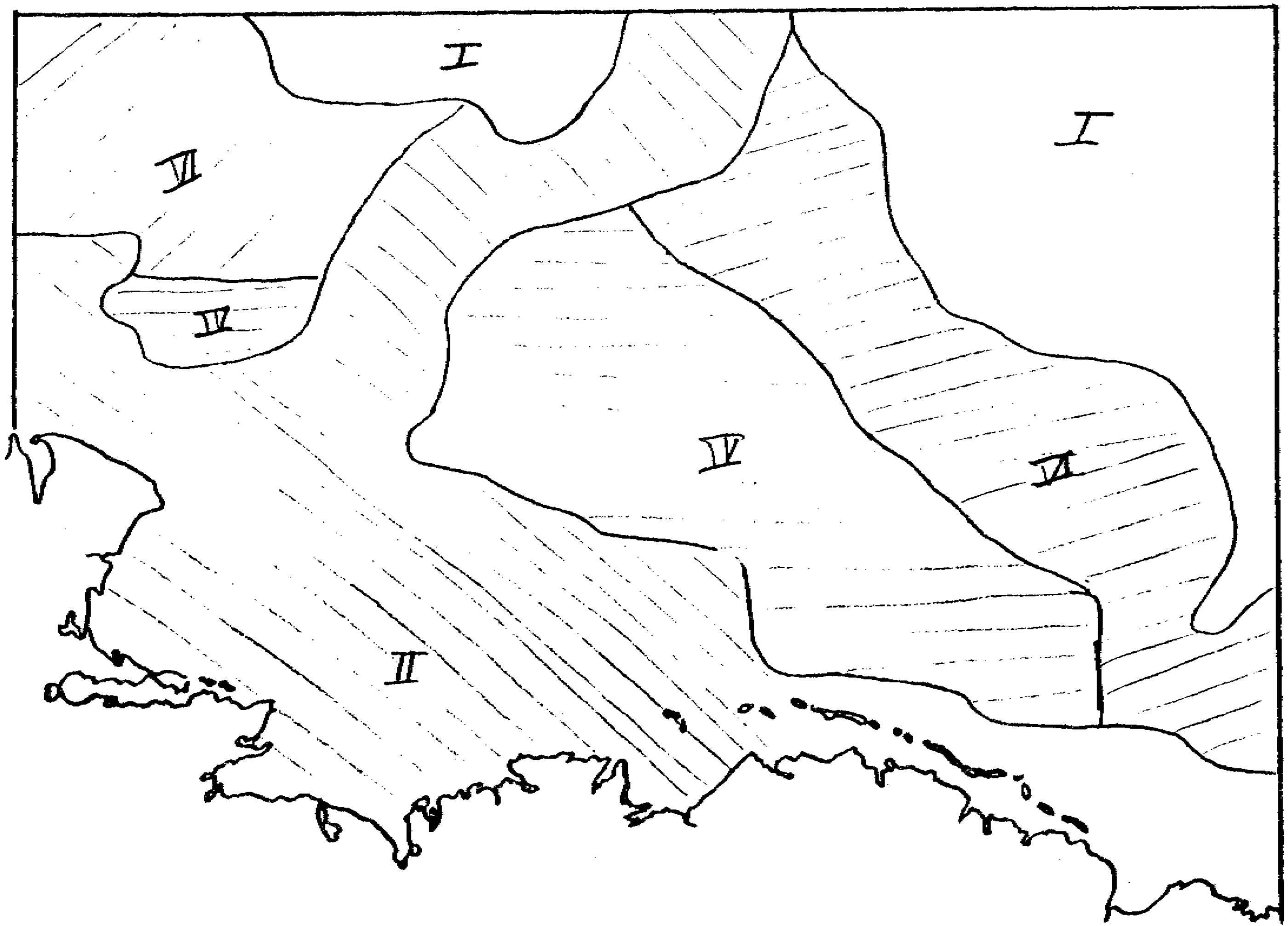
IV. Characterized by 0–50% ice cover on 50% or more of observed occasions

V. Characterized by 50–90% ice cover on 50% or more of observed occasions



Sept 1-15

I. Characterized by >90% ice cover on 50% or more of observed occasions
II. Characterized by zero ice cover on 50% or more of observed occasions
IV. Characterized by 0-50% ice cover on 50% or more of observed occasions
VI Characterized by variable ice cover generally greater than 50% concentration



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APPENDIX H

STUDIES OF THE BEHAVIOR OF OIL IN ICE, CONDUCTED BY THE OUTER CONTINENTAL SHELF ENVIRONMENTAL ASSESSMENT PROGRAM

by

William J. Stringer

and

Gunter Weller

Geophysical Institute
University of Alaska
Fairbanks, Alaska

July, 1980

Prepared for NOAA - OCS

Studies of the behavior of oil in ice, conducted by the Outer Continental Shelf Environmental Assessment Program

William Stringer
and
Gunter Weller

Arctic Project Office
Outer Continental Shelf Environmental Assessment Program
University of Alaska
Fairbanks, Alaska 99701

Abstract

The Outer Continental Shelf Environmental Assessment Program has studied the behavior of oil in ice over a number of years. Early work in tanks in which ice was grown under the action of winds and waves was followed by research on the behavior of oil under ice of various degrees of roughness in a flume, simulating different current velocities. Satellite, laser profilometer, impulse radar and drilling data have allowed an assessment of the natural underside roughness of ice in the Beaufort and Chukchi Seas, and drifting buoys and satellite observation have given bulk displacements of the ice. From all these observations and some numerical modeling a picture of oil behavior in ice has been synthesized. A summary of the major results to date is presented.

1.0 Introduction

Petroleum exploration and development is proceeding rapidly in the ice-covered waters of the arctic continental shelves. As a consequence of this development, environmental risks associated with oil spills are anticipated. The Outer Continental Shelf Environmental Assessment Program (OCSEAP) conducted for the U.S. Bureau of Land Management by NOAA - the National Oceanic and Atmospheric Administration - attempts to evaluate such risks in a multidisciplinary research program. This program started in 1975 and continues to date; studies are conducted in the Gulf of Alaska, the Bering Sea and the Chukchi and Beaufort Seas. As part of this research, the behavior of oil spilled in ice is addressed by OCSEAP. Oil spills in ice are a potential environmental problem along half of the Alaskan coastline for 6-10 months each year.

2.0 Small-scale behavior of oil in ice

This section discusses the small-scale (micro-scale) behavior of oil in ice. The spatial scale of processes discussed ranges from individual crystals to the crystal matrix of sea ice including brine drainage channels and to grease, frazil and pancake ice. Perhaps the most comprehensive knowledge of oil in ice on this scale is that of stable, stationary first-year ice. Martin (1980) gives a detailed description of oil entrainment by smooth first year ice, based on both OCSEAP data and a field experiment carried out for the Canadian Beaufort Sea Project. Oil behavior in the Beaufort Sea region can be divided into the following three characteristic periods:

a. November-February. When oil is first released under smooth first-year ice, it collects in natural undulations beneath the ice, which are caused by snowdrift-induced insulation. These undulations have an amplitude of order 0.1 m and a length scale of order 10 m. Some oil also flows a short distance up into the ice through the brine drainage channels.

b. March-May. In the spring as the ice warms, top-to-bottom brine channels open up in the ice and the oil rises through these channels to the ice surface where it spreads laterally, both under the snow and within the first few porous cm of the ice surface. The oil on the surface then absorbs solar radiation through the snow causing the snow above the oil to melt.

c. June-August. In the early part of the summer, the trapped oil continues to rise through the ice to the surface, where above the trapped oil melt ponds with oil surfaces form. Because the sun heats the oil and the winds blow the oil on the melt pond surfaces against the edges of the ponds, the oiled melt ponds grow both laterally and in depth faster than the un-oiled ponds. As the ice continues to decay throughout the summer, much of this oil in a weathered form will flow back into the ocean either off the tops of the floes or by melting through the ice bottom.

The description of the behavior of oil in growing ice which is stirred by wind and waves is a more difficult matter. Martin, et al., (1978) have examined this process by generating waves in a laboratory tank in which they produced grease ice. The experiments showed that most of the oil introduced into the ice ends up on the ice surface beyond a "dead zone". The dead zone marks the transition from liquid to solid behavior of the grease ice. Field observations (Martin, 1980; see section 3) confirm that if oil were spilled in the various polynya zones of a freezing ice front, some of the oil would end up on the grease ice surface, some would accumulate in the local dead zones, and a small fraction would be emulsified into oil droplets by wave breaking, where these droplets would then circulate around within both the grease ice and the ocean circulation at the ice front.

When grease ice freezes further it develops into pancake ice. Martin, et al., (1978) showed in the laboratory that when grease ice becomes so thick that the circulation within the ice is suppressed, the surface freezes into chunks of pancake ice floating over a grease ice layer. They also found that oil released under long linear pancakes came to the ice surface between the oscillating cakes and that the oscillating motion pumped about 50% of the oil onto the pancake surface. Because long linear cakes do not appear in nature the test was repeated in a two-dimensional wavefield, so that nearly circular cakes were formed. Despite ridges formed around the rims of the pancakes, oil was pumped over the rims onto the pancake interior. Approximately 25% of the spilled oil reached the surface of the pancakes in this manner. The rest was bound up in small droplets in grease ice under the pancakes.

Another interesting problem is the movement of oil by ocean currents under a rough or smooth solid ice cover. OCSEAP has investigated this problem set through a contract with ARCTEC (Schultz, 1980). ARCTEC, using a long, glass-walled flume constructed in a cold room was able to study the equilibrium thickness of an oil film beneath smooth freshwater ice and the current conditions required to cause that film to move. They found that the equilibrium thickness was linearly dependent on the difference in density between the oil and water beneath the ice. For the range of densities to be expected for crude oil this slick thickness ranges from one half to one cm.

Measurements of currents required to move an oil slick showed a marked dependence on small-scale roughness. Under smooth ice, as might be expected to be found after melting has begun in late spring, slick threshold velocities were between 3 and 7 cm/sec. However, with ice of 1 cm amplitude roughness, as might be found under growing salt ice from November to late May, the threshold velocity increased to the the vicinity of 25 cm/sec.

These results which are discussed in greater detail by Cox and Schultz (1980) indicate that a relatively large volume of oil can be spread beneath the ice cover in the form of a 0.5-1 cm thick slick and that for many months this slick can be immobile in the Beaufort Sea and perhaps other areas such as Kotzebue and Norton Sounds and some nearshore areas of the Chukchi Sea where underice current velocities are below the threshold required to cause the slick to move.

3.0 Meso-scale behavior of oil in ice

The previous section discussed the behavior of oil in ice on the microscale (individual crystals to pancake ice); the present section will examine oil behavior on the meso-scale (floes of pack ice to ice ridges and ice plumes near an open ice front). Ice characteristics, both static and dynamic, will be discussed and related to the observed and projected behavior of oil introduced into or under the ice.

One of the important characteristics of shore-fast ice is its underside configuration since this determines the amount of oil that can be stored under the ice in the absence of currents; this is referred to as the oil storage potential. In broken and moving pack ice this oil storage potential is less important, particularly if the ice floes are small, since it is likely that the bulk of the oil will flow into the leads between the floes. The underice contours can be determined by drilling holes and measuring ice thickness, by correlating ridge heights with keel depths (Wadhams, 1976; Tucker, et al., 1979), by examining the thickness of the snow cover on the ice (Barnes, et al., 1979) or by using remote-sensing techniques such as the use of impulse radar.

All the above methods have been used by OCSEAP. Correlating snow thickness with ice thickness, Barnes, et al., (1979) found some interesting results by cutting trenches parallel and perpendicular to sastrugi and snow ridges on shore-fast ice near Prudhoe Bay. Snow depth and ice thickness varied about 30-40 cm and exhibited a negative correlation -- thin ice coinciding with a thicker insulating snow cover. Elongate ridge and trough patterns on the under-ice surface paralleled the surface snow ridge pattern on wavelengths typically 10 m wide, yielding sub-ice voids of 0.02-0.047 m^3/m^2 (600-1200 barrels per acre). Diving observations indicated a smaller set of depressions 5 cm or less in depth, oriented parallel to the ice crystal fabric. The results imply that there is a seasonal stability to the snow ridge pattern and that oil concentrations under the ice would be indicated by surficial snow morphology in the fast ice zone.

The quickest and most reliable method of routinely determining under-ice contours is provided by impulse radar which has now been perfected to give reliable results over relatively large areas and with good resolution (Kovacs, 1977). The radar can provide profiles of annual as well as multiyear ice. Kovacs (1977) data show that annual ice of 1.91 m mean thickness had a storage potential above the mean ice thickness of 0.027 m^3/m^2; that of multiyear ice of 4.31 m thickness was 0.293 m^3/m^2. The results for annual ice are close to those obtained by Barnes, et al., (1979), as described above. Multiyear ice could theoretically hold approximately 1.8 million barrels of oil in a one square kilometer area. A variety of different ice types have been sampled since then with the impulse radar (Kovacs, 1980).

The above calculations of potential oil containment of multiyear ice have assumed that the oil will remain stationary under the ice. As has already been shown in section 2, it requires only a relatively small current to set at least some of the oil in motion. Measurements by current meters placed under the ice in shallow water show (Matthews, 1980) that velocities are generally small during most of the winter; around 5-10 cm/sec in waters less than 20 m deep in the vicinity of Prudhoe Bay. Continuous current measurements in these shallow waters are threatened by moving ice, particularly in spring, and it has been found to be very difficult to obtain good year-round current values. Weeks and Gow (1979) have discovered a unique, quick and cheap method to get prevailing current directions at least. Their findings show that ice crystals grow with their c-axis parallel to the prevailing current. Analysis of ice cores below 30 cm depth to determine crystal orientations show very good correlations with measured current directions. Similar results were obtained by Cherepanov (1971) in the Kara Sea. A quick survey of prevailing currents along the coastline, around islands and capes, is thus possible. In addition there is some indication that aligned ice is capable of entrapping more spilled oil than non-aligned ice (Martin, 1977) although it is not clear why this should be so. Strength properties of the ice, incidentally, are also affected by the crystal orientation (Shapiro, 1980).

Oil can also be moved by winds and currents in open water stretches between ice floes and can be swept under the ice. For example, the oil spill in Buzzards Bay, Massachusetts in January 1977 showed that tidal currents swept oil under the ice and collected it in the lee of rafted ice, eventually filling shallow surface ponds on the ice to a depth of 100-150 mm (Deslauriers, et al., 1977). Estimates from aerial photographs suggested that such ponds contained as much as 30% of the spilled oil.

Apart from currents moving oil under the ice and between ice floes, the ice itself can be displaced under the action of wind, water and other stresses. Oil entrained in the ice or located in pockets under the ice will move with the ice. The Buzzards Bay spill showed that oiled floes moved considerable distances before they melted and the oil was released. In the Arctic Ocean oiled floes may move hundreds of kilometers before releasing the oil. Large-scale bulk displacement of pack ice and any contained oil will be discussed in the next chapter, but the meso-scale process of shorefast ice displacement, transport of the oil in leads (including "lead pumping"), incorporation of oil into pressure ridges and the behavior of oil along an open ice front are the subjects of discussion in this section.

Shore-fast ice is relatively stable but horizontal movements up to 100 m are occasionally possible (Weeks, et al., 1977). Pack ice displacements of several tens of kilometers per day are possible in the Beaufort Sea (Untersteiner and Coon, 1977). When leads close, two processes may occur that affect the dispersal of the oil:

1. Oil in the open leads will be compressed to greater film thicknesses and lateral flow along the leads will occur from areas of thick oil films to unoiled parts of the leads. This process will continue until obstructions in the leads cause the oil to overflow over the surrounding ice. Campbell and Martin (1973) have hypothesized that long linear leads can transport oil very rapidly over long distances; the effectiveness of this "lead pumping" has been questioned, however, by Lewis (1976) who points out that leads are rarely long and linear without bends and projections which would stop the oil flow when they make contact with the other side of the lead.

Very large leads, on the other hand are a regular feature of the Beaufort Sea ice, particularly in spring, as seen on LANDSAT satellite imagery. Lead pumping on a small scale undoubtedly can occur, as discussed in chapter 2, quoting the results of Martin, et al. (1978).

2. The second process occurs when the leads close up completely and the ice on either side of the lead is deformed into pressure ridges. Before the leads close up, the bulk of the contained oil is spilled over the surrounding ice. As the ridge is formed, the oiled ice will be broken up and incorporated into the ridge. Some of the oil will be retained in the ridges, possibly over several years, but there are no reliable numbers of how much oil will be entrapped and when it will be released and how much will remain free in the initial ridging process. The process of ice ridging itself has been described in some detail by Parmeter and Coon (1972) and is now the starting-off point for studies by OCSEAP (Coon, et al., 1980) adding oil into the ridging process.

Quite different conditions exist for the interaction of oil and ice along an open ice front, such as exists in the Beaufort Sea at the beginning of freeze-up or during ice decay in spring. These processes were studied for OCSEAP by Martin (1980b) in the Bering Sea. The Bering Sea location was chosen for convenience of logistics support and for the longer operating period that is possible in those waters. In the lee-shore regions of the Bering Sea, ice formation is dominated by the presence of wind, waves and swell. Laboratory experiments (Martin, et al., 1978) and field observations (Martin, 1980b) showed that the kinds of ice which form in these regions are grease and pancake ice. The laboratory experiments also showed (see section 2) that much of the oil spilled within these kinds of ice accumulates on the surface.

LANDSAT satellite imagery in the Bering Sea showed freezing sea fronts often to consist of long linear ice plumes approximately parallel to the wind and extending 10-40 km downwind. Downwind of the ice plume accumulations of new grey ice were usually observed (Martin, 1980b). Dunbar and weeks (1974) suggest that oceanic Langmuir circulation leads to the formation of the grease ice plumes. If any oil in this zone were to be emulsified into small droplets by wave breaking, these droplets circulate around in the Langmuir rotors, which may have down-welling velocities of between 20-60 mms^{-1} (Pollard, 1978). This could lead to oil being distributed throughout the water column.

Another factor of oil-ice interaction near an open ice front that needs to be considered is the motion of ice floes under the action of ocean swell. The case of pancake ice in a wind-and wave-agitated tank was already discussed in the previous section and showed that oil will be pumped onto the floe surfaces by the oscillating motion of the ice. The amount of oil pumped to the surface was approximately 25% of the total oil. We can thus expect that a sizeable fraction of the oil will be deposited on the surface, with the remainder bound-up in the grease ice-pancake ice mixture. Experiments in the Bering Sea suggest that a similar effect will occur in nature in this region (Martin, 1980b).

Other meso-scale considerations involve the interaction of oil with obstructions under a solid ice cover as found in the extensive fast ice areas of the Beaufort and Chukchi Seas. Direct, full scale spills are difficult to manage and often it is not possible to perform such experiments under a variety of conditions. Flume tests by Arctec similar to those described in section 1 (Schultz, 1980) were therefore performed to measure the effect of small but abrupt under-ice obstructions on oil slick motion. The obstructions were triangular and rectangular in cross section and on the order of 30 cm deep. The experimentors have presented arguments that the mechanisms active at this scale are valid all the way to large scale obstructions -- such as ridge keels extending to 30 m depths or more.

Their results indicate that oil trapped upstream of such obstructions can be "flushed out" by currents with velocities in the 15 to 25 cm/sec range. Hence, small obstructions as found in many ice fields and even large ridge keels will not obstruct the motion of a slick if current velocities are sufficient to cause the slick to move under small-scale rough ice. (presumably these velocities would also be sufficient to "flush out" the undulating underice pockets measured in the Beaufort Sea by Kovacs, 1980).

Many areas of the Beaufort and Chukchi Seas and Norton Sound appear to be immune from 25 cm/sec underice currents under normal conditions. In these areas some deep pooling might be expected to take place if obstructions are close to the source of spilled oil. However, even in the absence of obstructions the equilibrium thickness (0.5 to 1.0 cm) is so great that large amounts of spilled oil can be contained in a relatively small area due to that mechanism alone. For instance, a 1 cm thick film represents 300 bbl/acre or 1.9×10^5 bbl/sq. mile.

4.0 Large scale transport of oil in ice

In order to understand the bulk transport of oil in ice, both static and dynamic aspects of sea ice on a large scale must be known. At the outset of OCSEAP little was known about Alaskan nearshore ice conditions except that during winter and spring fast ice generally extended to water depths of twenty meters or so and was usually bounded by grounded ice ridges. Beyond fast ice was the "shear zone" forming the boundary between fast ice and pack ice. The pack ice was thought to be generally in motion, constantly breaking and refreezing. In order to determine these characteristics more closely, Stringer (1978) mapped nearshore ice conditions along the Beaufort, Chukchi and Bering coasts of Alaska using Landsat imagery at 1:500,000 scale. These maps, produced for representative periods between February and September have been analyzed in terms of nearshore ice characteristics.

In particular, the location of the edge of fast ice was determined as a function of time for all three coastal areas. These results indicate that within statistical bounds the fast ice provides a stable reservoir for spilled oil for much of the year. Although these bounds generally coincide with the 20-m isobath in the Beaufort Sea region, in portions of the Chukchi coastal area and along the entire Bering coast this is not true. However, it was also found that for long periods of time (up to six or eight weeks' duration) fast ice in the Beaufort Sea can extend well beyond the twenty meter isobath. These periods are generally during February-March. During these months it is entirely possible that oil spilled beneath Beaufort Sea ice will remain completely beneath the ice (except for small quantities rising in thermal cracks and breathing holes made by marine mammals).

The situation along the Chukchi coast is quite different: the boundary of shorefast ice is defined by a constantly active flaw lead from Barrow to Cape Lisburne. The fast ice edge is much closer to shore along the Chukchi Sea coast than the Beaufort Sea. In addition, currents in the nearshore area are much stronger. As a result it is likely that an under-ice oil spill will not be entirely contained under fast ice, but will also be incorporated into newly-forming ice in the active flaw lead and will be transported as this ice is advected away from the coast.

When one considers coastal areas south of Cape Lisburne and in the Bering Sea a wide variety of nearshore ice conditions are encountered which again will have quite different effects on the oil-ice interaction problem. Generally the fast ice extent is limited to increasingly shallower waters as one proceeds southward. This behavior results from a combination of three factors:

1. moderation of climate with decreasing latitude
2. increased tidal action breaking nearshore ice
3. advection of ice away from the coast

As a result mobile pack ice and newly-forming ice is often found in very shallow areas. The likelihood that petroleum development activities will be confined to stable fast ice areas is very small. As a consequence, an oil spill will almost certainly involve interaction with a combination of ice floes, newly-forming ice and open water. Bering Sea ice is quite mobile and spilled oil is likely to be transported relatively quickly to the ice edge (Pease, 1980; McNutt, 1980) where it will be released in the ice-water transition zone (Martin, 1980b).

There is evidence that ice in the Bering Sea region is generally advected to the south while oceanic currents are northward. As a result, less buoyant weathered petroleum released from the ice may be transported back beneath the ice cover.

Satellite imagery and drifting buoys can be used to monitor ice motions to oil spill trajectories. As part of the OCSEAP studies satellite-interrogated and tracked buoys were placed in nearshore pack ice at various locations along the Beaufort Sea coast (Untersteiner and Coon, 1977). The trajectories obtained showed that while the general trend of ice movement is to the west, short duration reversals do take place, and for relatively long periods of time the pack ice can remain nearly motionless. OCSEAP extended these observations into the Chukchi Sea with buoys being deployed in pack ice at locations between Barrow and Cape Lisburne during March 1977 and 1978. By April 1 they had all been displaced southward towards Bering Strait over distances up to 80 km. However, after that date their drift was westward or northwestward. These results (Pritchard, 1978; Colony, 1979) indicate that oiled ice in the Chukchi during the spring of 1977 and 1978 would not have been transported into the Bering Sea but instead would drift northward and westward. Colony concluded that the probable fate of the surviving buoys was to be incorporated into the transpolar drift streams and exit into the Greenland Sea after two or three years.

As part of the OCSEAP 1977 Synthesis Meeting (OCSEAP, 1978), a working group chaired by K. Aagaard, constructed a scenario for an instanteous 25,000 barrel crude oil release in the pack ice of the Beaufort Sea. The scenario summarizes the results and information available to OCSEAP at that time. Oil is introduced into the main shear zone or moving pack ice off Prudhoe sometime after the fall freeze up. The oil would undergo a net westward translation together with the ice, but the movement would probably not exceed 50 km through February. Some of the oil would be trapped by the ice topography and some would also appear at the surface of both the leads and the ice as the ice field was constantly deformed. As the oil would come to the surface, it would become extremely viscous at temperatures below its pour point, which for Prudhoe crude is about -10C. Nonetheless, it would not be unreasonable to expect some lateral oil dispersion in association with blowing snow. This would continue intermittently throughout the winter and spring. Once at the lead surface, the oil might be transported long distances downwind, as some of the leads are very long indeed. However, except for windblown material, the oil would not appear inshore of the grounded ridge zone.

In April the westward ice drift would increase, moving the oil some 100-150 km to the west of the spill site by late May. Brine channels would bring oil to the ice surface, which, as before, would promote melting and drainage back into the water. Biodegradation would also be underway at this time, although the rate would still be relatively slow.

By late June, oil transported with the ice could be expected as far as Cape Simpson. The remaining oil fractions would by then have become quite dense, and some sinking should be expected. Oil within the water column over the outer shelf would probably move eastward with the Bering Sea water. In general, the oil would be very widely dispersed.

Some of the oil would probably have encountered the Colville River plume. As a result, some portion might have been moved further offshore due to the currents, and some would have settled to the bottom by bentonite adhesion.

Finally, any oil in open water in July and August is capable of coming onto the western Beaufort Sea beaches under the influence of summer winds. Ice with oil still entrained would move relatively rapidly northwest and become part of the pack ice.

5.0 Synthesis of Results

The overall direction of OCSEAP oil-ice interaction studies has been determined by a series of workshops involving OCSEAP principal investigators, and administrators, BLM environmental assessment personnel, representatives of the petroleum industry and local residents of the Beaufort Sea coastal region. The workshops synthesized current research findings and other results such as Canadian work in the eastern Beaufort Sea as reported by Milne and Simley (1976). The objective of the workshops has been to develop realistic arctic oil spill senarios in order to pinpoint research gaps and to provide BLM environmental assessment personnel with the most up-to-date oil spill fate and trajectory analyses. These senarios are being revised and considerably refined by Coon, et.al. (1980) as part of the OCSEAP research effort.

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ANNUAL REPORT

1 April 1980 - 31 March 1981

Research Unit 362

OCSEAP DATA BASE MANAGEMENT SUPPORT

John J. Audet
Sylvester J. Halminski
National Oceanographic Data Center

Michael S. Loughridge
Peter Sloss
National Geophysical & Solar-Terrestrial Data Center

31 March 1981

CONTENTS

NODC Data Management

I. INTRODUCTION

This Annual Report is presented in terms of primary data management tasks —data processing, data format development, inventories and catalogs, and requests for data and data products—in contrast to the annual report suggested for most OCSEAP investigators. The report consists of two sections; the first describing NODC data management activities in support of OCSEAP and the second describing similar activities by NGSDC.

II. DATA PROCESSING

A. Digital Data

The number of OCSEAP data sets received during the past year by NODC decreased significantly from previous years. The totals do not include data that have been submitted to either the Anchorage or University of Rhode Island facilities for preprocessing which have not yet been received by NODC. Resubmitted data, which totaled 42 data sets in the past year, also are not included in the table below. Geological and geophysical data submissions included in this table in previous years are discussed separately in the NGSDC portion of the report.

The data status described in Table 1 indicates that biological data submissions continue to dominate, similar to the past three years, although the number of chemical data sets have increased and nearly doubled with this year's submissions. The number of data sets which tend to increase the last quarter each year (January to March) did not materialize this year.

Table 1.

Quarterly Distribution of OCSEAP Data Received at NODC

	Apr-Jun 80	Jul-Sep 80	Oct-Dec 80	Jan-Mar 81	Total This Year	Total Last Year	Total to Date
Biological	9	48	6	12	75	414	1360
Physical	7	0	40	3	50	97	416
Chemical	16	2	0	13	31	6	75
TOTALS	32	50	46	28	156	517	1851

B. ROSCOPs

The number of ROSCOPs received this past year decreased from an average of well over 100 per year to only 4 during the past year. A total of 783 OCSEAP ROSCOPs have been received to date.

C. Data Processing Activities

Processing in the early part of this past year concentrated on conversion of master tapes of all final processed data for each file type from the IBM to the new UNIVAC system. The master tapes and all other data tapes not final processed were transferred to the UNIVAC in Suitland, Maryland by August, 1980.

Master tapes of File Type 027 (Marine Mammal Sightings) and File Type 034 (Marine Bird-Land Census) were completed and documented during the year. Copies of these master tapes plus those for file types 029 (Primary Productivity), 033 (Marine Bird-Ship/Aircraft Census), 037 (Feeding Flock) and 044 (Hydrocarbons) were forwarded to the Anchorage facility for potential product requests, particularly from the BLM-Anchorage office. These master tape copies supplement other types of data sent to Anchorage previously.

As a result of the conversion effort, the number of data sets final processed during the past year totaled only 116 in contrast to previous years which averaged between 300 and 400 data sets per year. Over 250 data sets were subjected to preliminary processing (QUADI) using either the IBM or the UNIVAC systems. Over 50 originator data tapes were returned to the investigators following completion of processing. Table 2 presents a brief summary of data processing status through March 15, 1981.

Table 2.

OCSEAP Data Processing Status (March 1981)

	Received	Finaled	In Processing	In Hold
Biological	1360	1127	224	9*
Physical	416	319	74	23
Chemical	75	32	43	0
TOTALS	1851	1478 (80%)	341 (18%)	32 (2%)

*Does not include data considered 'in hold' for biological file types 023, 030 and 032 sent to the Anchorage facility for more intensive editing and quality control.

Other data processing activities included the completion of an assessment of potential OCSEAP data yet to be received by NODC in FY81-82. This summary was forwarded to the Alaska Field Office prior to the departure of the Project Data Coordinator. A distribution was completed to OCSEAP management of NODC's draft of the new operating procedures (SOP) for handling OCSEAP and other project data submissions from receipt of data to final processing, inventories and return of originator's data.

III. REQUESTS

A. Summary of Requests

As shown in previous years, the greatest number of requests came from OCSEAP investigators, generally for OCSEAP data or products from the OCSEAP data files. The number of OCSEAP office and OCSEAP management requests decreased significantly from the previous year. This is no doubt due in part to the move of the Program Office operations from Boulder to Juneau, the change of project data managers, and the operation of a new OCSEAP data tracking system through the Data Projects Group at URI. In addition, some requests normally handled by NODC were forwarded to the Anchorage facility when the computer conversion prevented NODC from completing the request.

The request summary in Table 3 represents only those requests that have been handled or monitored by the NODC OCSEAP Data Coordinator. Requests handled directly by the NODC Data Services Division are not included unless they were identified as OCSEAP requests and service charges were to be made to the OCSEAP account. Routine requests such as copies of individual data formats or taxonomic code lists also are not included in these totals.

Table 3.

Summary of NODC Requests for OCSEAP

Requestor	Data Type	Apr-Jun 80	Jul-Sep 80	Oct-Dec 80	Jan-Mar 81	Totals	Last Year Totals
BLM	OCSEAP	0	2	0	6	8	6
	Archival	0	0	0	0	0	0
OCSEAP Offices*	OCSEAP	5	2	2	3	12	24
	Archival	0	0	2	0	2	2
OCSEAP PIs	OCSEAP	4	8	3	6	21	35
	Archival	0	2	2	3	7	7
Non-OCSEAP PIs	OCSEAP	2	2	4	4	12	15
	Archival	NA	NA	NA	NA	--	--
OCSEAP Mgmt	NA	4	2	6	4	16	29
TOTALS		15	18	19	26	78	106

*Includes Anchorage (AEIDC) and University of Rhode Island (DPG) facilities.

B. Major Requests

The major requests completed during the past year are briefly described below. More details are available in past quarterly and monthly reports.

Date Completed	Requestor	Type of Request
4/80	Gibson (Battell, Sequim, WA)	Ocean station and BT plots west of Juneau.
4/80	Petersen (URI)	Tape copy of NODC version of OCSEAP DTS.
5/80	Lyes (Nat'l Bd. Sci. Tech., Dublin, Ireland)	OCSEAP Catalogs and data management information.
5/80	Guzman (U. Calgary)	Plots of bird sightings, zooplankton, and fish species for specified areas.
5/80	Brower (Program Office)	Draft copies of OCSEAP Data Catalog for BLM-Anchorage meeting.
6/80	Hunt (U. Calif.-Irvine)	Summary plots of selected zooplankton species.
6/80	Mathison (Norway Cont. Shelf Inst.)	Tape copy of selected current meter and STD data - Arctic areas.
7/80	Kreutzer (Calif. St. U.-Northridge)	OCSEAP Catalogs, formats, plots of STD/hydrocargon station locations on special chart projections - also current drift summary plots and data listings.
7/80	Johnson (Arctic Office	Copies of RU 362/497 'ISM' action updates on CONFER file.
8/80	Arbegast (BLM-Anchorage)	Modified plot from OCSEAP Catalog of bird sightings for Bering Sea areas.
8/80	Hughes (NMFS/NAF)	Algorithm for checking Chemical Abstract Service (CAS) code values.
9/80	Crane (Anchorage) for Cowles (BLM)	Tape copy of 125 File Type 027 (Marine Mammal) data sets for species search.
9/80	Fischer (OMPA)	Summary of all OCSEAP and MESA data requests by file type, type of product and source of request.
9/80	Cutler (Calif. Acad. Sci.)	Copy of all NODC format cover sheets plus selected formats/codes.

Date Completed	Requestor	Type of Request
10/80	Pelto (AFO/OMPA)	Evaluation of available temperature data for potential Auke Bay (NMFS) request.
10/80	Crane (Anchorage)	Tape copy of selected file type 024/124 zooplankton data to support PI request.
10/80	Dale (AFO/OMPA)	Copy of all ROSCOPs received during past year for Alaska/OCSEAP areas.
11/80	Kendall (NMFS/NWAFC)	Subset of taxonomic codes for fishes on magnetic tape.
11/80	Grundlack (U. So. Carolina)	Copy of taxonomic codes and selected data formats.
11/80	Fischer (OMPA)	Itemized costs for development/maintenance of NODC version of OCSEAP tracking system during 1975-1980.
12/80	Dale (AFO/OMPA)	Copy of NODC 'SOP', 'NAPIS' entry form, CONFER manuals and data tracking information.
1/81	Quast (NMFS/Auke Bay)	Summary of ocean station temperatures at selected depths for specified zones in Gulf of Alaska.
1/81	Cutler (Calif. Acad. Sci.)	Selected lists of benthic organism data sets (FTP 032) - request forwarded to Crane for most up-to-date version of data.
1/81	Venkatesan (UCLA)	Clarification in use of FTP 144 and status of coding forms for the format.
1/81	Albert (BLM-Anchorage)	Status of data available for trace metal and hydrocarbon data sets and data reports in area of interest.
1/81	Kreutzer (Calif. St. U.-Northridge)	Tidal current and geophysical data - contacted NOS and NGSDC for completion of request.
1/81	McMurray (VTN Oregon)	Data Catalogs and identification of types of products needed to support studies in Alaska OCS areas.
2/81	Emerson (BLM-Anchorage)	Annotated station location plots and data listings for Norton, St. George and N. Aleutian areas (FTP 021, 043, 044 and 061) - some data sent to Crane on tape for possible future data requests from BLM.

Date Completed	Requestor	Type of Request
2/81	Lane (BLM-Washington)	Copy of Part 3 of the OCSEAP Catalog (Formats and Codes for complete set of Catalogs).
2/81	Crane (Anchorage) for Vogel (VTN Oregon)	Tape copy of 12 selected zooplankton data sets (FTP 024) for Crane data request.
2/81	Pelto (AFO/OMPA)	Inventory and status of current meter data (FTP 015) for RU 541 - sent via CONFER.
2/81	Lauria (Congressional Info. Svc.)	Copy of Part 3 of the OCSEAP Catalog (Formats and Codes).
2/81	Pelto (AFO/OMPA) for Erickson (U. Alaska)	Summary of available bottom current data in St. George area - sent via CONFER.
2/81	Dale (AFO/OMPA)	Copy of NIH procedures for processing microbiological data plus NIH FY80 report (RU 371).
2/81	Pelto (AFO/OMPA)	Inventory and status of all FTP 015 data for Norton and Chukchi areas.
2/81	Corre (BNDO, France)	Copies of OCSEAP Catalogs, data processing and tracking information and formats and codes.
3/81	Dale (AFO/OMPA)	Dendrogram product information - NODC and NIH capabilities.
3/81	Pelto (AFO/OMPA)	Magnetic tape to EDIS (CEAS) for generating copy of plume model software.
3/81	Kreutzer (Calif. St. U.-Northridge)	Current Meter rotary plots for selected Bering Sea sites.
3/81	McMurray (VTN Oregon)	Merged STD/Ocean Station temperature, salinity and oxygen summaries for 16 selected areas in Gulf of Alaska/Kodiak.
3/81	Quast (NMFS/Auke Bay)	Merged STD/Ocean Station temperature summaries for 12 zones in the Gulf of Alaska.

IV. FORMAT DEVELOPMENT

A. Data Formats and Codes

Final versions of new formats and related codes were distributed to OCSEAP data management and specified investigators for the following file types:

031 - Marine Bird Specimen
127 - Marine Animal Sighting and Census
135 - Marine Bird Colony
144 - Marine Toxic Substances and Pollutants

Only one 'FACT' sheet of format and code modifications was distributed, which concerned five format modifications and twenty code additions. Another 'FACT' sheet for five format modifications and eight code additions will be distributed in April 1981. Computer conversion activities have delayed the distribution of these changes, but individuals requiring the changes have been notified.

B. Taxonomic Codes

The NODC taxonomic code file continues to be updated, particularly in response to the editing activities of the Anchorage facility. A total of 110 new species codes were assigned during the past year for OCSEAP investigators.

A revision of the emergent plant codes (levels 33 and 34) was completed and distributed to users of the NODC Taxonomic Codes.

C. Chemical Codes

A supplement to the original Chemical Abstract Service (CAS) registry codes was distributed to all users of File Type 144. Several requests and clarifications of the use of the codes were completed during the year. The first OCSEAP data sets using this new code file have been received by NODC recently, one submission following pre-processing by the Anchorage facility and the other submission directly from an investigator.

A contract was completed between Information Science Corporation and EDIS's Environmental Science Information Center (ESIC) for accessing the NIH/EPA Chemical Information System. This contract will permit additional search capability for chemical compounds and associated CAS registry numbers used for the Toxic Substances and Pollutants format (File Type 144). Two NODC personnel are being scheduled for training in April to become more familiar with the system and to support requests from users of File Type 144.

V. INVENTORIES AND CATALOGS

A. Inventories

The new NODC data inventory and tracking system (DINDB), an interactive screen-formatted data entry system, was implemented in January 1981. Information from this file will be used to generate project file type summaries, including RU, lease area and file IDs for OCSEAP data submissions and to provide updates to the OMPA data tracking system later this year.

The NODC technical library automated file of data reports and other 'gray literature' held at NODC was demonstrated to OCSEAP data management and copies of the keyword list provided to the Alaska Field Office.

B. Catalogs

Part 1 (Revised) - Station Locations

Approximately 300 copies were distributed to BLM, OCSEAP and NOAA offices and specified investigators in May, 1980.

Part 2 (Revised) - Lease Area/RU Inventory

The last distribution of this part of the catalog was August, 1979. A small number of copies are still available. No reprinting or update is scheduled under this year's work statement.

Part 3 - Data Formats and Codes

Copies were distributed as subsets to investigators and managers at their request; entire sets of all NODC formats and codes were distributed to at least 12 individuals during the year.

Part 4 - Data Product Examples

Over 300 of the 600 copies printed were distributed in January, 1981. Additional requests for this Catalog continue and the supply is now about 200 copies.

The OCSEAP mailing list was updated prior to distribution of Part 4 of the Catalog and is now stored on NODC's minicomputer, the MODCOMP II.

VI. PRODUCT DEVELOPMENT

No new product development was completed for OCSEAP this past year. Improvements were made to specific products during the software conversion from the IBM to the UNIVAC and enhancements made to some of the products generated for Part 4 of the OCSEAP Catalog.

VII. ADMINISTRATIVE

A. Meetings

Meetings and travel were reduced somewhat in comparison to previous years. The major meetings were as follows:

- Chris Noe, Mike Crane, Sid Stillwaugh and Jim Audet attended the OCSEAP/OMPA Data Management meeting at Whidbey Island in July, 1980.
- Marilyn Allen of the AEIDC staff visited NODC in August 1980 to brief personnel on the use of the IBM 3741 workstation and the graphic capabilities available at their facility.
- The project review for RU 362 and other data management activities was held in October at the Alaska Field Office (Juneau). Sid Halminski, Bob Gelfeld, Mike Crane and Jim Audet participated from NODC and Peter Sloss and Mike Loughridge discussed the NGSDC tasks.
- In January, 1981, Hal Petersen, Wayne Fischer and Jim Audet participated in the NODC-sponsored Marine Pollution Workshop held at Frederick, MD. Dean Dale and Peter Sloss also participated in the digital data sessions of the Workshop.

B. Budget

Since the 'OCSEAP year' includes portions of two funding years, budget figures are provided below for FY81 expenditures through February, 1981. Some of these figures have been obtained from the recently implemented NODC Financial Reporting System, which is maintained on the ADP System 1022 in Waltham, MA.

The expenditures for major budget items are as follows:

Salaries/Benefits/Overhead		$ 67.6
Travel		5.1
Rent/Communication		4.1
Supplies		2.5
Computer (through February 15)		3.1
	Total	$ 82.4K

(Transferred to NGSDC - $56.1K)

The following are estimates for expenditures under major RU 362 tasks:

		Labor/Overhead	Computer
Data Processing/Validation		$ 13.8	$ 0.7
Data Products/Requests		18.3	2.3
Data Management Support		35.5*	0.1
	Totals	$ 67.6K	$ 3.1K

*Includes $12.1K for Wayne Fischer through December 1980.

C. Milestones

With directions from the Alaska Field Office to forego any OCSEAP Catalog printing during this year's activities and the elimination of quarterly reports, the only specified milestone for RU 362 is the submission of this Annual Report. Attendance at workshops and conferences and other data management activities will be completed as they are scheduled.

VIII. PROBLEMS

One of the major problems has been the question of OCSEAP funding for RU 362 and the effort involved in generating different versions of the renewal proposal which occupied a disproportionate amount of data management time. With this problem resolved in the past month, more attention can be paid to data flow and inventory problems and response to data requests.

The other major problem of the past year was the impact of the computer conversion at NODC. These impacts are noted elsewhere in this report. Operations gradually are returning to normal with most data processing, inventory and data product software tested and working on the UNIVAC or on the MODCOMP. Some areas, such as inventories of time series data, data entries in some NAPIS records (which are inputs to the OMPA data tracking system for OCSEAP data), and utilization of the more detailed land mass file on the UNIVAC, still need to be resolved.

Other problems include the continuing resubmissions of data that have been final processed that still require the same amount of effort and expense to process as the earlier incorrect submissions but are never reflected in summaries of data sets received or processed.

IX. GOALS

The NODC goals for the next quarter are as follows:

- Distribute a 'FACT Sheet' of format and code modifications to OCSEAP data management and investigators.
- Generate a final draft of a 'File Type Summary' for OCSEAP data from the new NODC inventory system on the UNIVAC.
- Reduce the number of data sets in processing to less than 10 percent.
- Continue to support OCSEAP management and investigators' needs for format and code modifications and new taxonomic codes as required.
- Continue to provide updates of master tapes to the Anchorage facility as updates are completed and provide similar products to the Data Project Group as requested.

NGSDC Addendum to OCSEAP RU 362 Annual Report

I. INTRODUCTION

This Addendum is structured in the same order as the NODC report and covers Geology/Geophysics data.

II. DATA PROCESSING

A. Digital Data Received

1. Seismology

a. 5 sets of punch cards.
b. 3 magnetic tapes.

2. Marine Geology

a. 1 tape of sediment texture (073) data.

B. Non-Digital Data Received

1. Marine geophysics
a. 2 Open-File Reports.
b. 1 Cruise data set.

C. Data Processing Activities

1. "Alaska - only" earthquake data base near complete. Data in several input formats were received; accidental erasure of disk pack by CDC engineer delayed loading of total data base.

2. All received digital data are in appropriate, accessible data base.

II. REQUESTS

A. Requests through OCSEAP were large in average size, requiring custom map plotting and multi-discipline data. Requests for Alaska-area from other than OCSEAP investigators were more numerous but more specific. One important aspect of OCSEAP requests appears to be a need for more coordination of existing map bases - a request was forwarded to NGSDC by the AFO/Juneau to produce a near duplicate of a portion of a BLM base map. At our suggestion, the needed map was produced photographically from the actual BLM map. It is obviously important that we educate the requestors in the appropriateness of various media (computer plot, diazo copy, process camera) for producting their maps. NGSDC received 6 requests directly identified as of OCSEAP-PI origin.

B. Major Requests

*Kreutzer for RU 206 (Fugro, Inc.) - Several large base maps, geophysical ship tracks & data seismicity data.
*Two requests from USGS Pacific/Arctic.
*Two requests from SAI.
*Over 100 other requests from Alaska-area interests for data which included OCSEAP related studies and complement OCSEAP data sets.

IV. FORMAT DEVELOPMENT

No activity.

V. INVENTORIES AND CATALOGS

A. No new inventories - Alaska earthquake file still under development.

B. Part 4: Data Product Examples. Several plots of tracklines and geologic sample sites.

VI. PRODUCT DEVELOPMENT

General evolutionary refinements to existing software. UNIVAC conversion has sidelined any major development efforts.

VII. ADMINISTRATIVE

A. Meetings
See this item in NODC report - RU362 10/80 review. (Juneau) and 1/81 Marine Pollution Workshop (Frederick, Md.)

B. Budget - 1. Prepared FY 81 proposal for all RU362.

C. Milestones 1. See NODC report.

VIII. PROBLEMS

See comment about map production in III A above.

IX. GOALS

NGSDC Goals for FY 81 are as follows
.Prepare for expected increases in FT073 and 074 data submissions.
.Complete the "Alaska-only" earthquake file to reduce cost of accessing Alaska data from world file.
.Continue to support OCSEAP management and investigators' needs as a high-priortiy task.

"ANCHORAGE INFORMATION SERVICE CENTER"

RU370
Contract No. 03-5-022-56

1 April 1980 to 31 December 1980

No Contract During the Period
1 January 1981 to 27 March 1981

31 March 1981

Larry Underwood
Principal Investigator

Willy Rensenbrink
Executive Officer

I. INTRODUCTION

This annual report for the period 1 April 1980 to 31 March 1981 is submitted for the activities of the Anchorage Information Service Center, University of Alaska/Arctic Environmental Information and Data Center (AEIDC), RU370. The AISC was under contract to the OCSEA Program from 1976 to 31 December 1980. Since January 1981, there has been no contract, even though the proposal was submitted in October 1980. A telegram was received on 27 March 1981. The report describes the activities for the twelve-month period ending 31 March 1981. The description is organized by functional tasks which were adopted in the format of the revised proposal.

II. SIGNIFICANT EVENTS

An outline of significant events is noted below. The outline format was selected to highlight important events during the year. Often OCSEAP management forgets the contributions of RU370. This list of accomplishments and events should remind OCSEAP managers and staff of the effective service by the AISC staff.

Significant Events:

A. Developed a 3741 Workstation users manual. An operational data network is in place between Seattle, Anchorage, and Washington, D.C.

B. Developed graphic services using an H-P 2647A intelligent graphics terminal and plotter. A users manual was developed and distributed to OCSEAP personnel in Juneau and Fairbanks.

C. Converted data from the Alaska tax code to the 1978 NODC tax code for three investigators and 48 data sets.

D. Tested the format conversion programs for data in FT023 to FT123. Twelve data sets from Jim Blackburn were converted.

E. Installed 42 new programs.

F. Received 110 plus 25 data sets, final processed 104 data sets, and forwarded 104 data sets to the NODC during the reporting period.

G. Mailed 59 letters to OCSEAP investigators and managers during the twelve-month period.

H. Received 58 requests from OCSEAP management and investigators. Graphic requests totaled 308 during the reporting period.

I. Updated the Parameter Checklist file. Waiting for further edits.

J. Updated the NODC 1978 taxonomic code master file. Created the new NODC 1981 taxonomic code master file.

K. At Mr. Dale's request, added four new file types for processing: FT028, FT029, FT124, and FT144. A total of eleven file types assigned to the AISC: nine biological and two chemical file types.

L. Forwarded twenty letters for new taxonomic codes at the request of OCSEAP investigators.

M. Created two special files of financial information for the BLM/OCS office.

III. DESCRIPTION OF ACTIVITIES

The operational functions of the Anchorage Information Service Center are separated into nine major categories. These categories are presented below in the order of "importance" to the OCSEA Program. The priority was compiled from the collection of requirements identified by the BLM/OCS office and the OCSEA Program from 1976 through 1981. The staff of the AISC has executed the tasks within these categories efficiently and effectively.

The nine categories span the range of services from management support to analysis of data from investigators. The emphasis is accuracy, and the staff has developed operating procedures to assure proper execution of each task. These categories are:

Taxonomic Code Conversion
Format Conversion
Data Evaluation
Data Rehabilitation
Management Services
Master File Development
Data Base Liaison
Investigator Liaison
BLM/OCS Support

A. Taxonomic Code Conversion

In 1975 the OCSEA Program funded the development of an Alaskan taxonomic code. Dr. George Mueller created this file in early 1976, and the OCSEA Program delivered this file to investigators. Weaknesses were identified, and a new coding scheme was devised in 1978. This code is called the NODC taxonomic code (1978 version). In 1980 the file was amended to accept more vascular plant taxa. This latest version is defined as the 1981 version of the NODC taxonomic code file.

Some investigators during the early phases of the studies program took liberties in adding new entries to the files. The problem was identified by the Anchorage staff and the NODC staff jointly when taxonomic codes were reviewed. This review continues today. The Alaskan code and the "Pre-Alaskan" code must be converted to valid NODC taxonomic codes. A taxonomic code check program isolates the identifications by name, and the investigators confirm the presence of each taxa.

The conversion of the taxonomic codes requires several steps. The first step is the checking of the codes for structural errors such as embedded blanks, odd length, and non-numbers in the fields. These errors are corrected first. Next the codes are translated to the scientific names. The investigator confirms the coding accuracy. A computer program tests for conversion feasibility by identifying a corresponding NODC tax code. If no code exists, then a message is printed. New codes are identified by this process. A new NODC code is requested from the NODC staff. This new code is added to the special conversion file of tax codes. Another computer program is run to convert the codes from the Alaskan version to the current NODC version. A follow-up check of codes assures the conversion was completed and correct.

The early steps were laborous and required extensive review by the Anchorage staff and the investigator's staff. The scale is significant because the largest biological data file is the fishery resource assessment file in FT023, and ninety percent of those data sets must be converted. The table below summarizes the data to be converted.

Table 1

Conversion of Alaska Tax Codes

RU	Name	File Type	Number of Data Sets	Subtotal	Total
019	Jackson	023	27		
064	Nelson	023	118		
174	Ronholt	023	1		
175	Wolotira	023	8		
233	Bendock	023	2		
427	Alexander	023	1		
485	Hartt	023	4		
486	Jackson	023	5		
				166	
027	Lees	023	4		
417	Lees	023	2		
				6	
027	Lees	030	6		
078	O'Clair	030	7		
079	Merrell	030	2		
417	Lees	030	5		
				20	
005	Feder	032	10		
281	Feder	032	11		
502	Feder	032	1		
517	Feder	032	4		
				26	218

Several computer programs are required to maintain and display the taxonomic code files. The conversion file is a very active file with frequent updates. Conversion software has also been implemented and maintained. The February report of activities to Dr. A. R. Picciolo has a special summary report. A copy of that report is attached to the OCSEAP annual report.

This conversion process must be executed properly, or the value of the data files is drastically reduced. In any biological endeavor, the proper identification of the taxa is a significant activity. Preserving that identification through a taxonomic coding system is equally significant. For this reason, the conversion of taxonomic codes is the highest priority.

B. Format Conversion

The BLM/OCS office has identified fishery data products as an important service from the data base. The design flows in file type 023 mode product generation, an awkward task. A new fishery format was designed and distributed in 1979/1980. The conversion to the new format is not "straight forward," because each investigator adopted a unique convention for station and sample nomenclature. Computer programs have been installed to convert the fields on a "station" basis. The fishery file is the largest biological data file.

A test case has been implemented for twelve data sets from Jim Blackburn, RU512. With Mr. Blackburn's assistance, new data were converted from FT023 to FT123. Computer programs were tuned to fit the coding strategy for these records. Problems encountered will be avoided in other conversions. One-hundred-eighty-nine data sets must be converted. Because the scale of this task is so large, this category has the second highest priority.

C. Data Evaluation

The most time consuming activity of the Anchorage office is the review of data in eleven file types. These file types are:

FT023	Fish Resource Assessment
FT025	Marine Mammal Specimen
FT028	Phytoplankton Species
FT029	Primary Productivity
FT030	Intertidal Biology
FT031	Bird Specimen
FT032	Benthic Biology
FT123	Fishery Resource Assessment
FT124	Zooplankton
FT127	Marine Mammal Sighting
FT144	Toxic Subsistence

The review process involves staff efforts and computer program services. Check programs and procedures are joined in a plan which is implemented by the staff. Each phase of the evaluation is repeated until all known errors are reconciled with program requirements and data base requirements. OCSEAP requirements are applied to each investigator as a separate item within the general framework. Procedures are modified and computer programs are upgraded to meet these individual review criteria.

The errors are summarized and presented to the investigator in correspondence. A log of the checks, edits, and correspondence is maintained. Special steps are executed as required. Reports are written, both on the status of the review plus on the action required to continue the evaluation. This annual report forms another level of summary.

Because the evaluation phase embraces scientific and administrative requirements, computer programs are needed to isolate the content of each data set. A summary of check programs is given in Table 2 below.

Table 2

OCSEAP Data Check Programs

Name	023	025	028	029	030	031	032	123	124	127	144
START	X	X	X	X	X	X	X	X	X	X	X
IDxxx	X	X	X	X	X	X	X	X	X	X	X
TCxxx	X	X	X	NA	X	X	X	X	X	X	X
TFILExxx	X	X	X	NA	X	X	X	X	X	X	X
TXExxx	X	X	X	NA	X	X	X	X	X	X	X
TXxxx	X	X	–	NA	X	X	X	X	–	NA	NA
PCxxx	?	X	NA	NA	NA	X	NA	X	NA	NA	NA
SQxxx	X	X	X	–	X	X	X	X	X	X	X
RAxxx	X	X	X	–	X	X	X	X	X	X	X
BLxxx	X	X	X	X	X	X	X	X	X	X	X
RLxxx	–	X	–	–	–	–	–	–	–	–	–
CFILExxx	X	X	NA	X	X	X	X	X	X	X	X
CDxxx	X	X	NA	X	X	X	X	X	X	X	X
SLxxx	X	X	–	–	X	X	X	X	–	X	–
SDxxx	X	X	NA	–	X	X	X	X	–	X	–
SUMxxx	X	X	X	–	X	X	X	X	X	X	X
EXxxx	X	X	X	–	X	X	X	X	X	X	X
MXMNxxx	X	X	X	–	X	X	X	X	X	X	X
RXxxx	X	NA	–	–	NA	NA	NA	NA	–	NA	–
PFILE	X	X	X	–	X	X	X	X	X	X	X

Legend

X = completed
? = format design problems
– = to be developed
NA = not applicable

The computer programs are continually updated for each coding technique or each new requirement for content. Enhancements to existing programs are made routinely, and new utility programs are installed as needed. The computer program maintenance is scheduled between processing tasks.

The programs and procedures are the first parts of the evaluation, and the data sets to be evaluated are the next part. The data noted in Table 1 in the Taxonomic Code Conversion section must be evaluated plus the data sets listed below in Table 3. These data sets use the NODC taxonomic code.

Table 3

Data Sets to be Processed (NODC Code)

RU	Name	File Type	Number of Data Sets	Subtotal	Total
512	Blackburn	023	5		
				5	
467	Johnson LGL	023/"123"	6		
417	Lees	023	5		
552	Wangerin	023	7		
				18	
024	Jackson	030	1		
417	Lees	030	2		
				3	
005	Feder	123	22		
512	Blackburn	123	12		
				34	
275	Shaw	144	4		
				4	
341	Sanger	031	74		
				74	138

A total of three-hundred-fifty data sets must be evaluated. These are divided into the following file types:

FT023	Fishery Resource Assessment	189 data sets
FT030	Intertidal Biology	23 data sets
FT031	Bird Specimen	74 data sets
FT032	Benthic Biology	26 data sets
FT123	Fishery Resource Assessment	34 data sets
FT144	Toxic Subsistences	4 data sets

A total of one-hundred-ten data sets were received during the reporting period (plus twenty-five subsets to be merged with existing data sets). The table below summarizes the data sets by file type received this year.

Table 4

Data Received

File Types -	025	028	029	030	032	123	124	144
Number of Data Sets -	50	1	2	1	5	34+15	7	10+10
Research Units Submitting these Data Sets -	230/ 194	359	359	356	005	005/ 512	359	275

Over one-hundred data sets were final processed and passed the evaluation criteria. Eight file types were completed. Table 5 summarizes the file types and the data sets which passed the evaluation criteria.

Table 5

Data Processed

File Types -	023	028	029	030	031	032	124	144	Total
Number of Data Sets -	50	1	2	16	1	22	7	5	104
Research Units -	230/ 194	359	359	536	476	005/ 467	359	275	

The same data sets were forwarded to the NODC for receipt and acceptance. A total of one-hundred-four data sets were forwarded.

The final evaluation of the data sets requires several iterations of review, edit, and evaluation. Letters to investigators are written and copies forwarded to OCSEAP management. Interaction with investigators and the data base is also required in this evaluation process. The requirements are identified and translated into operational tasks by the AISC staff. Because this evaluation phase is critical to the OCSEA Program, the activity has a high priority. When the tax codes are converted and the format FT023 is converted to FT123, the evaluation task will become the dominant activity.

D. Data Rehabilitation

The evaluation phase noted many errors in the coding and content of the data sets presented in Table 5 above. The successful completion of the review for the final processed data sets depended, in part, on prompt and effective response by the investigators or their staff. Many of the data sets noted in Table 4 (received this year) were final processed because there was rapid response. As indicated in an earlier report to OCSEAP, there has been fewer than ten data sets that did not require substantive rehabilitation by the Anchorage staff. The assistance of the investigator can mitigate this situation effectively.

The research units and investigators who have responded effectively are RU230 - Burns, Lowery, Frost, et al; RU356 - Broad; RU359 - Horner; RU467 - Johnson, et al; and RU194 - Fay. The completion of final processing is indicative of this response.

Another group is research units and investigators who have responded, but the response has only partially satisfied the requirements. This group includes RU512 - Blackburn; RU552 - Wangerin, Jackson, et al; RU275 - Shaw; RU005, 281, 502, 517 - Feder; and RU079 - Merrell.

But there is a group which has not responded or has given a negative response. This group includes RU341 - Sanger; RU024 - Jackson; and RU027/417 - Lees, who is waiting for an OCSEAP contract.

It probably cannot be stressed enough the role of the investigator in evaluating and rehabilitating data. The problems in handling these data from OCSEAP investigators is compounded by poor response time and poor standards. (See problem section for details.)

The rehabilitation process may become complex when partial data sets must be merged. Data resubmissions are the main cause of these problems. The conversion of fishery data from FT023 to FT123 many times requires extensive edits of the original coding in FT023 before conversion can be attempted. A partial solution is for OCSEAP to have a good tracking system and for OCSEAP to set adequate standards for data submissions. These two activities are primary management functions not delegated to the OCSEAP data manager but assigned to each OCSEAP staff person.

The table below summarizes the correspondence to investigators, OCSEAP management, and data processing personnel. The correspondent, research unit, file type, and number of letters span the period from 1 April 1980 to 31 March 1981.

Table 6

Data Rehabilitation Correspondence

Addressee	RU	File Type	Number of Letters
Mintell	174	023	1
Hadley	005	123	2
Hadley	005	032	1
Hadley	275	144	2
Merrell	079	030	1
Hadley	005	123	2
Hadley	005	032	1
Hadley	275	144	2
Merrell	079	030	1
Braham	069	027	1
Jackson	024	030	1
Keller	275	144	1
Keller	005	032	8
Keller	005	123	5
Wangerin	552	023	1
Horner	359	028	5
Blackburn	512	023	5
Broad	356	030	2
Cava	078, 079	030	1
Cava	552	023	1
Cava	024	030	1
Johnson	467	023	1
Dale	024	030	1
Feder	005	032	6
Jackson	024	030	1
Broad	356	030	2
Carey	006	032	2
Merrell	079	030	1

Another index of the data rehabilitation activity is the checkrun activity. A summary by research unit and file type is presented for each month in the appendix. This task is a thankless job and is executed in a thoroughly professional manner by the AISC staff. Because the trend has not improved, this task enjoys a high priority and is coupled closely to the evaluation task above.

E. Management Support

The task defined as management support has four components. The first is servicing requests from management; the second is graphic products; the third is the maintenance of special files; and the fourth is attending meetings. Woven among these activities are indirect support functions such as special reports, management assessments of problems, and data management expertise. The value of these indirect services are as significant as the tangible support presented in this section.

1. Requests

Requests for service have been an integral part of the OCSEAP activities. The Anchorage response capability has proven to be an important element in keeping OCSEAP plans on schedule. The completion of tasks is executed efficiently and on time. The staff in Anchorage many times have assured delivery as requested, even though a "rush" mode was necessary. The graphics requests this summer are examples of this situation. Many times OCSEAP management does not appreciate the effective service and continues to operate on "short notice only."

A list of requests is presented in Table 7 and covers the period from 1 April 1980 to 25 March 1981. This list was compiled from the requests presented in the monthly reports to NODC from the Anchorage office.

Table 7

Requests

May Requests

Requestor	Status	Description
Audet	Completed	Graphic slides for presentation at NODC

July Requests

Requestor	Status	Description
Cava/Johnson	Completed	Slides for OMPA meeting
Murphy	Completed	Data Catalog, Part I & II to Ray Morris, EPA
Johnson	Completed	Graphics User Guide
Murphy	Completed	Pick up TI operating diskettes and deliver to Coupeville, Washington
*Cava	Completed	Pie & bar charts for BLM briefings
Broad	Completed	Graphics User Guide
Johnson	Completed	Letter to Rita Horner concerning Northwind data in 1977
Fischer	Completed	User statistics generated by Jim Audet
Horner	Completed	Examples of graphic products sent for her review
Johnson	Completed	Delivered tape of FT031 data to Dr. Petersen

*18 pie and bar charts on two-day notice. Hand-delivered 23 July 1980.

August Requests

Requestor	Status	Description
Fischer	Completed	Requested summary - ADPF
Cava/Calder	Completed	Four pie diagrams
Johnson	Completed	Training on graphic terminal for Donna Becker
Johnson	Completed	Letter on 3741 workstation for marine mammal data entry
Thorsteinson	Completed	Sixteen bar and pie diagrams generated
Swanner	Completed	Generated samples of check program outputs in FT030

October Requests

Requestor	Status	Description
Johnson, Dale	Completed	Information for the Juneau review meeting
Johnson	Completed	Visit Drew Carey at OUS in October
Audet	Completed	Prepare slides/multiplot for the Juneau meeting
Dale, Johnson	Completed	Develop a draft tracking form
Stringer	Completed	Copies of meteorological data from Cape Romonzof, Alaska
Dale	Completed	Deliver copies of OCSEAP corresponding reports and material
Stringer, Hufford	Completed	Linear plots of pressure differences & barometric pressure
Johnson, Dale	Completed	Draft copy of OCSEAP Action Item typed
Hameedi, Zimmerman	Completed	Fishery & mammal inventories for Norton Sound meeting
Combellick	Completed	Graphic product of geological hazards matrix

October Requests (continued)

Requestor	Status	Description
Johnson	Completed	Mammal data inventory of the NMFS data in Norton Sound
Vogel	In progress	Printout of zooplankton data
Combellick	Completed	Produced a graphic matrix & corresponding key of environmental hazards in Norton Sound
Braham	Completed	Ran SL027 on his FT027 data to save the sighting latitude-longitude & taxonomic record types for Norton Sound boundaries; then ran SL027 on that condensed file to partition the data into four additional seasonal files. Ran TC027/TFILE on seasonal files plus original file for taxa listings; produced a graphic product of the taxa matrix by season
Feely	Completed	Produced a numeric table slide on paper & transparency for meeting
Nyquest	Completed	Listings of our two FT023 Ocean Dumping files plus copies of format sheets 023 & 123

November Requests

Requestor	Status	Description
DiCristoforo	Completed	DTS information from our system - tape mailed
Arbegast (BLM/OCS)	In progress	Design of management information file for lease area priority assessment
Johnson	Completed	Send Parameter Checklist data printout to Bud Fay, FT127 via DHL
Dale	Completed	Parameter Checklist printouts

November Requests (continued)

Requestor	Status	Description
Vogel VTN (OREGON)	Completed	TC124/TFILE124 of zooplankton data from RU551 and RU553
Combellick	Completed	Matrix of geohazards by operation type. See last month's report for details. Example in appendix with KUDO for Ms. Allen and Mr. Ard
Johnson	Completed	Graphic products and examples
Audet	Completed	Tracking information for RU006

December Requests

Requestor	Status	Description
Dale	In progress	Preprocess biological data from the University of Alaska
Braham	Completed	Taxonomic code and name printout for review by NMFS
Thorsteinson	Completed	Graphic request
Johnson	Completed	Type and transmit correspondence via OS6/452
Dale	Completed	Send printout of Parameter Checklist file
Stringer/Hufford	In progress	Give advice on analytic techniques, using the H-P 2647A graphics terminal
Scheidt (BLM)	In progress	Implement a management file of fiscal information
Carey	In progress	Taxonomic code request forwarded to Mary Hollinger

January Requests

Requestor	Status	Description
Dale	Completed	Printout, RT2 and RT3 for Feder historical data

January Requests (continued)

Requestor	Status	Description
Johnson	Completed	Printout of internal tracking file
Vogel	Completed	Printout of FT124 codes and blank DDF's

February Requests

Requestor	Status	Description
Vogel	Completed	FT024 data - TC/FILE
Cimberg	In progress	Coral taxa
Dale	Completed	Inventory of benthic data
Swanner	Completed	Gear code
Hadley	Completed	TC/TFILE - all FT123 data

March Requests

Requestor	Status	Description
Dale	Completed	Current tracking system input

2. Graphics

OCSEAP management and investigators have requested over three-hundred graphic products since the new graphics terminal and plotter were installed. A users notebook was developed and augmented as new programs were installed. Each OCSEAP office has a current version of the users manual. In addition to the programs supplied by the vendor, we have written seven new programs. These new programs are BAND GRAPH, TIMELINE, STD PLOT, STICK DIAGRAM, KITE DIAGRAM, SCATTER DIAGRAM, and LINEAR REGRESSION (for one variable).

The graph requests are presented in the appendix for all OCSEAP requests during the reporting year.

3. Special Files

The Parameter Checklist file was developed in 1978 and has been maintained since that time. New programs were written to exploit the information contained in these records. The Parameter Checklist file contains each field in the data formats on one axis and all the research units on the other axis. A matrix of required fields can be displayed for any or all of the research units. Comparisons among research units can easily be made. Another use is a comparison of the data content and the required fields for the research unit. This application is useful in determining contract compliance and data product potential.

The formatted output of the Parameter Checklist file is attached in the appendix.

4. Attend Meetings

Another management support function is attending OCSEAP meetings. These gatherings have been effective in facilitating communication among a widely dispersed group, plus informal meetings in Juneau and Anchorage have been useful in capturing information from OCSEAP management. The annual data management meeting is usually the most significant event during the year.

Table 8 below notes the meetings held during the reporting period.

Table 8

Meetings

May 18: Toni Johnson
June 12: Paul Becker
June 15: Donna Becker
June 26: Carter Broad
July 7 - 15: Coupeville meeting
September 5 - 14: NODC meetings
October 6 - 9: Dean Dale in Anchorage
October 20 - 23, Juneau: Data Management meeting
October 27 - 31, Corvallis, Oregon: Carey
October 28 - 30: Norton Sound Synthesis
November 12: Graphics Demonstration to Trudy Cain
December 8: Stringer & Huffort visit

In summary, the management supports are an important activity from an OCSEAP viewpoint and a necessary task in our viewpoint. We are anxious to be of service to the program management, but our main function is service to investigators and the data base. Management support drains resources from data management and underwrites project management with an already scarce resource.

F. Master File of Codes

There are three unique code files which are maintained by the AISC staff. The first is the taxonomic code files; second, the digital code files; and third, the Chemical Abstract Society codes of toxic substances. Individual formats were developed for these master files. The files are updated as changes or new codes are received. Maintenance procedures and programs have been implemented to assure efficient and accurate updates. The data submitted by investigators must be in valid codes, defined by the NODC or CAS.

The master files are used in checking the codes contained in the data submission. Special check programs invoke these master files in a "table lookup" scheme. A match in the file is one level of checking; a printed summary of all valid codes allows another level of checking. Without a current master, the checking process would be greatly diminished in value.

The taxonomic code update procedures are defined in the appendix under the taxonomic code report attached there. This master file is by far the largest, with over 70,000 entries. The digital code file has 5,000 entries and the CAS code file over 500 entries. Review procedures are also in place.

Additions to the files originate in Washington, D.C., but the request for new codes generally comes from the investigators and processing centers. The checking of codes in the data many times identifies new codes created by the investigator. A request for these new code values is forwarded to the NODC for action. For taxonomic codes, a total of twenty-three letters were sent to the NODC or investigator concerning new codes.

The maintenance of these master files is a continuing activity and requires extensive interaction with the data base. This interaction will be presented in the section below. The priority of this activity depends on the investigator's cooperation in advance (which relates to another section below). If investigators requested new codes before they submitted data, then a timely exchange of information between NODC and Anchorage would allow a routine update procedure to be put into action. If not, a crash update technique, which interrupts other processing, is inevitable. Current versions of these master files are available to investigators upon request.

G. Data Base Liaison

As noted above, frequent interaction with the NODC is an essential component in data review, taxonomic code conversion, format conversion, and master file maintenance. Because the NODC is the clearinghouse for all formats and codes, direct interaction facilitates timely response by the NODC. Communication with the NODC is by letter, message, report, or phone conversation. Letters on taxonomic codes are typical communication paths. A weekly status report/activity report is transmitted by message on Thursdays. A report of activities at the end of each month summarizes action items and information requests. Frequent phone conversation with staff at the NODC is effective in preventing problems or limiting delays.

This activity is a continuing task and has a lower priority than most tasks described above. Because the interaction is efficient and timely, the data base liaison task has been a routine activity.

H. Investigator Liaison

The primary purpose of the liaison activities with investigators is to prevent problems and improve communication among components of the OCSEA Program. Visits and phone conversations allow a timely exchange of new information and identification of potential problems before they become critical. During the reporting year, several investigators utilized this service effectively. Included in this group are Carter Broad, RU356; Andrew Carey, RU006; John Burns (staff), RU230; Allen Vogel, RU600; Rita Horner, RU359; and Jim Blackburn, RU512.

This group includes Arctic investigators or new investigators. Conspicuously absent are Juneau-monitored investigators. This activity would have a higher priority if OCSEAP management were serious about preventing problems and concerned about efficient exchange of information. At this point, the investigator liaison task is a low priority task.

I. BLM/OCS Support

The BLM/OCS supports a new activity which began in November 1980. An antecedent was a request by Cleve Cowles for a Marine mammal distribution product for the Norton Sound, Bering Sea area. A copy of a preliminary table is presented in Table 9 below.

The other major activity was the development of management information files for the planning of research activities. Two separate files were generated--one for regional planning and one for research unit planning. The formats and codes were designed to meet the current and many future objectives. These formats and codes are attached in the appendix. Computer programs were written to display the information in a formatted style. Check programs were also written. The original material was converted for keyentry, and new coding forms were devised. The regional planning for FY82 and the research unit planning for FY81 were entered into the system. Graphic products were also presented to the BLM staff in February. Both pie and bar charts displayed the information from the FY82 regional planning file. The historical file is the next activity and new diskettes will be keyentered with this information.

Trends will be displayed graphically at the conclusion of this historical phase.

The need to support the BLM/OCS requirements is a new task and the priority is uncertain at this point. From the BLM viewpoint, support by the Anchorage Information Service Center does not fit into the long-range plan. The Anchorage office cannot keep excess capacity available without stable funding. If BLM can link our services to their needs, then the priority of this task will increase in the future.

IV. DESCRIPTION OF PROBLEMS

Concerns were presented in the section above, but this section focuses on the problems which require immediate action by OCSEAP management. Some of these items were introduced years ago. The order of the problems does not imply any priority.

A. Data Tracking and Data Inventories

How much data were collected in 1978 through 1981, and what are the projections for new data in 1982 and 1983? The inventory of data from the present system must be updated to address this need. Without an accurate total and preliminary delivery schedules, the staff of the AISC cannot plan for the data evaluation and data rehabilitation activities.

B. Policies and Standards for Data

There are no written standards or policies for data so that contractual review of data can be implemented effectively. The Parameter Checklist is a start in developing these procedures and policies. Research contracts should contain the necessary information to develop standards for data. OCSEAP management should design a plan to create and update its data policies. Volume of data is only one criterion in establishing a digital-versus-nondigital format for the data. Policies should include the responsibilities of each component in the data management system--investigator, management, and data base. Data content is a critical issue defined, in part, by a policy and by definitive standards. This information would allow the data base to plan its activities, plus allow each data-handling center to implement rigorous control tasks.

C. Funding Stability - FY82, FY83, and FY84

OCSEAP management should review the data inventory presented in part A above and set funding levels in outlying years according to the level of effort.

D. Investigator Responce to Data Inquiries and Correspondence

Many more data sets could have been evaluated and rehabilitated if investigators placed a higher priority to responding to our inquiries and correspondence. A policy statement to investigators would help in this regard. Several investigators have responded so that the requirement has had successful antecedents.

E. Decision on FT031 Data from RU341

For over a year, the data from RU341 (USFWS) have been held waiting for adequate corrective action by the investigator. Because the errors are so extensive and the confidence in the data so low, a decision on how to proceed is needed. The current holdings require rigorous review by the investigator. The value of these data would be very suspect without this review. The review would probably cost money and time. OCSEAP should evaluate the alternatives and recommend a solution.

In summary, these problems require immediate attention, and the solutions should be instituted soon. When capital resources are decreasing, it is imperative that efficiency improve to meet the requirements. If OCSEAP management wishes to discuss solutions to these problems, we would be happy to schedule discussions at OCSEAP's convenience.

V. MILESTONES

The contract between AEIDC and OCSEAP will be completed soon. After the contract is in place, the items listed in the milestone chart will be executed. Many activities will be continuing activities, such as data evaluation.

Table 9

Milestone Chart

```
                         April 1981         October 1981              March 1982

Taxonomic Code
  Conversion                  X--------------------------------------------X

Format Conversion                       X----------------------------------X

Data Evaluation               X-------------------X    X-------------------X

Data Rehabilitation           X-------------------X     X------------------X

Data Meetings                           X         X              X

Graphic Services              X         X              X    X    X

Update Parameter
  Checklist                                       X                   X

Maintain Computer
  Programs                    X--------------------------------------------X

Document Computer
  Programs                         X---------X                   X---------X

Maintain Financial
  File for BLM                X----X         X----X              X---------X

Annual Report                                                              X
```

APPENDIX I

TAXONOMIC CODE REPORT

Introduction

The NODC has begun an effective program in data base management for biological information. The Center has developed and sponsored the NODC taxonomic code from earlier taxonomic coding schemes. It actively supports the file by assigning new codes to new taxa. Because this service elevates the NODC as a special data base on a national scale, the continued enhancements will add tremendous prestige to the NODC. It places NODC in a special niche, especially during severe budgetary restraints.

The Anchorage staff was hoping to demonstrate the taxonomic code file and various services to Mr. Ridley in March. Because travel funds have been reduced, this report will attempt to present the same information scheduled for demonstration to Mr. Ridley. The framework for new biological processing capability rests on a solid foundation of taxonomic coding. Unfortunately, this report is only a brief outline of the extensive services available in Anchorage.

Scope

This report will not be a discourse on systematics nor on the creation of new taxa or codes. It will be limited to the use and implementation of the code for the biological data files plus the maintenance and operation of the Anchorage services of the NODC master file.

Background

Because the rigors of identification and transcription to a code are fraught with dangers, AISC (formerly ADFP) staff has developed procedures to confirm proper identification/utilization of the NODC taxonomic coding scheme and master file. This regional office bridges the requirements of the science community and the national data centers. Early services used utility programs and standard procedures to sort codes by number or abbreviation. These labor-intensive techniques were replaced by automated techniques. Computer programs were tuned for each file type to isolate problems or data coding techniques. Maintenance programs assisted the staff in updating the master file of codes. Application programs were installed to exploit the power of the NODC taxonomic code for biological data. Conversion programs and files were created to allow transfer of the old codes to the new NODC 1981 version from earlier editions.

NODC Taxonomic Code Description

Code is a numeric representation of a specific taxonomic classification or identification. There is a functional relationship between name and code.

Purpose is to allow unique and accurate recording of biological identifications in digital formats. Only by means of a unified code can the biological sciences be upgraded to information management systems. NODC has the most comprehensive system of defining tax codes plus the formats to record the biological information on a broad scale.

This report is divided into three sections. An appendix defines specific file names. The sections are:

1. Display - user's interface to any system. Print formats designed to fit special situations.

2. File Management - maintenance of the file: add, delete, change, and reorder file numbers; check programs.

3. Application Programs - programs which use the file or the coding structure to display, analyze, or organize information.

The appendix contains two parts:

1. Programs and procedures to update file

2. Master file names and functions

The File Display section presents the products and programs to print the master files. User requirements have driven the development of report formats to fit specific needs. These programs generate similar products produced by the NODC. Future products will be generated to match the report procedures of the NODC.

The table below describes the products, and the program name is annotated within the parentheses.

I. File Display

A. Staggered print by taxonomic group designations (TAXPRINT)

B. Two-column print of only NODC names and numbers without addresses (NODCPAGE)

C. Two-Column print of both Alaska and NODC names and numbers without addresses (PAGETAX)

D. Two-column print of both Alaska and NODC names and numbers with addresses, double-spaced (IHTAX)

E. Normal print - one column only of Alaska and NODC (PFILE). This is possible to sort the file in two ways:

1. NODC code order - print type A through E available
2. Alphabetic name order - print type B through E available

II. File Maintenance

The maintenance of the taxonomic code master file is critical to the automated checking of tax codes. The files must be complete, accurate, and up-to-date. The maintenance process includes two phases. Changing the file and checking it is the first phase. Modifying the array which contains the first and last record on each master file diskette is the second. The first four programs address the first phase requirements, and the last two programs update the array defined in the second phase.

The maintenance tasks and programs are outlined below.

A. Conversion of the tax code file from IBM disks (soft-sectored) to WANG disks (hard-sectored) - TC-WANG. This program is loaded and executed from TC-TAX.

B. Check codes in the IBM file for ascending order, embedded blanks, or odd lengths. Lists the record on the IBM disk containing an error (TC-TAX).

C. Print the WANG tax code disks (PAKTAX).

D. Check the IBM disks for possible duplicated codes (TAXTEST).

E. Update the tax code array (TAX#S data file). Used in all tax code check programs for NODC codes (TAXDISK). Used when a major update was run and the beginning and ending record on each disk changed. The program updates the array.

F. Update the tax code array (TAX#S data file). Used in the tax code conversion file (CONDISK). The conversion from Alaska to NODC codes is an important task. Also used when a major update was run and the beginning and ending record on each disk was changed. The tax code conversion file has different diskettes than the NODC file.

The applcation programs are presented in two parts. The first is the correction or conversion of the taxonomic codes in the biological data formats. The second part includes all other applications from checking to data products. These programs and products are outlined below.

III. Applications, Part I - Corrections/Conversions of Taxonomic Codes

A. Convert Alaska codes to NODC codes when there is a one-to-one match and a valid Alaska code with a valid NODC code as a match (TXxxx). The conversion programs are tailored to fit each file type (i.e., TX030, TX025, etc.)

B. Convert only those codes entered into a special table. This is similar to an edit program. It is possible to change a valid code to another valid code (TX-SPL). This will be ideal for the conversion of the old botany codes to the new botany codes.

C. Convert an Alaska tax code to an NODC tax code for only one record type (TX-ANY). Therefore, this can be used very effectively for data not in a particular file type format or for a short data set that doesn't need the time spent to write a special TX program.

D. Remove pairs of trailing zeros on tax codes in the data files (TAXZERO).

III. Applications, Part II - Data Products/Analyses

A. Checks tax codes for each format in use; checks NODC codes for validity (TCxxx). This will print each code present, the number of occurrences, and the name from the master file. Also checks for special codes and lists them with their names.

B. Checks tax codes for data which have tax codes in more than one record type and do not have a TCxxx program written for that particular file type (TC-MANY). Determines validity of NODC tax codes.

C. Checks tax codes for data which are coded in the Alaska code and will need to be converted to the NODC codes. Determines if the Alaska code is a valid Alaska code and if each one has a valid NODC code match (TC-CONV).

D. Prints the tax code record which was flagged as an error with its disk address for each edit capability (TXExxx). The programs TXExxx are written to correspond to a particular file type.

E. Prints the tax code record which was flagged as an error with its disk address (TXE-NEW). This program does not relate to a particular format.

F. After the tax codes are checked on a data set and printed with or without errors, the entire data set may be listed, with the tax code name from the tax code master file printed to the right of each tax code record (TFILE).

G. For those files which have a four-character alpha species identification code to the right of each taxonomic record. This four-character species identification code can be inserted next to the tax code field (REFORMAT). This enables easier review and checking for possible edit, particularly if the file is sorted on the tax code field first.

H. Files in format 031 and 123 which contain predator/prey information may have that information selected and printed in a special form (PLxxx). The desired predator(s) may be selected by the tax code number. The selected predator name and number are printed, followed by the number of occurrences and then its prey tax code numbers, names, and number of occurrences. At the end of each selected predator's prey list, the number of unique prey is noted. Various numbers of predators may be selected.

I. Files in format 025 and 031 may have all of their predator/prey information printed (PCxxx). It is not possible to select only the predators desired from the file. Rather, each predator present is printed with its tax code number, name, number of occurrences, and number of stomachs sampled. Following, a list of that particular predator's prey is printed by tax code number, number of entries, percent of stomachs, and tax name.

J. Files in format 123 have predator/prey information in numerous record types. Record types M and N contain such information. These tax codes are looked up in the master file, and then each predator and its associated prey is listed (PR123).

K. Files in format 123 have predator/prey information for pooled stomachs in record types P and Q. These tax codes are looked up in the master file, and then each predator and its associated prey is listed (PRP123).

L. Critical fishery species may be printed by the BLM lease area(s) (FISHTAB). Each separate Alaskan offshore lease area may be printed with its corresponding critical species tax codes; or the total tax code species list may be printed with designations for each lease area. This was a service to BLM as a management application.

M. Tax codes in format 028 and 040 may be grouped into categories selected by the operator. All tax codes within each chosen category are placed in an array before further processing (CAT-028 and CAT-ARR).

N. Tax codes within format 028 and 040 may be grouped into predesignated taxonomic categories within the data (TAXCAT28) and TAXCAT40). Each taxonomic record within a station is reviewed, and the tax code is changed to the category tax code, using the category array. The "number of individuals" field is increased accordingly, and the category name is added to the right of each tax code record. The result is that all categories present within a station are lumped into one record.

O. Selected tax code records in format 040 may be written on another disk or printed (PTAX040 and SVTAX040). Any level of taxonomic coding may be selected--giving the possibility of listing only that species or all entries in that genus, family, order, etc.

P. Density values may be computed for taxonomic code records in format 040 (DEN040, SVDEN040). These may be written on a disk or merely printed. Originally designed to compute data which have already been placed in tax code categories. The total number of individuals, average density, number of records, and the area are listed at each station in a file. Each file is also given a total for number of individuals and average density. It is also possible to enter a constant for the area value. This will compute the density with greater accuracy for stations with portions where no organisms were present. Once the area constant is requested for each station, the density value is computed and each station printed as before, with the addition of the chosen constant value (CNDEN040).

Q. A summary table may be printed for each file in format 040 (STAT40). The table is constructed only with data previously grouped into tax categories and assigned a density value. Totals are computed for each file for the number of individuals and average density.

R. Special botany conversion file which converts the 1978 NODC botany codes to the 1981 NODC botany codes.

Appendices

The appendices contain the taxonomic code file names and the updating procedures to maintain the master files. The updating is presented first in an outline format.

Taxonomic Code Update

A. A major update occurs when the number of codes inserted on any one of the IBM tax code disks places the End of Data (EOD) address above 48003 or results in the disk containing more than 1251 records. A disk with an EOD address of 48003 contains 1251 records. All tax code update processes require that the IBM tax disks be transferred to WANG tax disks. The WANG disk sectoring is such that it will not accept more than 1251 IBM records.

B. Updates to the tax code files are received from Mrs. Mary Hollinger at NODC. These updates may have been requested by the ADPF or by a PI.

C. Each new code's name and number are then handwritten in their correct places on the correct tax code listing. These listings are then given to the IBM 3741 operator to be keyentered onto the IBM tax code disks.

D. After all of the tax code disks have been updated, each disk is copied, using the record-by-record copy method on the IBM 3741. Each disk is copied onto a receiving disk which has the End of Extent (EOE) set at 46026 and EOD set at 47001. This reduced disk size allows for numerous future updates to be made before it is necessary for another major update.

E. The program TAXTEST is then run on each new master file disk to check for possible duplicate records, etc.

F. The program TAXDISK is then run on each disk. TAXDISK inputs the beginning and ending tax code numbers from each disk of the master into a data array entitled TAX#S. These beginning and ending numbers will have changed after the copy function. The file TAX#S is located on each program disk which contains the tax code check program TCxxx. The data array is used by the TCxxx program to reference the tax code master file and to ensure that the correct master file disk is requested for each code verified. Each corresponding program disk must have its TAX#S data array updated.

G. After all of the data arrays have been updated, the program TC-TAX is run. This program checks the file for errors and then transfers the information on the updated IBM disks to the WANG master file disks.

H. The IBM master file disks are printed with the program IHTAX. It is printed with the title noting the disk number, date, and name of the tax code file. The new listings are placed on file and the previous listings removed.

Taxonomic Code Master Files In Use

A. NODC 1978 version (plus current updates) - on IBM soft-sectored disks. Disks #11 - #31.

B. NODC 1978 version (plus current updates) - on WANG hard-sectored disks. Disks #11 - #31.

C. NODC 1981 version (new botany codes) - on IBM soft-sectored disks. Disks #11 - #32.

D. NODC 1981 version (new botany codes*) - on WANG hard-sectored disks. Disks #11 - #32.

E. Alaska Master Code - on IBM soft-sectored disks. Disks #1 - #10 (stagnant file).

F. Alaska Master Code - on WANG hard-sectored disks. Disks #1 - #10.

G. Alaska Conversion Code (Alaska 1978 NODC) - on IBM soft-sectored disks. Disks #1 - #10. (Will contain new 1981 botany codes in the next generation of conversion capability.*)

H. Alaska Conversion Code (Alaska 1978 NODC) - on WANG hard-sectored disks. Disks #1 - #10. (Will contain new 1981 botany codes in the next generation of conversion capability.*)

I. Alphabetic Sort by Name of 1978 NODC Codes - on IBM soft-sectored disks. Disks #1 - #14.

J. Alphabetic Sort by Name of the 1981 NODC Codes - on IBM soft-sectored disks. Disks #1 - #14.

*Still in process. Waiting to order WANG diskettes.

APPENDIX II

<u>Number of Check Programs</u>
<u>Run by RU, File Type</u>

MAY -	027/023* 20**	417/023* 32**	417/023* 10**
	027/030* 24**	417/030* 10**	417/030* 4**
	512/023* 24**	552/023* 21**	467/123* 6**
	024/030* 2**	078/030* 14**	079/030* 4**
	356/030* 22**		
JUNE -	230/025* 378**	356/030* 47**	078/030* 14**
	079/030* 4**	024/030* 2**	512/023* 24**
JULY -	230/025* 378**	467/032* 18**	512/023* 96**
	356/032* 16**		
AUGUST -	502* 46**	281/032* 46**	517* 46**
	005/032* 46**	356/030* 12**	512/023* 24**
	356/030* 135**		
SEPTEMBER -	359/124* 60**	356/030* 139**	005/123* 117**
	083/031* 12**		

*RU/FT
**Check Runs

OCTOBER –	356/030* 166**	359/124* 12**	359/028* 8**
	359/029* 9**	005/123* 152**	005/032* 96**
	068/027* 125**	Crunch/027* 8**	
NOVEMBER –	359/124* 9**	359/028* 9**	357/029* 8**
	356/030* 144**	027/030* 54**	027/023* 36**
	417/030* 63**	417/023* 54**	005/032* 14**
	109/027* 80**	281/032* 10**	005/123* 138**
	502/032* 1**		
DECEMBER –	005/032* 56**	005/123* 388**	417/030* 10**
	106/100* 436**	024/030* 16**	194/025* 104**
	069/027* 262**	275/144* 75**	

*RU/FT
**Check Runs

APPENDIX III

GRAPHIC REQUESTS

Page 3 through Page 25

H-P DATA CARTRIDGES

Tape 3 - Audet Requests

File	Description
1	Data in MULDARS (Bar)
2	Task Funding Status May '80 (Bar)
3	MULDARS Processing (Pie)
4	Recept & Processing of OCSEAP Data (Linear)
5	Data for 4
6	Request for OCSEAP Products (Linear)
7	Data for 6
8	OCSEAP Data Requests (Bar)
9	Receipt & Processing of OCSEAP Data (Bar)
10	Distribution of OCSEAP data Users (Pie)
11	Distribution of OCSEAP Data Types (Pie)
12	Distribution of MULDARS Data (Pie)
13	OCSEAP vs. MULDARS (Bar)
14	OCSEAP vs. MULDARS Comparative % (Bar)
15	OCSEAP vs. MULDARS Relative % (Bar)
16	Receipt & Processing of OCSEAP data (Linear)
17	Data for 16

H-P DATA CARTRIDGES

Tape 6 - Cava Requests (OCSEAP)

File	Description
1	Bering Sea Program FY81 Funding (Pie)
2	Bering Sea Program FY77 Funding (Pie)
3	Bering Sea Program FY78 Funding (Pie)
4	Bering Sea Program FY79 Funding (Pie)
5	Bering Sea Program FY80 Funding (Pie)
6	Bering Sea Program Funding Level - Transport/Fate (N. Bar)
7	Bering Sea Program Funding Level - Biota (N. Bar)
8	Bering Sea Program Funding Level - Effects (N. Bar)
9	Bering Sea Program Funding Level - Hazards (N. Bar)
10	OCSEA Program FY81 Funding (Pie)
11	OCSEA Program FY80 Funding (Pie)
12	OCSEA Program FY79 Funding (Pie)
13	OCSEA Program FY78 Funding (Pie)
14	OCSEA Program FY77 Funding (Pie)
15	OCSEA Program Funding Level - Transport/Fate (Bar)
16	OCSEA Program Funding Level - Effects (Bar)
17	OCSEA Program Funding Level - Biota (Bar)
18	OCSEA Program Funding Level - Hazards (Bar)
19	Bering Sea - Funding by Lease Area, FY81 (Pie)
20	Bering Sea - Funding by Lease Area, FY77-80 (Pie)
21	Bering Sea - Funding by Organization, FY7780 (Pie)
22	Bering Sea - Funding by Organization, FY81 (Pie)

H-P DATA CARTRIDGES

Tape 7 - McQuitty Requests (August 14, 1980) [OCSEAP]

File	Description
1	Gulf of Alaska, Regional Funding (S. Bar)
4	Lower Cook Inlet, Funding by Lease Area (S. Bar)
5	South Aleutian, Funding by Lease Area (S. Bar)
6	Bristol Bay, Funding by Lease Area (S. Bar)
7	St. George, Funding by Lease Area (S. Bar)
8	Norton Sound Funding by Lease Area (S. Bar)
9	North Aleutian Shelf, Funding by Lease Area (S. Bar)
10	Navarin Basin, Funding by Lease Area (S. Bar)
11	Chukchi, Funding by Lease Area (S. Bar)
12	Beaufort, Funding by Lease Area (S. Bar)
13	Beaufort 71, Funding by Lease Area (S. Bar)
14	Hope, Funding by Lease Area (S. Bar)
15	Arctic, Funding by Region (S. Bar)
16	Bering Sea, Funding b6 Region (S. Bar)
17	NEGOA, Funding by Lease Area (S. Bar)
18	Kodiak, Funding by Lease Area (S. Bar)
19	OCSEAP Funding from C. McQuitty - 8/29/80 (S. Bar)

H-P DATA CARTRIDGES

Tape 8 - Seattle Meeting Graphics (Crane), Whidbey Island (Summer 1980)

File	Description
1	EDIS Wiring Chart (slide)
2	Data Flow Wiring Chart (slide)
4	National Data Base Requirements (S. Bar)
5	National Data Base Requirements (N. Bar)
6	OCSEAP Processing Status (Pie)
7	MESA Processing Status (Pie)
8	MESA Processing Less FT041 (Pie)
10	Process Status, All Projects (Pie)
11	Processing Status, All Projects Less FT041 (Pie)
12	Process Status by File Type (Bar)
13	MESA Data Sets by PI (Bar)
14	OCSEAP Data Processing Status, June 1980 (S. Bar)
15	OCSEAP Data Processing Status, July 1980 (Bar)
16	Hazardous Materials (slide)

H-P DATA CARTRIDGES

Tape 9 - Toni Johnson Requests (OCSEAP)
Whidbey Island Meeting (June 1980)

File	Description
1	OCSEAP FY81 Budget (slide)
2	OCSEAP FY81 Budget (Pie)
3	OCSEAP FY81 Budget (Bar)
4	Data Center by RU (Pie)
5	Data Center by File Type (Pie)
6	Data Center by RU & File Type (Bar)
7	Table (slide)
8	Table 10 (slide)
9	Table - Horizontal (slide)
10	Table 10, Part 1 - horizontal (slide)
11	Table 10, Part 2 - horizontal (slide)

H-P DATA CARTRIDGES

Tape 12 - Quarterly Report (September 1980)
*(Juneau Data Meeting - September 1980)

File	Description
1	Data in Processing - OCSEAP (Pie)
2	Long-Range Plans (slide)
3	Data Processing Activity, July - September (S. Bar)
*4	Services Offered to OCSEAP by ADPF (slide)
*5	Recommendations (slide)
*6	Purposes of ADPF (slide)
*7	Problem Solving (slide)
*8	Active by RU (slide)
*9	OCSEAP Processing by File Type (slide)

H-P DATA CARTRIDGES

Tape 16 - Audet Request (Juneau Data Meeting - October 1980)

File	Description
1	Purpose (slide)
2	Major Activities (slide)
3	Major Contributions (slide)
4	Future Directions (slide)
5	OCSEAP Format Activities (slide)
6	OCSEAP Data Inventory Activities - FY80 (slide)
7	OCSEAP Data Catalog - FY80 (slide)
8	OCSEAP Data Requests - FY80 (slide)
9	Taxonomic Code Activities (slide)
10	OCSEAP Data Processing (slide)
11	OCSEAP Data Sets in Hold Processing (slide)
12	Problem Areas (slide)

H-P DATA CARTRIDGES

Tape 17 - Bill Stringer Request

File	Description
1	Nome-Barrow Barometric Pressure, March 1973 (Linear)
2	Data for 1, Nome
3	Data for 1, Barrow
4	Nome vs. Barrow 1973 Barometric Pressure (Linear)
5	Data for 4
6	Nome-Barrow Barometric Pressure, April 1978 (Linear)
7	Data for 6
8	Nome vs. Barrow Barometric Pressure, April 1978 (Linear)
9	Data for 8
10	Nome-Barrow Barometric Pressure, May 1973 (Linear)
11	Data for 10
12	Data for 10
13	Barrow vs. Nome Barometric Pressure, May 1973 (Linear)
14	Data for 13
15	Data for 13 (zero line)
16	1974 Nome Barrow Barometric Pressure, February (Linear)
17	Data for 16
18	1974 Nome vs. Barrow Pressure Difference, February (Linear)
19	Data for 18
20	1974 Nome-Barrow Barometric Pressure, March (Linear)
21	Data for 20
22	1974 Nome vs. Barrow Pressure difference, March (Linear)
23	Data for 22
24	1974 Nome-Barrow Barometric Pressure, April (Linear)
25	Data for 24
26	1974 Nome vs. Barrow Pressure Difference, April (Linear)
27	Data for 26
28	1974 Nome-Barrow Barometric Pressure, May (Linear)
29	Data for 28
30	1974 Nome vs. Barrow Pressure Difference, May (Linear)
31	Data for 30

H-P DATA CARTRIDGES

Tape 18 - Bill Stringer Requests (November, December 1980)

File	Description
1	1974 Nome-Barrow Barometric Pressure, February (Linear)
2	Data for 1
3	1975 Nome vs. Barrow Pressure Difference, February (Linear)
4	Data for 3
5	1975 Nome-Barrow Barometric Pressure, March (Linear)
6	Data for 5
7	1975 Nome vs. Barrow Pressure Difference, March (Linear)
8	Data for 7
9	1975 Nome-Barrow Barometric Pressure, April (Linear)
10	Data for 9
11	1975 Nome vs. Barrow Pressure Difference, April (Linear)
12	Data fo 11
13	1975 Nome-Barrow Barometric Pressure, May (Linear)
14	Data fo 13
15	1975 Nome-Barrow Pressure Difference, May (Linear)
16	Data for 15
17	1975 Nome-Barrow Barometric Pressure, February (Linear)
18	Data for 17
19	1976 Nome vs. Barrow Pressure Difference, February (Linear)
20	Data for 19
21	1976 Nome-Barrow Barometric Pressure, March (Linear)
22	Data for 21
23	1976 Nome vs. Barrow Pressure Difference, March (Linear)
24	Data for 23
25	1976 Nome-Barrow Barometric Pressure, April (Linear)
26	Data for 25
27	1976 Nome vs. Barrow Pressure Difference, April (Linear)
28	Data for 27
29	1977 Nome-Barrow Barometric Pressure, March (Linear)
30	Data for 29
31	1977 Nome vs. Barrow Pressure Difference, March (Linear)
32	Data for 31
33	1977 Nome-Barrow Barometric Pressure, April (Linear)
34	Data for 33
35	1977 Nome vs. Barrow Pressure Difference, April (Linear)
36	Data for 35

Tape 18 - Bill Stringer Requests (continued)

37	1977 Nome-Barrow Barometric Pressure, May (Linear)
38	Data for 37
39	1977 Nome vs. Barrow Pressure Difference, May (Linear)
40	Data for 39

H-P DATA CARTRIDGES

Tape 19 - Bill Stringer Requests (November, December 1980)

File	Description
1	1978 Nome-Barrow Barometric Pressure, February (Linear)
2	Data for 1
3	1978 Nome vs. Barrow Pressure Difference, February (Linear)
4	Data for 3
5	1978 Nome-Barrow Barometric Pressure, March (Linear)
6	Data for 5
7	1978 Nome vs Barrow Pressure Difference, March (Linear)
8	Data for 7
9	1978 Nome-Barrow Barometric Pressure, April (Linear)
10	Data for 9
11	1978 Nome vs Barrow Pressure Difference, April (Linear)
12	Data for 11
13	1979 Nome-Barrow Barometric Pressure, February (Linear)
14	Data for 13
15	1979 Nome vs. Barrow Pressure Difference, February (Linear)
16	Data for 15

H-P DATA CARTRIDGES

Tape 20 - Norton Sound Synthesis Meeting Demo (October 1980)
[Feely, Braham, Combellick]

File	Description
1	Distribution of OCSEAP Data Users (Pie)
2	Norton Sound Funding by Lease Area (S. Bar)
3	Nome & Barrow Barometric Pressure, February 1974 (Linear)
4	Data for 3
5	EDIS Wiring Diagram (slide)
6	NMPIS Planned (Timeline)
7	Barometric Pressure Difference, February 1974 (B&)
8	Data for 7
9	Kite Diagram, Section 23 (Kite)
10	Dick Feely Table (slide)
11	Braham Slide, Norton Sound Taxa (slide)
12	Hazard Table, Part 1, Rod (slide)
13	Hazard Table, Part 2, Combellick (slide)
14	Key for Hazard Table (slide)

H-P DATA CARTRIDGES

Tape 22 - Lyman Thorstienson (December 4, 1980)

File	Description
	1977
1	Average Catch Per Troll Day, Fair Weather Grounds Menu
2	Data for 1 Chinook (# Chinook & Coho)
3	Data for 1 - Coho
4	Average Catch Per Troll Day Menu - Inner Banks (Linear)
5	Data for 4 - Chinook
6	Data for 4 - Chinook & Coho
7	Data for 4 - Coho
8	Average Catch Per Troll Day Menu - P.D. Grounds (Linear)
9	Data for 8 - Chinook
10	Data for 8 - Chinook & Coho
11	Data for 8 - Coho
12	Average Catch Per Troll Day Menu - Cafe Cross (Linear)
13	Data for 12 - Chinook
14	Data for 12 - Chinook & Coho
15	Data for 12 - Coho
16	Average Catch Per Troll Day Menu - Sitka Sound (Linear)
17	Data for 16 - Chinook
18	Data for 16 - Chinook & Coho
19	Data for 16 - Coho
20	Average Catch Per Troll Day Menu - Cape Ommaney (Linear)
21	Data for 20 - Chinook (# Chinook & Coho)
22	Data for 20 - Coho
23	Average Catch Per Troll Day Menu - Noyes Island (Linear)
24	Data for 23 - Chinook
25	Data for 23 - Chinook & Coho
26	Data for 23 - Coho
27	Average Catch Per Troll Day Menu - Ketchikan (Linear)
28	Data for 27 - Chinook
29	Data for 27 - Chinook & Coho
30	Data for 27 - Coho
	1976
31	Average Catch Per Troll Day Menu - Fairweather Grounds (Linear)
32	Data for 31 - Chinook
33	Data for 38 - Chinook & Coho
34	Data for 31 - Coho

Tape 22 - Lyman Thorstienson (continued)

35 Average Catch Per Troll Day Menu - Inner Banks (Linear)
36 Data for 35 - Chinook
37 Data for 35 - Chinook & Coho
38 Data for 35 - Coho
39 Average Catch Per Troll Day Menu - P.D. Grounds (Linear)
40 Data for 39 - Chinook
41 Data for 39 - Chinook & Coho
42 Data for 39 - Coho
43 Average Catch Per Troll Day Menu - Cape Cross (Linear)
44 Data for 43 - Chinook
45 Data for 43 - Chinook & Coho
46 Data for 43 - Coho
47 Average Catch Per Troll Day Menu - Sitka Sound (Linear)
48 Data for 47 - Chinook
49 Data for 47 - Chinook & Coho
50 Data for 47 - Coho
51 Average Catch Per Troll Day Menu - Cape Ommaney (Linear)
52 Data for 51 - Chinook
53 Data for 51 - Chinook & Coho
54 Data for 51 - Coho
55 Average Catch Per Troll Day Menu - Noyes Island (Linear)
56 Data for 55 - Chinook
57 Data for 55 - Chinook & Coho
58 Data for 55 - Coho
59 Average Catch Per Troll Day Menu - Ketchikan Linear)
60 Data for 59 - Chinook
61 Data for 59 - Chinook & Coho
62 Data for 59 - Coho

H-P DATA CARTRIDGES

Tape 23 - Lyman Thorstienson (December 5, 1980)

File	Description
	1977
1	Fairweather Grounds (Scatter) Linear
2	Data for 1
3	Inner Banks (Scatter) Linear
4	Data for 3
5	P.D. Grounds (Scatter) Linear
6	Data for 5
7	Cape Cross (Scatter) Linear
8	Data for 7
9	Sitka Sound (Scatter) Linear
10	Data for 9
11	Cape Ommaney (Scatter) Linear
12	Data for 11
13	Noyes Island (Scatter) Linear
14	Data for 13
15	Ketchikan (Scatter) Linear
16	Data for 16
	1976
17	Fairweather Grounds (Scatter) Linear
18	Data for 17
19	Inner Banks (Scatter) Linear
20	Data for 19
21	P.D. Grounds (Scatter) Linear
22	Data for 21
23	Cape Cross (Scatter) Linear
24	Data for 23
25	Sitka Sound (Scatter) Linear
26	Data for 25
27	Cape Ommaney (Scatter) Linear
28	Data for 27
29	Noyes Island (Scatter) Linear
30	Data for 29
31	Ketchikan (Scatter) Linear
32	Data for 31

APPENDIX IV

PARAMETER CHECKLIST

81/03/19   PROJECT OFFICE-ALL   RU-ALL

FILE TYPE 013
MARINE FISH PATHOLOGY

RT	NAME OF FIELD	RU 332
X	FILE IDENTIFIER	
X	RECORD TYPE	
1	VESSEL	
1	CRUISE NUMBER	
1	CRUISE DATES	
1	SENIOR SCIENTIST	
1	INVESTIGATOR/INSTIT	
2	STATION NUMBER	
2	LATITUDE	
2	LONGITUDE	
2	DATE	
2	TIME	
2	GEAR TYPE CODE	
2	DURATION/FISHING	
2	DISTANCE FISHED	
2	SURFACE TEMPERATURE	
2	WATER TEMP-AT GEAR	
2	AVG BOTTOM DEPTH-TOW	
2	BOTTOM TYPE CODE	
2	BOTTOM TRAWL TYPE	
3	STATION NUMBER	
3	TAXONOMIC CODE	
3	TOTAL WT SPECIES	
3	WEIGHT DETERMINATION	
3	TOTAL NUMBER	
3	NUMBER DETERMINATION	
3	SEX MATURITY CODE	
3	GROUP AGE	
3	WEIGHT-SUBSAMPLE	
3	NUMBER-SUBSAMPLE	
3	SEX CODE	
3	NUMBER EXAMINED	
3	DISEASE CODE	
3	INDIVIDUALS AFFECTED	
4	STATION NUMBER	
4	SPECIMEN NUMBER	
4	TAXONOMIC CODE	
4	SEX CODE	
4	SEX MATURITY CODE	
4	LENGTH-INDIVIDUAL	
4	LENGTH CODE	
4	WEIGHT-INDIVIDUAL	
4	WEIGHT DETERMINATION	
4	AGE	
4	AGE STRUCTURE	
4	DISEASE CODE	
4	FREQUENCE CODE	
4	GENERAL HEALTH CODE	
4	PIGMENTATION CODE	
4	LESION / ORGAN	
4	LESION LOCATION	
4	LENGTH-LESION	
4	WIDTH-LESION	
5	STATION NUMBER	
5	SPECIMEN NUMBER	
5	LESION/ORGAN	
5	LESION LOCATION CODE	
5	LENGTH-LESION	
5	WIDTH-LESION	
5	SEQUENCE NUMBER	
6	STATION NUMBER	
6	SPECIMEN NUMBER	

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PARAMETER CHECK LIST

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 013
MARINE FISH PATHOLOGY

RT	NAME OF FIELD	RU 332
6	DISEASE CODE	
6	LESION/ORGAN	
6	AVG LESION-LOCATION	
6	NUMBER LESIONS	
6	LESION LENGTH	
6	LESION WIDTH	
7	STATION NUMBER	
7	TAXONOMIC CODE	
7	TOTAL WEIGHT	
7	WT DETERMINATION	
7	TOTAL NUMBER	
7	NUM DETERMINATION	
7	SEX MATURITY	
7	GROUP AGE	
7	WT-SUBSAMPLE	
7	NUM SUBSAMPLE	
7	SEX	
7	NUMBER EXAMINED	
7	DISEASE (5)	
7	NUM AFFECTED (5)	
8	STATION NUMBER	
8	SPECIMEN NUMBER	
8	TAXONOMIC CODE	
8	SEX	
8	SEX MATURITY	
8	LENGTH	
8	LENGTH CODE	
8	WEIGHT	
8	WT DETERMINATION	
8	AGE	
8	AGE STRUCTURE	
8	DISEASE (3)	
8	FREQUENCY (3)	
8	GENERAL HEALTH	
8	PIGMENTATION	
8	LESION-ORGAN	
8	LESION-LOCATION	
8	LESION-LENGTH	
8	LESION-WIDTH (4)	
9	STATION NUMBER	
9	SPECIMEN NUMBER	
9	LESION-ORGAN	
9	LESION-LOCATION	
9	LESION LENGTH (10)	
9	LESION WIDTH (10)	
9	SEQ NUMBER	

PARAMETER CHECK LIST PAGE 1

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 015
CURRENT METER

RT	NAME OF FIELD	RU 091	RU 132	RU 141	RU 289	RU 526	RU 541	RU 549	RU 550	RU 583
X	FILE IDENTIFIER	X	X	X	X	X	X	X	X	X
X	RECORD TYPE	X	X	X	X	X	X	X	X	X
X	METER NUMBER	X	X	X	X	X	X	X	X	X
1	TEXT									
1	SEQUENCE NUMBER									
2	LATITUDE	X	X	X	X	X	X	X	X	X
2	LONGITUDE	X	X	X	X	X	X	X	X	X
2	DEPTH TO BOTTOM	X	X	X	X	X	X	X	X	X
2	DEPTH CURRENT METER	X	X	X	X	X	X	X	X	X
2	METER USAGE SEQ #	X	X	X	X	X	X	X	X	X
2	INSTITUTION CODE	X	X	X	X	X	X	X	X	X
2	AXIS ROTATION	X	X	X	X	X	X	X	X	X
2	LOCATION NAME	X	X	X	X	X	X	X	X	X
2	NO. DETAIL RECORDS	X	X	X	X	X	X	X	X	X
3	YEAR/MONTH/DAY	X	X	X	X	X	X	X	X	X
3	TIME	X	X	X	X	X	X	X	X	X
3	E-W CURRENT COMP	X	X	X	X	X	X	X	X	X
3	N-S CURRENT COMP	X	X	X	X	X	X	X	X	
3	CURRENT COMP. TEMP									
3	PRESSURE									
3	CONDUCTIVITY									
3	SEQUENCE NUMBER	X	X	X		X	X	X	X	X

PARAMETER CHECK LIST

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 017
PRESSURE GAUGE

RT	NAME OF FIELD	RU 138	RU 141	RU 289	RU 526	RU 541	RU 549	RU 550	RU 583
X	FILE IDENTIFICATION	X	X	X	X	X	X	X	X
X	RECORD TYPE	X	X	X	X	X	X	X	X
X	GAUGE NUMBER	X				X	X	X	X
1	TEXT								
1	SEQUENCE NUMBER								
2	LATITUDE	X	X	X	X	X	X	X	X
2	LONGITUDE	X	X	X	X	X	X	X	X
2	DEPTH PRESSURE GAUGE	X	X	X	X	X	X	X	X
2	NO. DETAIL RECORDS	X	X	X	X	X	X	X	X
3	DEPTH TO BOTTOM	X	X	X	X	X	X	X	X
3	METER USAGE SEQ #	X		X		X	X	X	X
3	INSTITUTION CODE	X	X	X	X	X		X	X
3	LOCATION NAME	X	X	X	X	X	X	X	X
4	YEAR/MONTH/DAY	X	X	X	X	X	X	X	X
4	TIME	X	X	X	X	X	X	X	X
4	TOTAL PRESSURE	X	X	X	X	X	X	X	X
4	SEQUENCE NUMBER	X	X	X	X	X	X	X	X
4	TEMPERATURE								

PARAMETER CHECK LIST

81/03/16 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 021
TRACE METALS

RT	NAME OF FIELD	RU 152
X	FILE IDENTIFIER	X
X	RECORD TYPE	X
X	SEQUENCE NUMBER	X
X	STATION NUMBER	X
A	SAMPLE DEPTH	X
A	REPLICATE NUMBER	X
A	LAB SAMPLE NUMBER	X
A	COCCOLITHS	X
A	DIATOMS	X
A	AGGREGATES	X
A	MINERAL GRAINS-FRAGM	X
A	PARTICLE SIZES	X
B	SAMPLE DEPTH	X
B	REPLICATE NUMBER	X
B	LAB SAMPLE NUMBER	X
B	PARTICLE SIZES	X
C	SAMPLE DEPTH	X
C	REPLICATE NUMBER	X
C	LAB SAMPLE NUMBER	X
C	PARTICLE SIZES	X
1	LATITUDE	X
1	LONGITUDE	X
1	SAMPLE COLLECT-DATE	X
1	TIME	X
1	DEPTH TO BOTTOM	X
1	SPHERE CODE	X
2	TEXT	C
3	SAMPLE DEPTH	X
3	REPLICATE NUMBER	X
3	LAB SAMPLE NUMBER	X
3	NEPHELS	X
3	TSM-SUSPENDED MATTER	X
3	TPC-PARTICULATE CARB	X
3	TRACE CODE	X
3	TPN-NITROGEN	X
3	MGO-MAGNESIUM OXIDE	X
3	ALUMINUM TRIOXIDE	X
3	SILICONE DIOXIDE	X
3	POTASSIUM OXIDE	X
3	CALCIUM OXIDE	X
4	SAMPLE DEPTH	X
4	REPLICATE NUMBER	X
4	LAB SAMPLE NUMBER	X
4	TITANIUM DIOXIDE	X
4	TRACE CODE	X
4	TOTAL CHROMIUM	X
4	TOTAL MANGANESE	X
4	TOTAL IRON	X
4	TOTAL NICKEL	X
4	TOTAL COPPER	X
4	TOTAL ZINC	X
4	TOTAL LEAD	X
5	SAMPLE DEPTH	X
5	REPLICATE NUMBER	X
5	LAB SAMPLE NUMBER	X
5	NEPHELS	X
5	SUSPENDED MATTER-TSM	X
5	PARTICULATE CARBON	X
5	TRACE CODE	X
5	PARTICULATE NITROGEN	X

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 021
TRACE METALS

RT	NAME OF FIELD	RU 152
5	MAGNESIUM OXIDE	X
5	ALUMINUM TRIOXIDE	X
5	SILICONE DIOXIDE	X
5	POTASSIUM OXIDE	X
5	CALCIUM OXIDE	X
6	SAMPLE DEPTH	X
6	REPLICATE NUMBER	X
6	LAB SAMPLE NUMBER	X
6	MAGNESIUM	X
6	TRACE CODE	X
6	CADMIUM	X
6	MERCURY	X
6	PHOSPHOROUS	X
6	ATP-//TRIPHOSPHATE	X

PARAMETER CHECK LIST

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 022 STD

RT	NAME OF FIELD	RU 138	RU 141	RU 151	RU 162	RU 289	RU 307	RU 427	RU 541	RU 549	RU 550	RU 583
X	FILE IDENTIFICATION	X	X	X	X	X	X	X	X	X	X	X
X	RECORD TYPE	X	X	X	X	X	X	X	X	X	X	X
X	CAST NUMBER	X	X	X	X	X		X	X	X	X	X
1	TEXT											
1	SEQUENCE NUMBER											
2	LATITUDE	X	X	X	X	X	X	X	X	X	X	X
2	LONGITUDE	X	X	X	X	X	X	X	X	X	X	X
2	CRUISE IDENT	X	X	X	X	X	X	X	X	X	X	X
2	NUMBER SCANS	X	X	X	X	X	X	X	X	X	X	X
2	DATE	X	X	X	X	X	X	X	X	X	X	X
2	TIME	X	X	X	X	X	X	X	X	X	X	X
2	DEPTH INTERVAL INDIC	X	X	X	X	X	X	X	X	X	X	X
2	DEPTH INTERVAL	X	X	X	X	X	X	X	X	X	X	X
2	BAROMETRIC PRESSURE											
2	WET BULB TEMP											
2	DRY BULB TEMP											
2	WIND DIRECTION											
2	WIND SPEED											
2	WEATHER CODE											
2	SEA STATE CODE											
2	VISIBILITY CODE											
2	CLOUD TYPE CODE											
2	CLOUD AMOUNT CODE											
2	INSTRUMENT	X	X	X	X	X	X	X	X	X	X	X
2	LOCATION NAME	X	X	X	X	X	X	X	X	X	X	X
2	DEPTH TO BOTTOM	X	X	X	X	X	X	X	X	X	X	X
2	MAX DEPTH OF CAST	X	X	X	X	X	X	X	X	X	X	X
3	DEPTH	X	X	X	X	X	X	X	X	X	X	X
3	TEMPERATURE	X	X	X	X	X	X	X	X	X	X	X
3	SALINITY	X	X	X	X	X	X	X	X	X	X	X
3	SIGMA-T	X	X	X	X	X	X	X	X	X	X	X
3	SCAN CONDITION CODE	X	X	X	X	X	X	X	X	X	X	X
3	SCAN DATA	X	X	X	X	X	X	X	X	X	X	X
3	SEQUENCE NUMBER	X	X	X	X	X	X	X	X	X	X	X
4	DEPTH				X	X	X	X		X		
4	DISSOLVED OXYGEN											
4	TRANSMISSIVITY											
4	SCAN CONDITION CODE				X	X	X	X		X		
4	SCAN DATA				X	X	X	X		X		
4	SEQUENCE NUMBER				X	X	X	X		X		

PARAMETER CHECK LIST

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 023
FISH RESOURCES

RT	NAME OF FIELD	RU 019	RU 027	RU 064	RU 174	RU 175	RU 233	RU 281	RU 284	RU 417	RU 427	RU 467	RU 485	RU 486	RU 512	RU 552	RU 553
X	FILE IDENTIFIER									X		X			X	X	X
X	RECORD TYPE									X		X			X	X	X
X	AGENCY CODE									X					X	X	X
X	VESSEL CODE									X					X	X	X
X	STATION NUMBER									X		X			X	X	X
X	SEQUENCE NUMBER									X		X			X	X	X
1	NUMBER HAULS									X					X		
1	INPFC AREA (OPT)									X					X		
1	LATITUDE									X		X			X	X	X
1	LONGITUDE									X		X			X	X	X
1	DATE									X		X			X	X	X
1	TIME									X		X			X	X	X
1	GEAR TYPE CODE									X		X				X	
1	DURATION-FISHING											X			X	X	X
1	DISTANCE FISHED														X	X	X
1	DIRECTION OF TOW															X	X
1	PERFORMANCE CODE															X	X
1	SURFACE TEMPERATURE																
1	GEAR TEMPERATURE																
1	AVG BOTTOM DEPTH-TOW									X					X	X	X
1	BOTTOM TYPE									X							
1	SOUNDING RECORD															X	
1	BOTTOM TRAWL TYPE															X	X
1	BOTTOM TRAWL ACCESOR															X	X
1	BOTTOM TRAWL WARP																X
1	AIR TEMPERATURE									X							X
1	PRESENT WEATHER CODE									X						X	X
1	CLOUD AMOUNT CODE									X					X	X	X
1	SEA STATE CODE									X					X	X	X
1	WIND DIRECTION									X					X		X
1	WIND FORCE									X					X		X
1	CURRENT DIRECTION																
1	CURRENT FORCE																
1	RECORD MODIFIER																
2	GEAR TYPE CODE									X					X	X	X
2	OPENING HEIGHT-TRAWL														X	X	X
2	OPENING WIDTH-TRAWL														X	X	X
2	OVERALL LENGTH-TRAWL														X	X	X
2	CODEND LENGTH														X	X	X
2	FOOT ROPE LENGTH														X	X	X
2	HEAD ROPE LENGTH														X	X	X
2	GEAR MATERIAL CODE															X	X
2	OPENING MESH														X	X	
2	AVERAGE BODY MESH														X	X	
2	CODEND MESH														X	X	
2	CODEND LINER															X	X
2	NUMBER OF FLOATS															X	
2	FLOAT DIAMETER															X	
2	TICKLER															X	X
2	ROLLER GEAR															X	X
2	LENGTH OF BRIDLES															X	X
2	LENGTH OF DOORS															X	X
2	WIDTH OF DOORS															X	X
2	WARP LENGTH															X	X
2	DEPTH OF GEAR															X	X
2	GEAR SALINITY																X
2	TRANSPARENCY																
2	TIDE														X		X
2	TIDE STAGE CODE														X		X
2	BOTTOM TEMP																
2	BOTTOM SALINITY																
2	RECORD MODIFIER																
3	GEAR TYPE CODE									X					X	X	X
3	UNIT LENGTH														X		X
3	NET DEPTH														X	X	X

PARAMETER CHECK LIST PAGE 2

31/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 023
FISH RESOURCES

RT	NAME OF FIELD	RU 019	RU 027	RU 064	RU 174	RU 175	RU 233	RU 281	RU 284	RU 417	RU 427	RU 467	RU 485	RU 486	RU 512	RU 552	RU 553
3	NUMBER OF UNITS																X
3	GANGION LENGTH																X
3	NUMBER OF SUBUNITS																X
3	GEAR MATERIAL CODE															X	X
3	BAIT-LURE CODE														X		
3	SEINE,END MESH-TOW														X		
3	SEINE,UPPER MESH														X		
3	SEINE,AVG BODY MESH															X	X
3	SEINE,BUNT MESH															X	X
3	GILLNET-# SHACKLES														X	X	X
3	GILLNET-MATERIAL														X	X	X
3	GILLNET-MESH														X	X	X
3	DEPTH OF GEAR														X	X	X
3	OUTSIDE-MESH/SEINE															X	X
3	MIDDLE MESH/SEINE															X	X
3	BAG MESH/SEINE															X	X
3	TRAMMEL-# SHACKLES														X		X
3	MATERIAL-OUTER PANEL														X		X
3	MESH-OUTER PANELS														X		X
3	MATERIAL INNER PANEL														X		X
3	MESH-INNER PANEL														X		X
3	GEAR SALINITY																
3	TIDE									X					X		X
3	TIDE STAGE CODE									X					X		X
3	RECORD MODIFIER																
4	SAMPLE NUMBER											X			X		X
4	TAXONOMIC CODE									X		X			X	X	X
4	TOTAL WT SPECIES														X	X	X
4	WEIGHT DETERMINATION														X	X	X
4	TOTAL NUMBER									X		X			X	X	X
4	NUMBER DETERMINATION									X					X	X	X
4	SEX MATURITY CODE														X		X
4	LIFE HISTORY CODE														X		X
4	NUMBER OF SPECIES														X		X
4	VOLUME OF CATCH														X		X
4	FISH PER LITER														X		X
4	WT SMALL CATCHES														X		X
4	RECORD MODIFIER														X		
5	SAMPLE NUMBER									X					X		X
5	TAXONOMIC CODE									X					X	X	X
5	SEX CODE									X						X	
5	LENGTH OF CLASS														X	X	X
5	LENGTH CODE														X	X	X
5	LENGTH FREQUENCY														X	X	X
5	LENGTH SAMPLE														X	X	X
5	RECORD MODIFIER														X		
6	SAMPLE NUMBER									X		X			X		X
6	TAX CODE PREDATOR									X		X			X	X	X
6	SEX CODE									X		X			X	X	X
6	SEX MATURITY CODE									X		X			X	X	X
6	LENGTH-INDIVIDUAL									X		X			X	X	X
6	LENGTH CODE											X			X	X	X
6	WEIGHT-INDIVIDUAL											X			X	X	X
6	WEIGHT DETERMINATION											X			X	X	X
6	AGE											X			X	X	X
6	AGE STRUCTURE											X			X	X	X
6	AGE DETERMINATION											X			X	X	X
6	SAMPLE TYPE														X	X	X
6	DATA TYPE CODE									X					X	X	X
6	STOMACH EXAMINED									X					X		X
6	GUT COLLECTED														X		X
6	FIN CLIP CODE																
6	CARAPACE WIDTH									X					X		X
6	SHELL CONDITION CODE									X					X		X
6	EGG COLOR CODE														X		

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 023
FISH RESOURCES

RT	NAME OF FIELD	RU 019	RU 027	RU 064	RU 174	RU 175	RU 233	RU 281	RU 284	RU 417	RU 427	RU 467	RU 485	RU 486	RU 512	RU 552	RU 553
6	EGG CONDITION CODE														X		
6	CLUTCH SIZE CODE									X					X		
6	CHELAE LENGTH																X
6	GONAD WEIGHT																
6	AVERAGE EGG LENGTH																
6	OVARIAN WEIGHT																
6	GONAD-SOMATIC INDEX																
6	GONAD WEIGHT																
6	PARASMA/THELYCUM																
6	RECORD MODIFIER																
7	SAMPLE NUMBER									X		X			X		X
7	TAX CODE PREDATOR											X			X		X
7	TAXONOMIC CODE-PREY									X		X			X		X
7	NUMBER OF PREY									X		X			X		X
7	VOLUME OF PREY									X					X		X
7	ORGAN CODE																
7	STOMACH FULLNESS									X					X		X
7	LIFE HISTORY CODE									X					X		X
7	STOMACH DIGESTION									X					X		X
7	WT-STOMACH CONTENTS														X		X
7	LIFE HISTORY-PREY									X					X		X
7	WET WEIGHT-PREY									X					X		X
7	WEIGHT METHOD CODE														X		X
7	GUT POSITION																
7	# STOM POOLED (PRED)																
8	TEXT																

PARAMETER CHECK LIST

81/02/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 024
ZOOPLANKTON

RT	NAME OF FIELD	RU 172	RU 353	RU 380	RU 424	RU 425	RU 426	RU 427	RU 551	RU 553
X	FILE IDENTIFIER	X	X		X				X	X
X	RECORD TYPE	X	X		X				X	X
1	VESSEL	X	X		X				X	X
1	CRUISE	X	X		X				X	X
1	CRUISE DATES		X		X				X	X
1	AREA/PROJECT	X	X		X				X	X
1	INVESTIGATOR/INSTITU	X	X		X				X	X
2	STATION NUMBER	X	X		X				X	X
2	LATITUDE	X	X		X				X	X
2	LONGITUDE	X	X		X				X	X
2	DATE	X	X		X				X	X
2	TIME	X	X		X				X	X
2	DEPTH TO BOTTOM	X	X		X				X	X
2	SAMP-INTERVAL/UPPER	X	X		X				X	X
2	SAMP-INTERVAL/LOWER	X	X		X				X	X
2	SHIP SPEED	X	X		X				X	X
2	SURFACE WATER TEMP	X	X		X					
2	SURFACE H2O SALINITY									
2	WATER TEMP-25 M									
2	WATER SALINITY-25 M									
2	WATER TEMP-50 M									
2	WATER SALINITY-50 M									
2	WATER TEMP-100 M									
2	WATER SALINITY-100 M									
3	STATION NUMBER	X	X		X				X	X
3	GEAR CODE	X	X		X				X	X
3	MESH SIZE	X	X		X				X	X
3	DURATION		X		X				X	X
3	HAUL LENGTH	X	X		X				X	X
3	TOTAL SETTLED VOLUME	X								
3	WATER DISPLACED	X							X	X
3	DRY WEIGHT OF HAUL	X								
3	WET WEIGHT OF HAUL	X								
3	VOL-WATER FILTERED	X	X		X				X	X
3	DURATION OF TOW	X	X		X				X	X
3	HAUL TYPE CODE	X	X		X				X	X
4	STATION NUMBER	X			X				X	X
4	SAMPLE NUMBER	X							X	X
4	TAXONOMIC CODE	X							X	X
4	LIFE HISTORY CODE	X							X	X
4	SIZE-SUBSAMPLE	X							X	X
4	NUMBER -SUBSAMPLE	X							X	X
4	CONCENTRATION	X								
4	DRY WEIGHT									
4	WET WEIGHT	X								
4	NUMBER-ADULTS	X							X	X
4	NUMBER-JUVENILES	X							X	X
4	NUMBER-EGGS	X							X	X
4	NUMBER-LARVAE	X							X	X
4	SEX CODE	X								
5	STATION NUMBER	C	C		C				C	C
5	SEQUENCE NUMBER	C	C							
5	TEXT	C	C							
6	STATION NUMBER	X	X		X				X	X
6	SAMPLE NUMBER	X			X				X	X
6	TAXONOMIC CODE	X	X		X				X	X
6	LIFE HISTORY CODE	X	X		X				X	X
6	SIZE OF SUBSAMPLE	X	X		X				X	X
6	NUMBER-SUBSAMPLE	X	X		X				X	X
6	CONCENTRATION	X	X		X					
6	DRY WEIGHT									
6	WET WEIGHT	X								

FILE TYPE 024
ZOOPLANKTON

RT	NAME OF FIELD	RU 172	RU 359	RU 380	RU 424	RU 425	RU 426	RU 427	RU 551	RU 553
6	NUMBER-ADULTS	X							X	X
6	NUMBER-JUVENILES	X							X	X
6	NUMBER-EGGS	X							X	X
6	NUMBER-LARVAE	X							X	X
6	SEX CODE	X								
7	STATION NUMBER									
7	SAMPLE NUMBER									
7	TEXT									
7	SAMPLE SIZE									
7	EST HOLOPLANKTON									
7	EST MEROPLANKTON									
7	% MEROLANKTON/HAUL									
8	STATION NUMBER									
8	SAMPLE NUMBER									
8	TEXT									
8	NODC TAXONOMIC CODE									
8	NUMBER CAUGHT									
8	MINIMUM SIZE									
8	MAXIMUM SIZE									
8	MEAN SIZE									
8	# EGGS THIS SPECIE									

PARAMETER CHECK LIST

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 025
MARINE MAMMAL SPECIMEN

PT	NAME OF FIELD	RU 229	RU 230	RU 232	RU 243	RU 612
X	FILE IDENTIFIER	X	X	X	X	X
X	RECORD TYPE	X	X	X	X	X
X	SPECIMEN NUMBER	X	X	X	X	X
X	SEQUENCE NUMBER	X	X	X	X	
1	LATITUDE	X	X	X	X	
1	LONGITUDE	X	X	X	X	X
1	DATE	X	X	X	X	X
1	TIME	X	X	X	X	X
1	WATER DEPTH					
1	TIDE STAGE					
1	HABITAT CODE	X			X	
1	BEHAVIOR CODE					
1	ICE CODES (7)		X			
1	DEFORMATION CODE					
1	TRANSECT WIDTH CODE					
2	TAXONOMIC CODE	X	X	X	X	X
2	SEX CODE	X	X	X	X	X
2	ACCOMPANIED BY PUP	X			X	
2	MAMMAL LACTATING					
2	MAMMAL SUNK					
2	GROUP SIZE					
2	COLLECTION METHOD	X	X		X	
2	WT HIDE & BLUBBER	X	X		X	
2	CURILINEAR LENGTH	X	X		X	
2	AXILLARY GIRTH	X	X		X	
2	MAXIMUM GIRTH	X	X		X	
2	FRONT FLIPPER LENGTH		X			
2	FRONT FLIPPER WIDTH		X			
2	HIND FLIPPER LENGTH	X	X		X	
2	HIND FLIPPER WIDTH		X			
3	NAVEL TO ANUS LENGTH		X			
3	PENIS TO ANUS LENGTH		X			
3	TAIL LENGTH		X			
3	BLUBBER /STERNUM	X	X		X	
3	BLUBBER /CHEST	X	X		X	
3	NECK CIRCUMFERENCE		X			
3	STOMACH CONDITION	X			X	
3	GROSS WEIGHT	X	X		X	
3	STANDARD LENGTH		X			X
3	CAUSE OF DEATH	X	X		X	
3	CAUSE OF ILLINESS					
4	AGE	X	X		X	
4	AGE UNIT CODE	X			X	
4	AGE DETERMINATION	X	X		X	
4	AGE ACCURACY CODE					
4	BACULUM LENGTH	X	X		X	C
4	BACULUM WEIGHT	X	X		X	C
4	TESTES WT WITH EPID	X	X		X	C
4	TESTES WT W/O EPID	X	X		X	C
4	TESTIS VOLUME	X	X		X	C
4	TESTIS LENGTH	X	X		X	C
4	TESTIS WIDTH	X	X		X	C
4	PRESENCE OF SPERM	X	X		X	C
4	SPERM DETERMINATION	X	X		X	C
5	AGE	X	X		X	
5	AGE UNIT CODE	X	X		X	
5	AGE DETERMINATION	X	X		X	
5	AGE ACCURACY CODE	X			X	
5	REPRODUCTIVE STATUS	X	X		X	C
5	REPRODUCTIVE COND	X			X	C
5	NUMBER OF FETUSES	X	X		X	C
5	OVARY WEIGHT	X	X		X	C
5	NO. CORPORA LUTEA	X	X		X	C

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 025
MARINE MAMMAL SPECIMEN

RT	NAME OF FIELD	RU 229	RU 230	RU 232	RU 243	RU 612
5	DIA LG CORPORA LUTEA	X	X		X	C
5	CORPORA ALBICANTIA	X	X		X	C
5	DIA COR. ALBICANTIA	X	X		X	C
5	FOLLICLES > 5MM	X	X		X	C
5	DIA LG FOLLICLE	X	X		X	C
5	UTERINE SCARS	X	X		X	C
6	WT FULL STOMACH					
6	WT EMPTY STOMACH					
6	WT FOOD CONTENTS	X			X	
6	TOTAL VOL CONTENTS	X		X	X	X
6	STOMACH CODE					
7	PREY TAXONOMIC CODE	X		X	X	X
7	LIFE HISTORY CODE					
7	MISC STOMACH CONTENT	X			X	
7	NO. ITEMS IDENTIFIED	X		X	X	X
7	VOL ITEMS IDENTIFIED	X		X	X	X
7	WT ITEMS IDENTIFIED	X			X	
7	MEAN LENGTH ITEMS					
7	MAX LENGTH ITEMS					
7	MIN LENGTH ITEMS					
7	DIGESTIVE ORGAN CODE	X			X	
8	TEXT	C	C	C	C	C
9	AGE			X		X
9	AGE ACCURACY CODE			X		X
9	AGE UNIT CODE			X		X
9	AGE DETERMINATION			X		X

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 026
MARINE MAMMAL SIGHTING 2

RT	NAME OF FIELD	RU 067	RU 069	RU 070	RU 230	RU 231	RU 240	RU 248	RU 481
X	FILE IDENTIFIER				X				
X	RECORD TYPE				X				
X	FLIGHT/STATION NO.				X				
X	SEQUENCE NUMBER				X				
1	START DATE-TIME				X				
1	START LATITUDE				X				
1	START LONGITUDE				X				
1	ENDING TIME				X				
1	ENDING LATITUDE				X				
1	ENDING LONGITUDE				X				
1	ELAPSED TIME								
1	DISTACE ALONG TRACK								
1	NUMBER-OBSERVERS				X				
1	TYPE OF LEG CODE								
2	PLATFORM TYPE CODE				X				
2	PLATFORM I.D.CODE				X				
2	PLATFORM DIRECTION				X				
2	ALTITUDE				X				
2	TRUE GROUND SPEED								
2	PRIMARY TRACK WIDTH				X				
2	SECONDARY -WIDTH				X				
2	TOTAL TRACK WIDTH				X				
2	AREA SURVEYED 1								
2	AREA SURVEYED 2								
2	VISIBILITY CODE								
2	CLOUD AMOUNT CODE								
2	AIR TEMPERATURE								
2	WIND DIRECTION								
2	WIND SPEED								
2	SEA STATE CODE								
2	WEATHER CODE								
2	COLLECTION METHOD				X				
3	TIME-OBSERVATION				X				
3	ICE TYPE CODE				X				
3	OCTAS ICE-COVERAGE				X				
3	CHARACTERISTICS ICE				X				
3	DEFORMATION CODE				X				
3	TRANSECT WIDTH				X				
4	TAXONOMIC CODE				X				
4	TOTAL-INDIVIDUALS-1				X				
4	CONFIDENCE CODE-1				X				
4	TOTAL INDIVIDUALS-2				X				
4	CONFIDENCE CODE-2				X				
4	TOTAL SIGHTED 1 AND2				X				
4	CONFIDENCE CODE				X				
4	NUMBER OF PUPS				X				
4	NUMBER OF GROUPS				X				
4	MAMMAL ACTIVITY								
4	TEXT								
4	TOTAL SIGHTED				X				
5	TAXONOMIC CODE				X				
5	TIME				X				
5	TRACK NUMBER				X				
5	GROUP # (1-16)				X				
6	TEXT				C				

PARAMETER CHECK LIST

81/03/19 PROJECT OFFICE ALL RU-ALL

FILE TYPE 027
MARINE MAMMAL SIGHTING

RT	NAME OF FIELD	RU 068	RU 194	RU 240	RU 243	RU 337	RU 481
X	FILE IDENTIFIER		X		X		
X	RECORD TYPE		X		X		
X	FLIGHT/STATION NO.		X		X		
X	SEQUENCE NUMBER		X		X		
1	START DATE		X		X		
1	START TIME		X		X		
1	START LATITUDE		X		X		
1	START LONGITUDE		X		X		
1	ELAPSED TIME				X		
1	DISTANCE ALONG TRACK				X		
1	COMPLETENESS CODE		X		X		
1	ENDING LATITUDE		X		X		
1	ENDING LONGITUDE		X		X		
2	SIGHTING DATE		X		X		
2	SIGHTING TIME		X		X		
2	SIGHTING LATITUDE				X		
2	SIGHTING LONGITUDE				X		
2	PLATFORM TYPE		X		X		
2	PLATFORM I.D.		X		X		
2	PLATFORM DIRECTION		X		X		
2	ALTITUDE		X		X		
2	AIR SPEED		X				
2	TIDE RANGE		X				
2	CURRENT SPEED		X		X		
2	CURRENT DIRECTION		X		X		
2	ICE CODES (6)		X		X		
2	DEFORMATION CODE		X		X		
2	TRANSECT WIDTH CODE						
3	SIGHTING DATE		X		X		
3	SIGHTING TIME		X		X		
3	SIGHTING LATITUDE				X		
3	SIGHTING LONGITUDE				X		
3	WIND SPEED		X		X		
3	WIND DIRECTION		X		X		
3	VISIBILITY		X		X		
3	CLOUD TYPE		X		X		
3	CLOUD AMOUNT		X		X		
3	WEATHER		X		X		
3	AIR TEMPERATURE						
3	SEA STATE		X		X		
3	WATER SURFACE TEMP						
3	WATER COLOR				X		
3	SURFACE VISIBILITY						
3	BAROMETRIC PRESSURE						
3	INCLINOMETER ANGLE						
3	WATER DEPTH						
4	SIGHTING DATE		X		X		
4	SIGHTING TIME		X		X		
4	SIGHTING LATITUDE				X		
4	SIGHTING LONGITUDE				X		
4	DISTANCE SURVEYED		X		X		
4	AREA SURVEYED		X		X		
4	MAMMAL ACTIVITY		X		X		
4	NUMBER-OBSERVERS		X		X		
4	COLLECION METHOD		X		X		
4	GROUP SIZE		X		X		
4	ANIMAL MOVEMENT DIR				X		
4	SIGHTING DISTANCE		X		X		
4	DISTANCE FROM PLAT		X		X		
4	BEARING TO ANIMALS		X		X		
4	PLATFORM HEADING		X		X		
5	TAXONOMIC CODE				X		
5	BEHAVIOR CODE				X		

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 027
MARINE MAMMAL SIGHTING

RT	NAME OF FIELD	RU 068	RU 194	RU 240	RU 243	RU 337	RU 481
5	CONFIDENCE CODES(5)				X		
5	NUMBER-INDIVIDUALS				X		
5	NUMBER-ADULTS				C		
5	NUMBER-PUPS		C		C		
5	TOTAL SUBADULTS		C		C		
5	TOTAL ADULT MALES		C		C		
5	TOTAL ADULT FEMALES		C		C		
5	MARKED ANIMAL CODE				C		
5	STATIC/TELEMETRY		X				
5	STAGE DECOMPOSITION		X				
5	COMPLETENESS		X		X		
6	DISTANCE-ICE EDGE		X				
6	DISTANCE -SHORE		X				
6	IDENT RELIABILITY		X		X		
6	GLARE AREA CODE		X		X		
6	DEBRIS CODE						
6	TEXT		C		C		
7	TEXT		C		C		
8	SIGHTING DATE				X		
8	SIGHTING TIME				X		
8	SIGHTING LATITUDE				X		
8	SIGHTING LONGITUDE				X		
8	ICE CODES (7)				X		
8	DEFORMATION CODE				X		
8	TRANSECT WIDTH CODE						

PARAMETER CHECK LIST   PAGE 1

81/03/19   PROJECT OFFICE-ALL   RU-ALL

FILE TYPE 028
PHYTOPLANKTON SPECIES

RT	NAME OF FIELD	RU 058	RU 359	RU 425	RU 427
X	FILE IDENTIFIER		X	X	
X	RECORD TYPE		X	X	
X	STATION NUMBER		X	X	
1	LATITUDE		X	X	
1	LONGITUDE		X	X	
1	DATE		X		
1	TIME		X	X	
1	TIME ZONE		X		
1	DEPTH TO BOTTOM		X	X	
2	TEXT			C	
2	SEQUENCE NUMBER			X	
3	SAMPLE NUMBER			X	
3	SAMPLE DEPTH			X	
3	TAXONOMIC CODE			X	
3	COUNT			X	
3	NUMBER-CELLS/LITER			X	
3	WET WEIGHT				
3	DRY WEIGHT				
3	VOL WATER FILTERED			X	
3	SEQUENCE NUMBER			X	
4	SAMPLE NUMBER			X	
4	SAMPLE DEPTH		X	X	
4	TAXONOMIC CODE		X	X	
4	CELLS PER LITER		X	X	
4	CARBON PER LITER			X	
4	PERCENT CELLS-LITER		X	X	
4	PERCENT CARBON-LITER			X	
4	SEQUENCE NUMBER		X	X	

PARAMETER CHECK LIST

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 029
PRIMARY PRODUCTIVITY

RT	NAME OF FIELD	RU 058	RU 359	RU 425	RU 427	RU 537
X	FILE IDENTIFIER	X	X	X	X	X
X	RECORD TYPE	X	X	X	X	X
0	VESSEL		X	X	X	X
0	CRUISE		X	X		X
0	CRUISE DATES		X	X		X
0	SENIOR SCIENTIST		X	X		X
0	PI-INSTITUTION		X	X		X
1	STATION NUMBER		X	X		X
1	LATITUDE		X	X		X
1	LONGITUDE		X	X		X
1	DATE		X	X		X
1	TIME		X	X		X
1	TIME ZONE		X	X		
1	DEPTH TO BOTTOM		X	X		X
1	CHLOROPHYLL-A		X	X		X
1	PHAEOPIGMENTS		X	X		
1	CARBON ASSIMILATION		X	X		
1	1% LIGHT DEPTH					
1	PHOSPHATE-REACT/TIME					
1	PH SCALE					
1	SITU CORRECTION-PH					
1	SECCHI DEPTH		X	X		
1	MIXED LAYER DEPTH					
1	LIGHT LEVEL-ABOARD			X		
1	QUANTA					
3	STATION NUMBER		X	X		X
3	DEPTH OF SAMPLE		X	X		X
3	CHLOROPHYLL-CON		X	X		
3	PHAEOPIGMENT-CON		X	X		
3	CARBON ASSIMILATION		X	X		
3	TIME-INCUBATION		X	X		
3	OXYGEN			X		
3	INORGANIC-PHOSPHATE			X		X
3	AMMONIA NH3-N			X		X
3	NITRATE NO3-O			X		X
3	NITRITE NO2-O			X		X
3	SILICATE SIO3-SI					
3	PH			X		
3	ALKALINITY-TOTAL					
3	TEMPERATURE		X	X		
3	SALINITY		X	X		X
3	SEQUENCE NUMBER		X	X		
4	STATION NUMBER			C		C
4	TEXT			C		
4	SEQUENCE NUMBER			C		

PARAMETER CHECK LIST

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 030
INTERTIDAL DATA

RT	NAME OF FIELD	RU 024	RU 027	RU 078	RU 079	RU 356	RU 417
X	FILE IDENTIFIER			X		X	X
X	RECORD TYPE			X		X	X
1	VESSEL NAME/FIELD			X		X	X
1	CRUISE NUMBER			X		X	X
1	START DATE			X		X	X
1	END DATE			X		X	X
1	SENIOR SCIENTIST			X		X	X
1	PI/INSTITUTION			X		X	X
2	STATION NUMBER			X		X	X
2	SEQUENCE NUMBER			X		X	X
2	LATITUDE			X		X	X
2	LONGITUDE			X		X	X
2	DATE			X		X	X
2	START TIME			X		X	X
2	ELAPSED TIME					X	
2	TIME ZONE					X	
2	SURFACE SALINITY					X	
2	SURFACE TEMPERATURE					X	X
2	AIR TEMPERATURE					X	X
2	SECCHI DISC DEPTH					X	
2	WEATHER CODE					X	X
2	CLOUD TYPE CODE					X	
2	CLOUD AMOUNT CODE					X	
2	WIND SPEED					X	X
2	WIND DIRECTION					X	X
2	SEA STATE CODE					X	X
2	BREAKER HEIGHT CODE					X	
2	EXPOSURE DIRECTION					X	X
2	SUBSTRATA (3)					X	X
2	BAROMETRIC PRESSURE						
2	HABITAT (4)					X	X
2	SECCHI VIS-BOTTOM					X	
3	STATION NUMBER			X		X	X
3	SEQUENCE NUMBER			X		X	X
3	CATALOG NUMBER						
3	PHOTOGRAPH NUMBER						
3	GEAR TYPE CODE					X	X
3	TRANSECT NUMBER					X	X
3	TRANSECT DIRECTION					X	X
3	METER NUMBER					X	
3	ZONE/ARROW/#-SAMPLE					X	X
3	QUADRAT SIZE					X	X
3	ELEVATION					X	X
3	SUBSTRATA TYPE (3)					X	X
3	SUR TOPOGRAPHY (3)					X	X
3	COLLECTION TIME					X	X
3	SIEVE SIZE					X	
3	DILUTION VOLUME					X	
3	QUADRAT SLOPE					X	
3	DIRECTION SLOPE					X	
3	GRAB NUMBER					X	X
3	SEDIMENT					X	
3	GRAIN SIZE					X	
3	PATCH GRID SIZE					X	
3	MED FRAME MULTIPLE					X	
3	LG FRAME MULTIPLE					X	
3	TOTAL WORK AREA					X	X
3	DEPTH					X	
3	DISTANCE-NET TOW					X	
3	LG SAMPLE QUADRAT					X	
3	DISTANCE-NET TOW					X	
4	STATION NUMBER			X		X	X
4	SEQUENCE NUMBER			X		X	X
4	TAXONOMIC CODE			X		X	X

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 030
INTERTIDAL DATA

RT	NAME OF FIELD	RU 024	RU 027	RU 078	RU 079	RU 356	RU 417
4	SEX CODE					X	X
4	CONDITION CODES (3)					X	
4	COVERAGE					X	
4	COUNT					X	X
4	WET WEIGHT					X	X
4	DRY WEIGHT						X
4	MIN LENGTH						
4	MAX LENGTH						
4	DISPLACEMENT VOL						
4	MEAN LENGTH						
4	MIN WIDTH						
4	MAX WIDTH						
4	MEAN WIDTH						
4	MIN AGE						
4	MAX AGE						
4	MEAN AGE						
4	SMALL FRAME					X	
4	MEDIUM FRAME					X	
4	LARGE FRAME					X	
4	DILUTION VOLUME						
4	PLANT HEIGHT						X
4	STARFISH CODE						
4	PLANT HEIGHT						X
5	STATION NUMBER			X		X	X
5	SEQUENCE NUMBER			X		X	X
5	TAXONOMIC CODE			X		X	X
5	SEX CODE					X	X
5	CONDITION CODES (3)					X	
5	AGE						X
5	WET WEIGHT					X	X
5	DRY WEIGHT						X
5	LENGTH						
5	WIDTH						
5	DISPLACEMENT VOL						
5	STARFISH CODE						
6	STATION NUMBER			X		X	
6	SEQUENCE NUMBER			X		X	
6	OXYGEN					X	
6	PH						
6	PH SCALE						
6	SALINITY					X	
6	INTERSTITIAL SALINIT					X	
6	PERMAFROST DEPTH					X	
6	WATER TEMPERATURE					X	
6	SECCHI DISK DEPTH					X	
6	GRAIN SIZE-PHI (11)					X	
7	STATION NUMBER			X		X	
7	SEQUENCE NUMBER			X		X	
7	COMMENTS					X	

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 031
MARINE BIRDS SPECIMEN/ FEEDING

RT	NAME OF FIELD	RU 083	RU 196	RU 341	RU 467
X	FILE IDENTIFER	X	X		X
X	RECORD TYPE	X	X		X
X	STATION NUMBER	X	X		X
X	SEQUENCE NUMBER		X		X
A	LATITUDE	X	X		X
A	LONGITUDE	X	X		X
A	DATE	X	X		X
A	TIME	X	X		
B	AIR TEMPERATURE				
B	SEA SURFACE TEMP				
B	WIND DIRECTION				
B	WIND SPEED				
B	PRESENT WEATHER		X		
B	BAROMETRIC PRESSURE				
B	PREVIOUS TIDE STAGE				
B	PREVIOUS TIDE HEIGHT				
B	PREVIOUS TIDE TIME				
B	PRESENT TIDE STAGE				
B	PRESENT TIDE HEIGHT				
B	FOLLOWING TIDE STAGE				
B	FOLLOWING TIDE HT				
B	FOLLOWING TIDE TIME				
B	METHOD TIDE MEASURE				
B	HABITAT		X		
B	MICROENVIRONMENT				
B	PREY SAMPLING		X		
C	ICE IN TRANSECT		X		
C	ICE OUTSIDE TRANSECT		X		
C	VISIBLE OPEN WATER		X		
C	VISIBLE ICE		X		
C	ARCTIC COD OBSERVED		X		
C	EXCESS SEDIMENT				
C	ICE ALGAE LAYER		X		
C	MAMMAL TRACE		X		
C	OTHER FEATURES		X		
C	ICE PATTERN		X		
C	SHIP IN WATER		X		
C	WIDTH OF LEAD		X		
C	DIST SHIP-LEAD/POLYN		X		
C	TIME OF ICE		X		
C	% WATER VERSUS LAND		X		
C	SIZE OF PONDS		X		
C	DESCRIP-OPEN H2O ICE		X		
C	COVER OPEN H2O ICE		X		
D	SPECIMEN NUMBER	X	X		X
D	TAXONOMIC CODE	X	X		X
D	COLLECT METHOD		X		
D	CARCASS DISPOSITION		X		
D	SEX		X		
D	AGE		X		
D	COLOR PHASE		X		
D	PLUMAGE		X		
D	BROOD PATCH		X		
D	BEHAVIOR ACTIVITY		X		
D	NUMBER OF BIRDS		X		
D	LINKAGE NUMBER				X
E	SPECIMEN NUMBER	X	X		
E	DIAGONAL TARSUS				
E	EXPOSED CULMEN		X		
E	INSIDE BILL WIDTH				
E	RIGHT WING LENGTH		X		
E	BURSA LENGTH				
E	TOTAL LENGTH				

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 031
MARINE BIRDS SPECIMEN/ FEEDING

PT	NAME OF FIELD	RU 083	RU 196	RU 341	RU 467
E	TOTAL WEIGHT	X	X		
E	DRY WEIGHT				
E	FAT FREE WEIGHT				
E	VISCERA WEIGHT		X		
E	LARGEST GONAD		X		
E	FAT INDEX		X		
F	SPECIMEN NUMBER	X	X		
F	FOOD SAMPLE ORIGIN				
F	STOMACH FULLNESS				
F	CUT PORTION		X		
F	WET WEIGHT		X		
F	DISPLACEMENT VOLUME		X		
F	DRY WEIGHT				
F	WEIGHT-NON-FOOD ITEM		X		
G	SPECIMEN NUMBER	X	X		X
G	PREY TAX CODE -GROUP	X	X		X
G	NON-FOOD ITEMS		X		
G	PREY PART IDENT		X		
G	#PREY OR PREY PARTS		X		X
G	ALIQUOT FACTOR				
G	WHOLE PREY EQUIVALNT				
G	LIFE HISTORY				
G	VOLUME METHOD		X		
G	PREY VOLUME		X		
G	PREY DRY WEIGHT				
G	PREY WET WEIGHT		X		
G	PREY VOLUME				
G	FOOD ORIGIN				
G	ITEM NUMBER				
H	SPECIMEN NUMBER	X	X		
H	METHOD A OR B				
H	SIZE CLASS				
H	MEASUREMENT				
H	FOOD ORIGIN				
H	ITEM NUMBER				
I	SPECIMEN NUMBER	X			
I	METHOD A OR B				
I	WEIGHT CLASS				
I	MEASUREMENT				
I	FOOD ORIGIN				
I	ITEM NUMBER				
T	SPECIMEN NUMBER	X			
T	CITATION				
T	TEXT		C		

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21/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 032
BENTHIC ORGANISMS

RT	NAME OF FIELD	RU 005	RU 095	RU 281	RU 467	RU 502	RU 517
X	FILE IDENTIFIER	X	X	X	X	X	X
X	RECORD TYPE	X	X	X	X	X	X
1	SHIP NAME	X	X	X		X	X
1	TEXT		C	C		C	C
1	SEQUENCE NUMBER	X	C	X		X	X
2	STATION NUMBER	X	X	X	X	X	X
2	START DEPTH	X	X	X	X	X	X
2	START DATE	X	X	X	X	X	X
2	START TIME	X	X	X		X	X
2	START LATITUDE	X	X		X		
2	START LONGITUDE	X	X		X		
2	END DEPTH	C	C		X		
2	END DATE	C	C		X		
2	END TIME	C	C				
2	END LATITUDE	C	C		X		
2	END LONGITUDE	C	C		X		
2	DISTANCE OFFSHORE		C	X		X	X
2	TOW DIRECTION		C				
2	BOTTOM TYPE		C				
3	STATION NUMBER	X	X	X	X	X	X
3	SEGMENT START DEPTH		C				
3	SEGMENT END DEPTH		C				
3	PENETRATION DEPTH		C				
3	AREA SAMPLED			X	X	X	X
3	BOTTOM SALINITY						
3	BOTTOM TEMPERATURE	X					
3	BOTTOM OXYGEN						
3	SEDIMENT ORG.CARBON			X		X	X
3	SEDIMENT -CARBON						
3	SAND	X		X		X	X
3	SILT	X		X		X	X
3	CLAY	X		X		X	X
3	MIN SIEVE SIZE	X	X	X		X	X
3	WIRE LENGTH		C				
3	WIRE ANGLE		C				
3	AVG PHI SIZE						
3	EQUIPMENT CODE	X		X	X	X	X
3	SAMPLE NUMBER		X	X	X	X	X
3	SEGMENT SEQUENCE		X	X		X	X
3	SAMPLE VOLUME	C	X	X	X	X	X
3	NUMBER OF GRABS	C	X		X		
5	STATION NUMBER	X	X	X	X	X	X
5	SPECIES CODE	X	X	X	X	X	X
5	NO. INDIVIDUALS	X	C	X	X	X	X
5	SPECIES-TOTAL WEIGHT	X	C	X	X	X	X
5	QUALITATIVE CODE	X	C	X		X	X
5	SEGMENT SEQUENCE #	X	X	X		X	X
6	STATION NUMBER		C	C		C	C
6	TEXT SEQUENCE NO.		C	C		C	C
6	TEXT		C	C		C	C
6	SEGMENT SEQUENCE #		X	X		X	X

FILE TYPE 033
SHIP AND AIRCRAFT CENSUS

RT	NAME OF FIELD	RU 083	RU 196	RU 237	RU 239	RU 337	RU 460	RU 467
X	FILE IDENTIFIER	X	X	X	X	X	X	X
X	RECORD TYPE	X	X	X	X	X	X	X
X	STATION NUMBER	X	X	X	X	X	X	X
1	START LATITUDE	X	X			X	X	X
1	START LONGITUDE	X	X			X	X	X
1	START DATE	X	X			X	X	X
1	START TIME	X	X			X	X	X
1	END LATITUDE	X				X	X	X
1	END LONGITUDE	X				X	X	X
1	ELAPSED TIME	X	X			X	X	X
1	TIME ZONE	X	X			X	X	X
1	SPEED MADE GOOD	X	X			X		X
1	COURSE MADE GOOD	X	X			X		X
1	HT ABOVE SEA/EYES	X	X			X	X	X
1	PLATFORM TYPE CODE	X	X			X	X	X
1	SAMPLING TECHNIQUE	X	X			X	X	X
1	SHIP ACTIVITY CODE		X			X		
1	PHOTOS TAKEN	O						
1	WIDTH-TRANSECT	X				X	X	
1	ANGLE OF VIEW CODE							
1	OBSER.CONDITIONS	X				X	X	
1	DISTANCE MADE GOOD		X			X		X
1	WATCH TYPE CODE		X					
1	TRANSECT WIDTH							X
2	DEPTH TO BOTTOM	X	X			X		
2	DEPTH-THERMOCLINE	X				X		
2	SURFACE TEMPERATURE	X	X			X		
2	SURFACE SALINITY	X				X		
2	DRY BULB TEMPERATURE		X			X		X
2	WET BULB TEMPERATURE		X			X		
2	RELATIVE HUMIDITY					X		
2	BAROMETRIC PRESSURE		X			X		
2	BAROMETRIC TREND		X			X		
2	WIND DIRECTION		X			X	X	
2	WIND SPEED		X			X	X	X
2	SEA STATE	X	X			X	X	
2	SWELL DIRECTION		X			X		
2	SWELL HEIGHT		X			X		
2	WEATHER	X	X			X	X	
2	CLOUD TYPE		X					
2	CLOUD AMOUNT		X					X
2	WATER COLOR							
2	VISIBILITY		X			X	X	
2	SUN DIRECTION					X		
2	GLARE INTENSITY					X		
2	GLARE AREA CODE					X		
2	LIGHT LEVEL							
2	MOON PHASE CODE							
2	TIDE HEIGHT CODE							
2	TIDE-RISE OR FALL							
2	DISTANCE-SHORELINE		X					
2	DISTANCE-SHELFBREAK		X					
2	SECCHI DEPTH							
2	DEBRIS CODE							
3	ICE IN TRANSECT	X	X					
3	ICE OUTSIDE TRANSECT	X	X					
3	VISIBLE OPEN WATER		X					
3	TYPE-OPENING		X					
3	DIRECTION-OPEN WATER		X					
3	DISTANCE-OPEN WATER		X					
3	LEAD/POLYNYA		X					
3	VISIBLE ICE		X					
3	ARCTIC COD OBSERVED		X					
3	EXCESS SEDIMENT							
3	ICE ALGAE LAYER		X					

FILE TYPE 033
SHIP AND AIRCRAFT CENSUS

RT	NAME OF FIELD	RU 083	RU 196	RU 237	RU 239	RU 337	RU 460	RU 467
3	MAMMAL TRACE CODE		X					
3	OTHER FEATURES		X					
3	PATTERN ICE IN TRAN		X					
3	PATTERN ICE OUTSIDE		X					
3	SHIP IN WATER		X					
3	WIDTH OF LEAD		X					
3	DISTANCE-SHIP-LEAD		X					
3	TIME-ICE CONDITIONS		X					
3	% WATER VS LAND		X					
3	SIZE OF PONDS		X					
3	OPEN WATER ICE DESCR		X					
3	OPEN WATER ICE COVER		X					
3	SEQUENCE NUMBER	X						
4	TE:T	C	C				C	
4	SEQUENCE NUMBER	C						
5	TIME	X	X			X	X	X
5	TAX CODE TO GROUP	X	X			X	X	X
5	AGE CLASS GROUP CODE		X			X	X	X
5	SEX CODE		X			X		
5	COLOR PHASE CODE	X	X			X		
5	PLUMAGE CODE	X	X			X		
5	MOLT CODE	X	X			X		
5	NO. INDIVIDUALS	X	X			X	X	X
5	COUNTING METHOD	X						
5	RELIABILITY CODE	X						
5	DIST. MEASUREMENT							
5	DISTANCE TO BIRDS							
5	DIRECTION-FLIGHT	X	X			X	X	
5	ASSOCIATION CODE	X	X			X	X	
5	LINKAGE-MULTISPECIES	X	X			X	X	
5	NUMBER OF SPECIES	X	X			X	X	
5	BEHAVIOR CODE		X				X	X
5	SPECIAL MARKS CODE							
5	BIRD CONDITION							
5	FOOD SOURCE ASSOC.						X	
5	TAXONOMIC-FOOD SPECI	X					X	
5	DEBRIS CODE		X			X		
5	OIL CODE					X		
5	DIST.BREEDING COLONY							
5	HABITAT CODE		X					
5	SEQUENCE NUMBER	X	X			X		X
5	SUBSTRATE CODE					X		
5	COVER CODE					X		
5	OUTSIDE ZONE CODE					X		

PARAMETER CHECK LIST

81/ 3/ 13 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 034
LAND CENSUS

RT	NAME OF FIELD	RU 033	RU 172	RU 441	RU 458
X	FILE IDENTIFIER		X		
X	RECORD TYPE		X		
X	STATION NUMBER		X		
1	START LATITUDE		X		
1	START LONGITUDE		X		
1	DATE		X		
1	TIME		X		
1	END LATITUDE		X		
1	END LONGITUDE		X		
1	ELAPSED TIME				
1	SPEED MADE GOOD				
1	UNIT DIMENSION		X		
1	UNITS- X-AXIS		X		
1	UNITS- Y-AXIS		X		
1	PHOTOS TAKEN				
2	SURFACE SALINITY				
2	DRY BULB TEMPERATURE		X		
2	WET BULB TEMPERATURE		X		
2	RELATIVE HUMIDITY				
2	BAROMETRIC PRESSURE				
2	BAROMETRIC TREND				
2	WIND DIRECTION		X		
2	WIND SPEED		X		
2	BREAKER HEIGHT				
2	WEATHER CODE		X		
2	CLOUD TYPE				
2	CLOUD AMOUNT				
2	VISIBILITY		X		
2	TIDE HEIGHT CODE				
2	TIDE-RISE/FALL				
2	DISTANCE-SHORELINE				
2	DEBRIS CODE				
3	ICE IN TRANSECT		X		
3	ICE OUTSIDE TRANSECT				
3	TYPE OPEN WATER				
3	DIR.OPEN WATER				
3	DIST. OPEN WATER				
4	TEXT		C		
4	SEQUENCE NUMBER		C		
5	X-COORDINATE				
5	Y-COORDINATE				
5	TAX CODE TO GROUP		X		
5	AGE CLASS GROUP CODE		X		
5	SEX CODE		X		
5	COLOR PHASE CODE				
5	PLUMAGE CODE				
5	MOLT CODE				
5	NO. INDIVIDUALS		X		
5	DIRECTION-FLIGHT				
5	ASSOCIATION CODE				
5	LINKAGE-MULTISPECIES				
5	NO. SPECIES		X		
5	BEHAVIOR CODE		X		
5	FOOD SOURCE ASSOC.		X		
5	TAXONOMIC-FOOD SPECI		X		
5	DEBRIS CODE				
5	OIL CODE				
5	DIST-BREEDING COLONY				
5	SEQUENCE NUMBER		X		

FILE TYPE 035
BIRD COLONY DATA

RT	NAME OF FIELD	RU 096	RU 441
X	FILE IDENTIFIER		
X	RECORD TYPE		
X	STATION NUMBER		
A	LATITUDE		
A	LONGITUDE		
A	START DATE-TIME		
A	END DATE-TIME		
A	PHOTOS TAKEN		
A	SEQUENCE NUMBER		
B	SAMPLE DATE-TIME		
B	WIND DIRECTION		
B	WIND SPEED		
B	SEA STATE		
B	WEATHER CODE		
B	VISIBILITY CODE		
B	TIDE RISE/FALL		
B	TIDE HEIGHT CODE		
B	SNOW DEPTH		
B	AIR TEMPERATURE		
B	CLOUD AMOUNT		
B	SEQUENCE NUMBER		
C	TEXT		
C	SEQUENCE NUMBER		
D	TAXONOMIC CODE		
D	SUBSTRATA TYPE CODE		
D	HABITAT CODE		
D	DIST-ABOVE--LOW TIDE		
D	NEST SITE SLOPE		
D	NEST EXPOSURE CODE		
D	COVER CODE		
D	DIRECTIONAL COVER		
D	INNER DIAMETER X-		
D	INNER DIAMETER Y-		
D	OUTER DIAM. X-AXIS		
D	OUTER DIAM. Y-AXIS		
D	DEPTH OF NEST		
D	DIST. NEIGHBOR-SAME		
D	DIST. NEIGHBOR-ANY		
D	SOIL SAMPLE CODE		
D	PERCENT NITROGEN		
D	% ORGANIC MATERIAL		
D	NO. PLANT SPECIES		
D	VEGETATION SAMPLE		
D	NEST MATERIAL SAMPLE		
D	PREDATOR CODE		
D	HEIGHT OF NEST		
D	SEQUENCE NUMBER		
E	TAXONOMIC CODE		
E	SUBSTRATA TYPE		
E	HABITAT CODE		
E	HT LEDGE-SEA LEVEL		
E	DEPTH-LEDGE		
E	LENGTH OF LEDGE		
E	ANGLE OF LEDGE		
E	SLOPE-BACKWALL		
E	CLIFF EXPOSURE CODE		
E	NEST LOCATION CODE		
E	%NEST UNDER OVERHANG		
E	ENTRANCE WIDTH		
E	ENTRANCE HEIGHT		
E	DISTANCE INTO NEST		
E	DIST. NEIGHBOR-SAME		
E	DIST. NEIGHBOR-ANY		

FILE TYPE 035
BIRD COLONY DATA

RT	NAME OF FIELD	RU 096	RU 441
E	TAXONOMIC-NEIGHBOR		
E	NO. OTHER SPECIES		
E	PREDATOR CODE		
E	SEQUENCE NUMBER		
F	SAMPLE DATE-TIME		
F	TAXONOMIC CODE		
F	STATION TYPE CODE		
F	NUMBER EGGS		
F	NUMBER CHICKS		
F	EGG MORTALITY		
F	CHICK MORTALITY		
F	NUMBER INCUBATORS		
F	NUMBER ADULT BIRDS		
F	NUMBER NESTS		
F	EGG MORTALITY CODE		
F	CHICK MORTALITY CODE		
F	ADULT ACTIVITY CODE		
F	NEST CONDITION CODE		
F	NUMBER ADULT PAIRS		
F	NUMBER NON-BREEDING		
F	NUMBER ADULTS		
F	SEQUENCE NUMBER		
G	SAMPLE DATE-TIME		
G	TAXONOMIC CODE		
G	EGG NUMBER		
G	EGG WEIGHT		
G	ENDOPARASITES CODE		
G	ECTOPARASITES CODE		
G	EGG MORTALITY CAUSE		
G	CHICK NUMBER		
G	CHECK WT. BEFORE		
G	CHICK WT. AFTER		
G	FOOD SAMPLE NO.		
G	CHICK MORTALITY CODE		
G	BAND NUMBER		
G	WING LENGTH		
G	SEQUENCE NUMBER		
G	ESTIM. DATE LAID		
G	ESTIM. DATE HATCHED		
G	CULMEN LENGTH		
G	TARSUS LENGTH		
H	SAMPLE DATE-TIME		
H	TAXONOMIC CODE		
H	SEX CODE		
H	AGE CLASS CODE		
H	FOOD PRESENT		
H	FOOD SAMPLE NUMBER		
H	ENDOPARASITE CODE		
H	ECTOPARASITE CODE		
H	GONAD SIZE		
H	WHOLE BODY WEIGHT		
H	BODY WT. -VISCERA		
H	FAT CLASSIFICATION		
H	STERNUM LENGTH		
H	GROSS ABNORMALITIES		
H	LAB SAMPLE CODE		
H	SEQUENCE NUMBER		
J	SAMPLE DATE-TIME		
5	TAXONOMIC CODE		
5	FOOD SAMPLE NUMBER		
5	MATERIAL CODE		
5	FOOD TAXONOMIC CODE		
5	FOOD QUANTITY		

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FILE TYPE 035
BIRD COLONY DATA

RT	NAME OF FIELD	RU 096	RU 441
5	WET WEIGHT-FOOD		
5	DRY WEIGHT-FOOD		
5	FOOD DISPLACEMENT-V		
5	LENGTH REPRESENT		
5	FOOD SAMPLE SOURCE		
5	SEQUENCE NUMBER		

PARAMETER CHECK LIST

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 037
FEEDING FLOCK FORMAT

RT	NAME OF FIELD	RU 105
/	FILE IDENTIFIER	
/	RECORD TYPE	
/	STATION NUMBER	
1	START LATITUDE	
1	START LONGITUDE	
1	START DATE	
1	START TIME	
1	END LATITUDE	
1	END LONGITUDE	
1	ELAPSED TIME	
1	TIME ZONE	
1	SPEED MADE GOOD	
1	COURSE MADE GOOD	
1	HT. ABOVE SEA-EYES	
1	PLATFORM TYPE CODE	
1	SAMPLING TECHNIQUE	
1	SHIP ACTIVITY CODE	
1	PHOTOS TAKEN	
1	WIDTH OF TRANSECT	
1	ANGLE OF VIEW	
1	OBSER. CONDITIONS	
1	DISTANCE MADE GOOD	
2	DEPTH TO BOTTOM	
2	DEPTH-THERMOCLINE	
2	SURFACE TEMPERATURE	
2	SURFACE SALINITY	
2	DRY BULB TEMPERATURE	
2	WET BULB TEMPERATURE	
2	RELATIVE HUMIDITY	
2	BAROMETRIC PRESSURE	
2	BAROMETRIC TREND	
2	WIND DIRECTION	
2	WIND SPEED	
2	SEA STATE	
2	SWELL DIRECTION	
2	SWELL HEIGHT	
2	WEATHER CODE	
2	CLOUD TYPE CODE	
2	CLOUD AMOUNT CODE	
2	WATER COLOR	
2	VISIBILITY CODE	
2	SUN DIRECTION	
2	GLARE INTENSITY CODE	
2	GLARE AREA CODE	
2	LIGHT LEVEL	
2	MOON PHASE CODE	
2	TIDE HEIGHT CODE	
2	TIDE RISE/FALL	
2	DIST-SHORELINE	
2	DIST-SHELF BREAK	
2	SECCHI DEPTH	
2	DEBRIS CODE	
3	ICE IN TRANSECT	
3	ICE OUTSIDE TRANSECT	
3	TYPE OPEN WATER CODE	
3	DIR.OPEN WATER	
3	DIST. OPEN WATER	
3	WIDTH LEAD/POLYNYA	
3	DESCRIP.VISIBLE ICE	
3	DIREC. VISIBLE ICE	
3	DIST. VISIBLE ICE	
3	ARCTIC COD OBSERVED	
3	EXCESS SEDIMENT	
3	ICE ALGAE LAYER	
3	MAMMAL TRACE CODE	

81-03-19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 037
FEEDING FLOCK FORMAT

RT	NAME OF FIELD	RU 102
3	OTHER FEATURES	
4	HEIGHT	
4	LENGTH	
4	WIDTH	
4	DIRECTION MOVEMENT	
4	WIND DIRECTION	
4	DISTANCE MOVED	
4	ELAPSED TIME	
4	NO. SPECIES	
4	PREY	
4	PREY DETERMINATION	
4	DIST. TO FLOCK	
4	OBSERVER ACTIVITY	
4	DEBRIS CODE	
4	OIL CODE	
4	SHIP ASSOCIATION	
4	DISTANCE TO LAND	
4	MAMMALS ASSOCIATION	
4	NO.MAMMAL SPECIES	
4	# MAMMAL-INDIVIDUALS	
4	TIME ELAPSED	
5	TAXONOMIC CODE-GROUP	
5	AGE CLASS GROUP CODE	
5	SEX CODE	
5	COLOR PHASE CODE	
5	NO. INDIVIDUALS	
5	COUNTING METHOD	
5	NO. THIS SPECIES	
5	COUNTING METHOD	
5	VERTICAL POSITION	
5	HORIZONTAL POSITION	
5	FLOCK BEHAVIOR CODE	
5	SUCCESS CODE	
5	DURATION-BEHAVIOR	
5	INTERACTION CODE	
5	INTERACTEE	
5	NO. INTERACTEES	
5	LINKAGE	
5	TIME ELAPSED	
6	TAXONOMIC CODE-GROUP	
6	AGE CLASS GROUP	
6	SEX CODE	
6	COLOR PHASE CODE	
6	ARRIVE/DEPART CODE	
6	NO. INDIVIDUALS	
6	COUNTING METHOD	
6	HOW ARRIVE/DEPART	
6	ACTUAL DIST. KNOWN	
6	DISTANCE	
6	VERTICAL POSITION	
6	HORIZONTAL POSITION	
6	WHERE BIRD CAME/WENT	
6	BEHAVIOR FIRST/LAST	
6	CUE CODE	
6	ABORT CODE	
6	ABORT DISTANCE	
6	ABORT CUE CODE	
6	LINKAGE	
6	TIME ELAPSED	

PARAMETER CHECK LIST

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 038
MIGRATORY BIRD SEA WATCH

RT	NAME OF FIELD	RU 341	RU 467
X	FILE IDENTIFIER		X
X	RECORD TYPE		X
X	STATION NUMBER		X
1	LATITUDE		X
1	LONGITUDE		X
1	DISTANCE -SHORE		
1	PLATFORM TYPE CODE		X
1	SAMPLING TECHNIQUE		X
1	HEIGHT ABOVE WATER		X
1	SCOPE BEARING		
1	SEQUENCE NUMBER		X
2	TEXT		C
2	SEQUENCE NUMBER		C
3	START DATE-TIME		X
3	ELAPSED TIME		
3	TAXONOMIC CODE		X
3	AGE CLASS CODE		X
3	SEX CODE		X
3	COLOR PHASE CODE		
3	PLUMAGE CODE		
3	MOLT CODE		
3	NO. INDIVIDUALS		X
3	COUNTING METHOD		
3	RELABILITY CODE		
3	DIRECTION-FLIGHT		X
3	SPECIES GROUP CODE		
3	WATCH TYPE CODE		
3	BEHAVIOR CODE		X
3	NO. SPECIES		
3	LINKAGE		
3	OBSER. CONDITIONS		X
3	SEQUENCE NUMBER		X
4	WEATHER CODE		X
4	TIDE TREND		
4	TIDE HEIGHT CODE		
4	SEA STATE CODE		
4	SEQUENCE NUMBER		X

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FILE TYPE 040
BIRD HABITAT

RT	NAME OF FIELD	RU 083
X	FILE IDENTIFIER	X
X	RECORD TYPE	X
X	STATION NUMBER	X
1	LATITUDE	X
1	LONGITUDE	X
1	DATE	X
1	TIME	X
1	ELAPSED TIME	X
1	SURVEY CONDITION	X
1	DISTANCE SURVEYED	X
1	AREA SURVEYED	X
1	SAMPLING TECHNIQUE	X
1	PLATFORM TYPE CODE	X
1	SPEED OF PLATFORM	X
1	ALTITUDE-PLATFORM	X
1	PREDOMINANT COURSE	
1	PHOTOS TAKEN	X
2	SURFACE TEMPERATURE	
2	SURFACE SALINITY	
2	DRY-BULB TEMPERATURE	
2	WET-BULB TEMPERATURE	
2	RELATIVE HUMIDITY	
2	BAROMETRIC PRESSURE	
2	BAROMETRIC TREND	
2	WIND DIRECTION	X
2	WIND SPEED	X
2	SEA STATE	X
2	SWELL DIRECTION	X
2	SWELL HEIGHT	X
2	WEATHER CODE	X
2	CLOUD TYPE	X
2	CLOUD AMOUNT	X
2	WATER COLOR	
2	VISIBILITY CODE	X
2	SUN DIRECTION	
2	GLARE INTENSITY	
2	GLARE AREA CODE	
2	LIGHT LEVEL	X
2	MOON PHASE CODE	
2	TIDE HEIGHT CODE	X
2	TIDE TREND	X
2	SECCHI DISK DEPTH	
2	DEBRIS CODE	
3	ICE IN TRANSECT	X
3	ICE OUTSIDE TRANSECT	X
3	OPEN WATER	X
3	WIDTH LEAD/POLYNYA	X
3	VISIBLE ICE	X
3	ARCTIC COD OBSERVED	
3	EXCESS SEDIMENT	
3	ICE ALGAE LAYER	
3	MAMMAL TRACE CODE	X
3	OTHER FEATURES	X
4	SEQUENCE NUMBER	X
4	TAXONOMIC CODE-GROUP	X
4	NO. INDIVIDUALS	X
4	WATER TYPE CODE	X
4	PHYSIOGRAPHIC FEATUR	X
4	SUBSTRATE TYPE	X
4	COVER TYPE	X
4	BEHAVIOR CODE	X
4	DIRECTION-FLIGHT	
4	DIST. SHORE-TO-BIRDS	X
4	DIST. BARRIER -BIRDS	X

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 040
BIRD HABITAT

RT	NAME OF FIELD	RU 003
4	DIST. DELTA-BIRDS	X
4	DEPTH	
4	MOLT CODE	
4	COLOR PHASE	
4	PLUMAGE CODE	
4	AGE CLASS GROUP	
4	SEX CODE	
4	ASSOCIATION TYPE	
4	LINKAGE	X
4	NO. SPECIES LINKED	X
4	NO. SPECIES-FLOCK	X
4	COUNTING METHOD	X
5	SEQUENCE NUMBER	C
5	TEXT	C

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 043
HYDROCARBON I

RT	NAME OF FIELD	RU 153	RU 480
X	FILE IDENTIFIER	X	X
X	RECORD TYPE	X	X
1	VESSEL	X	X
1	CRUISE NUMBER	X	X
1	CRUISE DATES	X	X
1	SENIOR SCIENTIST	X	X
1	INVESTIGATOR/INSTITU	X	X
2	STATION NUMBER	X	X
2	SEQUENCE NUMBER	X	X
2	LATITUDE	X	X
2	LONGITUDE	X	X
2	DATE		X
2	TIME	X	X
2	DEPTH TO BOTTOM	X	X
2	GEAR CODE	X	X
2	ANALYSIS CODE	X	X
2	SAMPLE TYPE	X	X
5	STATION NUMBER	X	X
5	SEQUENCE NUMBER	X	X
5	SAMPLE DEPTH	X	X
5	VOL OF SAMPLE	X	X
5	DISSOLVED HYDROCARBO	X	X
5	SIGN	X	X
5	EXPONENT	X	X
5	METHANE	X	X
5	SIGN	X	X
5	EXPONENT	X	X
5	TRACE	X	X
5	ETHANE	X	X
5	SIGN	X	X
5	EXPONENT	X	X
5	TRACE	X	X
5	ETHYLENE	X	X
5	SIGN	X	X
5	EXPONENT	X	X
5	TRACE	X	X
5	PROPANE	X	X
5	SIGN	X	X
5	EXPONENT	X	X
5	TRACE	X	X
5	PROPYLENE	X	X
5	SIGN	X	X
5	EXPONENT	X	X
5	TRACE	X	X
5	ISO-BUTANE	X	X
5	SIGN	X	X
5	EXPONENT	X	X
5	TRACE	X	X
5	N-BUTANE	X	X
5	SIGN	X	X
5	EXPONENT	X	X
5	TRACE	X	X
6	STATION NUMBER	X	X
6	SEQUENCE NUMBER	X	X
6	SAMPLE DEPTH	X	X
6	VOL OF SAMPLE	X	X
6	DISSOLVE HYDROCARBON	X	X
6	SIGN	X	X
6	EXPONENT	X	X
6	ETHANE+ETHYLENE	X	X
6	SIGN	X	X
6	EXPONENT	X	X
6	TRACE	X	X
6	PROPANE+PROPYLENE	X	X

PARAMETER CHECK LIST

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FILE TYPE 043
HYDROCARBON I

RT	NAME OF FIELD	RU 153	R? 43?
6	SIGN	[illegible]	[illegible]
6	EXPONENT	[illegible]	[illegible]
6	TRACE	[illegible]	[illegible]

PARAMETER CHECK LIST

PROJECT OFFICE-ALL

RU ALL

FILE TYPE 044
HYDROCARBON II

RT	NAME OF FIELD	RU 159	RU 275	RU 480
X	FILE IDENTIFIER	X		
X	RECORD TYPE	X	X	X
X	STATION NUMBER	X	X	X
A	START DATE/TIME	X	X	X
A	LATITUDE	X	X	X
A	LONGITUDE	X		X
A	TIDE STAGE CODE	X		
A	TIDE HEIGHT	X	X	
A	WAVE ENERGY	X	X	
A	WAVE HEIGHT	X	X	
A	WEATHER CODE	X	X	
A	WIND DIRECTION	X	X	
A	WIND SPEED	X		
A	AIR TEMPERATURE	X		
A	WATER SURFACE TEMP	X	X	
A	SEDIMENT TEMPERATURE	X	X	
A	SURFACE SALINITY	X	X	
A	PHOTO CODE	X	X	
A	SEQUENCE NUMBERS	X	X	X
B	SAMPLE TYPE CODE	X	X	X
B	SAMPLE NUMBER	X	X	X
B	GEAR TYPE CODE	X	X	X
B	SUBSAMPLE AREA	X	X	
B	SUBSAMPLE DEPTH	X	X	
B	NUMBER OF SUBSAMPLE	X	X	
B	SAMPLE ELEVATION	X	X	
B	LOW ELEVATION	X	X	
B	HIGH ELEVATION	X	X	
B	HORIZONTAL EXTENT	X		
B	BEACH ORGANICS CHAR.	X	X	
B	OIL CODE	X	X	
B	SEDIMENT COLOR CODE	X	X	X
B	SUBSTRATE-BIO-SAMPLE	X	X	
B	MEAN ORGANISM SIZE	X	X	
B	MIN ORGANISM SIZE	X	X	
B	MAX ORGANISM SIZE	X	X	
B	TAXONOMIC CODE	X	X	
B	LAB NUMBER	X	X	X
B	SEQUENCE NUMBER	X	X	X
C	SAMPLE TYPE CODE	X	X	X
C	SAMPLE NUMBER	X	X	X
C	DRY WEIGHT	X	X	X
C	WET WT-HYDROCARBON	X	X	
C	SEDIMENT SIZE(%PSI)	X	X	
C	MEAN GRAIN SIZE	X	X	
C	SAND-TO-MUD-RATIO	X	X	
C	ORGANIC CARBON	X	X	X
C	TOTAL LIPIDS	X	X	X
C	LAB NUMBER	X	X	X
C	SEQUENCE NUMBER	X	X	X
D	SAMPLE TYPE CODE	X	X	X
D	SAMPLE NUMBER	X	X	X
D	DEPTH OF SAMPLE	X	X	
D	VOL OF SAMPLE	X	X	
D	WATER/PARTICULATE	X	X	
D	FILTER CODE	X		
D	CORE DEPTH--TOP	X	X	
D	CORE DEPTH --BOTTOM	X		
D	LAB NUMBER	X		X
D	SEQUENCE NUMBER	X	X	X
E	SAMPLE TYPE CODE	X	X	X
E	SAMPLE NUMBER	X		X
E	METHOD CODE	X	X	

[illegible] PROJECT OFFICE-ALL RU-ALL

FILE TYPE 044
HYDROCARBON II

RT	NAME OF FIELD	RU 153	RU 275	RU 480
E	HYDROCARBON CONCENTR	X	X	X
E	TOTAL ALIPHATICS	X	X	X
E	TOTAL AROMATICS	X	X	X
E	LAB NUMBER	X	X	X
E	SEQUENCE NUMBER	X	X	X
F	SAMPLE TYPE CODE	X	X	X
F	SAMPLE NUMBER	X	X	X
F	METHOD CODE	X	X	X
F	HYDRO. CONCENTRATION	X	X	X
F	LAB NUMBER	X	X	X
F	SEQUENCE NUMBER	X	X	X
G	SAMPLE TYPE CODE	X	X	X
G	SAMPLE NUMBER	X	X	X
G	METHOD CODE	X	X	X
G	HYDRO. CONCENTRATION	X	X	X
G	TRISTANE	X	X	X
G	THYTANE	X	X	X
G	O-XYLENE	X	X	X
G	LAB NUMBER	X	X	X
G	SEQUENCE NUMBER	X	X	X
H	SAMPLE TYPE CODE	X	X	X
H	SAMPLE NUMBER	X	X	X
H	METHOD CODE	X	X	X
H	HYDRO CONCENTRATIONS	X	X	X
H	LAB NUMBER	X	X	X
H	SEQUENCE NUMBER	X	X	X
I	SAMPLE TYPE CODE	X	X	X
I	SAMPLE NUMBER	X	X	X
I	METHOD CODE	X	X	X
I	HYRO CONCENTRATIONS	X	X	X
I	LAB NUMBER	X	X	X
I	SEQUENCE NUMBER	X	X	X
J	SAMPLE TYPE CODE	X	X	X
J	SAMPLE NUMBER	X	X	X
J	METHOD CODE	X	X	X
J	HYDRO CONCENTRATIONS	X	X	X
J	LAB NUMBER	X	X	X
J	SEQUENCE NUMBER	X	X	X
Z	SAMPLE TYPE CODE	X	X	X
Z	SAMPLE NUMBER	X	X	X
Z	TEXT	C	C	C
Z	LAB NUMBER	X	X	X
Z	SEQUENCE NUMBER	X	X	X

PARAMETER CHECK LIST   PAGE 1

81 03 19   PROJECT OFFICE ALL   RU-ALL

FILE TYPE 056
LAGRANGIAN CURRENT MEASUREMENT

RT	NAME OF FIELD	RU 098	RU 217
X	FILE IDENTIFIER		X
X	RECORD TYPE		X
1	PLATFORM NAME		X
1	PLATFORM TYPE		X
1	PI NAME		X
1	START DATE		X
1	END DATE		X
1	PROGRAM NAME		X
1	DROGUE DEPTH		X
1	DROGUE TYPE		X
3	BUOY IDENTIFIER		X
3	SEQUENCE NUMBER		X
3	LATITUDE		X
3	LONGITUDE		X
3	DATE-TIME OBSERVE		X
3	SATELLITE PASS CODE		
3	LOAD CELL TENSION		
3	SEA SURFACE TEMP		
3	WIND SPEED		
3	COMPASS BEARING		
3	DEPTH-1ST INSTRUMENT		
3	CURRENT SPEED		
3	CURRENT DIRECTION		
3	DEPTH 2ND INSTRUMENT		
3	CURRENT SPEED-2ND		
3	DIREC.--SURFACE UNIT		
4	BUOY IDENTIFIER		
4	SEQUENCE NUMBER		
4	LATITUDE		
4	LONGITUDE		
4	DATE-TIME OBSERVE		
4	SATELLITE PASS CODE		
4	ATMOSPHERIC PRESSURE		

PARAMETER CHECK LIST

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 057
HERRING SPAWNING

RT	NAME OF FIELD	RU 019	RU 552
X	FILE IDENTIFIER		X
X	RECORD TYPE		X
1	SURVEY START DATE		X
1	SURVEY START TIME		X
1	ELAPSED TIME		X
1	START LATITUDE		X
1	START LONGITUDE		X
1	END LATITUDE		X
1	END LONGITUDE		X
1	AIRCRAFT LICENSE NO.		X
1	AIRCRAFT TYPE CODE		X
1	OBSERVER NAME		X
2	CENSUS AREA		X
2	LATITUDE		X
2	LONGITUDE		X
2	COASTAL DISTANCE		X
2	ALTITUDE-AIRCRAFT		X
2	AIRSPEED		X
2	CLOUD COVER		X
2	VISIBILITY		X
2	SEA STATE		X
2	WEATHER CODE		X
2	WIND DIRECTION		X
2	AIR ROUGHNESS INDEX		X
2	PREDOMINANT FISHING		X
2	PREDOMINANT GEAR		X
2	TIDE STAGE CODE		X
2	SURVEY RATING INDEX		X
2	WATER CLARITY INDEX		X
2	OBSERVATION DATE		X
2	OBSERVATION TIME		X
3	CENSUS AREA		X
3	SCHOOL NUMBER		X
3	LATITUDE		X
3	LONGITUDE		X
3	SCHOOL LOCATION		X
3	SCHOOL SPECIES		X
3	SCHOOL ACTIVITY		X
3	AREA OF SCHOOL		X
3	PREDOMINANT BEACH		X
3	PREDOMINANT BIOTA		X
3	ESCARPMENT TYPE		X
3	SCHOOL SIZE INDEX		X
3	NUMBER OF SCHOOLS		X
4	CENSUS AREA		X
4	TEXT		C
4	SEQUENCE NUMBER		C

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 061
TRACE ELEMENTS

RT	NAME OF FIELD	RU 152	RU 162	RU 506	RU 529
X	FILE IDENTIFIER	X	X	X	
X	RECORD TYPE	X	X	X	
X	STATION NUMBER	X	X	X	
1	SAMPLE DATE	X	X	X	
1	SAMPLE TIME	X	X	X	
1	LATITUDE	X	X	X	
1	LONGITUDE	X	X	X	
1	BOTTOM DEPTH	X	X	X	
1	SEQUENCE NUMBER	X	X	X	
3	SPHERE CODE	X	X	X	
3	MATERIAL ANALYZED	X	X	X	
3	TAXONOMIC CODE	X	X	X	
3	DEPTH OF SAMPLE	X	X	X	
3	WEIGHT CODE	X	X	X	
3	METHOD-ANALYSIS	X	X	X	
3	FILTER CODE	X	X	X	
3	ELEMENT CODE	X	X	X	
3	CONCENTRATION	X	X	X	
3	UNIT CODE	X	X	X	
3	DETECTION CODE	X	X	X	
3	LIMIT CONCENTRATION	X	X	X	
3	SAMPLE COMPOSITION	X	X	X	
3	UPPER LIMIT-CORE	X	X	X	
3	LOWER LIMIT-CORE	X	X	X	
3	SEQUENCE NUMBER	X	X	X	
4	TEXT	C	C	C	
4	SEQUENCE NUMBER	C	C	C	

PARAMETER CHECK LIST

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 063
MARINE INVERTEBRATE PATHOLOGY

RT	NAME OF FIELD	RU 332
X	FILE IDENTIFIER	
X	RECORD TYPE	
1	VESSEL	
1	CRUISE/LEG NUMBER	
1	CRUISE DATES	
1	SENIOR SCIENTIST	
1	PI/INSTITUTION	
2	CRUISE NUMBER	
2	HAUL/SET NUMBER	
2	LATITUDE	
2	LONGITUDE	
2	DATE	
2	TIME	
2	GEAR TYPE CODE	
2	DURATION-FISHED	
2	DISTANCE FISHED	
2	SURFACE TEMPERATURE	
2	WATER TEMP-GEAR	
2	AVG DEPTH--TOW	
2	BOTTOM TYPE CODE	
2	BOTTOM TRAWL TYPE	
3	CRUISE NUMBER	
3	HAUL/SET NUMBER	
3	TAXONOMIC CODE	
3	WT-SPECIES	
3	WT DETERMINATION	
3	TOTAL NUMBER	
3	NO. DETERMINATION	
3	SPECIES INITIALS	
3	WT OF SUB SAMPLE	
3	NO. IN SUBSAMPLE	
3	SEX CODE	
3	NO.EXAMINED	
3	DISEASE CONDITION	
3	INDIVIDUALS AFFECTED	
3	SEQUENCE NUMBER	
3	STATION CODE	
4	CRUISE NUMBER	
4	HAUL/SET NUMBER	
4	SPECIMEN NUMBER	
4	TAXONOMIC CODE	
4	SEX CODE	
4	SEX MATURITY CODE	
4	LENGTH	
4	INVERTEBRATE LENGTH	
4	WT INDIVIDUAL	
4	WT DETERMINATION	
4	PHOTOS TAKEN	
4	SAMPLE CODE	
4	PRESERVATIVE CODE	
4	DISEASE CONDITION	
4	FREQUENCY CODE	
4	GEN.LOC. LESION #	
4	APPENDAGE CODE	
4	SPECIFIC LOCATION	
4	LENGTH	
4	WIDTH	
4	COVERAGE CODE	
4	SEQUENCE NUMBER	
4	STATION CODE	
5	CURISE NUMBER	
5	HAUL OR SET NUMBER	
5	SPECIMEN NUMBER	

FILE TYPE 063
MARINE INVERTEBRATE PATHOLOGY

RT	NAME OF FIELD	RU 332
5	DISEASE CODE	
5	FREQUENCY CODE	
5	LESION CODE	
5	SEQUENCE NUMBER	
5	STATION CODE	

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 072
BEACH PROFILE FORMAT

RT	NAME OF FIELD	RU 059	RU 208	RU 431
X	FILE IDENTIFIER	X	X	
X	RECORD TYPE	X	X	
X	STATION ID	X	X	
X	PROFILE REPLICATE	X	X	
1	LATITUDE	X	X	
1	LONGITUDE	X	X	
1	DATE	X	X	
1	TIME	X	X	
1	NUMBER OF POSITIONS	X	X	
1	POSITION OF LHTS			
1	NUMBER AT WATERLINE	X	X	
2	PROFILE CARD	X	X	
2	HORIZONTAL INCREMENT	X	X	
2	ELEVATION INCREMENT	X	X	

PARAMETER CHECK LIST

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 073
GRAIN SIZE ANALYSIS

RT	NAME OF FIELD	RU 059	RU 206	RU 208	RU 212	RU 290	RU 327	RU 429	RU 430	RU 529
X	FILE IDENTIFICATION	X		X	X		X	X	X	
X	RECORD TYPE	X		X	X		X	X	X	
A	VESSEL	X		X	X		X	X	X	
A	CRUISE/PROJECT ID	X		X	X		X	X	X	
A	BEGIN DATE	X		X	X		X	X	X	
A	END DATE	X		X	X		X	X	X	
A	SENIOR SCIENTIST	X		X	X		X	X	X	
A	PI OR INSTITUTION	X		X	X		X	X	X	
B	STATION SEQUENCE NO.	X		X	X		X	X	X	
B	STATION NUMBER	X		X	X		X	X	X	
B	STATION DATE	X		X	X		X	X	X	
B	STATION TIME	X		X	X		X	X	X	
B	LATITUTE	X		X	X		X	X	X	
B	LONGITUDE	X		X	X		X	X	X	
B	NAVIGATION ACCURACY									
B	WATER DEPTH	X		X	X		X	X	X	
B	DEPTH C OR U	X		X	X		X	X	X	
B	NO. SAMPLES									
B	NO. BOTTOM PHOTOS									
B	UNDERWATER TV TIME									
C	STATION SEQUENCE #									
C	STATION NUMBER									
C	BAROMETRIC PRESSURE									
C	AIR TEMP/DRY BULB									
C	AIR TEMP/WET BULB									
C	WIND DIRECTION									
C	WIND SPEED									
C	SEA DIRECTION									
C	SEA HEIGHT									
C	SEA PERIOD									
C	SWELL DIRECTION									
C	SWELL HEIGHT									
C	SWELL PERIOD									
C	WEATHER CODE									
C	CLOUD TYPE CODE									
C	CLOUD COVER CODE									
C	VISIBILITY CODE									
C	SECCHI DISK DEPTH									
D	STATION SEQUENCE #	X		X	X		X	X	X	
D	STATION NUMBER	X		X	X		X	X		
D	SAMPLE NUMBER	X		X	X		X	X	X	
D	SAMPLE TYPE	X		X	X		X	X	X	
D	SUB-CORE NUMBER									
D	INTERVAL NUMBER									
D	REPLICATE NUMBER									
D	TOTAL LENGTH-CORE	X		X	X		X	X	X	
D	DEPTH-TOP/INTERVAL	X		X	X		X	X	X	
D	DEPTH-BOTTOM/INTERV	X		X	X		X	X	X	
D	REPLICATE WEIGHT	X		X	X		X	X	X	
D	METHOD-COARSE FRACT	X		X	X		X	X	X	
D	METHOD-FINE FRACTION	X		X	X		X	X	X	
D	SIZE BOUNDARY (C/F)									
D	MIN-COARSE END	X		X	X		X	X	X	
D	MAX-AT FINE END	X		X	X		X	X	X	
D	WT % COARSER/MIN	X		X	X		X	X	X	
D	WT % FINER / MAX	X		X	X		X	X	X	
E	COMMENTS									
F	WENTWORTH-WT-%GRAVEL									
F	WENTWORTH-WT-%SAND									
F	WENTWORTH-WT-%CLAY									
F	SOIL CLASSIFICATION									
F	WEIGHT % GRAVEL									

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FILE TYPE 073
GRAIN SIZE ANALYSIS

RT	NAME OF FIELD	RU 059	RU 206	RU 206	RU 212	RU 290	RU 327	RU 429	RU 430	RU 529
F	WEIGHT % SAND									
F	WEIGHT % FINES									
C	WT % 2 PHI -8 TO 12									
H	WT % 1 PHI -8 TO 12									
I	WT % 1 PHI -8 TO 12									
J	WT% 1/2 PHI -6 TO 12									
K	WT% 1/2 PHI -6 TO 12									
L	WT% 1/2 PHI -6 TO 12									
M	WT%1/3 PHI -6 TO 12									
N	WT%1/3 PHI -6 TO 12									
O	WT%1/3 PHI -6 TO 12									
P	WT%1/3 PHI -6 TO 12									
Q	WT%1/3 PHI -6 TO 12									
R	WT%1/4 PHI -6 TO 12									
S	WT%1/4 PHI -6 TO 12									
T	WT%1/4 PHI -6 TO 12									
U	WT%1/4 PHI -6 TO 12									
V	WT%1/4 PHI -6 TO 12									
W	WT%1/4 PHI -6 TO 12									
X	MEAN GRAIN SIZE									
X	MEDIAN GRAIN SIZE									
X	MODAL GRAIN SIZE									
X	STANDARD DEVIATION									
X	SKEWNESS									
X	KURTOSIS									

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FILE TYPE 101
WIND FORMAT

RT	NAME OF FIELD	RU 367	RU 519
X	FILE ID	X	X
X	RECORD TYPE	X	X
X	METER NUMBER	X	X
1	TEXT		
1	SEQUENCE NUMBER		
2	LATITUDE	X	X
2	LONGITUDE	X	X
2	PLATFORM TYPE	X	X
2	ELEVATION	X	X
2	HEIGHT OF PLATFORM	X	X
2	METER USE NUMBER	X	X
3	DATE/TIME	X	X
3	EAST-WEST WIND	X	X
3	NORTH-SOUTH WIND	X	X
3	AIR TEMPERATURE		
3	SEQUENCE NUMBER		
3	ATMOSPHERIC	X	X
3	DEWPOINT		

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 123
FISH/SHELLFISH RESOURCE ASSESS

RT	NAME OF FIELD	RU 467	RU 591	RU 005	RU 467	RU 591
X	FILE IDENTIFICATION			X		
X	RECORD TYPE			X		
A	VESSEL/PLATFORM NAME			X		
A	CRUISE NUMBER			X		
A	START DATE OF SURVEY			X		
A	END DATE OF SURVEY			X		
A	DATA SOURCE, PI,ETC					
A	INSTIT. OR AGENCY					
A	AGENCY CODE					
A	VESSEL CODE					
B	STATION NUMBER			X		
B	HAUL NUMBER					
B	NUMBER OF HAULS					
B	LATITUDE			X		
B	LONGITUDE			X		
B	DATE (GMT)			X		
B	TIME (GMT)			X		
B	GEAR TYPE					
B	FISHING DURATION					
B	DISTANCE FISHED					
B	DIRECTION OF TOW					
B	PERFORMANCE					
B	SEQUENCE NUMBER					
C	STATION NUMBER			X		
C	HAUL NUMBER					
C	GEAR DEPTH					
C	GEAR TEMPERATURE					
C	GEAR SALINITY					
C	AVERAGE BOTTOM DEPTH					
C	BOTTOM TYPE					
C	SOUNDING RECORD					
C	BOTTOM TEMPERATURE					
C	BOTTOM SALINITY					
C	SURFACE TEMPERATURE					
C	SURFACE SALINITY					
C	TRANSPARENCY					
C	TIDE HEIGHT					
C	TIDE STAGE					
C	AIR TEMPERATURE					
C	WEATHER					
C	CLOUD AMOUNT					
C	SEA STATE					
C	WIND DIRECTION(FROM)					
C	WIND SPEED					
C	CURRENT DIRECTION					
C	CURRENT SPEED					
C	SEQUENCE NUMBER					
D	STATION NUMBER			X		
D	HAUL NUMBER					
D	GEAR DEPTH					
D	GEAR TYPE					
D	BOTTOM TRAWL TYPE					
D	BOTTOM TRAWL ACCESR.					
D	OPENING HT. OF TRAWL					
D	OPENING WID.OF TRAWL					
D	OVERALL LENGTH					
D	CODEND LENGTH					
D	FOOT ROPE LENGTH					
D	HEAD ROPE LENGTH					
D	GEAR MATERIAL					
D	OPENING MESH					
D	AVERAGE BODY MESH					
D	CODEND MESH					
D	CODEND LINER					

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FILE TYPE 123
FISH/SHELLFISH RESOURCE ASSESS

RT	NAME OF FIELD	RU 467	RU 591	RU 005	RU 467	RU 591
D	NUMBER OF FLOATS					
D	FLOAT DIAMETER					
D	TICKLER					
D	ROLLER GEAR					
D	LENGTH OF BRIDLES					
D	LENGTH OF DOORS					
D	WIDTH OF DOORS					
D	WARP LENGTH					
D	SCOPE OF WARP					
D	SEQUENCE NUMBER					
E	STATION NUMBER			X		
E	HAUL NUMBER					
E	GEAR DEPTH					
E	GEAR TYPE					
E	NET DEPTH					
E	UNIT LENGTH					
E	NUMBER OF UNITS					
E	NUMBER OF SUBUNITS					
E	GEAR MATERIAL					
E	BAIT LURE					
E	SEINE MESH (7) END					
E	GILLNET-SHACKLES (4)					
E	GILLNET MATERIAL(4)					
E	GILLNET MESH(4)					
E	# SHACKLES TRAMMEL					
E	OUTER PANEL MAT.TRAM					
E	OUTER PANEL MESH TRM					
E	INNER PANEL MAT.TRAM					
E	INNER PANEL MESH TRM					
E	SEQUENCE NUMBER					
F	STATION NUMBER			X		
F	HAUL NUMBER					
F	TOTAL WET WEIGHT					
F	WEIGHT DETERMINATION					
F	TOTAL NUMBER					
F	NUMBER DETERMINATION					
F	VOLUME OF CATCH					
F	NUM.OF FISH/LITER					
F	NUM.SPECIES EXAMINED					
F	SEQUENCE NUMBER					
G	STATION NUMBER			X		
G	HAUL NUMBER					
G	SAMPLE NUMBER					
G	TAXONOMIC CODE			X		
G	PREDOM.SEX OF SAMPLE					
G	PREDOM.AGE OF SAMPLE					
G	AGE METHOD					
G	LENGTH OF CLASS					
G	LENGTH OF CODE					
G	LENGTH FREQUENCY					
G	LENGTH SAMPLE					
G	SEQUENCE NUMBER					
H	STATION NUMBER			X		
H	HAUL NUMBER					
H	SAMPLE NUMBER					
H	TAXONOMIC CODE			X		
H	AVG WET WT.CATCH/SPC					
H	WEIGHT DETERMINATION					
H	AVG NUM.CATCH/SPECIE					
H	NUMBER DETERMINATION					
H	PREDOM.SEX OF CATCH					
H	PREDOM. AGE OF CATCH					
H	AGE METHOD					
H	NUMBER OF DAYS					

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FILE TYPE 123
FISH/SHELLFISH RESOURCE ASSESS

RT	NAME OF FIELD	RU 467	RU 591	RU 005	RU 467	RU 591
H	NUM.OF SPECIES EXAMD					
H	SEQUENCE NUMBER					
J	STATION NUMBER			X		
J	HAUL NUMBER					
J	SAMPLE NUMBER					
J	TAXONOMIC CODE			X		
J	TOTAL WET WEIGHT					
J	WEIGHT DETERMINATION					
J	TOTAL NUMBER/SPECIES					
J	NUNBER DETERMINATION					
J	VOLUME OF CATCH					
J	NUM. OF FISH/LITER					
J	PREDOM.SEX/SPECIES					
J	PREDOM.AGE/SPECIES					
J	AGE METHOD					
J	SEQUENCE NUMBER					
K	STATION NUMBER			X		
K	HAUL NUMBER					
K	SAMPLE NUMBER					
K	SPECIMEN NUMBER					
K	TAXONOMIC CODE			X		
K	SEX					
K	SEX MATURITY					
K	LENGTH OF INDIVIDUAL					
K	LENGTH CODE					
K	WET WT. OF INDIVID.					
K	WEIGHT DETERMINATION					
K	AGE OF INDIVIDUAL					
K	AGE METHOD(STRUCTURE					
K	AGE DETERMINATION					
K	SAMPLE TYPE					
K	DATA TYPE					
K	STOMACH EXAMINED					
K	GUT COLLECTED					
K	FIN CLIP					
K	GONAD/OVARIAN WEIGHT					
K	GONAD-SOMATIC INDEX					
K	EGG COLOR					
K	EGG CONDITION					
K	CLUTCH SIZE					
K	SEQUENCE NUMBER					
L	STATION NUMBER			X		
L	HAUL NUMBER					
L	SAMPLE NUMBER					
L	SPECIMEN NUMBER					
L	TAXONOMIC CODE			X		
L	SEX					
L	SEX MATURITY					
L	CARAPACE WIDTH					
L	SHELL CONDITION					
L	WET WT.OF INDIVIDUAL					
L	WEIGHT DETERM.					
L	AGE OF INDIVIDUAL					
L	AGE METHOD					
L	AGE DETERMINATION					
L	SAMPLE TYPE					
L	DATA TYPE					
L	CHELAE LENGTH					
L	PETASMA/THELYCUM					
L	GONAD/OVARIAN WT.					
L	GONAD-SOMATIC INDEX					
L	EGG COLOR					
L	EGG CONDITION					
L	CLUTCH SIZE					
L	SEQUENCE NUMBER					

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FILE TYPE 123
FISH/SHELLFISH RESOURCE ASSESS

RT	NAME OF FIELD	RU 467	RU 591	RU 005	RU 467	RU 591
M	STATION NUMBER			X		
M	HAUL NUMBER					
M	SAMPLE NUMBER					
M	SPECIMEN NUMBER					
M	TAXONOMIC CODE			X		
M	LIFE HISTORY					
M	ORGAN CODE					
M	GUT POSITION					
M	STOMACH FULLNESS					
M	STOMACH DIGESTION					
M	WT. STOMACH CONTENT					
M	WEIGHT DETERMINATION					
M	SEQUENCE NUMBER					
N	STATION NUMBER			X		
N	HAUL NUMBER					
N	SAMPLE NUMBER					
N	SPECIMEN NUMBER					
N	TAXONOMIC CODE			X		
N	LIFE HISTORY					
N	WET WT.PREY SPECIMEN					
N	WEIGHT METHOD					
N	NUMBER OF PREY					
N	NUMBER DETERMINATION					
N	VOLUME OF PREY					
N	PREY OF PREY PART					
N	SEQUENCE NUMBER					
P	STATION NUMBER			X		
P	HAUL NUMBER					
P	SAMPLE NUMBER					
P	TAXONOMIC CODE			X		
P	NUM.STOMACHS POOLED					
P	TOTAL WET WEIGHT					
P	WEIGHT DETERMINATION					
P	SEQUENCE NUMBER					
Q	STATION NUMBER			X		
Q	HAUL NUMBER					
Q	SAMPLE NUMBER					
Q	TAXONOMIC CODE			X		
Q	TOTAL WET WEIGHT					
Q	WEIGHT METHOD					
Q	TOTAL NUMBER					
Q	NUMBER DETERMINATION					
Q	TOTAL VOLUME					
Q	PREY OR PREY PART					
Q	WT SMALL PREY					
Q	VOL SMALL PREY					
Q	SEQUENCE NUMBER					
T	STATION NUMBER			X		
T	HAUL NUMBER					
T	SAMPLE NUMBER					
T	SPECIMEN NUMBER					
T	TEXT					
T	SEQ #					

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FILE TYPE 124
ZOOPLANKTON

RT	NAME OF FIELD	RU 172	RU 359	RU 3
X	FILE IDENTIFIER		X	9
X	RECORD TYPE		X	9
A	VESSEL		X	9
A	CRUISE		X	9
A	CRUISE DATES		X	9
A	AREA/PROJECT		X	9
A	INVESTIGATOR/INSTIT		X	9
B	STATION NUMBER		X	9
B	LATITUDE		X	9
B	LONGITUDE		X	9
B	DATE IN GMT		X	9
B	TIME IN GMT		X	9
B	DEPTH TO BOTTOM		X	9
B	SAMP-INTERVAL/UPPER		X	9
B	SAMP-INTERVAL/LOWER		X	9
B	SHIP SPEED		X	9
B	SEQUENCE NUMBER			9
C	STATION NUMBER		X	9
C	DEPTH OF SAMPLE		X	9
C	TEMP AT SAMPLE DEPTH		X	9
C	SALINITY/SAMP DEPTH		X	9
C	SEQUENCE NUMBER		X	9
D	STATION NUMBER		X	9
D	GEAR CODE		X	9
D	MESH SIZE		X	9
D	HAUL LENGTH		X	9
D	VOL WATER FILTERED		X	9
D	TOTAL SETTLED VOLUME			9
D	TOTL WATER DISPLACED			9
D	TOTL DRY WT OF HAUL			9
D	TOTL WET WT OF HAUL			9
D	DURATION OF TOW		X	9
D	HAUL TYPE CODE		X	9
D	SEQUENCE NUMBER			9
E	STATION NUMBER			9
E	SAMPLE NUMBER			9
E	NODC TAXONOMIC CODE			9
E	LIFE HISTORY CODE			9
E	SEX CODE			9
E	SIZE OF SUBSAMPLE			9
E	NUMBER IN SUBSAMPLE			9
E	CONCENTRATION			9
E	NUMBER OF ADULTS			9
E	NUMBER OF JUVENILES			9
E	NUMBER OF EGGS			9
E	NUMBER OF LARVAE			9
E	SEQUENCE NUMBER		C	9
F	STATION NUMBER		C	9
F	SAMPLE NUMBER		C	9
F	NODC TAXONOMIC CODE			9
F	LIFE HISTORY CODE			9
F	SEX CODE			9
F	DRY WEIGHT			9
F	WET WEIGHT			9
F	SEQUENCE NUMBER			9
G	STATION NUMBER		X	9
G	TEXT			9
G	SEQUENCE NUMBER			9
H	STATION NUMBER			9
H	SAMPLE NUMBER			9

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81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 124
ZOOPLANKTON

RT	NAME OF FIELD	RU 172	RU 359	RU 3
H	SAMPLE SIZE			9
H	EST HOLOPLANKTON			9
H	EST MEROPLANKTON			9
H	Z MEROPLANKTON/HAUL			9
H	TEXT			9
H	SEQUENCE NUMBER			9
I	STATION NUMBER			9
I	SAMPLE NUMBER			9
I	NODC TAXONOMIC CODE			9
I	NUMBER CAUGHT			9
I	MINIMUM SIZE			9
I	MAXIMUM SIZE			9
I	MEAN SIZE			9
I	# EGGS THIS SPECIES			9
I	TEXT			9
I	SEQUENCE NUMBER			9

PARAMETER CHECK LIST PAGE 1

81. 3 19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 127
MARINE ANIMAL SIGHTING AND CEN

RT	NAME OF FIELD	RU 230	RU 233	RU 232	RU 612	RU 611	RU 613	RU 592	RU 605
	FILE IDENTIFIER			X	X	X	X		
	RECORD TYPE			X	X	X	X		
A	VESSEL/PLATFORM NAME								
A	CRUISE ID			X	X	X	X		
A	SURVEY START DATE			X	X	X	X		
A	SURVEY END DATE			X	X	X	X		
A	DATA SOURCE, PI. SCI								
A	INSTIT. OR AGENCY			X	X	X	X		
A	PLATFORM ID			X	X	X	X		
A	PLATFORM TYPE			X	X	X	X		
B	STATION NUMBER			X	X	X	X		
B	BEGIN LATITUDE			X	X	X	X		
B	BEGIN LONGITUDE			X	X	X	X		
B	END LATITUDE			X	X	X	X		
B	END LONGITUDE			X	X	X	X		
B	BEGIN DATE			X	X	X	X		
B	BEGIN TIME			X	X	X	X		
B	END TIME			X	X	X	X		
B	WIDTH OF TRACK			X	X	X	X		
B	PLATFORM DIRECTION			X	X	X	X		
B	PLATFORM SPEED			X	X	X	X		
B	PLATFORM ALTITUDE			X	X	X	X		
B	LEG MADE GOOD								
B	COMPLETENESS								
B	SEQUENCE NUMBER								
C	STATION NUMBER			X	X	X	X		
C	SIGHTING NUMBER			X	X	X	X		
C	WATER DEPTH								
C	CURRENT DIRECTION								
C	CURRENT SPEED								
C	WIND DIRECTION			X	X	X	X		
C	WIND SPEED			X	X	X	X		
C	CLOUD TYPE								
C	CLOUD AMOUNT			X	X	X	X		
C	WEATHER								
C	AIR TEMPERATURE			X	X	X	X		
C	SEA SURFACE TEMP.			X	X	X	X		
C	SEA STATE			X	X	X	X		
C	WATER COLOR								
C	SURFACE VISIBILITY			X	X	X	X		
C	GLARE AMOUNT								
C	GLARE LOCATION								
C	DEBRIS								
C	ICE CODES (7)			X	X	X	X		
C	DEFORMATION								
C	TRANSECT WIDTH (ICE)								
C	PLATFORM ACTIVITY								
C	HUMAN ACTIVITY								
C	SEQUENCE NUMBER								
D	STATION NUMBER			X	X	X	X		
D	SIGHTING NUMBER			X	X	X	X		
D	SIGHTING LATITUDE			X	X	X	X		
D	SIGHTING LONGITUDE			X	X	X	X		
D	SIGHTING DATE			X	X	X	X		
D	SIGHTING TIME			X	X	X	X		
D	ANIMAL SIGHTED CODE								
D	DIST.-ANIMALS-PLAT.								
D	BEARING OF ANIMALS								
D	DIST.-ANIMALS-SHORE								
D	DIST.-ANIMALS-ICE								
D	ANIMAL HEADING								
D	PLATFORM ALTITUDE								
D	SEQUENCE NUMBER								

PARAMETER CHECK LIST

PAGE 2

[illegible] PROJECT OFFICE ALL RU-ALL

FILE TYPE 127
MARINE ANIMAL SIGHTING AND CEN

[illegible]	NAME OF FIELD	RU 230	RU 262	RU 230	RU 612	RU 611	RU 613	RU 592	RU 605
E	STATION NUMBER			X	X	X	X		
E	SIGHTING NUMBER			X	X	X	X		
E	TAXONOMIC CODE			X	X	X	X		
E	IDENT. RELIABILITY				X		X		
E	TOT. # OF INDIVID.			X	X	X	X		
E	CONFIDENCE								
E	COLLECTION METHOD								
E	NUMBER OF ADULTS			X	X	X	X		
E	NUMBER OF SUBADULTS								
E	# OF JUVENILES			X	X	X	X		
E	NUMBER OF UNKNOWN								
E	SEQUENCE NUMBER								
F	STATION NUMBER								
F	SIGHTING NUMBER								
F	TAXONOMIC CODE								
F	IDENT. RELIABILITY								
F	NUMBER OF INDIVID.								
F	CONFIDENCE								
F	COLLECTION METHOD								
F	BEHAVIOR (3)								
F	NUMBER OF GROUPS								
F	GROUP SIZE								
F	NUMBER OF ADULTS								
F	NUMBER OF SUBADULTS								
F	# OF JUVENILES								
F	# OF ADULT MALES								
F	# OF ADULT FEMALES								
F	SPECIAL MARKS,TAGS								
F	DECOMPOSITION								
F	PHOTOS TAKEN								
F	DIVE TIME								
F	SEQUENCE NUMBER								
T	STATION NUMBER			X	X	X	X		
T	SIGHTING NUMBER			X	X	X	X		
T	TEXT			X	X	X	X		
T	SEQUENCE NUMBER								

PARAMETER CHECK LIST

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 135
BIRD COLONY

RT	NAME OF FIELD	RU 237	RU 341	RU 460
X	FILE IDENTIFIER		X	X
X	RECORD TYPE		X	X
X	STATION NUMBER		X	
A	MAP CODE NUMBER		X	
A	AREA NUMBER		X	X
A	SUB-AREA NUMBER		X	X
A	STUDY PLOT/SAMPLE #		X	
A	STATION ID CODE		X	
A	LATITUDE		X	X
A	LONGITUDE		X	X
A	START STUDY DATE		X	X
A	END STUDY DATE		X	X
A	NUMBER OF VISITS		X	X
A	LOCATION CODE		X	
A	HISTORY CODE		X	
A	ICE BREAK-UP		X	
A	TYPE OF STUDY		X	X
A	SEQUENCE NUMBER		X	X
B	MEASUREMENT OF AREA		X	
B	APPLICABLE AREA		X	
B	STUDY AREA		X	
B	HIGHEST ELEVATION		X	
B	LOWEST ELEVATIONS		X	
B	SLOPE CODE		X	
B	EXPOSURE CODE		X	
B	GEOGRAPHIC SITUATION		X	
B	TOTAL NESTS IN AREA		X	
B	NESTS INCLUDED/STUDY		X	
B	PHYSIOGRAPHIC TYPE		X	
B	SUBSTRATE CODE		X	
B	VEGETATION CODE		X	
B	PERCENT OF AREA		X	
B	PERCENT OF COLONY		X	
B	SEQUENCE NUMBER		X	
C	SPECIES TAXONOMIC #		X	
C	DOMINANT AGE CODE		X	
C	DOMINANT SEX CODE		X	
C	CHRONOLOGICAL EVENTS		X	
C	CHRONOLOGY OF EVENT		X	
C	DATE/PEAK ACTIVITY		X	
C	NO. BIRDS IN EVENT		X	
C	PERCENT ON PEAK DAY		X	
C	SEQUENCE NUMBER		X	
D	SPECIES TAXONOMIC #		X	
D	DEVELOPMENT STAGE		X	
D	FREQUENCY-SIZE GROUP		X	
D	SEQUENCE NUMBER		X	
E	SPECIES TAXONOMIC #		X	
E	AGE CLASS CODE		X	
E	CAUSE OF DEATH		X	
E	PREDATOR		X	
E	PERCENT OF TOTAL		X	
E	TOTAL DEATHS-SPECIES		X	
E	SEQUENCE NUMBER		X	
F	SPECIES TAXONOMIC #		X	X
F	NEST NUMBER		X	X
F	EGG NUMBER		X	X
F	CHECK NUMBER		X	X
F	OBSERVATION DATE		X	X
F	OBSERVATION TIME		X	X
F	AGE-DAYS OR CLASS		X	X
F	CROP CODE		X	

PARAMETER CHECK LIST

81/03/19 PROJECT OFFICE-ALL RU ALL

FILE TYPE 135
BIRD COLONY

RT	NAME OF FIELD	RU 237	RU 341	RU 460
F	WEIGHT		X	X
F	CHICK MEASUREMENTS		X	
F	FLEDGED CODE		X	X
F	AGE AT DEATH		X	X
F	CAUSE OF DEATH		X	X
F	PREDATOR		X	X
F	SEQUENCE NUMBER		X	X
G	SPECIES TAXONOMIC #		X	X
G	NEST NUMBER		X	X
G	FIRST SITE DATE		X	X
G	NEST INITIATED DATE		X	X
G	NEST ATTEMPT		X	X
G	DATE FIRST EGG		X	X
G	CLUTCH SIZE		X	X
G	FIRST HATCHING DATE		X	X
G	BROOD SIZE		X	X
G	DATE FIRST FLEDGING		X	X
G	FLEDGED NUMBER		X	X
G	DIST-NEAR NEIGHBOR		X	
G	% ADULTS AT ACTIVITY		X	
G	MAXIMUM ABSENCE DATE		X	
G	DATE ABANDONED		X	X
G	SEQUENCE NUMBER		X	X
H	SPECIES TAXONOMIC #		X	
H	NEST NUMBER		X	
H	EGG NUMBER		X	
H	DATE LAID		X	
H	DATE HATCHED		X	
H	CHICK NUMBER		X	
H	USF&W BAND NUMBER		X	
H	SEX CODE		X	
H	DATE FLEDGED		X	
H	DATE LEFT AREA		X	
H	EGG FATE CODE		X	
H	CHICK FATE CODE		X	
H	AGE AT DEATH		X	
H	CAUSE OF DEATH		X	
H	PREDATOR		X	
H	SEQUENCE NUMBER		X	
I	SPECIES TAXONOMIC #		X	
I	NEST NUMBER		X	
I	EGG NUMBER		X	
I	CHECK NUMBER		X	
I	DATE-OBSERVATION		X	
I	TIME OBSERVATION		X	
I	AGE-DAYS OR CLASS		X	
I	CROP CODE		X	
I	WEIGHT		X	
I	CHICK MEASUREMENTS		X	
I	SEQUENCE NUMBER		X	
J	SPECIES TAXONOMIC #			X
J	BEGIN CENSUS DATE			X
J	BEGIN CENSUS TIME			X
J	DURATION OF CENSUS			X
J	PHATFORM CODE			X
J	METHOD CODE			X
J	OBSERVATION METHOD			X
J	#-ADULTS/SUBADULTS			
J	NO. BREEDERS			X
J	NO. NESTS			X
J	NO. CHICKS SEEN			X
J	#-NESTS UNKNOWN CONT			X
J	DOMINANT AGE CLASS			
J	EVENT CODE			X

PARAMETER CHECK LIST

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 135
BIRD COLONY

RT	NAME OF FIELD	RU 237	RU 341	RU 460
J	SEQUENCE NUMBER			X
K	SPECIES TAXONOMIC #			
K	BEGIN DATE			
K	DURATION OF VISIT			
K	DEVELOPMENT STAGE			
K	FREQUENCY SIZE GROUP			
K	SEQUENCE NUMBER			
T	CITATION (LINK)			X
T	TEXT			C
T	SEQUENCE NUMBER			X

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81/03/19 PROJECT OFFICE ALL RU-ALL

FILE TYPE 144
MARINE TOXIC SUBSTANCES AND PO

RT	NAME OF FIELD	RU 275
X	FILE IDENTIFIER	
X	RECORD TYPE	
A	PLATFORM	
A	SURVEY IDENT	
A	SURVEY DATE-FROM	
A	SURVEY DATE-TO	
A	INV/DATA/MUN/CONTR	
A	INSTITUTION-AGENCY	
B	EFFLUENT IDENTIFIER	
B	LATITUDE	
B	LONGITUDE	
B	DIST FROM SHORE-DISC	
B	DEPTH OF DISCHARGE	
B	AVG DISCH-SURVEY PER	
B	AREA OF ZID	
B	DISCHARGE DESC	
B	PERIODIC DISCHARGE	
B	WET OR DRY PERIOD	
B	PRIMARY INDUSTRY	
C	STATION NUMBER	
C	LATITUDE	
C	LONGITUDE	
C	DATE 'GMT'	
C	TIME 'GMT'	
C	EFFLUENT IDENTIFIER	
C	STATION INSIDE ZID	
C	DIST-NEAREST ZID	
C	SEQUENCE NUMBER	
D	STATION NUMBER	
D	BOTTOM DEPTH	
D	BOTTOM TYPE	
D	CURRENT SPEED	
D	CURRENT DIRECTION	
D	WIND SPEED	
D	WIND DIRECTION	
D	SEA STATE	
D	TIDE HEIGHT	
D	TIDE STAGE	
D	DEPTH OF THERMOCLINE	
D	TRANSPARENCY	
D	AIR TEMPERATURE	
D	WATER SURFACE TEMP	
D	WATER SURF SALINITY	
D	SEQUENCE NUMBER	
E	STATION NUMBER	
E	SAMPLE NUMBER	
E	REPLICATE NUMBER	
E	SPECIMEN NUMBER	
E	SAMPLE TYPE	
E	SAMPLE DEPTH-UPPER	
E	SAMPLE DEPTH-LOWER	
E	SAMPLE ELEV-INTER	
E	SPHERE	
E	METHOD	
E	GEAR TYPE	
E	TYPE OF TOW	
E	TAXONOMIC CODE	
E	NUMBER OF INDIVIDUAL	
E	PREDOMINANT SEX	
E	LIFE STAGE	
E	ORGAN SAMPLED	
E	BIOLOGICAL NICHE	
E	WET WEIGHT	

PARAMETER CHECK LIST

PAGE 2

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 144
MARINE TOXIC SUBSTANCES AND PO

RT	NAME OF FIELD	RU 275
E	DRY WEIGHT	
E	SEQUENCE NUMBER	
F	STATION NUMBER	
F	SAMPLE NUMBER	
F	REPLICATE NUMBER	
F	SPECIMEN NUMBER	
F	PARAMETER CODE (3)*	
F	MEASUREMENT CD (3)*	
F	TRACE CODE (3)*	
F	CONCENTRATION (3)*	
F	SIGN (3)*	
F	EXPONENT (3)*	
F	SEQUENCE NUMBER	
T	STATION NUMBER	
T	SAMPLE NUMBER	
T	REPLICATE NUMBER	
T	SPECIMEN NUMBER	
T	TEXT	
T	SEQUENCE NUMBER	

PARAMETER CHECK LIST PAGE 1

81/03/19 PROJECT OFFICE-ALL RU-ALL

FILE TYPE 401
HYPOCENTER

RT	NAME OF FIELD	RU 016	RU 210	RU 251	RU 483	RU 579
X	DATA SOURCE	X	X	X		
X	YEAR	X	X	X		
X	DATE	X	X	X		
X	ORIGIN TIME	X	X	X		
X	LATITUDE	X	X	X		
X	LONGITUDE	X	X	X		
X	FOCAL DEPTH	X	X	X		
X	BODY-WAVE/AVG VALUE					
X	MB					
X	ISOSEISMAL MAP					
X	MAX INTENSITY					
X	DIASTOPHISM CODE					
X	TSUNAMI CODE					
X	SEICHE CODE					
X	VOLCANISM					
X	NONTECTONIC CODE					
X	WAVES GENERATED CODE					
X	FLINN-ENGDAHL/REGION					
X	SURFACE-WAVE AVG VAL					
X	MS					
X	COMPONENT Z OR H					
X	CULTURAL EFFECTS					
X	OTHER MAGNITUDE	C	C	C		
X	AUTHORITY					
X	SPECIAL EVENT					
X	DEPTH CONTROL					
X	# STATIONS/QUALITY	X	X	X		
X	AUTHORITY-TIME/OTHER					
X	LOCAL MAGNITUDE	C	C	C		
X	GENERALLY ML	X	X	X		
X	AUTHORITY	X	X	X		

APPENDIX V

BLM FILE OF MANAGEMENT INFORMATION

Regional Summary Record

Name of File	Columns	Value
Record type	1, 2	"01"
Region code	3, 5	GOA, BER, or ARC
Year	6, 7	YY
Study code	8, 10	See study code table
Blank	11, 12	--
Study name	13, 38	Controlled vocabulary of names
Science (labor)	39, 43	($k)
Logistics	44, 48	($k)
Equipment	49, 53	($k)
Data management	54, 58	($k)
OCSEAP management	59, 63	($k)
Blank	64	--
Total	65, 69	($k)
Blank	70	--
Level of effort	71, 73	Percentage
Alaska ranking	74, 77	Numeric field
National ranking	78, 80	Numeric field
Text	81, 124	Alphanumeric field
Sequence number	125, 128	

BLM FILE OF MANAGEMENT INFORMATION

Lease Sale Summary

Name of File	Columns	Value
Record type	1, 2	"02"
Region code	3, 5	GOA, BER, or ARC
Year	6, 7	YY
Study code	8, 10	See study code table
Sale number	11, 12	See lease sale table
Study name	13, 38	Controlled vocabulary of names
Science (labor)	39, 43	($k)
Logistics	44, 48	($k)
Equipment	49, 53	($k)
Data management	54, 58	($k)
OCSEAP management	59, 63	($k)
Blank	64	--
Total	65, 69	($k)
Blank	70	--
Level of effort	71, 73	Percentage
Alaska ranking	74, 77	Numeric field
National ranking	78, 80	Numeric field
Text	81, 124	Alphanumeric field
Sequence number	125, 128	

BLM FILE OF MANAGEMENT INFORMATION

RU Summary Record

Name of File	Columns	Value
Record type	1, 2	"03"
Region code	3, 5	GOA, BER, or ARC
Year	6, 7	YY
Study code	8, 10	See study code table
Sale number	11, 12	See lease sale table
RU or PU number	13, 18	
Author & Title	19, 38	
Science (labor)	39, 43	($k)
Logistics	44, 48	($k)
Equipment	49, 53	($k)
Data management	54, 58	($k)
OCSEAP management	59, 63	($k)
Blank	64	--
Total	65, 69	($k)
Blank	70	--
Level of effort	71, 73	Percentage
Alaska ranking	74, 77	Numeric field
National ranking	78, 80	Numeric field
Text	81, 124	Alphanumeric field
Sequence number	125, 128	

BLM STUDY CODES

		Categories
C01	Contaminants - air/water	C = contaminant/chemical
G01	Geohazards	G = geological
G02	Post-Sale Seismic Monitor	
G03	Permafrost	
P01	Oceanographic Hazards	P = physical
P02	Tsunami Hazards	
P03	Pollutant Transport	
P04	Meteorological Hazards	
P05	Sea Ice	
B01	Birds and Mammals	B = living resources
B02	Comm/Subsistence Species	
B03	Endangered Species	
B04	Ecosystems	
E01	Cumulative Impacts	E = effects
E02	Effects	
S01	Socioeconomics	S = socioeconomic
X01	Special Studies - any type	

NORTON SOUND TAXA RU 069

	SPRING	SUMMER	FALL	WINTER
DELPHINAPTERUS LEUCAS	X	X		
ESCHRICHTIUS ROBUSTUS	X	X		
BALAENOPTERIDAE			X	
URSUS MARITIMUS	X			
PINNIPEDIA	X	X		
ODOBENUS ROSMARUS	X	X		X
PHOCA HISPIDA	X			
PHOCA FASCIATA	X			
PHOCA LARGHA	X			
ERIGNATHUS BARBATUS	X			X

ANNUAL REPORT

Contract Number: 03-7-022-35139
Research Unit Number: 527
Reporting Period: 4/1/80 - 3/31/81

OCSEAP Data Processing Services

Harold Petersen, Jr.
William C. Johnson II
Data Projects Group
Pastore Laboratory
University of Rhode Island
Kingston, Rhode Island 02881

1 April 1981

Background and Objectives

The Data Projects Group (DPG) at the University of Rhode Island (URI) provides a variety of services to the OCSEAP Program in general, and to the Juneau Project Office (JPO) in particular. Through these auspices, services are also made available to several Research Units (RU).

Through the early lifetime of this task of Contract Number 03-7-022-35139 with URI, DPG used a data management system known as the MARMAP Information System (MIS). The MIS was designed and developed by DPG for the National Marine Fisheries Service. As related to this work, the MIS has provided the means to carry out batch-styled data set validations, to create and maintain a significant data base, and to retrieve those portions of the data base appropriate to any of a variety of analysis products.

Later, as the need for real-time data validation arose among the OCSEAP RUs, DPG responded by developing the Interactive Data Entry and Analysis (IDEA) System for use in addition to the MIS. This system was described in a previous quarterly report submitted by this RU. It has significance in allowing investigators to validate field data during their initial entry into the OCSEAP/NODC formats, thereby reducing the time needed for the validation process under previously used procedures.

The coupling of the IDEA and MIS systems then provided the resources necessary to efficiently carry out the primary objectives of this work, which include the orderly conveyance of validated data from investigator sites to the Program, and the provision of data analysis support to selected investigators.

Partly as a result of work carried out in association with another task under this contract, and partly owing to an increasing need for processing flexibility not readily available through the MIS, the DPG has recently begun a migration of data processing activities from the MIS, which has been used on an IBM, and then ITEL mainframe, to a new system known as the Program Tracking System (PTS), based on a Prime computer. Combined with IDEAS, the PTS makes available a contemporary set of data management tools necessary for continuing and expanding the services provided to OCSEAP.

Report Overview

Efforts were made in four major areas during this past year, including:

- Analytical product support
- Development, enhancement and distribution of the IDEA System
- Further processing of data sets submitted to DPG
- Development of the new Program Tracking System

The remainder of the report is dedicated to a discussion of each of these activities.

Analytical Product Support

A number of products were generated at the DPG in conjunction with our OCSEAP contract. The production amounted to a significant volume as demonstrated by the list below. Included in the list is information as to which RU(s) benefited from the request, and the quarter during which they were produced.

time interval	RU(s)	requested product
April 1980 - July 1980		
	083	1 magnetic computer tape of FT033 data
	083	1 magnetic computer tape of bird density data (FT033)
	083	93 Food Analysis Tables (FT031)
	083	70 Mean Density versus Sample Variance Ratio Tables (FT033)
	083	8 Mean Density Symbol Plots (FT033)
	083	4 Effort Plots (FT033)
	083	3 Data Summary Tables (FT033)
	196	19 diskettes containing 16 data sets of FT033
July 1980 - Oct. 1980		
	T. Johnson APO	1 magnetic computer tape of FT031 data
	083	125 Graduated Symbol Plots (FT033)
	083	9 Bering Sea Effort Plots (FT033)
	083	3 Pribilof Island Effort Plots (FT033)

	083	3 Mean Density versus Sample Variance Ratio Tables (FT033)
	W. Fischer	1 list of everything we have done during our OCSEAP contract
Oct. 1980 - Jan. 1981		
	083	1 magnetic computer tape of File Type 031 data
	172	1 magnetic computer tape of File Type 034 data
	083	1 magnetic computer tape of bird densities (FT033)
	172	1 magnetic computer tape of bird habitat data
	083	13 Graduated Symbol Plots (FT033)
	083	7 Data Summary Tables (FT033)
	083	1 Mean Density versus Sample Variance Ratio Table (FT033)
	083	1 Graduated Symbol Plot (FT033)
	083	1 set of Parameter Update Requests
	196	Samples of Digital Density Plots
	196	Samples of Density Histograms based on distance from land
	196	Samples of Star Diagrams
	196	Samples of Sightings Effort Tables
	196	Samples of Sightings Effort Plots
	196	Samples of Ice Condition Plots

	196	Samples of Density Histograms based on ice condition
	L. Haas	1 updated list of everything we have done during our OCSEAP contract
Jan. 1981 - April 1981		
	196	1 magnetic computer tape of File Type 033 data
	196	172 Star Diagrams (FT033)
	196	24 Distance Histograms (FT033)
	196	22 Migrations Tables (FT033)
	196	12 Ice Histograms (FT033)
	083	3 Graduated Symbol Plots (FT033)

Several of these products were developed during this year. They are (1) Species Summary Table, (2) Migration Table I, Wind Speed and Direction Summary, (3) Migration Table II, Species Flight Direction Summary, (4) Density Histogram Based on Ice Conditions, (5) Density Histogram Based on Distance from Land. Descriptions of these five products are incuded herein as Appendix I. A product compendium which includes these, as well as other products is available upon request from the Juneau Project Office.

Development, Enhancement and Distribution of the IDEA System

The work done in this area of our activities can be summarized in tabular form as was done in the last section. The list is as follows:

time interval	RU(s)	requested product
April 1980 - July 1980		
	083, 172, 196, 237, 337	5 diskettes with word processing software for TI771 and appropriate documentation
	083, 172, 237, 337	TI 990 BASIC manuals
	083, 196, 337	Computer program SUMMARY

	460	Computer programs SEPRATE, CATNATE and STAR
	083, 196, 337	Data file TAXONS
	196	Data file TAX8891
	172, 460	TI data entry program for FT031 and documentation
	083, 337	TI data entry program for FT033 and documentation
July 1980 - Oct. 1980		
	172	1 data entry program for bird habitat data (HOM2)
	083, 196	Computer programs SEPRATE and CATNATE
	083	8 statistical programs written in BASIC
	083	TI data entry programs for FT031 and documentation
	083, 196	Computer programs SEPRAT7 and CATNAT7 and documentation
	083	2 QUAIL word processing system diskettes
	172	Computer programs DIVIDE1 and COMBIN1 and documentation
	196	Data file TAX8891
Oct. 1980 - Jan. 1981		
	196	1 TI utilities diskette
	083	Computer programs UPDATE2, CHOP2, CATNAT7, SEPRAT7 and documentation
	083, 172, 196	Computer programs SEPRAT8, CATNAT8
	172	Computer programs PRINT1 and SUMMARY

	083, 172	Data file TAXONS
	083	Documentation for computer program SUMMARY
Jan. 1981 - April 1981		
	083, 172 196, 237	9 statistical programs written in BASIC with extensive documentation (see below)
	T. Johnson APO	TI demonstration and user's discussion session at Bodega Bay
	083, 172	TI data entry program for FT031 and documentation
	196	TI data entry program for FT033 and documentation
	083	Computer programs SUMMARY, STAR2 and PRINT1
	083, 172 196	Data file TAXONS

Although the DPG had previously distributed statistical programs written in the BASIC computer language, extensive documentation was developed to enhance this tool for use by the RUs. The list of available programs has been expanded to include the following:

ANOVA	Analysis of Variance
CHISQR	Chi-square Test
CHSQCT	Chi-square Test for Contingency Tables
CORCOEF	Correlation Coefficient
LINREG	Linear Regression
MLR	Multiple Linear Regression
MVSDCI	Mean, Variance, Standard Deviation, Standard Error and 95% Confidence Interval for the Mean
SPEARMN	Spearman's Ranked Correlation Coefficient

STEPREG Stepwise Linear Regression

Further processing of data sets submitted to DEG

During the year data validation began on eight File Type 033 Field Operations and one File Type 034 data set. Nine Field Operations of File Type 033 data were submitted to NODC, two were resubmitted and three postsubmission errors were brought to NODC's attention. RU 033's File Type 031 data, as well as one large File Type 034 Field Operation and two File Type 038 Field Operations' data were submitted to NODC. In addition to the normal validation work that we performed, a number of data sets were edited to make them usable in the production of analyses for RU 196. This information is summarized in the Data Set Status Table which is included as Appendix II.

Development of the new Program Tracking System (PTS)

The Program Tracking System (PTS) is the new name given to the assemblage of scientific and administrative data processing capabilities being developed by DPG on a Prime, Inc. Model 550 computer. As indicated in the Background and Objectives, the initial need for this development stemmed from another task in this contract, aimed primarily at administrative support for the Office of Marine Pollution Assessment. Throughout the lifetime of the OCSEAP-related task, however, needs also arose for new types of data manipulation not readily available from the mainframe system on which the MARMAP Information System (MIS), the management system which DPG has used for several years, was implemented. The IDEA System is an example of one such facility.

Migration of all data processing activities (carried out through use of the MIS) from the mainframe system to an in-house Prime, Inc. system will give DPG all the previous capabilities plus the resources necessary for implementation of new concepts. This work has just begun as of this writing, and will require an estimated two months to complete. Two examples of new capabilites available as a result of this migration are interactive access to data bases, and an increase in interactive analyses such as graphics. As new freatures are brought on-line, progress reports and bulletins concerning these features will be provided to OCSEAP and other RUs with whom DPG interacts.

APPENDIX I

New Analysis Products

SPECIES SUMMARY TABLE

The Species Summary Table provides the user with a list of species observed during a particular field operation. The table can be generated for one or several field operations at one time. For each field operation under consideration, the species sighted are listed alphabetically, along with the number of transects during which each species was sighted, and the actual number of separate sightings.

DENSITY HISTOGRAM
Based on Distance from Land

The Density Histogram based on distance from land displays densities (number of species per square kilometer) as either a function of distance from nearest shore or as a function of angle and distance from a given point source. Each column contains four entries for each species group being studied. These are 1) Mean density, 2) Maximum density, 3) Minimum density, and 4) Percentage of stations during which the species was sighted. Alternatively, the user may elect to have displayed only the Mean density. At the top of each column will be found the number of transects used in the calculation of the densities in that column and the distance range from the nearest shore or from the central point to the area in which the transects occurred.

Densities may be displayed for any number of species groups with respect to any combination of parameters residing in the applicable data base. Along with placing conditions on the species to be studied, the user may desire to exercise any one or a combination of a number of other useful options. The width of the "distance to shore" bands and the width of the arc into which the area around the central point may be sectioned are at the discretion of the user. Also a maximum distance boundary may be set so that only transects within a given distance of the nearest land or the central point will appear in the histogram. Finally, densities may be calculated only from transects for which distance to nearest shore information is available or all transects may be used by approximating the distance to the nearest shore through the use of the distance between the midpoint of the transect and the central point source (This applies only to histograms using the distance from a central point.). This output may portray data from as many field operations as desired.

DENSITY HISTOGRAM
Based on Ice Conditions

The Density Histogram based on ice conditions displays densities (number of species per square kilometer) as a function of ice cover. If no ice cover is recorded but some ice information is available, then the density will be included in a column with the heading "V". If no ice information at all is present, then the density will be included in a column with the heading "+". Each column contains four entries for each species group being studied. These are 1) Mean density, 2) Maximum density, 3) Minimum density, and 4) Percentage of stations during which the species was sighted. Alternatively, the user may elect to have displayed only the Mean density. At the top of each column will be found the number of transects used in the calculation of the densities in that column and the ice cover codes (V, +, and codes 0 through 9).

Densities may be displayed for any number of species groups with respect to any combination of parameters residing in the applicable data base. This output may portray data from as many field operations as desired.

APPENDIX II

Data Set Status Table

DATA_SET_STATUS_TABLE

RU	FILE ID	RECEIVED	CP & LL SENT OUT	CP & LL RETURNED	EDITED	SENT TO NODC
File_Type_031						
083	UCI031	10/08/79	04/10/80a	NA	05/07/80	03/27/81
File_Type_033						
083	UCI180	06/16/80	06/16/80	NA	06/24/80	07/03/80
083	UCI280	06/27/80	07/03/80	07/24/80	08/05/80	08/18/80
083	UCI380	07/24/80	08/01/80	09/22/80	09/30/80	10/06/80
083	UCI680	08/12/80	02/12/81	03/04/81	03/05/81	03/11/81b
083	UCI480	10/06/80	02/12/81	03/04/81	03/04/81	03/11/81b
083	UCI580	11/12/80	02/12/81	03/04/81	03/05/81	03/10/81
196	1DI577	07/18/78	08/31/78			
196	1SR377	07/18/78	08/31/78			
196	1SR477	07/18/78	08/31/78			
196	1SR578	05/18/79	06/11/79			
196	1SR678	05/18/79	06/11/79			
196	3AL877	05/18/79	06/11/79	11/21/80	11/26/80	
196	3AL878	05/18/79	06/11/79	04/22/80	04/29/80	
196	3GL877	05/18/79	06/11/79	12/05/80	12/15/80	
196	AL3878	05/18/79	06/11/79	04/22/80	04/29/80	05/29/80c
196	2GL876	12/04/79	01/14/80	12/05/80	12/19/80	
196	2GL976	12/04/79	01/14/80			
196	3AL876	12/04/79	01/14/80	04/22/80	04/29/80	
196	AL3876	12/04/79	01/14/80	04/22/80	04/29/80	05/29/80c
196	2BI776	02/04/80	02/07/80			

196	2GL875	02/04/80	02/07/80			
196	2GLA76	02/04/80	02/07/80			
196	3NW878	02/04/80	02/07/80	11/21/80	11/26/80	
196	2BW076	03/25/80	01/13/81	01/21/81	02/18/81	
196	2BW576	03/25/80	01/13/81			
196	2BW776	03/25/80	01/13/81	01/21/81	02/18/81	
196	3BB776	03/25/80	01/13/81	01/21/81	02/18/81	
196	3BL676	03/25/80	01/13/81	01/21/81	02/18/81	
196	3BR776	03/25/80	01/13/81	01/21/81	02/18/81	
196	3C0676	03/25/80	01/13/81	01/21/81	02/18/81	
196	3C0776	03/25/80	01/13/81	01/21/81	02/18/81	
196	3C0876	03/25/80	01/13/81	01/21/81	02/18/81	
196	3OK676	03/25/80	01/13/81	01/21/81	02/18/81	
196	3OK776	03/25/80	01/13/81	01/21/81	02/18/81	
196	3OK976	03/25/80	01/13/81	01/21/81	02/18/81	
196	3PB876	03/25/80	01/13/81	01/21/81	02/18/81	
196	3PI776	03/25/80	01/13/81	01/21/81	02/18/81	
196	3PP776	03/25/80	01/13/81	01/21/81	02/18/81	
196	3PP876	03/25/80	01/13/81	01/21/81	02/18/81	
196	3GL976	12/16/80	12/17/80	03/04/81	03/04/81	
196	3C0976	02/13/81	NA	NA	02/17/81	
337	FW4001	02/04/80	02/15/80	NA	NA	04/01/80
337	FW5038	02/04/80	02/15/80	NA	NA	04/01/80
337	FW9002	02/04/80	02/15/80	NA	NA	04/01/80

File_Type.034

172	PC1978	11/14/80	NA	NA	NA	02/04/81

File_Type_038

467	77PGI-3	11/14/78	12/01/78	02/16/80	05/05/80	05/30/80
467	MWAT78	09/20/79	10/09/79	02/16/80	05/05/80	05/30/80

a. The validation products for File Type 031 are not as extensive as a true CODEPULL and LOGLIST would be.

b. These are PROBES data which geographically compliment the OCSEAP data. Their entry through the DPG has had OCSEAP management's blessing.

c. Resubmission of data to NODC.

MIGRATION TABLE, II
Species Flight Direction Summary

The Species Flight Direction Summary displays recorded flight direction data for a given field operation or combination of field operations. The data are sorted by date, species, and flight direction. The table indicates, by date, which species were observed in flight, and for a given flight direction, how many of the species in total and how many birds of the species per hour were seen. The calculation of birds per hour was done by summing the elapsed times for transects starting on the given date, and dividing the total number flying in each direction by the total elapsed time. Flight directions, originally coded to the nearest ten degrees, have been grouped into 30 degree partitions.

This table is designed to be used in conjunction with the MIGRATION TABLE, part I, which displays the wind speed and direction information which might have some bearing on the species flight directions.

QUALITY ASSURANCE PROGRAM

FOR

TRACE PETROLEUM COMPONENT ANALYSIS

by

William D. MacLeod, Jr.*

Margaret M. Krahn

Frank T. Piskur

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*Principal Investigator, National Analytical Facility, Environmental Conservation Division, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 2725 Montlake Boulevard East, Seattle, Washington 98112.

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

A. SUMMARY OF OBJECTIVES

1. Intercalibration. To coordinate and conduct an analytical quality-assurance program that evaluates hydrocarbon data from Principal Investigators (PI's) in the OCSEA Program and other BLM-funded programs.

2. Metabolite Research. To improve analytical techniques, particularly those dealing with polar organic compounds associated with petroleum.

B. SUMMARY OF CONCLUSIONS

1. Intercalibration. Analyses for hydrocarbons in the Duwamish II subtidal sediment performed by nine analytical laboratories show that comparable results can now be obtained by experienced laboratories, even though different extraction procedures are followed. Rigorous adherence to use of (a) published extraction procedures, (b) capillary gas chromatographic (GC) analysis, and, (c) a specified list of hydrocarbons made this intercalibration exercise measurably better than earlier studies sponsored by the OCSEA Program.

2. Metabolite Research. Numerous metabolites arising from a pair of polynuclear aromatic hydrocarbons (PAHs) found in petroleum can be analyzed by high-pressure liquid chromatography (HPLC) with ultraviolet (UV) absorption and fluorescence detectors. Interferences by other xenobiotic and natural organic compounds can be suppressed by appropriate choice of UV fluorescence (UVF) excitation and emission wavelengths.

C. SUMMARY OF IMPLICATIONS

The advances in analytical chemical methodology reported herein represent significant improvements in the state-of-the-art analyses for hydrocarbons and other petroleum-related compounds in marine samples.

II. INTRODUCTION

A. GENERAL NATURE AND SCOPE OF STUDY

1. Intercalibration. A quality-assurance program for chemical analyses of petroleum components among BLM/OCS environmental studies is an objective of the BLM/OCS and OCSEA Programs. The NOAA National Analytical Facility (NAF) conducts interlaboratory calibration studies among qualified marine analytical laboratories associated with the BLM/OCS program. Previously, an Interim Reference Material (IRM) was prepared from an intertidal harbor sediment (Duwamish I) known to be contaminated with aliphatic and aromatic hydrocarbons. This IRM was distributed in multiple 100-g portions to the laboratories participating in the intercalibration. Analytical results returned to NAF are evaluated by analytical chemists and statisticians. As a continuation of these studies, OCSEAP requested NAF to prepare and distribute a second IRM. For this, NAF selected a finer grained sediment from mid-channel of the Duwamish River (Duwamish II). Distribution of this IRM was restricted to experienced analysts who observe the highest of standards.

2. Metabolite Research. Recent research with marine organisms exposed to aromatic hydrocarbons suggests that aromatic hydrocarbons are converted to a complex array of metabolic products which are retained for significant periods. Some of the aromatic hydrocarbons found in petroleum are not only among EPA's "Priority Pollutants" but are also carcinogenic. In order to delineate metabolite formation and retention, and to determine the nature of the chemical structures formed, suitable analytical procedures must be developed for these compounds.

B. SPECIFIC OBJECTIVES

1. Intercalibration.

   a. Evaluate results of Duwamish I intercalibration.

   b. Distribute Duwamish II sediment intercalibration material to selected PI's for analysis of residual hydrocarbons.

   c. Tabulate the analytical results of Duwamish II sediments reported by contract laboratories and have these results evaluated statistically.

2. Metabolite Research. Evaluate existing methods and develop new methods to analyze hydrocarbons and petroleum-related polar compounds in environmental samples. Recommend procedural modifications and improvements to OCSEAP/BLM.

C. RELEVANCE TO PROBLEMS OF PETROLEUM DEVELOPMENT

1. Intercalibration. OCSEAP and BLM have regarded analyses of environmental samples for hydrocarbons as essential to their environmental studies pertaining to petroleum development on the outer continental shelf (OCS). Effective measurement of hydrocarbons in marine sediments requires standardized extraction procedures that are efficient and reproducible. Our studies that compare results from existing and new analytical methodology address this issue.

2. Metabolite Research. Petroleum contains many organic compounds such as the PAHs that are converted in biota to metabolites not only more polar, but also possibly more toxic, than their parent hydrocarbons. Analytical methodology to extract and analyze marine environmental samples for such petroleum-related compounds and their metabolites, remains inadequate. Nevertheless, establishment of efficient, validated,

ultra-sensitive analytical procedures for these polar compounds is essential to an understanding of the fate and effects of petroleum on the marine environment. Development of analytical methods for metabolites of PAHs reported herein represent a significant advance.

III. CURRENT STATE OF KNOWLEDGE

A. INTERCALIBRATION

Concern over oil pollution has led to considerable interest in determining petroleum components in the marine environment [1]. For example, a number of researchers have developed specialized procedures for analyzing hydrocarbons in marine sediments [2-8]. In the past, these various procedures have been employed in environmental studies without having been adequately assessed or correlated [2,3]. As a result, it has been difficult to relate analytical data developed under one study with those of another. To surmount this problem, NAF has undertaken to compare four analytical methods for hydrocarbons in marine sediments as applied to a representative set of individual hydrocarbons [8]. Our subsequent interlaboratory hydrocarbon calibration program with the interim reference materials addresses the relation of data produced by one laboratory with those of another.

B. METABOLITE RESEARCH

Large numbers of chemicals enter the marine environment from various sources including petroleum spills, industrial waste, sewage, and aerial fallout of combustion products [9,10]. Many of these foreign substances are resistant to chemical and biochemical changes and persist indefinitely. Others, such as PAHs, are readily converted through oxygen addition into products more polar than the parent compounds

[11]. A number of these xenobiotic compounds and their oxygenated transformation products are toxic to aquatic organisms [12]. Because hundreds of foreign chemicals may be present in an organism, interactive effects related to the mixture of these xenobiotic compounds are also of concern. However, we cannot properly assess the effects of these contaminants on the health of exposed organisms because we do not have the analytical techniques necessary to separate, detect, and identify the diverse foreign compounds and their metabolic products that may be present.

Current analytical methodology can determine only a small fraction of the pollutants present in environmental samples. Gas chromatography is routinely employed to analyze for nonpolar aliphatic and aromatic hydrocarbons, but it is not a suitable method for many polar transformation products which are nonvolatile or labile. Polar compounds can be separated by thin layer chomatography or HPLC; however, most detection and quantitation procedures for compounds separated by these methods are unsuited for environmental samples. For example, test compounds radiolabeled with ^{3}H or ^{14}C can be used in laboratory metabolic studies but radioisotopes clearly cannot be used for studying the fates of a multiplicity of contaminants in a natural environment. Compounds separated by HPLC can be quantitated by UV absorbance, but this technique is neither sufficiently sensitive nor selective for analysis of most trace-level organic compounds [13-15]. We have previously reported [15] a more promising approach to trace-level quantitation of aromatic compounds in environmental samples using HPLC with ultraviolet fluorescence detection. This method selectively screens out background interferences from the sample matrix while providing a sensitive method of quantitation.

IV. RESULTS

A. INTERCALIBRATION

1. Duwamish I. Results from our analyses of the Duwamish intertidal sediment (Duwamish I) using four extraction methods were published in Advances in Chemistry [8]; a reprint is attached.

Revised analytical results from PIs participating in the Duwamish I intercalibration appear in Tables 1 and 2. Our published data [8] plus the unshaded portions of Tables 1 and 2 constitute the data base utilized by statistician Ron Gowan in his evaluation. His report appears in its entirety as the Appendix, which should be consulted for further details; NAF's reference data appears there under "Lab K." Because some laboratories did not analyze for all compounds requested, not all data submitted by others could be utilized (e.g., shaded portions of Tables 1 and 2). Table 3 identifies those PI's and laboratories whose trimmed data were included in the statistical evaluation (Appendix). NAF (Lab K) data used in our visual comparisons with data from other PIs appear in Tables 4 and 5.

Duwamish II. A second and finer grained Interim Reference Material has been prepared from a mid-channel sediment from the Duwamish Waterway in Seattle. This IRM has been designated as Duwamish II sediment. Analytical results for aromatic hydrocarbons found in the Duwamish II sediment by NAF and eight collaborating laboratories are summarized in Figure 1.

Table 1. Mean concentrations of arenes (ng/g, dry wt) found in Interim Reference Material: Duwamish I intertidal Sediment. Method: 1=Soxhlet; 2=Sonication; 3=Shaker/tumbler; 4=Reflux. Solvent: b=benzene; c=chloroform; d=dichlomethane; h=hexane; m=methanol t=toluene. Shaded area denotes data not included in statistical evaluation (see Appendix). Double hyphen (--) denotes no data submitted.

Laboratory, set :	A	B	C	D1	D2	E	F	G	H1	H2	H3	I	J1	J2	J3	L
method, solvent :	1bm	1bm	1tm	1t	2c	2dm	1hm	1tm	3dm	4m	4dm	1tm	1tm	1bm	3dm	3d
No. of Anal. (n):	3	5	3	3	3	4	3	3	5	3	3	4	3	3	3	2
Arene	Concentration, ng/g dry wt															
fluorene	--	--	25	--	--	--	38	48	36	39	200	330	--	--	--	33
dibenzothiophene	--	22	240	14	13	--	--	--	25	26	130	460	7	15	5	32
phenanthrene	410	--	480	--	--	360	740	460	430	240	2,200	840	350	400	250	420
anthracene	71	--	32	--	--	80	--	120	96	65	520	160	--	--	--	98
1-methylphenanthrene	110	200	130*	--	--	--	--	135	77	60	330	64	16	59	25	190
fluoranthene	670	--	750	1,000	1,300	750	1,100	810	750	450	3,300	960	520	680	380	800
pyrene	570	160	740	630	770	610	1,100	680	690	410	2,600	1,000	560	620	460	890
benz[a]anthracene	280	--	1,800	610	1,100	330	--	770	64	49	98	220	19	180	150	390
chrysene	450	250	600	810	800	400	720	530	330	260	540	230	8	160	110	190
benzo[e]pyrene	360*	--	430	--	--	240	--	280	61	56	230	130	10	70	88	180
benzo[a]pyrene	450	--	25	--	--	310	--	300	190	190	680	170	0	--	47	200
perylene	100	--	130	--	--	85	520	74	22	23	82	60	0	--	4	70

*Statistical estimate for value not reported

Table 2. Mean concentrations of alkanes (ng/g, dry wt) found in Interim Reference Material: Duwamish I intertidal sediment. Methods: 1=Soxhlet; 2=Sonication; 3=Shaker/tumbler; 4=Reflux. Solvents: b=benzene, c=chloroform d=dichloromethane; h=hexane; m=methanol; t=toluene. Shaded area denotes data not included in statistical evaluation (see Appendix). Double hyphen (--) denotes no data submitted.

Laboratory, set:	A	B	C	D1	D2	E	F	G	H1	H2	H3	I	J1	J2	J3	L
Method, solvent:	1bm	1bm	1tm	1t	2c	2dm	1hm	1tm	3dm	4m	4dm	1tm	1tm	1bm	3dm	3d
No. of Anal.(n):	3	5	3	3	3	1	3	3	5	3	3	5	3	3	3	2
Alkane	Concentration, ng/g dry wt															
n-C_{14}	5	0	5	16	6	[illegible]	44	10	8	--	8	12	4	5	5	11
n-C_{15}	18	5	10	13	10	[illegible]	32	20	16	55	18	34	18	15	13	42
n-C_{16}	29	24	16	42	16	[illegible]	38	31	23	56	33	38	30	26	25	31
n-C_{17}	50	35	20	39	24	42	64	48	37	92	54	65	47	44	41	64
pristane	70	51	28	51	29	[illegible]	105	56	56	99	71	80	60	51	42	69
n-C_{18}	59	53	29	40	24	40	71	56	41	91	61	50	52	51	45	81
phytane	59	51	25	39	20	--	81	46	46	89	58	58	54	42	34	68
n-C_{19}	78	73	37	--	--	60	170	72	47	92	64	36	77	65	56	70
n-C_{20}	60	110	34	65	21	10	120	59	46	66	63	26	59	54	48	84
n-C_{21}	52	36	27	--	--	--	84	60	53	68	66	30	45	44	39	69
n-C_{22}	64	49	32	55	19	--	135	83	32	57	50	24	51	47	36	39
n-C_{23}	81	48	49	--	--	--	160	130	40	75	54	21	48	55	45	43

Table 2, cont'd.

n-C_{24}	77	52	35	70	20	--	150	89	41	78	64	17	52	61	50	53
n-C_{25}	120	96	65	--	--	--	180	100	52	88	77	17	75	79	81	54
n-C_{26}	160	83	86	120	48	--	170	76	57	100	65	14	40	60	47	59
n-C_{27}	220	57*	53	--	--	--	220	120	41	72	85	12	24	41	45	60
n-C_{28}	240	310	120	240	96	--	270	120	97	100	69	16	38	52	54	100
n-C_{29}	310	48*	52	--	--	--	110	130	90	120	90	14	15	37	47	68
n-C_{30}	--	410	36	--	--	--	270	100	91	120	76	[illegible]	[illegible]	[illegible]	[illegible]	27
n-C_{31}	--	--	32	230	100	--	--	180	40	87	120	7	7	[illegible]	[illegible]	46

*Statistical estimate for value not reported.

Table 3. Collaborative laboratories and Principal Investigators whose hydrocarbon analytical data were utilizable in the statistical evaluation.

Lab A. Dr. Robert G. Riley
Battelle Northwest Lab
Environmental Chemistry LS-L2,
Rm 310, Battelle Blvd.
Richland, WA 99352

Lab B.* Dr. David Page
Department of Chemistry
Bowdoin College
Brunswick, ME 04011

Lab C. Dr. Paul Boehm
ERCO
185 Alewife Brook Pkwy
Cambridge, MA 02138

Lab F.* Dr. David Shaw
Institute of Marine Science
Univ. of Alaska
Fairbanks, AK 99701

Lab G. Dr. Ian Kaplan
Inst. of Geophysics & Planetary Physics
University of California
Los Angeles, CA 90024

Lab H. Dr. John Laseter
Center for Bio-organic Studies
Univ. of New Orleans
New Orleans, LA 70122

Lab I. Dr. Rudolph H. Bieri
Virginia Institute of Marine Science
Gloucester Point, VA 23062

Lab J.* Dr. James Payne
Science Applications, Inc.
1200 Prospect St.
La Jolla, CA 92038

Lab L. Dr. Ronald M. Atlas
Department of Biology
Univ. of Louisville
Louisville, KY 40208

* Utilizable alkane data only

Table 4. Mean concentrations of arenes (ng/g, dry wt) found by NAF in Interim Reference Material: Duwamish I intertidal sediment by two extraction methods; $\bar{x}$=mean, n=number of analyses. RSD=relative standard deviation ($100s/\bar{x}$). Shaded area denotes data not included in statistical evaluation (Appendix, Lab K).

Arene	CH_2Cl_2/CH_3OH Tumble			Soxhlet Benzene/CH_3OH	
	$\bar{x}$ (n=11)	RSD		$\bar{x}$ (n=4)	RSD
2-Methylnaphthalene	10 ng/g	[illegible]		[illegible]	[illegible]
1-Methylnaphthalene	6	[illegible]		[illegible]	[illegible]
Biphenyl	[illegible]	[illegible]		[illegible]	[illegible]
2,6-Dimethylnaphthalene	[illegible]	[illegible]		[illegible]	[illegible]
2,3,5-Trimethylnaphthalene	6	[illegible]		[illegible]	[illegible]
Fluorene	[illegible]	[illegible]		[illegible]	[illegible]
Dibenzothiophene	[illegible]	[illegible]		[illegible]	[illegible]
Phenanthrene	[illegible]	[illegible]		[illegible]	[illegible]
Anthracene	57	26		120	50
1-Methylphenanthrene	22	24		56	38
Fluoranthene	570	23		840	40
Pyrene	760	21		1100	38
Benz[*a*]anthracene	440	23		870	71
Chrysene	270	20		530	48
Benzo[*e*]pyrene	150	26		230	31
Benzo[*a*]pyrene	170	33		410	45
Perylene	36	36		97	22

Table 5. Mean concentrations of alkanes (ng/g, dry wt) found by NAF in Interim Reference Material: Duwamish I intertidal sediment by two extraction methods; $\bar{x}$=mean, n= number of analyses, RSD= relative standard deviation (100s/$\bar{x}$). Shaded area denotes data not included in statistical evaluation (Appendix, Lab K).

n-Alkane	CH_2Cl_2/CH_3OH Tumble $\bar{x}$ (n=14)	RSD		Soxhlet Benzene/CH_3OH $\bar{x}$ (n=5)	RSD
C_{13}	6 ng/g	23%		6 ng/g	14%
C_{14}	11	25		11	15
C_{15}	18	19		18	16
C_{16}	23	26		23	16
C_{17}	36	16		29	24
Pristane*	51	18		40	42
C_{18}	44	15		39	17
Phytane*	39	16		33	29
C_{19}	54	15		41	33
C_{20}	40	14		38	20
C_{21}	28	24		39	15
C_{22}	29	14		30	15
C_{23}	39	15		34	12
C_{24}	36	15		35	13
C_{25}	52	15		44	8
C_{26}	43	23		47	15
C_{27}	51	32		62	23
C_{28}	54	33		110	15
C_{29}	72	30		100	17
C_{30}	[illegible]	[illegible]		[illegible]	[illegible]
C_{31}	[illegible]	[illegible]		[illegible]	[illegible]

* A branched alkane

B. METABOLITE RESEARCH

Progress continued in developing efficient and reproducible analytical methods for traces of polar petroleum-related organic compounds from marine environmental samples. We have achieved initial success in developing a non-radiometric analytical method for identifying and measuring trace levels of a PAH such as naphthalene, 2,6-dimethylnaphthalene (DMN) or benzo[a]pyrene (BaP) and the respective metabolites in fish. The method employs UVF detection in conjuction with HPLC separation.

We have extended this method to the determination of metabolites from two PAHs, benzo[a] pyrene (BaP) and 2,6-dimethylnaphthalene (DMN), in the same sample. Both PAHs were incubated with liver microsomes of coho salmon (Oncorhynchus kisutch) to form their respective metabolites. HPLC separation and UVF quantitation enabled us to determine BaP metabolites and DMN metabolites separately or together in the same sample (see attached manuscript). This technique has potential for use in multi-PAH systems in both laboratory and field studies.

VII. DISCUSSION

A. INTERCALIBRATION

The initial intercalibration study was designed to explore the adequacy of the various analytical procedures for hydrocarbons in sediment and to compare the results statistically. The general analytical scheme for hydrocarbons in sediment involves solvent extractions, followed by chromatography to prepare the hydrocarbons for capillary GC analysis.

1. Duwamish I. Each participating laboratory was sent frozen 100-g subsamples of a homogenized intertidal sediment IRM (Duwamish I), with the request that the sediment be analyzed for a suggested list of thirty-eight aliphatic and aromatic hydrocarbons. We recommended specific analytical procedures but no particular procedure was required. Of the twelve laboratories (including NAF) that participated, nine used Soxhlet solvent extraction, four used reflux solvent extraction, two used shaker solvent extraction, two used tumbler solvent extraction, and one used ultrasonic solvent extraction. A variety of solvents were employed.

The Duwamish I intercalibration exercise was a major improvement over the previous intercalibration conducted by the National Bureau of Standards (NBS) (3). In the NBS study, few laboratories reported data for the same compounds; consequently, few intercalibration comparisons could be made between laboratories. In our Duwamish I study, most laboratories reported levels for many of the same compounds from a suggested list of thirty-eight (see Tables 1 and 2). This greatly facilitated comparisons between analytical data.

In certain instances analytical results that diverged substantially from the main body of data could be associated with specific shortcomings in analytical practices. For example, comparatively low values for the most volatile compounds (those at the top of Tables 1 and 2) could have resulted from excessive evaporation of the solvent from the extract (e.g., Table 2, Labs B,C,D). Conversely, low values for the least volatile compounds (those toward the bottom of Tables 1 and 2) could have resulted in the GC analysis step (e.g., Table 2, Labs I, J). Finally, laboratories not employing the best resolving GC columns (i.e., glass capillaries) tended to report the poorest results (e.g., Table 2, Labs D,F).

Our published hydrocarbon data [8] on the Duwamish I sediment included comparisons of the four conventional extraction procedures. These data sets were used as the reference data with which the collaborative data was compared statistically (see Appendix); NAF data appears under the designation "Lab K."

For comparison by simple inspection, we emphasized data from the two most common solvent extraction procedures: Soxhlet and mechanical agitation (tumbler). Tables 4 and 5 contain the portion of our published data [8] that was compared with the collaborative data in Tables 1 and 2 by inspection.

We observed that arene data from laboratories A,C,E,G,H_1, I and L (Table 1) compared reasonably well with our data in Table 4. Not surprisingly, laboratories using Soxhlet extraction tended to report values closer to our Soxhlet data than to our tumbler data (Table 4). [We have previously discussed our arene data according to method [8]; see attached reprint]. Similar inspection indicated that the alkane data (Table 2) of Laboratories C,G,H_1, and J compared reasonably well with ours (Table 5). Thus, only Laboratories C,G, and H_1 submitted analytical data for both arenes and alkanes that appeared to be reasonably comparable to ours by simple inspection.

2. <u>Duwamish II</u>. The recent receipt of Duwamish II arene and alkane data has not permitted an extensive evaluation of this intercalibration exercise. However, inspection of the arene data in bargraph form (Figure

1a-1e) fosters the belief that the state-of-the-art has advanced since the Duwamish I intercalibration.

Most notable is the agreement of arene data between NAF and Virginia Institute of Marine Science (VIMS). The similarity of the concentration levels and the overall distribution pattern is quite evident in comparing Figure 1a with Figure 1b, yet the sample preparation methods were quite different. VIMS analysts freeze-dried the sediment, then extracted it in Soxhlet apparatus with benzene-methanol solvent; whereas, we dewatered our sediment with methanol and extracted it with dichloromethane-methanol solvent in a tumbler. Both extracts were then analyzed on a Hewlett-Packard 5840 gas chromatograph using a capillary column. The striking similarity of the resultant arene levels cannot be ascribed to coincidence. Rather it strongly suggests that both laboratories have followed sound analytical chemical principles in their effort to analyze Duwamish II sediment for arenes.

The arene and alkane data from the Duwamish II intercalibration will be evaluated statistically, as was done for the Duwamish I intercalibration (Appendix).

B. METABOLITE RESEARCH

Several analytical techniques have been effective in determining metabolites arising from a single PAH. However, when two (or more) aromatic compounds are metabolized simultaneously, resolution of the respective metabolites in samples that contain naturally-occurring organic compounds is more difficult. The problem is further compounded with complex mixtures of xenobiotic compounds (including PAHs) in environmentally exposed organisms. In simultaneous determinations of metabolites from two PAHs, one is usually labeled with radioactive ^{14}C and the other with ^{3}H. Metabolites corresponding to the two labels are then determined by liquid scintillation counting techniques. We report here our alternative procedure for determining the PAH metabolites in a binary exposure, using the selectivity inherent in HPLC/UVF analysis; a preprint of the accepted manuscript is attached [16].

Three solutions were prepared for incubation with coho salmon liver microsomes; one contained DMN, the second contained BaP, and the third contained a mixture of the two. Metabolic products from each incubation were separated by HPLC and quantitated by UVF. UVF wavelengths for excitation (λex) and emission (λem) of each PAH and its metabolites were selected to maximize sensitivity and minimize interferences. Although the excitation and emission spectra were similar among the metabolites of a single parent compound, compromises were necessary in selecting the specific wavelengths for the analysis. For example, BaP is monitored best at λex 380 nm and λem 403 nm; however, λex 380 nm and λem 430 nm were chosen to enhance the response of the hydroxy BaP metabolites which were present in smaller quantities than BaP itself.

In separate chromatograms of DMN and BaP metabolites, we found no interferences arising from one PAH in the chromatogram of the other. That is, the DMN excitation-emission wavelength combination completely screened out the BaP metabolite HPLC peaks from the DMN chromatogram, and vice versa. [Incubation blanks, identical to the test solutions, but omitting NADPH, showed no metabolites.] Metabolites of radiolabeled

BaP (^{14}C) and DMN (^{3}H) were analyzed by the HPLC/radiometric procedure to assure that no significant metabolites escaped detection; results were comparable to those obtained by HPLC/UVF analysis.

Binary determinations by UVF succeeded for BaP and DMN metabolites because no interferences arising from either parent compound occurred in the chromatogram of the other. However, decreased specificity would be expected with complex mixtures of PAHs found in environmental samples because interference at the excitation and emission wavelengths of choice would be virtually unavoidable. Analysis for metabolites of large numbers of PAHs would require additional separation and analysis techniques.

In future work, we plan to conduct *in vivo* experiments with fish, that require the conjugated metabolites be determined. Methods are being developed for separating the conjugated metabolites from the nonconjugates to cope with the complex metabolite mixtures relevant to field studies. We are also working on a promising method for separating PAHs and their metabolites from large volumes of sample of varying matrices (e.g. serum, bile, liver homogenate), using an extractor/ concentrator instrument. This technique allows concentration of metabolites into a small volume of solvent suitable for direct injection into the HPLC instrument

Future refinement of these analytical techniques is intended to lead ultimately to experiments which will determine the xenobiotic metabolites in organisms exposed via contamination in natural environments. Only then can the interactive effects of xenobiotics on marine organisms be established.

VIII. CONCLUSIONS

A. INTERCALIBRATION

Analytical data for hydrocarbons in the Duwamish I IRM (sediment) from eleven participating OCS PI's have been evaluated by statisticians. All PI's reported data for many more individual hydrocarbons than in the previous OCSEAP intercalibration conducted by the National Bureau of Standards. Preliminary examination of Duwamish II data from eight collaborating PI's indicates further improvement since the Duwamish I intercalibration.

B. METABOLITE RESEARCH

We have developed a HPLC/UVF method that is rapid, sensitive and discriminating in determining metabolic products from selected pairs of PAHs. This technique has potential application for multiple PAH exposures in laboratory and field studies. Metabolites of several PAHs having different excitation-emission wavelength settings may now be determined by UVF in the presence of each other without interference. This could lead ultimately to a general method for the assay of xenobiotic metabolites in organisms exposed to pollutants in their natural environment.

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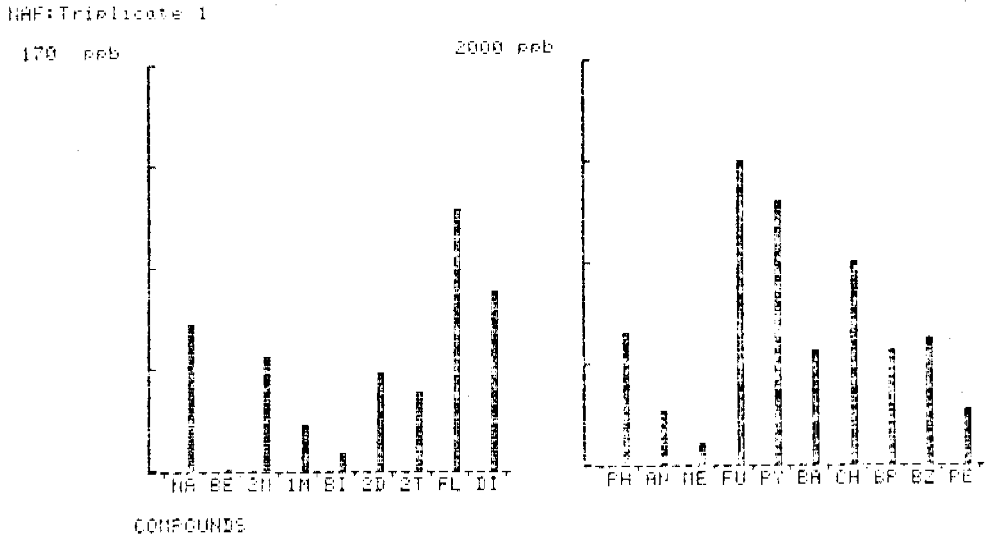
a: National Analytical Facility; Method, Tumbler.



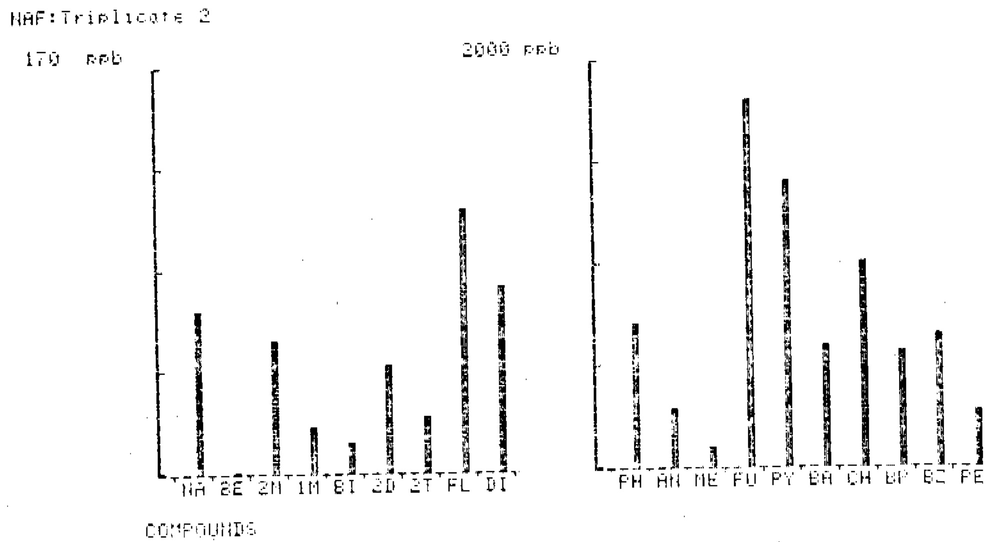
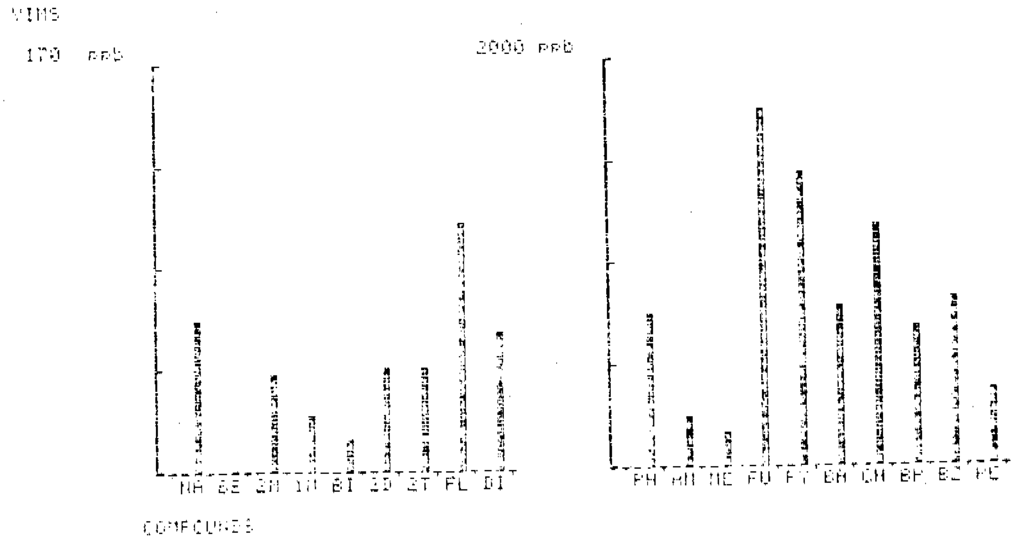
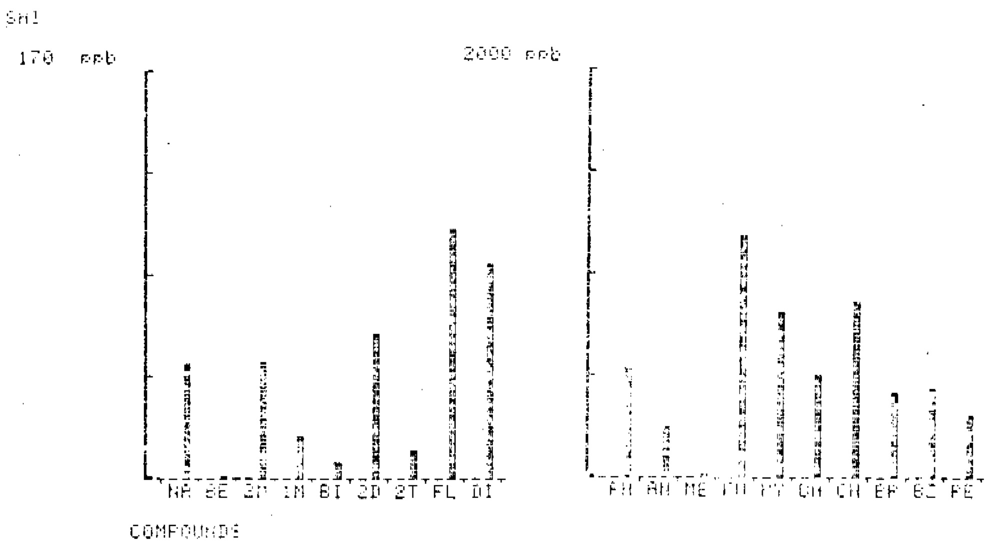


Figure 1. Dry weight concentrations of selected aromatic compounds found in Duwamish II sediment, according to laboratory (a-h). Compounds: NA=naphthalene; BE=benzothiophene; 2M=2-methylnaphthalene; 1M=1-methylnaphthalene; BI=biphenyl; 2D=2,6-dimethylnaphthalene; 2T=2,3,5-trimethylnaphthalene; FL=fluorene; DI=dibenzothiophene; PH=phenanthrene; AN=anthracene; ME=1-methylphenanthrene; FU=fluoranthrene; PY=pyrene; BA=benz(a)anthrcene; CH=chrysene; BP=benzo(e)-pyrene; BZ=benzo(e)pyrene; PE=perylene.

b: Virginia Institute of Marine Sciences ; Method, Soxhlet.



c: Science Applications, Inc. ; Method, Shaker.



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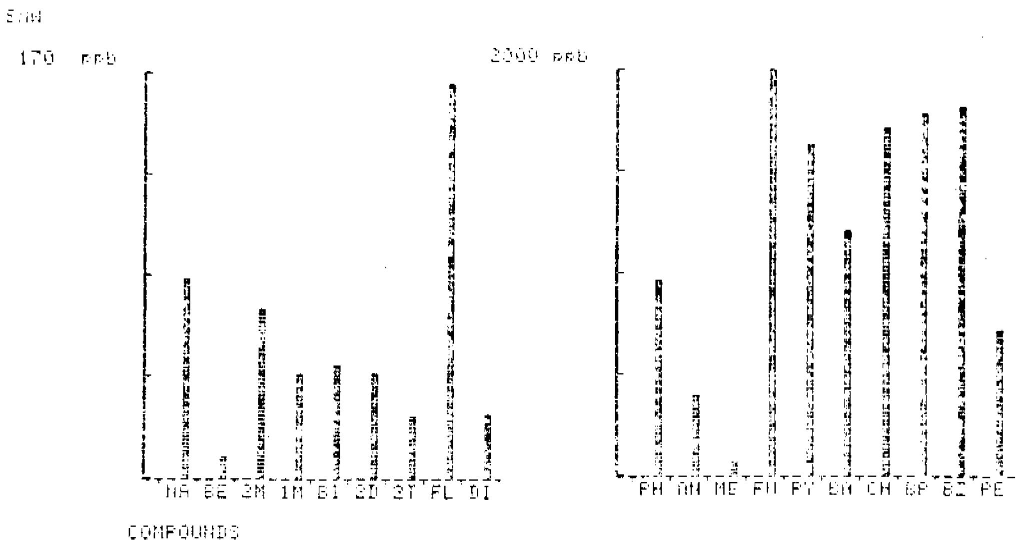
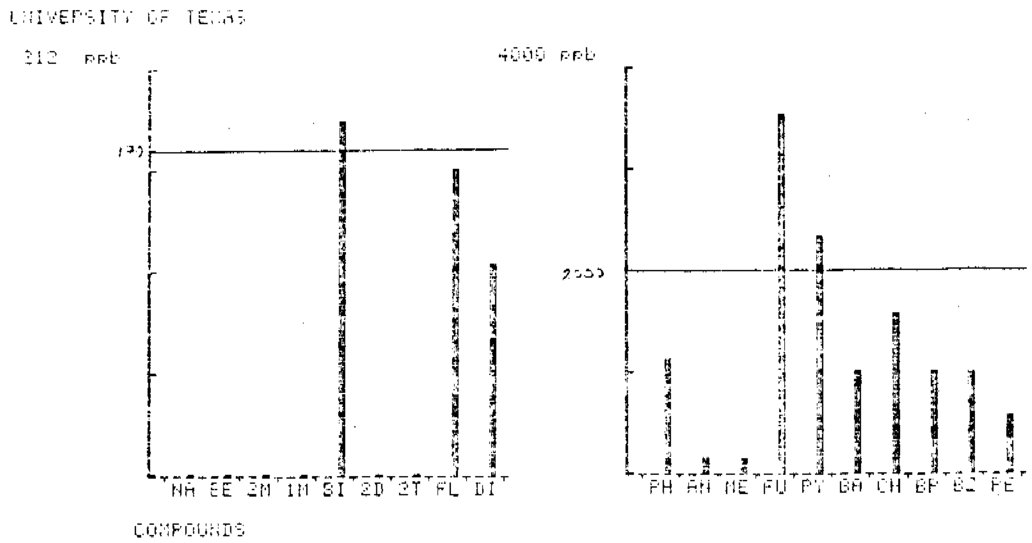
f: Battelle Northwest Laboratory; Method, Soxhlet.



g: University of Texas, Port Aransas; Method, Soxhlet.



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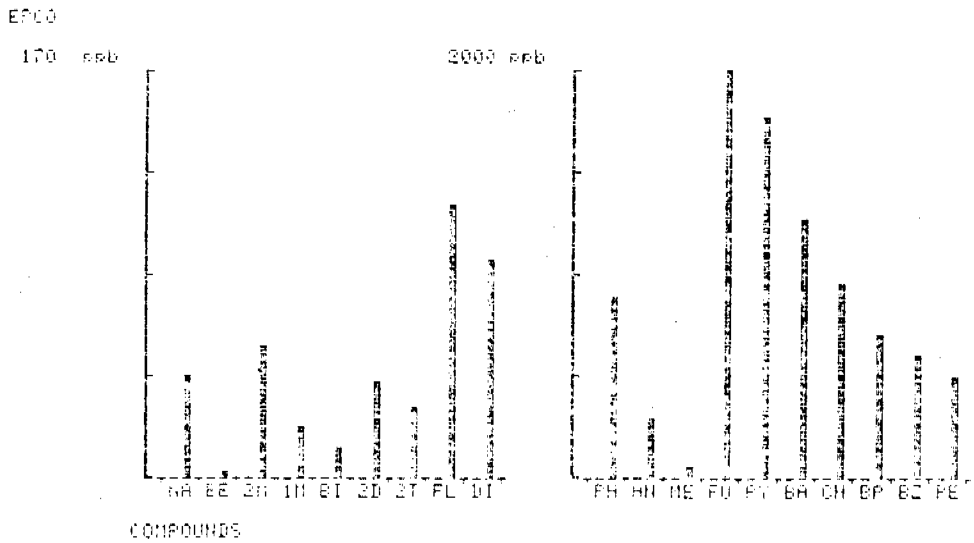
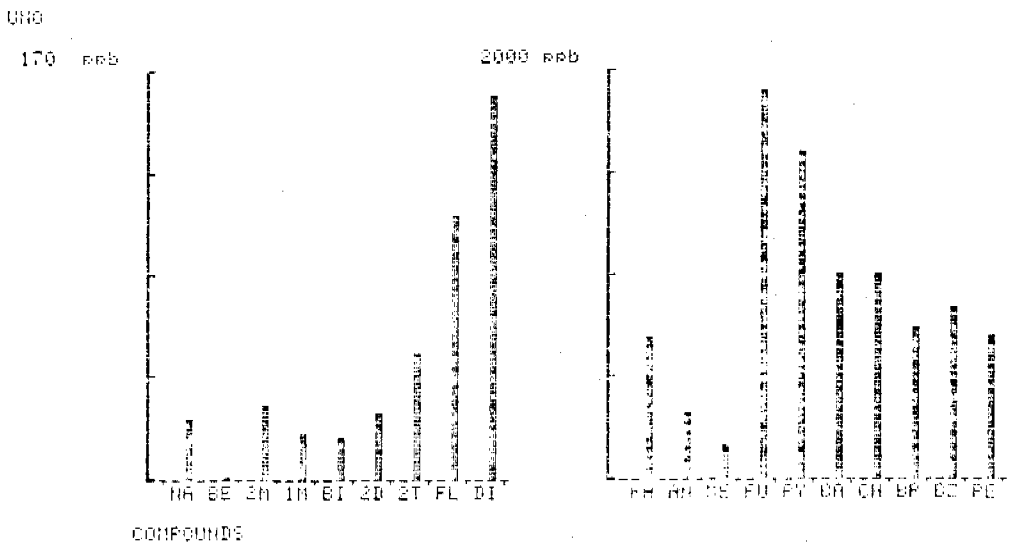
d: Energy Resources Co.; Method, Shaker.



e: University of New Orleans; Method, Shaker.



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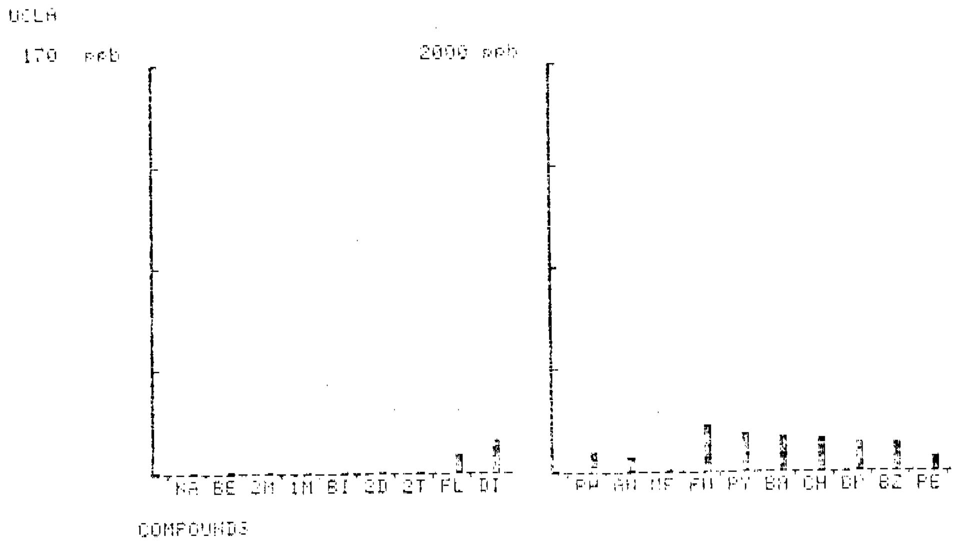
h: UCLA, Inst. of Geophys. & Planetary Physics; Method, Soxhlet.



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APPENDIX

STATISTICAL EVALUATION OF INTERLABORATORY CALIBRATION FOR HYDROCARBONS IN A DUWAMISH INTERTIDAL SEDIMENT

BY

Ron Gowan

College of Fisheries
University of Washington
Seattle, Washington 98195

PREFACE

In this statistical report, Mr. Gowan recognizes that he and his associates know of no established statistical methods by which the Duwamish I sediment hydrocarbon data can be quantitatively compared. However, he offers reasonable methods for performing qualitative comparisons between these types of data sets.

In his evaluation of randomness of results within a series of trials, he uses a qualitative measurement of how the differences between pairs of results vary according to sign (+, -), i.e., which sign predominates and how often (frequency). This is known as the "replicate effect". He also tests to see how the concentrations within a subsample vary in profile (or shape). This is known as the "series effect". In the case of the replicate effect, results of repeated analyses of subsamples are compared by a statistically valid sign-test to evaluate the null hypothesis that differences between the reported concentrations in compared subsamples do not differ significantly in predominance of sign (+,-). Rejection of this hypothesis indicates that the overall magnitudes of the reported concentrations (predominance of sign) of the subsamples compared are significantly different.

In the test of relative concentration profiles, a similar sign-test has been validly applied to results of repeated analyses to test the null hypothesis that the concentration profiles of the subsample results do not differ significantly in overall shape. Similarly, rejection indicates that their shapes are different. This test more easily rejects the null hypothesis than does the test of magnitudes.

In the third test, a statistically valid F-test for univariate analyses is extended to a multivariate problem. Results of analyses of subsamples are compared by a combined F-ratio test using the null hypothesis that results of the reference laboratory, NAF (Lab K), for a particular method, had a greater variability than the laboratory to which it was compared. Note that the F-test requires substantial differences in variances to reject the null hypothesis that the F-test is sensitive to differences in the distribution of results (e.g., gaussian vs. skewed), and that the comparisons are performed in a compound by compound manner.

Good results in the sign-test for frequency of sign predominance in differences between pairs (replicates test) is consistent with reasonably good overall reproducibility of measurements. Good results would be essential for use of tests of the mean, such as a Chi-squared test. Poor results may be caused by quantitation errors such as errors in dilution, loss of sample, errors in percent H_2O found, calculation errors or weighing errors.

Good results in the sign-test of relative concentration profiles (series test or runs test) are also consistent with good reproducibility of the measurements; this would be required before considering use of many common statistical methods. Poor results here may be due to systematic errors such as variations in extraction procedures which result in differences in dissolution of different compounds or errors in chromatographic separations.

Good results for the F-test indicate that the overall precision of the data sets is similar to or better than that for the reference set. This test portrays similarities of variances for the respective component compounds. Poor results indicate that overall precisions of measurement differ greatly.

All three tests provide information about the quality of the data sets; information regarding accuracy is not tested. Good results on all three tests would indicate that the concentration profiles of the compared data sets are consistent within the sets and that the precisions of measurement for the component compounds were similar. If this were so, appropriate mathematical calculations might then be used to relate the data sets.

The statistical procedures applied herein indicate that common statistical methods utilizing comparisons of analytical data means are not applicable to these data sets, because the data from the individual laboratories are not sufficiently reproducible. Moreover, the measurements of individual compounds are not mathematically independent of each other within a subsample, and independent comparisons of coefficients of variation among the list of hydrocarbons are not statistically sound.

The lack of good agreement among the laboratories in the sign-tests and F-test does not indicate that the overall results are unacceptable, nor does it indicate that the lack of good agreement is inexplicable. Clearly, most of the laboratories found and measured most of the compounds desired. Furthermore, most of the laboratories reported results for the individual compounds that agreed within a factor of 4. That is no trivial matter; historically, differences of orders of magnitude have not been uncommon.

The good results shown by NAF (Lab K) and others on the sign-test (replicate test) and the F-test indicate that homogeneity of the sample is not a major problem. Indeed, only one trial out of 15 for Lab K's tumble method was distinctly different than the others. The marked difference of this single set from the others could be due to a procedural error (such as a misweighing or a miscalculation), or could be due to occasional nonhomogeneity of the subsamples. In either case, acceptable data screening methods (e.g., Dixon's outlier) could be used to reject such inordinately different results.

The analyses of the data show areas where improvements may be made. For example:

1. Some methods could be discarded unless they could be shown to give acceptably reproducible results.
2. Screening methods could be employed to reject a small fraction of data sets which are markedly different from the others.
3. All labs should continue efforts to reduce uncertainties in all phases of measurement.
4. All labs should continue to reduce the possibility of selective dissolution or selective elution of one compound with respect to another.
5. For data sets which pass the sign-tests and the F-test, it might be reasonable to develop appropriate mathematical transforms to relate their results (e.g., simple constants of proportionately relating results between labs).

6. As the data quality improves, more statistical tests could be performed in order to make acceptance of agreement between data sets more demanding (e.g., Chi-squared tests or t-tests, which are not presently valid).
7. Statistical procedures should be included in the planning stages of experimental design in the future.

F-ratio tests could be performed for all the data sets, independent of method, to compare them to Lab K's tumble method. The good reproducibility and internal consistency of the NAF (Lab K) tumbler data is consistent with the use of its data as an appropriate reference set.

Minimum standards could be employed for data including: (a) rejection of the null hypothesis at α=.07 for aliphatic compounds using the sign test for predominance of sign in differences of pairs (replicates test), in fewer than 50% of the trials; and (b) rejection of the F-ratio test, for all compounds as compared to NAF's tumble method, for fewer than 25% of the aliphatic compounds. An inability to achieve these minimum criteria indicates serious problems in data quality.

Until the state-of-art improves and stabilizes, questions on data quality, rejection of the signs test for concentration profiles, and rejection of the sign-test for frequency of differences between pairs of aromatics at α=0.11, should not yet be a major concern. A continuing program noting improvements in data quality, perhaps by comparisons depicted herein, would help alleviate confusion in this complex and challenging field of chemical analysis.

Analytical Applications and Consulting
P.O. Box 881
Bellevue, WA 98009

INTRODUCTION

The objective of this statistical evaluation of intercalibration data for hydrocarbons in sediment was to determine whether the data reported from different laboratories and their methods were comparable. The problem in such an evaluation is the large number of variables in combination with small sets of replicates. Ideally, the entire data set should be used in a single evaluation, but there is no known statistical technique which can accomplish this. The small number of replicates require the use of univariate procedures to explore, in part, a multivariate problem.

The hydrocarbon data was screened by the procedure of Mandel and Lashof (1959); certain missing values had to be estimated. The data set used in the statistical evaluation was reduced to 16 aliphatic compounds measured by 10 laboratories and 10 aromatic compounds measured by 7 laboratories. The investigation was divided into two components, the aliphatic and aromatic compounds, and each component treated separately.

STATISTICAL ANALYSIS

The analysis of the hydrocarbon data is divided into two main sections. The first is the within-laboratory (intralaboratory) comparison, i.e., how well an individual laboratory repeats its measurement with respect to randomness. The evaluation of randomness can be divided into two measurements: a "replicate effect" which is a measure of an overall difference; and a series effect which is a measure of the distribution of the replicates.

The procedure used to make the series effect comparison is the Wilcoxin sign test. This sign test is a distribution-free procedure, which means that it is not necessary to assume that the samples are drawn from a normal distribution. The procedure is a univariate procedure extended to a multi-variate problem. The extension is not completely satisfactory, but it provides a technique to identify differences between two sets of data at a prespecified level. An example illustrating the method is shown below.

Laboratory F (Soxhlet-Methanol, Hexane), Replicate #1 vs #2

	#1 - #2	Δ		#1 - #2	Δ
C_{16}	31 - 49	<0	C_{22}	67 - 100	<0
C_{17}	43 - 95	<0	C_{23}	130 - 160	<0
Pri	69 - 160	<0	24	120 - 140	<0
C_{18}	51 - 80	<0	25	240 - 110	>0
Phy	58 - 120	<0	26	170 - 130	>0
c_{19}	120 - 210	<0	27	160 - 220	<0
C_{20}	100 - 140	<0	28	210 - 260	<0
C_{21}	54 - 100	<0	29	59 - 100	<0

Total comparisons, 16. Replicate #1 is lower in 14 of 16 comparisons.

If the differences between the two replicates were due soley to random sampling error then no particular replicate would be consistently higher or lower. If the two distributions are similar then it is expected that, for a given hydrocarbon pair, the probability of replicate #1 being higher is 0.5 and the probability of it being lower is also 0.5. The null hypothesis in this example is that respective values for replicate #1 exceed those for replicate #2 in half of the entries. If replicate #1 is greater in most of the comparisons (or conversely, less in most of the comparisons), then it is likely that differences between the data sets are significant. The rejection region for the null hypothesis can be found by computing the probability associated with each result. In this example there are 16 pairs. We desired to detect significant differences 90 to 95% of the time when the null hypothesis is not true. The least likely outcome is that replicate #1 is always less or always greater. The probability of that occurring is found by using the probability distribution of the binomial random variable:

$$\alpha = p(o) + p(16) = C_0^{16}(.5)^{16} + C_{16}^{16}(.5)^{16} =$$

$$.00003$$

$$\alpha = p(o) + p(1) + p(15) + p(16) =$$

$$C_0^{16}(.5)^{16} + C_1^{16}(.5)^{16} + C_{15}^{16}(.5)^{16} + C^{16}_{16}(.5)^{16}$$

again by the binomial expansion

$$= .000510$$

$\alpha = p(o) + p(1) + p(2) + p(14) + p(15) = p(16)$

$= C_o{}^{16}(.5)^{16} = C_1{}^{16}(.5)^{16} + C_2{}^{16}(.5)^{16} + C_{14}{}^{16}(.5)^{16} + C_{15}{}^{16}(.5)^{16} + C_{16}{}^{16}(.5)^{16}$

$= .004172$

adding additional terms

$\alpha = p(o) + p(1) + p(2) + p(3) + p(13) + p(14) + p(15) + p(16)$

$= C_o{}^{16}(.5)^{16} + C_1{}^{16}(.5)^{16} + C_2{}^{16}(.5)^{16} + C_3{}^{16}(.5)^{16} + C_{13}{}^{16}(.5)^{16} + C_{14}{}^{16}\ (.5)^{16} +$

$C_{15}{}^{16}(.5)^{16} + C_{16}{}^{16}(.5)^{16}$

$= .020972$

$\alpha = p(o)+p(2)+p(3)+p(4)+p(12)+p(13)+p(14)+p(15)+p(16)$

again by the same expression.

$= .075572$

If the null hypothesis holds, then the probability that in 16 comparisons replicate #1 will be less than replicate #2 fewer than 4 times or greater more than 12 times is .08. In the example, replicate #1 is less than replicate #2 in 14 comparisons and the null hypotheses of equal distributions is therefore rejected. Rejection of the null hypotheses implies that the two population distributions are different. In this study this test is used to compare replicates and methods on the basis of a qualitative difference; it is not a test of the absolute difference in mean or expected values.

The second comparison is the use of an F-ratio test to determine consistency within a laboratory according to a given analytical method. The F-ratio test is a univariate procedure which is applied here to a multivariate problem. This application is not entirely satisfactory, but it may be used for approximate comparisons, as follows. If, in the case of the hydrocarbons, we consider that we are drawing 16 independent samples at a rejection level, α, of .05, then it is expected through chance that $.8 \approx 1$ would be significantly different. If more than one comparison is significant, then it is likely in a one-tailed test that there is a significant difference in the variability of the results of the laboratories. For the variance comparison, NAF (laboratory K) was selected as the reference laboratory, and all other laboratories were compared with it. The working hypothesis was:

Ho: Lab K (method) had greater variability than Lab i (method).

Ha: Lab K (method) had less variability than Lab i (method).

DISCUSSION OF COMPARISONS

Sign test for replicate effect

Aliphatic compounds were compared within laboratory by method for existence of an effect due to repeated measurements. Four laboratories using different methods had no replicate effect identified. One laboratory with 5 replicates (10 comparisons) had one significant replicate effect which may be due to random error. The remaining laboratory methods had significant replicate effects in more than 30% of the comparisons.

Hypotheses tested:

Ho: There is no difference in the distribution from which the samples are drawn.

Ha: Samples are drawn from different distributions.

The stated rejection region of .07 implies that the number of expected significant results from the comparisons would be ca.8. For aliphatic compounds, 33 comparisons were significant which implies that repeated measurements have some positive (or negative) tendency due to repeated runs. Failure to reject the null hypotheses does not *necessarily* imply that the differences between the replicates are random. Table 1 summarizes the results.

All replicate comparisons for aliphatics showed a series effect (runs test). A series effect is one where the differences appear in a non-random order. If differences were random, then the occurrence of plusses or minuses in the comparison should occur in a random order. For example, in 16 comparisons, if there are 8 consecutive plusses

Table 1. Results of sign test comparison for replicate effect in aliphatic compounds.

Lab	Method	# of replicates	# of comparisons	# significant
A	Soxhlet (MeOH, Benzene)	3	3	2
B	" " "	5	10	5
C	Soxhlet (MeOH, Toluene)	3	3	1
F	Soxhlet (MeOH, Hexane)	3	3	2
G	Soxhlet (Methanol, Toluene)	3	3	0
H	Shaker (MeOH, $MeCl_2$)	5	10	3
H	Reflux (MeOH)	3	3	2
H	Reflux (MeOH, $MeCl_2$)	3	3	2
I	Soxhlet (MeOH, Toluene)	5	10	1
J	" " "	3	3	2
J	Soxhlet (MeOH, Benzene)	3	3	0
J	Shaker (MeOH, $CHCl_3$)	3	3	0
K	Tumble (MeOH, $MeCl_2$)	5	10	2
K	Tumble (MeOH, $MeCl_2$)	5	10	0
K	" " "	4	6	2
K	Reflux (MeOH, KOH)	5	10	2
K	Soxhlet (MeOH, Benzene)	5	10	4
K	Soxhlet (MeOH, $MeCl_2$)	4	6	2
L	Unknown	2	1	1
TOTAL			110	33

$\alpha = .07$

followed by 8 consecutive minuses, it is reasonably certain that these differences are not random. The non-random order observed may be due to a compound replicate interaction. The interaction would occur if the concentrations of compounds are not independent of each other (which is likely), or if the way one compound in a replicate is prepared for analysis affects the other compounds. This interaction could be demonstrated by profile analysis, but, as previously stated, the multivariate techniques do strictly apply. If this interaction effect occurs, the coefficient of variation for compounds between replicates must be biased, and the low value of the cv in a series is simply the point at which the interaction effect is equal or is of minimum effect. The cv in a series is not necessarily a measure of the precision of measurement.

Aromatic compounds were compared within laboratories according to extraction method in the same manner as with the aliphatic compounds. The computed α was .11 which meant that .11 x 69 $\simeq$ 8 comparisons would be significant by random chance. Of 69 comparisons, 59 showed a significant replicate effect; in the remaining comparisons, a series (runs) effect was evident. Table 2 summarizes the results of the sign test for aromatic compounds. It is interesting to note that as the replicate effect increases, the coefficient of variation becomes more constant, which again implies the existence of an interaction effect.

Ratio test for comparing equality of variance

The F-ratio test is a parametric procedure used to test hypotheses that samples are drawn from populations with equal variances. This is also a univariate procedure applied to approximate the solution to a multivariate problem. Proceeding, if n comparisons are made at a prespecified level, the number of significant comparisons due to randomness would be $\alpha \cdot n$. In this analysis a one-tailed test was used to test the hypotheses that for a particular method:

Ho: σ^2 lab$_k \geq \sigma^2$lab n

Ha: σ^2 lab$_k \leq \sigma^2$lab n

In the study comparison α=.05 (1)

NAF (Lab K) was selected as the reference laboratory and all other laboratories were tested against it according to analytical method. Table 3 illustrates a computational example of an F-ratio test.

Aliphatic Compounds. The tumble procedure (Table 4) was used by Lab K in three trials of 5 replicates. The first set (K1) had variances significantly lower in over 70% of the comparisons of aliphatic hydrocarbon data. The Soxhlet method (Table 5) was compared between labs using benzene/methanol solvents. Table 6 illustrates the variance comparisons of the Soxhlet method, independent of solvents. In these comparisons, the null hypothesis was rejected seven times for Lab A and six times for Lab B. The variances of sampling results of Laboratories C, I and J appear to be equal to, or lower than the K1 results. Other comparisons of laboratory results showed rejections from 5 to 16 times. No significant differences were shown between the two labs using the shaker method (Table 7). Reflux comparisons with Lab K showed rejections 9 of 16 times for the two sets of results from Lab H compared to Lab K (Table 8).

Aromatic Compounds. The aromatic results from Lab K1 were compared to those of all other laboratories, using the null hypotheses that Lab $K\sigma^2 \geq$ Lab i σ^2 The null hypothesis with Lab K as a reference was not rejected in any comparison of the Soxhlet method (Table 9). The tumble method used by Lab K in three runs (Table 10) gave consistent results (only 2 significant differences in 20 comparisons). The results from the reflux method (Table 11) used by three laboratories showed significant differences in all F-test comparisons when compared to Lab K.

COMMENTS AND SUGGESTIONS

1. The assumption has been made that the sample from which the subsamples were drawn is homogeneous. To test the validity of that assumption would require 17 replicates within one laboratory by method in the case of the aliphatic compounds.
2. If multivariate analysis of variance is to be performed, at least p-1 replicates have to be performed for each hydrocarbon. The expense of performing so many replicates does not appear to be justified for the sole purpose of performing a particular statistical test. However, if a single laboratory could perform several replicates for given method, the homogeneity question could be addressed.
3. One method (Soxhlet) gives differing results depending on the solvent used. If the objective is uniformity, the solvent should be specified.
4. Discussion with Mr. D.W. Brown has led me to believe that there is considerable latitude in procedures used by the various laboratories. The originating lab should require that a specific procedure be followed as exactly as possible.

5. Different methods appear to give a different pattern of results over the range compounds reported. Within a particular method, if standardized procedures are used, pattern analysis might then be used to estimate correction factors between methods.
6. Each laboratory should screen its data. One laboratory presented replicates which differed by an order of magnitude. A straightforward Wilcoxian test could be used to screen out this sort of data. The probability distribution for the test can be derived from a binomial expansion.

It is assumed that consistency of results is the primary object of the analyses. Mere specification of a lab or their replicate data as a reference does not imply that the reference values are true or correct; it is simply a convenience in determining whether the labs and their methods are comparable in their results.

SUMMARY

There is no known statistical technique which can utilize all of the hydrocarbon data generated in this intercalibration study in a single, multivariate procedure. The limiting factor is the small number of replicates within each cell. Mandel (1959) described a procedure for intra-laboratory comparison, but it does not apply to this experiment. Application of Mandel's model requires the assumption that compounds are independent (which cannot be made). The use of different solvents within the methods further confounds the problem. The sign test used in the analysis is a procedure intended to show qualitative differences in paired comparisons. Comparison of replicates indicate that measurements within the same sample are not independent of each other.

Significant series effects are also an indication that something in the measurement process is not consistent from replicate to replicate.

Overall, within a method the F-ratio test provides a reasonable estimate of the equality of the measurement process by the laboratories. To some degree this procedure is independent of the homogeneity issue, and it allows an evaluation of the equivalency of the measurements. It is not appropriate to analyze the results between laboratories independent of method; rather, laboratories should be compared on the basis of similar methods. With the limited number of replicates it is not possible to separate the two components of the error. The first error component is due to the measuring process; the second component is the variation associated with the material itself.

The analysis presented provides a comparison of how well the laboratories repeat (replicate) their measurements and whether they measure with the same error. The F-ratio analysis used was a one-tailed procedure with the null hypothesis that variability by method was greater in Lab K than for the Lab being compared to Lab K. A two-tailed hypothesis could have been as easily applied. The sign test used in the evaluation of differences between replicates can also be used to test for the equality of variance.

REFERENCE

J. Mandel and T.W. Lashof, "The Interlaboratory Evaluation of Testing Methods," Bull No. 239, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. (July 1959).

Table 2. Results of sign test comparisons for replicate effect in Aromatics

Lab	Method	# of replicates	# of comparisons	# significant
A	Soxhlet Methanol, Benzene	3	3	3
C	Soxhlet Methanol, Toluene	3	3	2
G	Soxhlet Methanol, Toluene	3	3	2
H	Shaker, Methanol, Methylene Chloride	5	10	9
H	Reflux, Methanol	3	3	2
H	Reflux, Methanol, Methylene Chloride	3	3	2
I	Soxhlet Methanol Toluene	4	6	5
K	Tumble, Methanol Methylene Chloride	3	3	3
K	Tumble, Methanol Methylene Chloride	4	6	6
K	Tumble, Methanol Methylene Chloride	5	10	8
K	Reflux Methanol, KOH	4	6	4
K	Soxhlet Methanol, Benzene	4	6	4
K	Soxhlet Methanol, Benzene	4	6	5
L	Unk	2	1	1
Total			69	56

$\alpha = .11$

Table 3. Computational example of an F ratio test for differences in variance estimates

	Lab B Method: Soxhlet Solvent: Methanol, Benzene		Lab K Method: Soxhlet Solvent: Methanol, Benzene
	σ_1^2 n=4	F ratio σ_1^2/σ_2^2	σ_2^2 n=5
C_{16}	35.16	3.41	10.30
C_{17}	67.24	1.38	48.72
Pri	122.77	.43	284.93
C_{18}	389.27	6.42*	60.68
Phy	229.22	2.68	85.56
C_{19}	438.06	2.33	187.69
C_{20}	4658.06	74.83*	62.25
C_{21}	370.18	12.70*	29.16
C_{22}	446.05	21.08*	21.16
C_{23}	63.36	3.52	17.98
C_{24}	62.25	2.56	24.31
C_{25}	344.47	22.20*	15.52
C_{26}	441.84	8.62*	51.27
C_{27}	32.49	.17	197.40
C_{28}	8584.02	35.87*	239.32
C_{29}	32.49	.11	298.60

* = significant at $\alpha(1)$ 4,4 .05

Ho $\alpha_{2i}^2 \geq \alpha_{1i}^2$ Where $i = C_1 \ldots . C_n$

$F = \alpha_{1i}^2/\alpha_{2i}^2$

α (1) 4,4 .05 = 6.39

Table 4. Tumble method for lab K compared against three runs. Laboratories K2 and K3 compared to K1.

Compound	Replicates K2 n=5 α^2	K3 n=5 α^2	K1 n= 5 α^2
C_{14}	3.80	9.18*	.79
C_{15}	6.30	27.67*	3.20
C_{16}	7.29	227.41*	4.00
C_{17}	3.80	2409.83*	8.82
Pri	174.50*	5721.41*	1.69
C_{18}	25.50	6332.98*	21.34
Phy	105.27*	7291.45*	1.21
C_{19}	60.53*	11257.21*	2.69
C_{20}	14.21	7106.49*	8.29
C_{21}	29.27*	3247.86*	.71
C_{22}	4.00	4548.15*	3.31
C_{23}	2.31	1181.98*	4.00
C_{24}	1.21	1332.98*	12.67
C_{25}	8.70	1688.39*	9.18
C_{26}	117.72*	898.80*	12.53
C_{27}	157.75	1129.63*	109.41
C_{28}	88.74	1367.52*	19.98
C_{29}	488.41*	1735.56*	13.76
C_{30}	166.74*	1639.44*	12.32
C_{31}	7.29	5843.07*	15.29

$\alpha^{.05}_{4,4}(1) = 6.39$

K2 compared to K1, 7 significantly greater

K3 compared to K1, 20 (all) significantly greater

* denotes signficantly greater variance

Table 5. F-ratio comparisons of Soxhlet; Methanol, Benzene, with Lab K1 as a reference.

Compound	Laboratory A n=3	Laboratory B n=5	Laboratory K1 n=5	Laboratory K2 n=4
C_{16}	6.35	35.16	10.30	21.62
C_{17}	8.35	67.24	48.72	17.98
Pri	24.30	122.77	284.93	33.64
C_{18}	26.32	389.27	60.68	50.69
Phy	11.97	229.22	85.56	21.62
C_{19}	13.03	438.06	187.69	4.24
C_{20}	22.37	4658.06*	62.25	1.99
C_{21}	10.30	370.18*	29.16	2.25
C_{22}	124.10	446.05*	21.16	3.65
C_{23}	57.00	63.36	17.98	64.32
C_{24}	226.20*	62.25	24.30	92.35
C_{25}	996.03*	344.47*	15.52	1431.11*
C_{26}	694.32*	441.84*	51.27	1105.56*
C_{27}	1542.13*	32.49	197.40	8832.24*
C_{28}	9240.98*	8584.02*	239.32	9974.02*
C_{29}	12923.40*	32.49	298.60	5115.11*
No. significant	6	6	Reference	5

F.05 (1), 2,4 = 6.94
F.05(1), 3,4 = 6.59
F.05 (1) 4,4 = 6.39

* denotes significantly greater variance

Table 6. Soxhlet method over F-ratio comparisons for aliphatic compounds compared to Lab K1.

Lab Compound	A n=3	B n=5	C n=3	F n=3	G n=3	I n=5	J1 n=3	K1 n=5	K2 n=4
C_{16}	6.35	35.16	63.04	97.42	56.40	55.65	36.97	10.30	21.62
C_{17}	8.35	67.24	37.33	750.56	84.09	156.50	41.34	48.72	17.98
PRI	24.30	122.27	91.01	2340.62	108.99	243.98	49.28	284.93	33.64
C_{18}	26.32	389.27	44.36	652.29	61.00	129.05	44.36	60.68	50.69
PHY	11.97	229.22	38.94	1137.04	22.37	150.55	34.34	85.56	21.62
C_{19}	13.03	438.06	56.40	2100.39	110.25	82.26	27.98	187.69	4.24
C_{20}	22.37	4658.06	49.28	433.47	72.93	23.52	12.32	62.25	1.99
C_{21}	10.30	370.18	12.32	676.00	381.03	40.70	26.32	29.16	2.25
C_{22}	124.10	446.05	1.00	8436.42	2586.74	33.52	108.99	21.16	3.65
C_{23}	57.00	63.36	46.38	633.53	12336.54	22.47	36.36	17.98	64.32
C_{24}	226.20	62.25	13.03	933.30	3408.22	11.22	27.04	24.30	92.35
C_{25}	996.03	344.47	210.25	4232.80	2027.70	19.27	66.26	15.52	1431.11
C_{26}	694.32	441.84	258.89	1600.00	1483.02	13.32	63.04	51.27	1105.56
C_{27}	1542.13	32.49	316.48	4232.80	2032.21	23.72	26.32	197.40	8832.21
C_{28}	9240.98	8584.02	43.03	3633.68	1807.10	79.92	121.44	239.32	9974.02
C_{29}	12923.40	32.49	50.27	2580.64	3424.59	37.70	38.94	298.60	5115.11
# sig.	7	6	1	16	8	0	0	Reference Lab	5

Table 7. F-ratio comparison of Shaker Methods with Lab J as reference

	Lab H n=3	Lab J n=3
C_{16}	2.99	13.03
C_{17}	21.72	91.01
PRI	8.53	1.00
C_{18}	4.28	48.02
PHY	7.29	10.30
C_{19}	4.20	26.32
C_{20}	4.71	6.35
C_{21}	5.20	2.99
C_{22}	34.34	20.34
C_{23}	87.42	30.34
C_{24}	215.21	36.00
C_{25}	219.63	100.40
C_{26}	183.60	79.03
C_{27}	113.42	225.30
C_{28}	105.27	225.30
C_{29}	15.21	336.36

$\alpha^{.05}_{2,2}$ (1) = 19.00

Table 8. F-ratio comparison of reflux methods Lab K as reference.

	Lab H1 n=3	Lab H2 n=3	Lab K n=5
C_{16}	12.32	64.64*	4.71
C_{17}	202.21*	51.98*	4.28
PRI	75.00*	148.11*	9.80
C_{18}	129.28*	91.01*	7.51
PHY	1.00	46.38*	4.71
C_{19}	50.27*	76.04*	2.69
C_{20}	26.32	41.34	8.70
C_{21}	93.51	32.38	16.81
C_{22}	151.04*	66.26*	2.99
C_{23}	305.20*	50.27*	3.31
C_{24}	320.41*	43.03*	2.31
C_{25}	297.22*	8.35	13.32
C_{26}	297.22*	158.26*	14.29
C_{27}	102.41	97.42	77.26
C_{28}	74.30	142.32	26.52
C_{29}	124.10	38.94	21.58
No. significant	9	9	

$\alpha^{.05}_{2,4}$ (1) =6.94

* denotes significantly greater variance

Table 9. F-ratio test aromatic compounds, laboratories using soxhlet method compared to Laboratory K1

	Laboratory K n=3	Laboratory C n=3	Laboratory G n=3	Laboratory I n=4
PHN	33182.27*	12678.76	41538.32	69253.19
ANT	243.98*	1.00	3871.33	2038.52
MPH	2408.85*	571.21	4236.71	306.25
FLA	75559.01*	13030.22	15269.54	62915.675
PYR	44175.63*	32346.02	4107.53	1015.06
BAA	3011.81*	425104.00	432.22	881.50
CHK	16207.84*	40433.17	16.32	1002.36
BEP	10658.50*	13616.56	702.78	916.88
BAP	1672.64*	60.37	1486.10	293.78
PER	1346.16*	530.38	76.04	

	Methanol Benzene Laboratory K1 n=5	Methanol Benzene Laboratory K3 n=4
PHN	71508.11	30123.07
ANT	3504.64	1032.98
MPH	430.98	244.30
FLA	110699.33	53024.27
PYR	180565.50	64221.70
BRA	379838.02	36722.06
CHK	65982.20	12210.25
BEP	5443.49	13391.12
BAP	34162.13	16646.16
PER	434.72	10976.75

α (1).05 2,4 = 6.94
α (1).05 3,4 = 6.59
α (1).05 2,2 19.00

* denotes significantly greater variance

Table 10. F-ratio test of Aromatic compounds by laboratories using the tumble method.

	Lab K1 n=3	Lab K2 n=4	Lab K3 n=5
PHN	11058.63	4611.77	18873.26
ANT	257.28	202.21	828.86
MPH	12.32*	13.62*	1.21
FLA	24398.44	10710.18	29131.66
PYR	22788.92	17870.34	54494.23
BAA	19029.96	7862.37	23675.98
CHK	4987.18	2868.67	7096.38
BEP	1036.20	1348.36	4505.09
BAP	6796.35	4690.88	9078.28
PER	72.93	222.90	151.78

α (1).05 2,4= 6.94

α (1).05 3,4 = 6.59

* denotes significantly greater variance

Table 11. F-ratio test of Aromatic Compounds. Laboratories using reflux method compared to Lab K.

	Lab H2 Reflux Methanol n=3	Lab H3 Reflux Methanol Methylene chloride n=3	Lab K Reflux Methanol KOH n=4
PHN	8464.00*	1322960.04*	20.88
ANT	1637.01*	71824.00*	6.92
MPH	746.38*	22557.04*	2.25
FLA	32446.82*	2328523.40*	83.54
PYR	34856.89*	1152488.13*	170.30
BAA	470.89*	2096.72*	19.62
CHK	11295.44*	63232.13*	98.21
BEP	752.35*	13907.48*	55.35
BAP	9296.86*	82834.60*	59.60
PER	161.29*	1343.96*	7.34

$\alpha^{.05}_{2,2} = 19.00$

* denotes significantly greater variance

ANNUAL REPORT
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Archival of Voucher Specimens of Biological Materials Collected under the Outer Continental Shelf Environmental Assessment Program (OCSEAP) Support

Period of Performance: May 1, 1978 - March 31, 1981
Subsequent support subject to availability of funding.

Period Covered by This Report: April 1, 1980 - March 31, 1981

Institution: California Academy of Sciences
Golden Gate Park
San Francisco, CA 94118

Principal Investigator:

William N. Eschmeyer
Director of Research
(415) 221-5100

Collection Manager:

Scott Cutler
(415) 221-5100

Archival of Voucher Specimens of Biological Materials Collected Under OCSEAP Support

I. Summary of Objectives, Conclusions and Implications:

The baseline data collected for the fauna and flora in the OCSEAP study area is based on extensive biological collections made by many separate research units. OCSEAP has established the California Academy of Sciences as a central repository for representative specimens from these collections. This will ensure that materials are permanently available for reference and for confirmation and upgrading of identifications made by research units. This project was initiated on 1 May 1978, and the contract awarded on 24 May 1978.

A policy for the preservation and labeling of voucher specimens was formulated in the first year of the project. A subsequent revision, for phytoplankton samples, finalized the procedures.

Several thousand lots of voucher specimens from over 16 research units have been archived. More voucher specimens are expected as projects are completed.

An under-representation of preserved Alaskan fauna in most major research collections makes most of this material unique. Combined with the very high quality of the specimens and the accompanying extensive documentation, this material comprises a very important and useful collection.

II. Introduction

A. General Nature and Scope of Study:

As outlined above, a voucher specimen repository was established so that extensive biological collections made by OCSEAP would be documented with voucher samples. A rather specific voucher policy was needed such that the quality and integrity of the biological data taken would be maximized. The fauna (or parts of it) are poorly known for the area under study. Field identifications need to be made by knowledgeable people, and by reference to actual voucher or reference specimens that can be saved and forwarded to the central repository. The essential point is that the voucher specimen be of the same species as the other specimens analyzed and discarded, even if the state of systematic knowledge permits only partial identification. If the field identifications are faulty then the usefulness of the data is much reduced. Upgrading identifications and changing scientific names as nomenclature improves will, through the years, increase the usefulness of the data in the NODC.

The California Academy of Sciences has had extensive experience as a repository of voucher specimens from the scientific community and from Federal, State, and some private agencies. The Academy collections are world-wide in composition, with especially strong representation of the flora and fauna of western North America, including Alaska. The Academy was selected as the voucher specimen repository and charged with the specific tasks outlined below.

Principal investigators will deposit representative voucher specimens with the Academy. All of the data will be coded on an electronic data storage system and sent to NODC. The specimens will be maintained as a separate collection for a period of 5 years, marked distinctly, and then integrated into the main collections of the Academy.

B. Specific Objectives:

The California Academy of Sciences is responsible for:

1. Specifying preservation techniques for archival voucher specimens.

2. Coordinating the shipment of materials.

3. Establishing and maintaining a fully catalogued repository for the collections; and

4. Providing quarterly data summaries on the status and content of the collections.

C. Relevance to Problems of Petroleum Development:

Management decisions and monitoring that may be necessary to protect the OCS marine environment from damage during petroleum development are based on the accumulation of a data base. The permanent voucher specimen collection and policy, including the identification policy for field personnel, are aimed at increasing the reliability of the data collected. The voucher specimens are permanently available for reference and for confirmation and upgrading of identifications made by field personnel during the data gathering phase.

III. Current State of Knowledge:

The fauna of Alaska, while similar to that of other parts of the North Pacific, is not very well known. Identifications of certain groups of organisms are difficult because of a lack of adequate literature or prior studies. The utilization of the identification and voucher policy will increase the reliability and usefulness of the biological baseline data collected by OCSEAP.

IV. Study Area:

Voucher specimens will be received from studies conducted throughout the OCSEAP study area.

V. Sources, Methods and Rationale of Data Collection:

All specimens will be provided by the individual project principal investigators. Standard curation techniques will be used to process the incoming materials. Once each voucher specimen shipment is processed, the specimen data information will be electronically processed and transferred to NODC and the principal investigators.

VI. Results:

Eleven shipments of voucher specimens, totaling 2931 lots, were received from 8 Research Units during the period from 1 April 1980 to 31 March 1981. These were:

RU#	P.I.	Acc.#/Date Recvd.	# Lots/type	Lease Areas	Status
172	Connors	1980-V:29B	26/invertebrates, bird stomach contents	Beaufort Sea Chuckchi Sea	awaiting cataloguing
73	McCain	1980-VII:21	3/flatfish	Prince William Sound	awaiting cataloguing
194	Fay	1980-IX:26A	17/marine mammal parasites	Bering Sea	awaiting cataloguing
284	Smith	1980-IX:26B	60/invertebrates	Bering Sea	awaiting cataloguing
359	Horner	1979-X:15/ rec. 1 Oct. 1980	336/zooplankton	Bering Sea Chukchi Sea	awaiting cataloguing
5	Feder	1980-II:11/ rec. 25 Nov. 1980, 1 Dec. 1980	458/invertebrates	Gulf of Alaska	2 shipments, awaiting cataloguing
427	Alexander	1980-XII:6	710/phytoplankton	Bering Sea	awaiting cataloguing
356	Broad	1980-IX:12	1321/fish, invertebrates	Beaufort Sea Chukchi Sea	3 shipments, awaiting cataloguing
		total lots received	2931		

Cataloguing was completed on material from 7 Research Units involving 3182 lots. The Research Units completed were:

RU#	P.I.	Acc.#/Date Recvd.	# Lots/type	Lease Areas	Comments
359	Horner	1979-X:15	242/zooplankton, phytoplankton	Beaufort Sea Chukchi Sea	completion of 864 lots
6	Carey	1979-X:29	38/mollusc	Beaufort Sea	
78/79	O'Clair	1979-XII:13	316/algae, invertebrates	Gulf of Alaska Bristol Bay Pribilof Islands	
551	Hayes	1980-I:2	287/fish, invertebrates	Gulf of Alaska	
341	Sanger	1980-I:15	170/bird gut contents	Kodiak Island Cook Inlet	
83	Hunt	1980-II:6	113/bird gut contents	Pribilof Islands	
5	Feder	1980-II:11	2016/fish, invertebrates	Bering Sea Prince William Sd. N.E.G.O.A	
		lots catalogued	3182		

VII. Discussion:

A total of 3,182 lots were catalogued over the past year, while another 2,931 lots were received and transferred to final storage containers to await further processing.

The processing of all material progressed smoothly although at differing rates. Some of the voucher specimens arrived with specimen tags containing key data and cross-reference numbers to allow access to data sheets for important data needed to complete the data base for each lot. Time involved in processing these specimen lots is greatly increased over those specimen lots received with completed Voucher Specimen Labels. Additionally, mistakes generated in the preparation of specimen tags to cross-reference the specimen lot with its data has the proven potential for perpetuating errors in the data base.

It would be advisable, where budgetary considerations allow, to have the researchers, familiar with the specimens and the conditions under which they were collected, supervise the completion of Voucher Specimen Labels to accompany each specimen lot to the archive. This would greatly reduce the number of transcription errors that occur when data is copied repeatedly by different groups of people, each group being further removed from direct experience with the data they are copying.

Two work curatorial assistants were hired during the final quarter to assist in processing specimen lots.

VIII. Conclusions:

Material is arriving sporadically but in such quantities that a substantial backlog of material remains to be processed. Specimen lots on hand at this time will be processed within the coming year.

IX. Needs for Further Study:

The voucher specimen policy and field identification procedures should be continued through the OCSEAP data gathering phase.

X. Summary of January-March Quarter:

A. Laboratory Activities:

One shipment of voucher specimens was received during the quarter.

RU#	P.I.	# Lots/type	Acc.#/date recvd.
356	Broad	155/invertebrates	1980-IX:12/ 16 Jan. 1981

Material completed during the quarter was Dr. Feder's material received from the University of Alaska, Fairbanks.

RU#	P.I.	# Lots/type	Acc.#/date recvd
5	Feder	remainder of 2016/fish & invertebrates	1980-II:11

1. Ship or Field Trip Schedule: Not applicable

2. Scientific Party:

Dr. William N. Eschmeyer, Chairman and Curator, Department of Ichthyology. Principal Investigator.
Mr. Dustin Chivers, Senior Scientific Assistant, Department of Invertebrate Zoology. Invertebrate Coordinator.
Mr. Scott Cutler, Collection Manager.
Mr. Dan Latham, Curatorial Assistant.
Ms. Marta McGrath, Curatorial Assistant.
Other Academy curators as needed.

3. Methods:

All of the incoming voucher specimens are curated by the procedures outlined in the Voucher Specimen Policy. Final bottle labels and data capture are made on an electronic data storage systemn

D. Sample Localities:

Voucher specimens will be received from throughout the OCSEAP study area.

E. Data Collected or Analyzed:

Since the inception of the Voucher Specimen program, 7371 lots of specimens have been deposited with the archive. 4440 lots have been fully catalogued with the remaining lots being processed as rapidly as possible.

XI. Auxiliary Material: Not applicable at this time.

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