Distribution of Clay Minerals in Lower Cook Inlet and Kodiak Shelf Sediment, Alaska

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INTRODUCTION

Twenty-five surface samples from lower Cook Inlet and forty-three from Kodiak shelf, Alaska, were analyzed for clay mineralogy (Fig. 1). Also, mineralogy was determined on three lithified bedrock samples (110D, 111D, and 116D) from the Kodiak shelf. Most samples of unconsolidated sediment from these areas contain very low percentages of clay minerals. This is because modern ocean currents vigorously rework surficial sediment through much of lower Cook Inlet and the Kodiak shelf. Currents winnow out clay minerals and other fine-grained material and transport them to the bays along Cook Inlet, Shelikof Strait, the sea valleys on the Kodiak shelf and onto the continental slope (Bouma and Hampton, 1976).

Methods of sample preparation and clay mineral identification are provided by Hein, Scholl, and Gutmacher (1976). A brief outline of the procedure is as follows: Carbonate and organic matter are removed by Morgan's solution (sodium acetate plus glacial acetic acid diluted with distilled water) and 30% hydrogen peroxide respectively. The less than 2 μm fraction is isolated by centrifugation. This clay size fraction is Mg-saturated, glycolated, and heat treated (550°C for one hour). An x-ray diffractogram is taken after each treatment. If the presence of vermiculite is indicated on these diffractograms, Ba-saturated samples are x-rayed to confirm this. Peak areas rather than peak heights are measured and the clay mineral percentages are then calculated from them. Biscayes' (1965) weighting factors are used in this calculation; kaolinite, chlorite, illite, and smectite are summed to equal 100 percent. In general, percentages are reproducible to within three percent of the value given, and values rarely change by as much as five percent. Percentages of chlorite and kaolinite are obtained by a slow scan of the 24 to 26 °2Θ region (Biscaye, 1964). Kaolinite is a minor component of Cook Inlet and Kodiak shelf sediment (Table 1). The percentage values of kaolinite and chlorite are considered together (Table 1 and 2) because an accurate determination of kaolinite is difficult when it occurs in small quantities. The percent expandable layers in the mixed layer smectite/illite phase is determined from the charts of Perry and Hower (1970) and Reynolds and Hower (1970). Illite crystallinity (Y) is measured as the ratio of the 10Å peak width at mid-height to the peak height.

DISTRIBUTION OF CLAY MINERALS IN LOWER COOK INLET

Sample locations and the distribution of different clay minerals are shown in Figures 2 - 5. The clay mineral percentages are also listed in Table 1. Chlorite and illite are the dominant clay minerals in Cook Inlet. They average 52% (including kaolinite) and 45% respectively (Table 2). Smectite averages 3%. There is a major difference in the clay mineralogy from near the Barren Islands across the inlet to Kamishak Bay and farther to the north. In general, illite increases in abundance in northwestern and northern lower Cook Inlet, whereas, chlorite + kaolinite dominates the clay mineral suite near the Barren Islands (Figs. 3 and 4). Chlorite + kaolinite is also abundant in Kachemak Bay. Smectite percentages are lowest in central lower Cook Inlet and increase both to the northwest and to the southeast; it is most abundant in Kachemak Bay. Illite has a higher crystallinity (lower numbers) in samples from Kachemak Bay and northwestern and northern lower Cook Inlet than it does in samples near the Barren Islands (Fig. 5).

DISTRIBUTION OF CLAY MINERALS ON KODIAK SHELF

Clay mineral percentages from Kodiak shelf sediment samples show some large variations over relatively short distances. However, in general, three trends are apparent. First, most samples to the south and east of the eastern end of Afognak Island have a clay mineral assemblage representative of the average for the Kodiak shelf taken as a whole; that is about 60% chlorite+kaolinite, 33% illite, and 6% smectite (Table 1 and 2). Smectite is most variable, whereas chlorite+kaolinite is exceedingly uniform through this area. Second, in general, clay mineral percentages on southern, middle, and northern Albatross Banks are similar, but, these values are distinctive from those from the intervening troughs. Samples from these topographic lows contain relatively more illite and less chlorite+kaolinite. Third, dart cores were taken on bedrock ridges (sample numbers in Table 1 followed by the letter D; Fig. 6; Bouma and Hampton, 1976). The clay mineral percentages from the semi-consolidated bedrock material collected in these dart cores are different from those of other shelf samples. The illite crystallinity is especially distinctive and averages 0.15 (excluding sample 125D which did not contain bedrock) as compared to 0.38 for the shelf in general (Table 2). This value of 0.15 is essentially the same as the average value for lower Cook Inlet, 0.16. Local variation in the clay mineralogy on a bank or within a single trough can be attributed to small-scale topography and some mixing. For example, sample 115 has a distinctive clay mineral assemblage; it was taken from a broad outer shelf basin superimposed on middle Albatross Bank.

COMPARISON OF LOWER COOK INLET AND KODIAK SHELF CLAY MINERALOGY

Overall, lower Cook inlet has an illite-dominated clay mineral suite in contrast to the chorite-rich suite on the Kodiak shelf (Table 2). Illite crystallinity is much higher (lower values) in lower Cook Inlet as compared to the Kodiak shelf. Samples from southeastern Cook Inlet have a clay mineral suite more like Kodiak shelf than like the rest of lower Cook Inlet (Table 2); for example, chlorite+kaolinite is the same as on the Kodiak shelf and illite and illite crystallinity show values intermediate between the average shelf and inlet samples. Thus, samples from northwestern lower Cook Inlet are very rich in illite, which constitutes about half of the clay mineral suite. Chlorite+kaolinite (55%) and illite (38%) values on the outer Kodiak shelf bedrock ridges, however, are intermediate between those average values for the shelf and for lower Cook Inlet.

REGIONAL DISTRIBUTION OF CLAY MINERALS

Average values for the clay mineral composition of suspended sediment from the Copper River, bottom samples from the Copper River delta, and bottom samples from the continental shelf in the northern Gulf of Alaska are listed in Table 2. Copper River samples are comparable to those from the shelf seaward of that river, but chlorite+kaolinite is diluted and illite enriched in the offshore bottom samples (Molnia and Fuller, 1977; J.R. Hein, unpublished data, 1977; Table 2.) In general, the samples offshore of the Copper River, have the same clay mineral percentages as samples from Southeastern lower Cook Inlet, and values that are closely comparable to Kodiak shelf samples (Table 2).

Bottom samples from upper Cook Inlet, including Knik Arm and Turnagain Arm are illite rich. Most commonly, illite is greater than 50 percent of the clay mineral suite (N.R. O'Brien, SUNY at Potsdam, personal communication, 1977). This illite-rich suite is derived from the Susitna River and is widely distributed in upper Cook Inlet.

PRELIMINARY INTERPRETATION: SOURCES AND DISPERSAL PATTERNS OF CLAY MINERALS

The Copper River is the primary supplier of Holocene sediment to the northern Gulf of Alaska. We infer from the regional distribution of clay minerals that currents flowing parallel to the Alaskan coast carry Copper River sediment west and southwestward. This sediment is the main source of clay minerals found on the continental shelf and perhaps the upper slope from the Copper River west to at least the south-western limit of Kodiak Island. This Cooper River clay mineral suite is also carried into Cook Inlet, maintains its identity around the Barren Islands, and can be traced north to as far as Homer and into Kachemak Bay. Near Homer, the chlorite-rich Copper River suite mixes extensively with the illite-rich Susitna River or upper Cook Inlet suite. Apparently, currents flowing out of Cook Inlet hug the northwestern shore (Bouma and others, 1977) and deposit the Susitna River suite on that side of lower Cook Inlet south of the latitude of Homer. This illite suite is evident as far south as Kamishak Bay, where our sampling stops. The fate of this characteristic suite is unknown. Shelikof Strait, and Cook Inlet, from Homer north to the Susitna River, must be sampled to further delineate the current patterns and to confirm our speculations about the available data. Apparently the Susitna River suite does not enter the Pacific through Stevenson Trough because this area contains the characteristic Copper River clay mineral suite.

The origin of clay minerals on Kodiak shelf is speculative. In general, the Copper River clays appear to collect on the banks. But, on outer shelf bedrock ridges, a mixture of locally derived bedrock clays (Quaternary (?) mudstone) and transported Copper River clays is likely. Further, local depressions on the banks and bedrock exposures across the shelf complicate the interpretation of any single sample. Apparently, some small-scale depressions are filled with clays eroded from local bedrock outcrops. There may be a minor contribution of clays to the shelf from erosion on Kodiak Island. Sediment-filled fiords on the southern coast could easily be churned during storms resulting in the movement of fine-grained sediment seaward onto the shelf. Kodiak Island fiords should be sampled to verify this conclusion. Seismic records show that the troughs cutting across the Kodiak shelf are partly filled with sediment (Bouma and Hampton, 1976). Clay mineralogy suggest that the fine fraction of this trough fill is primarily derived from the Copper River suite. The clays are probably swept into the troughs from the adjacent banks and are mixed partly with Kodiak Island derived clay minerals or clay minerals eroded from shelf bedrock outcrops.

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Table 1. Clay Minerals In Bottom Sediments From Southern Cook Inlet And Kodiak Shelf, Alaska.

Sample No.	K + C	Kaol.	Chlor.	Illite	Smectite	Others	X*	Y†
				COOK INLET				
2 top	55%	14%	41%	38%	7%		70	0.11
2 bot.	56	12	44	39	5		75	0.11
4	42	10	31	56	3		95	0.08
5	43	13	29	53	4		90	0.08
7	44	11	31	55	2		80	0.12
8	47	7	40	45	6		80	0.13
9	43	7	36	54	4		95	0.12
9V1	37	6	31	61	2		70	0.17
12	43	6	36	55	3		95	0.11
14V1	49	9	40	49	2		75	0.14
15	47	10	37	49	4		85	0.10
16 top	43	8	35	55	2		90	0.10
16 bot.	45	14	30	55	0		-	0.10
17	57	8	49	41	2		100	0.14
19	59	14	45	39	3		75	0.12
22S	58	8	49	40	3		75	0.39
23	61	18	42	39	1		80	0.13
24S1	60	10	51	38	2		70	0.24
25	60	7	53	38	2		75	0.21
26	64	0	64	35	1		?	0.26
29	59	15	43	41	0	Sepiolite	-	0.22
34	53	11	42	44	3		70	0.15
36	54	13	41	45	1	Sepiolite	?	0.28
37S1	55	8	46	45	1		70	0.20
43	49	10	39	32	19		90	0.10
48	40	9	31	59	2		95	0.15
150	58	9	49	39	3		85	0.24
				KODIAK SHELF				
1	66	15	52	28	6		80	0.21
52	62	16	46	37	1		70	0.28
54	63	14	49	36	2		70	0.31
55	63	9	54	29	7		75	0.25
56S	63	13	49	27	10	Sepiolite	80	0.28
56S1	64	17	47	32	4	Vermiculite	75	?
58	63	12	51	34	3		85	0.24
60	61	13	48	33	6	Sepiolite	85	0.39
61	60	14	46	29	11		75	0.50
63	64	13	51	34	2		70	0.25
64	62	14	48	33	5		80	0.35
66	62	13	50	35	3		75	0.21
67	60	16	45	36	4		80	0.28
68S2	59	8	52	37	4		70	0.36
69	58	16	42	27	15		80	0.96
70	72	14	59	25	2		70	0.51
75	69	39	30	30	1	Sepiolite	?	0.87
82	56	13	42	34	11		80	0.20
85	66	0	66	33	1		75	0.57
87S1	66	9	57	29	3		95	0.58
88	52	7	45	42	6		85	0.28
91	63	13	50	30	8		70	0.35

Table 1 cont.

Sample No.	K + C	Kaol.	Chlor.	Illite	Smectite	Others	X*	Y[+]
92	57	11	46	38	5		80	0.28
93	59	11	48	37	4		80	0.30
96	52	11	40	43	6		85	0.33
98	64	13	51	34	3		75	0.23
103D	41	7	38	34	24		70	0.09
110	54	11	44	38	7		75	0.14
110D2	56	12	44	39	5		75	0.19
111D1	58	9	49	38	4		70	0.15
113B	58	10	48	35	7	Sepiolite	75	0.17
114	61	17	45	38	1		?	0.39
115	72	20	53	19	9		70	1.70
116D2	56	8	48	38	6		70	0.12
117D	59	8	51	41	0		-	0.17
120D	54	8	46	37	9		65	0.13
125D	40	?	?	30	30		55	1.37
127	58	12	46	34	8		75	0.36
128	60	14	46	33	7		85	0.29
130	62	13	49	33	5		80	0.48
132	64	13	51	33	4		80	0.21
133G	60	9	52	33	6		75	0.15
134	60	11	48	35	5		75	0.30
136	62	12	50	33	5		80	0.24
141	66	13	53	29	5		80	0.23
147D	60	8	52	36	4		70	0.18

* Percent expandable layers in the smectite/illite mixed layer phase.

[+] Illite crystallinity.

Table 2. Average And Range Of Clay Mineral Percentages From Lower Cook Inlet, Kodiak Shelf, Southeastern Cook Inlet*, Copper River And Delta, And The Shelf Off The Copper River**.

	Cook Inlet		Kodiak Shelf		SE Cook Inlet		Copper River & Delta		Shelf Off Copper R.	
	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
K + C	51	37-64	60	40-72	60	57-64	68	61-73	62	44-70
Kaol.	10	0-18	13	0-39	10	0-18	12	6-17	9	7-10
Chlor.	41	29-64	48	30-66	49	42-64	56	53-64	53	37-60
Illite	46	32-61	33	19-43	39	35-41	31	27-39	38	30-56
Smectite	3	0-19	6	0-30	2	0- 3	<1	0- 1	<1	0- 1
X^+	82	70-100	76	55-95	80	70-100	?	?	?	?
Y^+	0.16	0.08-0.38	0.38	0.09-1.70	0.22	0.12-0.38	0.27	0.18-0.33	?	?

* Includes samples 17, 19, 22, 23, 24, 25, 26, 29, and 150.

**Number of samples analyzed from each area is, 25, 43, 9, 5, and 19 respectively. Data for Copper River and delta and for the shelf off the Copper River are unpublished data of James R. Hein,and B.F. Molnia and P.T. Fuller 1977).

+ X = percent expandable layers in the smectite/illite mixed layer phase; Y = illite crystallinity.

FIGURE CAPTIONS

Figure 1. Location of areas of study: Cook Inlet and the Kodiak shelf.

Figure 2. Distribution of samples analyzed for clay mineralogy and sample numbers from lower Cook Inlet.

Figure 3. Distribution of chlorite+kaolinite in lower Cook Inlet. Numbers are the percentage of chlorite+kaolinite in the clay mineral suite. The percentage values are contoured at a five percent interval.

Figure 4. Distribution of illite in lower Cook Inlet. Numbers are the percentage of illite in the clay mineral suite. The percentage values are contoured at a five percent interval.

Figure 5. Variation of the crystallinity of illite in lower Cook Inlet sediment samples. Contour interval is 0.05.

Figure 6. Generalized physiography and distribution of samples analyzed for clay mineralogy on Kodiak shelf. Sample numbers are listed next to the station locations. Contour intervals in meters.

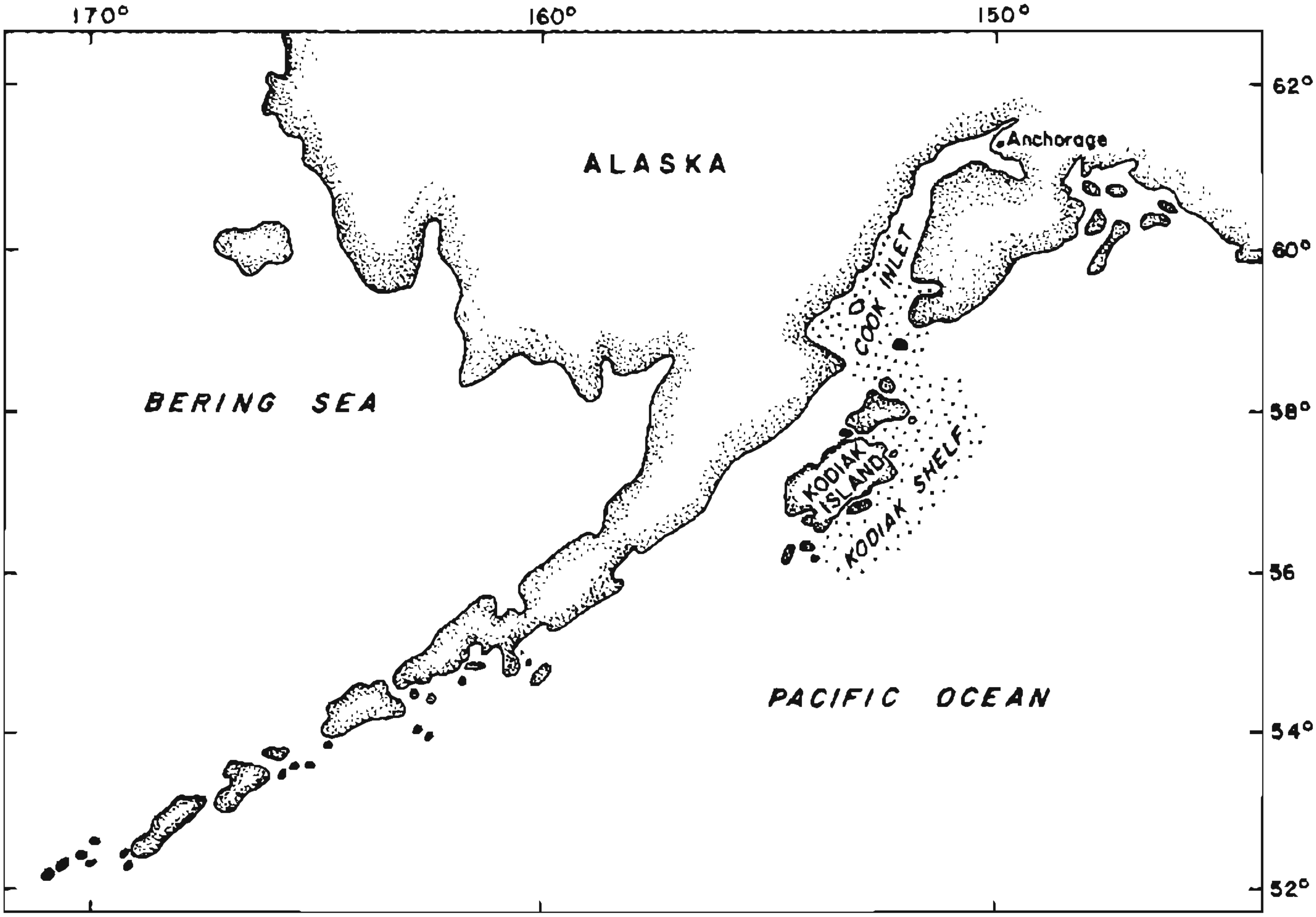
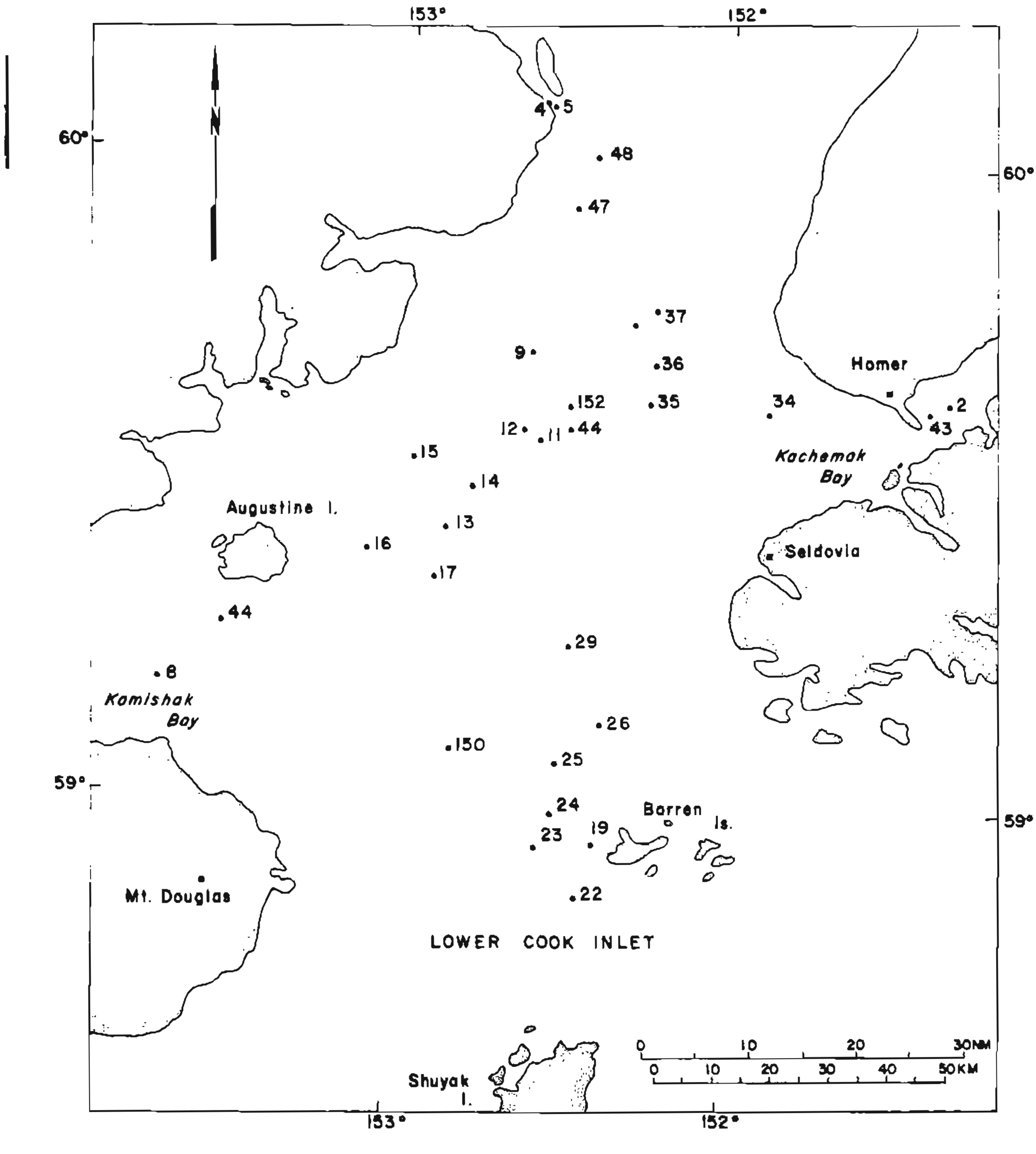


Figure 1.- Generalized location map of the study area



153°
152°
60°
59°
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4
5
48
47
37
36
35
34
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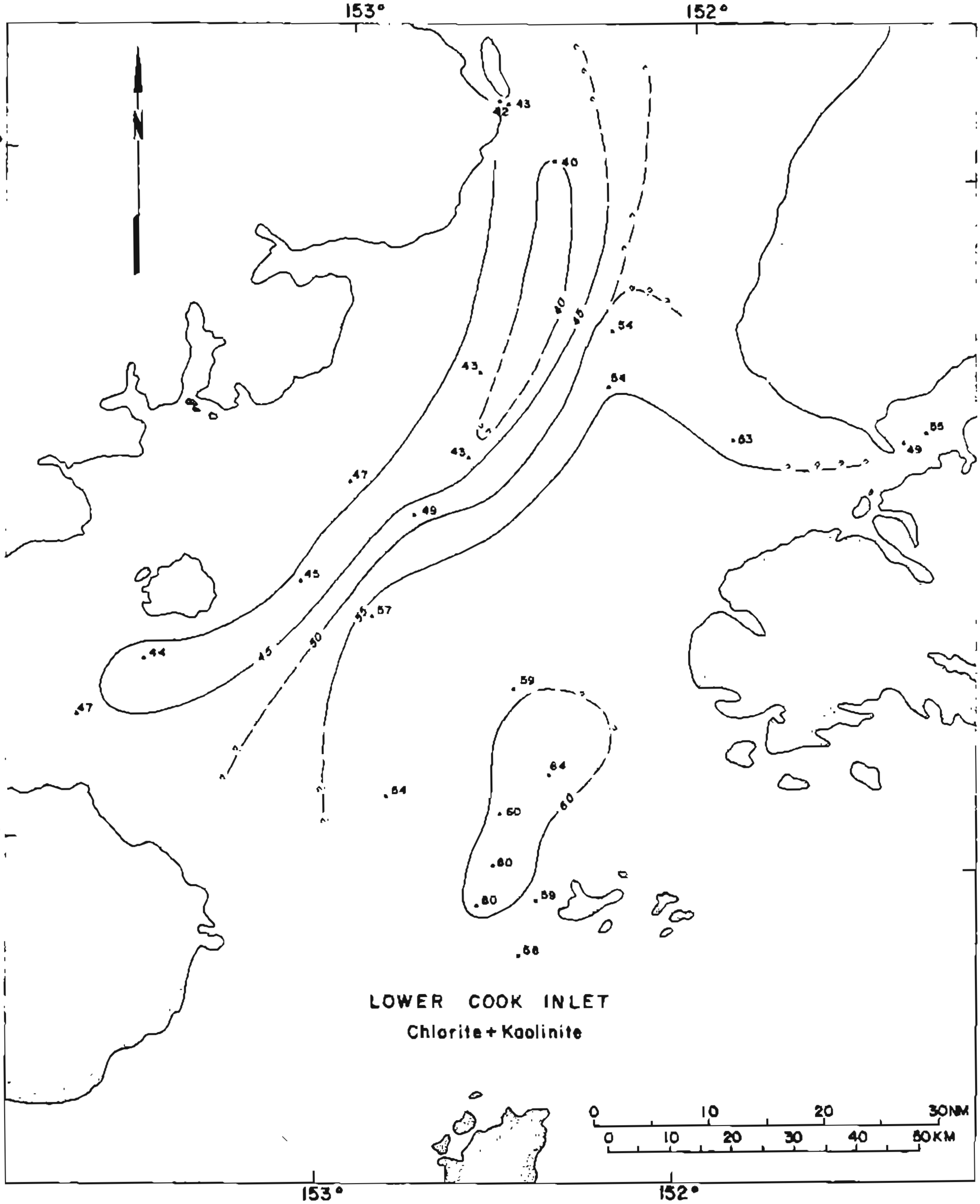
152
12
11
44
15
14
13
16
17
44
8
29
26
150
25
24
23
19
22
2
43
Homer
Kachemak Bay
Seldovia
Augustine I.
Kamishak Bay
Barren Is.
Mt. Douglas
LOWER COOK INLET
Shuyak I.
0 10 20 30NM
0 10 20 30 40 50KM



153°
152°
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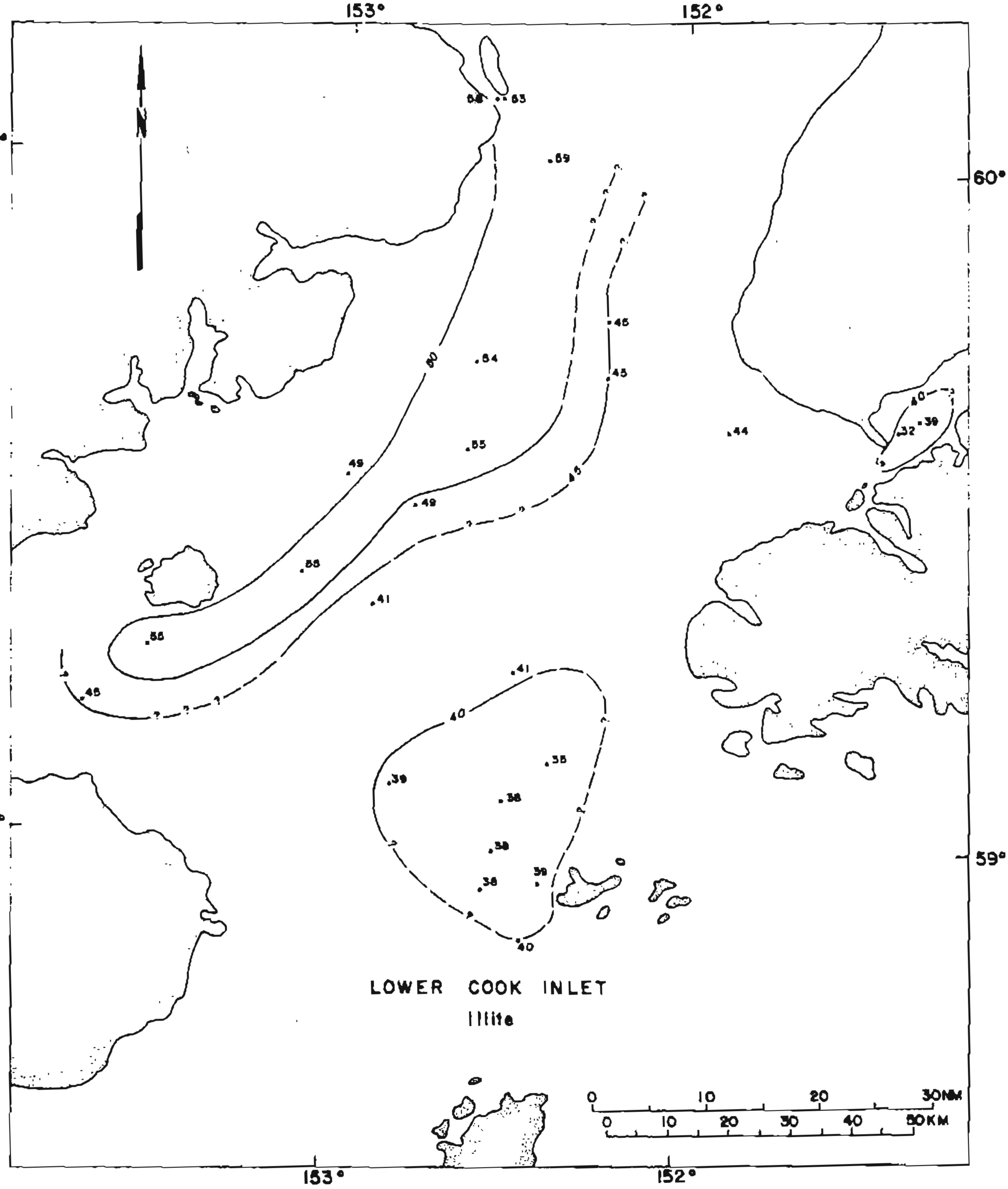
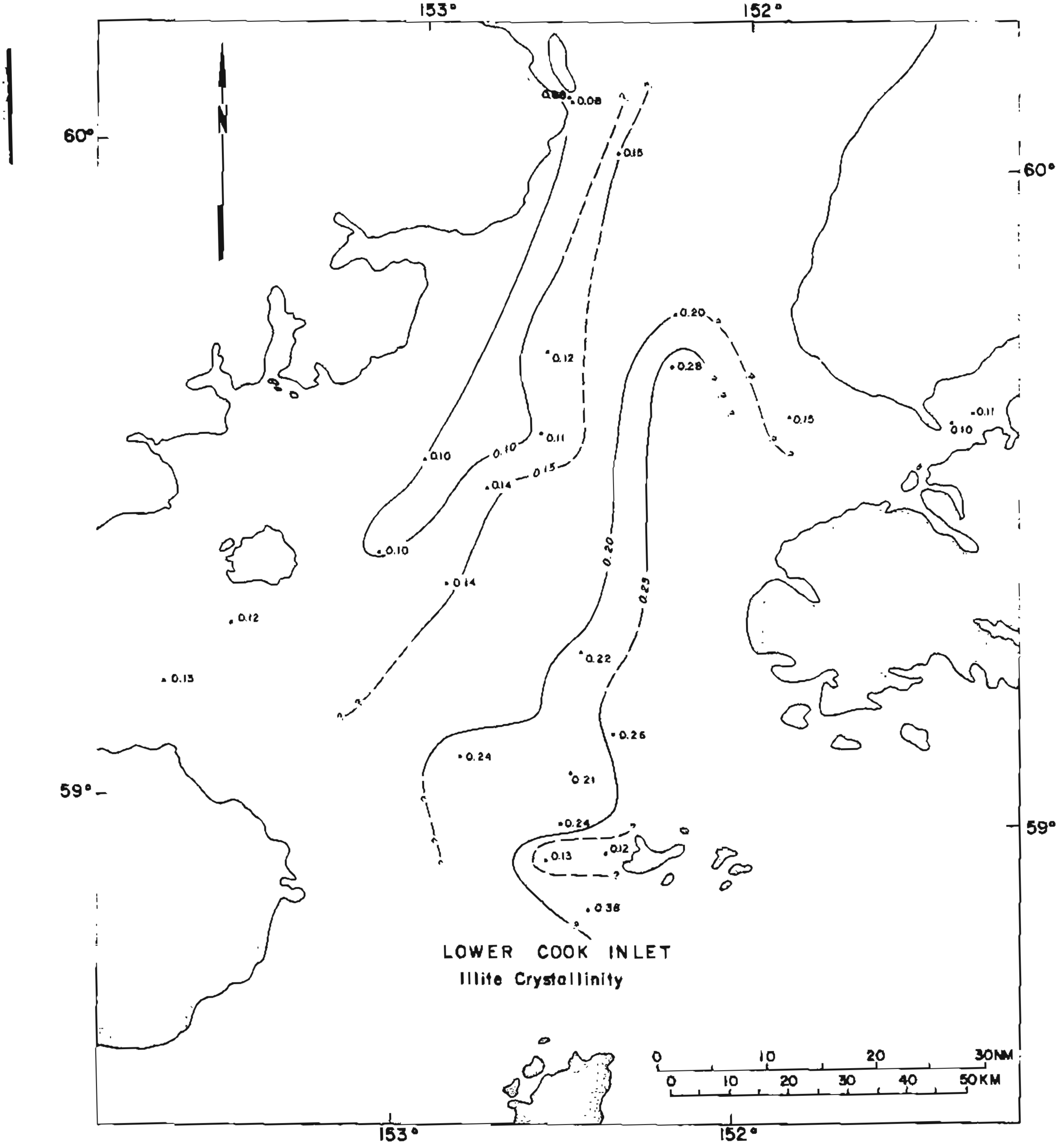
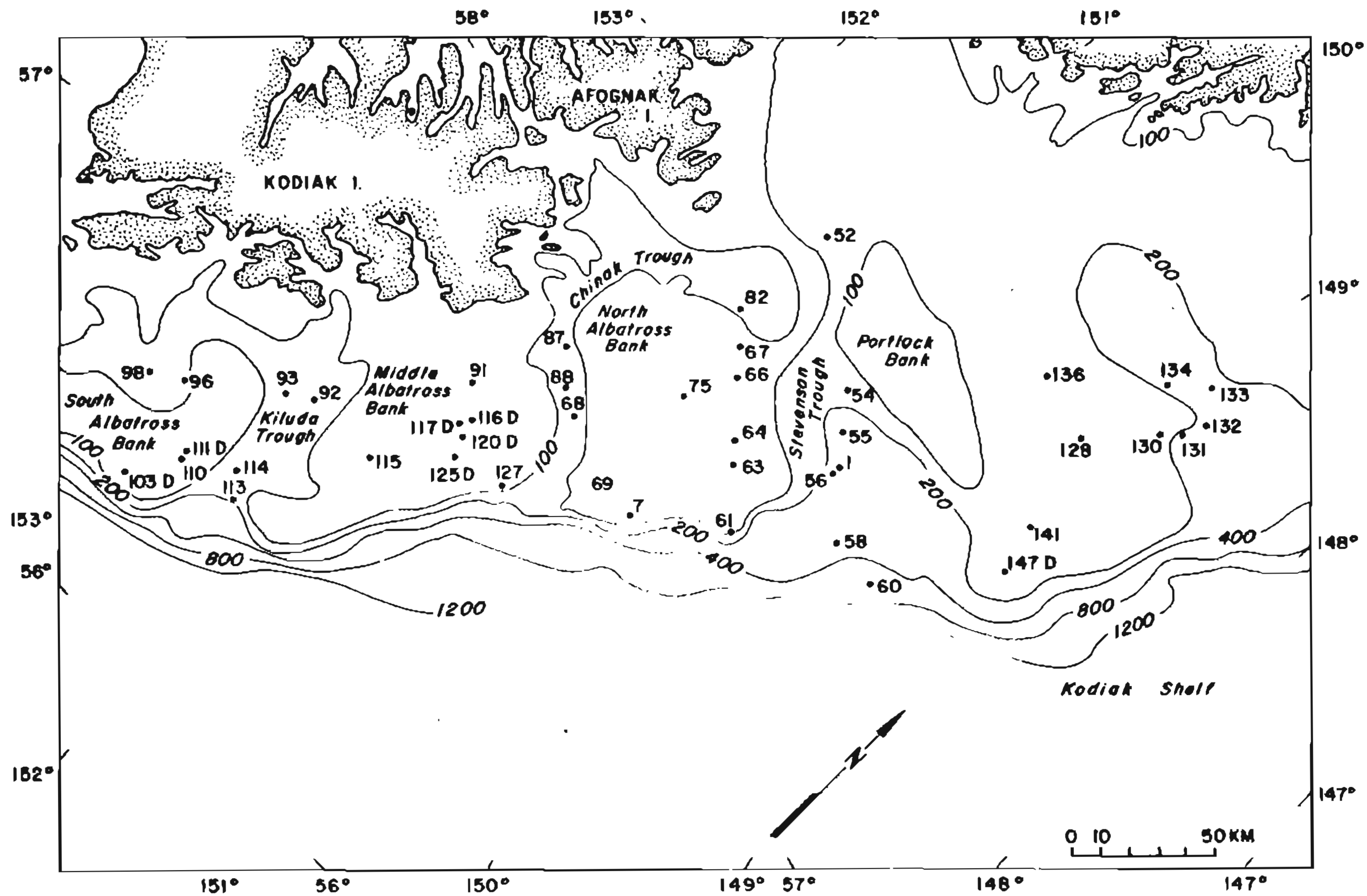
N
LOWER COOK INLET
Chlorite + Kaolinite
0 10 20 30NM
0 10 20 30 40 50KM



LOWER COOK INLET
Illite



LOWER COOK INLET
Illite Crystallinity



KODIAK I.
AFOGNAK I.
South Albatross Bank
Kiluda Trough
Middle Albatross Bank
Chiniak Trough
North Albatross Bank
Stevenson Trough
Portlock Bank
Kodiak Shelf
N
0 10 50 KM
100
200
400
800
1200
98
96
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