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CONTRIBUTIONS TO CLAY MINERALOGY AND PETROLOGY, COOK INLET BASIN, ALASKA

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INTRODUCTION

This report includes two studies on the clay mineralogy and petrology of sediments from the Cook Inlet region. The first deals with modern sediments, the second with Tertiary sedimentary rocks. They are included together because an understanding of modern sediment distribution may be useful in interpreting the origin of Tertiary rocks in the area.

Both studies were conducted at the Tulsa Research Laboratory of Sinclair Oil Corporation (now Atlantic-Richfield Company) and issued as company reports in 1966. Atlantic-Richfield Company has kindly granted permission to place these in open-file status (written commun., R.L. Tabbert, 1974).

The primary purpose of reissuing these reports is to make the data and conclusions available to the public. Only minor modifications of the original reports have been made and no attempt was undertaken to update them by taking into account more recent information. In essence, these are previously unpublished data and ideas that may be useful in interpreting the geology of the Cook Inlet region.

PART I - CLAY MINERALOGY OR RECENT SEDIMENTS, NORTHERN COOK INLET, ALASKA

INTRODUCTION TO PART I

The purpose of this study is to determine the clay mineral composition of fine-grained sediments currently being carried into Cook Inlet by major rivers. If differences exist among the rivers, clay mineral composition may be used to characterize different source terranes in the present geological setting. Such information should be useful in interpreting sediment distribution systems within Cook Inlet today, and also in interpreting the source areas for mudrocks within the Cook Inlet Tertiary basin.

In very generalized terms, northern Cook Inlet may be considered a large graben - - an elongate, continuously negative area bordered by distinct, relatively straight faults. It was filled with up to 23,000 feet of Tertiary sediments. The fact that these sediments are almost entirely nonmarine sands, silts, and shales implies that deposition stayed a little ahead of subsidence; i.e., the basin surface probably never passed below sea level. The present configuration of Cook Inlet - - with its marine-brackish waters, high tides, and swift currents - - was shaped largely by Pleistocene activity, particularly glaciers.

The Cook Inlet graben or basin had a long and complex history and it seems very likely that sediment provenance changed with time and place within the basin. Since the surrounding positive areas consist of different kinds of rocks, one would expect variations in sediment mineralogy. Knowledge of any three-dimensional variations in mineralogy within the Tertiary rocks would be useful for:

(1) Correlation (which is difficult within this thick accumulation of nonmarine sediments representing a narrow range of depositional environments).

(2) Reconstruction of geologic history (particularly the sequence of tectonic events and paleogeography).

An investigation of the Tertiary Kenai Formation - - based on outcrops, cuttings, and a few cores - - has been in progress at the Tulsa Research Center since 1965. As a supplement to this, it seemed desirable to study the provenance of sediments currently being transported into northern Cook Inlet, bearing in mind the probable differences between the modern Cook Inlet and the Tertiary Cook Inlet basin.

For this study, during June-July, 1966, sediment samples were collected from all major rivers and many minor streams flowing into northern Cook Inlet. The present report is primarily restricted to the clay mineralogy of fine fractions (less than 2 microns in diameter).

Concurrent with a study of regional provenance, it also seemed desirable to study in more detail the sediments deposited in various local environments (backswamps, ponds, levees, sand bars, etc.) associated with a major river. There were two main objectives of this work:

(1) To seek systematic distributions of clay minerals within the various continental subenvironments which would be applicable to the ancient continental sediments deposited in the Cook Inlet basin.

(2) To determine the local variability in clay mineralogy of sediments deposited by a single large river.

The broad plain of the lower Susitna River was selected for such a detailed study.

METHODS OF INVESTIGATION

Samples Investigated

All samples were collected in plastic bottles to maintain them in their original moist condition.

Thirty-eight samples of river sediments were collected for the regional provenance study. Only one of these was of the suspended load actually in transport. All others consisted of argillaceous material collected immediately adjacent to the rivers; usually from clay films or pond deposits on sand bars. Although not in transport at the time, such material was obviously related to recent, slightly higher river levels. Locations and descriptions of these samples are listed in table 1-1.

Thirty-one samples were collected in the lower Susitna River area (table 1-2). A few of these may be older glacial or tidal deposits not actually deposited by the Susitna River or in its associated swamps and ponds. It is not always easy to identify these older deposits in the field (or from their mineralogy, as will be discussed later).

In addition, 13 samples (table 1-3) were taken from miscellaneous locations which might provide useful information for interpreting source

Table 1-1. Samples collected for regional provenance study.

SAMPLE NUMBER	LOCATION	DESCRIPTION	PEAK-HEIGHT PERCENTAGES MONTMORILLONITE (17Å)	ILLITE (10Å)	CHLORITE (7Å)
* 1	Susitna R., near Susitna	Clay layer 1' below sand bar surface	2	52	46
A17	Tokositna R., near Ruth Glac.	Clay among cobbles on gravel bar	0	69	31
A20	Chulitna R., near Ruth Glac.	Mud-capped ripples on sand bar	0	57	43
D22	Susitna R., near Curry	Mud-capped ripples on sand bar	51	20	29
A26	Kahlitna R., near Kahl. Glac.	Sandy mud on gravel bar	0	69	31
A28	Yentna R., N. of Youngstown	Mud-capped ripples on sand bar	0	63	37
A30	Kichatna R., S. of Youngstown	Mud 1' below sand bar surface	0	64	36
32	Skwentna R., above Hayes R. jct.	Mud-capped ripples on sand bar	18	42	40
34	Hayes R., above Skwentna R. jct.	Clay among cobbles on gravel bar	20	29	51
36	Skwentna R., near Skwentna	Mud film from dry pond on bar	11	37	52
A38	Yentna R., above Skwentna R. jct.	Mud film from dry pond on bar	0	63	37
A39	Yentna R., below Skwentna R. jct.	Argill. sand, edge of main channel	0	52	48
A42	Kahlitna R., N. of McDougall	Clay among cobbles on gravel bar	6	59	35
A44	Susitna R., just S. of Talkeetna	Mud-capped ripples on sand bar	0	57	43
D46	Talkeetna R., 10 mi. from Talk.	Mud film from dry pond on bar	37	17	46
D48	Sheep Cr., about 14 mi. from Sus. R.	Sandy clay trapped among plant roots	59	0	41
D50	Kashwitna R., E. of Caswell	Mud film on sand bar	8	42	50
D52	Willow Cr., E. of Willow	Clay among cobbles on gravel bar	0	36	64
59	Yentna R., just above Sus. R. jct.	Mud film on sand-gravel bar	5	52	43
62	Susitna R., just above Yentna R. jct.	Mud-capped ripples on sand-gravel bar	18	41	41
*67	Susitna R., N. end Big Is.	Mud-capped ripples on sand bar	18	43	39
*69	Susitna R., N. end Bell Is.	Suspended material, flocced with $CaCl_2$	12	51	37
C90	Indian Cr., near Girdwood	Sandy clay at edge of channel	0	36	64
C92	Glacier Cr., near Alyeska Vill.	Clay among cobbles, stream edge	0	44	56
C95	Resurrection Cr., near Hope	Clay among cobbles, stream edge	0	39	61
C97	Six-Mile Cr., above Sunrise	Clay among boulders, stream edge	0	35	65
C100	Ingram Cr., near Portage	Muddy sand along stream edge	0	36	64
C101	Eagle R., along Glenn Hwy.	Clay among cobbles on gravel bar	0	42	58
C104	Knik R., Glenn Hwy. bridge	Clay among cobbles on gravel bar	0	41	59
106	Matanuska R., near Palmer	Clay among cobbles on gravel bar	9	32	59
B109	Drift R., Westforeland area	Mud-capped ripples on gravel bar	59	16	25
B110	Chicchantna R., Capps Glac.	- - - - - - - do - - - - - - - -	45	19	36
B111	Straight Cr., near Capps Glac.	- - - - - - - do - - - - - - - -	81	6	13
B112	Nagiscaming R., W. of Mt. Spurr	- - - - - - - do - - - - - - - -	18	40	42
B113	Chacachatna R., S. of Mt. Spurr	- - - - - - - do - - - - - - - -	16	61	23
C114	Skilak R., above Skilak Lake	Mud film on sand bar	0	48	52
B115	Beluga R., above Beluga L.	- - - - - - - do - - - - - - - -	41	15	45
B116	Beluga R., above Beluga L.	- - - - - - - do - - - - - - - -	37	29	34

*Included in table 1-2 also.

Table 1-2. Samples collected for detailed study of lower Susitna area

SAMPLE NUMBER	LOCATION	DESCRIPTION	PEAK-HEIGHT PERCENTAGES MONTMORILLONITE (17Å)	ILLITE (10Å)	CHLORITE (7Å)
* 1	Island just S. of Susitna	Clay layer 1' below sand bar surface	2	52	46
2	E. side, opposite S. end Bell Is.	Surface mud from swamp	4	50	46
3	E. side, opposite N. end Bell Is.	1-1/2' from 4' bank of small stream	5	52	43
4	E. side, opposite N. end Bell Is.	Bottom sediment, small pond	16	42	42
5	E. side, just S. of Bell Is.	1-1/2-2' below top of Sus. R. levee	5	54	41
6	E. side, just S. of Bell Is.	Surface mud from swamp E. of levee	5	51	44
11	200' W. of Sus. levee, opposite Big Is.	Blue sdy. clay, 3' down in marsh	12	41	47
12	Middle of northern Big Is.	6" blue clay below org. layer in marsh	0	44	56
55	Western Sus. plain N.E. of Theodore R.	Blue-gray clay from 6'	13	44	43
56	Near VABM Tyro, central Big Is.	Clay-org. mixture, 4' down in old channel	10	45	45
57	E. side, opposite central Big. Is.	1' clay layer, middle of 10' levee	12	50	38
58	E. side, opposite central Big Is.	Clay-org. mixture, 2'-3' from top of 10' levee	9	49	42
64	1 mi. E. of Sus. R., 2 mi. S. of Sus.	Mud from 8" in old channel	13	45	42
* 67	Central Big. Is., along a main channel	Mud-capped ripples on sand bar	18	43	39
* 69	N. end of Bell Is.	Suspended material, flocced with $CaCl_2$	12	51	37
71	About 1 mi. E. of Maid L.	Org. material, 4' down in marsh	--	--	--
72	Figure 8 Lake, north edge	Org. material, 3' down at water edge	--	--	--
73	Figure 8 Lake, north edge	Org. material, in 1' water	--	--	--
74	W. edge Sus. plain, 3-1/2 mi. SE. of Alexander	Clay from 6', base of hill	16	43	41
77	S. of Lewis Slough, near Ivan R.	Gray mud from 4-1/2"	9	49	42
78	W. edge Sus. plain, 4-1/2 mi. SE of Alexander	Org. material just below surface	--	--	--
79	W. edge Sus. plain, 4-1/2 mi. SE of Alexander	Blue sdy. clay from 6'	16	37	47
80	Small Lake, 4-1/2 mi. SE of Alexander	Surface org. material from marsh	--	--	--
81	Small Lake, 4-1/2 mi. SE of Alexander	Brown org. material, at lake edge	--	--	--
82	Center of Sus. plain, 4 mi. SE. of Alexander	Surface, organic material from marsh	--	--	--
83	Center of Sus. plain, 4 mi. SE. of Alexander	Blue sdy. clay from 6'	9	36	55
84	4 mi. S. of Alex., 1/4 mi. W. of Sus. R.	Clay-org. mixture, 1' in old channel	10	49	41
85	4 mi. S. of Alexander, 1/4 mi. W. of Sus. R.	Surficial clay-org. material, marsh	4	53	43
86	4 mi. S. of Alexander, 1/4 mi. W. of Sus. R.	Clay from 6", old levee?	6	47	47
87	4 mi. S. of Alexander, 1/4 mi. W. of Sus. R.	Gray sdy. silt, 1-1/2' in old levee?	14	49	37
88	4-1/4 mi. S. of Alexander, W. shore Sus. R.	Bluish clay-org. mixture at shoreline	9	49	42

*These samples are also included in table 1-1 since they also apply to the regional provenance study.

Table 1-3. Miscellaneous samples.

SAMPLE NUMBER	LOCATION	DESCRIPTION	PEAK-HEIGHT PERCENTAGES MONTMORILLONITE (17Å)	ILLITE (10Å)	CHLORITE (7Å)
7	Hills on W. edge of plain, near Lewis R.	From 6' + bed, massive blue clay	24	43	33
8	Little Sus. R., inner edge of Sus. Flats	Blue tidal muds along R. bank	5	47	48
9	Sand flats of Susitna delta, 6 mi. offshore	Sand, very little clay	0	43	57
10	Tidal flat, 3 mi. W. of L. Sus., 1/4 mi. offshore	Soft, sticky brown clay	12	41	47
53	Hills on W. edge of plain, No. of Beluga R.	Firm blue silty clay	31	33	36
54	Hills on W. edge of plain, No. of Beluga R.	Organic material from swamp	--	--	--
63	Along Sus. R., 4-1/2 mi. N.E. of Susitna	20' + bed sticky blue clay	15	37	48
65	W. bank Sus. R., 3-1/2 mi. S.W. of Susitna	8' + bed of sticky blue clay	15	34	51
70	E. shore of Mud Lake	Firm blue clay, 2'-4' above water	15	39	46
75	Beluga R., at edge of Sus. plain	Blue boulder clay (glacial till)	20	33	47
76	Tidal flat 3 mi. E. of Little Sus. R.	Sticky gray silt from 1-1/2'	0	45	55
93	Tidal flat, Turnagain Arm, near Portage	Firm gray silt	5	44	51
96	Along 6-mile Cr., near Sunrise	Laminated blue silt (glacial?)	0	37	63
108	Eroded edge of tidal flat, E. of L. Sus. R.	Firm gray silt	5	47	48

areas and mineral distributions of the other samples. Most of these were from Cook Inlet tidal flats or from older deposits (glacial?) cut by the Susitna River.

Identification of Clay Minerals

Portions of each sample were dispersed with distilled water in a Waring Blender with <2μ fractions separated by centrifugation. These were pipetted onto glass slides to produce oriented clay films for X-ray diffraction analysis.

Clay minerals identified include montmorillonite, chlorite, illite, and trace quantities of kaolinite. Relative abundances of illite, chlorite, and montmorillonite were estimated by measuring simple peak-height intensities for the primary (001) reflections of these minerals and normalizing to a common basis of 100%. In other words, the intensities for the primary X-ray reflections[1] of montmorillonite, illite, and chlorite were added and the relative(?) contribution of each mineral to this total was calculated. It should be noted that these peak-height percentage data do not necessary reflect, and are probably quite different from, absolute percentages present.

Diagnostic reflections for chlorite and kaolinite are so close that a large amount of one essentially obscures the presence of the other. In the present case, the problem was to detect trace amount of kaolinite. Fifteen samples were heated at 80°C in 1N HCl for 8 hours to remove chlorite and reveal the presence, if any, of kaolinite. The majority of these contained a trace of kaolinite, a lesser number contained no detectable kaolinite, and two contained more than a trace of kaolinite.

RESULTS AND DISCUSSION

Regional Provenance Study

Clay Mineralogy of Stream Sediments

Peak-height percentages of montmorillonite, chlorite, and illite in river samples are listed in table 1-1 and shown according to location in figure 1-1. Also shown in figure 1-1 are clay mineral compositions of six tidal flat sediments: samples 8, 9, 10, 76, 93, and 108.

Four areas of distinctive mineralogy are apparent in figure 1-1:

(1) Area A, in the northern Susitna basin, containing streams which drain the southern Alaska Range south of Mt. McKinley.

(2) Area B, containing streams draining the northern Aleutian Range between Redoubt Volcano and Mt. Gerdine.

(3) Area C, containing streams flowing from the Chugach and Kenai ranges.

(4) Area D, containing streams from the Talkeetna Mountains.

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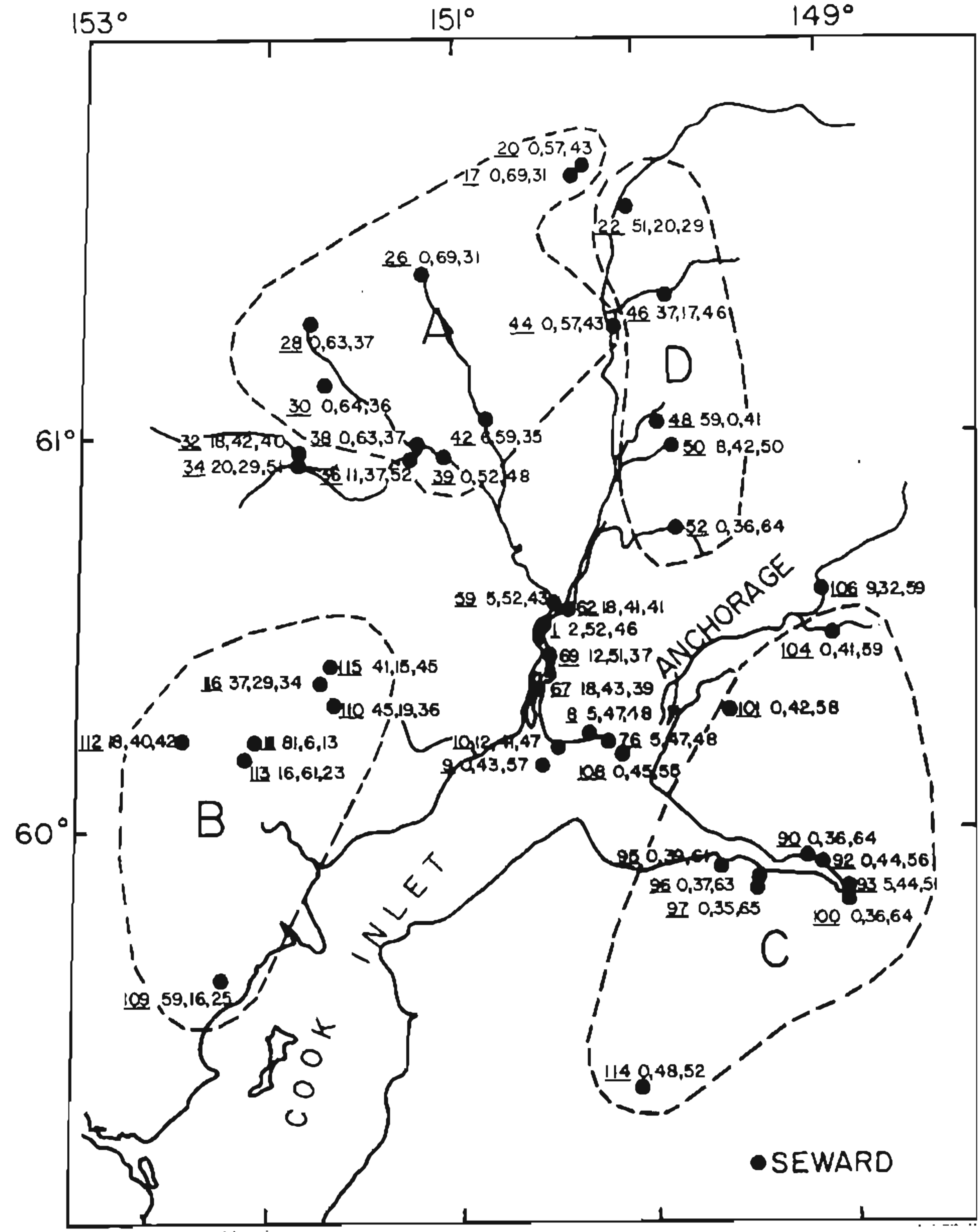
[1] Glycol-treated specimens were used. Montmorillonite intensities were measured at 17Å, illite at 10Å, and chlorite (plus traces of kaolinite if present) at 7Å.



SAMPLE NUMBERS = numbers underlined

AREAS W/ DISTINCT CLAY MINERAL SUITES = — — —

PEAK HEIGHT % OF MONTMORILLONITE, ILLITE & CHLORITE = no's not underlined

0 50

MILES

Figure 1-1. Map showing clay mineral distribution in recent sediment samples.

Area A stream sediments are dominated by illite (52-69 peak-height percent), lesser amounts of chlorite (31-48 peak-height percent) and no montmorillonite (except for a small amount in sample 42). Stream sediments in area C are dominated by chlorite (52-65 peak-height percent), lesser amounts of illite, and, again, no montmorillonite. Stream sediments in area B contain variable but significant amounts of montmorillonite (16-81 peak-height percent) and generally less illite than chlorite. Area D streams also contain variable but significant amounts of montmorillonite (except for sample 52) and less illite than chlorite.

Samples 32, 34, and 36 occur between areas A and B. These sediments contain moderate amounts of montmorillonite and generally less illite than chlorite, perhaps indicating a closer relationship to area B than to area A.

The five sample (1, 59, 62, 67, and 69) from the lower Susitna River should be, and apparently are, mixtures of sediments from areas A and D. Sample 59, from the Skwentna River, for example, is dominated by illite, reflecting a large contribution from area A, while sample 62 from the Susitna River appears to be a mixture of material from areas A and D.

Sample 106 from the Matanuska River, which is also a major stream, probably contains contributions from both the Talkeetna and Chugach ranges.

Samples 22 and 44, both from the upper Susitna River, illustrate the great differences which may be found in sediments from a single river. Sample 44, from just south of Talkeetna, differs markedly from sample 22, collected about 25 miles upstream (in peak-height percent):

	Montmorillonite	Illite	Chlorite
Sample 22	51	20	29
Sample 44	0	57	43

In this case it is suggested that sample 22 represents material deposited from a slightly higher-water stage due to flooding of the Chulitna River and its tributaries in area A. At this time the sediment contribution from the upper Susitna River was probably negligable. If samples had been taken of sediments actively in transport rather than those already deposited adjacent to the streams, such contrasts probably would not be as striking (except during times of flood from particular areas).

Although this method of determining abundances of clay minerals is crude, there is often good agreement for peak-height percentages from closely associated samples. For three samples taken from the Yentna River and one of its tributaries, the results are as follows:

	Montmorillonite	Illite	Chlorite
Sample 28	0	63	37
Sample 30	0	64	36
Sample 38	0	63	37

and for four closely related samples in area C:

Sample 95	0	39	61
Sample 96	0	37	63
Sample 97	0	35	65
Sample 100	0	36	64

These results tend to support the data as measures of real differences in sediment clay mineralogy.

Relationship to Bedrock Geology

Relating clay mineralogy of stream sediments to bedrock geology of source areas is difficult because (1) most of the areas are complex, and (2) for these remote regions not much information is available.

Some observations may be made, however. Montmorillonite is most abundant in area B, where there is active volcanism, and area D, which contains abundant ancient volcanic rocks. This is a reasonable relationship since montmorillonite is commonly thought to originate, to a large extent, from the alteration of volcanic ash.

Area C is dominated by chlorite in stream sediments. This may be logically related to an abundance of metamorphosed graywacke and shale here. Montmorillonite is absent, probably because volcanic rocks are probably of minor extent and there is no modern volcanism.

Area A is dominated by illite. This is a very complex area, but the illite might be a weathering product of feldspars and micas in the abundant intrusive rocks exposed here. The absence of montmorillonite is presumably due to a lack of volcanic ash as parent material.

Detailed Study of Lower Susitna River Area

The 31 samples collected in the lower Susitna area are listed in table 1-2, along with location, descriptions, and clay mineralogy. A variety of materials are represented, including surface sediments from swamps, levee deposits, bottom sediments from small lakes, mud-capped ripples, and one sample of clays actually in transport.

In general terms, these samples contain small to moderate amounts of montmorillonite (0-18 peak-height percent) and nearly equal amounts of illite and chlorite. Variability within the group is apparently not simply related to where the samples were collected (levee, swamp, etc.), grain size (argillaceous sands, silts, or fine clays), or association with organic material. The degree of variation, however, is less than that shown by tributaries upstream. It seems likely, therefore, that these variations are related to differing contributions of tributaries (and their source areas) during floods and/or shifts of the major stream channel.

Seven samples (71, 72, 73, 78, 80, 81, 82) were from swamps or ponds well removed from the Susitna River or its minor tributaries. None of these contained detectable clay minerals. Apparently such areas receive little or no inorganic detrital sediment (clay, silt, and sand) except during major floods or shifts of the channel. The extent of areas accumulating primarily organic sediment is noteworthy; the one in the west side of the Susitna River is about 12 miles long and 4 miles wide (maximum dimensions).

Miscellaneous Samples

Table 1-3 contains locations, descriptions, and peak-height percentages of clay minerals for 13 samples not directly a part of the previous studies.

Six of these (7, 53, 63, 65, 70, and 75) are from older material (Pleistocene(?), probably glacial in origin) underlying modern Susitna River sediments or from the surrounding uplands. They generally contain moderate amounts of montmorillonite (15-31 peak-height percent) and somewhat more chlorite than illite. Their clay mineral composition is variable, and overlaps the variations in clay mineralogy of modern Susitna River sediments. Clay mineralogy is therefore not sufficient to distinguish modern and Pleistocene(?) sediments. This is not unexpected, since they both probably had the same provenance.

The five samples of tidal flat sediments (8, 10, 76, 93, 108) are quite similar to modern Susitna River sediments in that they contain small amounts of montmorillonite and approximately equal amounts of illite and chlorite.

Sample 54 is from a marshy area on the upland west of the Susitna floodplain. It contained no detectable clay minerals. As was suggested for similar samples from the Susitna floodplain, such swamps are probably too far from the rivers to receive inorganic detrital material.

Sample 96 was collected on a mountainside several hundred feet above sea level from a road cut in laminated silt and clay. Most likely this is a glacial lake deposit - - several Pleistocene lakes, some as high as 700 feet above sea level, have been described in the literature. The clay mineralogy of this sample is essentially identical with that of modern streams in the area (see p. 8).

Relationship to Tertiary Sedimentary Rocks

Figure 1-2 shows the proposed stratigraphic nomenclature for Tertiary sedimentary rocks in the Cook Inlet Basin.

The upper part of the Tertiary Kenai Group contains abundant chlorite but very little kaolinite.[2] In the Tyonek-Middle Ground Shoals area this includes the Beluga River member of the Homer Formation and younger rocks. The general absence of kaolinite in modern sediments apparently represents a continuation of provenance conditions from later Tertiary times.

Below the Beluga River member, kaolinite gradually increases in abundance, eventually becoming more abundant than chlorite. A few samples of the Hemlock Formation (from the Swanson River field) contain only minor amounts of chlorite.

None of the modern rivers sampled contains significant amounts of kaolinite. Therefore, the source (in terms of provenance) of the abundant kaolinite in the lower Kenai Group remains unknown.

The major geologic problem here is to account for the abundant kaolinite in the lower Kenai Group and its gradual decrease upward until it is essentially absent in the upper part of the Group as well as in modern sediments. There are at least four alternative explanations:

(1) The supply of kaolinite may have been exhausted (eroded completely), covered up (by faulting or subsidence), or cut off (by major drainage changes.

[2] Illite and montmorillonite are usually present and are sometimes abundant. These clay minerals are not discussed here, however, because the significant relationship appears to be a reciprocal one between chlorite and kaolinite.

COOK INLET BASIN PROPOSED NOMENCLATURE*

	QAL				ALLUVIUM & GLACIAL DEPOSITS	
CENOZOIC	TERTIARY	KENAI GROUP	CLAM GULCH FORMATION 0' - 11,000'	BISHOP CREEK SANDSTONE MBR. 0' - 10,000'	Massive Sand & Conglomerate Beds, Occasional Thin Lignite Bed.	Pay Zones ☼
				COOK INLET SANDSTONE MBR. 300' - 700'	Sand & Conglomeratic Sand	☼
			HOMER FORMATION 6,000'-10,000'	BELUGA RIVER MBR. 0' - 5000'	Claystone & Siltstone, Thin Sub-Bituminous Coal Beds.	☼
				CHUIT RIVER MBR 1000'-2,000'	Siltstone, Claystone, Massive Sub-Bituminous Coal Beds.	
				MIDDLE GROUND SHOAL SANDSTONE MBR. 3,000'-5,000'	Sandstone, Claystone & Siltstone Interbeds, Occasional Coal Bed	○ ☼ ○
			HEMLOCK FORMATION 300'-900'		Sandstone & Conglomerate	○
			WEST FORELAND FORMATION 300'-1,000'		Tuffaceous Siltstone & Claystone Scattered Sand & Conglomerate Beds.	[illegible]
		RESTS UNCONFORMABLY ON OLDER TERTIARY, CRETACEOUS & JURASSIC				

*Presented by K. W. Calderwood and W. Fackler, Phillips Petroleum Company (Anchorage office), at October, 1966, meeting of the Rocky Mountain Section, Amer. Assoc. Petrol. Geol.

Figure 1-2. Cook Inlet Basin proposed nomenclature.

(2) The kaolinite may have been related to earlier Tertiary weathering conditions (warm, humid), rather than to any particular parent material. The colder climate of the later Tertiary may not have been conducive to kaolinite formation.

(3) The formation of kaolinite may have been related to the duration (length of time) of weathering. Low relief in the source area or slow deposition and low relief in the area of accumulation may have provided an opportunity for long-continued weathering during the earlier Tertiary.

(4) Kaolinite in the older rock may be diagenetic in origin, related to higher temperatures and pressures associated with deep burial.

If there have been no major changes in source conditions during later Tertiary times, results of the regional provenance study should provide some basis for deciphering the sources of upper Kenai Group sediments. Beds very rich in montmorillonite are probably related to volcanic ash falls from the northwest side of Cook Inlet. Beds lacking montmorillonite but rich in chlorite probably were derived from the Chugach-Kenai ranges in the southeast side of the Inlet. Illite-rich sediments presumably were derived from areas of acid intrusive rocks, such as that in the northern Susitna Basin. Thick intervals containing nearly equal amounts of illite and chlorite with moderate amounts of montmorillonite might be related to major rivers where mixing of clay minerals from different source areas occurs.

CONCLUSIONS

(1) Several areas can be distinguished which contain distinctive clay mineral suites in stream sediments. Differences in clay mineral suites are probably related to the particular source rocks which occur in each area.

(2) The clay mineralogy of sediments associated with the lower Susitna River is highly variable. These variations are probably related to differences in sediment contributions from tributary streams (which differ in clay mineralogy) during floods and/or shifts of the major stream channel. It does not seem likely that depositional environment (levee, swamp, sand bar, etc.) has any significant effect on clay mineralogy.

(3) This investigation of the clay mineralogy of modern sediments will be useful in interpreting the origin of the Kenai Group. Specifically it provides a basis for anticipating clay mineralogical changes in the Kenai Formation and information pertaining to the known lack of kaolinite in the upper part of this formation.

PART 2 - CLAY MINERALOGY AND PETROLOGY OF TERTIARY MUDROCKS

INTRODUCTION TO PART 2

The main purpose of this study was to describe the clay mineralogy of Tertiary mudrocks in the Cook Inlet region - - simply to see what's there. Although preliminary interpretations are derived from the very limited data - - in terms of provenance, diagenetic modifications, paleoclimates, etc. - - these should be considered only as tentative suggestions. Much more data are needed; furthermore, clay mineralogy and petrology are only a small part of the overall picture, and must be interpreted along with all other geological information.

This study is part of a report of the Sinclair Oil and Gas Company; it is reproduced with only minimal revisions.

Mineralogical examination was restricted to the clay minerals (or, more specifically, the -2 micron fractions) of predominantly argillaceous rocks. Sandstones and the mineralogy of material larger than 2 microns are not considered here.

Several other properties of argillaceous rocks were also examined as an aid to interpreting clay mineralogy and geologic history. These properties include bulk density, pH, sand-silt-clay ratios, and physical appearance.

The present writing is based on 150 samples, distributed as follows:

52 samples, Kachemak Bay section (Kenai Fm.)[3]
33 samples, Beluga and Chuitna section (Kenai Fm.)[3]
40 samples, Swanson River field cores (subsurface Kenai Fm.)[3]
25 samples, Winding Creek section (Chickaloon Fm.)

Each of these four groups will be described briefly, followed by a comparison and summary of the most significant aspects.

KACHEMAK BAY SECTION
(NE of Homer, along west side of Kachemak Bay)

This section consists of 2,000 feet of Kenai Formation;[3] the lower part is Homerian, the upper part Clamgulchian in age. Clays and silty clays predominate, with many continuous coal beds and lesser amounts of sand. The latter are apparently fluvial in origin; they are discontinuous and characterized by cut-and-fill structures.

Figure 2-1 shows clay mineral distribution, sand-silt-clay rations, and bulk density values within this section. Chlorite and illite are the most abundant clay minerals. Kaolinite was identified (by X-ray diffraction) in only one sample but may be present in nondetectable amounts in others. The relative absence of kaolinite is striking, especially compared with its distribution in the other Tertiary rocks.

Montmorillonite distribution is also significant. At two levels in the section it is very abundant, in a few samples almost to the exclusion of other

[3]Now the Kenai Group (Calderwood and Fackler, 1972, Amer. Assoc. Petroleum Geologists Bull., v. 56, p. 739-754).

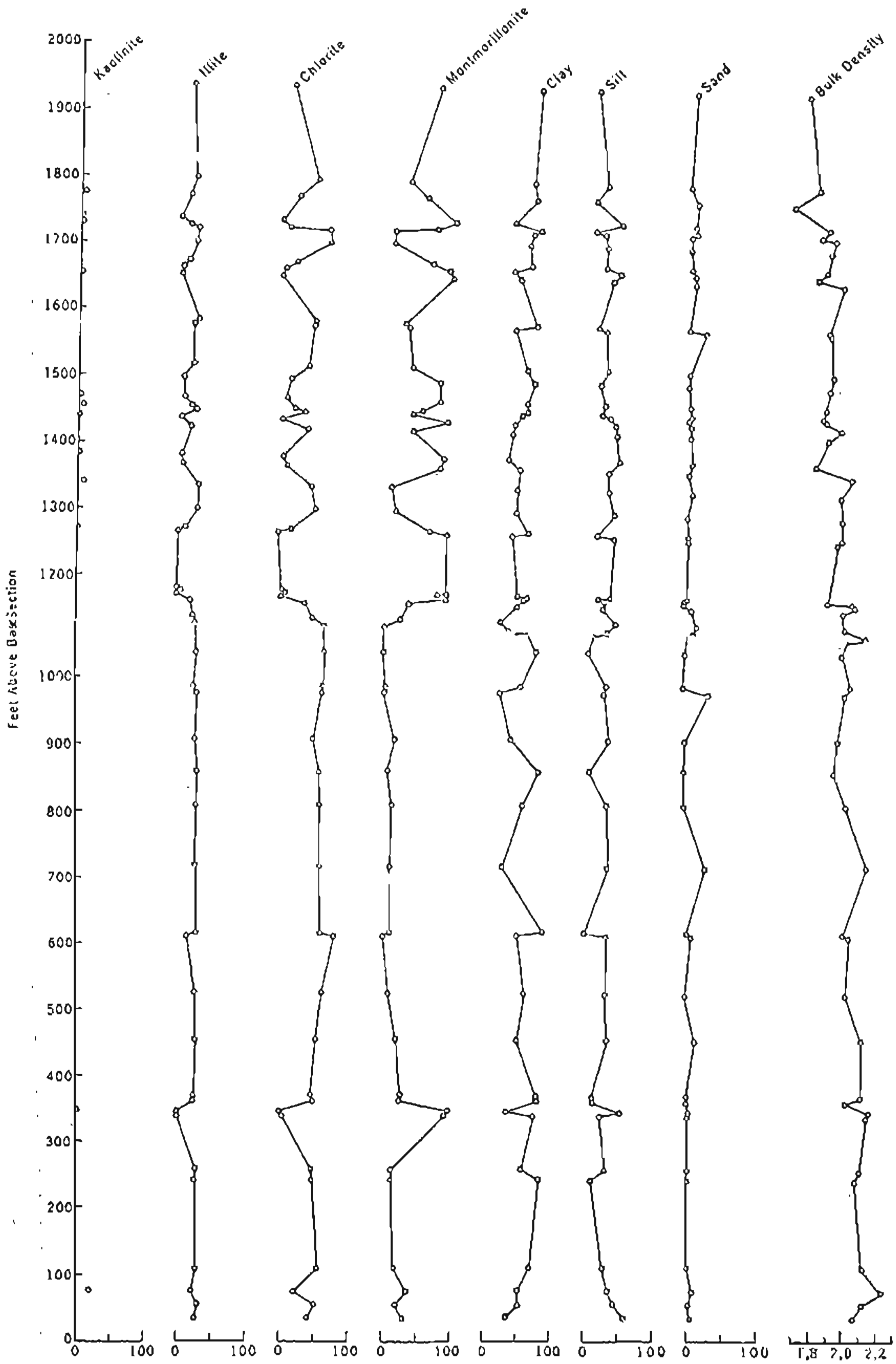


Figure 2-1. Kachemak Bay section - Clay mineralogy, sand-silt-clay ratios, and bulk density.

clay minerals. Through the rest of the section it is a minor component or virtually absent. As a preliminary interpretation, this suggests a periodic influx of montmorillonite associated with ash falls. It should be emphasized however, that none of these montmorillonite-rich samples appear as bentonite beds in the field - - they are normal, gray, argillaceous rocks.

Sand-silt-clay ratios apparently have no relationship to relative abundance of clay minerals - - bearing in mind that these are all argillaceous rocks. This suggests that there has been no differential sedimentation of clay minerals according to grain size.

Bulk densities show a definite regular decrease with depth in the section from about 1.8 to 2.1. No particular relationship of bulk densities with clay mineralogy or sand-silt-clay ratios is evident. Comparison of these density values with published depth-density curves suggests that the Kachemak Bay section was never buried by more than 2,000-3,000 feet of sediment. This value is consistent with the regional geological picture: about 3,000 feet of additional Kenai Formation has been reported overlying the section described here.

BELUGA AND CHUITNA RIVERS SECTIONS
(NW side of Cook Inlet)

Stratigraphic relationships of samples from this area are uncertain and no thick continuous sections were available. This limits any interpretation of mineralogical and other variations within the area although overall comparisons can be made with other sections.

The rocks are primarily argillaceous, with many thick coals, one conglomerate, and a few thick sands.

Kaolinite, chlorite, illite, and montmorillonite are all present but the relative abundances vary considerably. In general, montmorillonite is most variable in abundance and is associated with moderate amounts of illite and chlorite. Kaolinite is usually present in small to moderate amounts and is apparently absent from several samples.

Three samples (they may all be from the same stratigraphic interval) consisted almost entirely of kaolinite. This, combined with the apparent absence of kaolinite in some samples, suggests that kaolinite is secondary in origin; i.e., that it is not an ordinary detrital mineral. Perhaps kaolinite, like montmorillonite, is related to the periodic influx of ash falls.

Bulk densities range from about 1.75 to 2.2. Again, there is no apparent relationship of bulk densities to clay mineralogy or sand-silt-clay ratios. The range of bulk densities suggests that some of the samples were never buried more than 2,000-3,000 feet and others not more than 3,000-4,000 feet.

SWANSON RIVER FIELD CORES
(Upper Kenai Peninsula)

Scattered samples were selected from cores of 13 wells. Some stratigraphic identification (Upper, Middle, Lower Kenai Formation) was provided with the cores, but this subsurface terminology does not correspond exactly to that for surface exposures of the Kenai Formation. Sample depth ranges from about 4,000 to 12,000 feet.

Illite, kaolinite, chlorite, and montmorillonite were present in all samples. Montmorillonite is most variable in abundance, followed closely by illite. Chlorite and kaolinite are also present in variable amounts but are generally less abundant.

Bulk densities range from about 2.05 to 2.57, with no relationship to mineralogy or clay content. When compared to published depth-density curves, these samples are distinctly low in density for their corresponding depths. Since these are relatively young rocks, this suggests that considerable time is required to achieve a uniform depth-density relationship. In other words, rate of compaction may lag behind the rate of burial.

Measured pH values for slurries range from 8.0 to 9.6. No interpretation is offered, but the absence of acid pH values is surprising since these are continental rocks.

WINDING CREEK SECTION
(Near Mile 92, along Glenn Highway northeast of Anchorage)

About 1,200 feet of shales, silts and sandstones were measured in the Chickaloon Formation here. Some black carbonaceous shales were present, but no coal beds.

Clay mineral distribution and bulk density values are shown in figure 2-2. Illite, chlorite, and mixed-layer clay (of undetermined composition) are present in approximately equal amounts. Kaolinite is generally present in small amounts or apparently absent. The most striking feature of clay mineral distribution is its relative uniformity; there is very little variation except for kaolinite, as mentioned above. There is no discrete montmorillonite.

Bulk densities are generally high (2.4-2.6). This suggests burial of at least 8,000 feet or probably more, considering the relatively young age of these rocks. It must be noted, however, that deformation (folding and faulting) could contribute to the high observed densities.

These rocks were too strongly lithified for disaggregation and sand-silt-clay analysis.

SUMMARY AND CONCLUSIONS

(1) The major mineralogical difference between the Kenai and Chickaloon Formations is the absence of montmorillonite and abundance of mixed-layer clay in the Chickaloon. This could be related to differences in provenance since the single Chickaloon section differs in age and geographic location from the Kenai samples. Another possibility is the postdepositional alteration of montmorillonite to mixed-layer clay related to the greater age and depth of burial of the Chickaloon.

(2) Montmorillonite seems to be variable in amount but generally present in samples from the Chuitna-Beluga area and the Swanson River field. These were mostly scattered samples, however. In the continuous section measured along Kachemak Bay, montmorillonite was concentrated only at discrete levels, which suggests a relationship to ash falls. The significance of the two different modes of distribution remains an enigma.

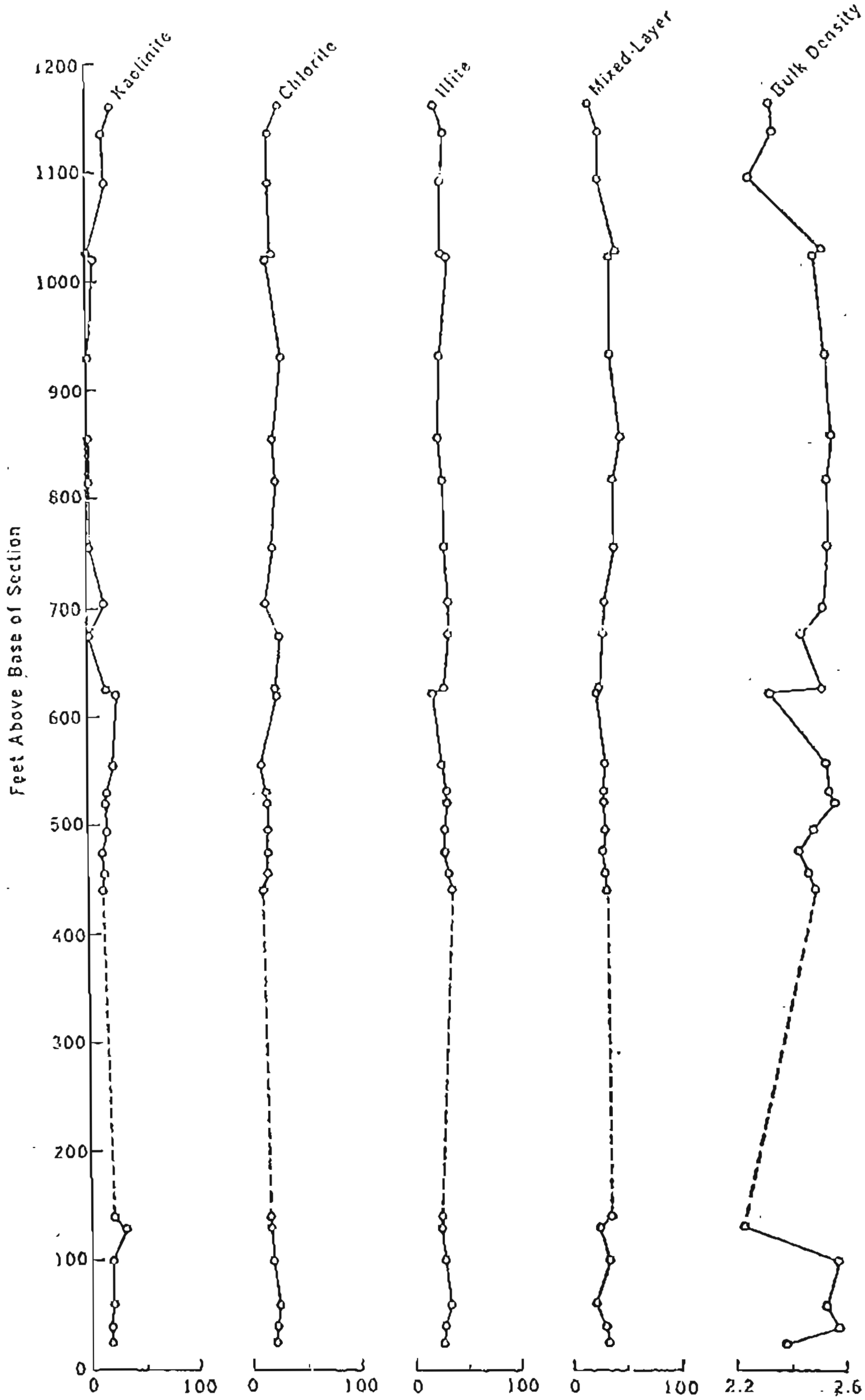


Figure 2-2. Winding Creek section - clay mineralogy and bulk density.

(3) Kaolinite distribution is also significant. It is usually present in small amounts or apparently absent in both the Kenai and Chickaloon formations. The major exception is the relatively pure bed of kaolinite in the Beluga area. This distribution suggests that kaolinite was not a part of the normal detrital sediment derived from land masses around the Cook Inlet area. Instead, it is probably related to some special process, such as the periodic influx of volcanic ash. If so, the alteration conditions resulting in kaolinite rather than montmorillonite need to be investigated.

(4) In none of the Kenai samples was there any relationship between clay mineralogy and sand-silt-clay ratios. Apparently the sedimentation processes were not effective in separating clay minerals according to grain size.