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THE SHUBLIK FORMATION AND ADJACENT STRATA IN NORTHEASTERN ALASKA; DESCRIPTION, MINOR ELEMENTS, DEPOSITIONAL ENVIRONMENTS AND DIAGENESIS

By

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Contents

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Abstract

The Shublik Formation (Middle and Late Triassic) is widespread in the surface and subsurface of northern Alaska. Four stratigraphic sections along about 70 miles of the front of the northeastern Brooks Range east of the Canning River were examined and sampled in detail in 1968. These sections and six-step spectrographic and carbon analyses of the samples combine with other data to provide a preliminary local description of the highly organic unit and of the paleoenvironments.

Thicknesses measured between the overlying Kingak Shale of Jurassic age and the underlying Sadlerochit Formation of Permian and Triassic age range from 400 to more than 800 feet but the 400 feet, obtained from the most completely exposed section, may be closer to the real thickness across the region. The sections consist of organic-rich, phosphatic, and fossiliferous muddy, silty, or carbonate rocks. The general sequence consists, from the bottom up, of a lower unit of phosphatic siltstone, a middle unit of phosphatic carbonate rocks, and an upper unit of shale and carbonate rocks near the Canning River and shale, carbonate rocks, and sandstone to the east.

Although previously designated a basal member of the Kingak Shale (Jurassic), the upper unit is here included with the Shublik on the basis of its regional lithologic relations.

The minor element compositions of the samples of the Shublik Formation are consistent with their carbonaceous and phosphatic natures in that relatively large amounts of copper, molybdenum, nickel, vanadium and rare earths are present. The predominantly sandy rocks of the underlying Sadlerochit Formation (Permian and Triassic) have low contents of most minor elements. The compositions of samples of Kingak Shale have a wide range not readily explicable by the nature of the rock: an efflorescent sulfate salt contains 1,500 ppm nickel and 1,500 ppm zinc and large amounts of other metals derived from weathering of pyrite and leaching of local shale. The only recorded occurrence of silver and 300 ppm lead in gouge along a shear plane may be the result of metals introduced from an extraneous source.

The deposits reflect a marine environment that deepened somewhat following deposition of the Sadlerochit Formation and then shoaled during deposition of the upper limestone-siltstone unit. This apparently resulted from a moderate transgression and regression of the sea with respect to a northwest-trending line between Barrow and the Brooks Range at the International Boundary. Nearer shore facies appear eastward.

The phosphate in nodules, fossil molds and oolites, appears to have formed diagenetically within the uncompacted sediment.

Introduction

The Shublik Formation in northeastern Alaska is a distinctive unit of dark-colored shale and carbonate rock of Triassic age. Originally defined in northeastern Alaska by Leffingwell (1919, p. 115-116), the unit has since been found to be a widespread blanket-type deposit that extends northwestward in the subsurface (Collins, 1958, p. 270) and westward to the Chukchi Sea (Keller and others, 1961; Patton and Tailleur, 1964; Chapman and others, 1964; and Campbell, 1967). The unit has been studied in some detail recently because of its low-grade oil shale content (Chapman and others, 1964, p. 349; Tailleur, 1964) and the content of trace metals in some beds (Tourtelot and others, 1967; and Ugolini and others, 1963). The recent discovery of oil in north coastal Alaska in rocks above and below the Shublik Formation has heightened interest in this organic-rich unit as a source for the petroleum.

In 1968, Tourtelot and Tailleur examined the Shublik Formation on the north side of the Brooks Range east of the Canning River as part of a reconnaissance search for trace elements and to obtain additional data on oil shale. This was partly an extension of the work done in 1965 by Tailleur and Donnell west of the Canning River with the support of the Naval Office of Petroleum and Oil Shale Reserves.

This report presents the stratigraphic sections measured east of the Canning River, sample descriptions, six-step spectrographic analyses, and analyses for forms of carbon and for equivalent uranium. The relation of the Shublik Formation to adjacent units and the facies changes evident within this relatively small area are discussed as a contribution to the further study of facies changes within northern Alaska as a whole.

Although some features of the composition of the rocks are mentioned, discussion of all the implications of the analyses are deferred.

Sections were measured by tape and compass methods, supplemented by direct measurement of beds in cliffs. The generally complex deformation in the region and poorly exposed or covered intervals in most of the sections makes the interpretation of stratigraphic thicknesses uncertain to some extent. This uncertainty probably is larger than the precision of measurement, which is believed to be on the order of 10 percent.

H. N. Reiser and A. K. Armstrong contributed much to Tourtelot's understanding of Alaska geology in the field. M. E. Johnson provided able assistance in the field. Discussion with E. G. Sable in the office was most helpful. N. J. Silberling identified the fossils of Triassic age. Support in the field was supplied in part by the Naval Arctic Research Laboratory, Barrow (Office of Naval Research).

General character of formations

In northeastern Alaska the Shublik Formation is of Middle and Late Triassic age and measured thicknesses range from about 400 to almost 800 feet. The formation consists of dark-colored carbonate rocks, very black sooty siltstone that is usually called shale, and dark-colored siltstone, some of which has a matrix of carbonate. Phosphate nodules are common in both the carbonate rock and the limy siltstone, and phosphate also occurs as disseminated matrix in both kinds of rocks. Many beds have a bluish cast from the bloom of the weathering phosphate. Fossils are abundant in the carbonate rocks and many beds are shell coquinas with fairly well-preserved fossils and other beds are bioclastic limestones, or fossil hash, made up of shell fragments.

Analyses

The Kingak Shale of Jurassic age (Leffingwell, 1919, p. 119) overlies the Shublik Formation and consists of several thousand feet of soft, flaky, dark-colored shale that is easily eroded.

The Sadlerochit Formation (Leffingwell, 1919, p. 113) underlies the Shublik Formation and is of Permian and Early Triassic age. The Sadlerochit Formation is about a thousand feet thick and consists mostly of sandstone and quartzite. Detterman (1970b) describes facies distributions and the sedimentary history of the Sadlerochit Formation in northeastern Alaska.

The narrow outcrop belt of the Shublik Formation is covered at most places by the debris from the Sadlerochit Formation and older rocks and vegetation. Hard ledges near the top of the Shublik are exposed locally and the characteristic dark carbonate-rock rubble and dark soils permit mapping the formation at many places. The formation is well enough exposed for detailed stratigraphic examination, however, only in cut banks and gorges of streams.

The results of the six-step spectrographic analyses are reported in table 1 to the nearest number in the series 1.0, 0.7, 0.5, 0.2, 0.15, and 0.1. The numbers represent approximate midpoints of intervals on a logarithmic scale. The assigned interval will include the true value about 60 percent of the time. The detection limits and a list of elements looked for but not found are included in the table.

The values for total carbon in table 1 are for all dark-colored samples except some samples of siltstone and sandstone and such materials as phosphate nodules and siderite. If the analyzed sample contained more than 5.0 percent total carbon, the amount of mineral carbon was determined and the amount of organic carbon determined by difference. The carbon in samples that contain less than 5.0 percent total carbon and less than a percent or so calcium can be interpreted to be mostly organic carbon.

Equivalent uranium values in table 1 are reported only for shale samples from the Kingak Shale to provide basic data that may help in the interpretation of gamma-ray logs in test wells for oil and gas.

Stratigraphic sections

Four stratigraphic sections are plotted on figure 1 and their descriptions are included in the text. These and other previously published sections are included in figure 1 to form a generally east-trending cross section about 135 miles long along the north flank of the Brooks Range from the Canning River east to just beyond the Canadian border. Eastward along this cross section, the interval between the Kingak Shale and pre-Shublik rocks thickens from about 400 feet at Fire Creek (sec. 2, fig. 1) to almost 800 feet on the Okpilak River (sec. 4, fig. 1) and then thins to about 500 feet at Joe Creek (sec. 6, fig. 1) and to about 300 feet at Loney Creek (sec. 7, fig. 1) in the northern Yukon Territory. Beds equivalent in age to the Shublik at Joe Creek are largely sandstone. At Loney Creek the beds of Triassic age are largely sandy carbonate rock that lies on pre-Sadlerochit rocks. These sections are presented below with discussion of the lithology of the Shublik Formation and its relation to equivalent beds and to the overlying Kingak Shale and underlying Sadlerochit Formation.

Cache Creek-Canning River section

The section of the upper part of the Shublik Formation and lower Kingak Shale was measured on the south side of Cache Creek in secs. 13 and 14, T. 1 N., R. 25 E. about 6 miles northeast of the junction of Cache Creek and the Canning River (sec. 1, fig. 1; p. 9-12). The lower part of the section forms bluffs at creek level and the upper part of the section has been faulted down and partly slumped against these bluffs. The thickness of these parts is believed to be a minimum.

The gumbo-weathering shale in the upper part (Unit 9, sec. 1; p. 10) represents a rock type not previously recorded for the Shublik Formation. The clay shale is black and limy but weathers to light-gray heavy gumbo, similar in many ways to that formed from bentonitic shales. The shale contains microcrystalline gypsum that represents the oxidation of pyrite.

The beds forming the bluff are two different types of limestone. The lowermost bed is predominantly a siltstone with a matrix of calcite but thin zones of coquina are present. The matrix of calcite consists of grains that appear to have grown in place and are interpreted to be of diagenetic origin, but the calcite shows no petrographic features that would suggest it represents pore filling. Phosphate concretions are abundant and many shell fragments are partly phosphatized. Limestone beds higher in the section seem to be predominantly coquinas. Pyrite is present in noncalcareous siltstone beds. Gypsum coats fracture surfaces and calcite fills seams and veins in some beds.

The uppermost bed of the Shublik (Unit 10, sec. 1; p. 10) is 6 feet of fossiliferous dolomitic limestone that is overlain by flaky silver-gray shale characteristic of the Kingak Shale. The unit contains the pelecypod

Monotis subcircularis cf. M. s. densistriata (Teller). Phosphate nodules are the result of phosphatization of limy mud, and at least one nodule is formed of collophane which accumulated in a shell lying concave upwards. Shell fragments also are replaced by phosphate.

The section of the Sadlerochit Formation shown in figure 1 is taken from Keller, Morris, and Detterman (1961, p. 179) and is their generalization of the Sadlerochit Formation near the Canning River rather than a section measured at a given locality. The formation consists of two members, the Ivishak Member of Early Triassic age and the underlying Echooka Member of Permian age. The upper part of the Ivishak Member consists of siltstone that lies on a cuesta-forming unit of sandstone. The siltstone part of the member contains more sandstone near the Canning River than in the region to the west (Keller and others, 1961, p. 178). The Cache Creek section follows; numbers preceded by "D" refer to analyses on table 1 of this report:

Unit Number	Thickness (feet)	Description
		Kingak(?) Shale, part
13	20 exposed	Shale, black, not silty, hard, flaky; weathers with faintly silver lustre.
		D139246, shale.
12	1	Ironstone concretion with pyritized wood; made up of tiny spherulitic rhomb-shaped masses of siderite that commonly are centered on what looks like quartz. Pyrite replaces rhombs and forms irregular lenses of nearly solid pyrite.
		D139245, siderite concretion.
11	40	Shale similar to Unit 13.
		D139244, shale, 5 ft above base.
	61	Total thickness measured of Kingak Shale.

Unit Number	Thickness (feet)	Description
		Shublik Formation, part
10	6	Limestone, dolomitic; contains fossils and weathers brown; also contains brown phosphate nodules that are the result of phosphatization of limy mud. One nodule still is bordered by shell that formed a trap for the limy mud. Pyrite is abundant as disseminated grains and coalesced solid masses of grains replacing shell fragments, limy matrix and phosphate nodules.
		D139243, limestone, phosphatic.
		USGS Mes. loc. M5054
		Monotis subcircularis cf. *M. s. densistriata* (Teller) *Gryphaea* sp. Indet. finely ribbed pectenacid pelecypod
		Age: early late Norian (or latest middle Norian)
9	100	Clay shale, black, limy; weathers to light gray heavy gumbo and "elephant backs" typical of bentonitic shales, but X-ray analysis shows only illite and calcite in <2 micron fractions; somewhat flaky in upper half. At 2 ft above base is 6-in. bed of olive-gray clay much stained with iron. Gypsum found by X-ray analysis.
		D139242, limy shale, 40 ft above base.
		D139241, shale, 10 ft above base.
		D139240, shale, 2 ft above base.
8	3	Limestone, dark gray to brown; is brecciated and heavily ironstained.
		USGS Mes. loc. M5055
		Halobia cf. *H. cordillerana* Smith *H.* cf. *H. austriaca* Mojsisovics
		Age: Karnian, probably late Karnian
7	25	Limestone, dark gray, shaly; has 0.2 to 0.4-ft hard ledges in upper 5 ft.

Unit Number	Thickness (feet)	Description
		Shublik Formation, part (cont.)
6	8	Limestone, dark gray to black, fossiliferous; is rubbly bedded with many phosphate nodules in upper 3 ft.
		D139239, limestone.
		USGS Mes. loc. M5056
		Undet. spiriferid brachiopod
		Age: indefinite between Middle and Upper Triassic
5	25	Interbedded microcalcarenite and black shale; calcarenite in beds 0.5 to 2.0 ft thick and shale in beds 0.1 to 1.0 ft thick.
		D139238, shale.
4	2	Siltstone, sooty black; contains seams of secondary calcite less than 1 mm thick along bedding planes and some gypsum.
		D139237, siltstone.
3	0.6-1.0	Siltstone, orange-brown, ferruginous, limy; cemented with iron oxides derived from pyrite; some pyrite still remains; represents in part an oxidized sulfide seam.
		D139236, shale.
2	2.5	Shale, dark sooty black, very silty, dolomitic and slightly limy. Bed is highly cleaved and breaks into pencil-like fragments; contains secondary gypsum.
		D139235, shale.
1	20 exposed	Siltstone, gray; weathers black; is slightly sandy and has matrix of calcite and thin zones of fossil hash. Main beds are 2 to 3 ft thick separated by shale partings less than 0.2 ft thick. Zone 1.5 ft thick 3 ft from top contains abundant phosphatic concretions an inch or so in diameter, and many shell fragments are partly phosphatized.
		D139234, limy siltstone.

Unit Number	Thickness (feet)	Description
		Shublik Formation, part (cont.)
		USGS Mes. loc. M5057
		Undet. spiriferid and rhynchonellid brachiopods Fragment of halobiid pelecypod
		Age: late Middle Triassic or younger within Triassic.
	193	Total thickness measured of Shublik Formation.

Exposures terminated at base by creek bed.

Composition

The composition of the Kingak Shale at the Cache Creek locality is expectable for these kinds of rocks. The limy siltstone (sample D139234) of Unit 1 at the base of the Shublik exposures at the Cache Creek locality contains 15,000 ppm (parts per million) or 1.5 percent barium. This relatively large amount of barium is equivalent to about 2.5 percent barite, the mineral in which the barium probably occurs in the sample even though barite is not evident in a thin section of the sample. The 2-foot sooty black siltstone of Unit 4 in the section (sample D139237) contains two to three times as much copper and nickel as the other samples.

Fire Creek section

Fire Creek is a western tributary to the Sadlerochit River and the section was measured in secs. 10, 11, and 15, T. 2 N., R. 28 E. in the narrow gorge of the stream where it leaves the east end of the Shublik Mountains (sec. 2, fig. 1; p. 17-24). The upper part of the Sadlerochit Formation, all of the Shublik Formation, and the lower part of the Kingak Shale are relatively well exposed and seem free of important structural complications.

The upper part of the Sadlerochit Formation consists of cliff-forming quartzitic sandstone overlain by dull to dark-colored soft nonresistant sandy siltstone. These two units seem to correspond to the cuesta-forming unit and the overlying finer grained beds of the Ivishak Member west of the Canning River (Keller and others, 1961, p. 179; see also Detterman, 1970b, p. 0-7).

The Shublik Formation also consists of two parts--a lower unit of dark-colored siltstone that contains many phosphate nodules and an upper, thicker unit of dark-gray to black limestone, interbedded shaly limestone and siltstone, and black shale. Most of the limestone beds contain phosphate nodules. Dark-gray gumbo-weathering shale like that at Cache Creek is present.

Although the uppermost part of the Sadlerochit Formation is so dark colored as to seem from a distance to be part of the Shublik Formation, the contact between the formations seems distinct. The lowermost unit classified here as Shublik (Unit 15, sec. 2) is a very dark-colored siltstone that contains abundant phosphate nodules in the lower 5 feet and in a zone 2 feet thick in the upper part of the 20-foot unit. A little more than 100 feet of the lower Shublik consist of this kind of siltstone although the phosphate content is variable. The siltstone makes a prominent ledge that stands above the underlying somewhat lighter dark-gray to black slightly micaceous siltstone of the uppermost Sadlerochit Formation. Detterman (1970b) reports a 6-inch bed of quartz and chert pebbles 5 feet above the base of the Shublik.

The lower siltstone unit of the Shublik seems to merge upwards into phosphatic limestone beds, some of which are coquinas, by interbedding of the siltstone and limestone. This middle carbonate unit, which forms prominent ledges, is overlain by the gumbo-weathering shale that, in turn, becomes more calcareous upwards by the interbedding of shaly limestone.

The uppermost ledge of the Shublik (Unit 26-28, sec. 2) consists of phosphatic and pyritic limestone and dolomite capped by a 2-foot bed of dolomite, the upper part of which has been altered to siderite. Monotis ochotica (Keyserling) and Gryphaea sp. are present in the limestone at the base of the ledge. The uppermost ledge is shown as sandstone by Detterman (1970b) and excluded from the Shublik Formation by him.

The phosphate nodules in Unit 28 (see section) differ from other nodules in that they contain oolites. The oolites are elliptical with a long axis measuring typically about 0.5 mm and the short axis 0.2 to 0.3 mm. Most are concentrically banded and some of them contain grains of quartz as apparent nuclei. The oolites, like the surrounding phosphatic material in the nodule, are isotropic and consist of carbonate fluorapatite. The long axes of the oolites show no preferred orientation and the oolites are distributed rather evenly through the nodule without being in contact with each other. These features suggest that the oolites did not accumulate as sedimented particles but formed in place in the nodule. Phosphate oolites also occur in the granular siderite at the top of Unit 28. The granular siderite consists of spherulitic aggregates 0.05 to 0.1 mm in maximum dimensions that replace parts of the margins of the oolites, and thus formed later than the oolites. The siderite is continuous along the top of the ledge within the hundred or so feet of outcrop and seems to represent the pervasive alteration of a previous rock, probably limestone. The oolites are similar in appearance to those in the nodules lower in the bed, but under crossed polarizers are seen to be made up of microcrystalline anisotropic phosphate, presumably carbonate fluorapatite.

Oolitic phosphatic nodules of isotropic carbonate fluorapatite in the Shublik Formation have been described by Reed (1968, p. 53) from an area near Lake Peters almost 13 miles south-southeast of the Fire Creek section. He also found oolites of anisotropic carbonate fluorapatite in beds in the same area that he assigned to the base of the Kingak Shale (Reed, 1968, p. 58).

The Kingak Shale on Fire Creek consists of dark gray to black shale and is exposed in patchy outcrops and cut banks for more than a mile downstream. Siderite concretions are common and Inoceramus was found in one of them at a point about 1 1/2 miles east of the mouth of the gorge of Fire Creek.

The Fire Creek section follows:

Unit Number	Thickness (feet)	Description
		Kingak Formation, part
		Note: The following exposures are in a cut bank about 1 1/2 miles northeast of the mouth of the Fire Creek gorge.
31	100 exposed	Shale, black, flaky; is much ironstained and contains ellipsoidal concretions and lenticular masses of siderite. Pyrite forms lenses 1 cm thick and 15-20 cm long. A thin section of shale shows fairly well rounded quartz grains as large as 1 mm in diameter scattered through the shale.
		D139273, shale around siderite.
		D139272, siderite concretion.
		D139271, pyrite.
		D139270, shale.
30	Undet.	Covered interval for 1 1/2 miles; seems to be mostly shale.

Unit Number	Thickness (feet)	Description
		Kingak Formation, part (cont.)
29	50	Shale, dark gray to black, silty, slightly micaceous, soft; weathers to flaky slope. Clay opaque from organic matter. Pyritic siderite concretion 20 ft above base is about 1 ft in diameter. Basal contact distinct.
		D139269, shale, 50 ft above base.
		D139268, siderite concretion.
		D139267, shale, 10 ft above base.
		Shublik Formation
28	2	Dolomite, dark gray; has distinct granular structure, contains irregular oolitic phosphate nodules of isotropic collophane as much as 3 in. in diameter at base; becomes siltstone upwards to middle and then passes upwards into granular siderite of secondary origin. Phosphatic oolites in the siderite are microcrystalline and anisotropic, perhaps as a result of alteration by the process that formed the siderite.
		D139266, siderite.
		D139265, siltstone.
		D139264, phosphatic nodule.
27	15	Dolomite(?), tan to gray; contains rounded phosphate nodules as much as 3 in. in diameter at base and near middle as well as sparsely throughout. Fossiliferous.
		USGS Mes. loc. M5058
		<u>Monotis</u> <u>ochotica</u> (Keyserling) <u>Gryphaea</u> sp. Indet. spiriferid brachiopod (one fragment only)
		Age: late Norian
26	10	Limestone, black, hard, forms ledge; has shaly partings near middle and becomes softer towards top. Upper half contains phosphate nodules as in Unit 27. Limestone is a fossil hash with some phosphate filling shell cavities and cementing matrix. Pyrite is locally abundant. Shale partings consist of tightly packed siltstone.

Unit Number	Thickness (feet)	Description
		Shublik Formation (cont.)
		D139263, pyritic shale.
		D139262, shale.
25	95	Covered interval; slope wash beneath snow bank indicates unit consists of soft slabby limestone with many fossils that probably is interbedded with limy shale. Many of the fossils are preserved as phosphatic steinkerns.
		USGS Mes. loc. M5059.
		Monotis cf. *M.* *subcircularis* Gabb *M.* *scutiformis* cf. *M.* *s.* *pinensis* Westermann *Halobia* sp. indet. *Gryphaea* sp.
		Age: middle and early late Norian
		USGS Mes. loc. M5060
		Halobia *cordillerana* Smith
		Age: late Karnian to early Norian
24	50	Covered interval; material washing out beneath snow bank consists of soft gumbo-weathering flaky shale.
		D139261, shale.
23	10	Limestone, dark gray to black, slabby; interbedded with black limy shale in lower part. Sample from base is entirely coquina made up of very thin and some thicker platy shell fragments; contains black opaque material that either resisted compaction or fills post-compaction voids and probably is phosphate.
		D139260, phosphatic limestone.
		USGS Mes. loc. M5061
		Indet. halobiid pelecypods *Lima* sp. Indet. spiriferid and other brachiopods Phosphatic internal gastropod and pelecypod molds Echinoid spines
		Age: late Middle Triassic to early Late Triassic

Unit Number	Thickness (feet)	Description
		Shublik Formation (cont.)
		USGS Mes. loc. M5062
		<u>Lima</u> sp. Phosphatic internal molds of gastropods and pelecypods
		Age: late Middle Triassic to Late Triassic
22	50	Covered interval.
21	30	Limestone, dark gray to black, silty; contains many crushed and broken fossils and has a bluish phosphatic bloom; is in 1- to 3-ft beds with minor black siltstone partings. Phosphate nodules are sparsely present and there appears to be considerable phosphate cement. Echinoid spines are abundant. Pyrite replaces fossil fragments and occurs as grains in matrix; both dolomite and siderite were found by X-ray analysis.
		D139259, phosphatic limy shale.
		D139258, phosphatic limestone.
		USGS Mes. loc. M5063
		Indet. halobiid pelecypods
		Age: late Middle Triassic to early Late Triassic
20	25	Limestone, dark gray to black interbedded with black limy shale. Beds of shale are 1 to 2 ft thick; fossiliferous.
		D139257, shale, 10 ft from top.
		USGS Mes. loc. M5064
		Phosphatic internal molds of gastropods and pelecypods Indet. pectenacid pelecypod Echinoid spines (slender, longitudinally striated rods like those present in M5061)
		Age: Middle to Late Triassic

Unit Number	Thickness (feet)	Description
		Shublik Formation (cont.)
19	20	Covered interval except for 2- to 4-ft black limestone at top. Phosphate nodules found on slope.
18	15	Covered interval with 3-ft black phosphatic limestone at top. Difficult accessible exposures on north side of creek indicate that Units 18 and 19 are made up of interbedded shale and limestone that constitutes a generally soft unit. Limestone consists of shell fragments and phosphate grains, oolites, and fragments of shell coated with phosphate. Some phosphate grains as large as 1 mm represent phosphatized mud but are deposited here as clastic particles. Thin section amounts to at least 25 percent phosphate or 8 to 10 percent P_2O_5.
		D139256, phosphatic limestone.
17	20	Phosphatic siltstone, black weathering gray, sparsely interbedded with a few beds of slightly micaceous silty shale; has slight bluish bloom. Matrix consists of phosphate. Many of the silt and very fine sand grains (40 to 100 microns) have been coated with isotropic collophane, increasing their size to as much as 200 microns. Irregular particles of silt-free collophane merge with intergranular collophane.
		D139255, phosphatic siltstone.
		D139254, phosphatic siltstone.
16	35	Siltstone, black weathering gray, interbedded in subequal amounts with slightly micaceous silty shale; forms soft unit on slope and contains vague bordered areas that are cemented by phosphate.
		D139253, phosphatic siltstone.
15	20	Siltstone, black, fine-grained; contains numerous black phosphate nodules 0.25 to 1 in. in diameter with some bluish phosphatic bloom in zone 5 ft thick at base and several vaguely defined zones as much as 2 ft thick in upper part. Nodules represent cementation of the siltstone and contain some pyrite. Vague areas of matrix are also phosphate.
		D139252, phosphatic siltstone.
	397	Total thickness Shublik Formation

Unit Number	Thickness (feet)	Description
		Partial section of Ivishak Member of Sadlerochit Formation of Keller, Morris, and Detterman (1961)
		Upper non-resistant unit
14	60	Siltstone, dark-gray to black, slightly micaceous, interbedded with black silty slightly micaceous shale. Bedding surfaces of siltstone show marks of borings or animal trails and prints of nuculid pelecypods. Siltstones are irregularly bedded and slabby; some joint planes have much iron oxide and a few quartz crystals.
		D139251, shale.
13	15	Shale, dark-gray to black, hard, flaky, very silty; unit contains a few 1- to 3-in. beds of siltstone. Pyrite amounts to several percent.
		D139250, shale.
12	10	Siltstone, dark-gray to black, in 3- to 12-in. beds with minor shaly partings.
11	40	Shale, black, silty, flaky, interbedded with black shaly siltstone; forms prominent black soft slope above next lower unit; some siltstone beds show fucoidal markings or trails, and contain obscure prints of pelecypods. Lower contact seems gradational by interbedding but from a distance appears sharp. Nonfucoidal siltstones contain pyrite.
		D139249, pyritic siltstone.
10	40	Siltstone and very fine grained sandstone, quartzitic; dark-gray weathering rusty brown; consists of upper and lower ledges about 15 ft thick in which beds are 1- to 2-ft thick separated by 10 ft of softer and thinner bedded material. Grains tightly intersutured. Pyrite amounts to more than 10 percent of the rock and replaces quartz in masses ranging from about 0.04 to 1 mm in size.
9	65	Covered interval reflecting relatively soft beds that probably consist of shaly sandstone and siltstone.
	230	Total thickness upper non-resistant unit

Unit Number	Thickness (feet)	Description
		Partial section of Ivishak Member of Sadlerochit Formation of Keller, Morris, and Detterman (1961) (cont.)
		Cuesta forming unit
8	90	Quartzitic, fine-grained sandstone in 1 to 4 ft beds separated by shaly sandstone in beds 1 to 2 ft thick; weathers rusty brown. Harder beds "pinch and swell" in thickness along outcrop. (Note: unit observed only in difficult accessible cut bank across creek).
7	3	Sandstone, gray, weathering brown, quartzitic, fine grained.
6	10	Covered interval.
5	5	Sandstone, gray weathering brown, quartzitic, fine grained.
4	5	Sandstone, gray weathering brown, soft and shaly in lower 2 ft; upper part poorly exposed.
		D139248, sandstone, shaly.
3	10	Siltstone, gray weathering brown, sandy, clayey, cemented by silica.
		D139247, siltstone.
2	20	Covered interval.
1	150 (est.)	Sandstone, quartzitic, gray weathering olive tan; in 1 to 2 ft beds that are more apparent at top of cliff formed by unit. About 1/3 of the grains are chert, and some of the remainder are grains of polycrystalline quartz from an igneous or metamorphic terrane. Grains are so completely intersutured that original shapes of most cannot be made out. Chert grains tend to be rounder than others.
	293	Total thickness measured of Cuesta forming unit.
		Total thickness measured of Sadlerochit Formation.

Composition

The rocks at the two localities in the Kingak Shale, at the mouth of the gorge of Fire Creek (Unit 29) and 1 1/2 miles to the northeast (Unit 31) have somewhat different compositions (table 1). The compositions of samples from Unit 29 at the base of the Kingak Shale (samples D139269, 268, and 267) shows no distinctive features. The shale of Unit 31, however, (sample D139270) contains 700 ppm vanadium, 200 ppm nickel, and 100 ppm copper, all of which amounts are distinctly higher than the other Kingak samples from Fire Creek. The pyrite from this locality contains relatively large amounts of copper, molybdenum, and nickel. The carbon content of this sample, 1.06 percent, is almost entirely organic carbon but is smaller than the carbon content of other Kingak samples.

The compositions of the samples of the Shublik Formation generally reflect their carbonaceous and phosphatic natures. The siderite, dolomitic siltstone, and phosphate nodule from Unit 28 (samples D139266, 265, and 264), the uppermost ledge of the Shublik, have unusual compositions that will be discussed separately.

The two shale samples from Units 24 and 20 (D139261 and D139257) probably have a typical heavy-metal composition for clayey rocks containing both organic matter and pyrite. Thus the relatively large contents of vanadium and nickel seem normal. The heavy-metal composition of the associated samples of phosphatic limestone and the samples of phosphatic siltstone from the lower part of the Shublik represent the interaction of two processes. The first is the contribution of rare earth elements, and perhaps some heavy metals, by the phosphate component of the samples. This is shown particularly by the lanthanum and yttrium contents. The second is the dilution of element content by calcium carbonate and silica. Although the effect of these processes is evident from the analyses, different elements are affected differently. Nickel values are erratic, and like chromium, nickel occurs in larger absolute amounts in the limy rocks than in the siltstones.

In general, the amounts of minor elements reported here seem to be smaller than those reported by Detterman for 5-foot channel samples (Detterman, 1970a). In addition, Detterman (1970a) reports zinc in two samples judged to be approximately equivalent to the interval from which samples D139257-258 were collected, whereas zinc was not reported in any of the present samples from Fire Creek.

The three samples from the complex uppermost ledge of the Shublik Formation (D139266, 265, 264) have unusual compositions. Sample D139264 is a phosphate nodule that includes grains of quartz and, from the amounts of aluminum and iron reported, other minerals as well. The phosphatic material is pure enough, however, for large amounts of the rare-earth elements such as cerium, lanthanum, neodymium and yttrium to be present. This sample is the only one in which dysprosium, erbium, and holmium were reported. The amounts of lanthanum, neodymium, and yttrium are about twice the modal values reported by Gulbrandsen (1966) for the Phosphoria Formation but the chromium content is about the same as Gulbrandsen's modal value. Nickel and vanadium are higher than the modal values but copper and molybdenum are distinctly lower. The samples of siltstone (D139265) and siderite (D139266) contain 1,500 ppm chromium and 700 ppm vanadium. The siderite also contains 100 ppm nickel. Judging from the amounts of iron, magnesium, calcium, and manganese reported, the siderite is nearly a pure iron carbonate. These amounts of chromium and vanadium are 5 to 10 times higher than those reported in siderites by Weber and Williams (1965) and Landergren (1948, p. 92) as well as higher than the amounts in samples of siderite from the Kingak Shale at Cache Creek (D139245), Fire Creek (D139268 and 272) and the Aichilik River (D139293). Perhaps these amounts represent contributions to the composition of the siderite and associated siltstone by the secondary processes suggested to be responsible for the siderite (see p. 16).

The composition of the Sadlerochit Formation is about normal for generally dark-colored siltstone and shale. Most elements are present in small amounts because of dilution with silica. The 100 to 150 ppm vanadium seems larger than would be expected for this kind of rock.

Hula Hula River section

The Hula Hula River section is poorly exposed, contains sheared and jumbled masses of rocks in the upper part, and evidently is not a reliable record of the thickness of the Shublik Formation (sec. 3, fig. 1, p. 29-32). The sequence of lithologies, however, seems comparable to that in the Fire Creek section. The section was measured in sec. 31, T. 2 N., R. 32 E. and sec. 6, T. 1 N., R. 32 E. on the east bank of the Hula Hula River.

The highest beds of the Sadlerochit Formation that are exposed are vertical standing, brown-weathering fine-grained quartzite (Unit 1) similar to the quartzite of the cuesta-forming unit in the country to the west. The stratigraphically overlying covered interval includes the soft beds at the top of the Ivishak Member at Fire Creek, and perhaps some of the Shublik Formation as well.

The oldest beds of the Shublik actually exposed are hard, sooty-black siltstone with many phosphate nodules (Unit 3) comparable to the lowest bed of the Shublik at Fire Creek. The siltstone stands vertically and seems to be followed in normal stratigraphic succession by dark-gray to black limestone containing phosphate nodules. The rocks are highly sheared and it seems likely that any soft beds between the siltstone and limestone may have squeezed out. The next group of poorly exposed rocks is mixed and sheared with large blocks lying in different attitudes. A shear plane cuts the base of the highest ledge of the Shublik and the underlying poorly exposed rocks are much jumbled.

This uppermost ledge of the Shublik is overlain by the Kingak Shale without an evident structural discontinuity. The ledge also can be traced by air to the Okpilak River and on to the Aichilik River almost 30 miles to the east. Although the ledge is a fine-grained quartzite at both places, it contains phosphate nodules and is correlated by us with the uppermost ledge of the Shublik Formation at the Fire Creek section to the west.

The Kingak Shale is more or less continuously exposed for a mile or more to the north in cut banks along the river.

The Hula Hula River section follows:

Unit Number	Thickness (feet)	Description
		Kingak Shale, part
14	Indet.	Kingak Shale is well exposed in bluffs along the east side of the river for a little more than a mile north of the ledge at the top of the Shublik Formation. The outcrops are distorted and jumbled and no section can be measured. The shale is black and flaky; much of it weathers to pencil-like pieces. Ironstone concretions are abundant in the southernmost exposures and decrease in numbers to the north. Several 1 X 10 cm lenses of pale-yellow sulfide minerals parallel the bedding in the southernmost exposure. In thin section, clay minerals are highly oriented and shale is silty with opaque organic matter making up matrix.
		D139286, shale from farthest north outcrop.
		D139285, shale.
		D139284, shale.
		D139283, pyrite-rich shale.
		Shublik Formation
13	135	Quartzite, gray stained brown, fine grained; in upper 20 ft weathers brown and supports abundant orange lichens. Contains sparse black phosphate nodules with irregular tomato-like forms in upper part. Grains tightly packed. Some diagenetic carbonate is present and unit is locally cut by silica veins less than 1 mm thick; forms prominent ledge and is overlain by Kingak Shale.
12	10	Strongly sheared zone of soft rocks; includes silty micaceous shale in pieces several feet in maximum dimension and much secondary calcite and sulfate minerals. Shale is petrographically similar to shale in Unit 13. Although sheared, nothing was seen that would indicate the unit is out of stratigraphic position. Some limestone with phosphate nodules is present.
		D139282, sulfate minerals.
		D139281, shale.

Unit Number	Thickness (feet)	Description
		Shublik Formation (cont.)
11	20	Quartzite, gray; weathers brown; fine-grained; in prominent 2-ft beds separated by 0.5-ft units of soft sandstone; contains phosphate nodules with irregular tomato-like forms in the upper 5 ft.
10	2	Intermixed sandy shale, sulfide minerals and secondary sulfate minerals; could represent a secondarily mineralized shear zone but similar zones were found in the same position on Fire Creek and the Aichilik River.
		D139280, pyritic shale.
9	100	Limestone and limy shale, jumbled and sheared; harder pieces contain sparse *Halobia* prints. Limestone is a shelly calcarenite. Thickness is a subjective estimate that compensates for beds appearing to be in low anticline.
		D139279, shaly phosphatic limestone.
8	200	Covered interval: thickness is estimate based on probable continuation of north dip suggested by Unit 7.
7	150	Jumbled blocks of calcarenite without recognizable fossils but containing black phosphate nodules. Attitudes of blocks 5 X 10 X 20 ft are chaotic but a north dip is inferable. Phosphate nodules represent pre-compaction cementation of a silty calcarenite. The matrix limestone is mostly recrystallized but contains the same shell fragments that are abundant in the nodules.
		D139278, limestone.
6	200	Covered interval: thickness is estimate based on probable continuation of vertical dips of Unit 5.
5	45	Limestone, black; contains many scattered black phosphate nodules; vertical lower contact could be a fault. In thin section rock is fundamentally a siltstone with a matrix of diagenetic calcite that amounts to 50 percent or more of the sample. The phosphate nodules seem to represent pre-compaction cementation. Very thin shell fragments occur in both nodules and matrix. Rock is veined with calcite and quartz.
		D139277, phosphatic limestone.

Unit Number	Thickness (feet)	Description
		Shublik Formation (cont.)
4	100	Quartzite, black, very fine-grained, silty, slightly micaceous; contains 1-in. or smaller black phosphate nodules that may amount to more than 30 percent of the rock in a bed about 2 ft thick near the top. Unit is highly cleaved and both upper and lower contacts could be faults in vertical beds. Nodules appear to represent pre-compaction cementation of siltstone. The nodules contain phosphatized echinoderm spinelets and some pyrite. The borders of the nodules are gradational and an individual quartz grain can extend from the main mass of sandstone into the nodules. Structural deformation has produced shear zones of micaceous clay; carbonate veins cut the rock.
		D139276, phosphatic quartzitic siltstone.
3	30	Siltstone, sandy, black; contains phosphate nodules at top. Unit is highly cleaved. Grains are closely packed; diagenetic carbonate is conspicuous.
		D139275, siltstone, 10 ft above base.
	992	Apparent thickness Shublik Formation: not to be used for isopoch studies.
		Sadlerochit Formation, part
2	300	Covered interval: thickness based on continuation of vertical beds between Units 3 and 1.
1	50 exposed	Quartzite, gray, weathering brown, fine grained; in beds about 1 ft thick. Many grains are chert. Grains closely packed and intersutured except where pyrite formed very early in diagenesis fills original porosity.
		D139274, sandstone, quartzitic.

Composition

The samples of Kingak Shale, Shublik and Sadlerochit Formations from the Hula Hula River (table 1) show no unusual features of composition.

Okpilak River section

This section in the east valley wall of the Okpilak River in sec. 27, T. 1 N., R. 33 E., described by Sable (U.S. Geol. Survey Prof. Paper ___, in press; see also Sable, 1959, p. 64-67; 1965, p. 62-66), consists of generalized data on the Sadlerochit Formation and measurements of the Shublik Formation (sec. 4, fig. 1). This section was not examined during this study.

The Sadlerochit Formation consists of a lower ferruginous sandstone member correlated by Sable with the Echooka Member, a middle shale member and an upper quartzite member that together are regarded by Sable as representing the Ivishak Member. The fine-grained beds in the upper part of the Ivishak Member in the Canning River region and in the Fire Creek section are missing in some sections near the Okpilak River (Sable, written commun., June 1970).

The basal bed of the Shublik Formation is a resistant, partly calcareous sandstone with phosphate nodules and the lithology contrasts sharply with the underlying quartzite of the Sadlerochit Formation. The lower part of the Shublik consists of sandy and silty limestone with phosphate nodules instead of the siltstone seen in other sections, but this sandy portion is overlain by limestone and shale comparable to the carbonate units of other sections. The main carbonate unit is succeeded by interbedded shale and carbonate.

A sequence of resistant light-colored siltstone and fine-grained sandstone above the carbonate was regarded by Sable as a siltstone unit at the base of the Kingak Shale (Sable, 1959, p. 80). This interpretation was based on the change in sedimentational regimen implied by the contrast between the light-colored clastic rocks and the underlying dark-colored carbonate-rich rocks. However, as discussed later, the unit seems best correlated with the uppermost ledge of the Shublik Formation noted in other sections.

Aichilik River section

The Aichilik River section (sec. 5, fig. 1; p. 35-37) was measured in the cut banks along the west side of the Aichilik River in sec. 16, T. 2 N., R. 37 E. but the Kingak Shale was examined for a distance of nearly 2 miles to the north.

The upper part of the Ivishak Member of the Sadlerochit Formation is not exposed. This covered interval above the top of a cliff-forming quartzite may include some beds of the Shublik Formation.

The phosphate-bearing siltstone sequence (Units 4-6) is overlain in normal fashion by a carbonate sequence (Units 7-10) that contains fewer phosphate nodules here than at other places. The overlying covered interval probably consists of interbedded limestone and shale; the covering soil is very dark colored. Above this covered interval is slightly limy siltstone that is ripple marked and contains vague boring-like structures.

The uppermost ledge (Unit 12.5) consists of quartzitic sandstone and siltstone. A 2-foot zone at the base contains much pyrite that in thin section is seen to fill pre-compaction voids in the sandstone and locally replaces quartz grains. Phosphate nodules are present but not abundant.

The overlying Kingak Shale is well exposed in the cut banks to the north along the river. The shale is highly deformed and no stratigraphic sequence could be made out from bluff to bluff. Siderite concretions are abundant and a few limestone concretions are present. Coating of efflorescent pale yellow salts are conspicuous at places and probably are similar to the pervasive efflorescence in the Kingak noted by Keller, Morris and Detterman, 1961 (p. 1962). The Aichilik River section follows:

Unit Number	Thickness (feet)	Description
		Kingak Shale, part
19	Indeterminate	Shale, dark-gray, slightly siliceous; shale flakiness result of cleavage; contains abundant pyritic siderite and slightly limy siderite concretions; many have calcite-filled septa; attitude steep; farthest north cut bank showing bed rock.
		D139301, efflorescent salt from pool along cut bank.
		D139300, shale.
18	0.3-0.5	Iron-stained gouge zone in second bluff south.
17	Indeterminate	Shale, black; pyritic siderite concretions abundant at south end of cut bank but decreases to none upwards at north end of bank 100 ft away; attitude steep.
		D139298, shale.
16	Indeterminate	Shale, dark-gray; clay minerals are highly oriented; contains siderite concretions and minor amounts of pyrite; attitude horizontal.
15	Indeterminate	Shale, dark-gray, silty; both shale and ledge-like pyritic siderite concretions are highly distorted. Outcrop coated with creamy-yellow efflorescent salt.
		D139297, efflorescent salt.
		D139296, shale.

Unit Number	Thickness (feet)	Description
		Kingak Shale, part (cont.)
14	Indeterminate	Shale, black, silty, highly oriented, pyritic; contains elliptical ironstone concretions.
		D139295, shale.
13	Indeterminate	Shale, black; contains abundant siderite concretions 6 to 10 in. in diameter. Outcrop cut by veins and seams of secondary quartz. Pyrite is moderately abundant.
		D139294, clayey shale.
		D139293, siderite concretion.
		Shublik Formation
12.5	100	Quartzite, gray, weathers brown; fine grained; contains sparse black phosphate nodules with irregular tomato-like forms. Beds seem massive but have irregular 1- to 6-in. depositional layers; upper 10 ft is slabby and consists of siltstone and fine-grained sandstone in 1- to 4-in. beds. At base is a highly pyritic zone about 2 ft thick that contains much secondary calcite and quartz in veins and seams; pyrite occurs as 1-in. nodules, as void filling of uncompacted original sand and partly as grain replacement. Diagenetic carbonate is present throughout but is most abundant in lower part.
		D139292, pyritic sandstone.
12	50	Siltstone, gray, locally slightly limy; is ripple bedded and local 6-in. beds are harder than rest of unit; shows vague boring-like structures; contains diagenetic carbonate.
11	120	Covered interval.
10	15	Limestone, black, slabby; forms ledge. Bedding is moderately irregular to wrinkled; contains sparse phosphate nodules and many disseminated silt-size particles of phosphate. Some of these particles are replacements and coatings of shell fragments; others probably are detrital particles.
		D139291, phosphatic limestone.

Unit Number	Thickness (feet)	Description
		Shublik Formation (cont.)
9	50	Poorly exposed; seems to consist of black shaly limestone and limy shale with scattered 3- to 6-in. beds of harder limestone. These beds consist of fossil hash with much diagenetic calcite in an opaque clay matrix.
		D139290, limy shale.
8	25	Limestone, black, thin-bedded, slabby; contains _Monotis_? and _Halobia_; forms ledge; is primarily a coquina with minor opaque clay and pyrite.
		D139289, limestone.
7	70	Limestone, black, soft, shaly, and black limy shale; forms reentrant and contains _Monotis_?
		D139288, limy shale.
6	50	Siltstone, black to gray, quartzitic; forms ledge. Unit inaccessible, but can be seen to contain black phosphate nodules and some shaly partings.
5	30	Siltstone, dark-gray, slabby; forms soft unit; is inaccessible.
4	50	Siltstone and very fine grained sandstone, gray, slabby; weathers brown; capped 2- to 5-ft ledge that seems to contain phosphate nodules; unit is inaccessible.
	560	Total thickness measured of Shublik Formation
		Sadlerochit Formation, part
3	200?	Covered interval. Thickness based on estimate from outcrop photographs.
2	10	Covered interval capped by 5-ft rib of dark-gray siltstone.
1	100 exposed	Quartzite, gray, very fine grained and silty, slightly micaceous; weathers brown and forms cliff; capped by 1-ft bed of siltstone that is contorted into flow rolls about 2 ft broad.
		D139287, quartzitic sandstone.

Composition

The nine samples of the Kingak Shale from the Aichilik River consist of five samples of shale, one sample of clayey siderite, two samples of an efflorescent salt that coats the outcrop and that accumulates along the margins of ephemeral pools at the foot of the cut banks, and one sample of ferruginous gouge along a shear plane.

The shale samples have expectable compositions for shales containing moderate amounts of organic matter and pyrite.

The efflorescent salts (samples D139297 and D139301) have quite different compositions. Sample D139301 contains 1,500 ppm each of zinc and nickel, 300 ppm each of copper, lithium, and yttrium, and 150 ppm cobalt, and is the only sample in this study in which lithium and zinc were found. Sample D139297 of efflorescent salt contains 150 ppm nickel but amounts of other elements similar to or less than those in shales. X-ray analysis of sample D139301 indicates that the salt is primarily an aluminum sulfate. The sulfate presumably is derived from the oxidation of pyrite in the shale and the metals also come from the shale. The salt on the outcrop probably forms each year during the summer and is washed away each winter and spring. The water in the pool may contain large amounts of dissolved metals appropriate for the amounts of nickel and zinc found in the salt. On the other hand, a relatively small amount of salt around a pool probably represents a fairly large volume of water and the metal content of the salt thus is a residual concentration of elements resulting from capillary seepage and evaporation along the margins of the pool. The nickel content of the shale ranges from 50 to 70 ppm, thus the 1,500 ppm in the salt represents a possible concentration of almost 30.

The same concentration factor probably is applicable to zinc, implying that zinc is present in amounts similar to those of nickel and other elements but much below the 400 ppm limit of detection for zinc by six-step spectrographic analysis. Concentration factors for the other metals are smaller than 30. If this approach is correct, the concentration factors for cobalt and copper, for instance, are only about 10. Lithium probably also comes from the shale. The lower limits of detection for lithium is 100 ppm so that sufficient amounts of lithium easily can be present. Other metals such as iron, lead, molybdenum and vanadium were not concentrated in the salt.

The composition of the ferruginous clayey gouge along a shear plane (sample D139299) has several unusual features. The sample contains 5 ppm silver, 300 ppm copper, 30 ppm molybdenum, 300 ppm nickel, 300 ppm lead, and more than 10 percent iron. The copper, nickel, and lead could be derived from the shale but it seems unlikely that the molybdenum and silver were derived from this nearby source. Molybdenum occurs in the Kingak Shale at Cache Creek and Fire Creek and is commonly present in samples of the Shublik Formation at all localities. Molybdenum was not found, however, in any of the samples of Kingak Shale along the Aichilik River, even with a lower limit of detection of 3 ppm. The lower detection limit of silver by six-step spectrographic analysis is 1 ppm and silver was not found in any of the samples from east of the Canning River except in this one. The large amount of iron in the sample indicates that iron has been introduced into the gouge zone, perhaps derived from the nearby rocks by the movement of ground water, although concentration of iron oxides along joints, minor shear planes, and other fractures was not noted in these outcrops. It seems possible that the iron, molybdenum, and silver, and perhaps some of the copper, nickel, and lead were derived from an extraneous source.

The samples of the Shublik Formation from the Aichilik River have expectable compositions except for the sample of limy shale from Unit 9 (D139290). This sample contains 100 ppm cobalt, 150 ppm copper, 300 ppm molybdenum, 500 ppm nickel, and 700 ppm vanadium. All of these values are large compared either to expectable values for this kind of rock or to the values in other samples of Shublik from the Aichilik River.

The sample of the Sadlerochit Formation contains 300 ppm vanadium, which is a rather large amount for a quartzitic sandstone. Otherwise, the composition of the sample is not unusual.

Joe Creek section

The Joe Creek section (sec. 6, fig. 1) of the Shublik(?) Formation (Mountjoy, 1967, p. 28-29) is located about 60 miles southeast of the Aichilik River section and is the easternmost Alaskan section for which a description is available. The rocks are markedly different from those in the Shublik Formation in the region to the west in that the rocks on Joe Creek consist of fine-grained sandstone. Mountjoy's assignment to the Shublik(?) Formation is based on the presence of *Monotis* sp. near the middle of the section. No mention is made of the presence of phosphate nodules. The base of the Shublik(?) Formation is placed at the top of resistant cliff- and ridge-forming sandstones assigned to the Ivishak Member of the Sadlerochit Formation by Mountjoy. The poorly exposed lower part of the Ivishak Member presumably contains more shale than the upper part. A costate spiriferoid interpreted as Permian in age is the basis for recognizing the Echooka Member of the Sadlerochit Formation.

Loney Creek section

The Loney Creek section (sec. 7, fig. 1) (Mountjoy, 1967, p. 31-34) is in the northern Yukon Territory, Canada, and is about 30 miles northeast of the Joe Creek section and 60 miles east of the Aichilik section. The beds equivalent to the Shublik Formation consist of only about 300 feet of sandy limestone; a white quartz conglomerate at the base lies unconformably on rocks assigned to the Neruokpuk Formation (Precambrian(?)-Devonian(?)). Monotis cf. M. ochotica (Keyserling) occurs in siltstone in the upper part of the formation and Oxytoma sp. occurs in the underlying limestone.

Discussion

The presently available information on the Shublik Formation and related strata present problems of correlation that can be discussed now even though positive solutions can be reached only after many more sections have been measured. Such discussion should be helpful in integrating the data from surface outcrops with the growing body of subsurface information in Alaska. These problems concern the assignment of the basal siltstone member of the Kingak Shale of Sable (1959) to the Kingak or to the Shublik Formation; and the meaning of the change in facies from the northeastern Brooks Range sections to the sections in northeasternmost Alaska and adjacent Canada. The nature and origin of the phosphate nodules in the Shublik Formation is of petrologic interest and may contribute to better understanding of the stratigraphy and to further consideration of this material as a potential resource.

Phosphate

The phosphate in the Shublik Formation occurs in siltstone as nodules of isotropic collophane with borders that range from moderately sharp to vague, and in carbonate rock as nodules representing primarily the infilling of mollusk or brachiopod shells or the spaces between shells and to a lesser extent the replacement of shell material itself. Some of the nodules in carbonate rock are oolitic. These characteristics indicate that the origin of the phosphate material is to be sought in the conditions within the sediment after deposition; that is, in the environment of diagenesis. This is in contrast to the origin ascribed to North American bedded phosphates (McKelvey and others, 1953) for which major features of ocean-bottom morphology and attendant sea-water composition and circulation are believed to be responsible for direct precipitation of phosphate on the sea floor (see also Gulbrandsen, 1960, p. 134-138). Many phosphate deposits throughout the world can be related to paleo-oceanographic features (Sheldon, 1964) but the relationship may reflect conditions for the diagenetic formation of the phosphorite within the original sediments rather than direct precipitation of phosphorite.

Although many features of the phosphate nodules in the Shublik have been mentioned previously, some of the petrographic features are repeated here or are expanded upon for completeness.

In the siltstone at Fire Creek (Unit 15), the nodules studied in thin section are isotropic collophane and are mostly equidimensional and rounded in form. Some are ellipsoidal and their long axes are not parallel to bedding. The silt content of the nodules varies considerably from nodule to nodule; some are nearly as silty as the surrounding closely packed siltstone barren of collophane. The boundary between the nodules and the siltstone, although relatively sharp, is gradational on a microscopic scale and grains in the siltstone extend into the nodules. Evidently, the masses formed in place. Within the nodules, the collophane is mostly uniform in appearance. In parts of the nodules where there is less silt than in other parts, rounded masses of collophane as much as half a millimeter in diameter are somewhat darker in color than the groundmass. This color difference may be the result of weathering or the amount of organic matter incorporated in the collophane. Some masses also have a vague concentric structure as though they were incipient oolites. Some silt grains in the nodules seem also to be coated with a layer of collophane a few microns thick that is darker than the groundmass as a whole.

The phosphate in Unit 20 at Fire Creek occurs in the matrix of the siltstone and also as coatings on silt grains. The coated grains are similar in size and shape to the grains that make up the bulk of the bed, but their diameter has been at least doubled by the collophane coatings. Inasmuch as these larger, heavier grains could not have been in hydraulic equilibrium with the other uncoated grains at the time of sedimentation and are not segregated into sedimentational units, it seems likely that the collophane was added to the grains after they were deposited.

The highly silty limestone in the Hula Hula River section (Unit 5) contains collophane nodules that incorporate many thin shell fragments. Although similar thin shell fragments occur in the calcareous siltstone that make up the bulk of the section, the fragments are much less numerous in the matrix than in the nodules, suggesting that solution and redeposition of the shell material contributed to the diagenetic carbonate that makes up much of the rock. Most of the shell fragments preserved in the matrix are armored with collophane analogous to the collophane coated silt grains mentioned above.

The collophane nodules in carbonate rock have two chief modes of occurrence. The most abundant represents cementation of an irregular volume of uncompacted coquina. The shell fragments are not highly oriented parallel to the original bedding surface and the interstices are filled with collophane. The collophane partly replaces the margins of some shell fragments and also replaces small irregular volumes within the shell material itself.

The other chief mode of occurrence is the in-filling of more or less complete shells. This kind of in-filling is responsible for the abundant gastropods and pelecypods preserved as phosphatic steinkerns in the upper and middle of Units 20 and 15 of the Fire Creek section. The filled-in pelecypod shells seen in thin section seem to have lain with the convex side up. This is inferred from the absence of any geopetal arrangement of fragments within the concavity of the shell, such as would seem to be expected if the shell lay with the concave side up. Smaller shell fragments within the concavity range in orientation from random to predominantly parallel to the bedding. The shell fragments are not tightly packed as they are in the limestone outside the shell so it is inferred that the collophane filled the shell before compaction. The collophane within the shell is essentially uniform, but vague areas of lighter and darker color can be seen, presumably reflecting different maounts of organic matter.

The filling of gastropod shells contains less silt and fragments of other shells than the pelecypod shells because of the greater difficulty of filling such shells during sedimentation. Consequently, there is relatively more phosphate in most filled gastropod shells. Remnants of gastropod shell material are replaced by collophane. The collophane is markedly differentiated into dark irregular bodies as large as 0.1 mm, but mostly smaller, in a matrix of lighter colored collophane. The dark bodies do not resemble fecal pellets. Some silt grains are coated with collophane that is continuous with the matrix collophane and the coating is thus indicated to have formed in place within the gastropod shell. No coated grains were seen in the silty carbonate outside the gastropod shell.

Higher in the section at Fire Creek (Bed 28) phosphate occurs in two additional forms. The first is in nodules that are as large as 3 inches in diameter. These nodules contain ellipsoidal oolites as much as 1 mm in maximum dimension, but most oolites are about half that. The oolites are very finely microcrystalline but essentially isotropic, concentrically banded, and show an extinction cross under crossed polars. The long axes of the oolites are randomly oriented, suggesting that the oolites did not arrive at their present position by a sedimentational process. The nodules are crudely layered, however, with bands of very loosely packed quartz grains as much as 0.3 mm in maximum dimension in a collophane matrix. The borders of these bands are completely vague. A few oolites, generally smaller than 0.3 mm occur with the quartz grains and also have random orientation. These quartz-rich bands alternate with collophane layers in which the oolites are loosely packed and in which there also are some quartz grains. Although some oolites have an apparent nucleus of a mineral grain, and a few seem to impinge on adjacent quartz grains, the oolites in general are free of included grains.

The second form of occurrence is as oolites of strongly anisotropic carbonate fluorapatite in the siderite at the top of Bed 28 at Fire Creek (see p. 18). The microcrystalline anisotropic carbonate fluorapatite is believed to represent the alteration of oolites similar to those in the lower part of Bed 28.

The petrographic data indicate that the phosphate in the Shublik Formation was formed diagenetically within the uncompacted primary sediments, whether these consisted mostly of silt or mostly of shell fragments. This is interpreted to mean that the phosphorous content of the interstitial water and other material was higher than in the overlying water. This seems to be the case in many parts of the modern ocean. Brooks and others (1968, p. 407) found phosphate in interstitial water increasing with depth in cores of modern sediments off the coast of southern California and reaching amounts as large as 25 ppm. The source of the phosphate was both organic matter and metal phosphates. Roberson (1966) and Kramer (1964) both suggest that deep ocean water is nearly saturated with phosphate with respect to apatite even where no phosphorite deposits are being formed. These data indicate that phosphate should be deposited primarily within sediments wherever conditions are appropriate.

The abundant organic matter in the Shublik rocks is regarded as an important element in the generation of the phosphate. The large amount of organic matter, however, does not necessarily require any specialized features of deposition such as stagnant basins, great depth of water, to explain its presence in the Shublik. Organic matter accumulates wherever it is produced faster than it is destroyed. The abundant benthonic pelecypods, brachiopods and gastropods in the Shublik indicate that the bottom was oxygenated enough to support these forms. The coquinas of broken shells may indicate that the bottom was close to wave base or otherwise was turbulent enough for shells to be broken. The shales in the upper part of the Shublik Formation at Fire Creek and Cache Creek do not necessarily indicate great depth of water (see p. 49 and 50).

It is possible that the evidently abundant organic production during the time of Shublik deposition resulted from upwelling currents, but the Shublik Formation in northeastern Alaska provides little evidence for the paleogeographic conditions necessary to adduce such a phenomenon.

Unit below shale of the Kingak Shale

Our work indicates that the basal siltstone member of the Kingak Shale of Sable (1959) is lithogenetically closer to the Shublik than to the Kingak. Sable separated it from the Shublik Formation in the Okpilak section on the basis that "the abrupt change from the phosphatic organic shale and limestone of the Shublik Formation to the variable thicknesses of clastic rocks in the basal part of the Kingak *** may indicate an erosional or nondepositional break before deposition of Kingak beds (Sable, 1965, p. 79)." In addition, he considered the possibility that the phosphate nodules in the siltstone had been derived from the older Shublik beds. He suggested also that the siltstone might represent initial clastic influx from a slowly rising eastern or southern source (Sable, 1965, p. 80). Reed (1968) recognized a similar unit at the top of the Shublik Formation in the Lake Peters area.

This clastic unit extends between the Hula Hula and Aichilik sections and seems to be reasonably correlated to the west with the fossiliferous phosphate-nodule-bearing carbonate ledges at the top of the Shublik at Fire Creek and Cache Creek. Although fossils were not found in the siltstone unit, the fossils in the carbonate ledges clearly indicate a Triassic age for them (see secs. 1 and 2, fig. 1). The phosphate nodules in both the siltstone unit and the carbonate ledges seem to provide a meaningful tie between the two contrasting lithologies.

Although it was logical to think that the phosphate nodules in the siltstone unit in the Okpilak section might have been eroded from the underlying Shublik, Sable (oral commun., March 1970) now concurs with Reed's determination (Reed, 1968, p. 58) that the nodules are authigenic in the siltstone. Reed describes phosphatic oolites in the siltstone unit in the Lake Peters area as being composed of anisotropic carbonate fluorapatite in contrast to the isotropic collophane in the Shublik Formation. The same contrast in character of oolites between the uppermost ledge of the Shublik and the underlying rocks is found at Fire Creek. The anisotropic fluorapatite in the siderite bed at Fire Creek is considered to be the result of alteration by the same processes that formed the siderite, and this characteristic of the oolites is regarded as secondary. Although Reed's section of the siltstone unit was not examined in the field, the highly deformed character of the outcrop (Reed, p. 54) makes it seem likely that the anisotropic carbonate fluorapatite there might also be the result of secondary alteration.

The correlation of the phosphate-nodule-bearing upper carbonate ledge of the Shublik Formation with the phosphate-nodule-bearing siltstone to the east also is consistent with the inferred sedimentational history of the region. The upper part of the Sadlerochit Formation is interpreted by Reed (1968, p. 51) to have been deposited in a shallow sea and by Detterman (1970b) to be deltaic in origin. Deposition of the lower part of the Shublik Formation thus represents deepening of the sea to shelf conditions that permitted the accumulation of organic matter. It seems likely that no great depth was reached because the overlying carbonate-rich beds contain shell coquinas that have been winnowed and shell fragments distributed as clastic particles. The shale sequence overlying the carbonate sequence, however, seems to represent a deeper water environment than that of the carbonate sequence, but this depth need not have been greater than the several hundred feet interpreted by Gill and Cobban (1966, p. A38) for black shales. The record up to this point, then, is one of gradual deepening which implies that the time interval was represented by general transgression of the Shublik sea. Based on this transgressive succession, sandstone would have been deposited near shore with organic muds; shell debris accumulated off shore from this, and shale was deposited even further from shore at any given time.

The carbonate ledges at the top of the Shublik at Fire Creek and Cache Creek then would represent a shallowing of the sea and in a horizontal sense reflect a regressive phase. The sandstone and siltstone at the Hula Hula section and country to the east then would represent the seaward retreat of near-shore conditions. The base of this tongue of sandstone and siltstone that merges seaward into carbonate rocks seems to be found in the Joe Creek section.

Facies

Some of the facies changes that take place along the line represented by the sections of the Shublik Formation and related rocks in figure 1 have already been mentioned. In northeastern Alaska and the northwestern Yukon, rocks equivalent to the Shublik Formation evidently represent near-shore conditions in which a lime-rich (Loney Creek section) and a lime-poor environment (Joe Creek section), and probably others as well, were developed (Mountjoy, 1967). These near-shore environments change westward along the line of sections into off-shore situations where much organic material accumulated along with siltstone, limestone, and shale, the latter rock seeming to increase somewhat in importance to the west. In the central and western Brooks Range farther to the west, chert becomes an important constituent of the Shublik Formation (Patton and Tailleur, 1964; Campbell, R. H., 1967) but coquinoid, presumably shallow-water, Monotis limestone is also present. Chert and associated black shale sometimes are interpreted as indicative of very deep water, but opinions differ on this general concept (Pettijohn, 1957, p. 443). No detailed study of chert from the Shublik has been published from which an interpretation of the depth of deposition can be made.

The apparent east to west change along the line of section from near-shore to off-shore deposits in the Shublik Formation may not represent the direction of change in Late Triassic time. In the first place, a present northwest trend of the old shore line is determined by the near-shore Triassic facies at Barrow and Joe Creek. In the second. the postulated counter-clockwise rotation or drift of northern Alaska (Hamilton, W., cited in Sheldon, 1964, p. C110; Tailleur, 1969) would have the palinspastic Triassic shore line continuing northerly from the Triassic shore lines in the Canadian cordillera.

In a region where detailed study is simpler than in northern Alaska, it is unlikely that the rocks at Joe Creek and Loney Creek would be called Shublik. Even though these eastern rocks seem to be the same age as the Shublik, their lithology is so different as to exclude them from that formation as long as the principles of lithostratigraphy are consistently applied. If these eastern rocks were to receive a local designation, it would then seem reasonable to call the sandstone and siltstone (Sable's

Basal Siltstone Member) included in the uppermost Shublik Formation in this study by a local name assigning the sandstone and correlative rocks to a tongue of whatever formation name is applied in the east. Both the sandstone and carbonate facies of the uppermost beds of the Shublik could logically be included in the tongue concept.

The general continuity of facies within the Shublik in sections in figure 1 cannot be followed into the sections west of the Canning River presented by Keller, Morris, and Detterman (1961) although many of the same rock types are present there. This may mean that further facies changes actually take place. It seems likely, however, that the conditions of their reconnaissance field work and the structural complexity of the area studied resulted in it not being possible for complete sections to be found. Even qualitative facies analysis hardly seems possible without additional stratigraphic data being obtained. It seems likely to us, for instance, that the section observed by Reed (1968) near Lake Peters consists only of the middle carbonate unit of the Shublik structurally juxtaposed with the upper sandstone unit of the Shublik, the intervening soft shales having been squeezed out. The seemingly erratic association of rock types, even though a general similarity is maintained, in the sections of Keller and others (1961) may have a similar explanation.

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Table 1. Analyses of samples of Shublik Formation and associated rocks, northeastern Alaska.

[6-step spectrographic analyses were made by B. Wayne Lanthorn. Values are reported to the nearest number in the series 1.0, 0.7, 0.5, 0.2, 0.15, and 0.1, which represent approximate midpoints of intervals on a logarithmic scale. The assigned interval will include the true value about 60 percent of the time. The samples were analyzed by a dilution technique in which SiO_2 was added to the sample to amount to 50 percent; Si, therefore, is not reported. The limits of determination listed below are about twice as large as limits of detection where the dilution technique is not used. Carbon was determined by I. C. Frost and Gaylord Shipley and equivalent uranium was determined by E. J. Fennelly.]

Approximate visual lower limits of determination for the elements analyzed by the 6-step spectrographic method at the Denver Laboratory, Analytical Services Branch. Revised December, 1967.

Element	Percent	Element	Part per million	Element	Part per million	Element	Part per million	Element	Part per million
Al	0.002	Mn	2	Er	100	Nd	140	Sm	200
Fe	.002	Ag	1	Eu	200	Ni	10	Ta	400
Mg	.004	As	2000	Ga	10	Os	100	Tb	600
Ca	.004	Au	40	Gd	10	Pb	20	Te	4000
		B	40	Ge	20	Pd	2	Th	400
Na	.1	Ba	3	Hf	200	Pr	200	Tl	100
K	.4	Be	2	Ho	40	Pt	60	Tm	40
Ti	.0004	Bi	20	In	20	Re	60	U	1000
P	.4	Cd	40	Ir	10	Rh	4	V	14
		Ce	300	La	60	Ru	20	W	200
		Co	6	Li	100	Sb	300	Y	20
		Cr	2	Lu	60	Sc	10	Yb	2
		Cu	2	Mo	6	Sn	20	Zn	400
		Dy	100	Nb	20	Sr	10	Zr	20

Pr, Nd, Sm and Eu looked for only when La or Ce are found. Gd, Tb, Dy, Ho, Er, Tm and Lu looked for only when Y is 50 ppm or more. Ir, Os, Rh and Ru looked for only when Pd or Pt are found.

% - S and PPm - S indicate values are in percent and parts per million and were determined spectrographically.

% - C indicates the values were determined chemically.

Sample abbreviations

The column headed Sample contains abbreviations drawn from the following list. Most of the abbreviations can serve as either a noun or adjective depending on its position where more than one abbreviation is required. The abbreviation farthest to the right is always a noun; the abbreviations to the left of this are adjectives. PHLSSH indicates phosphatic limy shale. The abbreviations for altered, carbonaceous and efflorescent can only be adjectives.

AL	Altered
BE	Bentonite or bentonitic
CB	Carbonaceous
CH	Chert or cherty
CL	Clay or clayey
DL	Dolomite or dolomitic
EF	Efflorescent
GG	Gouge along fault
LS	Limestone or limy
PH	Phosphate or phosphatic
PY	Pyrite or pyritic
QZ	Quartzite or quartzitic
SD	Siderite or sideritic
SH	Shale or shaly
SS	Sandstones or sandy
ST	Siltstone or silty
SU	Sulfate or sulfatic
WO	Wood

(All numbers in Laboratory Number column are prefixed by D139. The complete laboratory number this is D139246.)

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TOURTELOT AND TAILLEUR, 1971

NORTHEAST ALASKA ANALYSES

CACHE CREEK KINGAK SHALE

SAMPLE	LAB NO	AL %-S	FE %-S	MG %-S	CA %-S	K %-S	TI %-S	P %-S	AG PPM-S	B PPM-S
SH	246.	7.00	7.00	0.70	0.20	3.00	0.50	0.0 N	0.0 N	200.
SD	245.	3.00	10.00G	1.50	0.30	0.0 N	0.20	0.0 N	0.0 N	50.
SH	244.	7.00	3.00	0.50	0.30	2.00	0.50	0.0 N	0.0 N	200.

CACHE CREEK SHUBLIK FORMATION

SAMPLE	LAB NO	AL %-S	FE %-S	MG %-S	CA %-S	K %-S	TI %-S	P %-S	AG PPM-S	B PPM-S
PHLS	243.	1.50	2.00	1.00	10.00G	0.0 N	0.05	1.50	0.0 N	50.
LSSH	242.	3.00	1.50	0.70	10.00G	2.00	0.30	0.0 N	0.0 N	100.
SH	241.	5.00	2.00	0.30	10.00G	2.00	0.30	0.0 N	0.0 N	150.
SH	240.	5.00	7.00	0.30	7.00	2.00	0.30	0.0 N	0.0 N	100.
LS	239.	0.70	0.30	0.30	10.00G	0.0 N	0.02	2.00	0.0 N	0.N
SH	238.	0.30	0.20	0.30	10.00G	0.0 N	0.01	0.0 N	0.0 N	0.N
ST	237.	5.00	5.00	0.70	7.00	3.00	0.30	0.0 N	0.0 N	100.
SH	236.	2.00	1.50	0.70	10.00	1.50	0.30	0.0 N	0.0 N	70.
SH	235.	3.00	1.50	0.70	10.00	1.50	0.30	0.0 N	0.0 N	70.
LSST	234.	1.50	1.50	0.50	10.00G	0.0 N	0.15	3.00	0.0 N	50.

FIRE CREEK KINGAK SHALE

SAMPLE	LAB NO	AL %-S	FE %-S	MG %-S	CA %-S	K %-S	TI %-S	P %-S	AG PPM-S	B PPM-S
SH	273.	7.00	3.00	1.00	0.50	7.00	0.30	0.0 N	0.0 N	200.
SD	272.	2.00	10.00G	3.00	7.00	0.0 N	0.15	1.50	0.0 N	50.
PY	271.	0.70	10.00G	0.07	0.15	0.0 N	0.03	0.0 N	0.0 N	50.L
SH	270.	7.00	5.00	0.70	0.20	5.00	0.50	0.0 N	0.0 N	200.
SH	269.	7.00	3.00	0.70	0.05	3.00	0.50	0.0 N	0.0 N	300.
SD	268.	1.00	10.00G	1.50	1.50	0.0 N	0.07	0.0 N	0.0 N	50.
SH	267.	3.00	3.00	0.30	0.15	2.00	0.70	0.0 N	0.0 N	150.

FIRE CREEK SHUBLIK FORMATION

SAMPLE	LAB NO	AL %-S	FE %-S	MG %-S	CA %-S	K %-S	TI %-S	P %-S	AG PPM-S	B PPM-S
SD	266.	3.00	10.00G	1.50	0.70	0.0 N	0.30	0.0 N	0.0 N	50.
ST	265.	2.00	3.00	0.50	1.50	0.0 N	0.50	0.0 N	0.0 N	100.
PH	264.	1.50	7.00	0.50	10.00G	0.0 N	0.07	10.00G	0.0 N	50.
PYSH	263.	3.00	1.50	0.30	3.00	1.50L	0.30	0.50	0.0 N	150.
SH	262.	2.00	3.00	0.30	10.00G	0.0 N	0.15	5.00	0.0 N	70.
SH	261.	7.00	3.00	0.50	10.00G	2.00	0.30	0.0 N	0.0 N	100.
PHLS	260.	0.70	0.50	0.30	10.00G	0.0 N	0.15	1.50	0.0 N	50.
PHLYSH	259.	3.00	1.50	0.70	10.00G	2.00	0.30	1.50	0.0 N	150.
PHLS	258.	2.00	1.00	0.70	10.00G	1.50	0.15	1.00	0.0 N	100.
SH	257.	7.00	5.00	0.50	0.15	2.00	0.70	0.0 N	0.0 N	200.
PHLS	256.	1.50	1.50	0.70	10.00G	0.0 N	0.15	5.00	0.0 N	70.
PHST	255.	1.50	0.70	0.15	5.00	0.0 N	0.07	1.50	0.0 N	70.
PHST	254.	1.00	0.70	0.15	10.00G	0.0 N	0.07	7.00	0.0 N	70.
PHST	253.	2.00	1.50	0.20	1.50	1.50	0.30	0.50L	0.0 N	150.
PHST	252.	2.00	1.00	0.30	10.00G	0.0 N	0.20	3.00	0.0 N	100.

FIRE CREEK SADLEROCHIT FORMATION

SAMPLE	LAB NO	AL %-S	FE %-S	MG %-S	CA %-S	K %-S	TI %-S	P %-S	AG PPM-S	B PPM-S
SH	251.	3.00	3.00	0.30	1.00	1.50	0.30	0.0 N	0.0 N	150.

NORTHEAST ALASKA ANALYSES—CONTINUED

SAMPLE	LAB NO	BA PPM-S	BE PPM-S	CE PPM-S	CO PPM-S	CR PPM-S	CU PPM-S	DY PPM-S	ER PPM-S	GA PPM-S
CACHE CREEK KINGAK SHALE										
SH	246.	1500.	2.	300.L	10.	150.	30.	0.	0.	30.
SD	245.	150.	2.	300.L	10.	70.	30.	0.	0.	20.
SH	244.	700.	0.N	300.L	10.	200.	70.	0.	0.	20.
CACHE CREEK SHUBLIK FORMATION										
PHLS	243.	300.	0.N	0.N	7.	100.	30.	0.N	0.N	0.N
LSSH	242.	2000.	0.N	0.N	10.	150.	50.	0.	0.	15.
SH	241.	1500.	0.N	0.N	10.	200.	30.	0.	0.	15.
SH	240.	1500.	0.N	0.N	7.	150.	30.	0.	0.	15.
LS	239.	500.	0.N	0.N	0.N	70.	15.	0.	0.	0.N
SH	238.	200.	0.N	0.N	0.N	15.	10.	0.	0.	0.N
ST	237.	1500.	0.N	300.L	15.	150.	150.	0.	0.	30.
SH	236.	700.	0.N	0.N	7.	70.	10.	0.	0.	10.
SH	235.	700.	0.N	300.L	7.	150.	15.	0.N	0.N	15.
LSST	234.	15000.	0.N	300.L	7.	150.	30.	0.N	0.N	10.
FIRE CREEK KINGAK SHALE										
SH	273.	1000.	2.	0.N	15.	150.	50.	0.N	0.N	30.
SD	272.	300.	0.N	300.	7.	50.	15.	0.N	0.N	15.
PY	271.	700.	0.N	300.	10.	15.	150.	0.	0.	15.
SH	270.	1000.	5.	0.N	20.	150.	100.	0.	0.	30.
SH	269.	1000.	2.	300.L	7.	150.	15.	0.	0.	30.
SD	268.	300.	0.N	0.N	7.L	50.	15.	0.	0.	10.
SH	267.	700.	2.	0.N	15.	200.	70.	0.	0.	20.
FIRE CREEK SHUBLIK FORMATION										
SD	266.	100.	0.N	0.N	7.	1500.	20.	0.	0.	15.
ST	265.	300.	3.	300.	7.	1500.	20.	0.	0.	10.
PH	264.	200.	0.N	500.	20.	1000.	15.	200.	100.L	10.
PYSH	263.	300.	0.N	0.N	7.	70.	20.	0.	0.	10.
SH	262.	300.	0.N	0.N	7.	150.	20.	0.N	0.N	10.
SH	261.	1000.	0.N	0.N	10.	200.	50.	0.	0.	15.
PHLS	260.	300.	0.N	0.N	0.N	70.	30.	0.	0.	0.N
PHLYSH	259.	500.	0.N	0.N	10.	200.	70.	0.N	0.N	15.
PHLS	258.	300.	0.N	0.N	7.	150.	50.	0.N	0.N	10.
SH	257.	500.	2.	300.L	15.	150.	100.	0.	0.	15.
PHLS	256.	200.	0.N	0.N	7.	100.	30.	0.N	0.N	0.N
PHST	255.	300.	0.N	0.N	7.L	30.	10.	0.N	0.N	0.N
PHST	254.	200.	0.N	0.N	0.N	70.	15.	0.N	0.N	10.
PHST	253.	300.	0.N	0.N	7.	70.	15.	0.	0.	10.
PHST	252.	300.	0.N	300.L	7.	70.	15.	0.N	0.N	10.
FIRE CREEK SADLEROCHIT FORMATION										
SH	251.	300.	0.N	300.L	10.	70.	20.	0.N	0.N	10.

NORTHEAST ALASKA ANALYSES-CONTINUED

SAMPLE	LAB NO	HO PPM-S	LA PPM-S	LI PPM-S	MN PPM-S	MO PPM-S	NB PPM-S	ND PPM-S	NI PPM-S	PB PPM-S
CACHE CREEK KINGAK SHALE										
SH	246.	0.	70.	0.N	30.	0.N	0.N	0.N	50.	20.
SD	245.	0.	70.	0.N	70.	10.	0.N	0.N	70.	50.
SH	244.	0.	100.	0.N	15.	7.	0.N	0.N	70.	20.
CACHE CREEK SHUBLIK FORMATION										
PHLS	243.	0.N	0.N	0.N	70.	15.	0.N	0.	30.	0.N
LSSH	242.	0.	70.	0.N	70.	0.N	0.N	0.N	50.	0.N
SH	241.	0.	0.N	0.N	100.	0.N	0.N	0.	50.	20.
SH	240.	0.	0.N	0.N	15.	7.	0.N	0.	30.	20.
LS	239.	0.	0.N	0.N	30.	0.N	0.N	0.	20.	0.N
SH	238.	0.	0.N	0.N	30.	15.	0.N	0.	15.	0.N
ST	237.	0.	0.N	0.N	200.	15.	0.N	0.N	150.	30.
SH	236.	0.	0.N	0.N	150.	0.N	0.N	0.	30.	0.N
SH	235.	0.N	0.N	0.N	150.	0.N	0.N	0.N	30.	0.N
LSST	234.	0.N	150.	0.N	100.	50.	0.N	150.	70.	0.N
FIRE CREEK KINGAK SHALE										
SH	273.	0.N	100.	0.N	70.	7.	0.N	0.N	100.	30.
SD	272.	0.N	100.	0.N	500.	10.	0.N	150.L	50.	0.N
PY	271.	0.	150.	0.N	50.	100.	0.N	150.L	200.	70.
SH	270.	0.	100.	0.N	150.	0.N	0.N	150.L	200.	30.
SH	269.	0.	70.	0.N	70.	7.	0.N	0.N	30.	20.
SD	268.	0.	70.	0.N	200.	10.	0.N	0.N	15.	0.N
SH	267.	0.	70.	0.N	70.	30.	0.N	0.N	70.	20.
FIRE CREEK SHUBLIK FORMATION										
SD	266.	0.	0.N	0.N	150.	7.	0.N	0.	100.	20.
ST	265.	0.	70.L	0.N	70.	0.N	0.N	0.N	50.	20.
PH	264.	70.	500.	0.N	10.	0.N	0.N	700.	300.	30.
PYSH	263.	0.	70.L	0.N	70.	0.N	0.N	150.L	30.	0.N
SH	262.	0.N	100.	0.N	30.	15.	0.N	150.	70.	20.L
SH	261.	0.	0.N	0.N	150.	0.N	0.N	0.	100.	20.L
PHLS	260.	0.	0.N	0.N	50.	10.	0.N	0.	50.	0.N
PHLYSH	259.	0.N	70.	0.N	70.	7.	0.N	0.N	100.	0.N
PHLS	258.	0.N	70.	0.N	150.	7.	0.N	0.N	50.	0.N
SH	257.	0.	70.	0.N	70.	30.	0.N	0.N	200.	20.
PHLS	256.	0.N	70.	0.N	150.	10.	0.N	0.N	30.	0.N
PHST	255.	0.N	70.	0.N	15.	0.N	0.N	0.N	10.	0.N
PHST	254.	0.N	200.	0.N	7.	0.N	0.N	100.	15.	20.
PHST	253.	0.	0.N	0.N	70.	0.N	0.N	0.	30.	20.
PHST	252.	0.N	150.	0.N	50.	0.N	0.N	150.L	15.	20.
FIRE CREEK SADLEROCHIT FORMATION										
SH	251.	0.N	70.L	0.N	100.	0.N	0.N	0.N	30.	0.N

NORTHEAST ALASKA ANALYSES—CONTINUED

SAMPLE	LAB NO	SC PPM-S	SR PPM-S	V PPM-S	Y PPM-S	YB PPM-S	ZN PPM-S	ZR PPM-S	CORG %-C	CMIN %-C
CACHE CREEK KINGAK SHALE										
SH	246.	30.	150.	300.	30.	5.	0.N	150.	0.B	0.0 B
SD	245.	20.	50.	150.	30.	5.	0.N	70.	0.B	0.0 B
SH	244.	30.	100.	200.	50.	7.	0.N	300.	0.B	0.0 B
CACHE CREEK SHUBLIK FORMATION										
PHLS	243.	10.	700.	70.	70.	3.	0.N	30.	0.B	0.0 B
LSSH	242.	20.	300.	150.	30.	5.	0.N	70.	1.	4.34
SH	241.	20.	500.	200.	30.	3.	0.N	70.	0.B	0.0 B
SH	240.	15.	300.	200.	20.L	2.	0.N	70.	0.B	0.0 B
LS	239.	0.N	1000.	70.	20.	2.L	0.N	0.N	0.B	0.0 B
SH	238.	0.N	700.	100.	20.L	0.N	0.N	0.N	0.B	0.0 B
ST	237.	20.	150.	150.	30.	5.	0.N	200.	0.B	0.0 B
SH	236.	10.	200.	70.	20.	3.	0.N	200.	0.B	0.0 B
SH	235.	15.	300.	100.	70.	7.	0.N	100.	0.B	0.0 B
LSST	234.	30.	700.	150.	200.	15.	0.N	200.	0.B	0.0 B
FIRE CREEK KINGAK SHALE										
SH	273.	30.	150.	200.	70.	5.	0.N	70.	0.B	0.0 B
SD	272.	30.	150.	150.	150.	7.	0.N	30.	0.B	0.0 B
PY	271.	0.N	300.	15.	0.N	5.	0.N	0.N	0.B	0.0 B
SH	270.	30.	150.	700.	50.	5.	0.N	200.	0.B	0.0 B
SH	269.	20.	150.	150.	30.	3.	0.N	150.	0.B	0.0 B
SD	268.	10.	100.	50.	20.	2.	0.N	30.	0.B	0.0 B
SH	267.	30.	70.	200.	30.	5.	0.N	300.	0.B	0.0 B
FIRE CREEK SHUBLIK FORMATION										
SD	266.	20.	30.	700.	20.	7.	0.N	100.	0.B	0.0 B
ST	265.	20.	50.	700.	30.	3.	0.N	150.	0.B	0.0 B
PH	264.	50.	1000.	500.	1500.	70.	0.N	70.	0.B	0.0 B
PYSH	263.	15.	150.	150.	50.	3.	0.N	300.	0.B	0.0 B
SH	262.	15.	700.	100.	150.	7.	0.N	70.	2.	3.82
SH	261.	20.	300.	300.	30.	3.	0.N	70.	1.	4.09
PHLS	260.	10.L	1000.	200.	30.	2.	0.N	20.	0.B	0.0 B
PHLYSH	259.	15.	300.	150.	100.	7.	0.N	150.	0.B	0.0 B
PHLS	258.	15.	700.	100.	70.	5.	0.N	100.	1.	5.06
SH	257.	20.	70.	200.	30.	5.	0.N	300.	0.B	0.0 B
PHLS	256.	15.	700.	50.	100.	7.	0.N	150.	1.	5.35
PHST	255.	10.	150.	70.	70.	3.	0.N	70.	0.B	0.0 B
PHST	254.	15.	700.	150.	300.	15.	0.N	150.	0.B	0.0 B
PHST	253.	15.	70.	150.	30.	3.	0.N	300.	0.B	0.0 B
PHST	252.	15.	500.	70.	150.	7.	0.N	200.	0.B	0.0 B
FIRE CREEK SADLEROCHIT FORMATION										
SH	251.	15.	100.	100.	70.	5.	0.N	300.	0.B	0.0 B

NORTHEAST ALASKA ANALYSES--CONTINUED

SAMPLE	LAB NO	CTOT %-C	EQ U PPM
CACHE CREEK KINGAK SHALE			
SH	246.	1.83	0.8
SD	245.	0.0 B	0.8
SH	244.	3.46	0.8
CACHE CREEK SHUBLIK FORMATION			
PHLS	243.	0.0 B	0.8
LSSH	242.	5.45	0.8
SH	241.	0.0 B	0.8
SH	240.	1.48	0.8
LS	239.	0.0 B	0.8
SH	238.	0.0 B	0.8
ST	237.	4.56	0.8
SH	236.	0.0 B	0.8
SH	235.	3.10	0.8
LSST	234.	4.58	0.8
FIRE CREEK KINGAK SHALE			
SH	273.	0.0 B	30.
SD	272.	0.0 B	0.8
PY	271.	0.0 B	0.8
SH	270.	1.42	20.
SH	269.	1.06	0.8
SD	268.	0.0 B	0.8
SH	267.	2.65	0.8
FIRE CREEK SHUBLIK FORMATION			
SD	266.	0.0 B	0.8
ST	265.	0.0 B	0.8
PH	264.	0.0 B	0.8
PYSH	263.	0.0 B	0.8
SH	262.	5.62	0.8
SH	261.	5.37	0.8
PHLS	260.	0.0 B	0.8
PHLYSH	259.	4.65	0.8
PHLS	258.	6.07	0.8
SH	257.	4.01	0.8
PHLS	256.	6.56	0.8
PHST	255.	0.0 B	0.8
PHST	254.	0.0 B	0.8
PHST	253.	0.0 B	0.8
PHST	252.	0.0 B	0.8
FIRE CREEK SADLEROCHIT FORMATION			
SH	251.	0.70	0.8

NORTHEAST ALASKA ANALYSES—CONTINUED

SAMPLE	LAB NO	AL %-S	FE %-S	MG %-S	CA %-S	K %-S	TI %-S	P %-S	AG PPM-S	B PPM-S
FIRE CREEK SADLEROCHIT FORMATION (CONT.)										
SH	250.	5.00	7.00	0.30	0.70	1.50	0.50	0.0 N	0.0 N	200.
PYST	249.	3.00	3.00	0.30	0.30	1.50	0.50	0.0 N	0.0 N	150.
SHSS	248.	2.00	1.50	0.30	0.15	3.00	0.30	0.0 N	0.0 N	150.
ST	247.	3.00	5.00	0.50	0.15	1.50	0.50	0.0 N	0.0 N	70.
HULA HULA RIVER KINGAK SHALE										
SH	286.	10.00	7.00	1.00	0.20	5.00	0.70	0.0 N	0.0 N	150.
SH	285.	7.00	5.00	0.70	0.30	5.00	0.50	0.0 N	0.0 N	200.
SH	284.	7.00	3.00	0.70	1.50	3.00	0.50	0.0 N	0.0 N	150.
PYSH	283.	5.00	7.00	0.30	0.70	1.50	0.50	0.0 N	0.0 N	150.
HULA HULA RIVER SHUBLIK FORMATION										
SU	282.	5.00	10.00	3.00	10.00G	3.00	0.30	0.0 N	0.0 N	70.
SH	281.	7.00	1.50	0.30	0.30	3.00	0.70	0.0 N	0.0 N	150.
PYSH	280.	1.50	0.70	0.15	1.50	0.0 N	0.30	0.0 N	0.0 N	100.
SHPHLS	279.	1.50	0.70	1.00	10.00G	0.0 N	0.15	5.00	0.0 N	70.
LS	278.	1.00	0.30	0.30	10.00G	0.0 N	0.10	0.0 N	0.0 N	50.
PHLS	277.	1.50	1.50	0.70	10.00G	0.0 N	0.20	3.00	0.0 N	70.
PHQZST	276.	1.50	0.70	0.20	10.00G	0.0 N	0.15	7.00	0.0 N	70.
ST	275.	2.00	1.50	1.00	7.00	0.0 N	0.30	0.0 N	0.0 N	100.
HULA HULA RIVER SADLEROCHIT FORMATION										
QZSS	274.	0.70	0.50	0.10	0.15	0.0 N	0.07	0.0 N	0.0 N	20.
AICHILIK RIVER KINGAK SHALE										
EFSU	301.	2.00	0.70	1.00	0.50	0.0 N	0.03	0.0 N	0.0 N	50.L
SH	300.	7.00	10.00	2.00	1.00	3.00	0.30	0.0 N	0.0 N	150.
GG	299.	3.00	10.00G	0.30	0.70	0.0 N	0.15	0.0 N	5.00	50.
SH	298.	7.00	7.00	1.50	1.50	3.00	0.50	0.0 N	0.0 N	200.
EFSU	297.	10.00	7.00	0.70	0.20	5.00	0.70	0.0 N	0.0 N	200.
SH	296.	7.00	7.00	1.00	0.30	5.00	0.70	0.0 N	0.0 N	200.
SH	295.	7.00	5.00	1.00	0.70	3.00	0.50	0.0 N	0.0 N	300.
SH	294.	7.00	5.00	0.70	0.50	7.00	0.70	0.0 N	0.0 N	200.
SHSD	293.	10.00	7.00	1.50	0.50	5.00	0.70	0.0 N	0.0 N	200.
AICHILIK RIVER SHUBLIK FORMATION										
PYSS	292.	1.00	7.00	0.70	5.00	0.0 N	0.15	0.0 N	0.0 N	70.
PHLS	291.	0.70	0.20	0.50	10.00G	0.0 N	0.03	1.00	0.0 N	-0.N
LSSH	290.	2.00	2.00	0.70	10.00G	0.0 N	0.30	0.0 N	0.0 N	100.
LS	289.	0.70	0.30	0.30	10.00G	0.0 N	0.03	0.0 N	0.0 N	50.L
LSSH	288.	3.00	1.50	1.00	10.00G	1.50	0.30	0.0 N	0.0 N	100.
AICHILIK RIVER SADLEROCHIT FORMATION										
QZSS	287.	7.00	3.00	0.70	0.15	7.00	0.70	0.0 N	0.0 N	100.

NORTHEAST ALASKA ANALYSES—CONTINUED

SAMPLE	LAB NO	CA PPM-S	BE PPM-S	CE PPM-S	CO PPM-S	CR PPM-S	CU PPM-S	DY PPM-S	ER PPM-S	GA PPM-S
FIRE CREEK SADLEROCHIT FORMATION (CONT.)										
SH	250.	300.	0.N	300.L	15.	70.	20.	0.	0.	15.
PYST	249.	300.	0.N	0.N	10.	70.	15.	0.	0.	15.
SHSS	248.	700.	2.	0.N	20.	100.	30.	0.	0.	20.
ST	247.	500.	0.N	300.L	10.	70.	15.	0.	0.	15.
HULA HULA RIVER KINGAK SHALE										
SH	286.	700.	3.	0.N	20.	150.	50.	0.	0.	30.
SH	285.	1000.	3.	0.N	15.	150.	30.	0.	0.	30.
SH	284.	1000.	0.N	0.N	10.	200.	70.	0.	0.	20.
PYSH	283.	700.	0.N	0.N	7.L	150.	20.	0.	0.	15.
HULA HULA RIVER SHUBLIK FORMATION										
SH	282.	1500.	0.N	0.N	15.	200.	20.	0.	0.	20.
SH	281.	2000.	2.	300.L	0.N	150.	15.	0.N	0.N	30.
PYSH	280.	700.	0.N	300.L	7.	100.	15.	0.	0.	10.
SHPHLS	279.	1000.	0.N	0.N	7.L	150.	70.	0.N	0.N	10.L
LS	278.	150.	0.N	0.N	0.N	70.	5.	0.	0.	10.L
PHLS	277.	200.	0.N	0.N	7.	100.	30.	0.N	0.N	10.
PHQZST	276.	300.	0.N	300.L	7.	50.	15.	0.N	0.N	10.L
ST	275.	300.	0.N	0.N	7.	70.	7.	0.	0.	10.
HULA HULA RIVER SADLEROCHIT FORMATION										
QZSS	274.	100.	0.N	0.N	0.L	7.	5.	0.B	0.B	0.L
AICHILIK RIVER KINGAK SHALE										
EFSU	301.	70.	5.	0.N	150.	15.	300.	0.N	0.N	0.N
SH	300.	700.	2.	0.N	15.	70.	30.	0.	0.	30.
GG	299.	150.	0.N	0.N	30.	30.	300.	0.	0.	15.
SH	298.	500.	2.	0.N	15.	70.	30.	0.	0.	20.
EFSU	297.	700.	3.	0.N	15.	150.	50.	0.	0.	20.
SH	296.	700.	3.	0.N	15.	150.	50.	0.	0.	30.
SH	295.	700.	3.	0.N	15.	100.	30.	0.	0.	20.
SH	294.	700.	5.	0.N	20.	150.	30.	0.	0.	30.
SHSD	293.	1000.	5.	0.N	20.	200.	30.	0.	0.	30.
AICHILIK RIVER SHUBLIK FORMATION										
PYSS	292.	300.	0.N	0.N	0.N	70.	15.	0.	0.	10.L
PHLS	291.	500.	0.N	0.N	0.N	150.	7.	0.	0.	10.L
LSSH	290.	500.	0.N	0.N	15.	100.	150.	0.	0.	15.
LS	289.	70.	0.N	0.N	0.N	15.	7.	0.	0.	10.L
LSSH	288.	700.	0.N	0.N	10.	150.	30.	0.	0.	15.
AICHILIK RIVER SADLEROCHIT FORMATION										
QZSS	287.	1500.	2.	0.N	15.	150.	30.	0.	0.	20.

NORTHEAST ALASKA ANALYSES—CONTINUED

SAMPLE	LAB NO	HO PPM-S	LA PPM-S	LI PPM-S	MN PPM-S	MO PPM-S	NB PPM-S	ND PPM-S	NI PPM-S	PB PPM-S
FIRE CREEK SADLEROCHIT FORMATION (CONT.)										
SH	250.	0.	0.N	0.N	30.	0.N	0.N	0.	70.	20.
PYST	249.	0.	0.N	0.N	70.	0.N	0.N	0.	20.	20.
SHSS	248.	0.	70.	0.N	30.	0.N	0.N	0.N	50.	30.
ST	247.	0.	0.N	0.N	70.	0.N	0.N	0.	30.	0.N
HULA HULA RIVER KINGAK SHALE										
SH	286.	0.	70.	0.N	200.	0.N	50.	0.N	70.	20.
SH	285.	0.	70.L	0.N	100.	0.N	30.	0.N	50.	20.
SH	284.	0.	70.	0.N	150.	0.N	30.	0.N	50.	20.L
PYSH	283.	0.	0.N	0.N	50.	0.N	30.	0.	20.	20.
HULA HULA RIVER SHUBLIK FORMATION										
SU	282.	0.	70.	0.N	700.	20.	20.	0.N	70.	30.
SH	281.	0.N	100.	0.N	30.	0.N	30.	0.N	20.	20.
PYSH	280.	0.	0.N	0.N	50.	7.	20.	0.	15.	0.N
SHPHLS	279.	0.N	100.	0.N	70.	0.N	0.N	0.N	70.	0.N
LS	278.	0.	0.N	0.N	200.	7.	20.L	0.	10.	0.N
PHLS	277.	0.N	100.	0.N	150.	7.	20.L	0.N	50.	0.N
PHQZST	276.	0.N	150.	0.N	70.	7.	0.N	0.N	15.	0.N
ST	275.	0.	0.N	0.N	300.	0.N	20.	0.	15.	0.N
HULA HULA RIVER SADLEROCHIT FORMATION										
QZSS	274.	0.B	30.	0.L	70.	0.N	0.L	0.N	5.	0.N
AICHILIK RIVER KINGAK SHALE										
EFSU	301.	0.N	0.N	300.	500.	0.N	20.	0.	1500.	0.N
SH	300.	0.	70.	0.N	700.	0.N	30.	0.N	50.	20.
GS	299.	0.	0.N	0.N	70.	30.	20.	0.	300.	300.
SH	298.	0.	0.N	0.N	500.	0.N	30.	0.	50.	20.
EFSU	297.	0.	0.N	0.N	70.	0.N	30.	0.N	150.	30.
SH	296.	0.	0.N	0.N	100.	0.N	30.	0.	70.	20.
SH	295.	0.	0.N	0.N	150.	0.N	20.	0.	50.	20.
SH	294.	0.	70.	0.N	100.	0.N	20.	0.N	50.	20.
SHSD	293.	0.	70.	0.N	70.	0.N	20.	0.N	70.	30.
AICHILIK RIVER SHUBLIK FORMATION										
PYSS	292.	0.	0.N	0.N	200.	0.N	0.N	0.	20.	0.N
PHLS	291.	0.	0.N	0.N	50.	10.	0.N	0.	15.	0.N
LSSH	290.	0.	0.N	0.N	100.	300.	20.	0.	500.	20.
LS	289.	0.	0.N	0.N	150.	7.L	20.L	0.	10.	0.N
LSSH	288.	0.	70.L	0.N	150.	10.	30.	0.N	50.	0.N
AICHILIK RIVER SADLEROCHIT FORMATION										
QZSS	287.	0.	70.L	0.N	150.	0.N	30.	0.N	50.	0.N

NORTHEAST ALASKA ANALYSES-CONTINUED

SAMPLE	LAB NO	SC PPM-S	SR PPM-S	V PPM-S	Y PPM-S	YB PPM-S	ZN PPM-S	ZR PPM-S	CORG %-C	CMIN %-C
FIRE CREEK SADLEROCHIT FORMATION (CONT.)										
SH	250.	20.	100.	150.	30.	5.	0.N	200.	0.B	0.0 B
PYST	249.	20.	100.	100.	30.	5.	0.N	300.	0.B	0.0 B
SHSS	248.	50.	150.	150.	20.	3.	0.N	150.	0.B	0.0 B
ST	247.	15.	70.	100.	20.	3.	0.N	100.	0.B	0.0 B
HULA HULA RIVER KINGAK SHALE										
SH	286.	30.	150.	200.	20.	5.	0.N	200.	0.B	0.0 B
SH	285.	20.	100.	150.	20.	3.	0.N	150.	0.B	0.0 B
SH	284.	20.	150.	200.	50.	5.	0.N	300.	0.B	0.0 B
PYSH	283.	30.	100.	150.	30.	5.	0.N	300.	0.B	0.0 B
HULA HULA RIVER SHUBLIK FORMATION										
SH	282.	30.	300.	200.	20.	3.	0.N	200.	0.B	0.0 B
SH	281.	30.	200.	150.	70.	7.	0.N	300.	0.B	0.0 B
PYSH	280.	10.	150.	100.	50.	3.	0.N	200.	0.B	0.0 B
SHPHLS	279.	15.	1000.	70.	150.	7.	0.N	50.	3.	5.25
LS	278.	0.N	700.	70.	20.	2.	0.N	70.	0.	8.01
PHLS	277.	10.	700.	50.	100.	10.	0.N	150.	0.B	0.0 B
PHQZST	276.	10.	500.	70.	70.	7.	0.N	200.	0.B	0.0 B
ST	275.	10.L	150.	50.	30.	3.	0.N	300.	0.B	0.0 B
HULA HULA RIVER SADLEROCHIT FORMATION										
QZSS	274.	0.N	10.	20.	15.	1.	0.N	70.	0.B	0.0 B
AICHILIK RIVER KINGAK SHALE										
EFSU	301.	70.	70.	15.	300.	15.	1500.	0.N	0.B	0.0 B
SH	300.	30.	150.	150.	50.	3.	0.N	150.	0.B	0.0 B
GG	299.	0.N	70.	70.	20.L	3.	0.N	70.	0.B	0.0 B
SH	298.	20.	100.	150.	50.	3.	0.N	200.	0.B	0.0 B
EFSU	297.	30.	70.	150.	50.	5.	0.N	150.	0.B	0.0 B
SH	296.	30.	100.	150.	30.	3.	0.N	150.	0.B	0.0 B
SH	295.	20.	150.	150.	20.	3.	0.N	150.	0.B	0.0 B
SH	294.	30.	150.	200.	30.	3.	0.N	200.	0.B	0.0 B
SHSD	293.	30.	150.	200.	20.	5.	0.N	150.	0.B	0.0 B
AICHILIK RIVER SHUBLIK FORMATION										
PYSS	292.	10.	300.	70.	20.	3.	0.N	100.	0.B	0.0 B
PHLS	291.	0.N	3000.	100.	30.	2.	0.N	20.L	0.	10.30
LSSH	290.	20.	500.	700.	50.	7.	0.N	200.	4.	5.06
LS	289.	0.N	1000.	30.	20.L	2.	0.N	20.	2.	8.96
LSSH	288.	15.	300.	100.	30.	5.	0.N	300.	1.	4.09
AICHILIK RIVER SADLEROCHIT FORMATION										
QZSS	287.	30.	200.	300.	20.	5.	0.N	200.	0.B	0.0 B

NORTHEAST ALASKA ANALYSES-CONTINUED

SAMPLE	LAB NO	CTOT %-C	EQ U PPM
			FIRE CREEK SADLEROCHIT FORMATION (CONT.)
SH	250.	0.0 B	0.B
PYST	249.	0.0 B	0.B
SHSS	248.	0.0 B	0.B
ST	247.	0.0 B	0.B
			HULA HULA RIVER KINGAK SHALE
SH	286.	2.08	20.
SH	285.	0.86	20.
SH	284.	2.48	10.L
PYSH	283.	0.0 B	0.B
			HULA HULA RIVER SHUBLIK FORMATION
SU	282.	0.0 B	0.B
SH	281.	2.56	0.B
PYSH	280.	0.0 B	0.B
SHPHLS	279.	7.93	0.B
LS	278.	8.26	0.B
PHLS	277.	4.24	0.B
PHQZST	276.	0.0 B	0.B
ST	275.	1.82	0.B
			HULA HULA RIVER SADLEROCHIT FORMATION
QZSS	274.	0.0 B	0.B
			AICHILIK RIVER KINGAK SHALE
EFSU	301.	0.0 B	0.B
SH	300.	2.37	10.
GG	299.	0.0 B	10.
SH	298.	2.89	20.
EFSU	297.	0.0 B	0.B
SH	296.	1.41	20.
SH	295.	1.10	20.
SH	294.	0.95	20.
SHSU	293.	0.0 B	0.B
			AICHILIK RIVER SHUBLIK FORMATION
PYSS	292.	0.0 B	0.B
PHLS	291.	10.40	0.B
LSSH	290.	9.57	0.B
LS	289.	10.80	0.B
LSSH	288.	5.14	0.B
			AICHILIK RIVER SADLEROCHIT FORMATION
QZSS	287.	0.0 B	0.B