GEOLOGY of the SLANA DISTRICT, SOUTHCENTRAL ALASKA

By D. H. RICHTER

DIVISION OF MINES & MINERALS — GEOLOGIC REPORT NO. 21

DIVISION OF MINES & MINERALS
DEPARTMENT OF NATURAL RESOURCES
STATE OF ALASKA

JULY 1966

STATE OF ALASKA

William A. Eagan – Governor

DEPARTMENT OF NATURAL RESOURCES

Phil R. Holdsworth – Commissioner

DIVISION OF MINES AND MINERALS

James A. Williams – Director

GEOLOGIC REPORT NO. 21

Geology of the Slana District, Southcentral Alaska

By

D.H. Richter

Juneau, Alaska
June 1966

TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

GEOLOGY OF THE SLANA DISTRICT, SOUTHCENTRAL ALASKA

By D.H. Richter

ABSTRACT

The Slana district is a relatively isolated mountainous area in the eastern Alaska Range that lies north of the Copper River basin between the Chistochina and Slana Rivers. During the period 1963-1965 approximately 230 square miles were mapped in the Slana district and contiguous areas and more than 700 stream sediments collected for geochemical studies.

The mapped area is underlain by a thick assemblage of Permian andesitic volcanics and clastic marine sediments with minor limestone that have been intruded by a linear belt of complex diorite to quartz diorite rocks, a zoned quartz monzonite pluton, and a variety of hypabyssal rocks ranging in composition from gabbro to dacite. Granular schists and gneisses of possible Devonian age are exposed in one isolated area. Stream and glaciofluvial deposits and rock glaciers and landslides of Pleistocene to Recent age mantle much of the bedrock in the district.

The bedded volcanic and sedimentary rocks have been locally severely deformed by the strong, forceful multiple intrusions of the tectonic diorite-quartz diorite complex and domed by the intrusion of the quartz monzonite pluton. Intrusions of the diorite-quartz diorite rocks were accompanied by faulting and overthrusting within the igneous complex. Major faults in the district trend northwest, parallel to the structural grain of the Alaska Range.

Quartz and quartz-carbonate veins containing variable and subordinate amounts of galena, sphalerite, chalcopyrite, and argentiferous tetrahedrite are the principal ore metal deposits in the district. These veins and the major limonite-stained altered areas, together with the known gold placer deposits, occur in a relatively well-defined zone around the southern end of the quartz monzonite pluton. Elsewhere in the district disseminated chalcopyrite occurs locally throughout the diorite complex.

Three strong geochemical stream sediment anomalies are present in the mineralized zone peripheral to the southern end of the quartz monzonite pluton. Lead, zinc, and molybdenum are the principal enriched metals in the anomalies.

INTRODUCTION

The Slana district is a relatively isolated mountainous area in the eastern Alaska Range that lies north of the Copper River basin between the Chistochina and Slana Rivers. This report, which describes the geology, mineral deposits, and geochemistry of approximately 180 square miles in the district and a contiguous area of about 50 square miles east of the Slana River in the Mentasta Mountains, is the final report of a three-year study begun in 1963 by the Division of Mines and Minerals.

Accessibility

The Tok cutoff of the Glenn Highway borders, and runs through, the Slana district for a distance of about 23 miles between Milepost 52 and 75 (figure 1). A large part of the district north of the highway is accessible by tracked vehicle from the Grubstake trail, along Ahtell Creek, and the old Eagle Trail, along Porcupine and Indian Pass Creeks. The old Eagle Trail south of Ahtell Creek, as shown in the maps in figures 2, 5, and 6 is not passable, but the trail can be reached by a road and trail which leaves the highway at Milepost 61 on the north side of Ahtell Creek. No trails have been made in the Mentasta Mountains area east of the Slana River.

No suitable landing areas for wheel planes, other than the gravel strip at Duffy's Tavern on the highway, exist in the district. Float planes, however, can land on Long Lake, Indian Pass Lake, and Suslota Lake.

Previous work

Much of the Slana district has been prospected and since 1898 a number of base metal-silver vein deposits and gold placers have been found. Between 1898 and 1902 the War Department and the U.S. Geological Survey carried out reconnaissance topographic and geologic studies in the Copper River region, and in 1902 geologists Schrader and Mendenhall traversed through parts of the Slana district (Mendenhall and Schrader, 1903; and Mendenhall, 1905). In 1929 the U.S. Geological Survey, with F.H. Moffit as principal investigator, began a reconnaissance study of the eastern part of the Alaska Range with field work continuing up to 1942. The results of these studies have been published in four papers (Moffit, 1932, 1933, 1938, and 1954) all of which describe, at least in part, portions of the Slana district of this report.

Since 1942, when the U.S. Geological Survey completed its reconnaissance investigations in the district, most work has been directed toward economic geology. During Work War II the U.S. Bureau of Mines examined a number of lead prospects in the district as part of their exploration program for critical and essential minerals (Thorne, 1946) but failed to find anything

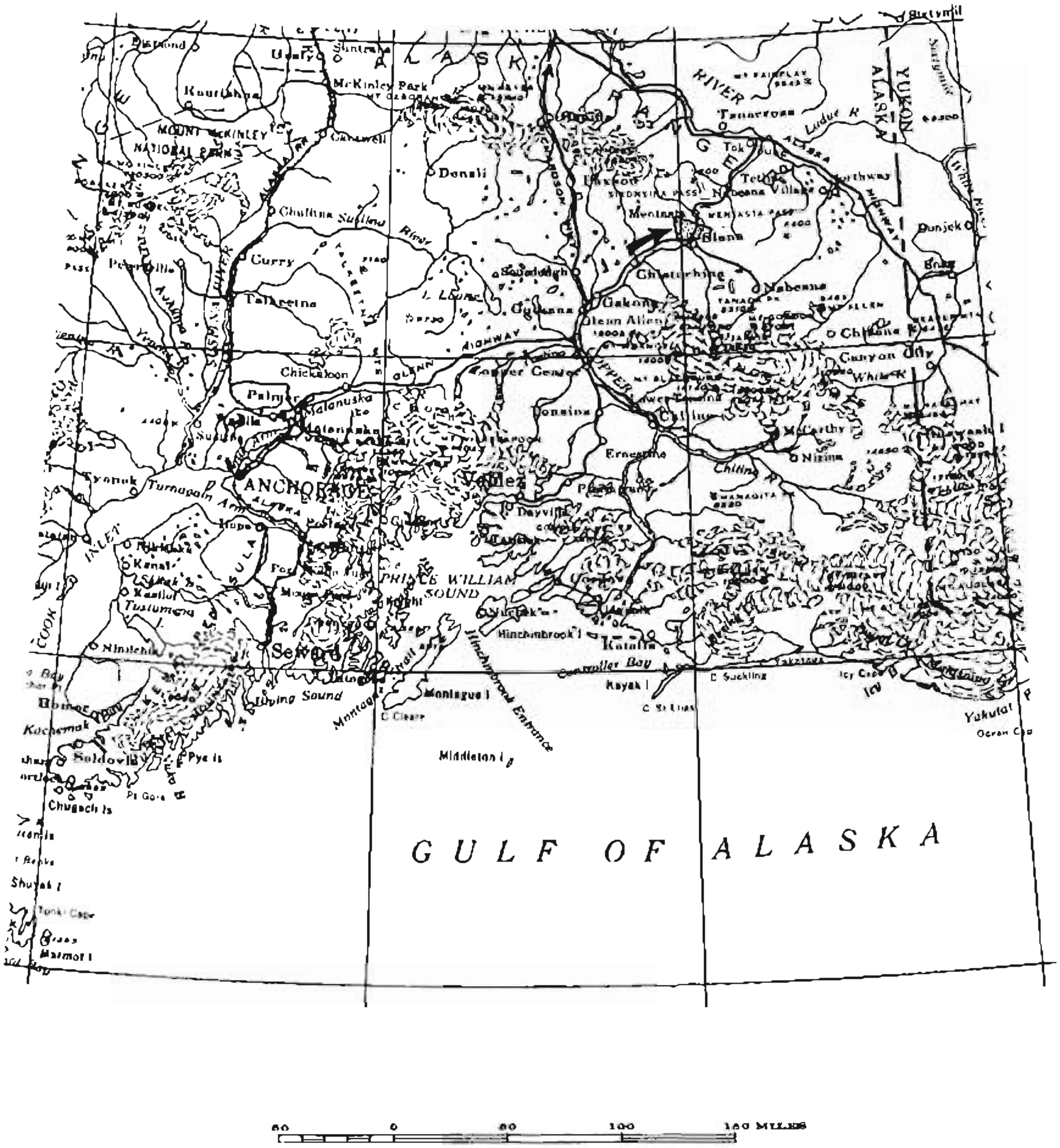

Figure I. Index map of southcentral Alaska showing location of Slana district.

warranting development. In 1955 a more thorough geologic reconnaissance was made in the district with particular attention to mineral occurrences (Stanley, 1958) and in the same year the Territorial Department of Mines examined a prospect in the district (Jasper, 1956).

Present Investigation

Approximately 230 square miles have been mapped in the Slana district and the contiguous Mentasta Mountains during the 1963, 1964, and 1965 field seasons. Concurrent with the geologic mapping all known prospects and mineral deposits were examined and about 700 stream sediments were collected for geochemical studies.

A total of 125 days were spent in the field during the three-year period of study. Travel throughout the area was largely by foot and tracked vehicle; float planes were used to a limited extent in the 1964 field season. Geologic mapping was done at a scale of 1 inch – ½ mile. All the daily field map sheets, showing detail of the traverses and rock outcrops, and the daily geochemical notes are on open file in the Anchorage office at the Division of Mines and Minerals.

Most of the stream sediment sampling and field testing of geochemical samples was carried out by geologic field assistants. In 1963 and 1965 the writer was assisted by Walter T. Phillips, Jr., and in 1964 by David A. Schwab, Richard Brocklehurst, and Ronne C. Richter.

This report includes and enlarges upon data already presented in two preliminary reports published by the Division of Mines and Minerals (Richter, 1964; 1965). A silver-lead discovery was described in the earlier report (Richter, 1964) and most of the geochemical anomalies in the district were described in the later report (Richter, 1965).

Acknowledgments

The writer wishes to express his appreciation to the residents of the Slana district who aided, both directly and indirectly, in this investigation. Special thanks are due the Duffy family, owners of Duffy's Tavern at Mile 63 on the Glenn Highway, for their hospitality and generosity in the use of their roadhouse facilities; and Fred Bronnicke and Oscar Hoagland of Slana whose knowledge of the area and its history proved invaluable. The writer is also indebted to Fred Rungee of the U.S. Bureau of Land Management at Glennallen, Alaska for use of the Bureau's fire control station facilities at Slana.

GEOLOGY

Setting

The Slana district is underlain by a thick assemblage of late Paleozoic andesitic volcanic and clastic marine sediments with minor limestone that have been intruded by a linear belt of complex diorite to quartz-diorite rocks and a quartz monzonite pluton. Although the Slana district is geographically a part of the Alaska Range, it has probably remained a positive element along the north edge of the Talkeetna geanticline since early Mesozoic time, contributing sediments to the Mesozoic Nutzotin segment of the Alaska Range geosyncline to the east and possibly to the main part of the geosyncline to the northwest as well. Intrusive activity in the district probably began in early Mesozoic time and continued intermittently until the end of the Mesozoic or possibly as late as early Tertiary. Quaternary glaciation has modified much of the land surface.

A brief outline of the rock types and geologic history of the Slana district is given below:

Age	Formation or rock type	Environment of deposition or nature of intrusive activity
Recent	Unconsolidated sand and gravel, rock glaciers, and landslides	Stream deposits, alluvial fans, mass movement
Pleistocene to Recent	Unconsolidated sand and gravel, and moraines	Glaciofluvial and glacial deposits
Mesozoic to early Tertiary (?)	Ahtell quartz monzonite pluton	Moderate forceful intrusion resulting in doming of country rock
Early Mesozoic to early Tertiary (?)	Tectonic diorite-quartz diorite	Strong forceful multiple intrusions, accompanied by faulting and overthrusting
Permian	Mankomen (?) formation	Shallow to deep water marine sediments ranging from conglomerate, sandstone, and minor reef limestone in the west to massive limestone in the east. Some interbedded volcanics.

Age	Formation or rock type	Environment of deposition or nature of intrusive activity
Permian and older (?)	Tetelna formation	Andesitic to basaltic lava flows, breccias, mud-avalanche deposits and tuffs, with interbedded discontinuous deposits of clastic sediments.
Paleozoic, possibly Devonian	Metamorphic rocks	Crystalline gneiss and schist

Metamorphic rocks

The apparent oldest rocks in the district are a series of crystalline gneisses and schists, with unusual mineral assemblages, exposed on the northeast side of a low isolated mountain in the Slana River valley. The rocks appear to be in fault contact with diorite (type I) that underlies the southwest half of the mountain. Most of the rocks are conspicuously banded with the bands ranging from one to six inches in width and varying in color from dark brown to light gray. The bands, which may possibly represent original bedding, and the foliation trend northeast and dip at moderate angles (30º - 60º) to the southeast. Lineations are not common, but where observed plunge to the southeast, generally paralleling the major faults in the area.

In general, the darker rocks, which contain biotite, are more schistose than the lighter ones, however, nowhere is the schistosity strongly developed. In thin section, the darker rocks have a fine- to medium-grained granular texture and consist of anhedral quartz (15%) and calcic oligoclase (35%), and euhedral biotite (25%), and green hornblende (20%), with minor magnetite. Scattered throughout the rock are lighter-colored porphyroblastic clots of plagioclase and poikilitic hypersthene as much as 5 mm in diameter. Poikilitic hypersthene also occurs in irregular veinlets throughout the rock. The light colored rocks, which in the field resemble fine-grained diorite, are quartz free and consist of cloudy potash feldspar (50%), weakly pleochroic green clinopyroxene (30%), wollastonite (15%), and sphene (5%).

The banding and metamorphic mineralogy suggests that the original rocks were interbedded siliceous and calcareous sediments and/or possibly tuffs. The mineral assemblages and fabric further suggests that the rocks are products of regional metamorphism as high as the almandine-amphibolites facies and possibly as high as the pyroxene granulite facies. However, it is possible that the hypersthene, on whose presence is based the higher grade of metamorphism, may be post-regional metamorphism and a product of local contact metamorphism (pyroxene – hornfels facies) along the diorite intrusive.

The age of the metamorphic rocks is not known. Based on their degree of metamorphism in comparison to the other rocks in the area, they are apparently pre-Permian in age. They are possibly correlative to the rocks on the east side of the Slana River, just north of the map area, which have been assigned a Devonian age by Moffit (1954, p. 94-100). Moffit's description, however, mentions only locally schistose rocks, the bulk of the strata being crystalline limestone, slate, sandstone, and basic lavas.

Bedded Rocks

Tetelna formation

The term "Tetelna volcanics" was first used by Mendenhall (1905, p. 36) to describe the "altered andesites" exposed in the Indian Creek drainage west of Ahtell Creek. Moffit in his first paper on the Slana district (1932, p. 115) refers briefly to the Tetelna volcanics, but in his two later and more comprehensive papers (Moffit, 1938 and 1954) he seems to carefully avoid using the name.

In view of our present knowledge of the Slana district it appears that the revival of the name Tetelna is justified. Used largely in the sense proposed by Mendenhall, it refers to the great thickness of andesitic to basaltic volcanics and minor interbedded sediments that constitute the principal bedded country rock in the district.

The bulk of the volcanic rocks in the Tetelna formation are andesitic in composition and consist of massive flows, fragmental rocks, and tuffs. Individual flow units appear to be upwards of hundreds of feet thick and are both porphyritic and nonporphyritic. Pillow structures were observed in only one restricted area southeast of Grubstake Creek. Textures range from trachytic and intersertal in the thinner units to intergranular in the more massive rocks. Fragmental rocks are abundant throughout the district and are apparently principally massive volcanic avalanche and volcanic mud flow deposits with minor breccias and agglomerate. These rocks contain subangular to subrounded fragments of volcanics as much as two feet in diameter in an extremely fine-grained dark matrix. In thin section the matrix is dark, turbid, and generally altered making it impossible to decipher the exact nature of the rock. Locally, and especially in the area east of Indian Pass Lake, the fragmental rocks and flow breccias contain irregular masses of red jasperoid as matrix material. The tuffaceous rocks are nonbedded and, in general, lighter colored than the flows and fragmental units. They consist principally of fine-grained quartz, feldspar, and minor chlorite and epidote and may be more acid in composition than andesite.

Basalt flows are present throughout the Tetelna formation but appear to be more prevalent in the upper part of the section. Both aa and pahoehoe type flows have been observed. Aa flows range in thickness from a few feet to more than 25 feet and exhibit scoriaceous tops and bottoms. An exceptional exposure of pahoehoe lavas outcrops on the north side of the 3137-foot hill between lower Ahtell Creek and the Glenn Highway. At this locality more than 50 feet of pillow-like tongues and lobes of lava with fresh-appearing glassy rinds are exposed. The basalts are dark green to black in color and consist of minor plagioclase (An_{60}) and augite phenocrysts set in a dense cloudy vesicular groundmass of plagioclase, augite, carbonate, chlorite, and iron oxide. Vesicles are generally filled with a chlorite-quartz mixture.

Interbedded with the darker rocks are occasional discontinuous strata of gray to light gray flows, or possibly welded tuffs, that probably are dacitic in composition. These rocks form homogenous units as much as 20 feet thick and locally display crude columnar jointing. In thin section they contain phenocrysts of euhedral to slightly rounded quartz, saussuritized plagioclase, chloritized hornblende, and muscovite-biotite set in a crypto-felsic groundmass of potash feldspar, quartz, and minor chlorite and epidote.

Interbedded sediments probably constitute as much as 10 percent of the Tetelna formation. The sedimentary rocks are principally thin bedded mudstone, siltstone, and shale with minor impure limestone. A unique occurrence of sedimentary jasper is exposed on a small knob at an elevation of 5,000 feet, two miles east of The Dome. The jasper unit, which averages about 20 feet in thickness and contains abundant veins and segregations of specular hematite and calcite, overlies a thin (.1 to 1-foot thick) green shale and grades upward into a reddish sandstone. Most of the sedimentary units are less than a hundred feet thick and characteristically thin, thicken, and pinch out over relatively short distances. The largest unit observed in the area outcrops along the base of the mountain northeast of The Dome and is traceable for almost three miles. It has a maximum thickness of approximately 900 feet.

With exception of the jasper unit, described above, most of the sedimentary rocks including the limestones are green in color and unless distinctly bedded are difficult to tell from some of the flows. In thin section the sandstones typically contain rock, quartz, and feldspar fragments in a dark obscure matrix of quartz, chlorite, and epidote.

Most of the Tetelna rocks have been subjected to low-grade contact metamorphism and hence are characteristically green in color due to the development of secondary chlorite and epidote. Around the Ahtell pluton and along the tectonic diorite-quartz diorite intrusive contact metamorphism as high as the hornblende-hornfels facies has affected the rocks. Phillips (oral communication) has also noted local development of pyroxene-hornfels rocks along the Ahtell pluton contact north of The Dome. The hornblende-hornfels zone is apparently very irregular and cannot be distinguished in the field; thin section data indicate a maximum width of about 2,000 feet. Volcanic rocks in this zone exhibit the development of hornblende, plagioclase, and biotite-chlorite. In the more siliceous rocks and sediments quartz and potash feldspar are also generally present. Impure limestone in the contact zone contains large diopside crystals in a matrix of quartz, tremolite, and calcite. Rocks of the hornblende-hornfels facies grade into rocks of the albite-epidote-hornfels facies in the outer limits of the contact aureole. The limit of this zone is also poorly known, but as a rule, at distances of 2 to 3 miles from the intrusive the rocks are relatively unmetamorphosed, but still contain chlorite, epidote, and occasionally minor zeolite minerals. Throughout the Tetelna formation, the rocks are locally carbonatized and pyritized, due presumably to metasomatic replacement by emanations from the intrusives.

Locally the Tetelna rocks are weakly foliated especially along shear zones near intrusive contacts, but in general most primary textures have been preserved. Hybrid dioritized volcanics and interbanded volcanic-quartz monzonite rocks, both of which occur along the volcanic-tectonic diorite-quartz diorite contact are discussed separately in a subsequent section.

The Tetelna rocks are predominantly of subaerial origin. The available evidence strongly suggests that the volcanics were laid down on the steep to moderate slopes of a volcano or chain of volcanoes, surrounded by a shallow sea, during late Paleozoic time. The interbedded sedimentary rocks were deposited in local transient basins along the shoreline. Deposition of sediments was interrupted by continued volcanic activity and possibly by eustatic changes in the level of the sea. The base of the Tetelna formation is not exposed in the Slana district. Based on exposures north of Indian Pass Lake a minimum of 3,500 feet of volcanic rocks are present in the area, but as would be expected in deposits such as these, great and variable thicknesses of rock are possible. The Tetelna formation is overlain, with apparent conformity, by sedimentary rocks of the Permian Mankomen (?) formation. The contact between the two formations is poorly defined and probably gradational. In fact, it is very possible that the two formations partly intertongue and hence are locally equivalent in age. On the accompanying geologic map of the area (figure 2) the top of the Tetelna formation is arbitrarily placed at the base of the first massive sedimentary unit in the bedded rock sequence.

Possibly correlative with the Tetelna rocks are the andesitic volcanics and interbedded graywackes mapped by Rose (1965, p. 7-8) in the Rainy Creek area, 80 miles northwest of the

Slana district. Although these rocks contain more sediments and tuffs than the rocks in the Slana district, their bulk composition, physical appearance, and mineralogy are very similar to the Slana Tetelna rocks. No diagnostic fossils were found by Rose (1965) but on the basis of similar lithologies he further correlated his rocks with those in the Rainbow Mountain area 20 miles to the east, which have been dated by Hanson (1963) as Pennsylvanian. Should these correlations prove reliable, the Tetelna rocks in the Slana district may be, at least in part, as old as upper Carboniferous.

Mankomen (?) formation

Mendenhall (1905, p. 40-51) first applied the term "Mankomen formation" to a series of predominatly sedimentary rocks of Permian age in the Mankomen Lake area, 20 miles northwest of the Slana district. Later, Moffit (1932, p. 117 and 1938, p. 19-26) on the basis of fossil evidence, correlated the isolated sedimentary rock sequence in the Slana district with the Mankomen formation. In this report, the name Mankomen is retained, but because of differences in lithology and stratigraphic succession between the Slana and Mankomen areas it is used with reservation.

In the Slana district, approximately 2,000 feet of Mankomen (?) rocks outcrop in a roughly triangular area between Porcupine Creek and the north Fork of Carlson Creek. A smaller area of Mankomen (?) rocks is exposed north of Suslositna Creek at the extreme east edge of the district. Three measured sections, which probably account for at least ¾ of the formation in the Porcupine-Carlson Creek area are shown in figure 3. The rocks consist of conglomerate, grit, and coarse sandstone with subordinate fine-grained clastics limestone, and dolomite. Thin interbedded flows and coarse pyroclastic rocks are scattered through the section and dark basalt sills are common in the upper part, especially in the Cottonwood Creek drainage area.

As shown in figure 3, the Mankomen (?) formation consists of about 50 percent massive conglomerate, ranging in coarseness from pebble to boulder. Conglomerate appears to be especially common in the lower part of the section where it occurs in massive units hundreds of feet thick. The conglomerate units are dark-colored and generally poorly sorted. Rounded to subangular volcanic fragments, as much as two feet in diameter make up the bulk of the rock; crystalline igneous fragments were not observed. Thin beds of green grit and coarse-to fine-grained green sandstone and occasional limestone are locally interbedded with the conglomerate.

Upwards in the section the rocks tend to become finer-grained and thinner bedded. In section B (figure 3) more than 600 feet of interbedded coarse- to fine-grained green to buff sandstone with minor maroon mudstone and siltstone is exposed. The beds range from less than an inch to upwards of a foot in thickness.

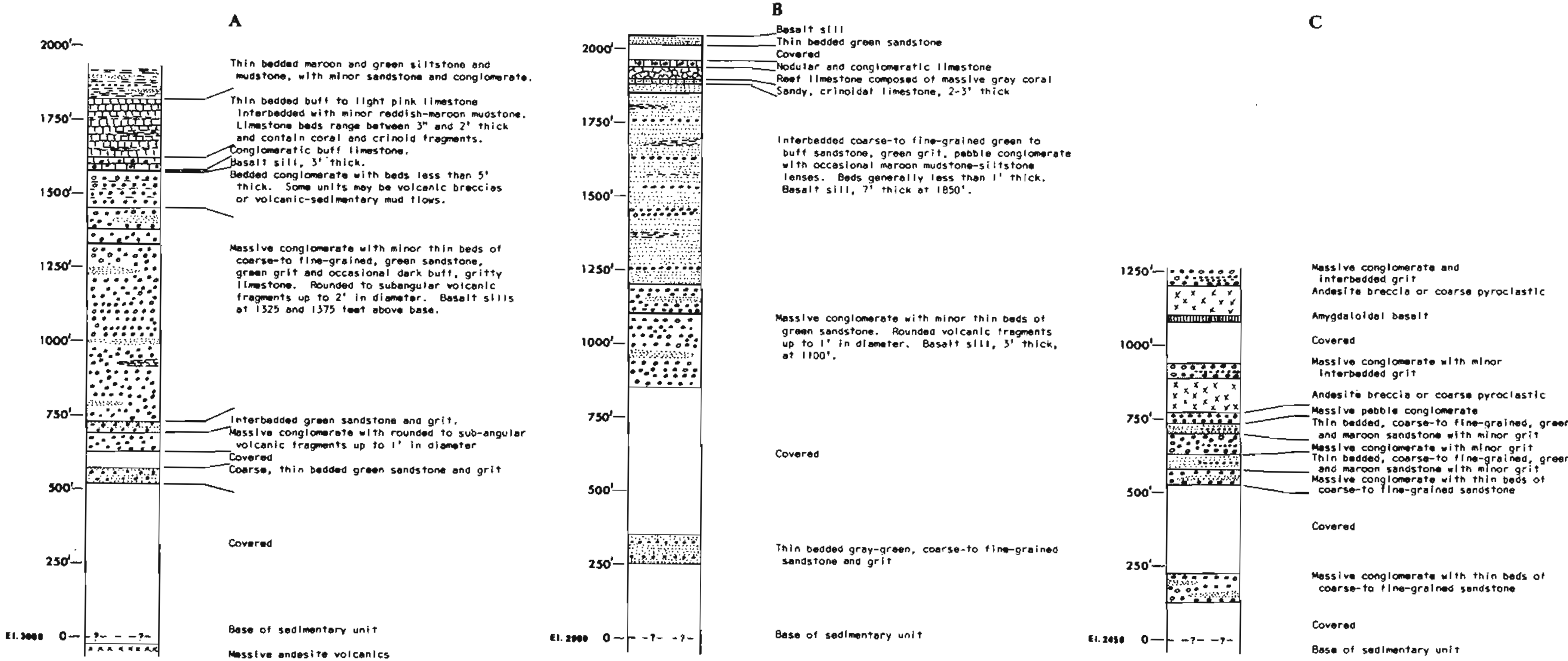

Figure 3. Sections of Mankomen(?) formation. Location of sections shown on Figure 2.

At 1600 feet above the base in section A (figure 2) more than 200 feet of thin-bedded buff to light pink limestone with reddish mudstone partings is exposed. Coral and crinoids fragments are locally abundant in some of the beds. In section B (figure 3) limestone, which is physically dissimilar to that in Section A, is exposed about 1850 feet above the base. Here the limestone is predominantly of reef origin and consists of massive gray coral overlain by a nodular limestone conglomerate with a total thickness of less than 100 feet.

At least another 200 feet of Mankomen (?) rocks are present above the top of section B, but the exposures are poor and marked by an abundance of thin, resistant basalt sills. Talus and float, however, indicate that the predominant sediments are fine-grained sandstones and mudstones. In the vicinity of peak 5234 at the head of Cottonwood Creek (figure 2) a number of think, fine-grained and relatively heavy, light gray strata of dolomite or ferroan-dolomite are exposed. Exposed surfaces of the rock exhibit a brown limonitic rind as much as ½ inch thick. X-ray fluorescent analyses of the rock indicate the presence of 4% iron (5%, FeO).

The Mankomen (?) rocks exposed in the small area north of Suslositna Creek are lithologically quite different than those in the principal sedimentary section eight miles to the west. The predominant rock in the Suslositna area is massive to thin-bedded gray limestone which as an aggregate thickness of at least 1000 feet. The limestone contains a number of thin limy argillaceous lenses and locally contains concretions of gray chert. It is abundantly fossiliferous with brachiopods and bryozoa, the common forms. North of the limestone exposures, and probably separated from it by a fault, are a series of interbedded gray limestones, calcareous fine-grained clastic rocks, and one vesicular basalt flow.

Metamorphism does not appear to have greatly affected the Mankomen (?) rocks. In general they are outside the contact aureole of the larger intrusives, but locally epidote, chlorite, and pumpellyite (?) are abundant, indicating conditions of zeolitic facies metamorphism.

The age of the Mankomen (?) rocks in both areas in the Slana district has been well established, on the basis of fossil evidence, as Permian (Moffit, 1933, p. 144-147 and 1938, p. 19-27). Nowhere in the district has the contact between the Mankomen (?) formation and the underlying Tetelna formation been observed; however, indirect evidence suggests that, other than local disconformities, the contact is conformable. Moreover, as discussed previously Tetelna volcanism and Mankomen (?) sedimentation may have been in part, contemporaneous resulting in local inter-tongueing of the two formations. In fact, basalt flows and andesitic flow breccias (?)

relatively high in the Mankomen (?) section (section C, figure 3) attest to the persistence of volcanic activity well into Mankomen (?) time. The nature of the sedimentary rocks in the Porcupine-Carlson Creek area indicate shallow near-shore marine deposition with local development of coral reefs. In the Suslositna area, on the other hand, the massive limestones and different faunal assemblage, indicates deposition in a deeper off-shore marine environment.

The Permian Mankomen (?) rocks are the youngest bedded rocks in the Slana district. A wedge of thick banded shale and sandstone of Mesozoic age is shown by Moffit (1954) to extend as far west as the upper Suslositna Creek area, where they appear to butt abruptly against Devonian (?) rocks. The Mesozoic rocks may have been originally more extensive but no evidence to support this has been found. Moreover, in the Soda Creek area, 25 miles east of the Slana district, the Mesozoic sediments conformably overlie a thick section of amygdaloidal basalt flows which also have not been observed in the map area.

Intrusive rocks

The bedded rocks in the Slana district have been intruded by two large igneous complexes, each with a variable but distinct composition and each with a different mode of emplacement. The older of the two igneous complexes is referred to in this report as the tectonic diorite-quartz diorite and the younger, predominantly of quartz monzonite composition, the Ahtell pluton. Smaller bodies of diorite and granodiorite in the Slana district are considered to be genetically related to the diorite-quartz diorite. Dikes ranging in composition from basic to acidic are also found throughout the map area cutting both the bedded rocks and the larger intrusive bodies.

Tectonic diorite-quartz diorite

Intrusive rocks of the tectonic diorite-quartz diorite complex are exposed in an irregular northwesterly trending belt that extends beyond both the northwest and southeast corners of the district. This trend is roughly parallel the Denali lineament, the major structural feature in this part of the Alaska Range and which apparently has controlled the course of the Slana River where it swings northwest immediately north of the map area. The intrusive is exceedingly complex with rock types ranging in composition from mafic diorite to granodiorite and textures ranging from subhedral granular to schistose. Eight units of the tectonic diorite-quartz diorite, designated as types I-VIII, have been mapped principally on the basis of megascopic mineralogy and/or texture, and are described separately below. Eleven modal analyses, representing six of the eight rock types (schistose and silicified types excluded) are given in table 1. In figure 4 these same modal analyses are plotted on a quartz-plagioclase-potash feldspar triangular diagram which shows that, regardless of diversity of rock type, the tectonic diorite-quartz diorite rocks occupy a relatively well-defined and distinct compositional field.

The geologic map in figure 2 does not adequately portray the complexity of the intrusive mass. Contacts between types are generally gradational, even across apparent thrust faults, and it is common to find lenses, masses, and segregations of one rock type in another. Evidently the diorite-quartz diorite intrusives were emplaced at different times during a relatively long period of Mesozoic mountain building. Deformational stress during this period ranged from nil to extreme as indicated by the nature and diversity of the fabric in the various rock types. Structures in the intrusive rocks and contacts between intrusive units are in general parallel the Denali lineament, and very likely the Denali lineament not only provided an avenue for upward movement of the dioritic magma but was also responsible for the intermittent and variable stresses applied to the irruptive rocks.

Type I, Heterogeneous diorite – Heterogeneous diorite comprises approximately 50 to 60 percent of the tectonic diorite-quartz diorite in the Slana district. The rocks generally exhibit a pronounced autobrecciation and autointrusion texture and in a single hand specimen may vary from dark, fine-grained diorite to light, coarse-grained diorite (samples 332 and S-100, table 1). Both biotite and hornblende are generally present, although biotite tends to be more common in the varieties richer in quartz. Plagioclase (An_{40-30}) which may constitute more than 50 percent of the rock, is universally saussuritized.

In the Mentasta Mountain area, east of the Slana River, the heterogeneous diorite appears to be more mafic, locally approaching gabbro in composition. Sample S-22 (table 1) contains hornblende, augite, and sodic labradorite; biotite and quartz are missing. East of Suslota Lake, around a small body of quartz monzonite, the rocks are of granodiorite composition (sample S-6, table 1).

Scattered throughout the heterogeneous diorite are bands and masses of quartz diorite, silicified diorite, and dikes (?) of quartz monzonite. Locally common, especially in the area northeast of Indian Pass Lake are irregular vein-like bands of leucocratic rock consisting of fine-grained anhedral quartz, plagioclase, and potash feldspar with 5 to 10 percent of interstitial prehenite and minor chlorite. These rocks apparently represent differentiates of the diorite which were squeezed out at various times during the crystallization of the magma.

Table I.

MODAL ANALYSES OF TECTONIC DIORITE-QUARTZ DIORITE ROCKS
Slana District, Alaska

	332	342	351	S-6	S-22	S-55	S-100	S-145	S-139	S-152	S-154
	Diorite	Quartz diorite	Quartz diorite	Granodiorite	Diorite	Quartz diorite	Diorite	Quartz-feldspar porphyry	Quartz diorite	Quartz diorite	Quartz diorite
Quartz	9	22	31	26	--	40	8	42 5/	39	15	26
Plagioclase 10/	56	42	57	41	42	38	39	48	38	56	50
		(An_{44})			(An_{55-42})		(An_{40-30})	(An_{38-22})	(An_{35})	(An_{40-25})	(An_{40-22})
Potash feldspar	2	2	2	13	tr	3	3	1	1	tr	3
Hornblende	23	23 1/	2 1/	3	22 2/	10 2/	48 1/	--	--	20 1/	15 1/
Augite	--	--	--	--	34 3/	2	--	--	-- 7/	--	--
Biotite	--	--	--	--	--	--	--	9 6/	19 6/	--	--
Biotite-chlorite	6 4/	6	4	15	--	6 4/	--	--	--	3	2
Opaques	2	2	1	2	2	1	1	tr	2	1	1
Sphene	tr	--	--	--	--	--	--	--	--	--	--
Garnet	--	--	--	--	--	--	--	tr	--	--	--
Chlorite 9/	--	5	3	tr	--	--	2	--	1	5	4 8/
Epidote 9/	--	--	--	--	--	tr	--	--	--	--	--
Carbonate 9/	2	--	--	--	--	--	tr	--	--	--	--
Color index	33	36	10	20	58	19	51	9	23	29	22

1/ Locally altered to chlorite
2/ Largely uralite and minor chlorite
3/ Altered to uralite
4/ Largely chlorite
5/ Phenocrysts, 22%; groundmass, 20%
6/ Minor interlayered chlorite
7/ Contains 1% hypersthene(?)
8/ After biotite, contains relatively abundant sphene
9/ Secondary minerals with no obvious primary mineral parent
10/ Plagioclase largely altered to saussurite with minor sericite

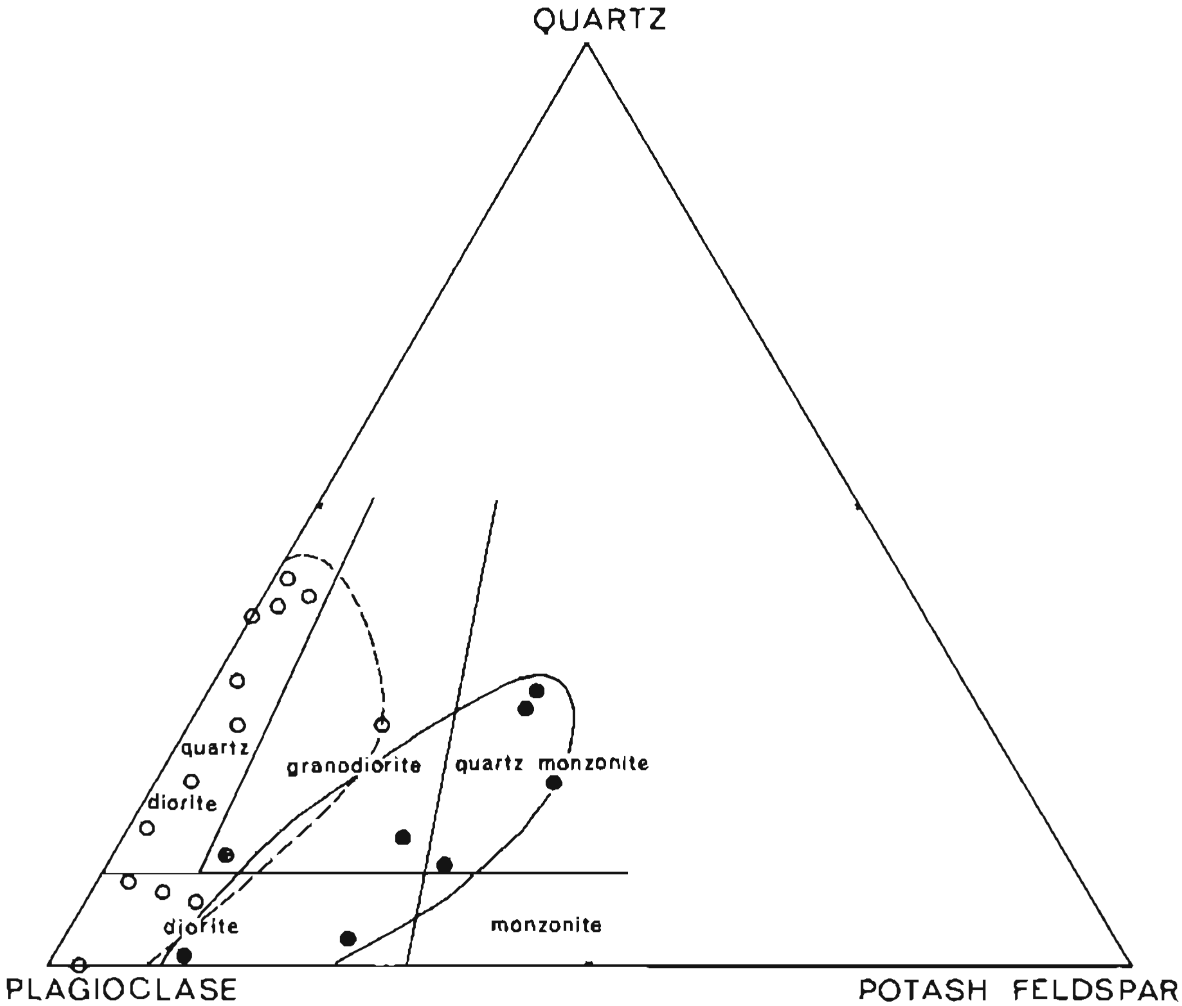

Figure 4. Modes of tectonic diorite-quartz diorite rocks (open circles), Ahtell pluton (black circles) and Suslota diorite (crossed circle) plotted on a quartz-potash-feldspar-plagioclase triangular diagram

Type II, Medium – to coarse – grained quartz diorite – Most of the high mountains northeast of the main branch of Ahtell Creek are composed of quartz diorite. The rocks are similar to some of the coarser-grained varieties of type I, but contain upwards of 30 percent quartz and appear mineralogically and texturally homogeneous (samples 351 and S-152, table 1). Hornblende and biotite are both present and occur with quartz and plagioclase (An $_{40\text{-}25}$) in a subhedral granular matrix ranging in grain size from 2 to 5 mm.

Type III, Coarse-grained leuco-quartz diorite – A small band of conspicuous, light-colored and coarse-grained quartz diorite is exposed at the head-waters of Granite Creek. Although mineralogically similar to type II quartz diorite it is physically distinct and hence was mapped as a separate unit. The rock has a subhedral granular texture with a maxium grain size of about 6 mm. Besides biotite, hornblende, quartz, and plagioclase, it contains about 3 percent microperthitic potash feldspar (sample S-154, table 1).

Type IV, Fine- to medium-grained quartz diorite – Three large lenticular bodies of fine- to medium-grained diorite have been mapped in the diorite-quartz diorite complex. Two of these occur in the heterogeneous diorite (type I) and the other is closely associated with silicified quartz diorite (type V). All the bodies characteristically contain bluish gray quartz phenocrysts, as much as ½ inch in diameter, in a subhedral granular matix of quartz, plagioclase, hornblende, and/or biotite (samples 342, S-55, and S-139, table 1). In the body associated with the silicified quartz diorite, rounded xenolithic-like inclusions of white quartz as much as three inches in diameter are also common.

Type V, Silicified quartz diorite – A large elongate mass of light-colored and fine- to medium-grained silica-rich rock upwards of a mile wide is exposed in the headwater region of Ahtell and Granite Creeks. It appears to be closely associated with both types II and IV of the diorite-quartz diorite complex and very likely represent, at least in part, silicified parts of these rock units. Smaller masses of silica-rich rock are found in association with some of the satelitic diorite bodies in the district. Megascopically the rock is generally dense and textureless with a characteristic blocky fracture, however, locally a remnant igneous texture is discernible. Thin sections show that the rock contains as much as 75 percent quartz, in tightly interlocked anhedral grains (.02 to .5 mm) and an occasional phenocryst, with less amounts of anhedral saussuritized plagioclase and minor chlorite, epidote, and carbonate. Total secondary mafic minerals never constitute more than 5 percent of the rock. Many weathered exposures of the rock exhibit a conspicuous variegated pattern of tan and light reddish brown due to alteration of the carbonate minerals and possibly some pyrite.

Type VI, Silicified-carbonatized quartz diorite – A conspicuous narrow band of brown to reddish-brown rock, as much as ¼ mile wide, outcrops over a length of more than seven miles in the northern part of the Slana district. The rock is very similar to the type V silicified quartz diorite but contains as much as 20 percent iron-bearing carbonate intermixed with the groundmass quartz and in veinlets. In some strongly weathered samples, lenses, streaks, and irregular patches of iron oxide are present and carbonate minerals missing. For almost five miles along its length this rock type forms the contact between coarse-grained quartz diorite (type II) and silicified quartz diorite (type V) or hybrid volcanic rock. To the north where it extends out of the map area, it appears to crosscut the coarse-grained quartz diorite (type II). The band dips steeply to vertically along most of its southern extremity, but northeast of lake 4021 it dips at moderate angles to the northeast. The mineralogy and linearity of occurrence suggests that the rock marks a fault or zone of weakness in the diorite-quartz diorite complex and is quartz diorite of types II and/or IV that has undergone a somewhat different type of alteration than that shown by the silicified quartz diorite (type V).

Type VII, Quartz-feldspar porphyry – A body of quartz-feldspar porphyry of quartz diorite composition (sample S-145, table 1) is exposed principally on the northeast slopes of two 5000-foot mountains northeast of Indian Pass. The rock is characteristically light-colored and generally strongly foliated; porphyroblasts of quartz and plagioclase, the latter as much as two inches long, are conspicuous. In thin section the matrix consists principally of fine- to medium-grained quartz with lenses and streaks of biotite, sericite, and chlorite. Garnet in porphyroblastic grains is always present in minor amounts and some interstitial potash feldspar was observed. The matrix quartz occurs as strongly sutured grains that exhibit severe straining and elongation parallel to the foliation. The presence of garnet is noteworthy. It occurs only in the foliated rocks of the complex (types VII and VIII) and is evidence of an early period of higher grade metamorphism.

Thin bands of quartz diorite catalcasite (type VIII) as much as five feet thick are relatively common in the upper part of the quartz-feldspar porphyry and locally the porphyry is interlaminated with foliated diorite. Field and mineralogical evidence suggests that the porphyry was thrust into its present position, over heterogeneous diorite (type I), while still partially fluid. The garnet apparently formed during this period of strong structural deformation as a consequence of increased pressures and temperatures.

Type VIII, Quartz diorite cataclasite – A band of quartz-feldspar-mica schist, 700 to 1000 feet thick, is present in two areas in the Slana district. West of the Slana River it overlies the quartz-feldspar porphyry (type VII) and east of the Slana River in the Mentasta Mountains it occurs as a band in heterogeneous diorite (type I). The rock is brown to dark brown in color with a well-developed schistosity. Locally it contains lenses of foliated diorite that still has an igneous appearance, and lenses and bands of light-colored quartz-feldspar porphyry. In thin section of the deformational fabric of the rock is well-displayed. Fragments of plagioclase and minor quartz and potash feldspar have been rolled and streaks of biotite and minor muscovite. Porphyroblasts of garnet are always present, in some samples constituting as much as five percent of the rock. Some of the matrix quartz in the rocks has apparently recrystallized forming relatively large elongate crystals with their long axes parallel the foliation.

The schist is interpreted as an original quartz diorite that has undergone strong cataclastic deformation in the sole of a large thrust plate within the diorite-quartz diorite complex. Comparison of the fabric of the cataclastic and foliated quartz-feldspar porphyry indicates that either the thrusting which involved the cataclasite was more intense or that the original quartz diorite was essentially all crystalline during the period of thrusting. Although the geologic map (figure 2) shows the cataclasite thrust over fine- to medium-grained quartz diorite (type IV) in the area west of the Slana River, the evidence is not compelling. The field evidence also suggests that both thrust faults steepen to the southwest, away from the direction of thrusting, eventually becoming high angle reverse faults. If this is true, the area is within the toe portion of the thrust and it is entirely possible that the cataclasite may grade into normal quartz diorite, over a relatively short distance, where the thrust pressures have been relieved by rupture along a singular, well-defined fault plane.

In both areas where the cataclasite is exposed it is overlain conformably by moderately-foliated heterogeneous diorite (type I). In the area west of the Slana River foliation is recognizable in the overlying diorite as much as 200 feet above the contact.

All of the crystalline rocks in the tectonic diorite-quartz diorite complex have suffered autometamorphism. Biotite is universally altered in varying degrees to chlorite, resulting in characteristic interlayered biotite-chlorite aggregates. Primary hornblende shows local development of chlorite, especially around crystal margins, and masses of secondary hornblende (uralite) and chlorite probably represent original augite. The garnet-bearing quartz-feldspar porphyry, which is regarded as a metamorphic rock, shows the effects of retrograde metamorphism with the development of interlayered biotite-chlorite. Only the schistose cataclasite, which contains garnet, unaltered biotite, and muscovite, appears to have escaped retrogressive metamorphism. Possibly the intense deformation, which produced the cataclasite, occurred during the end stages of tectonism and since then the change in physical conditions has not been sufficient to affect any noticeable mineralogical adjustment.

Ahtell pluton

The Ahtell pluton is a zoned intrusive mass, principally of quartz monzonite composition, that underlies much of the western part of the map area (see figure 2). It trends northerly in an irregular manner at an angle of about 45˚ to the structural grain of the Alaska Range. Field evidence indicates that the pluton was emplaced as two separate intrusions, but on the whole and in comparison to the tectonic diorite-quartz diorite complex, the structure of the pluton is relatively simple. Intrusion was forceful but only to the extent of moderately doming the intruded bedded country rock.

In the apparently older part of the pluton, from the vicinity of Long Lake south to the limit of exposure along the Glenn Highway, zoning is well-developed and three distinct zones or phases have been recognized: a core of porphyritic quartz monzonite (Ahtell phase), an intermediate zone of quartz monzonite (Grubstake phase), and a heterogeneous border zone of fine-grained altered rocks. The apparently younger part of the pluton, from Long Lake north, consists of a core of Ahtell phase rocks enclosed in a wide zone of potassic diorite (Long Lake phase). Both the Grubstake and border zone phases are missing. The strongest evidence suggesting an age difference between the northern and southern parts of the pluton is in the area immediately south of Long Lake where the Long Lake phase butts against, and apparently truncates, the Grubstake and border zone phases of the southern body. Five modal analyses of three phases of the Ahtell pluton are given in table 2, and together with two additional analyses are plotted in the quartz-plagioclase-potash feldspar triangular diagram in figure 4.

The quartz monzonite of the Ahtell phase is a coarse-grained (2-10 mm) porphyritic rock with a characteristic pinkish color on weathered surfaces. It contains abundant phenocrysts of orthoclase, as much as two inches long, set in a subhedral granular matrix of plagioclase (An_{35-30}), quartz, biotite, hornblende, and minor augite and potash feldspar (sample A-112, table 2). The biotite is locally interlayered with chlorite and the plagioclase largely altered to saussurite and sericite.

Rocks of the Grubstake phase are similar in general appearance and composition to those of the Ahtell phase, but the grain size is smaller (1-5 mm) and phenocrystic orthoclase is absent. Plagioclase (An_{38-25}), potash feldspar, and quartz with minor hornblende and biotite are the principal constituents (samples A-44 and 285, table 2). Hornblende, locally altered to a mixture of chlorite and epidote, appears to be more abundant than biotite, which when present is typically interlayered with chlorite.

MODAL ANALYSES OF AHTELL PLUTON ROCKS
Slana District, Alaska

Table 2.

	A-44 Grubstake phase Quartz monzonite	285 Grubstake phase Granodiorite	A-112 Ahtell phase Porphyritic Quartz monzonite	271 Long Lake phase Diorite	272 Long Lake phase Diorite
Quartz	20	14	11	3	1
Plagioclase 1/	35 (An_{38-30})	46 (An_{33-25})	45 (An_{35-30})	50 (An_{30-28})	60 (An_{40})
Potash feldspar	31	21	24	18	8
Hornblende	8 2/	2 2/	7	5	5
Augite	- - -	- - -	2	7 3/	7 3/
Biotite	- - -	- - -	8	- - -	12 4/
Biotite-chlorite	- - -	12	- - -	15	- -
Opaques	1	5	2	1	2
Apatite	tr	- - -	tr	tr	tr
Sphene	tr	tr	1	- - -	- -
Chlorite 5/	tr	- - -	- - -	- - -	- -
Actinolite 5/	- - -	- - -	- - -	- - -	4
Epidote 5/	4	- - -	tr	- - -	tr
Carbonate 5/	tr	- - -	- - -	- - -	2
Color index	13	19	20	28	30

1/ Plagioclase largely altered to saussurite with minor sericite. In 285 approximately 5% carbonate present.
2/ Largely altered to chlorite and epidote.
3/ Locally altered to amphibole and epidote.
4/ Minor interlayered chlorite.
5/ Secondary minerals with no obvious primary mineral parent.

The heterogeneous border zone phase, which is irregularly distributed around the southern part of the pluton consists of quartz monzonite, orthoclase rock, silica rock, silica-carbonate rock, and silica-tourmaline rocks. Disseminated pyrite is locally abundant in the border zone and is principally responsible for the bright colored areas of limonite alteration around the pluton. The rocks are typically massive, fine-grained and generally light-colored. Orthoclase rock and to some extent the fine-grained quartz monzonite are darker in color (green and pink) due to abundant chlorite and relative scarcity of quartz. Quartz, occurring as tightly interlocked anhedral grains, is the predominate mineral in most of the rocks. In the silica-carbonate rocks 5 to 20% anhedral iron-bearing carbonate is present, and in the silica-tourmaline rocks as much as 10% needle-like crystal aggregates of black tourmaline is present. Minor amounts of saussuritized plagioclase, biotite-chlorite, epidote, apatite, hematite, and sericite may be present in many of the border zone rocks. The tourmaline-bearing rocks are the only ones which appear to have a restricted occurrence in the border zone. These rocks have only been observed in the area south of Flat Creek, although a few quartz-tourmaline veins do occur in the Long Lake phase, near sample site 271 northeast of Long Lake.

The Long Lake potassic diorite phase apparently represents a wide intermediate border zone around a core of Ahtell phase rock in the younger part of the pluton. The rock is medium- to coarse-grained (3-5 mm) and consists of saussuritized plagioclase, potash feldspar, mafic minerals, and minor quartz with a subhedral granular texture (samples 271 and 272, table 2). Megascopically, the amount of biotite, augite, and hornblende in the rock appears to vary widely, however, in thin section, the proportions of the three mafic minerals are relatively constant. These apparent differences in mafic minerals content are due to the degree of alteration of the biotite, which in some rocks is extremely fresh and contains only minor interlayered chlorite, whereas in others it has been replaced almost entirely by chlorite.

Outside the Ahtell pluton, Grubstake type quartz monzonite occurs in two small bodies east of Suslota Lake and in the hybrid volcanic-quartz monzonite rocks which occur locally along the margin of the tectonic diorite-quartz diorite. In both of these areas the quartz monzonite is clearly later than the dioritic rocks and it is solely on the basis of this relationship that the Ahtell pluton is considered to be younger than the diorite-quartz diorite complex.

Hypabyssal rocks

Six distinct varieties of hypabyssal rocks have been recognized and mapped in the Slana district. In order of abundance, these are: Hornblende granodiortie porphyry, lamprophyre, andesite and andesite porphyry, gabbro basalt, and dacite (?) porphyry. Most occur as dikes, although sills of fine-grained basalt are locally abundant in some of the sedimentary strata. The dikes show a pronounced northeast orientation, normal to the structural grain of the district, and in a few cases can be traced for two to three miles.

An arcuate body of diorite, of larger proportion than the normal hypabyssal rocks but with mineralogical features of near surface intrusion is also described.

Hornblende granodiorite porphyry – Light colored dikes of hornblende granodiorite porphyry are by far the most common hypabyssal rock in the district. These dikes are found cutting all rock types with the possible exception of the tectonic diorite-quartz diorite. Their absence in the dioritic complex, however, may be more apparent than real as they could easily be overlooked because of similarity in color, texture, and mineralogy. Moreover, many of the smaller satellitic diorite bodies appear to have apophyses of hornblende granodiorite porphyry and locally within some of the diorite bodies, masses of hornblende porphyry are common. The dike rocks are light gray with phenocrysts of hornblende and plagioclase, as much as one inch long, in a medium-grained equigranular groundmass. Although fresh appearing in hand specimen; under the microscope they show the effects of profound alteration (sample A-43, table 3). The hornblende phenocrysts are replaced by a mixture of chlorite, epidote, and sericite, and the plagioclase by a cloudy mass of saussurite. Patches of secondary carbonate minerals, chlorite, and epidote are abundant throughout the groundmass.

Lamprophyre – Dark porphyritic dikes of vogesite (?) that weather reddish brown are relatively abundant in the northern part of the district where they intrude Ahtell quartz monzonite, tectonic diorite-quartz diorite, and Tetelna volcanics. The rocks consist of fresh augite and saussuritized plagioclase phenocrysts, as such as 10 mm long, in a fine-grained ground-mass of stubby orthoclase prisms, rods of plagioclase, interlayered biotite-chlorite, and minor quartz (sample S-49, table 3). Scattered throughout the rock are small segregations of sericite and large patches of chlorite intermixed with hydrous iron oxides.

Dikes, sills, and very irregular bodies of minette (?) intrude Mankomen (?) rocks in a very restricted area in the Cottonwood Creek Drainage. These rocks were originally interpreted

Table 3.

MODAL ANALYSES OF HYPABYSSAL ROCKS
Slana District, Alaska

	S-49 Lamprophyre	247 Gabbro	273 Andesite porphyry	S-130 Suslota diorite	A-43 Granodiorite porphyry
Quartz	3	--	--	12	21
Plagioclase	29 1/	51 (An_{55-30})	60	52 1/	47 1/
Potash feldspar	38	2 3/	--	7 5/	6
Hornblende	--	--	--	24 2/	8 2/
Augite	11	41 4/	--	--	--
Biotite	6 2/	--	10 2/	--	--
Opaques	2	5	10	4	1
Apatite	--	1	1	--	--
Carbonate 6/	--	--	--	--	10
Sericite 6/	1	--	--	--	--
Chlorite with Fe oxides 6/	11	--	--	1	--
Chlorite-epidote 6/	--	--	19	--	7
Color index	30	47	40	28	27

1/ Saussuritized
2/ Locally altered to chlorite
3/ Micropegmatite
4/ Locally altered to dark brown non-pleochroic material
5/ Sanidine(?)
6/ Secondary minerals with no obvious primary mineral parent

as mica peridotites on the basis of field identification (Richter, 1965, p. 2). The rocks are dark colored and consist of fresh biotite and green augite phenocrysts (3-10 mm) in a fine-grained groundmass of biotite, potash feldspar, and minor plagioclase and carbonate. Quartz is apparently absent. Some of the rocks show remarkable selective alteration. In one sample the euhedral phenocrysts of augite (?), still retaining their zonal texture, have been completely altered to an apple green mixture of carbonate and sericite. The groundmass of this sample also shows more alteration effects but the biotite is still relatively fresh.

Andesite and andesite porphyry – Dikes of andesite and andesite porphyry are found throughout the area but the latter appear to be especially common in the Long Lake and Grubstake phases of the Ahtell pluton in the vicinity of Long Lake. The porphyritic dikes are green-gray in color with abundant large phenocrysts of plagioclase zoned An_{50} to An_{25}. The phenocrysts are set in an intersertal fine-grained (0.1 mm) groundmass of plagioclase, biotite, opaque minerals, and interstitial mafic material consisting of chlorite and epidote (sample 273, table 3). The nonporphyritic andesites have a similar groundmass mineralogy but lack the conspicuous plagioclase phenocrysts in the porphyritic variety.

Gabbro – A few dikes of dark medium-grained gabbro have been observed in the Ahtell quartz monzonite, diorite complex, and Tetelna volcanics. The rocks have a subhedral-granular to subophitic texture and contain principally plagioclase (An_{55-30}) and augite with minor micropegmatite, and opagues (sample 247, table 3). The augite is locally altered to dark brown nonpleochoic material.

Basalt – Sills and minor dikes of dark brown to black fine-grained dense basalt are abundant in the wedge of Mankomen (?) rocks between porcupine Creek and Carlson Creek. The sills may be as much as 10 feet thick, but in general average 2 to 3 feet thick. In thin section the rocks consist of a sparse microphenocrysts of augite and plagioclase, up to 1 mm long, in cloudy groundmass of plagioclase, carbonate, chlorite, iron oxides, and augite. Small irregular red patches of hematite, chlorite, and carbonate, scattered through the rock, may represent original olivine.

Dacite (?) porphyry – One large dike or a series of dikes, of pink-buff dacite (?) porphyry is exposed south of Flat Creek and on the east side of Ahtell Creek. The dike is over 100 feet wide and contains abundant, slightly rounded phenocrysts of quartz and plagioclase, as much as 5 mm in diameter, in a cryptofelsic groundmass of quartz and sericite. The plagioclase is almost entirely replaced by salmon-pink carbonate and sericite.

Suslota diorite – A large arucate mass of diorite, or quartz diorite, referred to as the Suslota diorite, is exposed on the northwest flank of Suslo Mountain. Although probably genetically related to the tectonic diorite-quartz diorite complex its character and mineralogy is sufficiently distinct to warrant separate description. The intrusive is over three miles long and averages a little less than ¼ mile wide. A smaller body of diorite on the northeast flank of Suslo Mountain may represent an easterly extension of the Suslota diorite.

The rock is medium-grained with a subhedral-granular texture and consists principally of saussuritized plagiolclase, chloritized hornblende, and quartz (sample S-130, table 3). Associated with the anhedral interstitial quartz are small crystals of potash feldspar with optical properties similar to sanidine (small – 2 V). The presence of sanidine (?) and the arcuate shape of the massi is suggestive of a low pressure-high temperature ring-dike type of intrusion.

Hybrid rocks

Along the margin of the tectonic diorite-quartz diorite complex are two types of hybrid rocks that have been mapped as separate units. The most remarkable of these is an interbanded volcanic-quartz monzonite rock that appears to be restricted in occurrence to the area between upper Carlson Creek and upper Porcupine Creek. The unit is composed of bands of Grubstake-type quartz-monzonite ranging in thickness from one foot to over 10 feet separated by bands of Tetelna volcanic of about the same thickness. Occasionally bands or masses of dioritic rock and silicified diorite are also present. The distribution pattern of this hybrid unit suggests extreme structural and intrusive complexity. Linear zones of the hybrid rock in general parallel the front of the diorite complex but they pinch, swell, and disappear over relatively short distances. East of the upper Carlson Creek drainage, where the unit is upwards of a mile wide, long sinuous bands extend far back into the main mass of diorite. Cross-cutting relationships, between the various rock types, indicate that the quartz monzonite intruded the volcanic rocks toward the close or after the diorite tectonism. Possibly the intrusions of the diorite-quartz diorite complex prepared the ground for the quartz monzonite injections which are temporally related to the emplacement of the Ahtell pluton.

The other hybrid unit is a mixed rock referred to as dioritized greenstone. It occurs in scattered zones along the front of the diorite-quartz diorite complex, but is generally missing in the area where the volcanic-quartz monzonite hybrid occurs. The rock appears to be a Tetelna volcanic that has been partially recrystallized, due to proximity of the diorite mass, or injected by primary dioritic material or both. Over distances as short as a few feet the rock changes very gradually from a typical volcanic, exhibiting hornblende-hornfels metamorphism, to a crystalline diorite. Flow banding textures are generally common in the more crystalline phases indicative of at least local fluid movement.

Surficial deposits

Extensive valley glaciers covered most of the Slana district up to an elevation of 4,500-5,000 feet during Pleistocene and Recent time. All of the larger stream valleys are filled with unconsolidated glaciofluvial sediments that were deposited by glacial streams or in local lakes impounded by the glaciers. Some morainal deposits are present in the valleys above the forks of Ahtell Creek, and serpentine esker-like ridges have been observed in the Quartz Creek area. The thickness of the deposits is variable. Along Ahtell Creek, for example, the deposits are over 200 fee thick at the junction of the west and main forks, but downstream in the canyon area they form only a very thin mantle over bedrock.

Rock glaciers cover a total area of two to three square miles mostly in the rugged alpine country in the northern part of the area where the mountains rise above 6,000 feet.

Two large landslides of Recent age have modified the mountains above the broad Slana River valley in the northeast part of the district. Both landslides occurred in quartz-feldspar porphyry (type VII) of the diorite complex and spread over the glaciofluvial deposits in the river valley. The slides are characterized by a rough hummocky topography with the individual debris blocks of porphyry as large as 50 feet in diameter. The largest of the slides covers almost one square mile and contains in the order of 10,000,000 cubic yards of material.

Structure

The structure of the Tetelna and Mankomen (?) rocks in the Slana district is not complex, and with the exception of the hybrid rocks along the margin of the tectonic dirorite-quartz diorite intrusive belt, the bedded rocks are not severely deformed. In general, the present structures have been controlled principally by forceful igneous intrusion, although occasional steep dips and local anomalous strikes in the Tetelna volcanic suggest some relatively steep primary bedding.

Up to about a mile from the diorite-quartz diorite belt, the bedded rocks dip radially away, at low to moderate angles (10º to 50º), from the Ahtell pluton. Within the mile-wide zone paralleling the diorite-quartz diorite belt, the attitudes of the rocks have been controlled primarily by the dioritic intrusions imparting a moderate dip (20º to 50º) to the southwest. Locally, the resultant structure is a slightly asymmetric broad syncline that plunges gently to the southeast. This syncline can be traced from north of Indian Pass Lake to north of Carlson Lake, a distance of approximately six miles. A number of smaller anticlinal and synclinal corrugations, all plunging gently to the southeast, are present on the broad southwest limb of the large syncline.

In the small exposure of Mankomen (?) rocks in the Suslositna Creek area, the rocks dip at angles of 22º to 76º northwest. This attitude is unlike any observed elsewhere in the Slana district.

Faulting is not pronounced in the bedded rocks or in the Ahtell pluton of the Slana district. A major strike-slip (?) fault is exposed in the Suslositna Creek valley and apparently continued to the northwest, where it is covered by glaciofluvial deposits along the base of the mountain front paralleling the Slana River. This structure, and probably the northwest-trending fault across the isolated low mountain in the Slana River valley, are without much doubt integral parts of the Denali lineament. This major trans-Alaskan structure, however, has yet to be traced through the Mentasta Pass area which bounds the Slana district to the northeast. Even the Suslositna Creek fault, which locally has a well-defined topographic expression, appears to die out in the dioritic rocks of the Mentasta Mountains north of the Suslota Lake. The straight and abrupt southern front of the mountains along the Glenn Highway in the district may also indicate another major fault.

Elsewhere in the district a few normal faults, with a predominant northwest trent, cut and locally disrupt the bedded rocks. As a rule, however, the quaquaversal dip pattern around the Ahtell pluton is well displayed. The complex thrusting and faulting within the tectonic diorite-quartz diorite intrusives has been discussed previously in the section describing these rock units.

ECONOMIC GEOLOGY

A number of small base metal-silver vein deposits and gold placers have been prospected and worked in the Slana district. Some gold has been recovered, chiefly from the placer operations on Grubstake Creek and Slope Creek (locality 11), but no lode production of any ore is known from the district. On the economic geology map (figure 5) all the known veins, limonite-stained altered areas, disseminated chalcopyrite occurrences, placer operations, and significant geochemical anomalies are shown. With the exception of the disseminated chalcopyrite occurrences, most of these mineralized areas occur in the border zone of the Ahtell quartz monzonite pluton or in the bedded country rock peripheral to the southern lobe of the pluton.

The known sulfide-bearing veins in the district are typically thin and discontinuous. The veins consist of massive to vuggy quartz with subordinate calcite and/or barite. Although some veins are barren, most contain minor and variable amounts of galena, sphalerite, chalcopyrite, and occasionally argentiferous tetrahedrite. No free gold has been observed in any of the veins. Veins and veinlets of quartz-tourmaline, carrying minor gold values occur in a very restricted area north of Long Lake.

Limonite-stained altered zones range in size from a few square feet to upwards of a half square mile in area. Below the zone of weathering in these areas the rocks generally contain abundant disseminated, and locally massive, pyrite. Iron-bearing carbonate, quartz, and clay minerals are often present. In the large altered area south of Long Lake (locality 4), sericite along with quartz and pyrite are the principal alternation minerals.

Occurrences in disseminated chalcopyrite are found chiefly in the diorite-quartz diorite rocks or in the Tetelna volcanics close to the diorite contact. The occurrences are limited in size and consist of chalcopyrite, usually in association with epidote, disseminated in the country rock and scattered throughout the networks of irregular quartz and quartz-calcite veinlets. None of the occurrences appear to be of economic importance.

The larger lode deposits and the two productive placer localities in the Slana district are described below.

Lode Deposits

Locality 1* (Indian Group prospect, Blue Ridge lode) – At least two, and possibly more, galena and chalcopyrite-bearing quartz veins outcrop near the top of a 5,100-foot ridge on the Indian Creek Ahtell Creek divide in the western part of the district. A number of small pits and open cuts have been dug on the veins but at the time of our visit these were all caved. The exposures in the area are poor.

One of the two veins observed during this investigation is five feet wide, strikes N84ºW, and dips 86ºS. The vein consists of massive quartz with minor galena and copper stain and has been brecciated and recemented by calcite along its hanging wall. The other vein, about 200 feet southwest and 100 feet down the northwest side of the ridge, contains both minor galena and chalcopyrite, but due to poor exposures its width and attitude are unknown. Abundant vein

*Locality numbers refer to figure 5.

float and the numerous pits on the hillside indicate the possibility of more veins in the area. The country rock is Grubstake phase quartz monzonite, which locally is coarse-grained and relatively dark-colored. Eight hundred feet southwest along the ridge from the first vein is a 10-foot wide barren quartz vein trending N65ºW that fills a fault zone separating Ahtell pluton border zone rock from Tetelna volcanics. This vein can be traced about 1,000 feet to the northwest where it is eventually covered by talus.

Moffit visited the prospect in 1929 and described the veins in his report on the Slana district (1932, p. 122-124). In 1945 the U.S. Bureau of Mines examined the prospect and sampled some of the veins (Thorne, 1946). On his sketch map (elevations are in error) Thorne shows at least seven mineralized vein exposures besides the large barren quartz vein. Maximum values reported by Thorne were 15.56 oz/ton of silver and 19.92 percent lead over a width of nine inches.

Locality 2 – (West Fork Ahtell Creek prospect) – This prospect, locally referred to as the Conkle lead prospect, is on the north bank of the West Fork Ahtell Creek approximately 1-1/4 miles above the junction. Mr. Sam Gamblin of Glennallen, Alaska, presently holds title to the mining claims in the prospect area. At least three weak shear zones containing narrow irregular quartz veins have been explored by short adits and pits.

The westernmost mineralized zone, which has received the most attention by prospectors, has been explored by two adits, now caved, about 300 feet apart and about 100 feet different in elevation. At the portal of the lower adit, a four-inch quartz vein, with minor limonite staining, but with no visible sulfides, is exposed in Grubstake phase quartz monzonite. The vein strikes N24ºE and dips 63ºW. At the upper adit, which appears to be on the same structure, no exposures could be seen, but on the dump were a number of pieces of massive coarsely crystalline galena as much as six inches in diameter. Thorne (1946), who also visited this property, stated that the upper tunnel was 17 feet long and at the face three galena-bearing quartz veins, each striking N15ºE, and dipping 70ºW, were exposed in a six-foot wide shear zone. Evidently the galena now on the dump was discovered subsequent to Thorne's visit as he makes no mention of such massive material. One 42-inch sample cut by Throne contains a trace of silver, 6.58 percent lead, and 0.19 percent copper.

Three hundred feet east of the lower adit and at about the same elevation, a two-foot quartz vein in Grubstake phase quartz monzonite is exposed in a short trench. The vein, which strikes N5ºW, and dips 61ºW, contains minor chalcopyrite and pyrite.

Another three hundred feet east and still at the same elevation a third mineralized zone, consisting of a number of irregular and locally copper-stained quartz veins in sheared Grubstake phase quartz monzonite, is exposed in a small cut. The veins, which contain no visible sulfides, trend N70ºE, and dip steeply north.

Locality 3 – A stockwork of quartz and calcite veins in massive, light-colored silica rock of the Ahtell pluton border phase, is exposed at an elevation of about 3,700 feet on the steep northeast flank of The Dome. The veins, as much as one-foot wide, fill and are apparently controlled, by a local jointing system confined to the massive silica rock. Prominent joints strike N6ºW, and dip 59ºW, weaker joints strike N72ºW and dip 79ºN. Veins exposed in two shallow prospect pits exhibit weak copper staining and contain a few small grains of chalcopyrite and galena.

A few hundred feet southwest on the top of The Dome is a zone of disseminated pyrite and minor chalcopyrite mineralization. The sulfide-bearing rocks are hornfelsic flows and possibly some interbedded tuffs, conspicuously altered to limonite on the surface. A composite chip sample representing an area 400 feet long by 100 feet wide contained between 0.05 and 0.1 percent copper.

Locality 4 – A conspicuous brightly colored alteration area is exposed on the top and southeast flank of the 5,00 (THIS SHOULD BE 5,000, SHOULD I CHANGE IT?)-foot-high mountain south of Long Lake. The rocks in the area, which belong to the Ahtell pluton border phase, have been replaced by an intimate mixture of sericite, quartz, and clay minerals and locally contain veinlets and disseminations of pyrite and minor molybdenite. At an elevation of 4,980 feet on the ridge line, a two-foot-wide barren quartz vein striking N58ºW and dipping 61ºS, is exposed. About 300 feet lower on the Long Lake side of the ridge another two-foot quartz vein, or possibly an extension of the one higher up is exposed. This vein contains minor chalcopyrite and is strongly copper-stained.

Locality 5 – On the south side of the south fork of Grubstake Creek, at an elevation of about 3,700 feet, pyrite with minor chalcopyrite occurs in a limonite-stained band of dark green hornfels. A small pit dug into this rock a few feet above creek level exposes weakly copper-stained fractures trending N76ºW and dipping 73ºN. The hornfels is apparently an unassimilated inclusion of Tetelna volcanic in the border zone of the Ahtell pluton.

High on the ridge, south of this prospect, at an elevation of about 4,400 feet is a 10-foot adit and a number of shallow pits. These workings known as the J.D. Lyons prospect, expose a number of small, irregular, and discontinuous quartz veins, no more than six inches wide containing minor pyrite and chalcopyrite. The veins are in a dark chlorite-hornblende hornfels similar to the rock exposed in the valley below.

Locality 6 – Two miles south of Grubstake Creek at an elevation between 3,500 and 4,200 feet in the border zone of the Ahtell pluton, is a swarm of discontinuous quartz veins, ranging in width from a few inches to as much as three feet. The known veins strike between N20ºE and N80ºE and dip irregularly. Galena is present in most of the veins and locally occurs in concentrations of as much as 50 percent. Minor chalcopyrite was observed in a few veins, and float of vein quartz with tetrahedrite has been found in the area.

Most of the area has been staked during the past two years by the Slana Company in the course of exploring the Silver Shield prospect (locality 7), one mile to the south.

Locality 7 – (Silver Shield prospect) – This shear zone-vein deposit was discovered in 1963 during the first year of field investigation in the district by the Division of Mines and Minerals. Upon public release of the discovery in 1964, it was subsequently staked and at present is being explored by the Slana Company.

The prospect is on a steep hillside at an elevation of about 3,100 feet and 2-1/2 miles south of Grubstake Creek. The original discovery was a poorly exposed quartz vein, containing minor galena and tetrahedrite, that assayed 19.8 ounces of silver per ton over a width of three feet. Exploration by the Slana Company has disclosed that the quartz occurs in large veins or pods in a 35-foot wide sheared and brecciated fault zone trending N55ºE and dipping vertically. Locally the quartz veins contain segregations of massive barite and minor calcite and supergene cerussite. The ore minerals, galena and argentiferous tetrahedrite, appear to be restricted to the quartz veins. The galena occurs as disseminations of crystals as large as one inch in diameter throughout the quartz, whereas the tetrahedrite appears to be locally concentrated in vuggy zones along the margins of the quartz veins. Assays of grab samples of the tetrahedrite-rich rock run as high as 400 ounces of silver per ton.

Clastic sediments and volcanic flows of the Tetelna formation, dipping gently to the south and southwest, constitute the country rock in the prospect area.

Locality 8 – (Silver Creek prospect) – This silver prospect, one of the oldest known mineral occurrences in the area, is on Silver Creek a tributary of Ahtell Creek, about 1-½ miles southwest of the Silver Shield prospect (locality 7). Moffit (1938) was apparently the first to describe the prospect, but even at the time of his visit in 1936, the exploratory adits, shafts, and open-cuts were largely caved and buried. In 1945 the property was re-examined and sampled by Thorne (1946); however, from the description given no work had been done since Moffit's earlier visit. In 1963 a crude tractor road had been completed to the property from Ahtell Creek and some stripping done. The property is now controlled by Mr. Kirk Stanley of Anchorage.

The prospect consists of a number of quartz-carbonate veins, containing minor sulfides, that strike NW and dip steeply NE. The veins apparently occupy cross-fractures in a 100-foot, or more, wide fault zone trending N10º-20ºE and dipping 65º to 80ºW. Principal rock within the fault zone, in the prospect area, is a dense gray fine-grained silica rock containing abundant disseminated pyrite. To the east of the fault, volcanics and sediments of the Tetelna formation are exposed and to the west, dark hornblende diorite.

Near the veins the rock is carbonatized and limonite-stained. Chalcopyrite, galena, and sphalerite, and pyrite were observed in minor amounts in old dump material throughout the prospect area. Silver, which runs as high as 17.5 ounces per ton across one-foot channel samples, is evidently contained in associated tetrahedrite (Thorne, 1946).

Locality 9 – (Gold-Quartz prospect) – The Gold-Quartz prospect is on a quartz-carbonate vein that outcrops along a small cliff a few feet above the level of Ahtell Creek about 1 ½ miles southeast of the Silver Shield prospect (locality 7). In 1955-56 Mr. Fred Bronnicke of Slana drove an adit on the vein, but encountered glacial debris or an old Ahtell stream channel at a distance of 55 feet from the portal. No work has been done since. The prospect was examined by Jasper (1956) of the State Division of Mines and Minerals.

The vein strikes N5º to 8ºW and dips 67ºW. A dark serpentinized olivine basalt, containing abundant chrysotile-calcite veinlets, forms the hanging wall and a dense gray tuff (?) the foot wall. The wall rocks are brecciated and limonite-stained as much as five feet on both sides of the vein. Slickensides, plunging 50ºNW, along the hanging wall and local development of clay gouge, containing broken vein material, indicate strong post-mineral movement. The vein ranges from three to five feet in width and is composed principally of massive milky quartz, locally brecciated, and irregular pods of ankerite. Sphalerite, with subordinate amounts of chalcopyrite, galena, and pyrite occurs scattered throughout the vein. Samples collected in 1955 assayed between 0.02 and 0.90 ounces of gold per ton and as much as 0.76 ounces of silver per ton (Jasper, 1956).

Placer deposits

Locality 10 – (Grubstake Creek) – Gold placers on Grubstake Creek, a tributary of Ahtell Creek about five miles north of the Glenn Highway, have been worked intermittently from the early 1930's up to about 1959. Moffit visited Grubstake Creek in 1936 and described in considerable detail the history of the deposit and the current mining operations (1938, p. 48-50). The total gold production is unknown but local opinion puts the figures at less than $25,000.

The principal workings along Grubstake Creek were in the narrow v-shaped canyon between ¾ mile and 1- ¼ miles above its mouth. In the canyon, the rocks are predominantly Grubstake phase quartz monzonite; above the limit of workings, and extending up into the high drainage basin of the creek, border zone rocks of the pluton are poorly exposed. Hydrothermal alteration has been locally intense in this area and although only a few gold-free quartz veins have been discovered (locality 5) the altered border zone rocks are undoubtedly the source of the Grubstake gold.

Magnetite, ilmenite, native copper, silver, and gold have been recovered in the placer operations. The gold and silver is typically fine-grained and most is wiry or dendritic, showing little or no evidence of lengthy transport.

Locality 11 – Slope Creek, which flows into Porcupine Creek on the east side of the mountain from Grubstake Creek, was placer mined in the 1950's by Mr. Fred Bronnicke of Slana. The gold here was similar in size and shape to Grubstake gold and was recovered with magnetite, native copper, silver, and a bismuth mineral (Moffit, 1954, p. 195).

Other placer operations in the Slana district were on Boulder Creek, south of Slope Creek; Willow Creek, north of locality 9; Hidden Creek; and Ahtell Creek, two miles above its mouth. Most of these were apparently exploration ventures, with little or no gold recovery.

GEOCHEMISTRY

During the three years of investigation in the Slana district, approximately 700 stream sediment samples were collected and tested in the field for cold extractable heavy metals. The University of Alaska method (Mukherjee and Mark Anthony, 1957), was used in 1963 and 1964, on approximately 500 samples, and the method described by Hawkes (1963) in 1965. Quantitative analyses for total copper, zinc, lead, and molybdenum were performed on 384 of these samples by two of the Division laboratories, using the U.S. Geological Survey pyrosulfate fusion method (Ward and others, 1963) and by the Rocky Mountain Geochemical Laboratories of Salt Lake City, Utah, using the acid digestion techniques of Sandell (1959). The location of all laboratory analyzed samples are shown in figure 6, and the analytical and field test data for these samples are given in table 4. All of the 1963 and 1964 analytical results have been reported previously (Richter, 1965); this report includes new data from samples collect in 1965.

In addition to the stream sediments, 35 rock samples representative of the principal rock types in the district were collected and analyzed for total copper, zinc, lead, and molybdenum. These data, utilized to aid in determining meaningful background values for the metals, are given in table 5 and are also shown graphically in figure 7. The map numbers on table 5 refer to the sample site locations shown in figure 6.

All of the analytical work was performed on the -80 mesh fraction of the stream sediments, or in the case of the rock samples, on material ground to -80 mesh. Repeat analyses and cross-check samples indicate that the analytical results for copper, zinc, and lead from the three laboratories are in good agreement. Molybdenum, however, was consistently low from the Division Laboratories and as a rule went undetected where present in concentrations of less than 2 to 4 parts per million. Fair correspondence was generally obtained between the field test and laboratory data especially if zinc was among the enriched elements. Copper and/or lead enrichment was often missed by the field test, evidently in part due to the optimum extractability of copper at pH values significantly different from the hear neutral to weakly acid field test solutions and to the lower sensitivity of copper and lead. On the other hand, a number of anomalous field test samples proved to contain normal amounts of trace metals on the basis of the laboratory analyses. These discrepancies apparently are explained by extreme variations in the amount of metal soluble in the cold field test solutions.

Histogram frequency distribution graphs have been prepared for each of the four metal elements in the 384 analyzed samples (figure 7). A single population, log normal in distribution, is apparent for each element. Moreover, the mode, or concentration that occurs most often, for each metal element in the stream sediments of the Slana district is within a few percent of the crustal average estimate (Taylor, 1964). Approximate upper background limits (threshold values) for the metal elements were estimated on the basis of the known metal concentration range in the principal rock types of the district and by inspection of the histograms. These threshold values are: copper, 150 parts per million; zinc, 150 ppm; lead, 50 ppm; and molybdenum, 6 ppm.

Geochemical anomalies

Anomalous concentrations of heavy metals are present in many stream sediments in the Slana district (figure 6). Most of the anomalies are on streams draining the border zone of the Ahtell pluton and the tectonic diorite-quartz complex; a few are on streams draining the Grubstake and Long Lake phases of the Ahtell pluton and bedded country rock, but none were found

Table 4

COPPER, ZINC, LEAD AND MOLYBDENUM CONTENT OF
STREAM SEDIMENTS IN THE SLANA DISTRICT

Field Number	Map Number	Concentration (ppm) Cu	Zn	Pb	Mo	Field Test (ml of dye)
	1	20	30	5	2	1
	2	30	60	5	3	1
	3	20	65	5	2	1
	4	75	60	5	2	1
	5	30	50	10	2	1
	6	35	65	5	2	3
	7	75	175	70	4	3
	8	60	85	10		4
	9	65	190	60	8	6
	10	20	35	5	2	1
	11	40	85	10	2	1
	12	60	235	20	4	3
	13	45	70	15		1
	14	30	60	15	2	1
	15	30	65	15	2	1
	16	85	70	30	2	1
	17	100	300	55	6	5
	18	65	170	35	2	3
	19	50	140	30	2	2
	20	300	135	30	4	5
	21	75	80	25	2	2
	22	190	95	35	4	2
	23	40	55	15		2
	24	40	75	10	2	1
	25	30	70	5	2	1
	26	30	60	5	2	1
	27	40	90	5		2
	28	45	55	10	2	2
	29	55	90	10	2	2
	30	30	70	5	1	2
	31	55	60	5	2	2
	32	135	80	5	2	3
	33	30	55	5	2	3
	34	45	60	10		4
	35	50	110	15	2	3
	36	25	80	15	3	2
	37	50	125	45	3	2
	38	65	75	50	3	2
	39	90	140	55	4	4
	40	80	145	65	5	2

Table 4 (Continued)

Field Number	Map Number	Concentration (ppm) Cu	Zn	Pb	Mo	Field Test (ml of dye)
	41	160	205	140	4	2
	42	55	210	25	2	4
	43	40	60	20	4	2
	44	160	70	25	2	2
	45	185	175	25	3	2
	46	80	120	35	3	2
	47	70	210	50	2	18
	48	75	235	45	2	2
	49	45	160	40	2	2
	50	40	110	100	3	2
	51	45	100	30	2	2
	52	45	130	15	3	2
	53	35	65	15	2	2
	54	45	110	30	2	2
	55	50	75	20	1	2
	56	75	150	45	2	2
	57	75	110	20	2	2
	58	50	95	25	2	2
	59	30	60	10	1	2
	60	45	340	80	2	2
	61	70	135	15	2	2
	62	45	105	20		2
	63	60	140	80	2	2
	64	45	60	20		2
	65	35	55	5	5	2
	66	45	60	30		2
	67	40	55	25	2	2
	68	250	105	5		2
	69	80	105	45		2
	70	60	240	50		12
	71	35	60	35		4
	72	35	95	40		2
	73	50	190	45		6
	74	40	155	30		4
	75	40	110	45		8
	76	35	60	30		4
	77	40	140	50		8
	78	50	110	25		4
	79	45	145	15		4
	80	70	150	35		6

Table 4 (Continued)

Field Number	Map Number	Concentration (ppm) Cu	Zn	Pb	Mo	Field Test (ml of dye)
	81	40	150	25		5
	82	40	200	40	3	8
	83	100	110	5		2
	84	80	100	10		4
	85	400	160	55		2
	86	100	95	100		6
	87	90	70	50		2
	88	135	140	200		2
	89	85	95	150	4	2
	90	350	250	250	13	4
	91	110	115	70		2
	92	100	80	55		2
	93	95	90	50	4	2
	94	150	60	180	4	6
	95	100	185	80	4	6
	96	85	300	35	25	6
	97	45	110	100		2
	98	45	55	20		2
	99	50	60	30		2
	100	75	85	100	3	2
	101	100	120	75	1	2
	102	175	150	90	4	2
	103	50	65	30		2
	104	250	80	500	25	6
	105	1000	350	400	20	12
	106	125	75	250	6	4
	107	45	55	35	1	2
	108	50	60	25		2
	109	75	80	20	1	2
	110	55	75	20	2	2
	111	55	60	15		2
	112	40	40	10		2
	113	100	60	5		2
	114	125	50	20		2
	115	250	80	15		2
	116	175	80	20		2
	117	450	100	30		2
	118	55	115	65		6
	119	40	60	10		2
	120	55	190	55		2

Table 4 (Continued)

Field Number	Map Number	Concentration (ppm) Cu	Zn	Pb	Mo	Field Test (ml of dye)
	121	65	85	30		2
	122	70	115	200		2
	123	55	140	220	1	2
	124	50	250	125		20
	125	30	120	35		8
	126	55	300	100	1	25
	127	75	230	200	3	12
	128	40	180	180		2
	129	40	90	10		2
	130	100	150	125	5	4
	131	70	140	150		2
	132	80	150	75		2
	133	70	120	65		2
	134	140	60	40	1	2
	135	75	60	30		2
	136	140	55	35	2	2
	137	185	140	100	10	2
	138	125	75	50		2
	139	300	140	240		4
	140	250	220	400		4
	141	135	125	250		2
	142	75	105	30	2	4
	143	75	160	65	4	2
	144	45	125	25	2	4
	145	75	520	65		8
	146	40	130	20	2	4
	147	45	205	45	2	4
	148	70	365	50	3	8
	149	80	380	75	5	8
	150	55	150	55	4	2
	151	45	190	90	4	2
	152	60	300	215	4	4
	153	120	+1000	200	5	25
	154	40	70	45	3	2
	155	400	395	155	8	10
	156	75	250	55	4	4
	157	70	800	110	4	25
	158	35	205	35	2	4
	159	15	90	30	2	2
	160	60	95	15	2	2

Table 4 (Continued)

Field Number	Map Number	Concentration (ppm) Cu	Zn	Pb	Mo	Field Test (ml of dye)
	161	50	90	30	2	2
	162	20	150	60	3	3
	163	70	165	40	3	2
	164	50	80	20		6
	165	55	75	5		5
	166	45	70	5		3
	167	55	65	15		2
	168	55	95	15		3
	169	20	25	5		3
	170	40	70	10		2
	171	85	110	15		2
	172	135	75	10		2
	173	35	60	5		2
	174	175	85	10		2
	175	55	85	20		3
	176	65	75	30		3
	177	400	75	5		2
	178	450	70	10		2
	179	70	60	15		3
	180	50	90	5		2
	181	60	75	10		2
	182	70	45	15		4
	183	65	50	15		4
	184	45	45	10		3
	185	45	25	5		4
	186	55	60	5		2
	187	65	60	5		3
	188	75	55	15		3
	189	45	60	5		2
	190	40	45	10		2
	191	50	50	5		3
	192	20	50	10		4
	193	45	65	10		3
	194	225	135	10		2
	195	200	240	5		4
	196	200	210	30		2
	197	90	110	5		2
	198	150	145	20	1	2
	199	250	125	15		2
	200	200	125	5		6

Table 4 (Continued)

Field Number	Map Number	Concentration (ppm)				Field Test (ml of dye)
		Cu	Zn	Pb	Mo	
	201	400	180	15		2
	202	300	210	25		2
	203	140	115	15		2
	204	150	70	5		4
	205	130	120	20		2
	206	140	110	5		2
	207	150	110	10		2
	208	180	120	25		6
	209	130	80	10	3	3
	210	100	115	5		4
	211	140	85	5		2
	212	65	50	10		4
	213	90	70	10		7
	214	180	140			
	215	100	85	5		6
	216	80	45	5		2
	217	150	50	5		2
	218	300	60	15		2
	219	600	180	20		2
	220	150	95	20		4
	221	180	75	20		4
	222	100	50	10		2
	223	170	90	25		2
	224	80	80	15		4
	225	170	70	20		2
	226	110	75	10		2
	227	170	100	45		2
	228	250	100	20		2
	229	180	105	55		2
	230	110	65	20		2
	231	100	70	5		4
	232	90	70	10		2
	233	80	75	5		2
	234	80	55	10		2
	235	50	60	5	1	2
	236	50	65	5		2
	237	90	55	10	3	4
	238	80	65	5		4
	239	70	80	25		2
	240	60	90	25		2

Table 4 (Continued)

Field Number	Map Number	Concentration (ppm) Cu	Zn	Pb	Mo	Field Test (ml of dye)
	241	110	200	65		15
	242	110	150	40		6
	243	100	165	40		4
5D-100	244	215	90	30	4	
	245	50	80	25		2
5D-1	246	45	205	80	3	
5D-2	247	50	55	5	3	0
5D-3	248	50	55	5	4	0
5D-4	249	50	85	5	4	1
5D-5	250	50	70	5	4	0
5D-6	251	45	160	10	5	0
5D-7	252	40	55	-5	3	0
5D-8	253	80	115	5	5	0
5D-9	254	70	60	-5	3	1
5D-10	255	45	65	5	3	2
5D-11	256	50	50	5	4	0
5D-12	257	45	65	5	2	2
5D-13	258	40	45	5	3	1
5D-14	259	25	30	5	2	0
5D-15	260	45	60	5	3	0
5D-16	261	45	55	5	3	1
5D-17	262	50	50	5	3	0
5D-18	263	45	65	5	3	4
5D-19	264	65	55	5	2	0
5D-20	265	90	95	5	4	2
5D-21	266	95	215	25	7	0
5D-22	267	65	105	10	4	0
5D-23	268	40	45	5	3	2
5D-24	269	40	60	5	3	2
5D-25	270	25	50	5	3	0
5D-26	271	10	35	5	3	0
5D-27	272	45	60	-5	3	4
5D-28	273	65	75	-5	4	2
5D-31	274	50	120	5	4	1
5D-32	275	115	125	30	7	2
5D-33	276	85	100	10	3	0
5D-34	277	80	80	10	3	0
5D-35	278	250	110	20	7	1
5D-36	279	65	80	5	3	2
5D-37	280	65	130	5	3	0

Table 4 (Continued)

Field Number	Map Number	Concentration (ppm) Cu	Zn	Pb	Mo	Field Test (ml of dye)
5D-38	281	50	60	10	3	0
5D-39	282	90	60	5	3	0
5D-40	283	100	80	5	5	2
5D-41	284	140	115	10	4	1
5D-42	285	50	80	10	4	0
5D-43	286	20	35	5	2	0
5D-44	287	40	75	5	2	1
5D-45	288	40	85	5	4	0
5D-46	289	20	55	5	2	3
5D-47	290	40	60	5	3	0
5D-48	291	195	80	5	4	5
5D-49	292	25	60	-5	2	1
5D-50	293	50	85	5	3	0
5D-51	294	40	60	5	2	1
5D-52	295	50	70	5	3	1
5D-53	296	50	60	5	3	0
5D-54	297	50	60	5	4	0
5D-55	298	65	60	5	3	0
5D-56	299	145	75	10	4	1
5D-57	300	160	65	5	5	0
5D-58	301	200	85	10	7	0
5D-59	302	150	80	15	7	0
5D-60	303	95	85	10	5	0
5D-61	304	110	85	15	7	1
5D-62	305	115	90	10	5	3
5D-63	306	30	75	5	3	
5D-64	307	65	130	5	4	
5D-65	308	100	85	5	7	
5D-88	309	60	90	20	1	1
5D-89	310	60	135	50	2	0
5D-90	311	130	80	10	1	1
5D-91	312	135	95	15	2	2
5D-92	313	50	90	15	2	3
5D-93	314	55	65	15	1	2
5D-94	315	45	60	10	1	2
5D-95	316	50	60	15	1	0
5D-96	317	25	65	10	2	0
5D-97	318	40	105	15	1	0
5D-98	319	40	70	10	1	1
5D-99	320	20	65	10	1	0

Table 4 (Continued)

Field Number	Map Number	Concentration (ppm) Cu	Zn	Pb	Mo	Field Test (ml of dye)
5D-101	321	140	75	15	3	13
5D-102	322	205	95	10	5	9
5D-103	323	70	80	10	3	11
5D-104	324	130	80	10	5	4
5D-105	325	115	85	5	4	5
5D-106	326	110	80	10	4	5
5D-107	327	160	115	20	5	4
5D-108	328	150	115	15	3	5
5D-109	329	100	105	5	3	1
5D-110	330	120	125	10	3	1
5D-111	331	85	95	10	3	1
5D-112	332	60	50	5	2	6
5D-113	333	115	120	10	3	3
5D-114	334	95	75	10	3	2
5D-115	335	130	75	10	3	8
5D-116	336	125	70	10	3	3
5D-117	337	65	85	10	3	1
5D-118	338	95	65	10	2	3
5D-119	339	100	80	5	2	2
5D-120	340	155	95	10	2	9
5D-121	341	185	110	10	2	16
5D-122	342	115	120	10	2	3
5D-123	343	125	100	15	2	6
5D-124	344	125	90	10	2	6
5D-125	345	115	95	10	3	2
5D-126	346	80	80	5	2	3
5D-127	347	120	80	5	2	8
5D-128	348	55	65	5	2	4
5D-129	349	80	140	5	3	2
5D-130	350	30	95	5	3	5
5D-131	351	55	130	10	3	2
5D-132	352	110	185	10	4	1
5D-133	353	70	140	5	2	0
5D-134	354	45	90	5	2	1
5D-135	355	50	85	5	2	3
5D-136	356	60	80	10	2	2
5D-137	357	85	140	10	3	8
5D-138	358	210	220	20	5	4
5D-139	359	95	150	15	2	1
5D-140	360	85	120	10	3	4

Table 4 (Continued)

Field Number	Map Number	Concentration (ppm) Cu	Zn	Pb	Mo	Field Test (ml of dye)
5D-141	361	280	200	35	5	17
5D-142	362	75	105	20	3	12
5D-143	363	135	130	10	3	7
5D-144	364	130	85	10	3	7
5D-145	365	160	105	5	2	6
5D-146	366	175	90	5	4	5
5D-147	367	285	90	5	4	11
5D-148	368	145	95	5	3	7
5D-149	369	180	50	5	4	14
5D-150	370	90	80	5	2	1
5D-151	371	230	165	10	3	1
5D-152	372	105	95	5	3	3
5D-153	373	125	115	10	2	3
5D-154	374	140	125	5	2	3
5D-155	375	105	115	5	3	1
5D-156	376	105	100	5	3	1
5D-157	377	125	95	5	3	5
5D-158	378	75	90	5	2	2
5D-159	379	60	80	5	2	
5D-160	380	30	55	5	2	
5D-161	381	40	75	10	2	
5D-163	382	205	45	5	2	
5D-164	383	175	40	10	2	
5D-165	384	145	60	10	2	

Note: Blank space in Mo column indicates molybdenum was not detected.

Map numbers 1 to 245, excluding 244, are from 1964 field work and most have been reported previously (Richter, 1965).

Map numbers 244 and 246 to 384 are from 1965 field work and have not been reported previously.

Analytical Laboratories

Alaska Division of Mines and Minerals: Samples (map number) 8, 9, 13, 16-20, 23-29, 34, 39, 40, 47, 62-141 (with exception of Mo in 89, 90, 93, 94, 104, and 105), 164-243, and 245.

Rocky Mountain Geochemical Laboratory: Samples 1-7, 10-12, 14, 15, 21, 22, 30-33, 41-46, 48-61, 142-163, 244, and 246-384.

Table 5.

COPPER, ZINC, LEAD, AND MOLYBDENUM CONTENT OF ROCKS IN THE SLANA DISTRICT

	Map Number	Concentration (ppm) Cu	Zn	Pb	Mo	Remarks
Ahtell Pluton (quartz monzonite-diorite)	8	10	40	10	1	
	11	50	45	15	1	
	15	5	40	-5	1	
	23	5	35	-5	1	border zone
	27	5	55	5	5	border zone
	30	45	60	20	1	
	31	20	50	10	3	
	32	10	125	5	2	border zone
	35	10	40	20	2	
Range		5-50	35-125	-5-20	1-5	
Tectonic diorite-quartz diorite and schistose equivalents	1	15	100	35	4	
	2	5	20	5	3	
	4	40	60	10	3	
	5	25	95	5	1	
	6	150	85	10	4	visible sulfides
	7	105	105	5	2	
	9	10	25	10	3	
	18	35	40	10	2	
	20	5	80	5	3	
	25	10	60	10	2	
	28	110	140	10	4	
	33	265	110	10	3	visible sulfides
Range		5-265	20-140	5-35	1-4	
Hypabyssal rocks						
quartz monzonite	3	115	70	15	3	
andesite porphyry	10	90	60	15	3	
andesite porphyry	13	175	140	20	2	
gabbro	16	250	110	10	2	
lamprophyre	21	15	125	10	3	
dacite	24	5	15	20	2	
Volcanic and sedimentary rocks						
andesite breccia	14	15	95	5	1	
andesite flow	17	105	125	5	2	
sandstone	19	50	55	10	3	
limestone	22	5	30	5	3	
altered volcanic	26	15	60	15	3	
basalt	29	60	90	5	1	
porphyritic andesite flow	34	10	50	10	2	
Quartz tourmaline vein	12	5	20	10	2	

Analyses by Rocky Mountain Geochemical Laboratories.

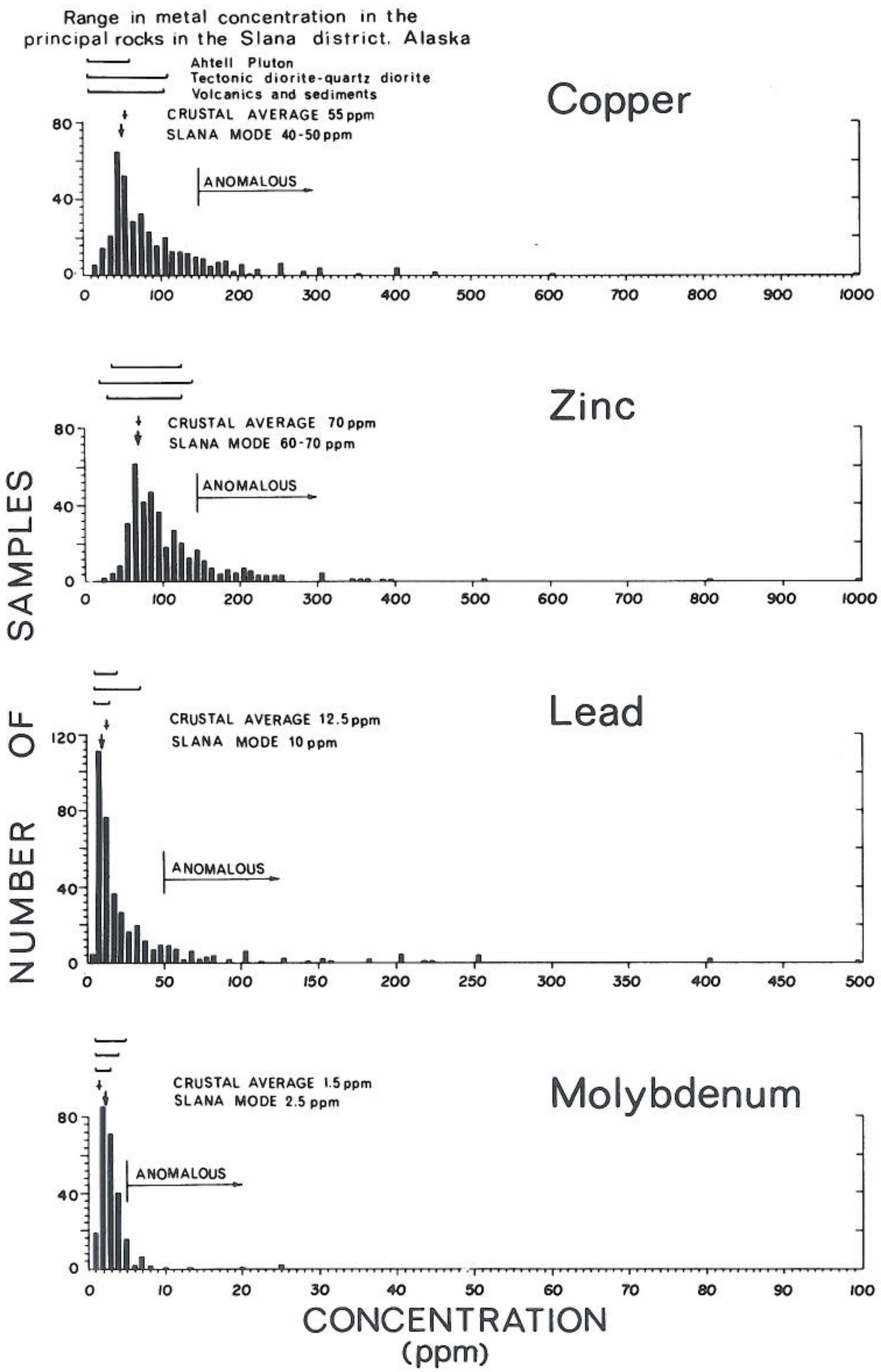

Figure 7. Frequency distribution graphs for copper, lead, zinc, and molybdenum in stream sediments in the Slana district, Alaska

draining only the Ahtell phase core of the pluton. Zinc and lead are the principal enriched metals in anomalies related to Ahtell pluton border zone rocks and associated altered area, whereas copper tends to be the principal metal in the anomalies in the dioritic rocks. Although the data are insufficient to determine which, if any, of the anomalies may be significant, at least three areas of high metal concentration – two in the vicinity of Long Lake and one south of Flat Creek – warrant further investigation (figure 5).

The largest anomaly in the Long Lake area, extends from the highly altered area south of Long Lake (locality 4, figure 5), south to an altered area on peak 4420. It includes an area of approximately two square miles underlain by Ahtell pluton border phase rocks and Tetelna volcanics. With the exception of the streams draining the molybdenite-bearing altered rocks at locality 4, which are high in all four metals, the anomaly is characterized by high lead values. Lead concentrations range from 35 to 500 ppm in 20 streams draining the anomalous area with 13 streams containing more than 100 ppm. In the four of these streams, which drain the altered area at locality 4, (map numbers 94 and 104-106, figure 6) copper ranges from 125 to 1000 ppm, zinc from 60 to 350 ppm, lead from 180 to 500 ppm, and molybdenum from 4 to 25 ppm.

A smaller lead anomaly is defined by four streams draining the area around locality 1 (figure 5) northwest of Long Lake. Highest lead concentration is 400 ppm (map number 140) in a stream which drains the opposite side of the Mountain ridge on which the galena-bearing quartz veins are exposed. Copper, and to a minor extent zinc, also show some enrichments in the four streams.

The third anomaly is in the mountains south of Flat Creek and is apparently restricted to streams draining the border zone phase of the Ahtell pluton. Unlike the two anomalies near Long Lake, zinc is the principal enriched element with five streams exhibiting concentrations of 300 to +1000 ppm (map number 145, 148, 149, 152, and 153, figure 6). High lead values (maximum 205 ppm, map number 152) are present in a number of streams, but copper does not appear to occur in amounts above threshold values. No obvious source of the anomaly is apparent from the geologic investigations conducted in the area. A number of barren quartz veins and one pyrite-bearing quartz vein in quartz-tourmaline border zone rocks are exposed between map number 48 and 146 in the main stream flowing north into Flat Lake (figure 6). To the east a small limonite-stained area and quartz-carbonate vein with pyrite is exposed below map number 153 and minor disseminated chalcopyrite and a few quartz-carbonate veins are present in quartz-rich border zone rocks below map number 39.

Elsewhere in the district, most of the anomalous sediments are enriched chiefly in copper and are from streams draining the tectonic diorite-quartz diorite complex. Many of these apparent copper anomalies, however, probably only reflect the relatively high background copper content (as much as 265 ppm) of the dioritic rocks.

Conclusions and Recommendations

In the Slana district silver-bearing base metal veins, areas of hydrothermal alteration, and base metal anomalies appear to be spatially and genetically related to the southern part of the Ahtell quartz monzonite pluton. These deposits and indications of mineral deposits occur chiefly in the border zone of the pluton and in the Tetelna volcanics adjacent to the pluton. Although at the present time none of the vein deposits around the pluton are known to be economically significant, they have been only superficially prospected, and at least three prospects (localities 2, 7, and 8) are currently being explored by private capital. Moreover, none of the geochemical anomalies in the area peripheral to the pluton have been known to be investigated, nor has there been any extensive search in most of the border zone areas for additional vein deposits.

In addition to the current exploration, the following three areas around the pluton warrant further investigatins:

1) the area including the Long Lake anomaly and altered areas west of Hidden Creek.

2) The Flat Lake anomaly.

3) The border zone of the pluton extending from Grubstake Creek south to the Silver Shield prospect (locality 7).

Detailed geochemical soil sampling over the altered areas and anomalies is recommended as preliminary to any more sophisticated exploration. In the border zone area south of Grubstake Creek, where the terrain is not amenable to soil sampling, detailed prospecting should be undertaken. The possibility of additional silver-bearing tetrahedrite veins in this area is excellent.

The scattered occurrences of copper minerals and related copper anomalies elsewhere in the district do not appear to have the grade or size to justify exploration.

References Cited

Hanson, L.G., 1963, Bedrock geology of the Rainbow Mountain area, Alaska Range, Alaska: Alaska Division of Mines and Minerals Geologic Report No. 2.

Hawkes, H.E., 1963, Dithizone field tests: Economic Geology, v. 58, p. 579-586.

Jasper, M.W., 1956, Fred Bronnicke's Gold-Quartz prospect, Ahtell Creek, Slana district, Alaska: unpublished Department of Miners, Territory of Alaska, Property Examination Report.

Mendenhall, W.C., 1905, Geology of the central Copper River region, Alaska: U.S. Geological Survey Professional Paper 41.

Mendenhall, W.C., and Schrader, F.C., 1903, The mineral resources of the Mount Wrangell district, Alaska: U.S. Geological Survey Professional Paper 15.

Moffit, F.H., 1932, The Slana district, upper Copper River region, Alaska: U.S. Geological Survey Bulletin 824, p. 111-124.

———1933, The Suslota Pass district, upper Copper River region, Alaska: U.S. Geologic Survey Bulletin 844-C, p. 137-162.

———1938, Geology of the Slana-Tok district, Alaska: U.S. Geological Survey Bulletin 904.

———1954, Geology of the eastern part of the Alaska Range and adjacent area: U.S. Geological Survey Bulletin 989-D, p. 65-218.

Mukherjee, N.R., and Mark Anthony, L., 1957, Geochemical prospecting: University of Alaska, School of Mines Bulletin 3.

Richter, D.H., 1964, Geology and mineral deposits of the Ahtell Creek area, Slana district, southcentral Alaska: Alaska Division of Mines and Minerals Geologic Report No. 6.

———1965, Geochemical investigation of the Slana district, southcentral Alaska, 1963 and 1964: Alaska Division of Mines and Minerals Geochemical Report No. 2.

Rose, A.W., 1965, Geology and mineral deposits of the Rainy Creek area, Mt. Hayes Quadrangle, Alaska: Alaska Division of Mines and Minerals Geologic Report No. 14.

Sandell, E.B., 1959, Colorimetric determination of traces of metals: Interscience Publishers, 3rd ed. New York.

Stanley, K.W., 1958, Economic geology of the Ahtell-Slana district, Alaska: unpublished Master of Science thesis, Montana School of Mines, Butte, Montana.

Taylor, W.R., 1964, Abundance of chemical elements in the continental crust: a new table: Geochemical et Cosmochim Acta, v. 28, p. 1273-1285.

Thorne, R.L., 1946, Exploration of argentiferous lead-copper deposits of the Slana district, Alaska: U.S. Bureau of Mines R.I. 3940.

Ward, F.N., and others, 1963, Analytical methods used in geochemical exploration by the U.S. Geological Survey: U.S. Geological Survey Bulletin 1152.