ECONOMIC GEOLOGY OF THE
AHTELL-SLANA DISTRICT, ALASKA

by

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ABSTRACT

The Ahtell-Slana district is located in the Eastern Alaska Range. In this area the Alaska Range trends northeast and forms the highest relief.

The only rocks identified as sedimentary were found south of Indian Pass, and were mapped as undifferentiated sediments.

Probably seventy-five percent of the bedrock of the Ahtell-Slana district consists of intrusive igneous rocks, of which diorite and quartz-monzonite are the principal types. The Ahtell Creek pluton is mainly diorite, whereas, quartz-monzonite is the important rock of the older Indian Creek pluton.

Basalts are widespread in the district and have been tentatively subdivided into two types; the Grubstake Creek basalts and the Long Lake basalts.

Metamorphic rocks underlie a relatively small part of the district and the majority of those cropping out are along the Ahtell Creek and the South Fork of the Slana River.

Structural adjustment has been a continuous process in the district since early geologic time and may have lessened only in the recent past. The trends of faulting are so located as to suggest regional orientation.

Modification of the land form was found to vary in different areas and because of that, this portion of the Alaska Range Province has been subdivided. The eastern part is called the Glacial sub-province and the western part the Periglacial sub-province.

Deposits containing molybdenite, lead-silver, chalcopyrite and gold were noted in the district.

INTRODUCTION

The field season began July 1, 1957 and ended September 24, 1957. Mr. Au Ngoc Ho, a geologist for Strandberg Mines Inc., joined the writer in the area August 12, 1957 and left September 7, 1957.

Travel within the area was on foot. Base camps were established at several lakes and supplies were flown in by float plane. In areas where lakes were not available, camp supplies and equipment were either air-dropped or back packed.

Aerial photographs were not available during the field season and sketch maps were made of all areas traversed. Later, aerial photographs, taken by the United States Air Force, were made available. These photographs were enlarged and Plate I was made with their aid.

Approximately 250 rock and ore specimens were collected from which eighty thin sections, twelve polished-thin sections, and thirty-two polished sections were prepared and studied.

Location and Area.

The Ahtell-Slana district is located in the Eastern Alaska Range in the Territory of Alaska and is a part of the larger Slana-Tok district. The district is approximately 260 miles southeast of Fairbanks and 200 miles northeast of Anchorage.

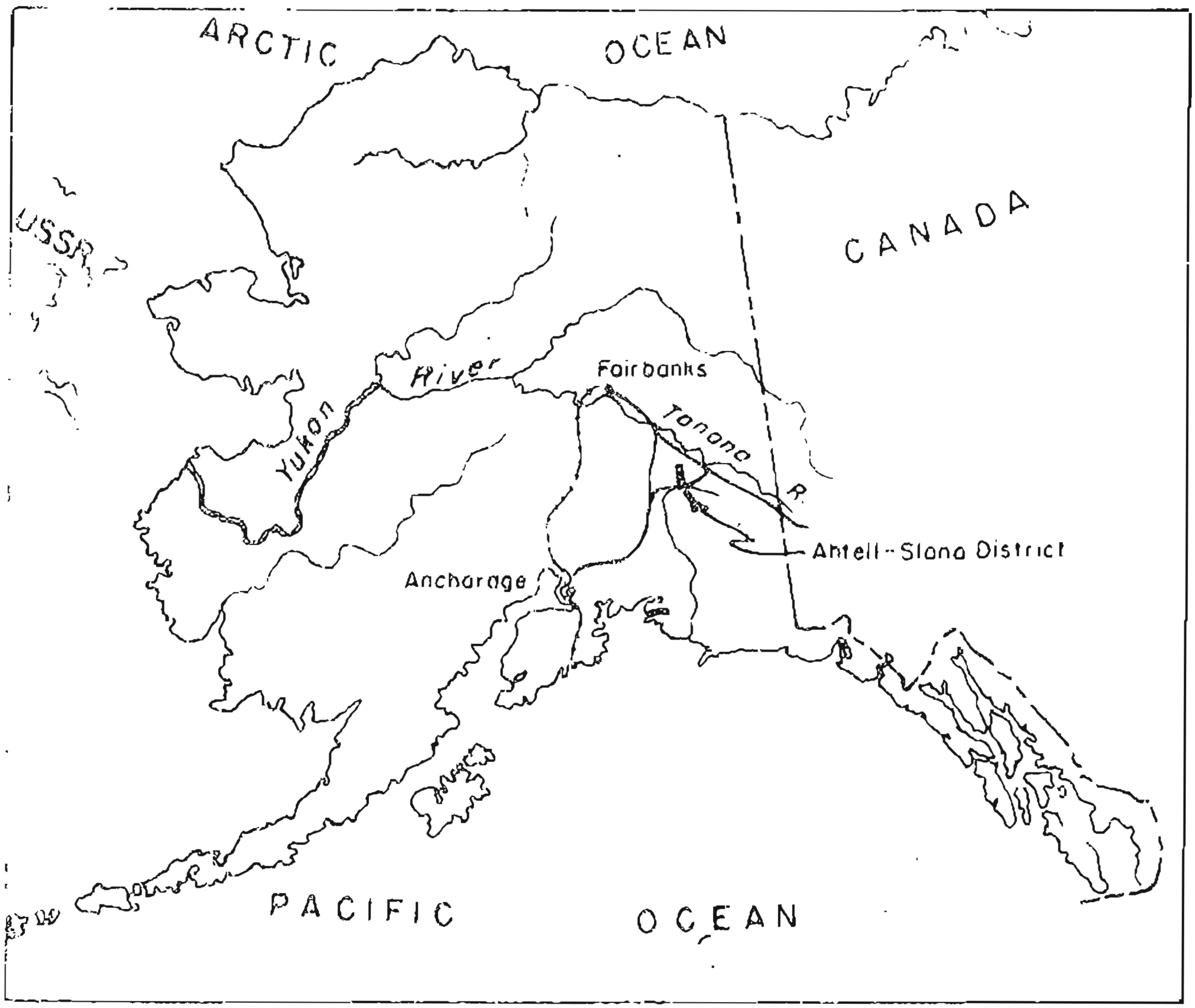
The area discussed in the following pages and covered by the general geologic map, Plate I, extends north approximately twenty miles from the Slana-Tok highway to the Slana River and includes an area of approximately 140 square miles. The area covered includes the drainage of Ahtell Creek and the South Fork of the Slana River. The location of this area in Alaska is shown in Figure 1.

Accessibility.

At present, there are no roads in the district and travel is generally by track equipped vehicles or by float equipped aircraft.

Previous Work.

All previous work in the area was in the nature of broad reconnaissance surveys carried out by Mr. Fred H. Moffit, a geologist for the United States Geological Survey. Moffit, in 1929, made a brief and preliminary traverse of the Slana-Tok district; however, he does not make mention in his published bulletin (1929, Bull. 824) of actually traversing the area as mapped on Plate I. In the summer of 1936, Moffit again visited the Slana-Tok district and continued the reconnaissance survey. The results of this work were published in bulletin 904, "Geology of the Slana-Tok District", and included an area of approximately 1,000 square miles. Mr. Moffit mentioned in this work the area included on Plate I, but merely referred to the



INDEX MAP SHOWING LOCATION OF AHTELL-SLANA DISTRICT rocks west of Ahtell Creek as undifferentiated igneous intrusives and extrusives and those to the east as a dioritic mass. Mendenhall, in 1901 and 1902, made a reconnaissance survey of the Central Copper River region which also included the upper Chistochina River country. Although Mendenhall did not enter the Ahtell Creek area he did traverse the Indian Creek region. His work was published in 1904 as Professional Paper 41 and titled "Geology of the Central Copper River Region". In 1954, Mr. Moffit had published United States Geological Survey Bulletin 989-D, a compilation of much of the information (much of it his original work) regarding the Eastern Alaska Range and titled "Geology of the Eastern Part of the Alaska Range and Adjacent Area". The bulletin is a credit to Mr. Moffit's long and distinguished service in contribution to Alaskan geology.

Purpose of Work.

The purpose of the field work was to carry out a geologic reconnaissance survey of the area drained by Ahtell Creek and the South Fork of the Slana River. The field work was planned to serve a dual purpose. (1) To examine all known mineral deposits and search for others, and (2) to use the data collected for thesis material in partial requirement for the Master of Science degree in geology from the Montana School of Mines.

Acknowledgments.

This writer wishes to express his appreciation to Mr. Harold Strandberg, President of the Strandberg Mines Inc., Anchorage, Alaska, who financed the total cost of the field work and other expenses incurred in the compilation of this thesis.

Additional thanks is extended to Mrs. Olga Doheny, Office Manager for Strandberg Mines Inc..

This writer would also like to express his appreciation to the following people who have contributed additional information about the district. Dr. John Reed, of the United States Geological Survey, who assisted in obtaining aerial photographs, Mr. Phil Holdsworth, Territorial Commissioner of Mines, Mr. Martin Jasper and Mr. William Powell of the Territorial Department of Mines.

Special thanks go to Mr. Au Ngoc Ho who accompanied this writer for part of the field season.

GEOGRAPHY

The Ahtell-Slana district is dominated by the Eastern Alaska Range and the Copper River drainage system. The former trends northwest through the district and forms the highest relief. The latter is to the south and west and forms a broad sloping lowland with many lakes and meandering rivers, but rises towards the south to form Mount Sanford in the Wrangle Mountains.

Relief.

The relief of the Ahtell-Slana district is considerably less than that of the western part of the Alaska Range. The highest point in the district is Ahtell Mountain which is approximately 7,000 feet. The lowest point is near the mouth of Ahtell Creek and is approximately 2,000 feet. Hence, the difference in maximum relief is nearly 5,000 feet.

Drainage.

The Ahtell-Slana district is drained by three major streams, Indian Creek, Ahtell Creek and the South Fork of the Slana River. All either flow directly into the Copper River or into tributaries of that river.

All of the streams are, in part, braided, but many have cut deep gorges, particularly along their lower courses. The Slana River is the major water course in the area mapped, however, it is a fast flowing highly braided river, not suitable for small boats. The name Slana is apparently derived from the Indian, sla meaning muddy and na river in the Athabascan language. Most rivers in the Interior of Alaska ending with na are derived from the Athabascan.

High water can generally be expected in July, due to active melting of glaciers. During periods of high water the Slana River may prove difficult to ford, but the other streams can be crossed at any time during the season.

Timber and Vegetation.

Timber suitable for large construction purposes is not available in the district, however, spruce and birch do grow in abundance within the Copper River lowland. The timber within the district is generally small in diameter, spruce, and is generally limited to areas below 2,500 feet.

Alder brush is common to all the lower valleys and grows in abundance in such areas.

Tundra and muskeg are abundant everywhere in the lower areas as well as in the higher flat country.

Climate.

The climate of the Ahtell-Slana district is sub-arctic and characteristically cold during the winter, warm and dry during the summer. The highest temperature, unofficially reported during the 1957 field season, was 102 degrees, in July. Snow is usually gone from the lower slopes by June first, but can be expected anytime after September fifteenth.

Population.

The only permanent residents in the area are along the Slana-Tok highway and near Mentasta Lake.

GENERAL GEOLOGY

The Ahtell-Slana district is located partly in a detached group of mountains locally referred to as the Ahtell Mountains. It is, geographically as well as geologically, part of the Alaska Range. (See areal map, Plate I). It is predominantly an igneous area, but includes a restricted number of metamorphic and sedimentary rocks.

Igneous intrusives constitute the most widespread assemblage of rocks in the district. Due to difference in composition and age, the intrusive rocks may be considered to be two separate plutons. The Indian Creek pluton, located to the west of Ahtell Creek, is the older and predominantly quartz-monzonite or related facies. The Ahtell Creek pluton is mainly diorite and covers a large area to the east of Ahtell Creek. Dikes of various composition are numerous and transect every rock type in the district. The dikes represent the latest igneous activity in the district.

All rocks have been subjected to prolonged structural deformation, and faults are common throughout the district. Many, but not all of the faults, have been mapped (Plate I). Some of the faults have resulted from local intrusion, but others may be related to regional stress. Structural readjustment in the very recent past is still evident in well defined fault-line-scarps. Some of the structural adjustment has occurred subsequent to glaciation, which fact is evidenced by the preservation of scarps. Glacial action was more active in the higher mountains east of Ahtell Creek than in the region to the west. As a consequence we find "biscuit-board" topography developed on the Indian Creek pluton and a more mature dissection in the glaciated mountains of Ahtell Creek.

Stratigraphy and History.

The marble north of the Slana River, of Devonian or early Permian in age, represents the oldest sediment in the district. A similar crystalline limestone or marble, noted by Moffit near the mouth of the Indian Creek suggests that Devonian or early Permian rocks were more extensive than is now apparent.

Submergence occurred during Permian time, as evidenced by the Permian marine sediments. Also, during the Permian period there was intensive volcanic activity throughout Alaska, except in the northern part. Mertie (1935, p. 301) has suggested that one of the major loci of volcanic activity was in the Eastern Alaska Range. Preceeding the volcanic activity a series of sediments (present day hornfels) were layed down, probably over the entire Ahtell-Slana district and adjacent regions to the west. These sediments are possibly equivalent to the Chisna formation that Mendenhall (1905, p. 34) first described in the upper Chistochina region, and regarded as pre-Permian. Mendenhall placed them in the Carboniferous Period. Moffit (1954, p. 103) states of these:

> "The assignment of the rocks of the Chisna formation to the Carboniferous is provisional..Future detailed study will probably show that rocks of the Permian age have been included in the Chisna formation".

Regardless of their absolute age, the hornfelsic rocks are, in a relative way, prior to Grubstake Creek basalt. Since there is good reason to believe the basalt represents the lower Permian and equivalent to the lower Mankomen formation, the hornfels would seem not younger than early Permian. However, should the Long Lake basalt and the Grubstake Creek basalt prove to be equivalent, the Indian Creek pluton would then have to be pre-Permian in age or at least prior to Grubstake Creek basalt, and the hornfelsic rocks would also probably be pre-Permian in age. Evidence to suggest the equivalence of Long Lake and Grubstake Creek basalts has not been found.

After the extrusion of the thick basalt series deposition of the undifferentiated sediments, accompanied by further volcanism, took place.

According to Moffit (1954, pp. 181-182) the area of the present Alaska Range was one of fluctuating land and sea levels between Permian and Tertiary time. After deposition of the sediments and later volcanic activity, intrusion of the Indian Creek pluton took place.

Capps, (1916, p. 85) and Cairnes (1914, pp. 12-28) have suggested there were at least two periods of igneous intrusion in the Chisana area and in adjacent parts of Canada. The early period was not later than upper Jurassic or lower Cretaceous and the later period was in Tertiary time. Wayland (1940, p. 152) concludes that the Klein Creek batholith (granodiorite) near the Canadian border, was post-Permian, but pre-upper Jurassic. Although the areas cited are some 100 miles east from the Ahtell-Slana district they are on the same structure and igneous activity in one area could have been contemporaneous elsewhere along the structure. Because of the similarities of the rock types in the above areas to those of the Indian Creek pluton, it seems further likely that these intrusives were contemporaneous, or, at least, nearly so. Hence, the Indian Creek pluton may be tentatively considered post-Permian, but pre-Cretaceous, in age.

After intrusion of the Indian Creek pluton dissection was probably accelerated. Intrusion of the Ahtell Creek pluton may have been near the climax of the Alaska Range orogeny and in post-Cretaceous time.

Structural deformation of the region presently occupied by the Alaska Range has been a continuing process since late Paleozoic time. Smith (1939, p. 27) has described strongly deformed Carboniferous rocks below only moderately deformed Triassic rocks in the area adjacent to the Canadian border. Moffit also believes the Alaska Range indicates a zone of structural weakness and one of repeated mountain building extending back as early as middle Paleozoic time. The climax of the present Alaska Range orogeny, according to Mertie (1930, p. 115) was in Tertiary time. The affect this had upon the Ahtell-Slana district is, for the most part, unknown. Only the last structural readjustment is recognized, but possibly the long continuous structural process and repeated orogeny have affected the district. The Denali fault, believed by Mendenhall (1905, p. 84) to be post-Eocene, may be a much older structure than many infer. The structural adjustment of the Ahtell-Slana district probably is related in some way to the Denali fault. This writer's proposed east-west direction for principal stress may be related to the articulate structure of Alaska Range.

Sedimentary Rocks.

The only rocks identified as sedimentary, excluding the recent alluvium, were found south of Indian Pass. This area, because of its complex structure, was not examined in detail and thin sections were not made of the rock types. In view of their complexity and composite nature they have been designated undifferentiated sediments.

Undifferentiated Sediments: Sedimentary rocks, as mapped on Plate I, consist of a series of sandstones, shales, impure limestones, conglomerates, and gritty tuffaceous beds all overlying a massive basalt flow. As a group, the sediments are much deformed by faulting and dike intrusion. The light brown color of these rocks contrasts sharply with the darker Grubstake Creek basalt as illustrated by Figure 2.

Thickness of the sediments is estimated to be at least 1,500 feet. Physically, the undifferentiated sediments closely resemble Permian rocks exposed to the southeast and may prove equivalent to them.

Intrusive Igneous Rocks.

Probably seventy-five percent of the bedrock of the Ahtell-Slana district consists of intrusive igneous rocks of which diorite and quartz-monzonite are the principal types. The Ahtell Creek pluton is mainly diorite with subordinate amounts of tonalite. Quartz-monzonite is the important rock of the Indian Creek pluton. Facies changes are common within both major plutons, but only a minor number of such changes were mapped on Plate I. However, the salient features of the two plutons are mapped on Plate I.

Dikes are common to abundant, but because of their small size only a restricted number were plotted.

The names and definitions of the rocks described in the following pages, as well as the mineralogic varieties are those corresponding to Grout's classification (1932). There are two exceptions and both rocks are described by prefixing a descriptive adjective.

Granite: Granite is found in a number of areas throughout the district, but not so widespread as other rock types such as diorite or quartz-monzonite.

The granite may be subdivided, although not so mapped on Plate I, into biotite granite and porphyritic granite. The former is darker, and is a medium to coarse equigranular rock. The porphyritic granite has a pink tint with phenocrysts of light colored potassium feldspars. The Dome (see Plate I) is composed essentially of biotite granite as is the restricted area to the south and adjacent to Long Lake. The other appears more prominent in the northern portion of the area between Niar and Ahtell Creeks. Both rocks are altered and iron staining of the weathered surface is common.

Orthoclase and, or, microcline are the dominant feldspars, generally cloudy, and commonly have a poikilitic texture. Microperthite is probably present, although not definitely identified. Carlsbad twinning is common and well developed in minerals not strongly affected by alteration. Plagioclase, when present, is in a state of almost complete alteration.

Quartz is interstitial often showing undulatory extinction, suggesting strain, but crushing or fragmentation as such was not observed. The mafic minerals consist of biotite and hornblende with the latter being more abundant. Both are closely associated with chlorite as well as with small grains of magnetite. Accessory minerals are apatite, monazite, sphene, magnetite, and hematite. The secondary minerals include sericite and kaolinite, both of which are widespread. All of the feldspars have undergone some form of sericitization or kaolinization and some to the extent that only relict outlines now appear. Alteration appears to affect first the plagioclase and then the potassium feldspar, starting along grain boundaries and cleavage. Alteration of the mafic minerals is mainly chloritization.

Quartz-Monzonite: Quartz monzonite is the principal intrusive rock of that portion of Indian Creek pluton mapped on Plate I. The quartz-monzonite, as mapped, probably includes a number of related facies, but the rock as a whole is best described as quartz-monzonite with the reservation that it may include other similar types. In many respects this rock is similar to the granodiorites, as described by Moffit and Capps, in other parts of the Alaska Range. Mendenhall (1905, p. 39) although not entering this area, believed the rocks were similar to those in the East Fork of the Chistochina area and called them, as a group, the Ahtell diorites.

The part of the Indian Creek pluton mapped on Plate I is an area of high, rounded mountains that were, in some areas, dissected to form peaks and ridges, but generally are far less rugged than the mountain mass east of Ahtell Creek. In many respects the rocks appear older and more highly altered than the diorite to the east. The rocks are dark with colors ranging from dark pink through dark green to dark reddish-brown. In some cases they are strikingly porphyritic while in others such textures are absent.

Several different types of structure were found within the borders of this rock and, while not studied in detail, some will be mentioned. In some areas the texture changes and becomes felsic and there the rocks tend to be massive, often fractured, but not jointed. The less felsic rocks are not so massive and may in areas have a slight suggestion of flow structure due apparently to the orientation of mafic minerals. In the less massive rocks fracturing as well as jointing is well developed. Some of the joints apparently were filled by dikes, but others are barren and cut across dikes. One joint set trends north to slightly west and the other north to slightly east. As noted on Plate I, this is also the general trend of many of the small tributary streams. An unusual occurrence is the intricately brecciated crushed zones that are completely healed, and associated with these are xenolith like structures. These zones do not appear to have originated as faults. Waters (1941, p. 1417) describes a similar type of structure in the Colville batholith in Washington and believed it was caused by the upward flow of magma already in an advanced stage of crystallization. The color of the rock generally changes in such areas, but does so gradually, the change ranging from a dark pink to dark green.

The common occurrence of a skarn type rock was often noted as float along the mountains north of Long Lake. The only area the rock was found in place was along the mountain slope south of Long Lake, apparently at or near the contact of granite and quartz-monzonite. The rock elsewhere could represent material formed along similar contacts.

Faulting is a common feature throughout the quartz-monzonite, but seems concentrated in certain areas. One such area of apparent active faulting was near and adjacent to Long Lake. The rocks there are often much altered and decomposed and sulphide mineralization has taken place.

When studied under the microscope, several interesting characteristics of the composition of the quartz-monzonite were noted. There is a suggested change in feldspar of the flesh colored variety to the greenish type. In the former, the plagioclases are in the range of oligoclase, and have thin, closely spaced twin lamellae which Emmons (1953, p. 46) believes indicate the mineral is approaching albite composition. Sericite has strongly attacked the plagioclase which is generally subhedral. Potassium feldspar is approximately equal to plagioclase, generally anhedral and poikilitic. Oligoclase is the principal feldspar, in the greenish rock, but is euhedral. The oligoclase generally has broader twin lamellae and the extinction angle was consistently higher than in the other, which suggests that the mineral is approaching andesine composition rather than albite. Sericitization has not affected the feldspars so strongly as in the oligoclase of the flesh colored rock. The two types of plagioclase are illustrated in Figures 3 and 4. Potassium feldspar occurs, but is subordinate to plagioclase. Quartz is approximately equal in both, and is generally an interstitial mineral.

Thin sections of the reddish-brown rock exposed south of The Dome had, in some cases, a granophyric texture of quartz and feldspars, as illustrated by Figure 5, however, the mineral composition is well within the quartz-monzonite range.

Mafic minerals are much the same in all the quartz-monzonite specimens examined. Brown biotite and green hornblende are the common mafic minerals.

Secondary products include widespread sericite and kaolinite as well as chlorite. One of the principal differences in the secondary mineralization is that magnetite is more commonly in the rocks south of The Dome than elsewhere.

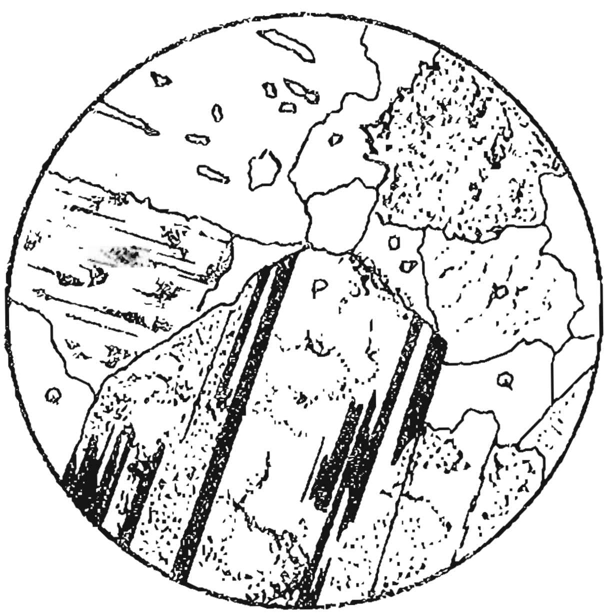


Figure 3

Euhedral plagioclase (p) in quartz-monzonite. Biotite (B). Quartz (Q). Potassium feldspar (or). X50. Nicols crossed.

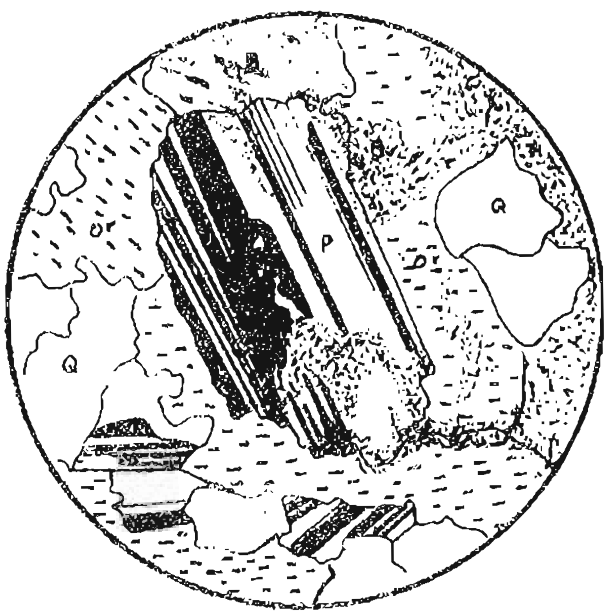


Figure 4

Anhedral plagioclase (p) in quartz-monzonite, biotite (B). Quartz (Q). Potassium feldspar (or). X50. Nicols crossed.

Myrmekitic Quartz-Monzonite: The widespread occurrence of myrmekite in what may basically be quartz-monzonite appears to warrant the qualifying adjective myrmekitic for descriptive purposes. The surface extent of this rock appears limited to the high peak approximately three quarters of a mile west of the molybdenum deposit. The rock is dark reddish-brown with a medium to fine grained equigranular texture. In general appearance, the rock closely resembles the quartz-monzonite south of The Dome which has a granophyric texture in certain areas. The myrmekitic texture cannot be recognized in the hand specimen, but may with the microscope.

The rock is composed essentially of potassium feldspar, plagioclase, quartz, and minor mafic minerals. Potassium feldspar is the most abundant mineral, anhedral in the large crystals and subhedral to euhedral in smaller crystals. In all cases the potassium feldspar has, to some extent, been altered to kaolinite or sericite. Twinning is either absent or poorly developed. Zoning, or what appears to be relict zoning is noted in many crystals. The plagioclase has been altered to clay or clay like minerals, in most cases, and twinning is, in most instances, obscured by alteration. The intergrowth of quartz and plagioclase, illustrated by Figure 6, has developed into the characteristic pattern of myrmekite. Quartz has undulatory extinction, suggesting strain. Other minerals are biotite and hornblende, with biotite the more

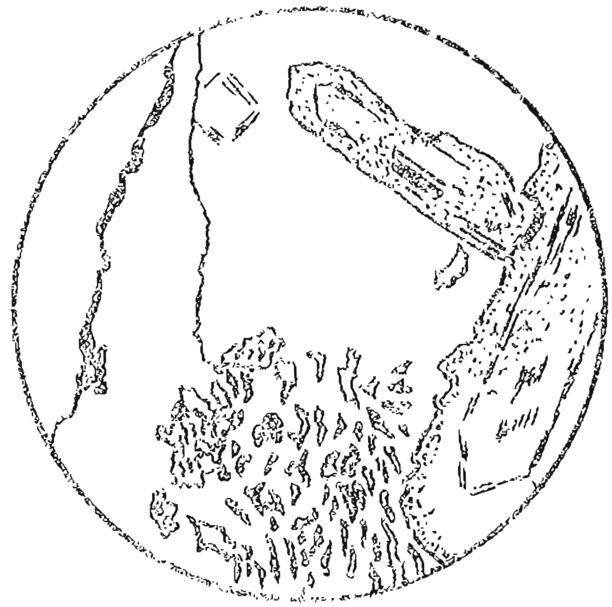


Figure 5

Granophyric texture.

X50. Nicols crossed

Figure 6

Myrmekitic texture.

X50. Nicols crossed

abundant. Both are partly altered to chlorite and, or, magnetite.

Myrmekite is generally considered to be a late reaction product in the consolidation of the rock (Johannsen 1955, p. 43).

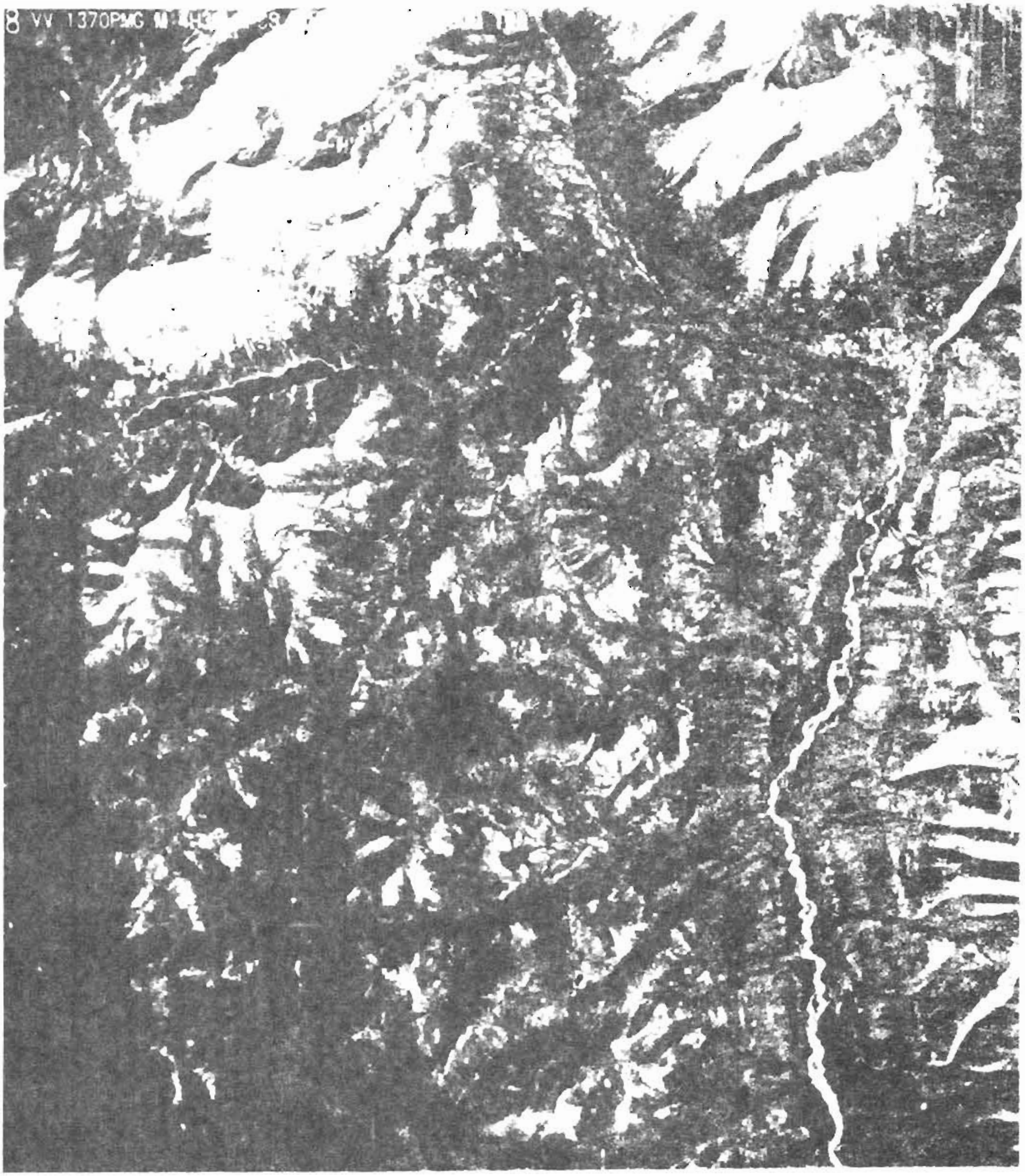
Diorite: The principal area of diorite is east of Ahtell Creek, and there it forms a fairly uniform plutonic mass at least twenty miles in length and nearly eight miles in width. Locally, outliers of diorite extend to the west beyond Ahtell Creek, but viewed on a regional basis, the outliers are small. The light color of the rock and whitish talus of the diorite forms a distinctive rock unit and is readily distinguishable from the darker quartz-monzonite and related rocks to the west. The aerial photographs in Figures 7 and 8 illustrate the contrast and the general topography of the dioritic pluton and adjacent rocks.

In general, the diorite is a fresh appearing, medium textured granular rock, with light colored feldspar as the principal mineral, but in a few places the rock is porphyritic. In certain areas, particularly along upper West Fork, potassium feldspar becomes conspicuous, but still subordinate to the plagioclase. In such areas the rocks could be termed granodiorite. Quartz is usually present in minor amounts, but increases in certain areas to the extent that the rock is a tonalite. One such area is on the summit between the forks

Figure 7

Aerial Photograph of Area East of [illegible] Creek

(Taken from 20,000 Feet)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of Ahtell Creek and the West Fork. There is also a decided increase in quartz along the higher elevations of the Ahtell Creek pluton. The quartz-rich diorite, or tonalite, is generally recognizable in the field by its darker color and greenish tint. The gradations of the contacts of diorite and quartz-rich diorite, as well as the lack of detailed work, does not justify the mapping, except in one area, of a separate lithology.

Faulting, as well as fracturing, is common within the dioritic rock, and in places the rock is conspicuously iron stained. This staining is often due to decomposing dikes or infaulted volcanics or metamorphics.

Dark, spherical inclusions resembling xenoliths which vary in size from several inches to over two feet were noted in many areas. Microscopic examination revealed that the inclusions consist of fine grained masses of well twinned subhedral crystals of brown biotite and green hornblende associated with sphene, quartz, and considerable opaque material, probably magnetite.

Alteration is not so widespread in the diorite as in the quartz-monzonite or other rocks west of Ahtell Creek, but the presence of epidote, as well as chlorite along fractures, suggests some alteration, and microscopic examination confirms this.

One unusual occurrence associated with the alteration is the presence of a pink material, along many of the fractures, that closely resembles erythrite in hand specimens, but was found to be a magnesium rich epidote.

The plagioclase, when examined with the microscope, generally proved to be high oligoclase or andesine and subhedral to euhedral. Oligoclase was more common in the quartz-rich rock, or tonalite, and andesine in the diorite. Potassium feldspars are minor, but variable in quantity. Where most abundant they form rather large ragged crystals. The mineral is nearly always cloudy and poikilitic. While quartz is present everywhere, it is more plentiful in the quartz-rich rock, where it occurs as interstitial, anhedral crystals. When in greater quantity, the quartz frequently has a mosaic-like structure as well as undulatory extinction.

As a rule, twinning is well developed in the plagioclase of the diorite, but is incompletely developed or absent in that of the tonalite or quartz-rich rock. The twin lamellae of the andesine are broad, but evenly spaced. There is also further suggestion that where potassium feldspar is abundant it is replacing plagioclase and still retaining the Carlsbad twin boundary, as illustrated in Figure 9, which would suggest a late stage introduction and replacement of the earlier rock forming minerals by the potassium feldspars.

The relative quantity of hornblende and pyroxene varies widely and these two minerals bear a complementary relationship to each other. When hornblende is plentiful, augite is

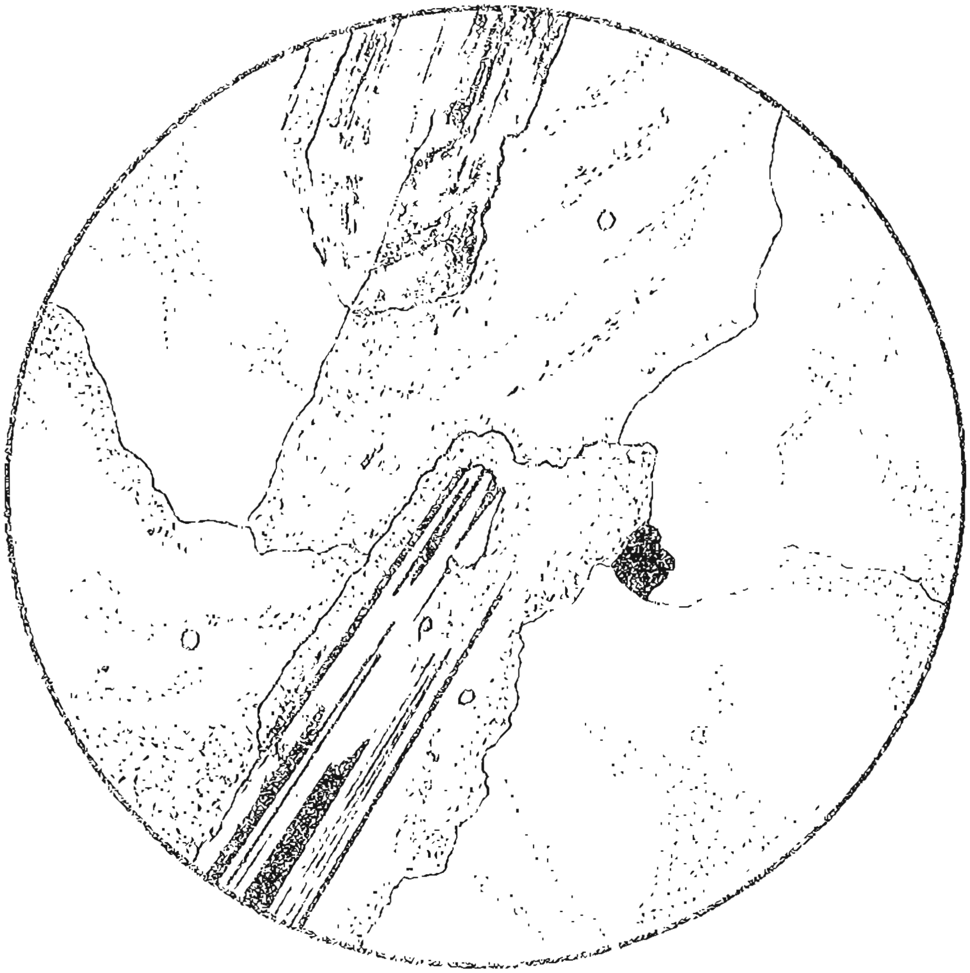

Figure 9

Potassium feldspar (o) replacing plagioclase (p). X50.
Nicols crossed.

scarce. Some of the hornblende is being replaced centripetally by pyroxene and is ragged in appearance. Hypersthene is characteristically pleochroic in pale red and green, but is not common.

Biotite is common, but not abundant, with its greatest development appearing in the tonalite. In all cases biotite is partially altered to chlorite and is generally ragged.

Associated minerals are generally euhedral sphene, apatite, magnetite, and, rarely, zircon. Secondary minerals vary, but include sericite, everywhere present, kaolinite, chlorite, minor calcite, epidote and magnetite.

<u>Monzonite</u>: With the exception of possible local occurrences of monzonite south of The Dome, the rock appears confined to the stock near and adjacent to Grubstake Creek. There is a facies change near the contact with the hornfelsic rock and considerable secondary quartz has been introduced along with appreciable quantities of chalcopyrite and pyrite.

Faulting, in certain areas, was severe and the rock is highly crushed and partially decomposed by later weathering, or hydrothermal action. The bedrock of the Creek is monzonite, but is now gritty and highly decomposed. Andesite dikes are common and while some are highly altered others are not, suggesting, at least in this area, that there was more than one andesite dike intrusion.

The color of the rock varies considerably from the light colored pinkish rock of the highly siliceous zone to a dark reddish-brown in the main mass. Discrimination between quartz-monzonite and monzonite is almost impossible in the hand specimen.

Extensive alteration to sericite and kaolinite was noted in microscopic study, however, these forms of alteration are common throughout the general district. Secondary quartz is very noticeable in microscopic study and has a mosaic-like texture.

Diabase: The massive outcrop of diabase along the mountain slope north of Indian Pass may be subdivided into diabase porphyry, and quartz-diabase depending upon mineral composition.

The quartz-diabase outcrops along the lower slopes of the mountain and appears above a hornfelsic rock, stratigraphically. However, the relation, whether concordant or discordant of the quartz-diabase, to the hornfels contact is not clear. Higher on the slope quartz-diabase appears to be gradational into diabase porphyry.

Fracturing and faulting is common to both igneous rocks, and wide shear zones have formed in which narrow quartz-calcite veins are often found. The rocks adjacent to, as well as within, the crushed zones are often bleached. Epidote, and chlorite are also common minerals found along the fractures as veins or stains.

Dikes, both acidic and basic, have intruded both types of diabase as well as the hornfelsic rocks. Acidic dikes are much altered, considerably iron stained, and have a high proportion of carbonates.

The dark dikes are not nearly so altered as the others, but they are generally highly fractured.

One of the puzzling problems of the quartz-diabase porphyry relationship is the apparent lower stratigraphic position of the quartz-rich type. Such a position is contrary to the usual mode of occurrence of diabase (Turner 1951, pp. 182-188). Typical diabase is generally fine grained and basic near the base becoming coarse towards the top, where it may be acidic (Schwartz 1940, p. 1136). The upper portion has a coarse texture, yet the quartz in the lower portion belies gravitational differentiation. A possible explanation is that intrusion of diabase into the hornfelsic rock resulted in silicification, but crystallization prevented any appreciable differentiation.

The quartz diabase is a dark green, hard, dense felsitic rock that much resembles the so called greenstones. The porphyry is, in the hand specimen, much like the other, but easily distinguished from it by the presence of large, light colored phenocrysts.

The texture of both may, in part, be described as ophitic to subophitic. The ground mass in both appears to consist of a crystalline mass of feldspar through which small well twinned plagioclase crystals are distributed. Zoning was noted, but does not appear common or well developed. The feldspar grains are subhedral to euhedral and in the range of Ab_{50} or slightly less.

Phenocrysts in the porphyry are plagioclase together with pyroxene, and the latter is altered, in part, to chlorite. Quartz was noted in both rock types, but is rare in the porphyry. The quartz is anhedral with undulatory extinction. In the quartz-diabase the quartz is generally in patches with minor amounts scattered throughout the groundmass. Olivine is present and often rimmed with a light colored mineral. Augite is common and generally rimmed with biotite or hornblende. Both of the latter minerals are in a stage of alteration of which chlorite is one product. In many instances the chlorite mineral is pennine. Apatite was noted, but is rare.

Propylitization may be considered the principal type of alteration and probably resulted in the rocks having a green tint. Kaolinization, sericitization, as well as carbonatization are also widespread.

Kaolinized-silicified Basic Rock: Mention is made of this rock for the purpose of pointing out its location and not to describe it in detail. The rock occurs northwest of Long Lake, as mapped on Plate I. The boundaries are not clear and the rock appears to grade into the surrounding quartz-monzonite. The rock is highly fractured and crushed and in some areas is decomposed to a clay like mass. In hand specimens the rock is fine grained, light yellow to dark reddish-brown.

Microscopic study reveals that the rock consists of an aggregate of micro-brecciated quartz, sericite, and kaolinite.

Dikes: Dikes are widely distributed throughout the district and are known to cut every rock type. By far the majority have sharp, well defined contacts and appear to have intruded fractures or joints. The dike rocks may be subdivided into three types, dark dikes, andesite porphyry, and granitoid dikes.

Dark colored dikes are common to every part of the district and as a group probably represent the predominant type. These dikes vary widely in texture and appearance, although similar in mineral composition, and include lamprophyre, basalt, trachybasalt, and diabase. In some, no minerals can be recognized with the hand lens, but in others, small flakes of biotite or other mafic minerals are visible. The dark dikes, as a group, are not strongly affected by alteration.

The dark dikes are numerous in several areas and appear localized by favorable structures. These areas of profuse dike occurrence are mapped on Plate I.

In thin sections the dark dikes were noted to consist of only a few minerals that do not differ widely in amount or grain size. In most dikes the groundmass consists of laths of feldspar, augite, magnetite, and biotite. Chlorite, sericite, calcite, and epidote are abundant locally.

Pyrite is common to abundant in some dikes, especially in those closely associated with mineral deposits.

Andesite porphyry dikes are probably subordinate to the dark dikes in number. They do, however, constitute an important assemblage of rocks, and while they cannot be closely associated with any one rock type, they do, nevertheless, occur in seemingly greater numbers in the granitic rocks west of Ahtell Creek than in other rock types.

In most cases, the andesite dikes are readily distinguishable from other types by their characteristic light color and porphyritic texture. The color is predominantly light to medium grey, but there are a number of reddish-brown dikes, especially west of Long Lake. Like the dark dikes, the contacts are sharp.

Alteration has strongly affected the dikes in some areas. The andesite dikes, unlike the more basic ones, are commonly decomposed. The andesites may represent two stages of intrusion, but both are older than the basic types.

Microscopically the dikes consist of a felty groundmass of feldspars through which euhedral laths of plagioclase and anhedral potassium feldspar are distributed.

The euhedral plagioclases are generally phenocrysts, but in the lighter colored dikes, orthoclase may be substituted for plagioclase. Quartz is common and is either patchy or randomly distributed throughout the rock. Chilled contacts are common. Figure 10 illustrates one such contact. The wall rock is scarcely affected in most cases. Relict zoning of the feldspars is common. Olivine is present, but is not an abundant mineral. The principal mafic minerals are biotite and hornblende with appreciable amounts of augite. Magnetite is common and generally associated with the mafic minerals. Pyrite is not common.

Granitoid dikes are far less common than either of the above mentioned types. As a group they include aplite, diorite, monzonite, and others of granitic texture. All are generally light colored, although iron staining may result in darkening of weathered surfaces.

The better examples of granitoid dikes are along Indian Pass. In that area some of the dikes are much altered, especially by carbonization. In the same area, aplite dikes show little, if any, sign of alteration. In the northern part of the area diorite dikes appear to dominate, and north

Figure 10

Dike, upper portion, in contact with quartz-monzonite, lower portion. X50. Nicols crossed.

of the Slana River many have intruded the marble.

The granitoid dikes could, and perhaps should, be subdivided into granitoid and aplitoid types, since the latter appears to be post-dark dikes and the former pre-dark dikes. However, due to the relative scarcity of aplites, the subdivision is not made.

Much uncertainty concerning the age of the various dike types remains. With some exception, each type was probably intruded as a group respective to their mineralogic composition, and intrusions were probably accomplished during certain periods of the major mountain building orogeny.

Granitoid dikes appear to be the oldest and may represent the first intrusives. Andesitic dikes may have intruded during the maximum period of stress and the dark dikes during the close or wanning stage.

The ages and orientation of dikes have considerable bearing on the structural history of the district and further study is certainly warranted.

Extrusive Igneous Rocks.

Basalts are widespread throughout the district, but are thickest in the southeast, thinning progressively towards the north. Basalts, possibly equivalent to those in this district, were reported by Mendenhall (1905, p. 37) in the East Fork of the Chistochina area, called the Tetelna volcanics.

On Plate I the basalts have been tentatively sub-divided into two types: (1) The Grubstake Creek basalts, and (2) the Long Lake basalts. The following is the basis upon which the sub-division is made:

(1) Hornfels and greenstone underlie the Grubstake Creek basalt, but not the Long Lake basalt.

(2) Evidence of low grade metamorphism is found in the Grubstake Creek basalt, but not in the other.

(3) Physical characteristics differ; such as, color, type of weathering and general appearance.

Grubstake Creek Basalt: The Grubstake Creek basalt, mapped on Plate I, extends from south of Grubstake Creek to the north along the ridge on either side of Ahtell Creek and the South Fork of the Slana, and along the Slana River proper. A similar basalt also outcrops along Indian Ridge.

The basalts are dark, fine grained, greenish rocks. The texture and color changes noticeably in some areas depending on the individual flow and degree of weathering. Fracturing, as well as jointing, is well developed, and a crude type of foliation, possibly due to low grade metamorphism, was noted in some areas. While the talus is often slabby, suggesting foliation, blocky talus is not uncommon. As a rule the basalts are not amygdaloidal, and ellipsoidal structure was not seen. Amygdaloidal basalts were noted along the south bank of the Slana River and may be quite extensive.

The width of individual flows varies, but generally ranges from fifty to one-hundred feet. The flows are best observed along the west wall of upper Ahtell Creek where differential erosion has resulted in steep, but step like slopes.

What may be a basal flow was noted west of the junction of Base and Ahtell Creeks. The lower portion of the basalt had xenoliths appearing to be water worn pebbles in a matrix of glass. The basalt may or may not be in its true position since hornfels was found stratigraphically above it, probably faulted into place.

Hornfels generally underlies the basalt, but in some cases has been infaulted or thrust over the rock.

Andesite is common, especially south of Grubstake Creek and there overlies the basalt. However, it has not been differentiated on Plate I, except in special cases.

Long Lake Basalt: The Long Lake basalt is rather limited in extent, but may be sub-divided into two types. The first, a porphyritic trachybasalt (Turner 1951, p. 162), and the second a normal basalt. The former outcrops along the south wall of Long Lake and to the west along Indian Ridge. The second is the more extensive and covers much of the area south of Long Lake. In general, both types have a fresher appearance than the Grubstake Creek basalt, but are nowhere as thick.

The porphyritic trachybasalt has a coal black groundmass through which phenocrysts of pink orthoclase, up to one inch in length, are distributed. The normal basalt is a bedded, fine grained, sometimes coal black, dark rock that may in areas have a purple cast. In both types weathering produces a blocky rather than a slabby talus.

The contact of basalt and altered quartz-monzonite was noted in several areas along the west slope of Cabin Creek. The basal member of the basalt is somewhat vesicular and is in some areas a basalt conglomerate due to included water worn pebbles of which andesite porphyry is prominent. The pebbles closely resemble the present day water worn pebbles found along many of the slopes.

The texture, as noted under the microscope, is generally pilotaxitic; ophitic texture was noted but generally subordinant to the former. Plagioclase is in the general range of Ab_{50}, and usually euhedral to subhedral. Many grains are broken although seldom bent. Polysynthetic twinning is well developed, and the twin lamellae are generally wide. Pericline twinning, while not common, is by no means rare. Poikilitic texture is common in nearly all the feldspars. The inclusions are too small for actual identification, yet their high birefringence suggests sericite. Although none of the plagioclase minerals are zoned, there is a suggestion some were, since sericite occurs along what appears to be relict zone boundaries. Zoning is developed in the augite and olivine. Olivine is a common, but not abundant mineral, and is generally subhedral and often rimmed with iddingsite. Antigorite is common in the micro-fractures. Biotite and hornblende are generally subhedral and closely associated with chlorite and magnetite.

Orthoclase was noted only in the trachybasalt where it occurs as phenocrysts. The mineral is anhedral and much altered. A better term for the orthoclase would be perthite due to intergrowth of plagioclase. The mineral is illustrated in Figure 11.

Accessory minerals include sphene, aplite, magnetite, and pyrite. The common secondary minerals are sericite and kaolinite.

Thickness of the Grubstake Creek basalt is at least 1,500 feet and the basalt along upper Ahtell Creek is nearly 1,000 feet thick. The Long Lake basalt between Long Lake and Flat Lake probably never exceeds several hundred feet and is generally less than one-hundred feet in thickness.

The ages of the two basalts appear to differ. The Grubstake Creek basalt may be equivalent to the lower Permian. Mendenhall described the Tetelna volcanics as pre-Carboniferous (1905, p. 38). Since the Tetelna volcanics and the Grubstake Creek basalts appear to resemble one another they

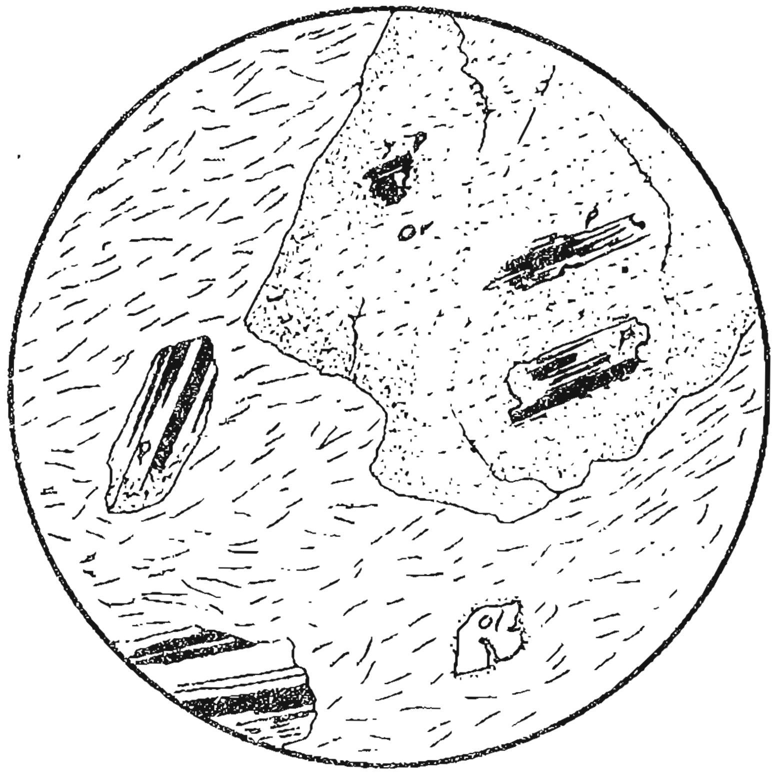

Figure 11

Inclusions of plagioclase (p) in potassium feldspar (or) in trachybasalt. X50. Nicols crossed.

may be correlative. An age of late Paleozoic would probably be more nearly correct for the Grubstake Creek basalts.

The Long Lake basalts are considered much younger than the former and may be late Mesozoic in age.

Metamorphic Rocks.

Metamorphic rocks underlie a relatively small part of the district and the majority of those cropping out are along Ahtell Creek, South Fork of the Slana River and along the north side of the Slana River. Similar types of metamorphic rocks have been reported to the north and west of this district.

Three broad types of metamorphic rocks were noted, hornfels, argillites and related rocks, and marble. The term hornfels is used in the broad sense as defined by Grout (1932, p. 370), and for convenience quartzites are included with the argillitic rocks.

Hornfels: Hornfels includes a group of highly siliceous rocks which appear to lie stratigraphically below the Grubstake Creek basalts. Variations are not uncommon, but usually the rocks are light colored, hard, sugary grained felsites. Seldom are the rocks visibly schistose, but lineation was often noted in thin sections. The original rocks apparently were both volcanic and fine grained sediments.

The greatest development of hornfels in the district is near Grubstake Creek and along the north side of Indian Pass.

Mendenhall (1905, p. 37) reports similar rocks along the East Fork of the Chistochina River and in other areas west of this district. The location known and reported, of the hornfels, or similar rocks is suggestive of a peripheral occurrence about the Indian Creek pluton.

In many areas a dark greenish, dense rock underlies the hornfels and is typical of the "greenstones" common to Interior Alaska.

The hornfels is probably thickest along Indian Pass and Base Creek, but the basal members have not been noted.

The matter of age, in part, depends on that ultimately assigned to the overlying basalts. If the Grubstake Creek basalt is the basal member of the Permian system then the hornfels and greenstone may be pre-Permian. Mendenhall (1904, p. 38) suggested the metamorphic rocks to the west of this area were probably pre-Permian. However, Moffit, as well as Mendenhall suggested the metamorphics in the Indian Creek area are equivalent to the Mankomen formation and Permian in age. The greenstones are probably equivalent to the hornfels in age.

Argillites and Related Rocks: Argillites, slates and quartzites were noted in several areas, but do not appear widespread. Possibly the rocks could be placed within the hornfels group, but their physical appearance as well as their apparent metamorphic history differs from that of this group. With the exception of the quartzites, the rocks are dark, often bedded, and generally soft. The quartzite is whitish, but often slightly iron stained. Bedding was not observed.

Stratigraphically the rocks appear to overlie the hornfelsic rocks; however, a clear stratigraphic section was not observed. Within the group, quartzite appears as the lower member and is overlain by slate and argillite.

One of the better exposures of argillite is mapped on Plate I, southwest of Long Lake, but there, the rock may have been faulted into position. A dark slate is common below the volcanics in places along Indian Ridge, and a similar rock was also noted near the marble north of the Slana River.

Quartzite was noted in several localized areas throughout the district and Moffit (1938, p. 20) has reported local occurrences in the Indian Creek area.

Thickness of the rocks is generally less than fifty feet. However, faulting is evident and displacement or offsets must be assumed. Moffit (1938, p. 20) believed the quartzite in the Indian Creek area was Permian in age and possibly the others are equivalent.

<u>Marble</u>: A former massive bed of limestone north of the

Slana River was intruded and metamorphosed to a light blue to buff bed of marble. Replacement of the limestone was typically erratic and incomplete as irregular blocks and lenses of partly replaced marble are common.

A hard dense iron stained skarn zone is present along the upper side of the main marble bed. Calcite as well as brecciated hematitic veins were noted to cut both the skarn material and marble.

A second marble exposure is located within the Slana Valley proper and crops out along the South Fork of the Slana River. The exposure is partially concealed by overburden, but that portion exposed closely resembles the marble just described, and the two are likely related.

The original thickness is impossible to determine, but that exposed along the slope is at least one-hundred feet thick.

The marble is believed to represent a segment of the limestone, or recrystalline limestone, as shown on Moffit's map (1954, p. 17) extending towards this area from both the northwest and southeast. Moffit has described the latter rocks as undifferentiated Devonian or Permian limestone.

Rock Alteration.

Nearly all of the rocks examined in thin section were, in part, altered and some so much so that identification of the rock forming minerals was not possible. Alteration is not always evident in hand specimen, but in many cases even casual examination reveals the widespread, thorough affects of the changes.

The diorite and related rocks east of Antell Creek are probably the least affected, but alteration, mainly in the form of epidote and chlorite is noticeable and sericitization is evident by microscopic examination. Alteration of the rocks of the Indian Creek pluton is far more advanced in many cases.

Two prominent types of regional alteration were found, sericitization and, or, kaolinization, and chloritization. Both types are usually found together and are associated with lesser types such as silicification, propylitization and carbonatization. Sericitization and, or, kaolinization are generally closely associated with the granitic, and chloritization with the more basic rocks.

The widespread habit of alteration in this district, the apparent selectivity for certain minerals and rock types, and the concentrating or intensifying effects in certain zones, suggest alteration may have been caused by a weathering cycle rather than by hydrothermal action. This widespread alteration is not to be confused with the hydrothermally altered zones along which sulphides are common.

In the literature concerning adjacent areas considerable mention is made of rock alteration, and the more intense alteration appears prevalent in the older granitics, or those possibly equivalent in age to the Indian Creek pluton.

Wayland (1940, p. 140), in his petrographic study of rocks from the Nutzotin Mountains southeast of this district, also found alteration to be widespread. From his study he concluded the alteration was hydrothermal in origin and regional in habit.

Although alteration is widespread in the Ahtell-Slana district, it is not intense, however local it may be, and physical changes such as bleaching or softening of the rocks are not readily apparent.

Locally, endometamorphism may have been expected to cause some changes, but it does not appear an important agent in the observed type of rock alteration.

Conclusions, from the present study, regarding Ahtell-Slana rock alteration, with the exception of sulphide zones already noted, are: (1) The main rock alteration is a result of normal weathering, and (2) The Indian Creek pluton has been exposed much longer than the other igneous areas and was not severely affected by glaciation.

Intrusive Relationships.

Adequate interpretation of the intrusive relationships to other rocks in the district must await additional and more detailed work to carefully outline the boundaries of intrusives, as well as additional criteria, of the contact relationship between the Indian Creek pluton and the Ahtell Creek pluton. However, data now available has brought to light certain conditions pertaining to the intrusive relationships.

Both plutons are probably composite igneous masses that were intruded during different time intervals. The Indian Creek pluton was likely the first to be intruded, but probably solidified at considerable depth causing little more than slight doming of the overlying sediments.

Greenstones are the lowest stratigraphic unit and their sedimentary equivalents were probably in contact with the intruding magma. Basic metasomatism may have, by the accession of basic ions, converted the original rock to a metamorphic rich in iron and magnesium. Overlying material was probably converted to a hornfelsic rock.

The composite nature of the Indian Creek pluton suggests differentiation or possibly multiple injection.

The present erosion surface of the Indian Creek pluton may represent the approximate roof of the original intrusive. Several features suggest the pluton has not been long exposed or deeply dissected. The erosion remnants of intruded material found throughout the higher portions of the pluton suggest removal by erosion is not yet complete. Furthermore, If projection of the bedded rocks along the periphery is made across the pluton, the line of projection closely coincides with the present erosion surface.

The diorite to the west of Ahtell Creek has been described as an outlier of the Ahtell Creek pluton. While that may be true, there is, also, the possibility that the diorite represents a border facies of the Indian Creek pluton.

Several features surrounding the Ahtell Creek pluton suggest it may have intruded at a later time than the other. The original roof portion, similar to the pluton to the west, may also be retained in certain areas. The maximum difference between the basal (?) basalt flows along Indian Ridge and those along the higher portions of the dioritic mass is approximately 1,000 feet. The Ahtell Creek pluton may then be suggested to have intruded approximately 1,000 feet nearer the surface than the other.

If the magma had undergone some differentiation, the quartz could, conceivably, have been concentrated in the upper portions, resulting in quartz rich diorite.

Gorai (1950) in his work with feldspars indicated that untwinned, or poorly twinned, plagioclase is often confined to the roof portions of magmatic bodies. Thin section study suggests twinning in the plagioclase of the tonalite is either absent or poorly developed. The absence of twinned feldspars in the tonalite may be considered additional evidence for its probable roof position.

Structural Geology.

Structural adjustment apparently has been a continuous process in the district since early geologic time, and may have lessened only in the recent geologic past. The preservation and sharpness of many of the fault line scarps testifies to the recent origin of some. Not only are the fault line scarps distinctive, but in some areas the Recent alluvium shows evidence of faulting. However well the fault line scarps are exposed there is an absence of actual fault scarps and those that are visible generally have poorly preserved surfaces, consequently the movement along many of the faults must be inferred from other criteria.

The more notable structural features of the district are the two and possibly three trends of faulting. The trends are so located as to strongly suggest regional orientation and appear related in some way to the major Denali fault that may well traverse the whole of Alaska.

The following is primarily a description of faulting, supplemented at the end by a discussion of origin. The faults are described by trends, but preceeded by a brief discussion of the structural features of the bedded rocks.

Structural Features of Bedded Rocks: Bedded rocks in the district have, as already mentioned, undergone varying degrees of metamorphism and probably several stages of structural deformation. The following describes the broader structural relationships with the various rock units.

Basalts along the west side of upper Ahtell Creek and South Fork have a trend of N. 40° to 60° W. and dip 40° S.W.. Those along the east have approximately the same trend, but dip 10° to 20° N. W.. Basalts along Indian Ridge west of Long Lake trend northwest and dip gently east.

Basalts, amygdaloidal, in part, were found within the Slana Valley and appear to dip gently south. However, outcrops are poorly exposed and reversals of the structure could occur without their being noted.

The two areas suggesting basal flows have already been described. In both cases the basalt showed some evidence of shearing and crushing. Such a structure suggests horizontal movement and may indicate bedding plane slippage or a type of sole thrusting.

Hornfels, where noted, appear to lie stratigraphically below the basalts and their general attitude conforms to the overlying rocks; but, faulting has, in areas, caused their attitude to change. Although none were noted to be visibly schistose, they may have been subjected to prolonged deformation.

The undifferentiated sediments near and south of Indian Pass overlie a basalt, as previously mentioned. The attitude of these rocks varies, but generally trend N. 30° - 35° E. and dips 25° - 30° SE..

The marble north of the Slana River strikes approximately N. 62° W. and dips 70° S. to vertical.

The other marble noted is along the South Fork of the Slana River and strikes N. 60° W. and dips 40° - 50° S..

North East Faults: Many of the northeast trending faults appear to be high angle thrust faults. Total displacement, either vertical or horizontal, for most of these faults is unknown, but generally the displacement appears to have been in tens or hundreds of feet rather than in thousands.

Grubstake Creek fault is one of the stronger known thrust faults and may be traced from Rainbow Creek to Indian Pass Lake, a distance of at least four miles. The occurrence of well aligned fault line scarps clearly delineates the fault. The fault strikes N. 40° - 50° E. and dips steeply northwest. Sheared and, or, crushed rock as well as mylonitic zones were noted along the fault trace. The width of the fault zone is generally less than twenty feet, but, in places, down slope migration of iron staining tends to exaggerate this width.

The south, or foot wall, appears to have moved down relative to the other, and movement of this nature could explain the hornfels-basalt contact along upper Grubstake Creek. Several other faults paralleling the above mentioned fault are noted on Plate I. The segment between the major fault and the next fault to the north may be a horst, and such is suggested by the apparent vertical displacement of monzonite on the left limit of Rainbow Creek. Another fault may occupy lower Grubstake Creek. This fault is not shown on the map, but certain factors suggest its presence. If the lower course of the stream above the bend is projected to the southwest, the line of projection would closely coincide with the natural depression through the mountain north of Flat Creek, which is nearly in line with the known fault south of Flat Lake.

The Jasper Creek fault is located north of Grubstake Creek. The fault strikes N. 65° to 75° E. and dips steeply south. If projected towards the northeast, the fault would intersect the Grubstake Creek fault just south of Indian Pass Lake. The south, or hanging wall, appears to have moved up relative to the other causing a contact between undifferentiated sediments on the north and the massive Grubstake Creek basalt on the south. If this is correct then the block between this fault and the Grubstake Creek fault may be considered a horst. If the basalt between the faults is actually the lower member of the undifferentiated sediments, relative vertical movement would have had to have been in thousands of feet.

West of Long Lake there are three separate, well preserved, fault line scarps that may be traced to the west beyond the area mapped. The most southerly ones are illustrated, and their eastward extensions are inferred. Projection of their known strikes with a slight bend would continue the trend in the faults traversing the Long Lake trough.

A wholly inferred fault is indicated on Plate I, striking approximately N. 80° E. through the trough of Long Lake. This fault is inferred in this area due to overburden. It is known, however, to continue to the west and there it is traceable by well preserved fault line scarps. The trough of Long Lake may well have been the result of this fault. To explain the origin of the trough by the present lake or streams is unreasonable. Origin would appear more likely to be the result of fault controlled subsequent dissection. The possibility of the inferred fault's extending towards Ahtell Creek is likely. The position of this fault with reference to the known fault crossing the divide between West Fork and Ahtell Creek seems more than a coincidence.

A second, but partly inferred, fault is noted along the south wall of Long Lake and from there may be projected towards the east. On top of the mountain, immediately south of Long Lake, the fault may occur just north of the molybdenum deposit. On The Dome there is no direct evidence of a fault

Figure 12. View looking east towards [illegible] illustrating recent fault scarp.

Figure 13. View looking across The Dome towards Grubstake Creek Mountain. Fault scarps in foreground.

Major northeast trending faults in the South Fork area are not as common as in the areas described.

North of the Slana River, and on the divide south of Gold Creek, faulting has been mainly northeast, resulting in the offsetting of the limestone and a basaltic rock.

North West Faults: Many of the northwest trending faults may be described as normal faults, but others, and there are a significant number of them, cannot be so conveniently grouped. For this reason the normal or tension faults will be described first.

Perhaps one of the better examples of normal faulting found in the area is along the west slope of The Dome opposite the molybdenum deposit. At this location four well exposed fault scarps strike approximately N. 40° W. and dip steeply west. All are approximately 1,000 feet in length and all appear to terminate at a common line which suggests offset by an east-west trending fault. Although the general strike is N. 40° W. the faults bend, and, where last exposed, strike almost due north.

Movement appears to have been vertical, with no apparent horizontal displacement. The vertical displacement may be estimated to be from 300 to 400 feet. The reference was a thin basaltic rock that has been displaced on the lower faults. On the opposite side of The Dome, as already mentioned, similar faults occur, and these may be the offset segments. Figure 13 is a view of The Dome and fault scarps.

A similar sort of faulting occurs along the first Creek north of Grubstake Creek. At that location, there are at least four normal faults. All strike approximately N. 55° W. and dip steeply southward. Total displacement is approximately 200 feet and appears to decrease towards the north.

There are north trending faults that appear to have the same general characteristics as the above types and will not be further described.

A second group of faults, while having much the same trend, cannot be so conveniently classified as the above. Movement along many of these faults has been vertical, yet there is also clear evidence of strike movement as well. Several of the more important ones will be described.

The East Fork Creek fault and others trending parallel to it are included in this type of faulting. All are within or adjacent to upper Ahtell Creek.

The East Fork Creek fault strikes N. 45° W., dips southwest, and may be traced along the strike by a series of well aligned fault line scarps. The fault has caused a contact between the diorite on the east and basalt on the west. It would appear the foot wall moved down relative to the other. The known length is at least three miles and projection to the northwest would intersect the Ahtell Creek fault. Several other faults, shown on Plate I, were noted along the eastern and western ends of Indian Pass. All the faults have approximately the same trend and are possibly related to each other. Similar to the trough of Long Lake, Indian Pass trough may have, also, been tectonic in origin.

Ahtell Creek fault is one of the strongest faults in the region. Its length is well over six miles and, if extended to a similar fault west of the South Fork of the Slana River, its length would be well over twelve miles. The strike of this fault along upper East Fork Creek is N. 65° to 75° W. and is vertical. It is easily traced along the strike by means of a wide crushed zone thoroughly stained by iron minerals. The width of the crushed zones varies, but is, in places, at least 200 feet wide, and where it crosses the ridge between East Fork and Ahtell Creeks, is nearly 500 feet wide.

One of the areas where movement may eventually be determined is on the high mountain above the small lake at the head of Ahtell Creek. At this location several basic sills on the north wall have their west segment faulted. However, the topography is such that careful examination was not made to determine if the faulted segments were on the opposite wall.

South of East Fork Creek and along the ridge there is some evidence that the west wall has moved west as well as down.

slickensides in other areas along the fault suggests a late westward movement for the west wall.

Insufficient knowledge of the area northwest of the fault towards the South Fork of Slana River prevents any but an inferred extension into that area or across the Slana Valley.

Beyond the South Fork of the Slana River and to the northwest is another similar fault and its position suggests it may be an extension of the Ahtell Creek fault. The strike is approximately the same, but the dip is steeply north. Should this fault be an extension of the Ahtell Creek fault the dip of the latter would have had to change somewhere in the vicinity of the South Fork of the Slana River. Movement along this fault is not clear, but some evidence suggests the footwall moved down.

Other large and similar faults were noted and some have been plotted on Plate I. One of the interesting facts concerning the major northwest and northeast faults is their nearly constant angle of intersection which varies between 60° to 70°.

<u>Major Inferred Fault</u>: The natural boundary, as well as the different lithology along either side of upper Ahtell Creek and the South Fork of the Slana River suggests a tectonic origin for the stream valley. Further evidence may

also be noted along Indian Pass and in the more distant area of the upper Slana River. A major fault is here suggested to have passed through the district from the upper Slana River area and continued along what is now upper South Fork of the Slana River and upper Ahtell Creek through Indian Pass and out of the area, as shown on Plates I and II. A branch or splay of this fault may have formed lower Ahtell Creek.

Although the evidence for this fault is entirely inferred, its presence in the areas mentioned would or could be used to explain conditions that could not otherwise be explained. The contact between Permian and Devonian sediments along the upper Slana River suggests a fault contact. The general trend of the upper Slana River south of the contact is nearly that of the natural boundary between the Ahtell Creek pluton on the east and the Indian Creek pluton on to the west. Beyond Indian Pass to the southeast the contact of Permian bedded rocks and diorite may be a fault contact or the position of a fault prior to intrusion. The fault possibly continues to the southeast and is an extension of the major fault shown on Moffit's map in the Totschunda Creek area.

Dikes: Dikes have a definite trend throughout the district. The basaltic dikes have a general trend of N. 5° to N. 20° E. and generally dip steeply east. The andesite porphyrys trend N. 60° to N. 80° W. and dip steeply south. There are, of course, basaltic dikes with the andesite trend and vice versa, but the general trends hold true over the district. The granitic dikes trend N. 70° W. to N. 80° E. and generally dip north. Although the dike groups trend at angles to one another no intersections were noted. There are, however, several instances where basaltic dikes were noted crossing andesite dikes, but at such locations, the andesite also trended north rather than east-west and may or may not be related to the same period as the east-west intrusion.

Strike faulting is common along the north-south trending dikes and many such dikes in this position are highly crushed. Similar faulting while noted along some of the east-west dikes is not there a common phenomenon. Age relationships of the dike intrusions can only be estimated in the most tentative sense. The dikes do appear to represent the latest intrusions and their intrusion appears to have been structurally controlled.

Origin of Faults.

Some of the faults apparently were locally formed by intrusion and later volume shrinkage, as suggested by Eulin (1948, p. 49) and many others. However, faulting formed under such conditions has as its principal stress component, vertically directed forces, and seldom is there any appreciable lateral movement, and such is not the general habit of the larger faults in this district. The principal faults in this district appear to have experienced both vertical and horizontal movement. The major faults are, therefore, thought to be the result of regional tangential forces acting upon the district.

When regional forces are considered, the structural features in adjacent areas must, in part, agree with the local structural conditions and must be taken into consideration when evaluating local structures. One of the largest faults of the eastern Alaska Range is the Denali fault (St. Amand, 1957, p. 1351). This fault is inferred through much of its course, but there is some evidence that the fault traverses the whole of Alaska from eastward beyond the Canadian border to the Bering Sea. The vertical movement of this fault was estimated by Mendenhall (1905, p. 83) to have been at least 10,000 feet. St. Amand (1957, p. 1366) suggests a possible lateral movement of 150 miles towards the west for the south block.

In the Ahtell-Slana district the fault is inferred and plotted on Plate I in the vicinity of the Slana River. The strike of the fault is approximately N. 65° W., dipping south.

The trend of the Denali fault is approximately parallel to the northwest trending faults as mapped on Plate I. These faults, although of much smaller magnitude, are also thrust faults with strike slip movement and may be complementary faults. The northwest and northeast faults intersect one another at angles between 50° to 70°. The northeast trending faults are also thrust faults.

West (1951, p. 82) in discussing the major stress direction in Alaska indicates (Figure 1 of his text) that the principal direction of thrust in this region of Alaska was from the northeast or approximately N. 20° to 40° E. (as illustrated on his figure). As noted, this direction is approximately perpendicular to the strike of the Denali fault, and in a direction to cause possible thrusting. However, there are several obvious inconsistencies for such a direction of principal stress when applied to this area. One objection is the Grubstake Creek fault would not be a shear fault, which it is, but would be in the tension direction. Another objection is the dip of the Denali fault is south and not north.

Another possible direction of principal stress is suggested and based on a modified version of Moody and Hills (1956, p. 1207) hypothesis of wrench faults. The reasoning for the following suggested direction of principal stress is: (1) The northeast and northwest faulting appears almost contemporaneous in as much as erosion has affected the fault line scarps in approximately the same manner, (2) Major faults in both trends are shear faults, (3) The Denali fault is parallel with the northwest trend and considered a relatively late fault and

(4) Other factors that will be discussed.

If, by using a modified version of Moody and Hills hypothesis the direction of principal stress could be assumed to be from the west, approximately N. 70° W., a direction that would result in the major shears making an angle of 30° to 40° to the principal stress direction. The northwest trend, including the Denali fault would be the primary right lateral shear faults and the northeast trend the complementary left lateral shear faults.

The question of dikes also bears on the general structure. As previously mentioned there are two trends of dikes, one nearly north-south and the other east-west. The intrustion of the east-west dikes into tension fractures would have likely taken place during maximum stress, and petrographically the andesites and granitoid dikes appear the older. During the period of relaxation, tension fractures would have opened perpendicular to the direction of principal stress and the dark dikes could have intruded such fractures.

With the possible exception of the Denali fault, the faults may represent orientation during the late or even the last stages of the Alaska Range orogeny.

The cause of such an orientation of principal stress, as assumed above, is not known. The articulate structure of the Alaska Range may, in some way, be a cause.

Geomorphology.

Since uplift of the Alaska Range Province, land forms of the Ahtell-Slana region have been in a continuing state of modification by various forces of erosion. The agents most active in modifying the area were water, ice, and frost action.

Although the duration of active modification by ice and its related agents is short when compared to the long sustained action of normal erosive forces it has, however, had a profound affect on the geomorphic cycle. Modifications of the land surface during Pleistocene time are still plainly observable and reconstruction of pre-Pleistocene as well as post-Pleistocene conditions are best understood by reference to the glacial events.

Present Glaciers: Continental glaciation is generally conceded not to have occurred in Alaska. Also, there is no proof that the period of glaciation in the Territory has actually ceased.

At present, there are two extensive active glacial areas near the Ahtell-Slana district. The larger is located sixty to seventy miles south, in the Wrangell Mountains, and covers several thousand square miles. The other is in the Mount Kimball region, approximately thirty miles to the northwest and continues from there along the higher elevation of the Alaska Range to Mount McKinley.

Pleistocene Modification: The role of glaciation in the Ahtell-Slana region was one of considerable influence on the land surface. Its role, nevertheless, was one of modification rather than evolutionary change.

The general relief prior to the Pleistocene was probably little changed from that of today. Since Pleistocene time, the drainage pattern of the major streams has probably remained approximately the same. Some changes which are evident may have resulted from a combination of causes such as glacial action, normal dissection and subsequent adjustment.

Modification of the land form was found to vary in different areas and because of that this portion of the Alaska Range Province has been subdivided. The eastern part is called the Glacial sub-province and the western the Periglacial sub-province. Ahtell Creek is the tentative boundary.

Periglacial Sub-province: Mr. Moffit, (1938, p. 41) in his examination of this area concluded that during Pleistocene time all but the higher mountain peaks were covered by ice. He further concluded that the ice originated in the Wrangell Mountains and by stages flowed out into the Copper River Valley and subsequently into the Ahtell-Slana district. Essentially he has three points of argument for his conclusion.

(1) Valleys which he recognizes as U shaped and probably glaciated.

(2) The rounded mountains west of Ahtell which he believes were so formed by overriding glaciers. Water worn material found on the tops of such mountains are used to further substantiate this argument.

(3) Erratics of vesicular basalts which are believed by Moffit to have originated in the Wrangell Mountains and to have been ice born to their present sites.

The following is not meant to discredit Mr. Moffit's field work or conclusions. Mr. Moffit's broad knowledge of Alaskan geology and particularly in this area is equaled by few persons, if at all. Nevertheless, field evidence observed in this present study does not substantiate the hypothesis that ice once covered all but the higher peaks. Instead, it would appear that the glaciers were confined to the higher elevations and the valleys were modified by the action of melt waters from these glaciers.

Concerning the present profile and other relevant features of the existing valleys west of Ahtell Creek, it was found that few had the general characteristics common to a highly glaciated area. With the exception of Indian Creek, all valleys appear to have had their general drainage pattern established prior to the Pleistocene Epoch. The valleys are relatively narrow, Ahtell Creek being an exception, and the streams occupy much of the valley floor. The tributary drainage is dendritic and valley spurs are overlapped rather than truncated. The stream slopes are not steep and many are graded. Nowhere is there clear evidence of morainal material, and hanging valleys are absent. The valley mouths are accordant, and finger lakes as such are not known.

The rounded and flat topped character of the mountains west of Ahtell Creek contrast sharply with the higher and more rugged mountains to the east, as illustrated in Figures 7 and 8. In the periglacial area the summits are nearly accordant. In general they are rounded or gently sloping surfaces. (See Figure 14). Aretes, pinnacles, and truncated spurs are rare. Rather than extensive ice sheets in this area, it is here suggested that glaciation was local and superimposed upon a late matured physiography that was contemporaneously undergoing structural readjustment. Modification by glaciation was confined to the higher elevations, generally along the north or northeast slopes in depressions previously formed by normal erosion. The presence of highland cirques indicates that glaciers were active in some areas, as illustrated by Figure 15, and their ice lobes may possibly have reached into the adjacent valleys. However, the glaciers were probably of limited extent, and nivation, rather than ice rasping and plucking, may be thought of as the more active method of modification in this area. The thin, approximately two inch cover of water worn gravel on the summits could have been formed by the combined action of nivation and distribution by small, shifting melt water streams. The upland gravels can in this way be explained as originating from a local source, as they apparently have. The gravels are not found above 4,500 feet and, while present, they are not ubiquitous. The gravels, as mentioned earlier, may have formed before glaciation.

Beside the upland gravels, there are found occasional 'erratics' of marble and vesicular basalt, but each are known to occur in the general area. While they are believed to be of local origin, there is no ready explanation for their method of transportation. Perhaps, ice rafting by glacial meltwater may be appealed to since they are indeed few in number.

Glacial Sub-province: Glaciation was much more extensive and active in this sub-province and the development of cirques, aretes and horns is common and widespread. Alpine or valley glaciers were the principal form. Such features are common throughout the area extending from the Slana River southward to Porcupine Creek and beyond. Although, Ahtell Creek and the upper portion of the South Fork of the Slana River is tentatively used as a boundary between provinces, there is clear evidence that the mountain slopes immediately to the west and

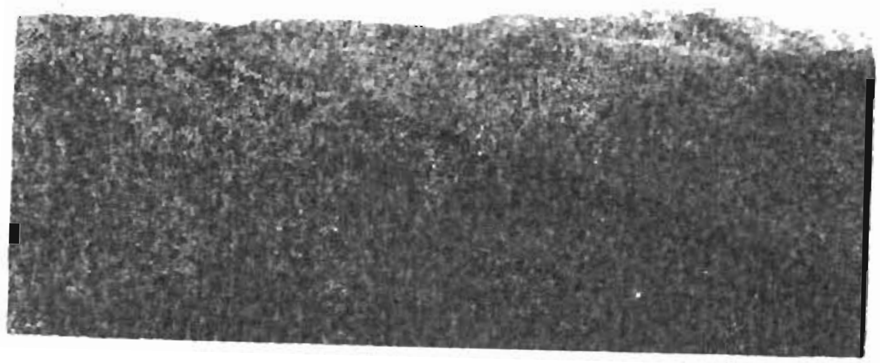

Figure 14. View illustrating flat topped mountain in Periglacial sub-province.

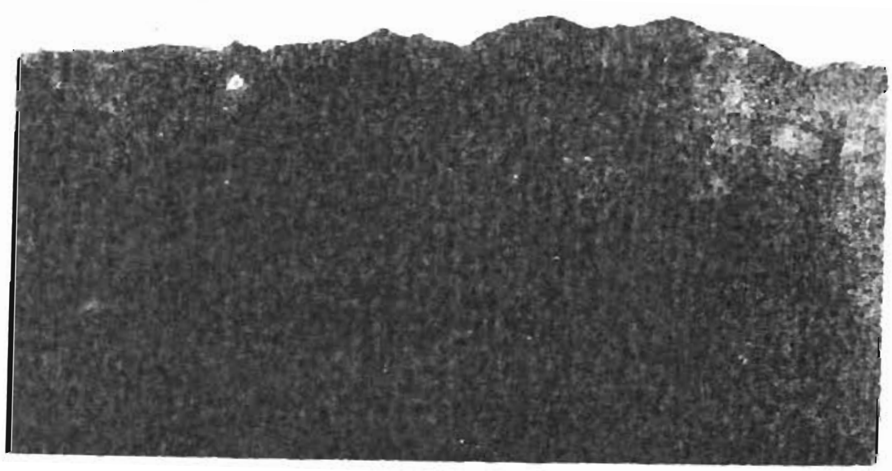

Figure 15. Poorly developed cirque in Periglacial sub-province.

adjacent to the tentative boundary have also undergone a similar type of glaciation, and, perhaps, should be more closely identified with the Glacial sub-province than the one in which they have been placed. Ahtell Creek and the South Fork of Slana River, however, are a natural geographic boundary and even though some forms are included in the Periglacial province that are geomorphologically incongruent there is obvious convenience in delineating the province with a natural topographic feature of some importance.

One of the better examples of cirques may be found along the upper part of the East Fork of Ahtell Creek. Evidence of glacial action is plain there and illustrates both lateral as well as headward expansion of the creek by glaciation. The topography there is one that is characteristic of recent and active glaciation.

Post-Pleistocene: The partition of post-Pleistocene and Pleistocene is an arbitrary separation. Events that were prevalent during Pleistocene time have certainly influenced and have continued to influence later conditions that have contributed to the general present-day land form.

Structural adjustment of the entire region has been a continuing process and, while it may have lessened in magnitude, it must still be considered an active modifying agent. Uplift probably occurred throughout Pleistocene time, but its strongest and, perhaps, latest rejuvenation effects appear to have occurred in late Pleistocene or early Recent time. The evidence for this is found in the well preserved fault scarps.

In Alaska, it would seem there is considerable evidence of Pleistocene as well as Recent uplift. Twenhofel (1952, p. 531), estimates uplift along certain areas of the coast to have been from a few feet to 500 feet. Wahrhaftig (1954, p. 1517) estimates that total displacement near Nenana was 1,000 feet. Bostock (1952, p. 9) suggests from his studies in the Shakwak Valley, Yukon Territory, that Recent alluvium has been faulted.

Stream Capture and Rejuvenation: Changes in stream courses were brought about by a combination of factors, including mild upwarp, glacial action, and piracy. Several examples of change in stream course may be noted in the region.

One of the best examples of complex stream capture is that of the South Fork of the Slana River. In reference to Plate I, the present course of the South Fork is approximately due north, but makes a right angle bend, and thence flows east to the Slana River. From the map it may also be noted that a wide valley continues north from this bend to the Slana River. The physiographic conditions appear to justify the assumption that a stream once flowed through the wide valley north of the bend and thence into the Slana River. The change was probably initiated by a gentle uplift to the north and continued alluviation of the old valley. Headward erosion of what is now lower South Fork would have been accentuated by uplift with the eventual capture of upper South Fork. The present floor of the older valley is now marshy and dotted with small lakes. Streams in the northern part of the valley have incised their channels - those in the southern part near the bend have not.

Both the upper and lower part of the present South Fork show evidence of rejuvenation, and benches along the lower portion are common. Another example of possible stream capture, but far less obvious, is that of upper Ahtell Creek. This portion of Ahtell Creek may have, at one time, actually been the head of South Fork.

Rejuvenation of upper Ahtell Creek is less obvious than for the lower portion. Well developed benches do occur on both West Fork and Ahtell Creeks. However, there is some question concerning the origin of such benches and they may well represent various levels of a former lake that has since breached its dam and emptied.

Lakebeds: There are two possible old lakebeds in the area, one in the valley of Ahtell Creek and its West Fork and one near the bend of the South Fork of the Slana River. Both are shown on Plate I. The larger is located in the Ahtell Creek drainage and there forms a large flat area above the junction of the above mentioned streams. The flat area is broken only by well preserved benches or beach lines and consists of well sorted material. A thickness of gravel exceeding 100 feet is located at and adjacent to the junction and extends in diminishing amount upstream as well as downstream from this point. Considerable quantities of light colored silt were noted along the West Fork, diminishing toward the head.

Suggestions of a second lake are, also, noted at the bend of the South Fork as shown on Plate I.

Cirques, Rock Glaciers and Soils: Cirques are prominent in the Glacial sub-province. The prevalent location is along the north or northeast slopes, a location that probably provided the maximum protection from the sun. Those occurring in the Periglacial sub-province are generally restricted to the highest mountains and are nowhere as well developed as the others. The cirques in the Glacial sub-province are all well developed and it is evident that the glaciers that once occupied them were active. It has been suggested by Ray (1940, p. 1911) that Pleistocene snow lines may be estimated by using the cirque floors as the lowest level of the snow line. These cirque floors are at an elevation of approximately 4,300 feet. If Ray's hypothesis is substantially correct on a regional scale, the Pleistocene snowline could be estimated to have been around 4,300 feet.

Rock glaciers now occupy nearly all of the cirques. Some of the rock glaciers are limited in size, but some that have actually flowed into valleys cover nearly a square mile. The rock glaciers appear to be composed of both coarse glacial and recent material that has, by a combination of increasing accumulation of rock material, frost action, and moisture, flowed in much the same way as an ice glacier does. The upper portion of such rock glaciers have ridges parallel to the direction of flow, but in the lower or lobe portion the parallel ridges give way to transverse concentric ridges. The rock glaciers suggest slow but steady movement. One of the best examples of such glaciers may be found on the East Fork of Antell Creek. There, the glaciers have flowed from the cirques on the southeast side and deflected the stream towards the north bank. The stream has seemingly removed the material as fast as it was deposited and damming has not resulted.

Solifluction, or down-slope soil creep, is a common feature of the soils in this region. Although common, it is nowhere as well developed as in northern Alaska. The hummocks or ridges formed are not particularly noticeable while walking over the ground, but are more obvious when viewed from a distance. The downward creep of soil is a process of freezing, thawing, and gravitational adjustment. Tabor (1940, p. 1459) gives a detailed account of this process.

Lakes: Many of the lakes are a result of a series of events in which landslides have played a major role. The characteristics common to each of the lakes are:

(1) All occupy depressions in relatively narrow steep-wall valleys.

(2) Their length is eight to ten times their width.

(3) All are in the process of being rapidly filled with sediments.

(4) Landslides found at the outlets appear to be the principal damming agent, with only one exception, Indian Pass Lake.

ECONOMIC GEOLOGY

Deposits containing molybdenite, lead-silver, chalcopyrite, and gold, were noted in the district. The more promising deposits are located in the southern portion of the district, and their locations are plotted on Plate I.

During the summer of 1957, only one placer mine was operating in the district. None of the lode prospects examined have had any work performed on them other than shallow trenching or short adits.

The following is a brief summary of the more promising prospects examined.

Distribution and Classification of Mineral Deposits.

Most of the known mineral deposits having promise of potential economic size, or grade, are located in or near the quartz-monzonite, but diorite as well as monzonite are favorable hosts in several cases. Considered on a regional basis, the rocks west of Ahtell Creek appear the more favorable host rocks, and the diorite east of that Creek, the least favorable for mineral deposits.

All the mineral deposits of promise in this district are hypogene in origin, and supergene products are either absent or of minor importance.

Mineral deposits in the district occur in three forms: (1) disseminated, (2) veins, and (3) placer.

Disseminated deposits represent the larger, but least common type, and include the molybdenum and copper deposits. The veins comprise the smaller, but more common form, and includes the lead-silver and gold-quartz veins. The placers are restricted to the streams.

Minerals of the Lode and Placer Deposits.

The following is a description of the more important metallic and non-metallic minerals occurring in the district. The minerals listed alphabetically are:

Bornite: Bornite was observed in only one area, near

Grubstake Creek. The mineral, associated with chalcopyrite, is disseminated through a diabase.

Chalcopyrite: Chalcopyrite was noted in nearly all mineral deposits, but occurs mainly as sparsely distributed early grains. The only area where the mineral occurs in important quantities is at Grubstake Creek, as disseminated grains throughout several rock types.

Galena: Except for pyrite, galena is the most abundant sulphide at all of the known lead-silver deposits in the district. The mineral has two general forms: (1) Massive and coarse grained, and (2) fine grained or 'steely'. The coarse massive galena is common at many of the prospects and is usually found as replacement veins that may or may not be associated with quartz. This type of galena occurs at the West Fork prospects, as five to eight inch wide veins. Fine grained, or 'steely' galena is associated with the massive type, but is, also, common as individual lenses or bunches. The 'steely' galena has a characteristically distorted or bent cleavage and Chapman (1941, p. 267) infers this to mean deformation after deposition.

Gold: Gold is common throughout the district and may be expected, usually in small amounts, wherever sulphides are found. In some cases the mineral is associated with magnetite and hematite.

At the Ahtell Creek prospect gold is associated with sphalerite and may be found within that mineral as small irregular bunches or narrow hair-like veins (See Figure 16). Irregular masses are the more common form and appear to have diffused into the sphalerite. These may have had an exsolution origin. In several other polished sections, gold was noted with galena. Hill (1933, p. 69) reports gold associated with jamesonite in the Fairbanks district, but apparently not with galena.

The placer gold noted on Grubstake Creek was coarse, but light colored, suggesting a high silver ratio.

Molybdenite: Molybdenite was identified only at the deposit near Long Lake and occurs there in two forms: (1) Small disseminated grains in the country rock, and (2) Quartz-molybdenite veins (See Figure 17).

The disseminated type is found in the wall rock, but is never in important quantities where veins are not present. As a rule, the disseminated grains are invisible in the hand specimen, but are plainly discernable in microscopic study. The country rock of the siliceous and clay zones often has a blue cast thought to indicate a relatively high dissemination of molybdenite. Examination of polished sections of this rock supported, to some extent, the above suggestion. However, the blue cast could not in every instance be ascribed to molybdenite. The disseminated molybdenite may represent a separate, probably

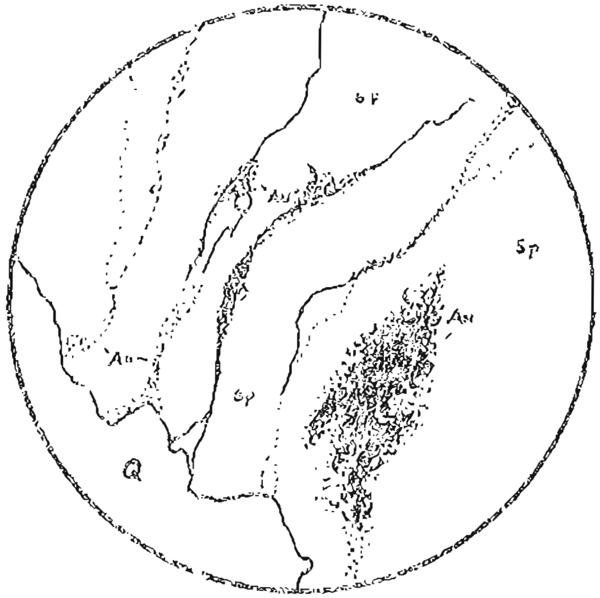

Figure 16a

Sketch of veinlets and bunches of gold (Au) in sphalerite (sp). Quartz (Q) X30.

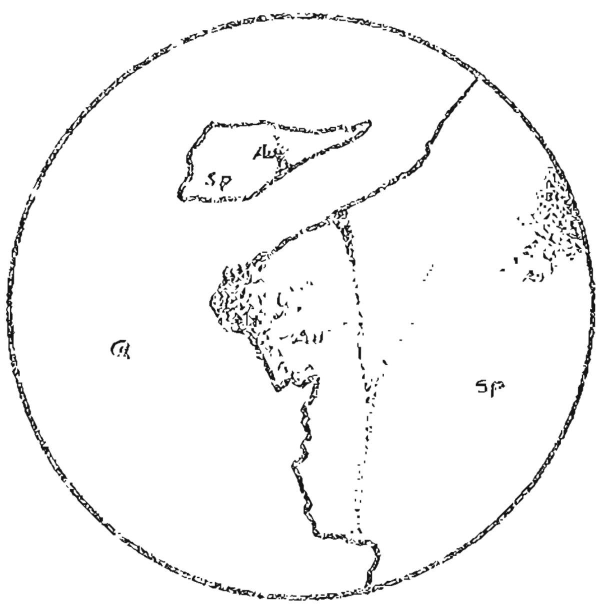

Figure 16b

Sketch of gold (Au) in hair-like veins in sphalerite (sp). X30.

early, and weak stage of mineralization.

Molybdenite mineralization of the second or vein type is more characteristic of the deposit than the former. Such veins are common throughout the exposures, but appear more numerous in the siliceous and clay zone than in the marginal zone. Molybdenite, where it does occur, is generally found along the walls of the quartz veins as well formed tabular crystals. Many of the crystals are slightly curved or bent and this may be due to either post-mineral deformation or to deposition along the veins as individual plates and clusters. The size of the crystals vary, but are close to one millimeter in length. Vanderwilt (1955, p. 45) describes similar veins at the Climax molybdenite deposit in Colorado.

A later stage of molybdenite mineralization was inferred from the occurrence of molybdenite and secondary orthoclase within the mid-portion of some of the quartz-molybdenite veins. If this last occurrence represents a separate molybdenite stage, there would then have been three separated periods of molybdenum mineralization.

Molybdite: Molybdite is not common, but does occur as an alteration product of the molybdenite along the weathered surface of the deposit.

Pyrite: Pyrite is a common mineral throughout the district and found in practically all mineral deposits. The mineral is represented by an early, as well as a late stage. The pyrite at the molybdenite deposit apparently entered in two stages. Pyrite of the first stage is mainly fine grained and disseminated throughout the country rock in the marginal zone. The second or late stage pyrite occurs as pyrite or quartz-pyrite veins which transect the quartz-molybdenite veins. The disseminated pyrite is often massive and may or may not follow fractures.

The vein pyrite is later than either the molybdenite or the disseminated pyrite. Butler (1933, p. 228) describes the disseminated pyrite at the Climax molybdenite deposit as early and the vein pyrite late. This closely coincides with the paragenesis at this deposit.

Quartz: Quartz is probably the most widespread, as well as the most common vein mineral in the district. At each of the mineral deposits it is the carrier of sulphides, and at some it is the dominant mineral of the host rock.

Silver Minerals: Argentite and native silver are the only silver minerals identified from the district. The latter was noted as a placer mineral from Grubstake Creek. Identification of argentite was made from polish sections of rocks from the Silver Creek and Indian Ridge deposits. In both cases argentite is closely associated with tetrahedrite.

In several cases the galena showed numerous platy or lath shaped inclusions where etched with nitric acid, especially along cleavage planes. These inclusions may be silver minerals. If they are, the rather high silver assays in specimens that have no visible silver minerals may be explained.

Sphalerite: Although sphalerite occurs at several locations it is important only at the lower Ahtell Creek deposit where it is gold bearing.

Tetrahedrite: Silver bearing tetrahedrite was noted at the Indian Ridge and Silver Creek deposits.

Hydrothermal Alteration: With few exceptions, the wall rock at each of the mineral deposits is altered to some extent. Completeness of the alteration process at several deposits has resulted in obliteration of all traces of former rock minerals. The culmination of wall rock alteration appears, in most instances, to have preceded the introduction of metallic minerals.

Three broad types of hydrothermal alteration were noted: (1) Silicification, (2) Sericitization and, or, kaolinization, and (3) pyritization. A hydrothermal origin may be considered for clay at the molybdenite deposit, since it is intimately associated with the sulphides, (Schwartz, 1955, p. 310). At other deposits, also, the clay is often closely associated with sulphide veins.

Several factors must be considered when evaluating alteration as a possible guide to ore. Many of the deposits are closely associated with one, or, all of the types of alteration. However, alteration does not appear, here, to be an infallible guide to ore. Many of the larger intensely altered zones contain only pyrite and no other recognizable sulphide.

Structural Relations.

The mineral deposits are located in or along fractured zones near one large fault. Faults are, however, plentiful in the district, and the majority are not associated with any known mineral deposits. The only structural trend so far recognized that includes more than one deposit is the east-west trend found at the Silver Creek, Molybdenum, and Indian Ridge deposits. In each of these the mineralization, although different, has followed an early east-west trend. Later, the first two deposits, but not the last, were cut by north-south trending structures not accompanied by mineralization. The last period of structural adjustment again trended nearly east-west and was followed by an intrusion of wide, relatively barren quartz veins.

No conclusions have yet been reached regarding the dikes found at the deposits. In most instances the dikes appear to be post-mineral, yet some are clearly pre-mineral. The most prolific period of dike intrusion at the molybdenite deposit was during the second, post-molybdenum, stage of structural adjustment. However, at the Indian Ridge deposit the dikes trend parallel to the mineralization as do the several large lamprophyric dikes at the quartz-calcite-hematite deposit on Tourmaline Creek.

Horizontal Zoning.

The arrangement of the various mineral deposits within the district is, in the writer's opinion, suggestive of horizontal zoning. The locations of the various mineral deposits have been plotted on Plate I. It will be noted that the high temperature mineral deposits, molybdenite and tourmaline, are in part encircled by lower temperature lead-silver deposits. The location of the copper deposits on Grubstake Creek precludes their being placed in this general pattern. However, it should be mentioned that lead-silver deposits were not noted between this area and the molybdenite deposit.

Even though the alleged zoning does not have an ideal concentric pattern, it does resemble one. There are, also, several contradictory occurrences that appear to reverse the 'standard' mineral succession noted elsewhere (Park, 1955, p. 235).

Genesis.

Tentative opinions regarding the order in which the metallic minerals, as well as the common gangue minerals, were deposited rests upon microscopic examination of typical ore specimens. The following is offered as a probable sequence of deposition for the more important metallic minerals and quartz.

Early -

Pyrite and quartz
Molybdenite and pyrite
Quartz-molybdenite
Pyrite, chalcopyrite and quartz
Sphalerite, gold and quartz
Galena, silver, copper (weak) and quartz
Quartz, pyrite and gold

Criteria suggesting a definite geologic time of mineral deposition were not recognized. Moffit (1954, p. 189) has suggested that mineralization in the Nabesna district was in mid or late Mesozoic time. Mineralization was probably at the same time in the Ahtell-Slana district.

Disseminated Deposits.

There are two disseminated mineral deposits in the district, one is molybdenite and the other chalcopyrite. The mineralization at the molybdenite deposit is generally confined to veinlets. However, by Ransome's (1919, p. 162) definition the deposit may be classified as disseminated.

Molybdenum Prospect: The molybdenum prospect is located in a cirque-like structure at the head of Lake Creek, approximately three-fourths of one mile south of Long Lake. The country rock is altered quartz-monzonite. In certain areas alteration has completely altered the rock to an aggregate of quartz, sericite and clay.

Development work has never been performed on this deposit and bedrock is exposed only where the small stream has dissected. The course of the stream is approximately perpendicular to the major structure and a relatively good cross section of the deposit is exposed.

Numerous dark basic dikes, trending N. 20° to 30° E. and dipping south, cut the deposit and contrast sharply with the light colored altered country rock, as illustrated by Figure 18.

The dikes are, as an average, twenty feet apart. With few exceptions the dikes are post-molybdenite. Many are badly crushed, probably due to late strike faulting.

Alteration at the deposit is widespread and zoned. The deposit is best described with reference to the zones. They are as follows:

(1) The Marginal Zone: This is the outermost zone, characterized by sericitization and pyritization along with lesser amounts of silicification. Molybdenite was found nowhere in this zone.

(2) The Intermediate Zone: Silicification is the predominant type of alteration in this zone, but sericite, as well as pyrite, is common and quartz-molybdenite veins are numerous. The approximate width of this zone is 600 feet, where exposed, along the stream. It is gradational into the

Figure 17

olybdenite (M) in quartz vein (Q). Pyrite (Py), [illegible] sericite (S). X50. Nicols crossed.

[illegible] 18. [illegible] alteration [illegible] dikes [illegible]
[illegible]

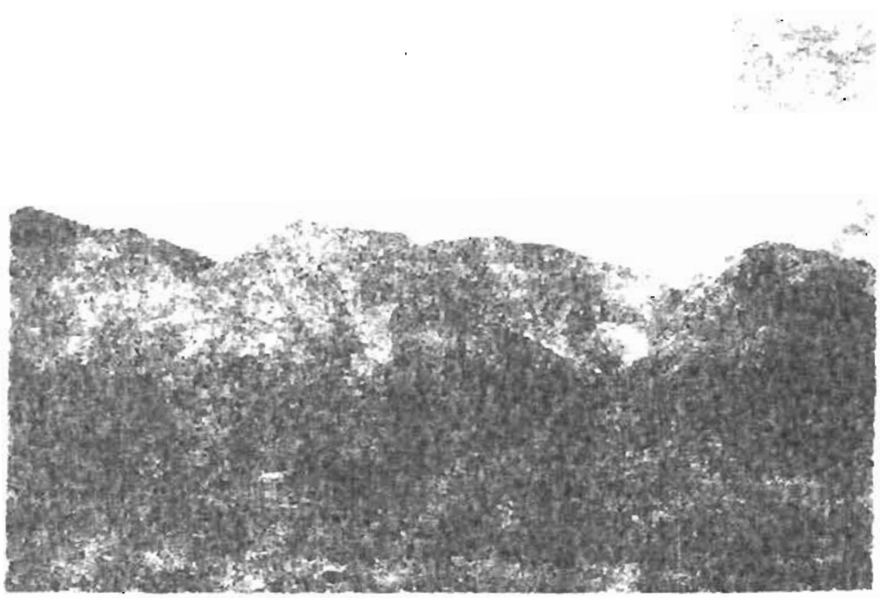

Figure 19. General view near [illegible]

Clay Zone.

(c) Clay Zone: The principal type of alteration in this zone is kaolinization. The rock is poorly exposed. Quartz-molybdenite veins are common and the tenor may prove to be better here than elsewhere in the deposit. Pyrite, also, is common, but is in lesser amounts than in the Intermediate Zone. As a group, the quartz-molybdenite veins have a preferred orientation, and trend N. 60° to 70° W. or approximately perpendicular to the strike of the dikes. Trends of individual veins, however, vary and coalescence is common. The veins are narrow, usually less than one-fourth of an inch wide, but often less than two inches apart. Molybdenite generally occurs along rather than in the veins.

The fracturing, in which the veins are found, is suggestive of a wide shear zone. However, microscopic study suggests the veins may be replacement rather than filling. Twenhofel (1946, p. 15) has described a similar type of molybdenite deposit in southeastern Alaska and suggests that, there, the quartz-molybdenite veins are fillings in joints.

The extent of the molybdenum mineralization aside from that exposed along the stream is unknown.

Grubstake Creek: Mineralization was noted in three separate locations within the drainage of Grubstake Creek: (1) Chalcopyrite disseminated in or near the monzonite intrusive, (2) Chalcopyrite and bornite disseminated in a diabase, (3) Chalcopyrite disseminated throughout part of an aplite dike. Copper mineralization was also noted in jasper float near the head of the Creek, but the source was not found.

The copper mineralization with the border facies (?) of the monzonite is in the form of widely disseminated chalcopyrite with considerable malachite.

Copper mineralization in the diabase is in much the same form as in the monzonitic rock, except bornite is associated with the chalcopyrite and pyrite is much more common. Although the diabase is not mapped on Plate I, it outcrops adjacent to and is faulted by the Grubstake Creek fault.

Several six to eight foot wide aplite dikes crop out in the Grubstake Creek area, but only one held any copper minerals. Chalcopyrite associated with pyrite is disseminated throughout the groundmass.

Vein Deposits.

Vein deposits are the more common form of mineralization in the Ahtell-Slana district. The two important types of veins are lead-silver and gold-quartz. The more important deposits include three lead-silver deposits and two gold-quartz deposits which will be briefly discussed.

West Fork Prospects: The West Fork prospects are located at the base of the mountain due east of the junction of Lake

Creek and the West Fork of Ahtell Creek (See Figure 19).

Development work consists of several shallow trenches and two short adits, all of which are now filled or caved.

The country rock is quartz-monzonite generally concealed by a thick growth of brush, tundra, or muskeg.

Galena, often silver bearing, is the principal ore mineral noted within a number of individual, and poorly exposed, outcrops. The width of the mineralized area is approximately 450 feet.

Galena, generally with small amounts of chalcopyrite, occurs as narrow veins within or along eight to ten foot wide sheared zones trending N. 20° to 40° E.. The mineralization consists of closely spaced, galena veins concentrated along the hanging wall and parallel with the shear zone.

The mineralized outcrops are from fifty to one-hundred feet apart, and at the same elevation. The intervening bedrock is completely concealed by overburden. It is possible that some mineralization has taken place within the presently concealed bedrock.

<u>Indian Ridge Prospect</u>: The Indian Ridge prospect is located approximately three-fourths of one mile west of Long Lake. The country rock at the prospect is quartz-monzonite that was intruded by several different sorts of east-west trending dikes.

Within the mineralized area, the rock is cut by numerous sheared zones paralleling the dikes. Quartz veins mineralized by galena and some silver are found within the crushed zones. The veins vary in width, but are generally between twelve to fifteen inches. Galena, with minor amounts of chalcopyrite and other copper minerals, is generally spotty and occurs as bunches or pods within the quartz.

The width of the mineralized zone is at least seventy-five feet.

Silver Creek Prospect: This prospect is located on Silver Creek approximately one-half mile upstream from the junction with Ahtell Creek.

Development work consists of several shallow trenches and one caved adit.

Diorite, or quartz-monsonite is the country rock. The rock is much altered at the deposit and concealed by tundra and muskeg, in adjacent areas. An altered volcanic hornfelsic rock outcrops on the opposite side of the stream and suggests that Silver Creek may be following a faulted zone.

A fault or shear zone, at least fifty feet wide and striking N. 60° W., cuts the country rock at the prospect and is mineralized in areas by quartz galena veins. In addition to the galena; tetrahedrite, chalcopyrite, and sphalerite were observed.

At least two stages of quartz are known. The earlier was mineralized with lead and copper minerals whereas the latest stage was mineralized mainly with pyrite and gold.

Ahtell Creek Prospect: The Ahtell Creek gold prospect is located approximately opposite the mouth of Silver Creek, but on the left limit of Ahtell Creek. Development work consists of a short adit driven on a three to four foot wide sheeted quartz vein trending northwest and dipping south.

The only mineralization noted was along the foot wall where sulphides occur. Free gold was not observed. However, with the aid of the microscope gold was noted closely associated with sphalerite.

Tourmaline Creek: Tourmaline Creek is the first major southward flowing Creek near the east end of Long Lake. The country rock, quartz-monzonite, is cut by several wide shear zones and lamprophyre dikes, both trending nearly west. Several, closely spaced, quartz-calcite-hematite veins with minor amounts of black tourmaline trend N. 50° W..

The only gold noted was in one polished-thin section. The gold was extremely fine grained, randomly distributed throughout the section, and closely associated with magnetite or corroded pyrite.

Placer Deposits.

Placer gold has been reported from many locations throughout the Ahtell-Slana district as well as the adjacent areas.

The only placer mine operating, in 1957, was at Grubstake Creek.

Grubstake Creek Placer Mine: Grubstake Creek is a westward flowing tributary of Ahtell Creek and is approximately two miles long. The bedrock in the upper part of the Creek is hornfels and basalt. Monzonite is the bedrock along the lower portion.

Mining to date has been mainly along the lower part of the stream as gold is not reported to occur in the upper portions. The depth of overburden in the lower portion varies but appears to average less than ten feet.

The concentrates examined contained a high proportion of magnetite, native silver and native copper. The gold is concentrated on or slightly within the decomposed bedrock and is generally coarse and light colored, suggesting a relatively high silver content.

Summary.

In a district such as this, where no comprehensive development work has been performed, predictions as to the future value of the known mineral deposits is not possible. However, there are several things that future workers in this district may possibly consider:

(1) The more promising mineral deposits to date have been found in the quartz-monzonite and the Indian Creek pluton appears a more favorable host for mineral deposits than does the Ahtell Creek pluton.

(2) Gold is widely distributed in quartz veins throughout the quartz-monzonite and potential placer ground derived from these may occur wherever favorable conditions exist.

(3) Rock alteration is closely associated with many of the deposits and may eventually prove a workable guide to ores.

(4) Although all the mineral deposits are associated with faulting or shearing, no specific conclusions have been reached as to possible district wide guides to ore deposits.

CONCLUSIONS

Tentative conclusions concerning many of the geologic problems encountered in the Ahtell-Slana district have already been discussed and further elaboration is not necessary. However, additional field work, detailed in nature, is certainly recommended in the district.

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