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GEOLOGIC REPORT NO. 14

# Geology and Mineral Deposits of the Rainy Creek Area, Mt. Hayes Quadrangle, Alaska

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Juneau, Alaska
May 1965

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ILLUSTRATIONS

## INTRODUCTION

The Rainy Creek area, covering about 100 square miles, is on the south slope of the Alaska Range just west of the Delta River and the Richardson Highway (figure 1). It lies in the Mt. Hayes B-4 and B-5 quadrangles. Within the area, gold placers have been worked on Rainy Creek and in Broxson Gulch, and copper has been reported in skarn and diorite at several locations in the Rainy Creek drainage (Martin, 1920, p. 20, Brooks, 1918, p. 43). Just east of the map area, nickel and copper showings associated with ultrabasic rocks have been prospected at Rainbow Mountain on the east side of the Delta River near Mile 213 and the Richardson Highway (Hanson, 1964). The area was chosen for geologic mapping because of (1) these known mineral occurrences and (2) the presence of several bodies of granitic rock shown on the reconnaissance maps of Moffit (1954).

A total of about a month was spent in the area during the summer of 1964. Walter Phillips served ably as field assistant, and carried out some of the geologic mapping. Stream sediment samples were collected by Phillips concurrently with the geologic mapping and analyzed in the field for readily extractable heavy metals. Total copper, lead, zinc, molybdenum and nickel values were later obtained in the lab. Because of complexities in the structure, stratigraphy, and petrology, some conclusions in this report must be considered tentative. Additional field work is planned during 1965.

The area is accessible in several ways. In the present project, access was by float plane landing on the Delta River just south of the area shown on figure 2, followed by backpacking to the Rainy Creek drainage. Considerable difficulty was encountered in crossing Eureka Creek because of high water. Later, supplies were flown into an airstrip on the East Fork of Broxson Gulch. Float plane landings are possible on Pioneer Lake at the south edge of the area, although the small size of the lake makes takeoffs marginal. The Delta River can be crossed by boat near Mile 212½ on the Richardson Highway (just below Phelan Creek), followed by back-packing into the area, preferably on the relatively bare terraces at about 3500 feet elevation. Dense timber along some portions of the river makes travel difficult.

Some ambiguity exists with the name "Broxson Gulch". The Mt. Hayes B-quadrangle shows this as the name of the valley below the large glacier draining southeastward into Eureka Creek just off the west edge of figure 2 Actually, the name seems to be based on gold placering by Archie Broxson in the easternmost branch of this group of drainages where the airstrip is shown, so probably this branch has a better claim to the name, with Eureka Creek applying to the large branches of the group. However, to conform to the published maps, the names East Fork and Middle Fork of Broxson Gulch are used in this report as shown on figure 2. The names

Specimen Creek and Pioneer Lake follow local usage.

Elevations range from 2500 feet on the Delta River to 7000 feet along the north edge of the area. Some timber exists along the Delta River and in the lower part of the Rainy Creek valley. The upper limit of brush is at about 4000 feet elevation. Above 4000 feet, talus forms the lower slopes, and outcrops are usually restricted to the upper slopes and ridges. The larger drainages are fed by glaciers, and many of the smaller drainages above 4500 feet have semi-permanent snow in the bottom. Due to high water during the early and middle summer, Rainy Creek, Eureka Creek and the larger forks of Broxson Gulch can be difficult to cross on foot.

## REGIONAL SETTING AND PREVIOUS WORK

The dominant geologic feature of the central Alaska Range is the Denali fault (St. Amand, 1957). This regional fault trends west-northwesterly along the Alaska Range, curving east-west and finally southwestward in western Alaska (figure 1). East of the Delta River, the fault separates schists and gneisses of Precambrian (?) age (Birch Creek schist) from a variety of rocks, most of which are relatively unmetamorphosed. St. Amand (1957) suggested 150 miles of right lateral strike-slip movement, but evidence for the direction and amount of movement is poor.

South of the map area, basaltic volcanics of Triassic (?) age form an east-west belt 10-15 miles wide in the northern part of the Copper River Basin (figure 1). Between the Triassic (?) rocks and the Denali fault, a variety of rocks are present, mostly in small fault blocks. In the northwest part of the Rainbow Mountain area east of the Delta River, Hanson (1964) mapped a pre-Mississippian sequence of phyllite, greenschist, and marble, separated by faults from Mississippian and Pennsylvanian greywacke, andesite, and limestone. These rocks were intruded by andesite, ultramafic rocks, quartz diorite to granodiorite, dacite, and dikes of diabase. Close folding along northwest axes and minor thrusting to the south is present locally. East of Hanson's area in the upper basin of the Gulkana glacier, Ragan and Hawkins (1964) report high grade metamorphic rocks to which they assign an early Precambrian age. Farther to the east, along the south side of the Denali fault near the headwaters of the upper Chistochina River, Mendenhall (1905) and Moffit (1954) mapped Pennsylvanian volcanics and sediments (Chisna formation) and Permian limestones, sandstones and black shales (Mankomen formation) in several fault blocks. Tertiary nonmarine coal-bearing sediments are exposed at several places along the south side of the range.

West of the map area beyond the Maclaren River, Triassic sediments lie north of the Triassic basaltic volcanics on the south slope on the range. Ultramafic rocks are also reported in this area (Kaufman, 1964).

During the summer of 1964, the area between Rainy Creek and the Delta River, northward across the Denali fault, was mapped by Jim Stout, a graduate student at the University of Alaska. The results of this mapping are not yet available, but discussions in the field indicate a continuation of the structures and lithology discussed in this report.

## ROCK UNITS OF THE RAINY CREEK AREA

### Precambrian (?), schist and gneiss

North of a line approximately coinciding with the present limits of glaciers in the Rainy Creek area, the rocks consist of schist and gneiss. The contact of these rocks with those to the south is a thrust fault (figure 2).

In hand specimens, the rocks are mostly well-foliated medium-grained gray to dark gray schist. Some of the schist is fine-grained, and locally medium-grained feldspathic gneiss is present. The schist and gneiss show compositional banding in layers a tenth of an inch to several feet in thickness. In a few outcrops complex folding of these layers is evident. Several carbonate-rich units are present in the schist near the thrust. A zone a few hundred feet wide just above the thrust has reddish and greenish tints when viewed from a distance, compared to dark gray colors of the rock farther from the thrust. Some iron-staining is present throughout the schist and gneiss, but appears to be most common near the thrust.

The composition of six schist specimens is shown in Table 1. Rocks from the zone near the thrust fault (samples 400, 401, 505, 524) have a mineralogy indicating the quartz-albite-muscovite-chlorite subfacies of the greenschist facies (Turner and Verhoogen, 1960). Sample 507, from the gray schist zone away from the thrust, appears to belong to the quartz-albite-biotite-epidote subfacies - i.e., a slightly higher grade of metamorphism. Sample 333 has textures and mineral assemblages suggesting contact metamorphism. Large porphyroblasts of light colored euhedral andalusite (?) and dark prismatic staurolite (?) are post-kinematic, as is a considerable proportion of the biotite. These minerals may have developed during the emplacement of the granitic mass just south of the Denali fault and west of the Delta River. However, in the specimen studied, both minerals have suffered later retrograde alteration, the andalusite (?) to sericite, and the staurolite (?) to chlorite and biotite.

The schists seem most reasonably interpreted as a sequence of pelitic sediments in part calcareous, interlayered with intermediate to basic volcanic rock (sample 400) that has undergone regional metamorphism of at least upper greenschist facies followed by local contact metamorphism. Some retrograde metamorphism may have occurred adjacent to the Broxson Gulch thrust fault. From the information now available, it appears reasonable to correlate these rocks with "Birch Creek schist" of relatively low metamorphic grade (Ragan and Hawkins, 1964) north of the Denali fault. An age of Precambrian (?) is assigned from this correlation. The query reflects recent radioactive age-dating and tectonic analyses (Herreid, 1964, Wasserburg et al, 1962) which cast some doubt on the Precambrian age of the Birch Creek schist.

## Pre-Permian (?) sedimentary and volcanic rocks

A thick sequence of unmetamorphosed to weakly metamorphosed sedimentary and volcanic rocks is present in the Rainy Creek area. Undoubtedly these rocks correlate in part with the rocks described by Hanson (1964) in his Rainbow Mountain and McCallum Creek sequences, but because of uncertainties in correlating with his units, and between fault blocks within the Rainy Creek area, three groups of rocks are described in the following pages under the headings Group A, Group B, and Group C.

Group A (Greenstone, Av; slate, As; and diorite, Ad)
These rocks in sectors C-5 and D-5 differ from the surrounding rocks in being weakly to moderately foliated and metamorphosed, and in containing slate and diorite that do not appear elsewhere in the area. The group is bounded on the north side by a steep-dipping fault, and on the south by a moderately-dipping sheared zone that is interpreted as a thrust-fault.

The greenstone unit (Av) is the most abundant member of the group. The rock is mostly fine-grained, light to dark green in color, and locally shows weak foliation but more commonly is highly shattered with weak fracture cleavage. Thin sections suggest that the original rocks were andesites, dacites, and tuffs. One specimen is an agglomerate or breccia. In several outcrops the "foliation" could be orientation and flattening developed in tuffs or flows. The minerals present are quartz, albite (?), chlorite, epidote, and calcite, which are diagnostic of the quartz-albite-muscovite-chlorite subfacies of the greenschist facies. Foliation is much poorer than in the Precambrian(?) rocks despite the similar grade of metamorphism. Pyrite is common in the greenstone, but may have been formed by a later episode of alteration. Iron staining and bleaching have resulted from the oxidation of the pyrite, and obscure the character of the rock in many places.

The slate (As) is black and very fine-grained with fair slaty cleavage. Outcrops of the slate are not common, but abundant float marks the location of the unit. In the few outcrops, the slate is crumpled and contorted, and tends to break up into chips an inch or two across. Iron staining and minor amounts of pyrite are present at many locations, and veins of quartz and calcite are common. Parts of the slate are calcareous. The rock before metamorphism was apparently black shale and limy black shale.

Meta-diorite (Ad) crops out near the ridgeline between Specimen Creek and Broxson Gulch. The diorite is medium-grained, green to gray in color, with weak foliation. Minerals present are minor quartz, moderate amounts of albite, epidote, actinolite, and chlorite, and small amounts of calcite and pyrite. These minerals indicate a metamorphic grade similar to the meta-volcanics described above. Foliation or deformation are not obvious in thin section, and the original texture is partly preserved.

Other rock types present in the group are several thin highly sheared limestone units in the greenstone, and a mylonite near the north edge of the formation.

The origin and age of the slate, volcanic, and diorite groups of rocks seem explainable in either of two ways. Hanson (1964) proposed a pre-Mississippian age for a group of phyllites and greenschist just east of the Delta River and south of the Denali fault in the Rainbow Mountain area. The greenstone and diorite described above appear similar to those at Rainbow Mountain and the slate could be correlated with the phyllite, although the latter is noticeably coarser grained. Under this hypothesis, the slate, greenstone and diorite are pre-Mississippian rocks, possibly early Paleozoic, which were weakly metamorphosed before Mississippian time.

The second possible origin assumes that the volcanics and slate are part of the Pennsylvanian or Mississippian sequence that has been intruded by diorite and then metamorphosed and deformed. The deformation and metamorphism might be attributed to their location along a thrust zone. Possibly they have been faulted up or carried in as a large inclusion in the ultramafic rocks, thus accounting for differences from the nearby rocks of the Pennsylvanian sequence. The diorite could be a slightly deformed and altered equivalent of diorite and gabbro elsewhere in the area. The main argument against this viewpoint is the presence of the slate, which is not known to occur in the Pennsylvanian or Mississippian at Rainbow Mountain or in the Rainy Creek area. For this reason the writer favors the first alternative.

<u>Group B</u> (silicic volcanics, Bv; and limestone, Bl)

Rocks assigned to this group were mapped in several places between Rainy Creek and the East Fork of Broxson Gulch. The most prominent exposures are in an east-west belt between the West Fork and Rainy Creek and the large dunite body (sectors E-6, F-5, F-6, and G-6). Another belt crosses the West Fork of Rainy Creek in about the middle of its course. Other exposures are along the north side of the North Fork of Rainy Creek, possibly forming an extension of the first belt. In the latter two cases, the rocks may be large inclusions in "serpentinites".

The group is characterized by thin limestones, limy tuffs, and light colored silicic tuffs. Bedding and banding is commonly visible, but most units disappear in distances of several hundred feet. Some units appear to be impure quartzites, and one dark shale containing a few fossil fragments was found near the West Fork of Rainy Creek. Other dark fine-grained units were thought to be volcanics in the field, but thin section study indicates that similar rocks in other parts of the area are altered ultramafic rocks and it is possible that some of the dark aphanitic rocks within this group are also altered ultramafics. Green agglomerate was also noted in several places, apparently near the base of the sequence. Pyrite and iron-staining are common throughout, and impart red, brown, and yellow colors to the outcrop.

Most of the limestone occurs as thin units that cannot be traced more than a few tens of feet. A few thicker units are shown on the map. A triangular fault block just north of the West Fork of Rainy Creek consists largely of medium-bedded gray limestone. In the same belt, just south of the ultrabasic body, a light-colored thin-bedded limy tuff can be followed for about half a mile. The extent of other limestones shown on the map is inferred from very restricted outcrops. Tactites composed of garnet, epidote, diopside and other silicates have developed from the limy rocks in many places.

The age of these rocks is inferred to be upper Paleozoic from small suites of brachiopods and bryozoans collected from the triangular block of limestone and from the limy tuff described above. Two brachiopods from the triangular block of limestone were identified by G. Arthur Cooper of the U.S. National Museum as Neospirifer and a Chonetid or Megousia (letter of 3/17/65). The age significance of these fossils is uncertain. The rocks of Group B are tentatively considered as older than group C and the Mankomen formation because of their greater metamorphism and deformation, although it is possible they are part of the Permian Mankomen formation.

<u>Group C</u> (Andesitic volcanics and greywacke, Ca; limestone, Cl; and dacite and andesite intrusives, Ci)

Tuffs, flows and greywackes of andesitic to dacitic composition, plus minor amounts of impure limestone, are extensively exposed in the northern half of the map area. The volcanics and most of the greywacke are characterized by light green to yellow-green colors resulting from development of chlorite and epidote. Some zones consist of clastic sediments and tuffs with distinct bedding or banding, but relatively massive andesites and andesitic tuffs with only local bedding are more common. The limestones are usually clastic with a considerable proportion of silicate mineral grains in a calcareous cement. The general characteristics of this volcanic-sedimentar unit are very similar to those of the Rainbow Mountain and McCallum Creek sequences described by Hanson (1964), but no precise correlation can be made.

Rocks of group C in sector B-6 are massive andesites, but further north in sector C-7 they are poorly to distinctly bedded. A few thin limy units are present. Across the valley in sector C-6 and D-6, many outcrops show bedding in the southern part of the fault block (just north of the airstrip), but in the northern third of sector D-6 and E-6 bedding and sedimentary character is only locally visible. Once clastic limestone unit about 50 feet thick is present in this zone. The belt of group C rocks just south of the Broxson Gulch thrust in sectors F-8, G-8, and H-7 to J-7 is mostly bedded, and nearly horizontal beds of light-colored rock are visible. Along the west side of the Delta River in sector L-6 and vicinity, andesite and dacite tuffs and flows predominate.

Hypabyssal intrusives into group C are present in several locations. A body of dacite porphyry with quartz and plagioclase phenocrysts in a silicic aphanitic groundmass intrudes banded tuffs and sediments in sector G-7. The peripheral zones of this intrusive are composed of fragments of dacite porphyry in a matrix of siliceous aphanitic volcanic material, giving it the character of a breccia. It seems likely that this body was a feeder for tuffs and flows higher in the section. A second intrusive(?) body of porphyritic dacite containing phenocrysts of plagioclase and hornblende in an aphanitic siliceous groundmass outcrops northeast of the airstrip (sector D-6) on the East Fork of Broxson Gulch. In many other exposures, it is not clear whether the rock is a flow or a shallow intrusive. This is true also of the andesites south of group A and the dacite or quartz latite on the low hill in sector K-5.

The principal alteration products in group C rocks are chlorite, epidote, saussurite, and albite, with smaller amounts of calcite, sericite, pyrite, and leucoxene. This alteration or metamorphism is probably best considered as propylitization. The mineralogy of the alteration is similar to the mineralogy of group A rocks except that no actinolite has been noted. The original character of group C rocks in hand specimens is usually less obscured by alteration than in group A.

Some of the limestones in group C contain fossil fragments, but no well-preserved fossils were found. The tentative lithologic correlation with Hanson's Rainbow Mountain and McCallum Creek sequences indicates a Pennsylvanian or Mississippian age.

## Permian Mankomen Formation

A sequence composed dominantly of limestone and black shale is expose between Rainy Creek and Eureka Creek. The lithologic character of these rocks is similar to the upper part of the Permian Mankomen formation described by Mendenhall (1905) in the area north of Mankomen Lake. Moffit (1954, p. 104) refers to beds on the Delta River as Permian, and fossils discussed on a following page indicate a Permian age. The thick sequence of limestone and black shale south of Rainy Creek is therefore correlated with the Mankomen formation.

The rocks referred to the Mankomen formation dip moderately south, but it appears that one or more faults of unknown magnitude cut the exposures, so a true stratigraphic section is not available. The apparent lowest unit is composed of fine-grained pyritized quartz-rich tuffs which are exposed just south of the mouth of Rainy Creek. A thin section of this rock shows major amounts of quartz and plagioclase, in grain sizes up to 0.5 mm but mostly about 0.01 mm, along with fine sericite, clay, chlorite, pyrite, and traces of calcite. Probable acidic flow rocks were observed in a few outcrops.

In exposures along Rainy Creek and the Delta River, the tuff appears to be faulted against the next higher unit, which is black shale, although the geometry and displacement of the faulting are not clear. Thin limestones and limy shale beds occur within the black shale. The shale must be at least four hundred feet thick. Bedding shows local crumples, and it seems likely that additional faults are present.

The thickest unit of the formation consists of relatively pure limestone with some interbedded poorly outcropping black shale and shaly limestone. The shale appears to be more abundant near the bottom of the section. Exposures on the top and north slope of the hill in sector J-2 are composed of medium-bedded light gray limestone. The thickness of this part of the section is about 2000 feet if no undetected faults are present. Several gabbro sills have bleached the limestone for a few tens of feet above and below them. Some zones contain abundant crinoid stems, and brachiopods are common throughout the limestone. Some dark gray chert is present.

Above the limestone on the north side of the hill in sector J-2, several hundred feet of poorly exposed thin-bedded gray shale and impure poorly-sorted greywacke are present. Above the shale and greywacke is a very massive thick-bedded light gray limestone with abundant brachiopods in some zones. Apparently the same unit is exposed in a box canyon on the next major drainage to the west. A small exposure of black shale overlies a gabbro sill a few hundred feet farther south.

Westward in sector G-3, limestone, and chert conglomerate are overlain by black shale and intruded by gabbro along the south side of the West Fork of Rainy Creek.

The upper half of the section of Permian rocks in the Mankomen Lake area described by Mendenhall (1905) and also Moffit (1954, p. 107) matches in a general way the lithology described above.

The best fossil evidence concerning the age of these rocks is given by a collection of fossils identified by J.T. Dutro and Helen Duncan of the U.S. Geological Survey. These fossils were collected in 1958 from "along the Delta River between Rainy and Eureka Creeks" in the Mt. Hayes B-4 quadrangle (Shipment A-59-1, U.S. Geological Survey locality 18115 PC). Mr. Dutro has kindly allowed the quotation of their conclusions on the lot of fossils (letter and report of 3/12/65).

"The collection contains:

crinoid columnals, indt.
Scheiia cf. S. tuberosa Tschernyschew and Stepanow
"Caninophyllum" sp.
Heritschioides n. sp.
bryozoan fragments, indt.
Yakovlevia aff. Y. transversa (Cooper)
Antiquatonia? sp.
linoproductid brachiopod, indet. (probably Megousia)
Neospirifer? sp.
Spiriferella aff. S. saranae Verneuil

"This single collection contains fossils that are commonly found in rocks of Permian age in central and eastern Alaska. The brachiopoda Spiriferella and Yakovlevia are of types found in the nearby Mankomen formation (see Moffit, 1938, Bulletin 904, p. 24-26). The productoid now referred to the genus Yakovlevia was listed earlier as belonging to the "group of Productus multistriatus". Similar species also are reported from the Tahkandit limestone in the Eagle-Circle district (see Bulletin 836-C, p. 431) where the Yakovlevia was listed as "Productus cf. P. geniculatus". All these rocks are generally considered to be of post-Wolfcamp age, possibly late Leonard or Word equivalents.

"Miss Duncan makes the following statement concerning the sponge and corals:

"The sponge, Scheiia, is comparable to a species described from the Permian of King Oscar's land (Ellesmer land). The forms identified as Hindia from the Permian of Timor are probably related."

In addition to this collection, a few fossils collected by the writer were identified by G. Arthur Cooper of the U.S. National Museum (letter of 3/17/65). He has identified the following fossils from the limestone unit of the Mankomen:

| | | |
|---|---|---|
| Location | AR263 | Antiquatonia (possibly related to A. reticulata Cooper) |
| " | AR269 | Crurithyris |
| " | AR768 | Cleiorthyridina |
| " | AR769 | Megousia |
| " | AR252 | Sponge like Hindia |

Cooper also concludes that the specimens belong in the Permian.

Additional fossils were collected but have not yet been identified.

A somewhat problematical series of outcrops is present on the west side of the Delta River just north of Rainy Creek. From south to north these are as follows: fine-grained, nonfossiliferous limestone with one interlayered basic flow; fine clastic sediments and chert; a diabase dike, and siliceous acid volcanic tuffs with one unit of light green rhyolite containing flattened rock fragments. A gap of several hundred yards separates these exposures from outcrops of dense light gray argillite with some thin limestone and quartzite beds, a thick gabbro sill (?), then thin to medium bedded fine dense argillite, calcarenite, and limy sandstone, with a few basic flows or tuffs. This sequence is tentatively considered to be a lower part of the Mankomen formation.

Based on aerial observations and the reconnaissance mapping of Moffit, more limestone appears to be present in the gorge of lower Eureka Creek.

## Triassic(?) basaltic flows

A sequence of mafic volcanic rocks is exposed along the southern edge of the map area. These rocks are dark brown to purplish, locally contain amygdules and vesicles, and are similar to extensive exposures along the Denali Highway west of Paxson. Most units appear to be flows but a few agglomerates and tuffs may be present. A thin section of a sample from near the Delta River is an albitized basalt composed of 30% augite, 35% chlorite, 35% albite and traces of calcite and ilmenite or magnetite. The origin of the chlorite, which occurs as irregular patches, is not clear. The texture is subophitic, and the grain size is 0.1 to 0.5 mm.

The flows are tenatively correlated with the Triassic Nikolai greenstone of the southern Copper River Basin.

Amphibole "serpentinite"

The most abundant rock in the area seems best described as amphibole "serpentinite". It is characterized by medium to dark gray colors and an aphanitic dense appearance in hand specimen. Many weathered exposures have the appearance of a fine breccia of subrounded medium gray fragments : a slightly darker matrix. The fragments are 1/10 to 1/4 inch in diameter. Usually a few small spots of finely crystalline material are visible with a hand lens. In some specimens from just south of the Airstrip fault in sector D-5 and E-5, remnants of olivine crystals are recognizable. Fin cracks and spalls in the aphanitic material show pale greenish to gray shades. The rock is quite hard and breaks into angular fragments an inch or less in size. The high density (above 3.0) is a useful identifying characteristic.

In the field, these rocks were thought to be a volcanic flow or tuff-breccia, and consequently were not always distinguished from volcanics of groups B and C. However, study of 12 thin sections and 9 X-ray patterns indicates that the composition is ultramafic, and that fine actinolite is the main constituent. The actinolite is colorless to pale green and occurs in ragged grains from 0.1 mm down to beyond the limit of resolution of the microscope. Patches of relatively coarse actinolite are separated from each other by nearly isotropic material with only a few fine grains of identifiable actinolite. In some specimens, remnants of olivine crystal occur instead of the coarser patches, and pseudomorphic outlines of olivin crystals can be recognized in many of the specimens. The olivine and olivine pseudomorphs, which make up 20 to 40 percent of the rock, average about 1 mm in diameter, although a few larger crystals were seen. In about half the specimens, a few percent of serpentine and chlorite are recognizable. Pyrite is a common constituent and is disseminated through the rock. Other minerals detected in amounts of a few percent are plagioclase, epidote, and talc. Prehnite is common as white veinlets and coatin in sector G-4. Analcite and stilbite were tentatively identified in several specimens. The samples with a fragmental appearance contain actinolite, but adjacent fragments have differing grain size and texture, and in two thin sections an appreciable proportion of aphanitic feldspathi volcanic fragments is present.

The amphibole "serpentinite" appears to have originated as a peridotite composed of olivine crystals in a matrix largely of clinopyroxene and perhaps some anorthite-rich plagioclase. Uner appropriate conditions of temperature and pressure, alteration of the peridotite in the presence c a moderate amount of water is thought to have resulted in the development of actinolite. Possibly the temperature of alteration was higher than that required for the development of serpentine. This difference, combinec with the calcium-rich composition, could lead to the development of actinolite rather than serpentine. Actinolite in small quantities is not uncommon in serpentines, but the writer has not been able to find any previously-described case of actinolite developing almost to the exclusion of serpentine. The fragmental appearance may result from brecciation of solid material during intrusion. Incorporation of fragments of country rock or metasomatic alteration of fragmental volcanics adjacent to an ultramafic intrusive has apparently occurred in some cases. The presence of included "leaves" of country rock is typical of serpentines in California (Taliaferro, 1943).

What appears to be a metamorphosed phase of the "serpentinite" was detected in several thin sections. In hand specimens, these rocks look very similar to the serpentinite described above, but a brownish or purplish cast is evident, and a larger proportion of the rock consists of fine crystals visible with the hand lens. In thin section, the main constituent of these rocks is a light brown hornblende (X-ray pattern similar to the actinolite), along with small amounts of fine granular diopside and olivine. The maximum grain size is about 0.2 mm. The hornblende has formed from the matrix of the rock, and the pyroxene and olivine apparently from the areas of original olivine grains. Pyrite and chlorite are present to the extent of a few percent, and small amounts of plagioclase are present in one sample. Four specimens which contain brown hornblende came from near gabbro bodies, one from just north of the gabbro in sector I-4, one from north of the large gabbro body in sector F-4, one from northwest of the gabbro plug in sector F-5, and one from between gabbro and dunite in the middle of sector C-7. A fifth specimen was collected adjacent to dunite in sector C-7. In all cases an origin of the hornblende-bearing rock by contact metamorphism of amphibole "serpentinite" seems probable. The mineral assemblages have some similarities to those reported by Green (1964) adjacent to high temperature peridotites, but more study of this topic is needed for firm conclusions.

Also present within the "serpentinite" are numerous occurrences of light-colored hornfels and tactite. Epidote, diopside, and garnet are the main constituents of the tactites. Pyrite and chalcopyrite have been introduced into some tactites, and the addition of sodium is indicated by the presence of glaucophane in two localities (mineral localities 15 and 16). Metasomatic addition of other elements has probably taken place. Minerals present in the hornfels are diopside, albite, quartz, calcite, and epidote, based on two thin sections and several X-ray patterns. The facies of metamorphism is not clear, but the presence of diopside suggests a relatively high temperature. Some of the light-colored hornfels shows bedding and apparently originated by metamorphism of blocks of sediments caught up in the amphibole "serpentinite". It is not clear whether the hornfels developed before or after the actinolite in the amphibole "serpentinite". It is also possible that some hornfels and tactite are metasomatic effects of the later peridotite and gabbro. A few of these bodies occur near contacts with the later rocks, but many do not.

Peridotite

One large body of dunite and numerous smaller bodies of dunite and peridotite are exposed in the area. The large mass of dunite extends in a west-northwest direction from sector E-7 eastward to at least I-6. This body is composed almost entirely of dunite that weathers a characteristic orange-brown color. From a distance the appearance is similar to an oxidized pyritic rock. Thin sections show that the rock is composed of olivine with a percent or two of chrome-bearing spinel. In most parts of the mass, serpentine occurs only on widely-spaced fractures, but near the margins and in a few localities near the center of the body the veinlets are spaced a few inches apart or the entire rock is serpentinized. Most of the serpentine is antigorite, but some veinlets in the interior of the dunite are cross-fiber chrysotile. Secondary magnetite is present where the rock has been serpentized. The olivine composition is $Fo_{90}$, based on U-stage measurements of 2V in two samples. The olivine is slightly to moderately granulated and shows some translation lamellae, possibly indicating intrusion as a solid.

A possible extension of this body is exposed in sector C-7 and D-7. Apparently, the exposures here are near the top of the dunite mass. Small to moderate amounts of pyrite are disseminated through this dunite, which is similar to the larger mass in composition and texture. The pyritized dunite weathers to a redder color than the normal dunite. Similar but smaller bodies of dunite are exposed in sectors M-7 and K-4.

The peridotite in sector D-5 and westward along the Airstrip fault, in sector C-4, the dikes in sectors C-8 and D-8, and parts of the large body in D-8, are partly to completely serpentinized. A banded appearance in shades of green is common in the serpentinized peridotite. No thin sections of these bodies have been made, but small amounts of pyroxene appear to be present in hand specimens.

The ridge in sector K-7 was not mapped, but float suggests a considerable amount of peridotite may be present. Dikes of partly serpentinized peridotite crop out at several places in the gullies.

The peridotite cuts across the bedding and flows of group B and C rocks in a number of places, but is not in contact with the Permian and Triassic(?) rocks. Based on inclusions of dunite in some gabbro, the gabbro appears to be younger than the peridotite, and is probably a differentiation product of the same magma. The gabbro intrudes the Permian and it is presumed that the peridotite is also younger than Permian.

Several lines of evidence indicate that the peridotite and dunite are later than the amphibole "serpentinite". Dikes of serpentinized peridotite cut the amphibole "serpentinite" in sector C-7 and D-7. Although these "dikes" could be zones of serpentinization along faults or veins, some of them retain a granular texture similar to the peridotite. A granular texture is not evident in the amphibole "serpentinites". The contacts of the dunite with the serpentinite can usually be located within a few feet where exposures are good, and partial alteration of dunite to amphibole was not noted. Instead, a specimen of amphibole "serpentinite" near the contact in sector C-7 and another about 50 feet from the dunite contact in the northeast corner of C-7 contain abundant fine brown hornblende that appears to be a metamorphic effect of the dunite. It is therefore concluded that there were two episodes of ultrabasic intrusion in the area. The rocks of the first episode were almost completely altered to actinolite before the second group of ultramafic rocks was intruded.

Dikes and irregular masses of troctolite and light-colored hornblende gabbro occur locally in the dunite. A bright orange-brown alteration of the dunite in sectors H-5 and D-7 was found to consist mainly of a carbonate, probably magnesite, along with small amounts of quartz and other minerals.

Gabbro and related rock

Dikes, sills, plugs, and lenses of gabbro are common in the southern two-thirds of the area. The dikes and sills are composed of relatively uniform medium-grained gabbro containing about 50% mafics. The larger bodies are more variable in composition, and grade from pyroxenite and mafic-rich olivine gabbro to gabbro with only 25-30% mafics. Textures are usually ophitic. The large bodies in sectors F-6 and F-4 vary from pyroxenite and peridotite to gabbro over distances of a few tens of feet without any apparent pattern. This local variability probably results from reaction of early-formed rock with residual material and later differentiates.

Figure 3 summarizes the composition of the mafic and ultramafic rocks of the area. More complete data are in Table 2. The dunites, composed of nearly 100% olivine, form one extreme. Augite-bearing peridotites with a few percent plagioclase (usually saussuritized) fall next in sequence, and grade into mafic-rich gabbros. A small amount of hypersthene is present in some of the peridotites and mafic-rich gabbros, but augite is the dominant pyroxene. A few percent red-brown hornblende and biotite are characteristic of many of the gabbros. Chromite is the common opaque mineral in the peridotites and mafic-rich gabbros. Pyrrhotite, chalcopyrite, and pyrite are present in some of the olivine gabbros. The lighter colored rocks contain ilmenite and magnetite. The plagioclase has a composition of An 60-70 in unaltered samples, but is saussuritized or albitized in many samples.

Small bodies of gabbro in sectors F-5 and G-5 were called diorite in the field because of their low mafic content, but in thin sections they are composed mainly of labradorite and clinopyroxene, with some alteration of the latter to actinolite, so the term gabbro seems more appropriate.

The gabbro clearly intrudes all the sedimentary units of the area, and in a few cases, as in sector D-5, it intrudes faults cutting the other rocks. No intrusive relationships to the Triassic(?) basic volcanics are evident, but the gabbro appears to be cut off by the Pioneer fault (in sector F-3) which cuts the Triassic(?) rocks. It is possible that more than one age of gabbro exists, but no distinctions have yet been made either in the field or in thin section. A Mesozoic(?) age seems the most reasonable that can be assigned.

## Tertiary Gakona formation

Poorly consolidated sandstones, shales, and conglomerates with thin coaly layers are exposed in lower Broxson Gulch and near the junction of Eureka Creek and the Delta River (just off the map south of sector K-1). The bedding in these rocks is nearly horizontal. Based on the lithologic character, these sediments are correlated with Tertiary sediments in the southern part of the Rainbow Mountain area, and with the Gakona formation near Gakona glacier (Mendenhall, 1905). Exposures of Tertiary rock are also reported by Moffit (1954) a few miles west of the area. An age of Eocene or Miocene has been assigned to similar rocks on the north side of the Alaska Range and near Gakona glacier.

An interesting difference between the Tertiary sediments and the recent gravels in the exposures along Broxson Gulch is the lack of schist and gneiss cobbles in the Tertiary rocks. Either they were derived from the south, or else the schist and gneiss did not have their present position a few miles to the north when the Tertiary sediments were deposited

## Pleistocene and Recent deposits

Sands and gravels of Pleistocene or Recent age are extensively exposed along lower Rainy Creek, and along Eureka Creek in sectors E-2, F-2, and G-2. The gravels are bedded and relatively flat-lying. Their upper surface forms benches several hundred feet above the present stream levels. The streams have cut through the gravels to expose lower units in the gravels. Apparently the gravel was deposited as outwash in the late Pleistocene during an epoch of active glacial erosion in the headwaters of Rainy Creek and other drainages.

Two units can be distinguished in the sand and gravel deposits. The lower unit is present downstream from the junction of the North and West Forks of Rainy Creek. It is characterized by an orange to brown color and an abundance of clay. Possibly this layer results from erosion of well-weathered material during an interglacial period, or from weathering during an interglacial period. Some placer gold apparently is derived from this lower unit. The upper unit is gray in color and contains relatively little clay. It extends from sector G-5 downstream to I-3, and is extensively developed along the Delta River.

More recent deposits consist of alluvium in present stream valleys, terminal and lateral moraines below some of the glaciers, and widespread ground moraine and tulus.

## STRUCTURAL GEOLOGY

Because of uncertainties in the stratigraphy, local structural complexities, and extensive taulus and glacial drift in some areas, the structure of the area is not completely understood. In this section, the important structures will be discussed as they are understood at present, but the probability of revisions from further work should be recognized. The structures will be discussed approximately from north to south.

### Schist and gneiss north of Broxson Gulch thrust fault

The schist and gneiss are separated from rocks to the south by the Broxson Gulch thrust fault. They were mapped only near the thrust, but in this zone the foliation strikes approximately east-west and dips to the north at 25-70°. The thrust fault has a dip of 35° in sector F-8, and about the same in H-8, based on observations made from across the valley. It appears that the foliation of the schist and gneiss dips slightly more steeply than the fault. Minor fold axes in the schist plunge 15-35° N60W. It seems possible that the foliation in the map area has been controlled in part by the thrust. No large change in strike is evident for a mile or so to the north based on observations from a distance. Some shearing and retrograde metamorphism of the schist appear to have occurred near the thrust.

### Broxson Gulch thrust fault

The Broxson Gulch thrust has been mapped from sector B-8 to sector F-8, and its location and attitude are clearly visible in sectors G-8 and H-8. Eastward from H-8, its exact location is not known, but discussions with James Stout of the University of Alaska and cursory observations at a distance indicate that it is present in approximately the location shown. If projected, it appears to intersect the Denali fault in the Delta River valley, although it may be involved in complex structures near the Denali fault in the Rainbow Mountain area. Observation from a distance and photogeology suggest that the fault is present on the west side of Broxson Gulch, but it may be cut by the Airstrip fault between Broxson Gulch and the East Fork of the Maclaren River. The lack of schist and gneiss pebbles in the Tertiary gravels suggest that the fault may have developed in middle or late Tertiary.

Rocks between the Broxson Gulch thrust and the Airstrip fault

In sectors C-7 and D-7, dunite and serpentinite are thrust over rocks of group C along a fault subparallel to the Broxson Gulch thrust. This fault is inferred to become a northeast-trending tear fault extending up the East Fork of Broxson Gulch.

The rocks of group C just south of this small thrust, and the similar rocks in sectors F-8, G-8, H-7, and I-7, all are distinctly bedded or layered, mostly fine-grained, and dip at shallow angles. Farther south in sector B-6, C-6, and D-6, a sequence of greywacke and tuffs dips moderately southward, and may be separated from rocks to the north by a fault.

Group C rocks in the north half of sectors D-6 and E-6 are only locally bedded but show mostly shallow dips where exposed. A northwest-trending fault is inferred to separate these rocks from the dunite, but more work is needed to confirm whether it is a fault or an intrusive contact.

The lens-shaped block of group B rocks in E-6, F-6, and vicinity appears to have complex internal structures. Even distinctive limestone units cannot usually be traced more than a few hundred feet. Most dips are at low to moderate angles to the northeast, but the triangular block of limestone has moderate to steep south dips. The south limit of the group B rocks is relatively well-defined, and is observed as a steep fault in several places along the trace of the Airstrip fault. The northwest and west limit is less definite.

The Airstrip Fault

The Airstrip fault is one of the most continuous structures in the area. It separates distinctly different rock types along most of its course. From sector B-6 to F-5 its location is well-defined, and it is exposed as a zone of shearing and brecciation at several locations in this distance. Probably the best exposures are in the upper part of the West Fork of Rainy Creek. The fault strikes about N85W and dips steeply to the south. It may be offset slightly by a northwest-trending fault along the West Fork of Rainy Creek. East of sector F-5, the location of the fault is somewhat problematical. A fault separating limestone and other rocks from "serpentinite" was observed in sector F-8 and G-8, but this fault appears to have a more northeasterly strike. On the east side of Rainy Creek, the south side of the dunite body is relatively straight and lines up with the Airstrip fault. There are no exposures of the contact between serpentinite and dunite in this zone, so a fault contact seems possible. However, mapping by James Stout does not disclose any indication of the fault farther east. The nature of displacement on the Airstrip fault is not known. It could be either vertical or strike slip, but the apparent movement is up on the south. As noted in the discussion of the Broxson Gulch thrust, there is photogeologic evidence that the Airstrip fault offsets the thrust.

Rocks between the Airstrip fault and the Pioneer fault

The central part of this zone is composed of a large mass of amphibole "serpentinite" containing numerous slivers of sediments, and intruded by gabbro. Most sediments in sectors H-5 and I-5 seem to dip gently northward. The sediments in sector F-4 dip more steeply, generally to the north. Gabbro dikes trend N60W in the western part of the serpentinite and N25W in the eastern part in sector I-5. A dike of gabbro intrudes the zone of sedimentary inclusions in sectors H-5, and I-4. Gabbro plugs intrude the "serpentinite" in F-5, G-5, and G-4. Copper mineralization is found in the vicinity of all three of these plugs.

Group A rocks in C-5 and vicinity strike about east-west, and contacts between units indicate a north dip. However, attitudes within these rocks are erratic. A fault with a northwesterly trend defines the north limit of group A. This is presumed to be a normal fault dipping steeply north. Its extension to the east is unclear, and it may be cut off by a northeast fault. The south contact of group A appears to be a north-dipping thrust, as previously discussed, although it is possible that it is only a sheared zone and the andesitic rocks to the south are an unsheare part of the same unit.

A northeast fault along Specimen Creek is inferred to explain the offsets of units south of the thrust. A photogeologic lineament suggests it may cross the fault on the northwest side of group A. Irregular intrusive "serpentinite" containing blocks of sediments is present in sectors C-4, D-4, and E-4. This in turn has been intruded by dunite, basic gabbro and gabbro as a large elongate body and smaller dikes and lenses. Tertiary sediments unconformably overlie these rocks in lower Broxson Gulch.

Pioneer fault

A major fault of east-west trend is inferred to separate the Permian sediments from rocks to the north. This fault is named for Pioneer Lake, which lies along its trace. The bend in the East Fork of Broxson Gulch in sector B-3 lines up with this fault, and drainage alignments suggest its location as far eastward as sector K-4. The simplest interpretation of movement is normal with the north side up, but strike slip movement is possible.

Rocks south of the Pioneer Fault

In general, the Permian(?) rocks have moderate dips to the southwest, but locally there are numerous minor flexures. A number of small faults cut across the bedding, but because of limited exposures the picture is incomplete.

In sector L-3, the dips suggest the presence of a small anticline in the bedded rocks. The larger exposures of gabbro are sills, but dikes of various orientations are also present.

The Triassic(?) flows seem to lie unconformably on the Permian, although local faulting along the contact is not unlikely. The flows dip southward at 20-35 degrees, and apparently there was some folding and erosion of the Permian rocks before the Triassic flows were extruded.

Summary of Structure

The gross effect of structural deformation in the area has been to expose older rocks toward the north. The Triassic(?) and Permian(?) rocks south of the Pioneer fault have essentially a monoclinal dip to the south. The upper Paleozoic volcanics and sediments between the Pioneer and Broxson Gulch faults have been complexly faulted and folded. The most deep-seated rocks, the schist and gneiss, are thrust up over the younger rocks at the north.

Undoubtedly some deformation accompanied the emplacement of the ultramafic bodies, judging from the slivers of sediment in the "serpentinite". Some faults must have existed prior to the intrusion of the ultramafics. For instance, a peridotite dike intrudes the Airstrip fault in sector F-5 and a gabbro dike occupies the northwest-trending fault in C-5 and D-5. This suggests that thrusting of group A and initiation of movement on the Airstrip fault preceded intrusion of the ultramafic and mafic rocks.

The Broxson Gulch thrust and the smaller thrust in C-7 cut the ultramafic rocks. If the fault along the East Fork of Broxson Gulch is a tear fault, the movement on the small thrust was southwestward. This is consistent with structures found by Stout in the northeast part of the map area. The Broxson Gulch thrust may be late Tertiary if the lack of schist and gneiss in the Tertiary sediments is any indication. The slight changes in strike of the Denali fault in the region (figure 1) are such that left lateral movement could cause the observed thrusting to the southwest.

If the Airstrip fault cuts the Broxson Gulch thrust, as seems indicated by photogeologic work, then the last movement on this fault has been relatively recent. Upward movement on the north side of the Airstrip fault and the Pioneer fault may be responsible for much of the most recent uplift of the Alaska Range in this area.

## ECONOMIC GEOLOGY

Metals of possible economic interest in the area include copper, nickel, gold, lead and zinc. Occurrences of asbestos are also present. In addition, there are numerous pyritized zones that could be indicative of metallic mineralization.

In the following section the known mineral occurrences are discussed in turn. Locality numbers preceding each of the occurrences refer to figures 2 and 4.

### Locality 1 - Rainbow Mountain (Emerick) nickel-copper prospect

The Rainbow Mountain prospect is about 1 mile east of the Richardson Highway at Mile 213½ (see figure 4). A dirt road at this point leads from the highway into the prospect area. The mineralization in this area was discovered and staked in the early 1950's by Rollie Emerick of Delta Junction. About 40 claims called Red Rock Mining Company 1 to 30 are now held in the area by Emerick and associates. Trenching, mapping, and sampling were done at the prospect in 1962 by Newmont Mining Company.

Figure 4 shows the geology of the prospect area, based on mapping by Hanson (1964) and the writer. Rock types differ somewhat from those in the Rainy Creek area, so will be described here. A dark gray phyllite occurring along the Canwell Glacier is apparently the oldest metasedimentary rock. It is similar to the slate of group A previously discussed in the Broxson Gulch area, but is distinctly coarser grained. A few limy and quartz-rich beds occur within the phyllite. A dioritic gneiss is also thought to be among the oldest rocks in the area. It varies considerably in texture and appearance from unfoliated medium-grained diorite through foliated diorite to fine-grained banded material which in thin section shows some development of porphyroblasts. In some exposures the original rock seems to have been a layered volcanic or sediment.

The age relations of the rocks south of the ultramafic intrusive to those discussed above is not certain. Hanson (1964) included these greywackes, siliceous and intermediate tuffs and limy sediments with the phyllites in his pre-Mississippian group, and discusses them mainly under the heading of greenschists. The phyllite and diorite show district foliation in most exposures, but the greywackes and tuffs exhibit only local foliation and may be considerably younger. They have been distinguished as a separate unit on the map. Crackling and dark coatings on fractures are typical of the greywackes and tuffs, and they are difficult to identify in the field.

In the east central part of figure 4, andesitic volcanics and greywackes of the Pennsylvanian Rainbow Mountain sequence are exposed. They are locally intruded by porphyritic andesite.

A large body of quartz diorite occurs northeast of the Rainbow Mountain exposures. According to Hanson (1964) this intrusive is pre-Mississippian, and is faulted against the Pennsylvanian, but the evidence for pre-Mississippian age does not seem very strong. The quartz diorite is light-colored and characterized by clots of mafic minerals up to a centimeter or more in diameter.

Based on relationships of the ultramafic rocks to upper Paleozoic rocks in the Rainy Creek area, the ultramafic rock at the Rainbow Mountain prospect is considered to be Mesozoic. Hanson (1964, p. 76) assigns a pre-Mississippian age to the ultramafics, apparently because they occur only in the pre-Mississippian rocks, but this characteristic appears to be only an accident of erosion. The ultramafic rocks are highly serpentinized in most exposures, but apparently were originally peridotites composed of olivine, clinopyrozene, some orthopyroxene, and minor plagioclase (specimens 739 and 743, table 2, and Hanson, p. 18). At least three bodies are present in the area of figure 4. The largest body, which is covered in its central part, is about 1,800 feet wide at its east end where the copper-nickel showings are located, and narrows to the west-northwest. The other two bodies are much smaller and no elongation is evident.

Coarse hornblende-rich gabbro was observed at several locations in the southern part of the map area. The original hornblende and plagioclase in these rocks are partly altered or metamorphosed to actinolite, albite, and other minerals. It is not certain that these rocks are associated with the ultramafics, but this seems the most reasonable correlation.

Dikes of fine-grained diabase constitute the youngest consolidated rock in the vicinity of the prospect. They cut all the other rocks, including the ultramafics. Some alteration of the original pyroxene and plagioclase to actinolite, albite, epidote, chlorite, and other minerals is evident in most specimens.

The structure of the area near the Rainbow Mountain nickel-copper prospect appears to be complex, as might be expected from the location within a mile of the Denali fault. The most important structure is a northeast-trending fault which passes just east of the ultramafic intrusive. This fault is exposed near the southeast corner of the ultramafic intrusive as a zone of sheared rock with abundant white coatings on fractures. The fault extends southwest at least as far as the Delta

River although it may be offset slightly by cross-faults. It separates rocks of the pre-Mississippian serie from the Pennsylvanian rocks, and probably has moved many hundreds, and possibly thousands of feet up on the northwest side. The large movement on this fault is probably responsible for the fact that the ultramafic does not intrude the Rainbow Mountain sequence. The strike of this fault is similar to tear faults associated with the thrusts farther west, and some strike-slip movement may have occurred.

A number of smaller faults must be present in the pre-Mississippian rocks, but their exact location and relationships are not clear. A large northwest-trending fault separating dacite and rhyolite from dioritic gneiss is necessary just east of the largest ultramafic outcrop, but it is not known whether this fault cuts the fault mentioned above, or is cut by it. Another fault is inferred between the phyllite and the dioritic gneiss. It is possible that this fault is a thrust fault, either an extension of the Broxson Gulch thrust or one parallel to it. Shearing and small faults in the phyllite just north of the ultramafic outcrop dip 55 degrees to the northeast, and fit this interpretation. Shearing of approximately this trend also occurs in the ultramafic body. A fault trending approximately north-south probably separates the dioritic gneiss from the western outcrop of the large ultramafic body.

The greywackes and tuffs just south of the ultramafic strike northwest, but dip southwest in the more westerly exposures and northeast in the more easterly exposures. The same unit along the highway has northerly strikes, but variable dips.

Two types of nickel-copper occurrences exist in the area. Massive sulfide veins or lenses have been exposed in sheared peridotite in the most easterly exposures of the large peridotite body. Nine sulfide lenses are known in this area (Saunders, 1961). The lenses generally strike approximately parallel to the northwest trend of the peridotite intrusive. Extreme shearing and brecciation are evident in the country rock around most of the lenses, and locally the rock has the appearance of a fault gouge. Possibly, this results from thrusting in the ultramafic, as noted above. The trenching and pitting done to date indicate that the sulfide lenses are short and discontinuous, and do not persist more than 10-20 feet along the strike. The maximum width observed is about 10 feet. Table 3 shows the grade of the lenses based on sampling by Saunders (1961). Pyrrhotite, pentlandite, chalcopyrite, and pyrite are the major constituents. A polished section from the most northerly lens shows granular pyrrhotite and pentlandite in grains about a millimeter in size. The pyrrhotite shows much twinning, and some has a distinctly lamellar habit.

The second type of occurrence consists of chalcopyrite, pyrrhotite, and pentlandite disseminated in olivine gabbro (sample 704, table 2). The gabbro appears to be a dike at least 8 feet wide near the north edge of the peridotite body. The trend of the dike is not obvious; the one exposed contact appears to be a fault, but the amount of movement may be small. Based on one assay (sample 7, table 3), the grade of the disseminated mineralization amounts to over 2% combined nickel and copper. Much of the sulfide occurs as clumps about 1 mm in diameter in size, with numerous concave surfaces against the subhedral mafics, suggesting that the sulfides are later than the silicate minerals. Some sulfide also occurs as fine intergrowths or replacements of the mafic minerals.

Most of the sulfide occurrences exhibit some oxidation. Limonite and malachite are the most common oxidation products, but a bright green material (garnierite?) that contains nickel as a major constituent is present locally. This material gives an X-ray pattern of serpentine or garnierite, plus lines at 11.8A, 5.9A, and 4.9A, which may come from a mixed-layer clay mineral.

Nickel contents of 0.2 to 0.3% are reported for peridotite in the area of the prospect. It is believed that this nickel is present mainly as a minor constituent of the mafic silicates, and therefore could not be concentrated by any conventional benefication procedure. Nickel contents of this magnitude are common in ultramafic rocks.

Minor amounts of pyrrhotite, pyrite, and chalcopyrite are exposed in a pit on the small ultramafic body 1,500 feet southwest of the large one.

Gold, copper, and lead mineralization, plus considerable pyritization, occur in the greywackes of the Rainbow Mountain sequence near the nickel-copper prospect. The road to the main prospect passes through a narrow canyon about three-quarters of a mile south of the prospect. Rock for riprap has been taken from this canyon by the Highway Department. Copper staining and fine chalcopyrite veins cut the greywacke at several places in this canyon. A sample of pyritized conglomerate from the canyon contained 0.12 oz/T gold (Hanson, 1964, p. 71). Small amounts of lead were detected in the pyritized and iron-stained knob near the north end of the canyon, and a flat-lying quartz vein on the side of the valley opposite the iron-stained knob assayed 0.46 oz/T gold. A lens of galena is reported to have been found in an outcrop of pyritized greywacke on the east side of the valley opposite the ultramafic body. A sample of pyritized volcanic or greywacke from the south side of the ultramafic body contained 0.02 oz/T gold, 0.09 oz/T silver, and less than 0.1% copper and nickel.

None of the presently-known mineralization at the Rainbow Mountain prospect appears to be economic, mainly because of small tonnage. However, the variety and extent of sulfides in the area, combined with complex structure and gravel cover in much of the area, suggest that more prospectir is worthwhile. Geophysical methods, such as self-potential or some other electrical method, seem the most effective means of further prospecting. More detailed geological mapping would be desirable to direct and interpret the geophysical work.

Locality 2 - Glacier Lake claims (see figure 4)

About 7,000 feet east of the ultramafic intrusive at the Rainbow Mountain prospect and 1,200 feet south of the Canwell glacier a copper-nickel show was discovered by R.B. Forbes of the University of Alaska in 1962. The Glacier Lake claims of Emerick and associates cover this prospect. Geological relationships at the prospect are shown on figures 4 and 5. The serpentinized peridotite or mafic gabbro (sample 763, table 2) apparently occurs as an irregular intrusive into the quartz diorite. A fault may separate these two rock types from the dioritic gneiss.

Mineralization at point A (figure 5) had been exposed by the U.S. Bureau of Mines at the time the writer visited the prospect. Pyrrhotite, chalcopyrite, and pentlandite occur as a lens of massive sulfide on the contact between quartz diorite and peridotite, and as sulfides replacing the quartz diorite. In addition, small amounts of sulfides are disseminatec in the peridotite away from the contact. The sulfides show considerable oxidation to orange-brown limonite, along with some copper staining. The most strongly mineralized zone is about a foot wide, with lesser amounts for another foot or so. A sample of the massive sulfide material assayed 8.1% nickel. Chips of the disseminated mineralization collected across the contact for about 3 feet assayed 2.10% copper, 0.05% nickel, a trace of gold, and 0.35 oz/T silver. Hanson reports an assay of 6.6% nickel, 1.1% copper, and 0.04 ounces per ton of gold from this location. The mineralization is not evident where the same contact is exposed farther up the hill.

Locality 3 - Bee Mining Company claims (sectors L-7 and M-7, fig. 2)

These claims are on the west side of the Delta River a little over one mile west of the junction of the Delta River and Pheland Creek. They are owned by Rollie Emerick and Associates of Delta Junction. A zone of ultramafic and gabbroic rocks crops out along the north side of a valley cut by a small tributary of the Delta River. The zone appears to trend about east-west. North of the ultramafic rocks, the exposures are mainly dark siliceous sediments and light-colored tuffs. Limestone is present in the next valley to the north. The sediments and tuffs are tenatively included in group C, but it is possible that they are part of Hanson's pre-Mississippian sequence which is exposed directly across the river. South of the ultramafic zone, andesitic and dacitic volcanics predominate and are definitely included with group C.

The difference in lithology north and south of the ultramafic rocks suggests that they were intruded along an east-west fault zone. The most westerly exposures of the ultramafics consist of orange-brown weathering dunite showing relatively little serpentinization except near the contacts. Farther west along the canyon, the outcrops are peridotite or mafic-rich gabbro containing about 10% plagioclase altered to saussurite. Both orthopyroxene and clinopyroxene are present in this rock, in addition to olivine (table 2, sample 437). For convenience, this rock will be called mafic gabbro. A dike of serpentinized peridotite extends southeastward from the mafic gabbro. The ultramafic rocks appear to be cut off by a fault in this vicinity, but poor exposures of mafic gabbro are present about a thousand feet further west.

Near the stream at the east end of the ultramafic zone, shattered diorite or quartz diorite is in contact with the dunite. The contact of the dunite with the diorite is sheared and serpentinized, and the relative ages are not clear. This diorite could be either a phase of the dioritic gneiss of the Rainbow Mountain prospect area, or a dioritic differentiate of the ultramafic-gabbro sequence.

Mineralization at the prospect is similar to that at the Rainbow Mountain prospect. One lens of sulfide about 18 inches wide occurs in the mafic gabbro at locality 3. A sample collected by Saunders (1962, sample 31) contained 2.01% nickel and 0.61% copper. A polished section of the massive sulfide shows abundant pyrrhotite, some pentlandite and chalcopyrite, and traces of galena.

In addition to the massive sulfide lens, sulfides are disseminated through some of the mafic gabbro near the lens. A chip sample collected by the writer across 25 feet of the best disseminated mineralization contained 0.20% nickel, 0.17% copper, a trace of gold, and 0.2 ounces per ton of silver. It seems likely that most of the nickel occurs in the silicates. A sample collected by Saunders (1962, sample 29) from approximately the same location contained 0.46% nickel and 0.32% copper across 50 feet.

Other samples collected by Saunders from various locations in the ultramafic rocks contained from 0.17 to 0.30% nickel and 0.11 to 0.32% copper. One sample of mafic gabbro from the poor exposures at the west end of the ultramafic zone contained 0.57% nickel and 0.32% copper. A sample of sulfides collected from a 1-foot vein several hundred feet southwest of locality 3 contained 0.1% copper, 0.20 oz/T Au, and 0.32 oz/T Ag.

Locality 4 - (sector G-5)

Several sulfide lenses were found on the south side of a gully at an elevation of about 4,800 feet on the west side of the North Fork of Rainy Creek. The largest lens is about 10 feet long and up to 3 feet wide. The lenses occur along a zone trending N85E in altered amphibole "serpentinite" A polished section shows that pyrrhotite partly altered to marcasite is the main constituent along with small amounts of pyrite and chalcopyrite. An assay indicates less than 0.1% copper and nickel, 0.02 oz/T gold and 0.4 oz/T silver.

The country rock is epidotized and appears silicified, but judging from similar rocks examined in thin section, it is probably a hornfels containing pyroxene. A light-colored gabbro plug (table 2, sample 298) is exposed a few hundred feet south of the mineral occurrence, and a major fault passes a few hundred feet north. Talus covers the bedrock downhill from the sulfides.

Locality 5 - Rainbow, Eastern Star and Pioneer claims (sector F-5)

This group of claims is centered on copper occurrences exposed on the end of a small ridge about 1 mile southwest of Locality 4. The claims have been staked and prospected by Alfred Ghezzi of Fairbanks.

Figure 6 shows the geology of the mineralized area. The amphibole "serpentinite" has been intruded by several varieties of gabbro. A dark fine-grained gabbro is not mineralized, but lighter-colored gabbro occurring as small dikes or pods and as a larger plug contains disseminated chalcopyrite. In the mineralized rock (table 2, sample 353) plagioclase has been albitized and saussuritized, and mafic minerals altered to actinolite. The chalcopyrite occurs as grains less than 1 mm in diameter disseminated through the rock. A shear zone mineralized with chalcopyrite has been exposed in a pit on the west side of the area. An assay of 1.13% copper across 5 feet is reported for this zone. The area of disseminated mineralization in the northern part of the area is poorly exposed, but all the small pits in the area show the same type of disseminated mineralization. A composite of pieces of float and chips from the pits collected at random from this area assayed 1.0% copper, no nickel, no lead, no zinc, 0.01 oz/T gold, and 0.22 oz/T silver. The mineralized rock goes under talus and glacial deposits to the north. The next exposure, several hundred feet to the north, is fine-grained dark unmineralized gabbro. Rock to the south of of the prospect is amphibole "serpentinite" cut by a northwest-trending gabbro dike.

Locality 6 - (sector F-5)

Chalcopyrite and some bornite occurs in a fine grained tactite or hornfels composed mainly of diopside. The showing is on a ridge northwest of locality 5. The country rock is black meta-serpentinite composed mainly of pale brown hornblende and diopside. The light yellow diopside-bearing tactite is about 3 feet thick and appears to strike N55E. Copper minerals are found only at a few spots in the tactite. The occurrence was staked in 1964 by Mark Rogers for Moneta-Porcupine.

Locality 7 - (sector F-4)

This showing is in the valley of the West Fork of Rainy Creek south of locality 5. Copper occurs in a tactite of epidote, pyroxene and quartz which has replaced a zone several feet wide in a cherty limestone unit. The limestone strikes N75E and dips 68° SE. Some pitting and trenching was evidently done at one time on the showing, but exposures at present are poor. Iron stained float is present adjacent to the tactite in a zone 10-15 feet wide. A sample of the tactite contained 0.42% copper, 0.01 oz/T gold and 0.40 oz/T silver.

About 150 feet downstream, pieces of pyrite-magnetite mineralization with minor chalcopyrite have been excavated from a small sloughed pit. There are also pieces of garnet-bearing tactite containing some pyrite and chalcopyrite.

Locality 8 - (sector F-4)

The mineralized rock of this locality protrudes from an extensive talus slope at an elevation of about 5200 feet near the top of a small valley. A lens of sulfides 2-3 feet thick and exposed for 10 feet of strike length lies just above a fault trending N85W dipping 40° SW. The sulfides consist of lamellar marcasite, chalcopyrite, and minor pyrite as determined in a polished section. The marcasite is probably an alteration product of pyrrhotite. Rock from just above the lens consists mainly of brown garnet, olivine(?) and pyroxene. Rock for about 20 feet farther from the sulfide is altered to a white rock containing plagioclase(?) and a zeolite. The country rock is amphibole "serpentenite". An assay of the sulfide lens shows 0.37% copper, 0.50% nickel, 0.03 oz/T of gold and 0.33 oz/T of silver.

Locality 9 - (sector G-3)

Minor copper staining occurs in tactite composed of amphibole, epidote and calcite with local pods of pyrite. The tactite is adjacent to a gabbro dike.

Locality 10 - (sector E-4)

A bleached and mineralized zone outcrops at the top of a talus slope at about 5,200 feet elevation. The lowest outcrops appear to have been limestone, now altered to brown garnet and greenish pyroxene. Above the limestone is a few feet of highly pyritized rock, followed by a four foot relatively unaltered limestone bed. A polished section of float from just below the outcrops contains pyrrhotite, pyrite, and minor chalcopyrite and marcasite in a gangue of calc-silicate minerals. The limestone appears to occur as an inclusion in the amphibole "serpentinite".

Locality 11 - (sector C-4)

Float showing copper staining and strong iron staining was found at this locality at about elevation 4,300. The float is amphibole "serpentinite" but recrystallized limestone is exposed a few feet up the hill, and light-colored hornfelsic amphibole "serpentinite" above the limestone. An old claim monument was found at this location.

Locality 12 - (sector C-4)

Copper-stained altered limestone, and chalcopyrite in a five-foot iron-stained zone in serpentinite were observed here. The iron-stained zone trends N60W. The limestone appears to be a block or inclusion in the "serpentinite".

Locality 13 - (sector C-4)

This showing was staked as the Green Wonder claim and minor trenching was done by Moneta-Porcupine during the summer of 1964. The country rock is dark grey to black amphibole "serpentinite" but in the vicinity of the prospect this is altered to a white rock composed of garnet, quartz, and diopside. The mineralized rock is bright green and less than a foot wide. It consists of sphalerite (identified by X-ray) and uvarovite(?), a chrome garnet, plus minor amounts of pyrite. X-ray analysis of the garnet-sphalerite rock shows: 10% zinc, 4% chrome, 2% nickel, and less than 0.1% lead and arsenic. No nickel minerals were observed in the sample.

Locality 14 - (sector D-5)

Minor amounts of copper staining occur in highly fractured dark andesites in at least two places on the west bank of Specimen Creek.

Locality 15 - (sector E-5)

Chalcopyrite and copper-staining occur on the south side of a ridge composed of amphibole "serpentinite". The most obvious shows are along a zone a few feet wide trending about N35E. Irregular pods of dark and light colored rock are present along the zone, and some rock is recrystallized. A thin section of dark recrystallized rock discloses major olivine and amphibole, and small amounts of epidote, pyrite, and chalcopyrite. Some of the amphibole is pale green actinolite, but a large proportion is a pleochroic blue amphibole that must be rich in the glaucophane molecule. The glaucophane probably indicates some addition of sodium. Quartz is present in the lighter-colored rock.

A chip sample across four feet contained 0.75% copper, trace nickel, 0.09 oz/T gold, 1.18 oz/T silver and less than 0.1% lead and zinc.

Locality 16 - (sector E-6)

The north end of a limestone unit in a gully at 5,000 feet elevation is altered to tactite containing chalcopyrite, magnetite, and pyrite. A thin section of dark green mineralized tactite contains major amounts of clinopyroxene, garnet, and magnetite, and small amounts of glaucophane, biotite, calcite, pyrite, and chalcopyrite. Pyrrhotite is present in other specimens of the dark green tactite. The mineralized material replaces several beds in thicknesses of a foot or so, and is exposed along strike for only a few feet.

Locality 17 - (sector G-7)

Chalcopyrite and copper staining occur in a sheared zone about six inches wide in dacite porphyry and dacite porphyry breccia. The zone strikes N70E, and is exposed for about 10 feet. The dacite porphyry and adjacent rocks are moderately pyritized.

Locality 18 - (sector D-7)

Several copper showings were found along the contact between peridotite and amphibole "serpentinite" in this vicinity. Some gabbro is present with the peridotite. The showings are at an elevation of about 4,800 feet. Some peridotite is serpentinized, but most, especially away from the contact, is relatively unaltered dunite. The best area of exposed mineralization contains six lenses of massive sulfides in a radius of about 100 feet. The largest lens is about three feet wide and six feet long. A polished section of the sulfide shows mainly marcasite with minor chalcopyrite and pyrrhotite, but other pieces from the lenses contain larger amounts of chalcopyrite, mainly along fractures in the iron sulfides. Some parts of the lenses are moderately magnetic and may contain magnetite.

Several other small copper shows occur over a distance of several hundred feet along the peridotite contact. This vicinity has more widespread mineralization than most of the localities discussed above, and seems deserving of more thorough prospecting.

Locality 19 - (sector C-7)

Massive sulfide boulders were found at and below this locality. A zone 20 feet wide on the hillside contained numerous boulders of pyrite, chalcopyrite, and pyrrhotite. Several pieces of this mineralized rock assayed 0.9% copper, less than 0.1% nickel and trace zinc. About 50 feet south there is a pod of pyrrhotite a few inches wide and several feet long. Amphibole "serpentinite" in the area is considerably pyritized and sheared. A thrust fault is inferred to pass beneath the locality. Further prospecting in this vicinity seems worthwhile.

Locality 20 - (sector G-7)

An outcrop of iron-stained, silicified and hornfelsic sandstone at this location contained disseminated pyrrhotite. Chips from the outcrop assayed 0.2% nickel, trace copper, trace gold, and 0.18 oz/T silver. The presence of nickel, plus the existence of a stream sediment geochemical anomaly below the area, suggests that further prospecting may be worthwhile.

## Other copper occurrences

Minor amounts of copper staining were seen in the schist in sectors B-8 and F-8, in both cases along with some pyrite. A few spots of malachite were observed in the pyritized group A rocks in sector C-5.

## Pyritization

Pyritization is widespread in the area, as is shown on figure 2. The most intense pyritization forms an east-west trending zone in the diorite and volcanics of groups A in sectors C-5 and D-5. The pyritized rock forms a prominent stained zone, and there has been considerable bleaching at the surface. This alteration, which apparently consists of weak argillization, appears to result entirely from weathering and the pyrite coexists with chlorite, epidote, and albite in the unweathered rock.

The slate unit just to the north of this pyrite-bearing zone shows sporadic iron-staining and pyritization. A sample of the pyritized slate contained 0.10 oz/T gold, 0.15 oz/T silver, 0.11% nickel, and no copper, lead, or zinc. Apparently the nickel and gold have been introduced, although some pyrite could be syngenetic.

The largest pyritized zone extends along the Airstrip fault, affecting the silicic volcanics (Bv) and some adjacent amphibole "serpentinite" and volcanics. The amphibole "serpentinite" shows no obvious difference in alteration where it is pyritized. The other rocks appear considerably hornfelsed.

Pyritized amphibole "serpentinite" also occurs in sectors D-5 and E-4 to F-4. The pyritic zone in E-4 and F-5 may contain considerable hornfelsic sediment.

Origin of sulfide mineralization

At least six types of copper and nickel sulfide mineralization can be distinquished in the Rainy Creek and Rainbow Mountain areas. These are as follows:

1. Copper, iron, and nickel sulfides disseminated in gabbro or feldspar-bearing peridotite.

2. Lenses and pods of iron, copper, and nickel sulfide in or on the contact of peridotite.

3. Lenses, pods, and veins of copper and iron sulfides, mainly in "serpentinite".

4. Copper and iron sulfides in tactites developed from limestone.

5. Disseminated nickeliferous pyrrhotite in hornfelsic sediments.

6. Thin chalcopyrite and chalcopyrite-galena veins in greywacke, andesite and dacite.

The first type of mineralization, consisting of copper, iron, and nickel sulfides in gabbro, is found in localities 1 (Rainbow Mountain prospect), 2 (Glacier Lake claims), 3 (Bee Mining claims) and 5 (Rainbow claims). At the first three localities, the host rock is a peridotite or mafic-rich gabbro containing about 10% plagioclase. The sulfides consist of pyrrhotite, pentlandite and chalcopyrite disseminated through the rock. Textures suggest that the sulfides crystallized from an interstitial liquid late in the solidification period of the rock. It seems likely that the mafic gabbro is a differentiation product of the peridotite. Presumably the nickel, copper, and iron were concentrated in this late fraction, along with some sulfur, and separated from the gabbro as immiscible liquid droplet during crystallization of the rocks.

The disseminated chalcopyrite at locality 5 is associated with a relatively light-colored gabbro, and apparently no nickel remained in the parent magma. An origin by liquid immiscibility seems less certain here but the even dissemination of chalcopyrite through only one phase of the gabbro suggests that the copper was a constitutent of the light-colored gabbro magma and migrated very little after emplacement of the gabbro. It is not clear why mafic gabbro at localities 1, 2, and 3 contains disseminate copper and nickel sulfides, but gabbro farther west in the Rainy Creek area does not. Possibly the peridotite at Rainbow Mountain had a different chemical composition from peridotite elsewhere, or tectonic movement there occurred at just the right times to separate the sulfide-rich differentiate from the peridotite. More study of this question is needed.

The second type of mineralization, consisting of lenses and pods of iron, copper, and nickel sulfides is present at localities 1, 2, 3, and possibly 18 and 19. The sulfides occur in peridotite or at the contact of peridotite that is presumed to be the source. Alteration associated wit the lenses is not obvious, although there may be some serpentinization, and at locality 2, some development of pyroxene. These sulfides seem reasonably interpreted as the result of immiscible sulfide separation from the peridotite, followed by migration of the liquids into relatively open fractures and shears, perhaps under the influence of tectonic forces. Sulfide minerals present are pyrrhotite, pentlandite, and chalcopyrite.

The third type of mineralization consists of veins, lenses, and pods of copper and iron sulfides occuring mainly in amphibole "serpentinite". This type of mineralization was found at localities 4, 6, 8, 9, 10, 11, 12, and 15. The host rock is either amphibole "serpentinite" or inclusions in the "serpentinite". Alteration to light-colored hornfels or tactite compos of diopside, garnet, epidote, and quartz is characteristic. Pyrrhotite (Usually partly altered to marcasite) and minor chalcopyrite, containing only traces of nickel, are the sulfide constituents.

The alteration, and the addition of silica, soda, and probably other elements, suggest that a relatively larger amount of water may have been present in the ore fluid as compared to type 2 mineralization. Most of the occurrences are near gabbro or peridotite bodies, but not in them. The sulfides may have originated by normal hydrothermal processes, with the source for both the metals and the sulfur in the peridotite and gabbro. However, the amphibole "serpentinite" host rock is relatively high in coppe and it seems possible that fluids-emanating from the gabbro and peridotite (or perhaps from the "serpentinite" itself) leached some or all the copper from the amphibole "serpentinite" and redeposited it at greater distances from the intrusives.

The limestone replacement occurrences (localities 7 and 16) appear similar in origin to the veins described above, except that the ore has replaced a highly reactive limestone rather than a "serpentinite". The loss of calcium, carbon dioxide, and probably other constituents in the process of replacement suggests the existence of an aqueous ore fluid to carry away the replaced constituents.

Disseminated nickeliferous pyrrhotite in altered sediments occurs only at locality 20. This mineralization may be a disseminated version of the second type, or a halo around higher-grade sulfide mineralization.

The chromium-nickel-zinc mineralization at locality 13 appears to be unique.

Hanson (1964) indicates that quartz-chalcopyrite-galena veins at Rainbow Mountain cut dacite dikes and fill northwest fractures developed during a Mesozoic(?) orogeny. He suggests that the veins may be related to the hornblende granodiorite in the northeast part of that area. There is no such granodiorite present in the Rainy Creek area near locality 17. Possibly these copper occurrences originated from minor hydrothermal activity associated with hypabyssal andesite and dacite intrusives of Pennsylvanian age.

The amphibole "serpentinite" in pyritized areas shows no mineralogical differences from other amphibole "serpentinite" except for the presence of fine disseminated pyrite. Very little structural control for the pyritization is evident. Minor amounts of pyrite are widespread in the amphibole "serpentinite". For these reasons, the pyritization in these rocks is believed to have occurred at the same time as the development of the actinoli and is probably a deuteric product. Pyritization of sediments and volcanics probably resulted largely from fluids given off by the amphibole "serpentinite", although some may be related to the later peridotite and gabbro. In some areas, in particular the pyritized greywackes east of the Rainbow Mountain prospect, the pyritization and minor copper-lead mineralization may be near-surface manifestations of the alteration and nickel-copper mineralization associated with peridotites at depth.

## Gold Placers

Gold placers on Rainy Creek were worked sporadically from 1900 to at least 1930. In general, the placer mining was apparently not very profitable. It is reported that at least some of the gold occurred in a sticky clay which would not break down to release the gold, and that large boulders also caused difficulties. Evidence of placer work, consisting of ditches, cuts, piles of boulders, and remnants of camps and cabins, were noted for about a mile and a half downstream from the junction of the North and West Forks of Rainy Creek. A collapsed cabin, a trail, and a cut through the timber were seen near the mouth of Rainy Creek.

The reported occurrence of gold in clay suggests that it may have been concentrated in the orange-brown older glacial drift, perhaps with some later re-concentration in the present drainage. Bedrock is not exposed along the present stream, and may be several tens of feet deep. The origin of the gold is probably in the copper-iron sulfide deposits previously discussed, although some gold may be present in the pyritized rocks. No placer workings were noted on the North Fork, but some were seen near locality 7 on the West Fork, so it seems likely that the source of the gold is mainly in the latter drainage.

Several placer claims and remnants of sluices were found on the upper part of Specimen Creek. It seems likely that the gold is derived from pyritized group A rocks, although a source in the ultrabasic rocks to the northwest or in the high gravels to the north is also possible.

The most recent placer mining has been at the mouth of the creek just north of the airstrip on the East Fork of Broxson Gulch (sector C-6). The operator is reported to have been Archie Broxson. A wanigan, a shed, a small caterpiller tractor, and numerous other pieces of machinery and equipment are scattered around the north end of the airstrip. Gravel in the mouth of the small creek has been dozed out and run through a screening plant and sluice. A ditch at least 2 miles in length along the East Fork, plus smaller ditches from streams south of the workings, supplied water. The type of machinery suggests that these workings were active about 25 years ago, although some more recent work may have been done. Bedrock is not exposed in the dozed area, but may be present at a shallow depth.

The restriction of operations to the one small drainage suggests that the source of the gold is probably in that drainage. Pans from within a foot or two of the surface in this area contained 4-7 colors per pan along with considerable magnetite, pink garnet, and epidote. The headwaters of the drainage, above 4500 feet, consist mostly of gravel deposited during an earlier glacial epoch. The gold may be coming from this gravel, but the ultimate source is probably the pyritized group A rocks. However, some admixture of material from the schist and gneiss seems necessary to explain the garnet.

## Chromite and Asbestos

Chromite is the main accessory mineral in the dunite and peridotite of the area, but no concentrations above the accessory mineral level were seen. Chromite is an important constituent of stream sediments in the area.

Veinlets of cross-fiber chrysotile asbestos were noted in the dunite, but in no location did the content appear to approach economic proportions. However, the dunite was not thoroughly examined for asbestos, and as the asbestos would probably be poorly exposed, further search of the area could prove worthwhile.

## Platinum

No platinum has ever been reported from Rainy Creek, but some may be present. Minor amounts of platinum are present with placer gold at Slate Creek about 35 miles east of Rainy Creek. Small bodies of orange-brown weathering peridotite are reported in that district by Martin W. Jasper, and are the probable source of the platinum. It seems possible that some platinum is present in the peridotites of Rainy Creek and has been concentrated with the gold, but perhaps no one has looked for it. Platinum has been recovered from a small placer operation at the head of a short creek in the extreme southwest portion of the area shown in figure 4.

## Mercury

In the California Coast Range, mercury commonly occurs with the bright orange silica-carbonate alteration of peridotite. No mercury was noted in the Rainy Creek area, but no special searches were made around the silica-carbonate rock, which was noted in dunite on the south side of sector H-6 and along the thrust in the east part of sector C-7. Thin red coatings in sector G-4 contained no mercury.

# STREAM SEDIMENT GEOCHEMISTRY

One hundred twenty-five stream sediment samples were collected in the area. The locations are shown on figure 2 and analyses in table 4. The samples (with one exception) consisted of silt and sand from beneath the water surface of streams. They were analyzed in the field for readily extractable heavy metals by the University of Alaska procedure, Method I for soils (Mukherjee and Mark Anthony, 1957). This method uses a water solution of sodium chloride to dissolve readily extractable metal, and dithizone dissolved in white gasoline as a means of estimation. Field analyses are recorded in milliliters of dithizone solution required to obtain the green color of unreacted dithizone. The amount of dithizone dissolved in the gasoline was checked for each batch of solution by tests with a standard zinc solution. A field result of three milliliters is approximately equivalent to one microgram of zinc, and larger amounts of lead and copper.

The samples also were brought back to the lab, sieved to minus 80 mesh, and analyzed by colorimetric methods for total copper, lead, zinc, molybdenum and nickel. All nickel analyses were done by Rocky Mountain Geochemical Laboratories, as were copper, lead, zinc, and molybdenum analyses of samples 4WP260-321 and 4AR356-471. Most of the remaining analyses are by the Division of Mines and Minerals laboratories. Numerous checks between labs indicate fair to good agreement between labs, except for zinc in a few samples.

The background for copper varies moderately depending on the rock type. Analyses of nine rock samples (table 4), data from the literature (Turekian and Wedepohl, 1961), and the observed values for stream sediments indicate that background is a few tens of parts per million for dunite, 40-80 ppm for schist and gneiss, 50-100 ppm for gabbro, 100-150 ppm in amphibole serpentinite, 50-150 ppm in greywacke and andesite of group C, and 40-60 ppm in the other sedimentary rocks. For simplification, a value of 200 ppm is taken as the threshold of copper anomalies in the area, although lower values might be appropriate locally. Values over 500 ppm are considered strongly anomalous.

There is no apparent large variation of zinc background with rock type. Values of 100-150 ppm are common for streams draining schist and gneiss, dunite, gabbro, serpentinite, andesite, greywacke, and most other rocks of the area. A value of 200 ppm is therefore selected as a threshold, with more than 500 ppm as strongly anomalous.

For lead, most samples contain 0 to 10 ppm, and only three samples contain more than 15 ppm. These three samples are considered as moderately anomalous.

Most molybdenum values are 0-4 ppm, and no anomalous values are recognized.

Variations in background for nickel are extreme. Based on analyses of rock samples, dunite contains 2500-2900 ppm nickel, serpentinite 1100-1200 ppm and gabbro 80-450, varying with amount of mafics. According to data in the literature (Turekian and Wedepohl, 1961), the nickel content of sedimentary rocks varies from a few ppm in limestones and pure quartzites to more than 100 ppm in some shales. Andesites probably contain 50-200 ppm, although no specific data are available. Because the variations are so large, no single value can be used for a threshold. The nickel anomalies on figure 1 have been selected by comparison with the values given above, and with values in nearby samples draining similar rock types. Because of the very high nickel content of dunite, none of the streams draining dunite or peridotite is shown as anomalous, although nickel deposits could be present in these drainages. In streams not draining dunite, peridotite or amphibole "serpentinite", values greater than a few hundred ppm are shown as moderately anomalous. Some of these "anomalies" may result from unmapped bodies of peridotite but no better criterion for anomalies is apparent.

## Discussion of Anomalies

Sector M-7 (samples 260,261,256, 257, 263 and 264). Two weak zinc anomalies and four possible nickel anomalies are present in small streams here. The nickel anomalies may be derived from an unmapped extension of the peridotite and mafic gabbro of locality 3; the origin of the zinc anomaly is unknown.

Sector M-6 (Sample 266). A possible nickel anomaly of unknown origin is found here.

Sector K-6, J-6, and J-7 (Samples 272, 455, 460, 462, 463, 464, 470, 471). Numerous anomalies for copper and zinc are present in this vicinity. A strong field anomaly was also obtained. The source is believed to be mineralization associated with an unmapped peridotite body in sector J-7 and K-7. Further prospecting and mapping is suggested for this area.

Sector G-6 (Samples 157 and 158). Sediments from these two moderatesized streams contain 374 and 220 ppm copper. The streams drain dunite and the stream sediments also contain large amounts of nickel, which is presumed to be derived from the dunite. Further stream sediment sampling, prospecting and mapping in these drainages is suggested.

Sector G-5 (Sample 356). This sample is from a small gully draining the disseminated copper mineralization at locality 5. The sample is strongly anomalous in copper (750 ppm). Pieces of copper-stained float were present in the stream. Note that sample 147 about 1/2 mile down the larger stream is not anomalous. This suggests that anomalies on the larger streams are caused by stronger sources of metal than locality 5.

Sector E-5 (Samples 212 and 214). Sample 212 contained 750 ppm zinc (strongly anomalous) and a weakly anomalous amount of lead. Sample 214 is weakly anomalous in zinc. Iron staining is abundant in the drainage represented by sample 212, but no zinc minerals were noted.

Sectors D-4 and D-5 ( Samples 210, 219, 220, 223, 237, and 238). Most of these samples are moderately anomalous in copper and three are weakly anomalous in zinc. Samples 210 and 220 may be anomalous in nickel. Several of these samples gave field anomalies. Sample 220 differs from the rest in being a sample of a white incrustation from next to a very small stream. The incrustation is noncalcareous and had a slightly bitter taste. It may be formed from material dissolved by oxidation of strongly pyritized diorite and diorite talus up the slope to the west. This sample contains 2500 ppm copper and 400 ppm nickel. The copper could be derived from trace amounts in the pyritized diorite, but this source is less reasonable for the nickel. Several faults intersect in the area of sample 219 and 220, and this seems a favorable location for mineralization. The source of copper and zinc in samples 210, 237, and 238 appears to be the pyritized diorite and volcanic to the south, but no specific source is evident. Weak anomalies in readily extractable heavy metals were obtained on sample 220 and 238.

Sectors C-6 and D-7 (Samples 182, 192, and 193). These three samples are possibly anomalous in nickel, sample 193 giving the strongest anomaly. The cause of the anomalies may be an unmapped body of ultramafic rock, talus or moraine of ultramafic rock, an unusually high nickel content in andesite of group C, or an ore body. Further mapping and sampling is needed to evaluate these anomalies.

Sector C-7 (Sample 289). The sample is weakly anomalous in copper (245 ppm). In addition, samples 284 and 288 downstream from 289 gave weak to moderate field anomalies, and low-grade nickel mineralization was detected at locality 20. This seems a favorable area for further prospecting.

Sector B-6 and C-7 (Samples 281 and 282). These samples are weakly anomalous in lead and zinc. The source of these anomalies is not known.

Sector C-8 and B-8 (Numerous samples). Many samples from the streams draining the glaciers at the head of the Middle Fork of Broxson Gulch gave moderate to strong field anomalies. In addition, sample 321 from the smaller glacial drainage about a mile west of the Middle Fork, and sample 324 from the largest glacier in Broxson Gulch gave field anomalies. The anomalous results were obtained from three separate batches of solution, bright pink colors were obtained, and checks on blanks and samples from other areas gave normal results, so there is little question that the measurements are valid. However, none of these samples are anomalous in total metal content, and the cause of the field anomalies is unknown. A percent or so of pyrite is present in some schist in the moraines, but a specimen of this pyritized schist contained only 75 ppm copper. Further work is needed to determine the cause of these field anomalies.

## Comments on Field Method

Of 33 samples considered anomalous in total metal, only 18 gave anomalies by the field method, assuming that 5 ml. or greater is anomalous. Among the samples not giving a field anomaly were sample 158 and 356, which contained 370 and 750 ppm copper, respectively. Seventeen samples gave field anomalies but not lab anomalies. Most of the latter samples were from streams draining the glacier in the Middle Fork of Broxson Gulch.

The field and lab results may differ for the following reasons:

1. The field test detects only metal that is loosely adsorbed to grain surfaces or that is present as minerals soluble in nearly neutral solution. If chemical breakdown of sulfides is proceding rapidly but the mineralized rock is not being physically weathered as fast as unmineralized parts of the drainage, the metal absorbed from solution onto stream sediment would give a field anomaly without contributing a lab anomaly. This is possible because using a 0.2 gram sample, a strong field anomaly of 20 ml represents the extraction of about 35 ppm zinc from the sample. Larger amounts of lead and copper would be needed. If the zinc background is 100-150 ppm, an increase of 35 ppm might not be recognized as an anomaly. The behavior of sample 270 is believed to be a good example of this. This sample is not anomalous in total metal (150 ppm zinc), but gave a reading of 13 ml by the field test. Sample 455 about 3/4 miles upstream was at the zinc threshold of 200 ppm. Samples further up the drainage are increasingly anomalous. The field anomaly can thus be recognized farther downstream than the total zinc anomaly.

2. If physical erosion is going more rapidly than chemical decomposition, the heavy metals may be present in the sediment as sulfides or other difficultly soluble minerals that do not dissolve under the weak attack of the field solution.

3. The sensitivity of the field test for copper and lead is much lower than for zinc, so that weak anomalies in copper and lead may be missed by the test.

The lack of field anomalies in samples showing total metal anomalies is probably due to a combination of reasons 2 and 3. As stated before, the cause of field anomalies below the Middle Fork Glacier is not understood.

Recent tests using the field method of Hawkes (1963) for heavy metal show better agreement with lab results for samples 158 and 356.

## SUGGESTIONS FOR PROSPECTING

As was described in the section on economic geology, a variety of mineral showings are present in the Rainy Creek and Rainbow Mountain areas. Copper, nickel, lead, zinc, gold, silver, and asbestos are known in at least minor amounts, and platinum, chromite, and mercury could be present. Of these, copper and nickel-copper deposits associated with the ultramafic and mafic rocks seem the most likely to occur as deposits of economic grade and tonnage. Two types of nickel-copper sulfide deposits are recognized in other areas (International Nickel Company, 1959). In the Sudbury type, the nickel and copper sulfides occur in roughly equal proportions either disseminated in gabbroic rocks near the base of differentiated lopoliths or other large floored intrusives, or as massive sulfide bodies at and near the base of floored intrusives. The deposits at Sudbury, Ontario, and Yakobi Island, Alaska, are this type. The second type consists of nickel-copper sulfide bodies associated with ultramafic rocks. These bodies characteristically contain considerably greater amounts of nickel than copper, and are usually massive sulfide bodies of magmatic or replacement origin. Ores of this type are mined at Thompson, Manitoba, and the Giant Nickel Mine, British Columbia. Nickel showings associated with ultramafic rocks have been prospected near Lake Kluane in the Yukon, a few miles south of the Denali fault (Campbell, 1960).

The known nickel-copper prospects of the Rainy Creek area are mainly of the second type, although the disseminated sulfides in gabbro at localities 1 and 3 have some aspects of the first type. Prospecting for this type of deposit should concentrate on the peridotite intrusives and their contact zones, especially any pre-peridotite faults and other structures. Localities 18, 19, and 20 seem the best part of the mapped area for deposits of this type, but several of the stream sediment copper anomalies, especially sample 158, may have this source.

It is clear from the mapping presented here that the ultramafic rocks are not restricted to the map area. Present data indicates that this zone of ultramafic intrusives extends at least from Gulkana galcier about 10 miles east of the Delta River (Hawkins and Ragan, 1964), to Broxson Gulch, a distance of about 22 miles. "Diorite" intrusives mapped by Moffit (1912) farther west may be additional bodies of gabbro. Dunite is reported about 20 miles west of Broxson Gulch in the West Fork of the Maclaren River (Kaufman, 1964). The type of mineralization discussed in this report may therefore occur in a much larger zone. In addition, it seems possible that ultramafic rocks occur near the Denali fault in a number of other localities. Peridotite and associated nickel prospects are known in Yukon Territory near Kluane Lake just south of the Denali fault, and peridotite or pyroxenite is reported close to the Denali fault on the upper Chistochina River, where platinum is present in minor amounts in the gold placers. Small amounts of platinum are reported from Platinum Creek north of Nabesna, also near the Denali fault (P.R. Holdsworth, personal communication). It therefore seems likely that zones of ultramafic rocks, possibly with associated nickel, copper, platinum, and other minerals, are present in many localities just south of the Denali fault. Some of the geologic concepts and types of deposits discussed in this report probably apply in these other areas.

A second type of ore that may exist in the area is copper ore, occurring either disseminated in gabbro as at locality 5, or as veins and replacements as at localities 4, 7, 8, 15, 16, and others. From the data available at present, none of the latter occurrences seem to contain much copper, and all are apparently rather small. However, higher-grade extensions of these showings, or higher-grade and larger bodies of similar type, would be of interest. The relatively common limestone units seem a favorable host for replacement ore. At localities 7 and 16, sulfides and magnetite replace limestone. No prospecting was evident at locality 16. At locality 5, additional investigation of the grade of the disseminated mineralization and its extent under cover to the northwest might be rewarding, although a considerable increase in either tonnage or grade would be necessary to make ore. Disseminated chalcopyrite in gabbro bodies elsewhere in the region constitutes a possible exploration target.

Because of the large amount of ultramafic rock in the area, and the presence of platinum with ultramafics in the upper Chistochina area, an investigation of the placers in Rainy Creek for platinium should be undertaken. An appreciable amount of platinum might make the gold placers profitable.

As noted in the discussion of stream sediments, follow-up work on the anomalies is recommended. Anomalies in sectors K-6 and vicinity, G-6, D-4, D-5 and C-7 seem the most interesting.

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TABLE 1

MINERALOGICAL COMPOSITION OF PRECAMBRIAN(?) SCHIST

| Sample No. | 333 | 400 | 401 | 505 | 507 | 524 |
|---|---|---|---|---|---|---|
| Quartz | 20 | 27 | 7 | 20 | 15 | 10 |
| Plagioclase (%An) | | 25(0-5) | 30(0-2) | 43(0-10) | 53(0-5) | 26(0-1 |
| Sericite | 42 | | 20 | 5 | | 35 |
| Biotite | 15 | | | | 10 | |
| Chlorite | 20 | 5 | 20 | 7 | | 25 |
| Actinolite | | 38 | | 7 | | |
| Calcite | | 8 | 10 | 10 | | |
| Epidote | | 20 | 10? | 3 | 10 | |
| Andalusite(?) | * | | | | | |
| Staurolite(?) | * | | | | | |
| Graphite | 3 | | 3 | 5 | | 2 |
| Leucoxene | | 2 | tr | | 2 | 1 |
| Pyrite | | | | | | tr |
| Magnetite | tr | | | | | 1 |
| Apatite | | tr | tr | | tr | tr |

* Composition based on estimates made from thin section. Andalusite(?) crystals altered t sericite, and staurolite(?) to chlorite and biotite.

Location

333 Float derived from head of Rainy Creek drainage.

400 Schist on east side of ridge, sector F-8, elev. 5800

401 Schist on east side of ridge, sector F-8, elev. 6300

505 Schist on ridge, sector D-8, elev. 5850

507 Schist on ridge, sector D-8, elev. 6300

524 Schist, sector C-8, from exposure within western branch of glacier in Middle Fork of Broxson Gulch, elev. 5100

TABLE 2

MINERALOGICAL COMPOSITION OF ULTRAMAFIC AND GABBROIC ROCKS

| Sample No. | 265 | 273 | 281 | 285a | 285b | 298 | 302 | 332 | 338 | 353 | 354 | 355 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plagioclase | 48 | 25 | 45 | 57 | | 20 | 25 | | 40 | 30 | 47 | 5 |
| %An | 10 | 65 | 68 | 72 | | 60 | 65 | | 55 | 0-10 | 60 | 0-5 |
| Saussurite | | 7 | 5 | | | 50 | tr | | 20 | 35 | | 30 |
| Olivine | ? | | 5 | | 50 | | 15 | 93 | | | | |
| Clinopyroxene | 30 | 39 | 30 | 35 | | 25 | 55 | | 15 | 20 | 45 | 15 |
| Orthopyroxene | | 2 | 15 | | | | | | | | | |
| Hornblende | | 15* | tr | 3* | | 4* | 3 | | 15 | | 2 | |
| Actinolite | | | | | | | | | | 3 | | 45 |
| Biotite | 8 | 5 | tr | | | | tr | | 5 | | | |
| Chlorite | 2 | 3 | | | | | | | 1 | tr | 1 | |
| Serpentine | | 3 | 1 | | 48 | tr | | 5 | | | | |
| Quartz | 3 | | | | | tr | | | 3 | 2 | 3 | |
| Opaque Oxides | 2 | 1 | tr | 2 | tr | 1 | 1 | 2 | 1 | | 2 | 1 |
| Calcite | 2 | | | 1 | | | | | | 5 | | 2 |
| Sericite-talc | | 10 | | | | | | | tr | | | 2 |
| Pyrite | tr | tr | | | 2 | | 1 | | | | | |
| Pyrrhotite | | | 1 | | | | | | | | | |
| Chalcopyrite | | | | | | | | | | 3 | | |
| Sphene | | | | | | | | | | 1 | | |
| Apatite | | tr | | | | | | | | tr | | |
| Limonite | | | | | | | | | | 2 | | |
| Rock Name | Gabbro | Gabbro | Gabbro | Gabbro dike | Dunite | Gabbro | Gabbro | Dunite | Gabbro | Gabbro | Gabbro | Gabbro |
| Location(sector) | K2(NC) | J2(C) | J4(NC) | 15(NW) | 15(NW) | G5(NW) | F6(SE) | H7(SW) | G3(NW) | F5(C) | F5(C) | F5(C) |

Under Location, K2 (NC) indicates North-central part of sector K2 on Figure 2; "1" indicates locality 1 under economic geology.

* Brownish-green lamellar alteration of pyroxene

Table 2 - Continued

| Sample No. | 369a | 369b | 437 | 447 | 453 | 701 | 704 | 739 | 743 | 763 |
|---|---|---|---|---|---|---|---|---|---|---|
| Plagioclase | 15 | | | 25 | 26 | | | | | |
| %An | 65 | | | 55 | 70 | | | | | |
| Saussurite | 20 | 10 | 10 | 25 | 30 | 20 | 25 | | 3 | 5 |
| Olivine | 20 | | 45 | | | 2 | | 42 | 25 | 45 |
| Clinopyroxene | 28 | 3 | 20 | 30 | 25 | 55 | 25 | 10 | 27 | 33 |
| Orthopyroxene | 10 | | 10 | | | | 5 | 3 | | |
| Hornblende | | | 3 | 1 | 5 | | 10 | | 10 | 2 |
| Actinolite | | 78 | | | | 2 | 18 | | 20 | |
| Biotite | 3 | 3 | 1 | | 3 | | tr | 2 | tr | 2 |
| Chlorite | | 5 | | 15 | tr | | 15 | | | |
| Serpentine | | | 5 | | | 15 | | 25 | 10 | 10 |
| Quartz | | | | | 7 | | | | | |
| Opaque oxides | 1 | 1 | 1 | | 1 | | 1 | 2 | 1 | 1 |
| Calcite | | | tr | | | 5 | | | | |
| Sericite-talc | 3 | | tr | | | | | | 1 | |
| Pyrite | | | | | | | | | | |
| Pyrrhotite | | | 2 | | | | 7 | tr | 3 | 2 |
| Chalcopyrite | | | 1 | | | | 1 | | | |
| Apatite | | | | | | | | | | |
| Limonite | | | | | | | | | | |
| Rock Name | Gabbro | Alt. Gabbro | Perid. | Gabbro | Gabbro | Mafic Gabbro | Mafic Gabbro | Perid. | Perid. | Perid. |
| Location(sector) | F6(WC) | F6(WC) | L7(SE) | M7(SW) | K4(NC) | 1 | 1 | 1 | 1 | 2 |

## TABLE 3

### ASSAYS ON SAMPLES FROM RAINBOW MOUNTAIN PROSPECT

| Sample No. | Type sample | Cu | Ni | Au | Ag | Location |
|---|---|---|---|---|---|---|
| 4 | 12 inch channel | 0.46% | 3.03% | Nil | Nil | Northernmost showing and pit |
| 5 | 6 inch channel | 1.46% | 2.58% | Nil | Nil | Northernmost showing and pit |
| 6 | 24 inch channel | 0.82% | 4.73% | Nil | Nil | Northernmost showing and pit |
| 7 | 8 foot channel | 0.99% | 1.27% | Nil | Nil | About 100' south of sample 4 |
| 8 | Grab | 1.22% | 14.02% | Nil | Nil | About 100' south of sample 4 |
| 9 | 4 inch channel | 2.68% | 8.07% | Nil | Nil | About 330' south of sample 4 |
| 1F | 8 inch channel | 0.58% | 2.55% | Nil | Nil | About 100' north of sample 3F |
| 2F | 6 inch channel | 0.70% | 2.87% | Nil | Nil | Southernmost pit (1000' south of sample |
| 3F | 6 inch channel | 1.05% | 6.39% | Nil | Nil | Southernmost pit (1000' south of sample |
| 4F | 24 inch channel | 1.40% | 4.84% | Nil | Nil | Southernmost pit (1000' south of sample |
| 11F | 5 foot channel | | 0.73% | | | Southernmost pit (1000' south of sample |
| 112F | 5 foot channel | | 0.38% | | | Southernmost pit (1000' south of sample |
| 13F | 2 foot channel | | 0.38% | | | Southernmost pit (1000' south of sample |

Samples collected by R.H. Saunders (1961) and assayed by Donald Stein.

GEOCHEMICAL ANALYSES OF STREAM SEDIMENTS AND ROCKS

| Sample No. | Field Results (ml of dye) | Copper (ppm) | Lead (ppm) | Zinc (ppm) | Molybdenum (ppm) | Nickel (ppm) |
|---|---|---|---|---|---|---|
| 4WP134 | 4 | 100 | 5 | 120 | | |
| 4WP135 | 5 | 90 | 5 | 125 | | |
| 4WP136 | 7 | 100 | 10 | 125 | | |
| 4WP137 | 2 | 85 | 0 | 125 | | |
| 4WP138 | 2 | 50* | 5 | 85 | 1 | 120 |
| 4WP139 | 2 | 40 | 5 | 145 | | |
| 4WP140 | 1 | 55 | 0 | 150 | | |
| 4WP141 | 1 | 50 | 5 | 105 | | |
| 4WP146 | 1 | 115 | 10 | 140 | | |
| 4WP147 | 1 | 105 | 10 | 130 | | |
| 4WP148 | 1 | 175 | 0 | 110 | | |
| 4WP151 | 1 | 170 | 5 | 95 | 1 | 520 |
| 4WP152 | 1 | 80 | 0 | 90 | 0 | 870 |
| 4WP153 | 1 | 145 | 0 | 100 | 0 | 1100 |
| 4WP154 | 1 | 95 | 0 | 100 | 0 | 1050 |
| 4WP155 | 1 | 90 | 0 | 110 | 0 | 1000 |
| 4WP156 | 1 | 85 | 0 | 120 | 1 | 780 |
| 4WP157 | 5 | 330* | 25 | 145 | 3 | 1500 |
| 4WP158 | 2 | 370* | 5 | 110 | 3 | 2300 |
| 4WP159 | 1 | 135 | 0 | 145 | 1 | 1300 |
| 4WP160 | 1 | 40 | 0 | 90 | 0 | 40 |
| 4WP161 | 1 | 60 | 0 | 190 | 0 | 2100 |
| 4WP162 | 1 | 70 | 0 | 85 | 0 | 800 |
| 4WP163 | 3? | 85 | 0 | 105 | 0 | 460 |
| 4WP172 | 1 | 70 | 0 | 90 | 1 | 210 |
| 4WP173 | 1 | 45 | 0 | 105 | 0 | 55 |
| 4WP175 | 1 | 75 | 0 | 135 | 0 | 225 |
| 4WP182 | 2 | 135 | 0 | 135 | 0 | 240 |
| 4WP183 | 2 | 45 | 0 | 110 | 0 | 240 |
| 4WP184 | 1 | 120# | 0 | 170 | 3 | 100 |
| 4WP185 | 1 | 70# | 0 | 115 | 0 | 210 |
| 4WP186 | 2 | 70 | 0 | 60 | 0 | 420 |
| 4WP187 | 1 | 105 | 0 | 145 | 1 | 320 |
| 4WP188 | 1 | 185* | 5 | 105 | 2 | 340 |
| 4WP189 | 3 | 55* | 5 | 125 | 1 | 50 |
| 4WP190 | 2 | 45 | 0 | 125 | 0 | 80 |
| 4WP191 | 1 | 65 | 0 | 120 | 0 | 1200 |
| 4WP192 | 1 | 70 | 0 | 150 | 1 | 1200 |
| 4WP193 | 2 | 145 | 0 | 150 | 0 | 300 |
| 4WP210 | 2 | 120 | 0 | 200 | 4 | 330 |
| 4WP211 | 1 | 140 | 0 | 65 | 0 | 420 |
| 4WP212 | 5 | 170* | 35 | 750 | 2 | 175 |
| 4WP214 | 5 | 55 | 0 | 210 | 2 | 75 |

| Sample No. | Field Results (ml of dye) | Copper (ppm) | Lead (ppm) | Zinc (ppm) | Molybdenum (ppm) | Nickel (ppm) |
|---|---|---|---|---|---|---|
| 4WP215 | 1 | 50 | 0 | 180 | 0 | 70 |
| 4WP219 | 9 | 325# | 0 | 85 | 0 | 615 |
| 4WP220 | 10 | 2500 | 0 | 125 | 1 | 400 whit encrustatio |
| 4WP221 | 1 | 185# | 0 | 60 | 0 | 435 |
| 4WP222 | 1 | 105# | 0 | 30 | 0 | 240 |
| 4WP223 | 1 | 305# | 5 | 210 | 0 | 40 |
| 4WP224 | 1 | 115# | 0 | 95 | 1 | 530 |
| 4WP225 | 1 | 145# | 0 | 100 | 0 | 330 |
| 4WP226 | 2 | 90# | 0 | 115 | 0 | 260 |
| 4WP228 | 1 | 70# | 0 | 110 | 0 | 340 |
| 4WP229 | 1 | 70* | 5 | 90 | 2 | 260 |
| 4WP231 | 3 | 160# | 0 | 90 | 0 | 615 |
| 4WP232 | 1 | 165# | 0 | 95 | 0 | 375 |
| 4WP233 | 1 | 135* | 5 | 70 | 2 | 250 |
| 4WP234 | | 105 | 0 | 130 | 3 | 45 |
| 4WP235 | 1 | 140 | 0 | 85 | 0 | 270 |
| 4WP236 | 1 | 75 | 0 | 90 | 0 | 270 |
| 4WP237 | 1 | 185* | 0 | 150 | 2 | 280 |
| 4WP238 | 5 | 215* | 5 | 270 | 3 | 290 |
| 4WP255 | 5 | | | | | |
| 4WP256 | 3 | 100 | 0 | 90 | 0 | 550 |
| 4WP257 | 3 | 70 | 0 | 95 | 0 | 420 |
| 4WP258 | 1 | 145* | 5 | 140 | 2 | 135 |
| 4WP259 | 1 | 150 | 0 | 135 | 0 | 180 |
| 4WP260 | 7 | 415* | 5 | 210 | 3 | 175 |
| 4WP261 | 4 | 155* | 15 | 300 | 2 | 85 |
| 4WP262 | 1 | 110* | 5 | 115 | 2 | 175 |
| 4WP263 | 5 | 150* | 10 | 150 | 3 | 260 |
| 4WP264 | 3 | 130* | 10 | 140 | 3 | 350 |
| 4WP265 | 4 | 180* | 5 | 100 | 3 | 260 |
| 4WP266 | 2 | 65* | 10 | 80 | 3 | 240 |
| 4WP267 | 5 | 130* | 10 | 80 | 2 | 360 |
| 4WP268 | 3 | 130* | 10 | 95 | 2 | 60 |
| 4WP269 | 6 | 65* | 5 | 45 | 1 | 60 |
| 4WP270 | 13 | 120* | 5 | 150 | 3 | 500 |
| 4WP271 | 2 | 70* | 10 | 85 | 2 | 80 |
| 4WP272 | 4 | 200* | 5 | 125 | 2 | 120 |
| 4WP281 | 1 | 110* | 70 | 290 | 2 | 105 |
| 4WP282 | 7 | 80* | 25 | 130 | 2 | 180 |
| 4WP283 | 7 | 110* | 5 | 45 | 1 | 220 |
| 4WP284 | 6 | 140* | 5 | 160 | 3 | 410 |
| 4WP285 | 14 | 55* | 5 | 70 | 1 | 35 |
| 4WP286 | 21 | 50* | 5 | 95 | 1 | 40 |
| 4WP287 | 5 | 55 | 15 | 60? | 0 | 80 |
| 4WP288 | 14 | 175 | 15 | 40? | 0 | 550 |

Table 4 - Continued

| Sample No. | Field Results (ml of dye) | Copper (ppm) | Lead (ppm) | Zinc (ppm) | Molybdenum (ppm) | Nickel (ppm) |
|---|---|---|---|---|---|---|
| 4WP289 | 3 | 245* | 5 | 150 | 2 | 435 |
| 4WP301 | 4 | 70 | 0 | 125 | 0 | 70 |
| 4WP303 | 3 | | | | | |
| 4WP304 | 2 | 85 | 15 | 145 | 1 | 75 |
| 4WP305 | 2 | | | | | |
| 4WP306 | 8 | 65* | 5 | 125 | 1 | 45 |
| 4WP307 | 12 | 65* | 5 | 85 | 1 | 40 |
| 4WP308 | 1 | 70* | 10 | 125 | 1 | 75 |
| 4WP309 | 7 | 70 | 15 | 125 | 1 | |
| 4WP310 | 4 | 65 | 20 | 125 | 1 | |
| 4WP311 | 8 | 55* | 5 | 105 | 1 | 50 |
| 4WP312 | 1 | 100* | 10 | 205 | 4 | 200 |
| 4WP318 | 14 | 45* | 5 | 110 | 2 | 45 |
| 4WP319 | 2 | 80* | 10 | 175 | 3 | 85 |
| 4WP320 | 4 | 60 | 10 | 100? | 0 | 45 |
| 4WP321 | 9 | 35* | 5 | 50 | 1 | 25 |
| 4WP322 | 4 | 60 | 5 | 200? | 0 | 60 |
| 4WP323 | 3 | 80 | 5 | 200? | 0 | 55 |
| 4WP324 | 10+ | 60* | 15 | 110 | 2 | 40 |
| 4WP325 | | 45 | 5 | 60 | 0 | 35 |
| 4WP326 | | 50 | 5 | 110 | 0 | 35 |
| 4AR356 | 3 | 750* | 5 | 125 | 4 | 500 |
| 4AR454 | 1 | 130* | 5 | 110 | 3 | 835 |
| 4AR455 | 7 | 170* | 5 | 200 | 3 | 740 |
| 4AR457 | 4 | 125* | 5 | 145 | 2 | 115 |
| 4AR458 | 2 | | | | | |
| 4AR459 | 4 | 135* | 5 | 125 | 2 | 240 |
| 4AR460 | 7 | 105* | 5 | 90 | 2 | 460 |
| 4AR461 | 3 | 160* | 10 | 105 | 3 | 1100 |
| 4AR462 | 10 | 235* | 5 | 235 | 3 | 835 |
| 4AR463 | 8 | 215* | 0 | 200 | 3 | 1700 |
| 4AR464 | 19 | 230* | 10 | 310 | 3 | 145 |
| 4AR466 | 20 | 240* | 5 | 140 | 3 | 120 |
| 4AR467 | 6 | 110* | 5 | 100 | 3 | 130 |
| 4AR469 | 5 | 135* | 5 | 130 | 3 | 105 |
| 4AR470 | 11 | 300* | 5 | 135 | 4 | 130 |
| 4AR471 | 7 | 305* | 5 | 140 | 3 | 130 |

ROCK SAMPLES

| Sample No. | Copper (ppm) | Nickel (ppm) | |
|---|---|---|---|
| 4AR281 | 60* | 180 | Gabbro |
| 4AR282 | 220* | 1100 | Amphibole "serpentin-ite" |
| 4AR 298 | 80* | 80 | Gabbro |

Table 4 - Continued

| Sample No. | Copper (ppm) | Nickel (ppm) | |
|---|---|---|---|
| 4AR336 | 10# | 115 | Volcanic inclusion in "serpentinite" |
| 4AR369 | 85# | 450 | Mafic Gabbro |
| 4AR377 | 125# | 1200 | Amphibole "serpentinit |
| 4AR397s | 20# | 2700 | Serpentinized dunite |
| 4AR397d | 10# | 2600 | Dunite |
| 4AR524b | 75# | | Schist |
| 4AR705 | 20# | 2900 | Peridotite |
| 4AR718 | 90# | 15 | Pyritized tuff |

* Copper, lead, zinc, molybdenum analyses by Rocky Mountain Geochemical Laboratories

\# Copper analysis by Rocky Mountain Geochemical Laboratories

All Nickel analyses by Rocky Mountain Geochemical Laboratories

Remaining analyses by Alaska Division of Mines and Minerals

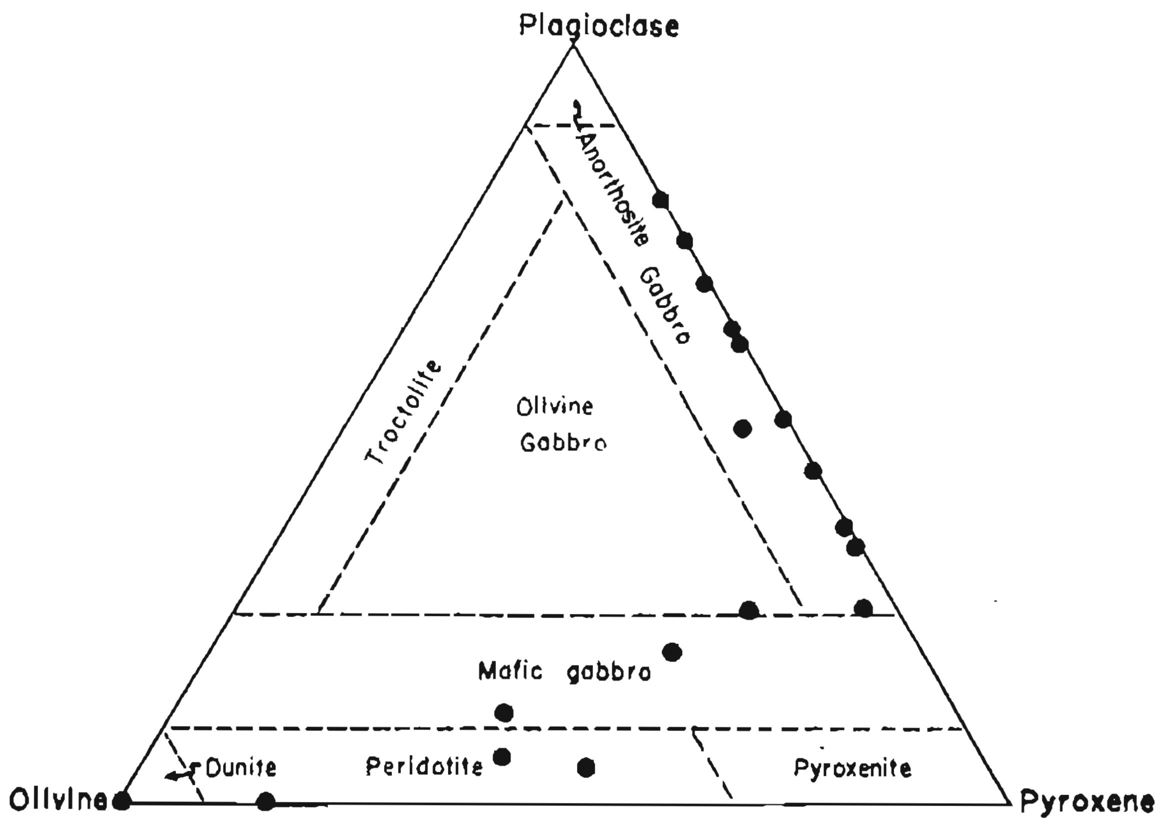


Figure 3. Mineralogical composition of mafic and ultramafic rocks from the Rainy Creek and Rainbow Mountain areas.

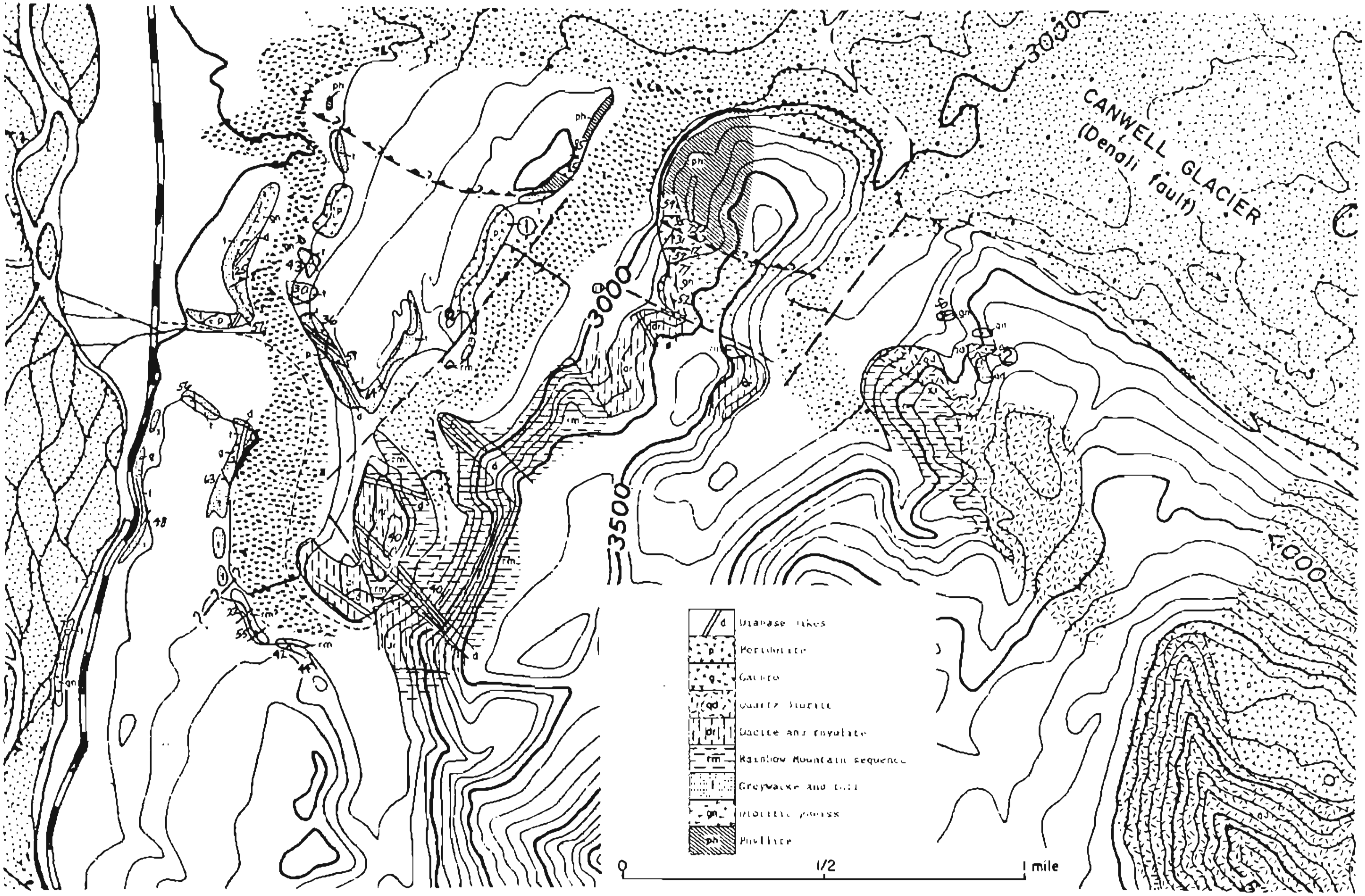


FIGURE 4. Geologic Map of the Rainbow Mountain prospect and vicinity. Geology by Hanson (1964) and Rose.

# LOCALITY 2

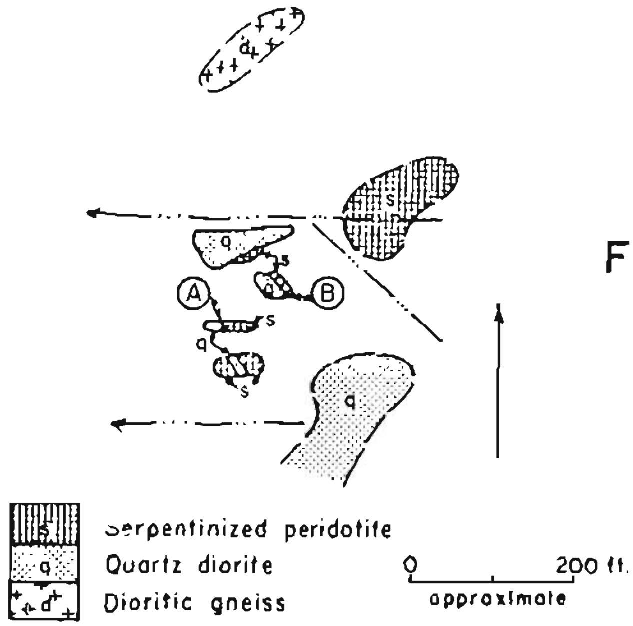


Figure 5

# LOCALITY 5

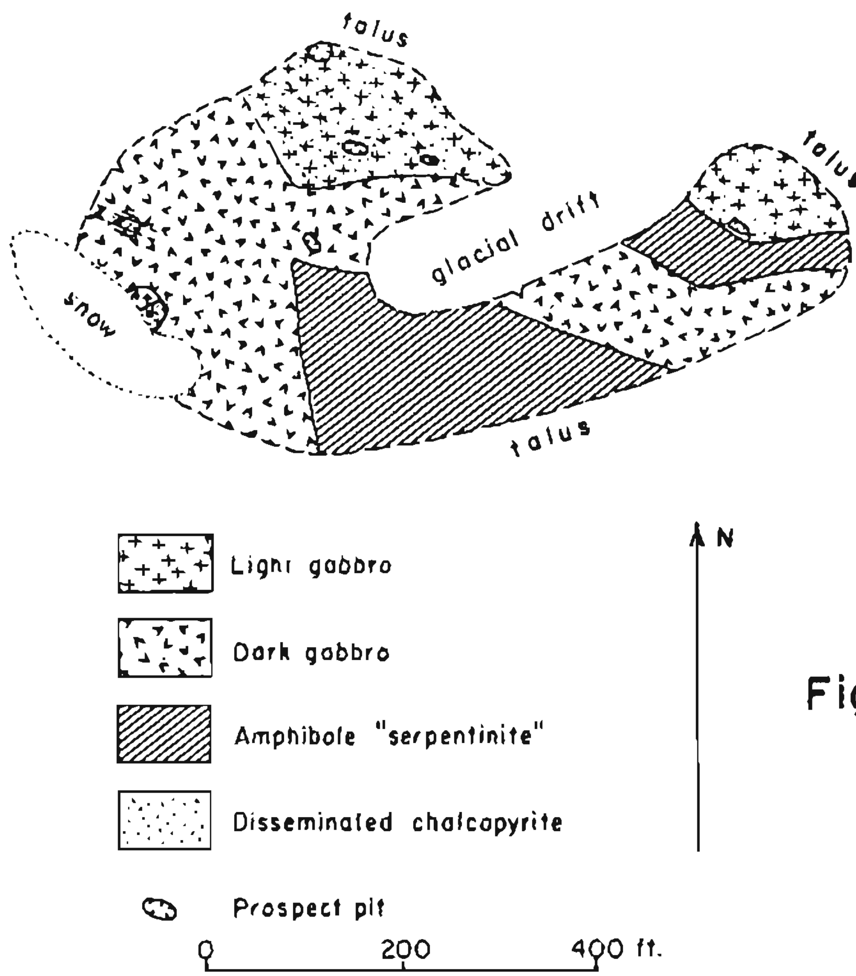


Figure 6