STATE OF ALASKA

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GEOLOGIC REPORT NO. 40

Geology of the Spirit Mountain Nickel-Copper Prospect and Surrounding Area

By

Gordon Herreid

College, Alaska

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ILLUSTRATIONS

GEOLOGY OF THE SPIRIT MOUNTAIN NICKEL-COPPER PROSPECT

AND SURROUNDING AREA

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A B S T R A C T

An area of 20 square miles was mapped and 126 geochemical samples were taken in the vicinity of the Spirit Mountain nickel-copper prospect, located near the northern edge of the Chugach Geosyncline.

Bedded rocks in the area are a moderately to steeply north dipping sequence of meta-volcanics, impure chert, and limestone belonging to the Mississippian Strelna formation. These rocks are up to 12,000 feet thick and represent at least eight deposition cycles, each cycle consisting of a basal volcanic graywacke overlain by fine-grained clastic sediments and impure chert and limestone.

These bedded rocks have been intruded by a quartz diorite batholith at the south edge of the map area and, farther north, by two west-northwest trending belts of lenticular sills ranging from quartz monzonite to hornblendite and peridotite. Most are quartz diorite. The Spirit Mountain nickel-copper prospect is located along the southernmost belt, about 1200 feet north of the batholith. Two and one-half miles farther north, a second zone of sills has mostly a quartz monzonite to quartz diorite composition. Some of these sills have produced minor enrichments of copper and lead in pyritized wall rocks.

Geochemical samples were anlayzed for copper, lead, zinc, and nickel by atomic absorption and for 30 elements by emission spectrograph. Results show little expression of the Spirit Mountain prospect in the stream sediments. However, an area two miles to the west and on strike with this prospect, has moderate stream sediment anomalies for copper and nickel. This area is beyond the geologic mapping of this report. Pyritized zones in the northern area are responsible for moderate copper, lead, and zinc anomalies. The two zones of sill intrusions favorable for deposits of nickel-copper and copper, respectively, extend to the east and west beyond the mapped area.

INTRODUCTION

The area is 16 miles southeast of Chitina (*fig 1*). It was chosen for mapping because it contains a nickel occurrence near a major tectonic lineament, the northern margin of the Chugach Geosyncline, and the geology of the deposit and the surrounding area were so little known that no good assessment could be made of the ore possibilities of the area.

Field work was done from June 10 to July 20, 1969. Access was by float plane from Chitina to Summit Lake and traverses were made from there on foot. There is one old trail along the north side of Summit Lake which extends to the Copper River near Chitina, but is reportedly overgrown with brush (Jasper, 1960A). There are no inhabitants in the map area. Able assistance was given by Robert Timmer, who took most of the stream sediment samples. Flying was by Bob Wilson, Chitina, for the Cordova Air Service.

The area is above timberline, except for a few spruce in the western part. Brush is present along Summit Lake, but not enough to seriously impede walking in most places. Bedrock crops out on the steeper slopes and on roches moutonnees in the low area between Canyon Creek and Summit Lake. The Spirit Mountain prospect is reported by Jasper to be snow free during July, August, and September. During June of 1969, there was little snow, except in deep draws. Canyon Creek was fordable, except that due to glacial melt water there were difficulties on warm afternoons.

PREVIOUS GEOLOGICAL INVESTIGATIONS

The area was first mapped in 1911 by Moffit (1914). He mapped the rocks as: (1) Carboniferous(?) "slate and schist, locally containing many intrusive masses, mostly of dioritic character, but with some more basic types"; (2) Carboniferous(?) limestone; and (3) Post-Carboniferous to Post-Jurassic "diorite and closely related granular intrusives". He showed the locations of the Spirit Mountain prospect on Canyon Creek and two copper prospects on Falls Creek, more or less on strike with the slightly cupriferous gossans north of Summit Lake.

Overbeck (1920) visited the Canyon Creek prospect in 1917. He repeated Moffit's map of the region and described the peridotite and ore body on Canyon Creek.

Kingston and Miller (1945) examined the prospect in 1942. They made a map of the peridotite body and described its mineralogy in some detail.

Jasper (1960A and 1960B), in two brief reports, summarized the earlier work and presented several assays and a sketch map of the deposits west of Canyon Creek.

Between the time of Jasper's visits in 1959 and 1969 the deposit was drilled by a Canadian company. The results of this work are not known.

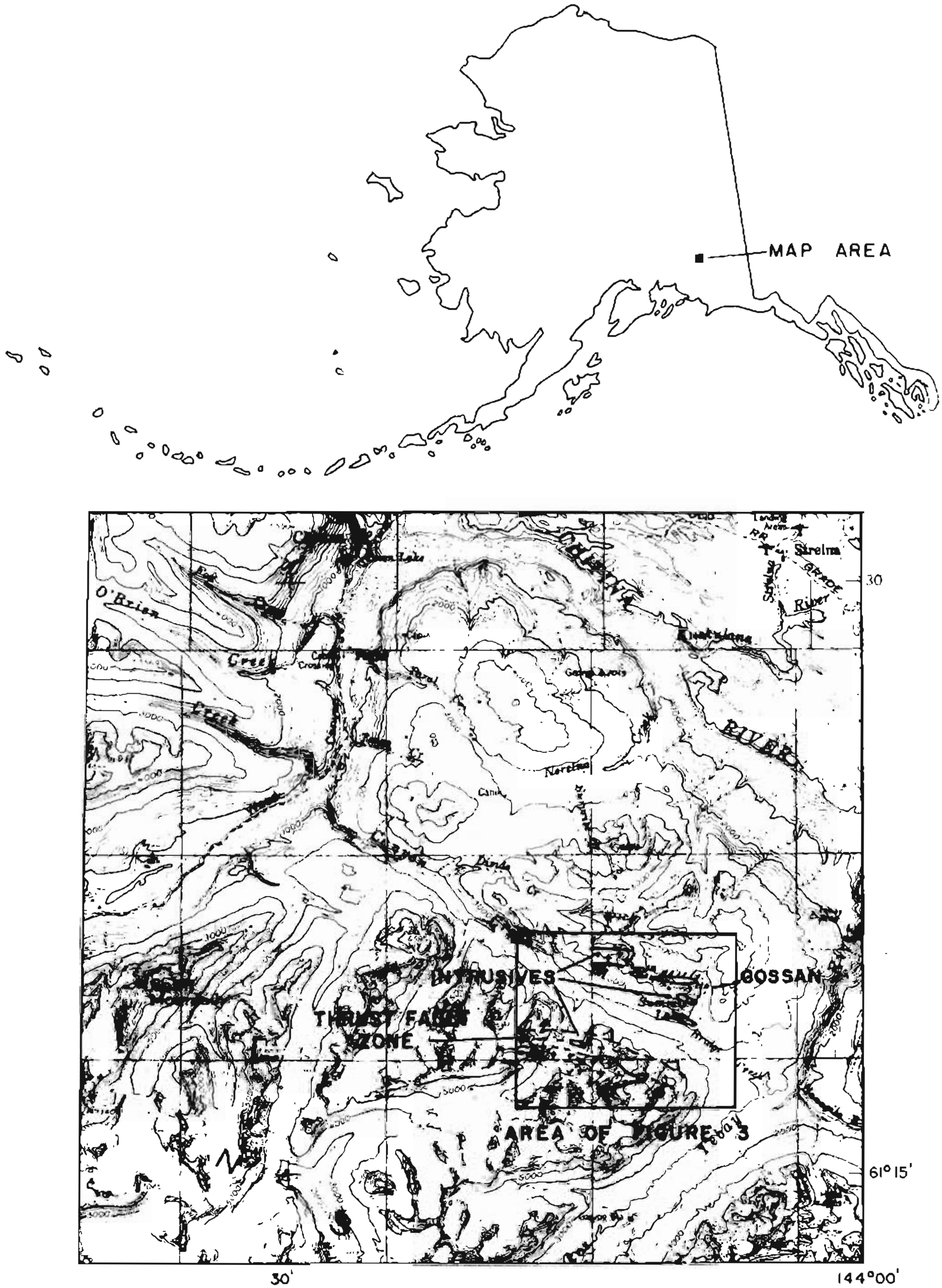

Figure 1 Location of the map area

G E O L O G Y

GENERAL GEOLOGY

Bedrock in the map area is a moderately to steeply north-dipping eugeosynclinal sequence of metavolcanics, impure chert, and limestone of Mississippian(?) age. All belong to the Strelna formation (Moffit, 1938, p 22). South of the map area this formation extends under the Cretaceous sediments that fill the Chugach geosyncline. The Strelna rocks in the map area seem to represent about eight great cycles, each consisting of volcanic graywacke (greenstone) overlain by fine-grained clastic sediments, impure chert, and limestone (*appendix*).

The Strelna rocks have been intruded by three more or less parallel zones of igneous rock, which range in composition from quartz monzonite to hornblendite, but are mostly quartz diorite. These are, from south to north, (1) a quartz diorite batholith; (2) a swarm of lenticular sills ranging from quartz diorite to peridotite that was localized along a great thrust fault and carry one known nickel-copper deposit; and (3) a swarm of quartz diorite to quartz monzonite sills and dikes associated with gossans in cherty wall rocks that carry minor amounts of copper, lead, and zinc. Old copper prospects on Falls Creek, west of the map area, are on strike with the third zone.

TECTONICS

A great shear zone, here called the Spirit Mountain thrust zone, along the north side of the quartz diorite batholith extends east and west beyond the map area. It is a half-mile or more wide and is marked by a 60° north-dipping fault bounded by lenses of country rock tens to hundreds of feet thick. These are braided faults visible in exposures on the steep canyon walls north of the batholith. The limy chert and graywacke unit and the amphibolite have been thrust southward, toward the batholith.

A similar zone of major thrusting is probably responsible from the location of the great zone of sill intrusions north of Summit Lake. However, no field evidence was found for this.

METAMORPHISM

The old Strelna rocks are of greenschist facies metamorphism except where they have been heated by intrusion of igneous rocks. In such places the feldspar is oligoclase or andesine, rather than albite, and unrotated sieve textured garnet is often present. These rocks are described in the appendix.

RELATIONS OF LAND FORMS TO GEOLOGY

The ridges run west-northwest parallel to bedding and intrusive belts. Many of the streams run north-northeast and are probably controlled by faulting.

GLACIAL FEATURES

Summit Lake occupies a flat-bottomed, steep-sided, structurally controlled glacial trough that extends in an almost straight line for 16 miles. Along its north side, creeks have cut gorges (100-200 feet deep) into the valley wall and have well-developed deltas extending down to the lake. The deltas bulge out into the lake. They were obviously formed after valley glaciation scoured out the Summit Lake valley. The lake itself is a result of damming of the main valley by active delta building of the south-flowing stream with a particularly large drainage basin that enters the valley at the east end of the lake. The deltas are covered with brush and grass and some of the creeks disappear before they reach the lake. Delta building took place during a period when erosion was more active than at present.

Deltas are present only on the north side of the lake. On the south side there are hanging valleys with cirques, fresh moraines in the upper portions, a glacier, and small gorges down into the lake. Erosion and delta building were active on the warmer south facing slopes, whereas in the colder north-facing valleys a glacial regime has persisted in some valleys until the present.

The preservation of roches moutonnees in the low area west of Summit Lake is an indication that glaciation in the main valley took place during Wisconsin time. Delta formation resulted from a more recent and a warmer period.

Above many of the steep glacially scoured mountain slopes are remnants of an old erosion surface with a mature rounded topography. Flat-topped ridges showing this surface are present east of the Spirit Mountain prospect and in the northeast corner of the map. Evidently several thousand feet of rapid uplift immediately preceeded Pleistocene glaciation.

S P I R I T   M O U N T A I N   N I C K E L - C O P P E R   P R O S P E C T

The only prospect in the map area on which any work has been done is the Spirit Mountain prospect on Canyon Creek (*fig 2*).

> "Discovery of nickel was first reported in the Canyon Creek area in 1907. Sixteen claims were staked and consolidated as the Spirit Mountain nickel prospect, under ownership of B. O. Peterson, Charley Young, and Andrew Halvorsen, and a "double ender" road was constructed along Canyon Creek from the Copper River to the prospect. Several mineralized outcrops were explored by test-pits, and two short tunnels were driven at the base of the most promising outcrop, but no ore was shipped. The prospect was abandoned in 1917." (Kingston and Miller, 1945)

According to Jasper (1960A)

> "The area was apparently neglected by prospectors until 1954 when 6 mineral claims - Spirit Mountain No.s 1 to 6 - were relocated by Andrew Halvorsen, Neil Finnisand, and Art Nelson. These claims are located on the west side of Canyon Creek, and cover the area in which the more interesting nickel-copper showings were originally found in 1907, and upon which the early day work was largely confined."

The Spirit Mountain prospect consists of massive and disseminated nickel and copper sulfides in small basic and ultrabasic intrusions on Canyon Creek (*figs 2 & 3*). The richest part of the prospect is west of Canyon Creek in a serpentinized peridotite body. A few hundred feet east of this body an old adit has been driven on a narrow hornblendite dike that also carries nickel and copper sulfides. East of Canyon Creek intrusive rock of variable composition, from mafic quartz diorite to hornblendite, has lower grade nickel and copper sulfides. All of these intrusives belong to a belt of small basic and ultrabasic intrusives along a major north dipping thrust zone. The only known peridotite is the body west of Canyon Creek.

Country rock north of the deposit is the limy chert and graywacke unit. In this area it is a fine-grained, slightly foliated, semi-schist (quartz-sericite-chlorite) with thin carbonate layers in some places. South of the intrusive belt garnet and hornblende are present here and there in the rock and it has been mapped as transformed limy chert and graywacke. The intrusives have rusty looking outcrops, lenticular shapes, and sheared contacts with the country rock. Unmineralized, crosscutting feldspar-quartz veinlets are common in both the country rock and the intrusives. Larger unmineralized pegmatites are also common.

Most of the intrusive bodies are fine-grained, hornblende-oligoclase quartz-clinopyroxene rock (quartz diorite to hornblendite unit, *appendix*). The rocks of this unit are platy due to preferred orientation of hornblende. They are variable in composition, and some have well developed composition banding. They have a thin rusty coating, but are quite fresh internally. Several pits and trenches expose fresh rock. Assays 16A, 16B, and 16C (*table 2*) show up to 0.18% nickel and 0.37% copper. Jasper (1960B) reported a 15-inch zone containing sphalerite and galena veinlets in the vicinity of sample 16A. No such veins were noticed, but they must not be wide spread as sample 16A does not contain greater than background amounts of lead and zinc. Jasper also repeats the reported occurrence of ullmannite, a sulphantimonide of nickel in this area. The antimony anomalies at #8, down Canyon Creek, and at #21, may be related to such mineralization of the basic intrusives. There are no showings associated with the diorite to hornblendite intrusives which offer much indication of economic mineral deposits.

The original discovery showings lie west of Canyon Creek. These are mineralized pods of altered intrusive peridotite (antigorite-tremolite-talc rock). The open cut at approximately 3770 feet elevation explores the disseminated pyrrhotite-pyrite-pentlandite-chalcopyrite-bravoite-sphalerite deposit in this rock (*detail, fig 2*). This peridotite is a distinctly different rock than any other in the map area. It originally contained much olivine, now altered to antigorite. The only other olivine-bearing rock seen was the unmineralized altered gabbro, just a few feet to the south. These two rocks are probably related in origin. Samples of disseminated ore from the open cut in the peridotite (18 D thru H) run as high as 0.88% nickel and 0.89% copper. Large amounts of such rock would be ore, but the small size of the exposed body, or bodies, and the complex structural setting give little hope that a large body of ore is present at depth.

The short adit down the mountain west of the open cut (*detail, fig 1*) was driven before 1917. It contains disseminated sulfides similar to those in the open cut above, but the dike in the adit is a hornblende-altered feldspar rock with no olivine or pyroxene. It is similar to the hornblendite, but its proximity and similar mineralization link it to the peridotite. It may be transitional between the two. Near the portal the dike is three feet wide and contains 0.18% nickel and 0.89% copper. It is not of ore grade or size.

G E O C H E M I S T R Y

Analyses of geochemical stream sediment and soil samples and chip samples of gossans and mineralized rock, are shown on table 2. Suggested thresholds of anomalous values, determined from the table by inspection, are given at the bottom of each column.

Sampling shows no nickel or copper anomalies in Canyon Creek below the Spirit Mountain prospect. Only one moderately anomalous chromium sample from a small side creek is present. The small size of the deposit, in relation to the large size of Canyon Creek, and glaciation are factors in the lack of geochemical expression of this deposit.

Several copper, nickel, zinc, and lead anomalies show up west of the area mapped geologically. These are downstream from the westward projection of the belt of mafic and ultramafic intrusives. The area should be investigated with more detailed sampling.

The low copper-silver-chromium anomaly at sample site 43 (*fig 3*) marks the contact zone of the quartz diorite and is of no economic interest. This assessment is also true of samples 45 and 49.

The copper, lead, zinc soil and stream sediment anomalies from the ridge north of Summit Lake are due to slightly mineralized cherty rocks along quartz dioritic sills. Samples 73, 79, 82, and 84 are representative of the grade of these zones, which form bright gossans high on the ridge, and are restricted to mineralized fine-grained sediments. The dikes themselves are not iron stained and are fresh except for slight sericitization of feldspar. The gossans do not seem to offer hope of economic deposits in the map area, but they should be traced along strike beyond the map area.

S U G G E S T I O N S   T O   P R O S P E C T O R S

A discontinuous zone of basic to nickel-copper-bearing ultrabasic intrusive lenses extends east-west along a major north dipping thrust zone.

A deposit similar to that in the peridotite on Canyon Creek would be ore, if it were large enough.

A geochemical stream sediment anomaly for copper, nickel, lead, and zinc indicates a bedrock source west of the map area, more or less on strike with the favorable fault zone. This zone has almost surely been examined by prospectors previously, but geochemical sampling followed by a magnetic survey, if results are favorable, might be more effective than past efforts.

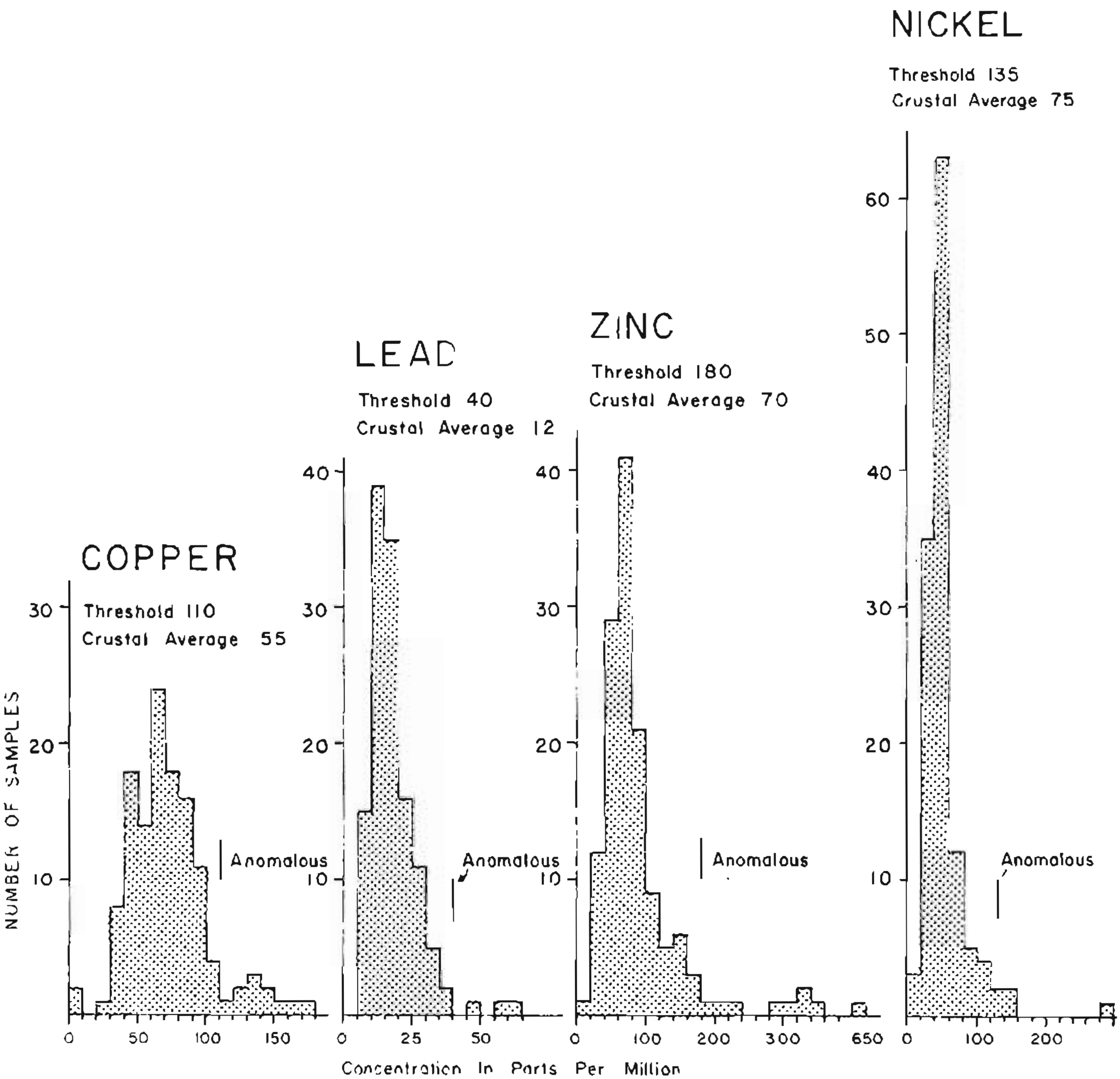

Figure 4 Frequency-concentration graphs for copper, lead, zinc, and nickel from the Spirit Mountain area. Atomic absorption analysis

Table I

INTERVALS OF ESTIMATION AND DETECTION LIMITS

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSES

Copper ppm*	Lead ppm	Zinc ppm	Molybdenum ppm	Silver ppm	Cobalt ppm	Chromium ppm	Nickel ppm	Manganese ppm	Titanium ppm	Iron (%)	Magnesium (%)	Calcium (%)	Barium ppm	Strontium ppm
20,000	20,000	10,000	2,000	5,000	2,000	5,000	5,000	5,000	10,000	20	10	20	5,000	5,000
10,000	10,000	5,000	1,000	2,000	1,000	2,000	2,000	2,000	5,000	10	5	10	2,000	2,000
5,000	5,000	2,000	500	1,000	500	1,000	1,000	1,000	2,000	5	2	5	1,000	1,000
2,000	2,000	1,000	200	500	200	500	500	500	1,000	2	1	2	500	500
1,000	1,000	500	100	200	100	200	100	200	500	1	0.5	1	200	200
500	500	200	50	100	50	100	50	100	200	0.5	0.2	0.5	100	100
200	200	100	20	50	20	50	20	50	100	0.2	0.1	0.2	50	50
100	100	L	10	20	10	20	10	20	50	0.1	0.05	0.1	20	L
50	50		5	10	L	10	5	L	L	L	L	0.05	L	
20	20		L	5		5	L					L		
10	10			2		L								
5	L			1										
2				L										
L**														

Boron ppm	Beryllium ppm	Tin ppm	Tungsten ppm	Zirconium ppm	Lanthanum ppm	Niobium ppm	Scandium ppm	Yttrium ppm	Vanadium ppm	Gold ppm	Bismuth ppm	Cadmium ppm	Antimony ppm	Arsenic ppm
2,000	1,000	1,000	10,000	1,000	1,000	2,000	100	200	10,000	500	1,000	500	10,000	10,000
1,000	500	500	5,000	500	500	1,000	50	100	5,000	200	500	200	5,000	5,000
500	200	200	2,000	200	200	500	20	50	1,000	100	200	100	2,000	2,000
200	100	100	1,000	100	100	200	10	20	500	50	100	L	1,000	1,000
100	50	50	500	50	50	100	5	10	200	20	50		500	500
50	20	20	200	20	20	50	L	L	100	10	20		200	L
20	10	10	100	L	L	20			50	L	10		100	
10	5	L	50			10			20		5		50	
L	2		L			L			10		L		L	
	1								L					
	L													

*ppm indicates parts per million
**L = Lowest limit of detection

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A P P E N D I X

EXPANDED LEGEND FOR FIGURE 3

Rock Units

1. *Banded slate and argillite* - Greenish-gray argillite interbedded with medium-dark-gray, locally red, slate. In places greenstone clasts and dark-gray slaty layers are present in the argillite. Gash quartz veins, mostly less than four inches thick and less than 10 feet long are common in the slate.

2. *Greenstone* - Greenish-gray, fine-grained to aphanitic, massive to slightly foliated, unbedded rock. Contains irregular layers and patches of moderate-red hematite. The rock has epidote veins, a little disseminated pyrite, and occassional greenstone clasts floating in the aphanitic matrix. The rock is mainly chlorite, hematite, and in places has tiny feldspar microlites. The fine-grain size for such a thick unit that indicates origin as basic lava flows rather than an intrusive.

3. *Quartz diorite* - A medium-gray to medium-dark-gray, medium-grained rock. Forms a batholith in the southern part of the map area. It is slightly to strongly banded due to segregation into feldspar-quartz and mafic layers up to a few inches wide. Textures range from nearly granitic to slightly directional granoblastic. Minerals are sericitized oligoclase to andesine, quartz, hornblende, biotite, and in one thin section, graphite and sieve-textured garnet. Where the feldspathic layers reach a width greater than about a foot they are considered to be pegmatites and tend to be boudined or crosscutting and irregular in shape. Jointing parallel to the layering gives the rock a sheeted appearance in some places. In another area that is mostly medium-grained slightly foliated quartz diorite, pegmatized thin-bedded metasediments have been preserved. These have been converted to quartz-feldspar-white mica rock with a structure of folded thin beds.

The quartz diorite, exposed on a prominent knob east of Canyon Creek and 0.2 miles south of the Spirit Mountain prospect, is medium-grained, sericitized oligoclase-hornblende-quartz rock. It has rudely directional texture, similar to partly transformed limy chert and graywacke unit to the north. In outcrop it has the appearance of an igneous rock.

On distant outcrops the diorite can be distinguished from greenstone by its jagged pointed peaks and steep rough cliffs, not visibly layered, and by white pegmatite dikes up to several feet across, which both crosscut and parallel foliation. The strong foliation, in places with minor folds typical of sediments, and the irregular gradations to greenstone on the south and partly transformed limy chert and graywacke rocks on the north indicate that the diorite is at least in part a transformed sedimentary rock. Its rather abrupt and sheared north and south contacts suggest that it was formed at greater depth and has been faulted (and intruded?) into its present position.

An idea of the diversity of this unit, with perhaps some admixture of rocks from the rather similar partly transformed limy chert and graywacke unit, is shown by a list of the glacial float at geochemical station 43 on the floor of a cirque cut into diorite: holo-mafic rock, mafic with scattered 1-2 mm feldspar, holo-feldspar rock, banded feldspar-rich rock, medium-grained diorite, fine-grained diorite, leucodiorite with pegmatite veins, gabbro, fine-grained mafic rocks with ptygmatic pegmatite veins, rusty weathering coarse-grained hornblendite, rusty weathering chloritic felsite.

4. *Partly transformed limy chert and graywacke* - Fine- to medium-grained, rudely foliated; ranges from greenish-gray, quartz-sericite, semi-schist to greenish black amphibolite.

West of Canyon Creek this unit is greenish-gray, rudely-foliated, fine-grained, granoblastic textured semi-schist made up of quartz (80%)-sericite-(garnet). The garnet was seen only in thin section. Grains are along fractures, and are sieve textured and unrotated. They formed after shearing in the rock had ceased and are probably of contact metamorphic origin, related to intrusion of igneous rocks either to the north or the south. The original rock, an impure chert, has recrystallized to form coarser-grained quartz and sericite, and has been pervasively sheared.

On the east side of Canyon Creek this unit has been transformed to a weakly foliated greenish-gray rock of dioritic aspect. Just south of the Spirit Mountain prospect it is fine-grained (0.01 mm) granoblastic textured quartz-albite-hornblende rock. Farther south, near the quartz diorite contact, the grain size is larger (0.05 mm), the feldspar is more calcic (oligoclase), and the rock contains more mafic material (chlorite). The quartz diorite farther south, mentioned under unit 3 is coarser-grained, less well layered, and has a more granitic texture.

East of the Canyon Creek drainage this unit is mainly amphibolite. It is fine- to medium-grained, greenish-black, well to poorly banded and foliated, granoblastic textured quartz-oligoclase to andesine hornblende-biotite rock. In many areas there is felsic and mafic banding. Crosscutting pegmatites are common.

5. *Limestone* - Fine-grained, light gray rock, moderately foliated and streaked due to internal shearing. It contains boudined quartz veins and mafic dikes, and large fault-bounded lenses due to north-dipping thrust faults.

6. *Quartz diorite to hornblendite* - Fine- to medium-grained, medium-dark-gray to greenish-black rock composed of widely varying proportions of sericitized oligoclase-hornblended-quartz-phlogopite-clinopyroxene with accessory sphene and zircon. The rocks of this unit are platy due to preferred orientation of hornblende, and some have well developed composition banding. They have a thin rusty coating, but are fresh internally, except for sericitization of feldspar. This unit forms lenticular fault-bounded intrusive bodies in the Spirit Mountain thrust zone.

Brief descriptions of the various bodies indicate their diversity: (*letters shown on figs 2 & 3*)

A (9C111-P) - Hornblendite, medium-grained, oriented crystals, some euhederal, with minor interstitial altered feldspar. A nickel-bearing three-foot dike in the adit west of Canyon Creek at about 3580 feet elevation. (*Fig 2 and text section Spirit Mountain Nickel-Copper Prospect*)

B (9C111-L) - Hornblendite, medium-grained, foliated, mafic and felsic banded (hornblende-sericitized plagioclase-quartz-(apatite)).

C (111-J) - Mafic diorite, fine-grained, well banded with irregular crosscutting pegmatite bodies.

D (9C81-B) - Conspicuously banded mafic quartz diorite. Mafic bands: hornblende-sericitized oligoclase. Intermediate bands: clinopyroxene-sericitized oligoclase-hornblende. Felsic bands: sericitized oligoclase-clinopyroxene.

E (9C81-M) - Hornblendite, rudely foliated, fine-grained: hornblende-minor clinopyroxene-minor sericitized feldspar.

F (9C96) - Mafic diorite, a massive rock of variable composition and grain size, ranging from coarse to medium, and roughly 60% to 95% hornblende with interstitial sericitized oligoclase. Often contains enough magnetite to deflect compass; also sparcely disseminated pyrrhotite. Unaltered rock with border zones up to 200 feet wide of finer-grained, less mafic "diorite" with pale blue sericitized(?) feldspar. The border zones grade into recrystallized limy chert and graywacke.

G (9C28) - Hornblendite, coarse-grained, with 1-2% disseminated pyrite. Has chloritized limy chert and graywacke unit on south side.

H (9C141) - Hornblendite, medium-grained, with phlogopite. Cut by prehnite-quartz veins.

7. *Peridotite* - Unbanded, medium- to coarse-grained, grayish black dike rock which locally contains both massive and disseminated nickel-bearing sulfides (section on Spirit Mountain Nickel-Copper Prospect). In the map area the rock is known only in one complex body at about 3770 feet elevation on the west side of Canyon Creek (*fig 1*). One sample contains irregular blebs of pyrrhotite and chalcopyrite in a rock composed of antigorite, which has replaced olivine, and possible minor forsterite, tremolite, and diopside (X-ray diffraction by Nam Ok Cho, DMG Laboratory). According to Kingston and Miller (1945, p 53) "the original olivine crystals are represented by rounded masses of antigorite with serpentine-chlorite veinlets and magnetite. The original matrix of pyroxene is entirely replaced by tremolite, which in turn is partially altered to talc."

The hornblendite dike (unit 6-A) in the short adit northwest of the peridotite body has been considered by Kingston and Miller (1945, p 53) to have been derived from the same magma source as the peridotite because of the similarity of the sulfide minerals in the two bodies. If so, the peridotite is similarily linked to all of the quartz diorite to hornblendite intrusives. They are both very basic, in the same structure, and have similar sulfide deposits, so they are probably closely related in origin.

8. *Gabbro* - Medium-grained, unmineralized rock. Contains altered olivine(?), uralitized pyroxene, and fresh (late) garnet and magnetite. Occurs just south of the peridotite (*fig 1*).

9. *Quartz-feldspar veinlets and pegmatite dikes* - Fine- to medium-grained, unmineralized, with veinlets and dikes up to several feet wide, which cut, with sharp contacts, PTLCG, LGC, and all igneous rocks south of Summit Lake. Pegmatites have medium-grained oligoclase feldspar cut by later fine-grained granoblastic quartz. In places pegmatites cutting LCG and marble are bounded by mafic (chloritic?) halos several feet wide. Narrow quartz-feldspar veinlets, commonly cut the limy chert and graywacke unit. These are generally less than one inch wide and six feet long, crosscutting or parallel to bedding, en echelon, horsetail, or in other arrangements. They make up as much as 5% of the rock.

10. *Limy chert and graywacke* - Massive to thin bedded, aphanitic, greenish gray, slightly sericitic and chloritic, limy to non-limy, impure chert or silt-sized graywacke. Much of the rock is not calcareous, but thin (1-5 mm) brown weathering limy layers are common. In the southern part of the unit, shearing may convert it to a semi-schist. The rock is composed of quartz-albite-chlorite-biotite-carbonate and sericite. In some areas it is a greenish and light brown banded albite-biotite rock. Near intrusive rocks diopside and epidote may be present. Glassy quartz eyes megascopically visible here and there are recrystallized chert. Sparcely disseminated pyrite is locally present. The rock weathers light to medium gray, and can be distinguished by color on distant outcrops from the more brownish gray weathering greenstone.

In a few places flamboyant folding of interbedded limestone and chert indicate plastic deformation shortly after the rocks were deposited. These folds indicate that the silica content is original and not due to silicification of a pre-existing limestone.

Near the southeast part of the mapped area a black slate bed about 600 feet thick is present. It is overlain by about 100 feet of dolomite. Black slate is also present in the extreme southeast corner of the mapped area, but the outcrop was not visited.

The limy chert and graywacke unit grades into the overlying sedimentary greenstone through a distance of roughly 15 to 50 feet. Foliation in the greenstone and small quartz veins in the LCG indicate that some shearing has taken place along what appears to be a sedimentary contact.

11. Volcanic graywacke (greenstone) - A non-foliated, greenish-gray rock with roughly 20 percent dusky-red oxidized patches and layers and numerous epidote veinlets; mainly quartz-albite-chlorite rock. It has no clear cut bedding but in places south of Summit Lake the rock has three to four foot beds(?) bounded by irregular surfaces. Rounded greenstone "mudballs" up to three feet across were seen at two localities. These have slickensided surfaces and are aphanitic greenish gray in a similar, but darker, matrix. North of the lake cherty clasts are common and the rock is cut by irregular, replacement quartz-calcite veins. The chert clasts are partly resorbed and converted into banded vein quartz. In places the greenstone is a sand-sized volcanic sediment. North of the lake this unit is more sheared and has a cracked appearance in weathered outcrops. It is in irregular sedimentary contact with the overlying chloritic chert.

12. Greenstone-chert - This unit contains cycles of lenticular greenstone and chert layers from 50 to several hundred feet thick (*figs 5 & 6*).

Chert - Translucent light gray, aphanitic, massive to locally schistose with sparse disseminated pyrite. Undulating bedding planes, beds thin to two feet. Weathers pinkish gray, yellowish gray, light greenish gray, and light brown. The more pyritic areas weather to a moderate brown gossan. Much of the chert contains chlorite and sericite and is somewhat foliated or platy.

Greenstone - Aphanitic to fine-grained, massive to slightly foliated due to crude orientation of chlorite. It is composed of albite or oligoclase, hornblende, chlorite, quartz, and minor garnet, magnetite, and pyrite. Originally it was silt to sand sized volcanic sediment, submarine pillow lava flows, and fine-grained diabase dikes.

Post regional metamorphic reheating in the greenstone is indicated by the variable composition of plagioclase (albite to oligoclase) and the presence, in a few places of unrotated sieve-textured garnet. These minerals indicate the rocks were locally raised to a higher metamorphic grade than the albite-bearing volcanic graywacke (greenstone) south of Summit Lake. The source of heat is the many quartz diorite sills and dikes exposed on the ridge north of Summit Lake.

Interbedded volcanic graywacke, basic lava flows and impure chert form a typical eugeosynclinal assembledge. There is no limestone or banded siltstone in this unit.

13. Siltstone-limestone-impure chert - Clastic bedded sedimentary rocks predominate: siltstone, limestone, argillite, volcanic graywacke (greenstone), graywacke, impure chert, and lava flows (greenstone). (*figs 5, 6, & 7*)

Siltstone - greenish gray, banded, composed of quartz, hornblende, biotite, and carbonate.

Black argillite - may be interbanded with siltstone, also as large units which grade into siltstone.

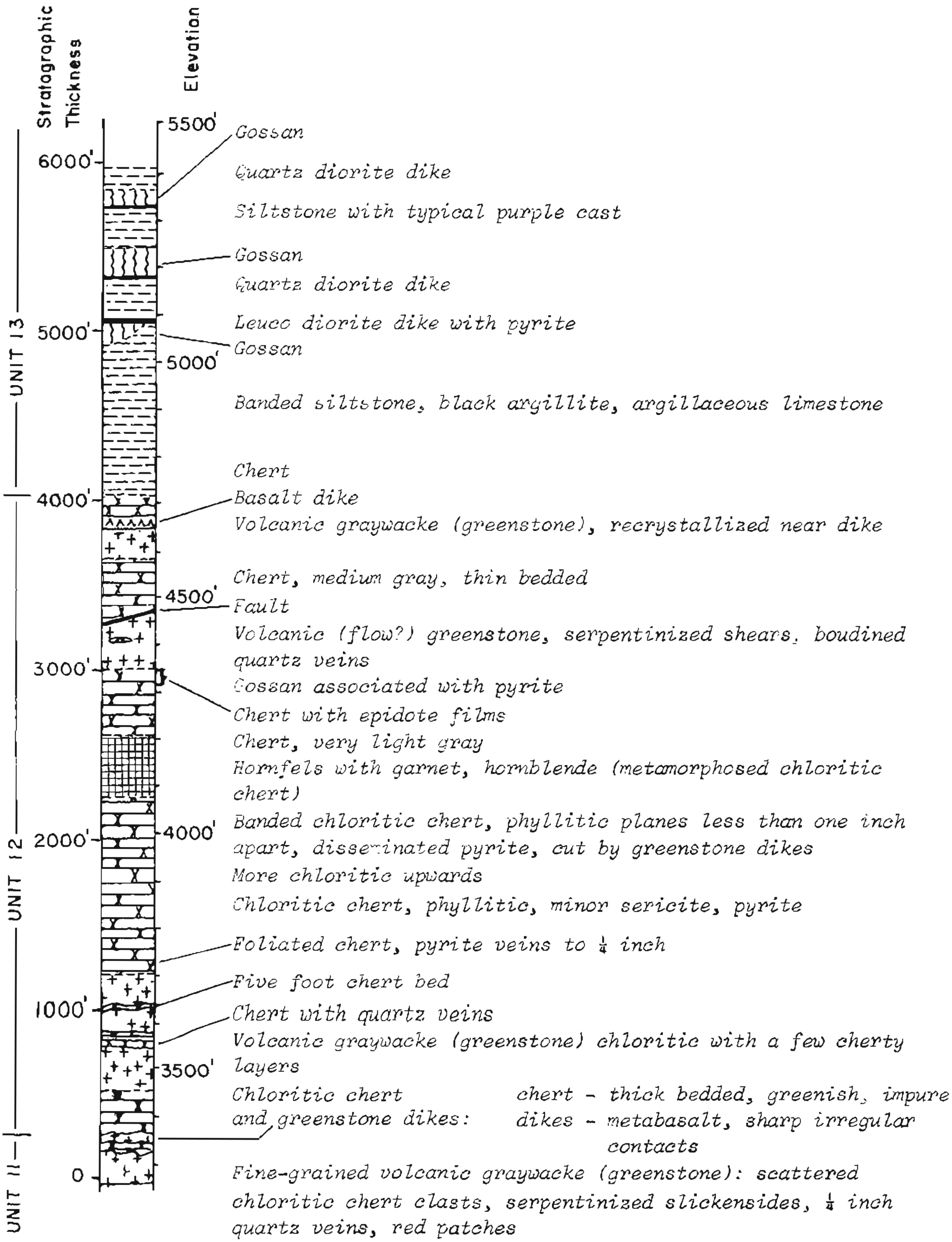


Figure 5 SECTION B, UP A CREEK NORTH OF SUMMIT LAKE
Altimeter traverse, thicknesses are only approximate

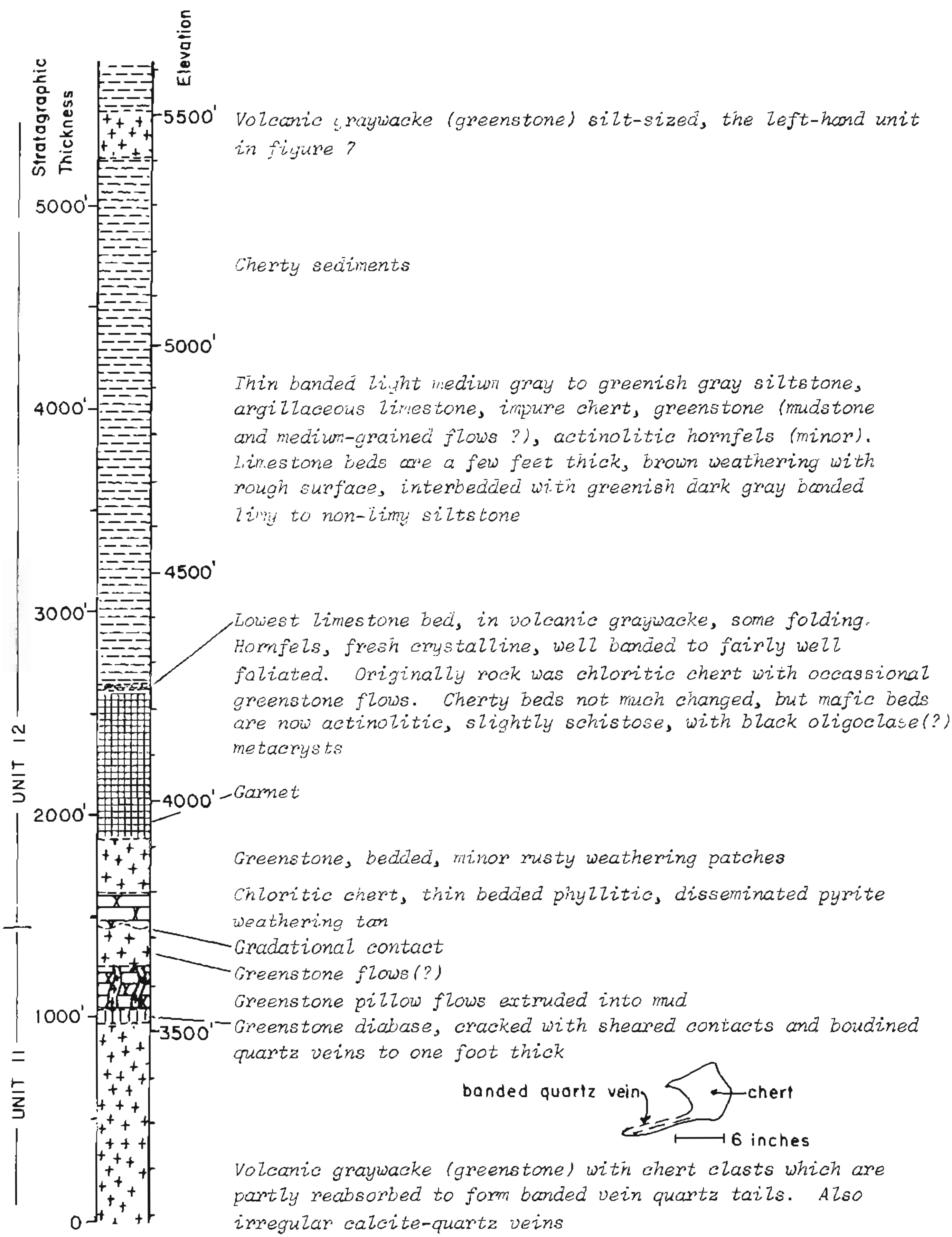
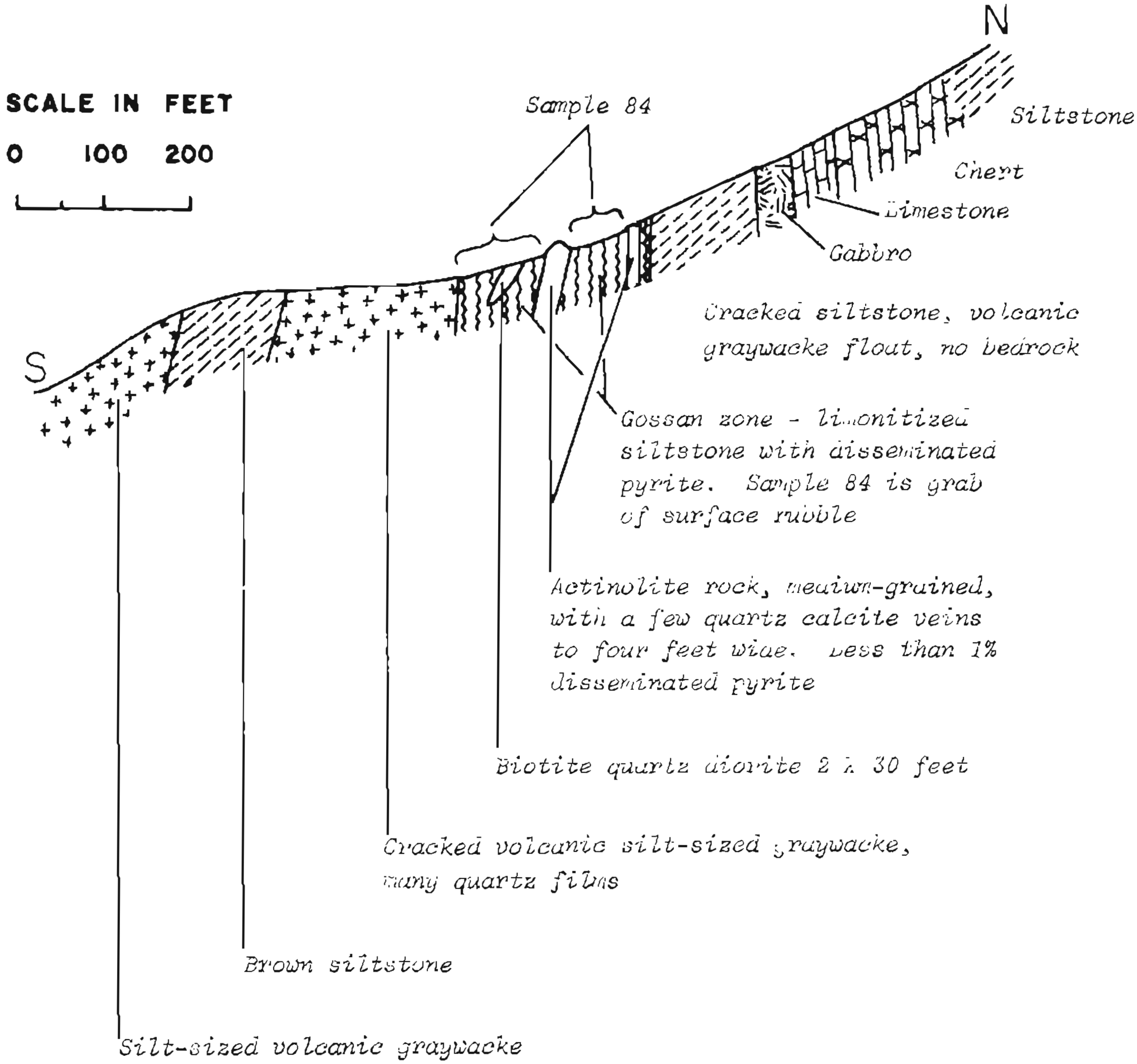


Figure 6 SECTION C, NORTH OF SUMMIT LAKE
Altimeter traverse, thicknesses are only approximate

Figure 7 CROSS SECTION SKETCH OF A GOSSAN ZONE ASSOCIATED WITH QUARTZ DIORITE DIKES NORTH OF SUMMIT LAKE, ELEVATION ABOUT 5550 FEET



Mineralized zone is 180 feet of moderately limonitized chlorite-quartz siltstone with two layers of actinolite rock (amphibolitized siltstone). No copper stain. Pyritization is probably related to the quartz diorite dike. A grab sample of surface gossan material contained 35 ppm copper, 170 ppm lead, 115 ppm zinc, 1.4 ppm silver, and less than 0.02 ppm gold.

Limestone - chloritic, fine-grained, medium light gray, slightly foliated; weathers greenish gray with rough surface.

Volcanic graywacke (greenstone) - silt sized, light-medium-gray rock containing "floating" rounded aphanitic greenstone clasts that do not touch one another. A volcanic mudflow deposit.

Impure chert - light medium gray, beds up to a foot or more thick with undulating contacts.

Volcanic flows (greenstone) - medium-grained, non-foliated, chloritic, unbedded.

Dioritic intrusives affect the different rock types in various ways. Siltstone near many dikes is brecciated and somewhat sheared (*B on fig 3*). The resultant rock has siltstone clasts in a silicified matrix and weathers light brown. Near some intrusives graywacke is cracked, silicified, and shot through with quartz veinlets. This rock forms prominent blocky cliffs north of the west end of Summit Lake. Near sills chert carries disseminated pyrite which forms bright gossan zones high on the ridge north of Summit Lake.

14. Quartz diorite - Medium-grained dikes and sills with compositions ranging from nearly pure feldspar to nearly pure hornblende form a swarm of intrusives on the ridge north of Summit Lake. These are mostly quartz diorite to granodiorite. The mafic mineral is mostly hornblende, but biotite is present in some bodies. Moderately colored gossan zones (described under #13) in the adjacent sediments indicate a minor but widespread addition of pyrite to the wall rocks.

15. Quartz monzonite - Light gray, medium-grained, well jointed rock made up of quartz, partly sericitized oligoclase feldspar, microcline perthite, and about five percent partly chloritized biotite. An intrusive igneous rock.

16. Greenstone - Fine-grained, greenish-gray, amygdaloidal greenstone without banding. Contains shreds of partly chloritized hornblende in a matrix of sausuritized albite, epidote, and sphere. Probably originally andesitic flow rocks.

17. Limestone - Medium gray, light olive gray weathering, thin bedded, slightly foliated, crinoidal limestone. Fossils are abundantly visible on weathered surfaces. Concerning this bed, Moffit (1914, p 20) states:

> "Fossils were collected from a highly siliceous thin-bedded limestone exposed on the ridge between Divide and Falls creeks. They appear only on the weathered surface of the limestone and were obtained with considerable difficulty. G. H. Girty, who examined the two lots both collected at the same locality, makes the following report on them:
>
> These collections contain the following:
>
> 11 AC 40. Crinoid stems very abundant and some of them very large; other specimens possibly inorganic but having a shape suggesting the genus Productus.
>
> 11 AM 43. Crinoid stems very abundant; Zaphrentis? sp. The Zaphrentoid coral appears to be a Paleozoic type; and from the abundance and size of the crinoid stems and the wide distribution of Carboniferous rocks in Alaska it seems probable that the horizon is Carboniferous."

18. Siliceous slate - Thin bedded black slate, banded green and black slate, chloritic argillite, aphanitic meta-andesite(?) sills or tuff, layers (10-20 feet thick light gray, unbanded), meta-diorite sills (100 feet thick, sheared, chloritized). These rocks give a brownish small-blocky talus, which even at a distance is distinctive from the greenish talus of the greenstone. A large area north and west of the map area is underlain by similar(?) sediments with dark brownish gray, yellow- and reddish-ochre talus.

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Errata

Page 12. The first sentence in the second paragraph of Section 6 should read -- Brief descriptions of the various bodies indicates their diversity: (letters A thru E shown on fig 2, F thru G shown on fig 3).

Page 13, section 8. The last parenthesis in this paragraph should read -- fig 3 instead of fig 1.

Page 13, section 9. In the first sentence PTLCG refers to rock unit 4 (partly transformed limy chert and graywacke) and LGC refers to rock unit 10 (limy chert and graywacke).

Figure 2. On the detail of the adit at about 3580 feet elevation, the dike in the adit is shown as peridotite (unit 7). It is hornblendite (unit 6) and is described under 6A on page 12. Letters B thru E on this figure give locations of rock descriptions given on page 12 and 13 of text.

Table 2. Sample 18D contains 6.2% nickel and 3.4% copper.
Sample 18E contains 2.5% nickel and 1.6% copper.