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IGC GUIDEBOOK
EXCURSION A06-C06

in this ice field. For the next couple of miles (3 km) the bus will be passing through a "belt of dykes" which strikes easterly and southeasterly for more than 40 miles (64 km). Within the belt are innumerable large and small quartz-feldspar porphyry dykes, some parallel and some forming linked, braided structures. Light-coloured rocks seen at intervals along the road cut and prominently visible across the Salmon River glacier, south of the tributary glacier, are some of these porphyry dykes. On the 49-Summit to the right a number of high-grade silver showings occur in volcanic rocks along dyke contacts.

Mile 22 (Km 36) The ice-choked surface of Summit Lake appears on the left, its pre-1958 beach being clearly marked. In that year, the lake discharged suddenly southward beneath the Salmon glacier, extensively damaging the road and other works downstream in the Salmon River valley. Since that time the lake has discharged several times but has never regained its 1958 level.

The old buildings seen to the left across Summit Lake near the toe of a small glacier mark the site of the Morris Summit mine, which was extensively developed by several adit levels but never achieved production. The ore bodies, localized along westerly-trending shear zones, consisted of massive replacements of pyrite, pyrrhotite and arsenopyrite with moderate to locally high values in gold. Because of its high arsenic content the ore was refractory to ordinary milling methods. The deposits are in fragmental volcanic rocks, pyritized and epidotized peripheral to an eastward-projecting lobe of coarse-grained granodiorite.

Mile 25 (Km 41) Slaty rocks along the road cuts, closely folded with well-developed axial plane cleavage are part of a small projection of the Upper Jurassic Bowser Group, which to the northeast attains thicknesses of as much as 10,000 feet (3,050 m). The surface plant of the Granduc mine at the southern end of the Tide Lake valley can now be seen ahead. The flat gravel floor of this valley is the bed of former Tide Lake which was released in 1947 by melting of the Frank Mackie glacier which formed an ice dam at its northern end about 10 miles (16 km) north of the Granduc townsite.

VISIT TO GRANDUC MINE

0800 to 2000 hours

The following article on the geology of Granduc is reprinted from "Tectonic History and Mineral Deposits of the Western Cordillera;" Canadian Institute of Mining and Metallurgy, Special Volume #8, 1966. The geological picture has not changed appreciably since that time. Published ore reserves total more than 43,000,000 tons averaging 1.73% copper. Mill capacity is 8,600 tons per day. A unique feature of the operation is its 10.6-mile (17 km) mine access tunnel.

RELATION OF ORE TO FOLD PATTERNS AT GRANDUC, B.C.*

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Abstract

The Granduc ore bodies occur in a folded metasedimentary member 200 feet thick between a thick massive porphyritic andesite footwall and a limestone hangingwall 40 feet thick which underlies argillite and greywacke. These formations are Triassic in age and lie one mile east of Coast Range granodiorite. The structuro at Granduc consists of cross folds and faults striking N.N.E. across earlier-formed N.W. folds. Drag folding accompanied both the earlier folding and later cross folding.

The latest drag folds are nearly at right angles to the trend of earlier folds. Granduc ore bodies occur in folds striking N20°E which are parallel to the latest drag folds of the area. The plunge of ore bodies roughly coincides with the average plunge of nearby drag folds. The south plunge of drag folds and ore bodies appears to steepen with depth and may reverse to a north plunge in the deeper levels of the mine.

Introduction

The Granduc deposit, now being prepared for production, lies four miles east of the Alaska Panhandle and 560 miles in a straight line northwest of Vancouver. Stewart, the nearest town, is 25 miles southeast at the north end of Portland Canal and provides port facilities for ocean going vessels.

The first recorded discovery of mineral in Granduc Mountain was made by Wendell Dawson and W. Fromholz on a prospecting trip up the Leduc River to its source in 1931. (Annual Report, Minister of Mines B. C. 1931, page 47). Claims had been staked on Unuk River, 9 miles north of Granduc, as early as 1899 but there is no record that prospectors at that time followed the Unuk Glacier to its source at Granduc Mountain. It is even probable that in 1900 the lower Granduc showings were concealed by ice of the glacier which is decreasing in elevation at an annual rate of about 10 feet.

*Permission from Granduc Mines, Limited to publish this contribution is gratefully acknowledged.

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The copper showings at Granduc Mountain were subsequently staked in 1951 for Helicopter Exploration Co. Ltd., by E. Kvale and T. J. McQuillan. Granby Mining Company examined the claims in 1952 and started the surface and underground exploration of the property in 1953. Granby was joined by Newmont later in 1953 to continue the underground exploration work. Total work to date consists of approximately 18,500 feet of drifting and crosscutting and 361 diamond drill holes totalling 138,600 feet. The work has been done 3600, 3100 and 2475 feet above sea level. A 560-foot raise connects the 3600 and 3100 levels; and a 625-foot shaft connects the 3100 to the 2475. The bulk of the drilling has been carried out underground with holes averaging 384 feet in length. Surface drilling amounts to about 22 percent of the total with holes averaging 600 feet in length.

General Geology

The deposit lies in a northwest-trending belt of Mesozoic volcanic and sedimentary rocks, assigned to the Hazelton Group, close to the east side of the "Coast Range Batholith" of granitic rocks. The sedimentary rocks in which this deposit occurs are unfossiliferous at Granduc Mountain, but can be traced north into beds at Unuk River containing fossils of Upper Triassic age (Karnian). These are overlain by argillite, andesite, greywacke and a conglomerate with granitic boulders. The conglomerate is part of sedimentary beds containing early Jurassic (Hettangian) fossils. The Coast Range Intrusives may include, therefore, members of Triassic or earlier age.

The intrusive rocks at Granduc belong to three main groups whose relative ages are not certainly established. The oldest group is apparently confined to an area of Triassic rocks and consists of crosscutting stocks and irregular bodies ranging from diorite to granodiorite. The granodiorite of the oldest group is well foliated, suggesting introduction during deformation, but the diorites are unfoliated and in part are intensely sheared and converted to chloritic schist. Andesite and andesite porphyry dikes occur in the mine. These predate the ore and have been strongly sheared and folded. They may be assigned to the oldest of the three igneous suites (Triassic?) or to a cupriferous syenite group (post-early Jurassic) that occur directly north of the mine area.

The other two groups of intrusive rocks are unfoliated. One group occurs as a northwesterly dike swarm, which crosscuts the Granduc ore zone and consists of diorite and quartz diorite with chilled margins of andesite. These dikes are offset a few hundred feet by the latest movements on the Granduc and other parallel faults. Although clearly faulted by the late fault movements, they do send out sill-like extensions within or marginal to the Granduc fault zone, suggesting that the early fault movements predate the dike swarm injection.

The Coast granodiorite masses, which are the other unfoliated group at Granduc, have not been seen to contact the dike swarm. The general evidence suggests that these masses are also faulted by the late movements on the Granduc fault, but were emplaced either after or very late in the series of events that produced the complex fold-fault patterns at Granduc. A large specimen with biotite alteration, associated with the ore, was taken by Dr. E. D. Kindle of the Canadian Geological Survey, and may provide data on the age of the ore. This might supply information on the relative age of the Coast Range granitic rocks and the Granduc structures.

Geology of Granduc Mountain
(see Fig. 19-1)

Ore Horizon. The Granduc ore bodies A, B, C and F, now being developed, see Figures 19-2,-3 and -5, lie in a sedimentary unit 200 feet thick, the ore horizon, between a limestone member above and a porphyritic andesite member below. Figures 2 and 3 indicate that mineralization is virtually continuous in the ore horizon. The larger ore bodies are connected by strands of weakly mineralized rock. The E and D ore bodies,, not shown in the figures, are wider sections of the connecting strands between C and F ore bodies. It has been possible to trace the altered strata in the ore horizon into less altered types in a few places. The less altered phases are fine grained, well laminated argillites, silty argillites, argillaceous siltstones, and medium grained feldspathic and andesitic tuff. Recrystallization of these rocks in the ore horizon has converted the fine grained laminated rocks to extremely well compositionally banded, brown to pale grey quartz-rich biotite and sericite rocks, which have been variously classed as schists, quartzites, and phyllonites. The feldspathic and andesitic tuffs are converted to massive, or banded biotite, and biotite epidote antinolite schists, which contain 10 to 40 percent quartz, 10 to 55 percent plagioclase, 5 to 25 percent actinolite, 5 to 20 percent epidote, with either brown and/or green biotite forming 15 to

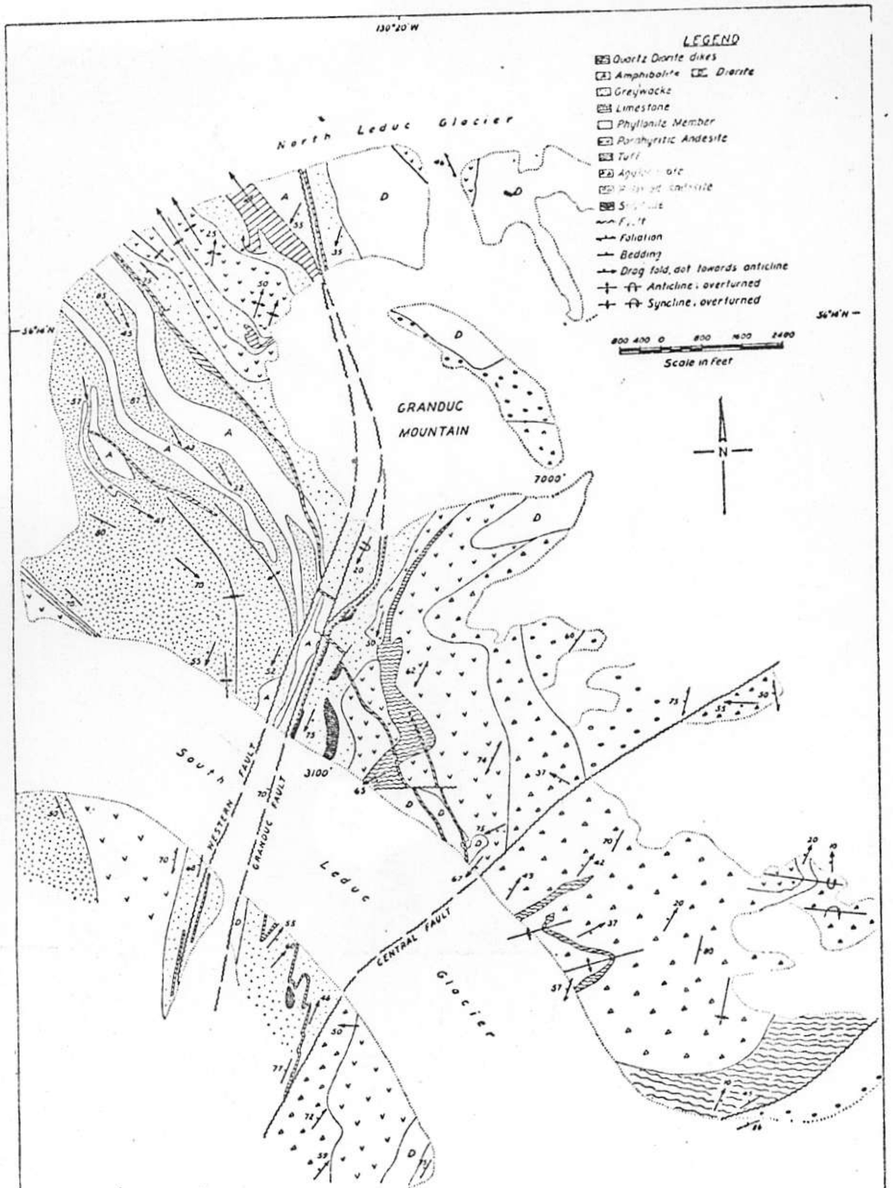

Figure 19-1

GEOLOGY AND STRUCTURE OF GRANDUC MOUNTAIN

SULPHIDE BODIES SHOWN IN DIAGRAMMATIC PROJECTION

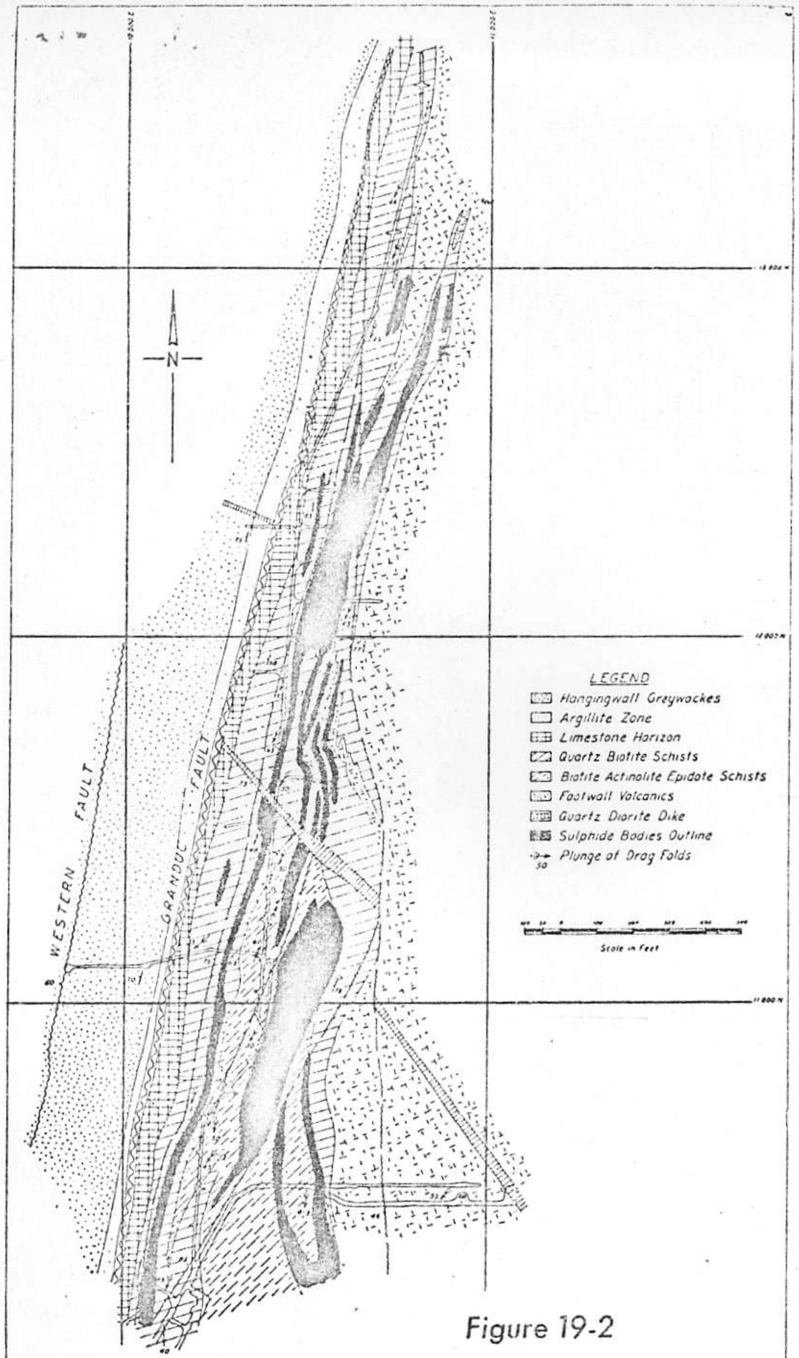

Figure 19-2

GRANDUC MINE – 3100' LEVEL

ROUTE MAP EXCURSION 06

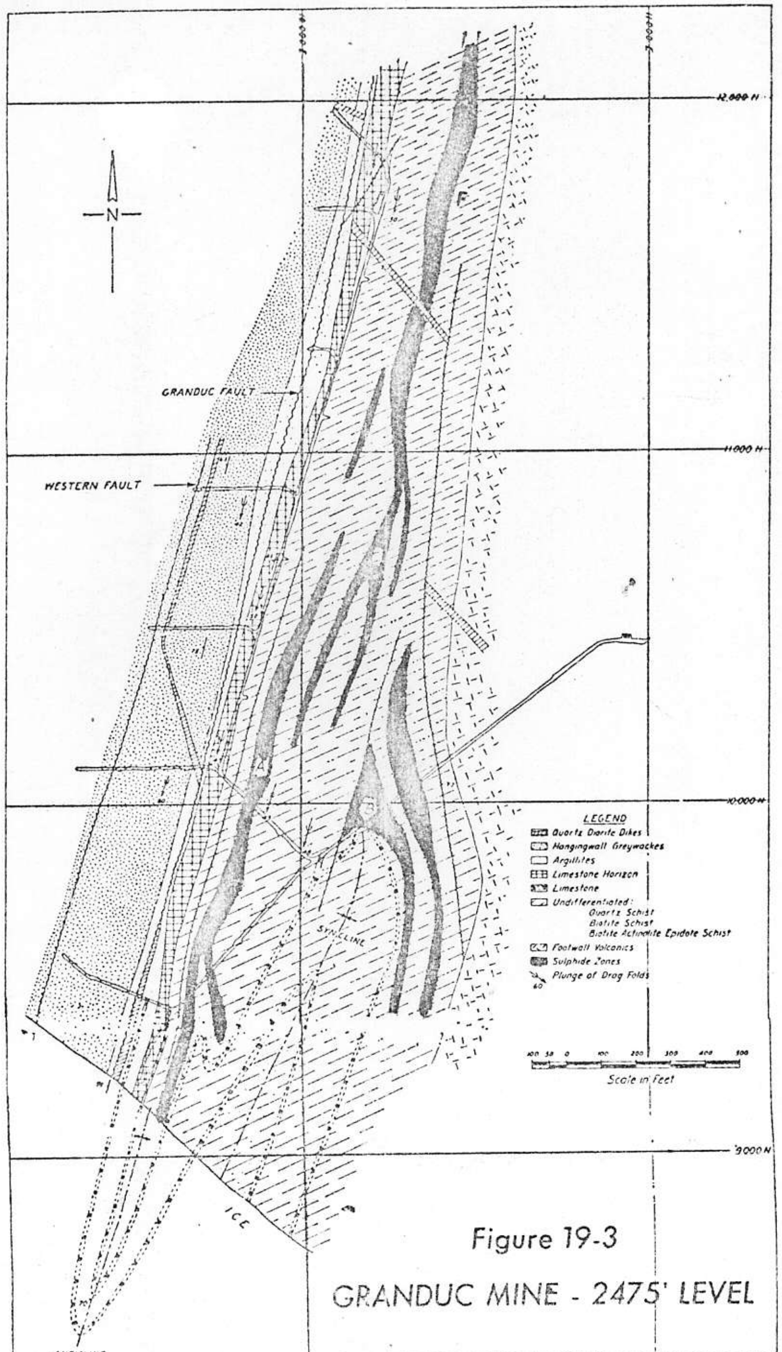

Figure 19-3

GRANDUC MINE - 2475' LEVEL

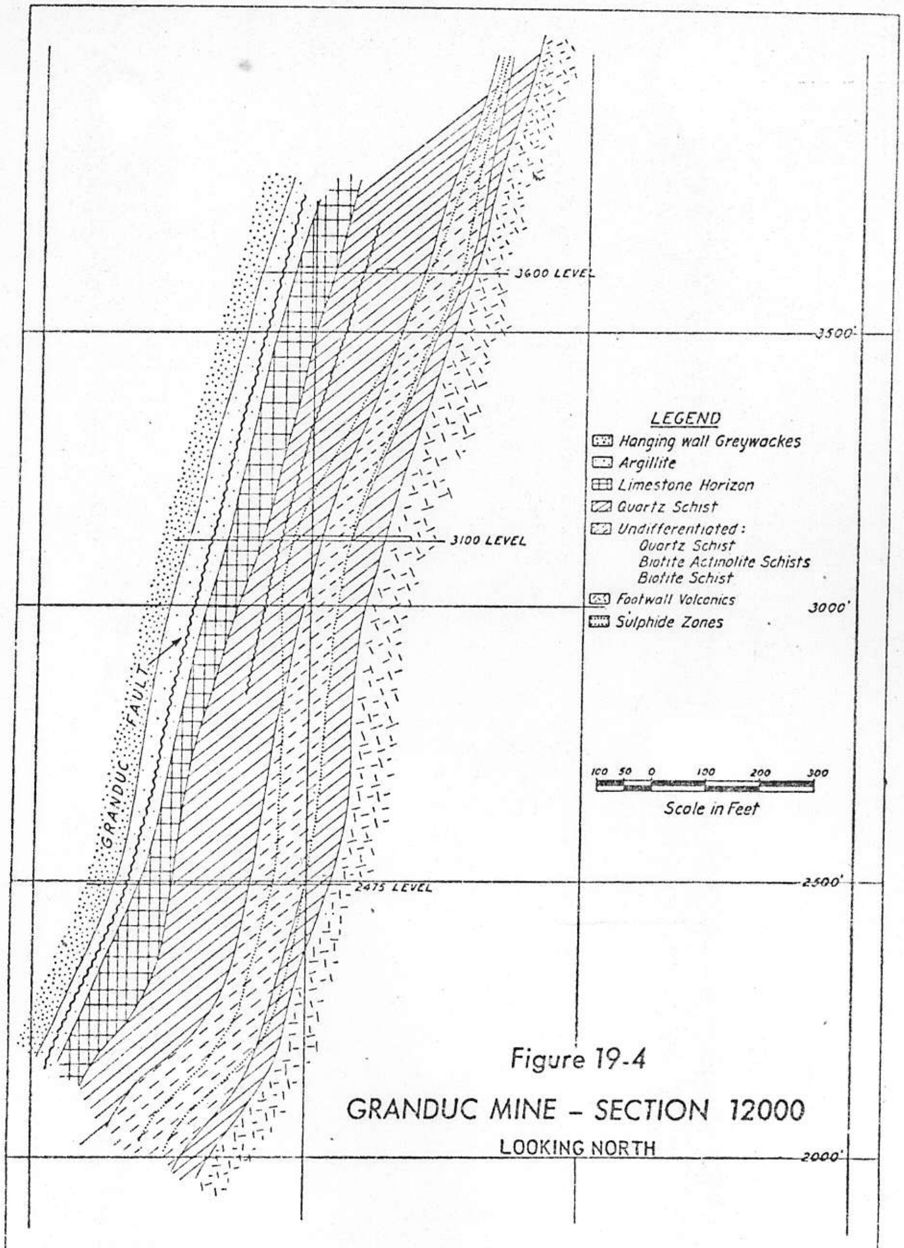

Figure 19-4

GRANDUC MINE – SECTION 12000

LOOKING NORTH

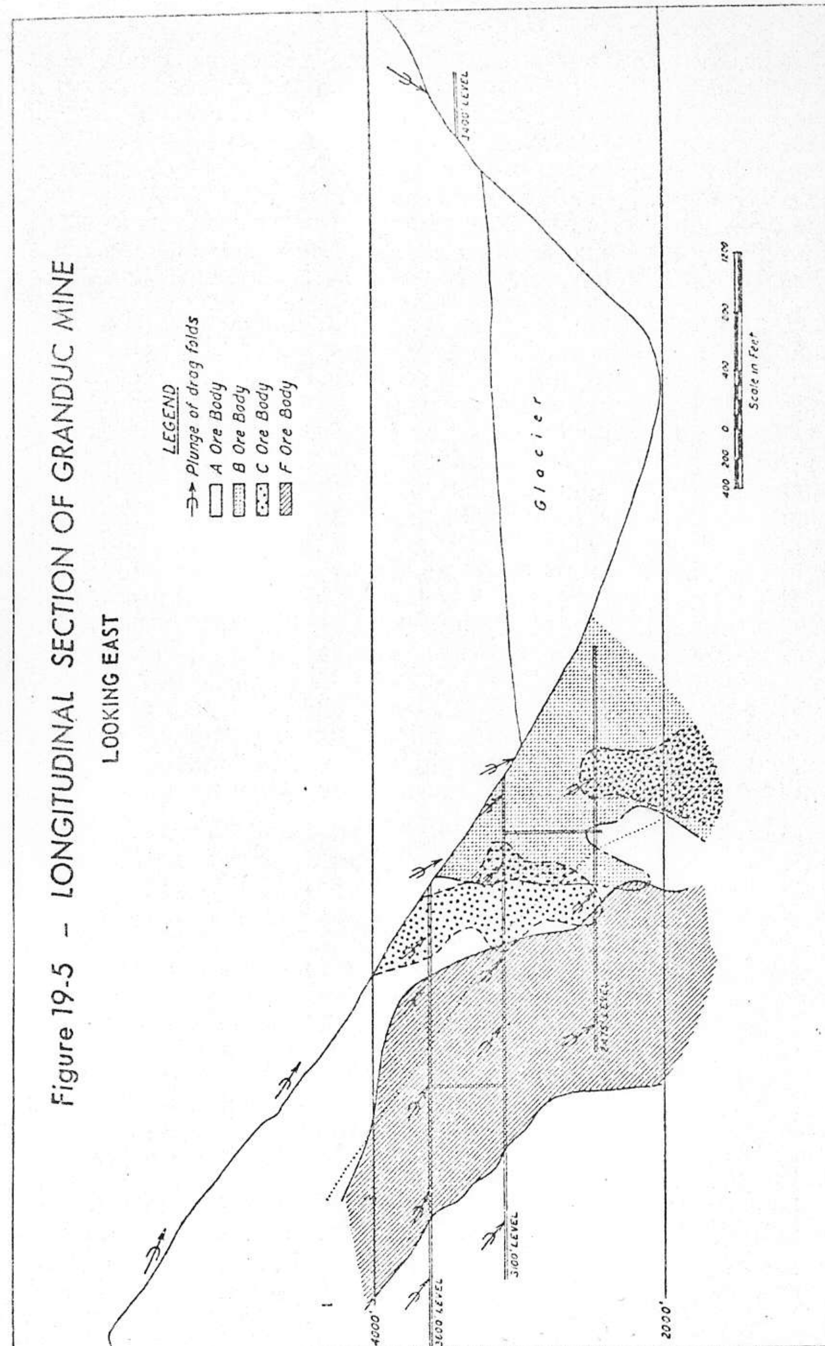

Figure 19-5 – LONGITUDINAL SECTION OF GRANDUC MINE

LOOKING EAST

45 percent. The more massive rocks are more common in the lower half of the ore horizon and form the host rock for the C ore body and the lower parts of the B and F. The A, and upper parts of the F and B, occur in the finely laminated quartz-rich brown biotite schists which are derived from silty argillites. The carbonate content of rocks in the ore zone averages 3 or 4 percent. Chlorite occurs in small amounts only. Tourmaline, zircon, sphene and leucoxene are characteristically present.

Hangingwall Strata. The limestone horizon on the west side of the A, C, and F ore bodies is about 40 feet thick and consists of several limestone beds, one to eight feet thick, interbedded with calcareous argillite that is partially biotitized, and is locally fractured and recemented by calcite. The limestone varies from pure carbonate rock to arenaceous varieties with a high content of sand grains or small fragments of volcanic rocks. The limestone horizon, west of the B ore body and on the south side of the glacier, contains a volcanic conglomerate member above the lowest limestone bed. This conglomerate bed is inconspicuous on the northern side of Granduc Mountain, and may wedge out to the north. The rocks above the limestone horizon form the west side of Granduc Mountain west of the Granduc ore zone and consist of brown biotite-rich greywacke locally grading into altered argillite or green argillaceous greywacke or tuffs. They are interlayered with old diorite sills, that have been altered to amphibolite and hornblende schist.

Footwall Rocks. The andesite member below the ore horizon consists of porphyritic andesite with small to conspicuously large hornblende or altered augite phenocrysts. These rocks contain members with a uniform massive appearance suggesting flow rocks and have vague structures resembling pillows southeast of the mine. The most common type contains fragments identical in composition to the enclosing matrix but lighter in colour. The fragments may be drawn out to several times their original length, and the rocks may be so highly cleaved and foliated and they have the appearance of thin-bedded tuffs er sediments. Interbedded with the andesite member are thin well-bedded andesite tuffs, similar in gneral appearance to members of the ore horizon.

The porphyritic andesite member is in contact on the east with well-pillowed andesite lava. These rocks underlie the east side of Granduc Mountain east of the ore zone, and are cut by diorites.

Folds. The contacts of the ore horizon with the limestone horizon above, and the porphyritic andesite below, provide marker horizons for determining the broader aspects of the structure of the mine as indicated on the accompanying level plans (Fig. 19-2 and 19-3) and cross section (Fig. 19-4). Complex stretching and internal minor crumpling, folding, and thickening, are present. The A, C, and F ore bodies lie in a south-plunging anticlinal structure with an east limb that has been partially eliminated by shearing. The B ore body lies on the east limb of a syncline directly east of this anticline. On the 2475 level, the B ore body thickens toward the axial part of this syncline.

The axial planes of the mine folds trend N 20° E, and dip about 70° west, roughly parallel to, or slightly divergent eastward from the Granduc Fault, which also dips about 70° west. This fault is a bedding plane fault along argillites with a deep gully as strong surface expression. It lies a few hundred feet in the footwall of a much larger west-dipping fault. Along the larger fault, called the Western Fault, rocks have been converted to a speckled green-white carbonate chlorite breccia in a zone about 100 feet wide. The Western Fault separates the N 20° E trending folds of the mine from flexed folds on the western side of Granduc Mountain. The flexing warps folds striking about N 35° W at the northwest end of the mountain to a trend nearly parallel to the Western-Granduc Faults on the west side of the Granduc ore zone.

Axial planes of folds 7,000 feet southeast of the mine strike N 73° E and dip steeply north. Surface mapping eastward indicates that the axial planes of these folds swing from N 73° E to S 86° E in 5,000 feet. In the east end of the mountain, where folds striking S 86° E disappear beneath permanent snow and ice, they are overturned south with axial planes dipping about 30° north. The east-striking folds, east of the mine, are separated from the mine folds striking N 20° E by a large fault called the Central Fault.

Granduc Mountain is, therefore, broken into three main fault blocks by the Western-Granduc Fault on the west, and Central Fault on the east. If the pattern of folds in plan at Granduc Mountain is followed across the fault blocks from northwest to southeast, it will be seen that the Northwest Cordillera trend at the northwest corner of Granduc Mountain is flexed to the N 20° E direction at the mine; east of the mine the trend is N 73° E, and farther east S 86° E. This pattern suggests that the earlier Cordillera-trending folds were gradually buckled south-westward by forces acting nearly parallel to the Cordillera trend. The buckling or cross folding, developed by these forces, was followed or accompanied by cross faulting which broke the structure at Granduc Mountain into the three main fault blocks. The older northwesterly-trending folds on the north side of Granduc Mountain are crossed by minor folds trending N 15° E. The minor folds are roughly parallel to the mine folds and the Western-Granduc Fault zone. They furnish evidence that folding was superimposed on folding at Granduc Mountain. No attempt has been made to date the various folds. It seems plausible to assume that the deformation of rocks at Granduc Mountain was a continuous process that started with initial buckling of earlier-formed folds to the point of rupture and cross folding without any slackening of the compressional stresses producing the deformation.

There is clear evidence underground that the Granduc ore was emplaced after the host rocks at the headwaters of the Unuk and Leduc rivers were opened by a very conspicuous set of joint planes, dipping gently north, along which quartz was introduced to form a multitude of veins, one to twelve inches wide, containing pyrite and traces of chalcopyrite. The system of joints indicates that tensional forces acted on the rocks before the ore was introduced and provided openings for short spurs of sulphide that extend out from ore bodies. Biotitization of wall rocks along the quartz veins is conspicuous locally for distances of one foot or more, and is indistinguishable from strong biotitization of the host rock of all Granduc ore bodies.

Drag Folds. The strike and dip of the axial planes of folds give the pattern of folding in plan. The plunge of the major folds is indicated to some extent at least by the pattern of drag folding, which is well developed in the bedded sedimentary rocks, and to some extent in foliated metamorphic rocks.

Directly east of the Granduc Fault, on the south slope of the mountain, the plunge of drag folds increases from about 20° south at the top of the mountain to about 65° south near the glacier below the 3100 Level. On the south side of the glacier, opposite the 3100 Level, the plunge of drag folds is about 60° north. The change from 20° to 65° south down the mountain north of the glacier to 60° north 3500 feet further south on the south side of the glacier suggests a continuation of the steepening of drag fold axes to vertical and finally to the overturned north plunge on the south side of the ice. The accompanying longitudinal section (Fig. 19-5) indicates that there is an apparent relationship between the directions of plunge of the ore bodies and the drag folds.

Drag folds form one of the ore controls of the mine. The ore bodies are "stringer lodes" of disseminations, specks, streaks, stringers, and irregular masses of chalcopyrite, pyrrhotite, magnetite, and minor pyrite in crumpled zones. Sulphide replacements along the crests of minor folds are conspicuous in ore bodies, and in general, the better grade sections of ore bodies are in the parts that have been most intensely crumpled by small drag folds.

Drag folds formed throughout the entire period of deformation at Granduc. Initially drag folds formed as minor structures on flanks and crests of Cordillera-trending folds trending N 30° to 35° W on the west side of Granduc Mountain. On the west side of the Western-Granduc fault, on the north side of Granduc Mountain, the Cordillera folds are crossed by a set of minor folds trending N 10° to 17° E that plunge 35° to 50° north. Folds with amplitudes of 100 feet ± and axial planes trending S 86° E, near the permanent snow line east of the Central Fault were overturned southward first and subsequently cross folded by drag folds (amplitude 10 feet ±) striking north. In these two cases, the plunge of drag folds appears clearly to be controlled by the attitude of beds prior to drag folding.

Drag folds in the "Ore" block between the Granduc and Central Faults increase in plunge southward from 20° to 60° on the south side of Granduc Mountain, to 60° north across the glacier to the south. The increase southward may be due to overturning of larger folds before drag folding developed or to internal differential rotation of the block. The internal differential rotation may have developed by revolution about a horizontal axes as this block was wedged southward between the blocks on either side.

Drag folds in the "Ore" block northwest of the Central Fault on the north side of the glacier plunge south with a 90° discordance to the north-plunging drag folds southeast of the Central Fault. The sharp discordance is compatible with a strong northeasterly offset of the S.E. block, or uplift of the S.E. block exposing north-plunging drag folds believed to occur deeper down in the Ore block.

Drag Fold Anomalies. Drag folds in the mine, with few exceptions, were formed by a relative movement of west side south and up. This couple of forces produces the same effect as is produced during the relative slippage of beds on the west side of a south-plunging anticline. The important exceptions lie in a narrow zone between the C and the A and F ore zones. In this anomalous zone, the relative slippage is reversed with west side south and down and the drag folds produced by this action plunge northward. The movements indicated by the anomalous zone are of an order of magnitude that seems unlikely to terminate abruptly, and may represent a form of shear in which the shear planes are sufficiently widely spaced to permit deformation by differential laminar flow, (O'Driscoll, 1964).

Along strike to the north where this zone passes into the massive andesite, there is evidence that this structure becomes a true shear zone, in which massive andesite is converted to a schist.

Dikes and Channelways. Folds at Granduc are cut by a series of andesite porphyry dikes ranging from inches to ten feet or more wide, that apparently are related to the earliest intrusive phase. Some dikes are intensely schistose and drag-folded and even the phenocrysts have been contorted by micro drag folds. The dikes cut through folds and, though in part folded, must have been injected after the folding was established. The dikes are closely associated with mineralization, and acted apparently as channel ways for mineralizing solutions. This is suggested by the common occurrence of concentrations of sulphides along their margins although the dikes internally are in general only very slightly replaced by ore. Solutions appear to have used faults and dike zones as channels to reach the contorted drag-folded zones in which they deposited their mineral content to form ore bodies. The available workings at Granduc have not yet supplied clear evidence on the exact localization of ore bodies in the crests, axial planes, or limbs of the folds. The tabular nature of some of the ore bodies rules out the crests of folds as a single control.

Summary and Conclusion

The structural pattern at Granduc is interpreted as an example of folded and faulted folds. The cross folding was one of the important preparatory conditions which controlled ore emplacement. The ore was deposited after injection of dikes which crosscut folds. Dikes form an important ore control and their age relative to the folds and to the sedimentary rocks should rule out a syngenetic origin for the

ore. Introduction of chalcopyrite was preceded by much magnetite, epidote, actinolite and small amounts of garnet.

Tourmaline (schorlite) is present in small streaks parallel to bedding throughout the Granduc deposit. The only intrusive rocks in Granduc Mountain that are known to contain tourmaline are small bodies of light-coloured diorite (albite syenite), and the amount of tourmaline in the rocks appears to increase towards this diorite.

Green and brown biotitization of the wall rock is closely associated with the ore. A study of this alteration should define the area affected by ore solutions and indicate whether the diorite and the ore have a common origin.

END

SHIP'S LOG, continued

Aug 13
0400 hours — The ship has turned from Portland Canal with its massive granitic rocks and its unmetamorphosed volcanic pendants into Portland Inlet, where the massive granitic rock gives place to granitic gneiss and dark-coloured migmatite, much of it essentially amphibolite. Foliation trends "box the compass". Dips are low to moderate. Both migmatite and granite gneiss are crossed with white pegmatite and feldspar augen are plentiful.

0530 hours — Turning south into Chatham Sound, land in sight to port, of low to moderate relief, is the Tsimpsean Peninsula which extends 30 miles (50 km) southward nearly to the Skeena River. This peninsula and fringing islands are composed mainly of metamorphosed and strongly deformed sediments which originally included unknown but probably great thicknesses of thin-bedded greywacke and shale, with some beds of limestone and dolomite, but with little or no volcanic products. These rocks, in large part converted into quartzite, mica schist, slate and calc-silicates, are intensely deformed into low angle or recumbent and isoclinal folds and domes. The age of the rocks of the Tsimpsean Peninsula is unknown but is most likely Paleozoic. These rocks may well represent a southern continuation, displaced some 50 miles (80 km) eastward, of the Ordovician to Permian strata of the Alaska Panhandle. Dundas Island and other outer islands seen in the distance to starboard consist of volcanic rocks of probably Mesozoic age intruded by large and small bodies of unfoliated quartz diorite.

0700 hours — The city of Prince Rupert, population about 17,000, concealed behind low lying Digby Island to port. Digby Island and the other small islands in the vicinity are composed of isoclinally folded sub-horizontal sediments.

0800 hours — Porcher Island, the large island to starboard, consists of both metavolcanic and metasedimentary rocks intricately folded and intruded by foliated quartz diorite.