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STRUCTURAL GEOLOGY OF EMPIRE MINE

EMPIRE DEVELOPMENT COMPANY LIMITED

PORT McNEILL, B.C.

by

John C. Lund
B.Sc., University of British Columbia, 1962

A thesis submitted in partial fulfilment of

the requirements for the degree of

Master of Science

in the Department

of

Geology

We accept this thesis as conforming to the required standard.

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XREF 92L045 Kingfisher

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Foreword

Empire mine has been described by Jeffery (1960), Wittur (1961), Sangster (1964) and briefly by Eastwood (1965). Each of these writers has dealt essentially with general geology, mineralogy, geochemistry and ore genesis. Prior to this thesis no detailed examination has been made of structures and their relation to ore deposition.

Regional geology is based in part on work by Dr. W. G. Jeffery and in part on personal observations, as assistant to Dr. Jeffery in field seasons of 1960 and 1961 and as geologist for Empire Development Company Limited since 1962.

Both Merry Widow open pit and underground workings were re-examined, where possible, with special emphasis on structural relations. This work was supplemented by Company maps and reports by J. Lamb and the author.

It is hoped that this thesis may provide answers to at least some of the structural problems and possibly emphasize the importance of structural control in ore deposition.

Abstract

Empire mine is located on north-central Vancouver Island about two miles south of Benson Lake. Orebodies are typical of the many contact metasomatic iron deposits of the West Coast of British Columbia. They occur in Bonanza volcanic rocks and Quatsino limestone of Upper Triassic age near the margins of a small granitic stock of intermediate composition.

Structural controls at Empire mine are in part the configuration of the intrusion contact and in part the intersection of steep northeasterly faults with (a) folded and fractured volcanic rocks at the Merry Widow deposit and (b) with swarms of northwesterly striking greenstone dykes in the Kingfisher deposits. The Kingfisher fault transects both the Merry Widow and Kingfisher orebodies as well as the West Pipe and is considered one of the main channels for mineralizing solutions.

Relatively intense folding occurs near margins of the Coast Copper stock. In the Merry Widow area, plot of poles to bedding on Schmidt equal area net indicate a north-northwesterly plunging major fold. Superimposed on this are minor drag and disharmonic folds. Fold axes all strike northerly sub-parallel to the intrusion contact and folding is considered a direct response to emplacement of the Coast Copper stock.

Relation between intrusive greenstone and local folding would suggest that final stages of Bonanza volcanism, regional folding and emplacement of the stock with local folding and mineralization may be nearly contemporaneous.

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The Vancouver group is cut by a host of dykes, sills, and small irregular-shaped masses of greenstone. These intrusions vary in composition and texture but are essentially fine-grained greenish andesite, very easily confused with extrusive rocks of Karmutsen and Bonanza groups which they invade. Jeffery (1960) and Hoadley (1953) have suggested that these greenstones are genetically related to Bonanza volcanism.

Structural Geology

Rock units mapped to southeast and northwest of Empire mine, not affected by possible disturbance during emplacement of Coast Copper stock, have a persistent northwesterly-southeasterly strike and southwesterly dip. Jeffery (1960) has described these units as forming part of a southwesterly dipping monocline. Eastwood (1963) reports rocks resembling Karmutsen in character near Power River, 16 miles southwest of Empire mine. He has also noted a limestone unit, much thinner than Quatsino, overlain by rocks resembling those of Bonanza group. It is probable that rocks mapped in the Empire area form the eastern limb of a broad syncline folded about a northwesterly trending axis.

Bedded Quatsino limestone strikes northwesterly and dips southwesterly at 25^{o} to 35^{o}. Small variations in strike and dip reflect gentle flexures. Immediately east and extending along the Coast Copper stock, limestone strikes northerly, generally parallel to the axis of elongation of intrusion. At the north end of the stock it swings sharply northwest. At first glance the sharp change in strike appears to mark the nose of a southwesterly plunging syncline with Coast Copper stock intruded into this nose. Change to a northerly strike is confined to rocks adjacent to and east of Coast Copper stock. It is likely that this change in strike is due in part to intrusion of the stock. This stock, therefore, is not intruded into the nose of a southwesterly plunging syncline (Sangster 1964 p 185) but rather the rocks are deformed as a result of the intrusion. Where the intrusion has invaded volcanic rocks, these have only been mildly deformed. Where limestone is in contact with the intrusion, folding is more pronounced. In Craft Creek Quatsino limestone is folded into isoclinal folds against Coast Copper stock.

Faulting is prevalent in three sets: northwesterly, northerly and northeasterly faults. Northwesterly faulting is more prevalent in the Alice Lake area northwest of Empire. Here, along a ridge between Neroutsis Inlet and Alice Lake, a prominent northwesterly fault has thrown Quatsino limestone against Cretaceous sandstones (Jeffery 1962). Northwesterly faults near Empire mine show little or no displacement. The valleys of Kwois Creek to the south, Benson River, Maynard and Three Isle Lakes, east of the mine, form a prominent north-south topographic lineation that may reflect north-south faulting.

North-striking Benson River fault, east of Empire mine, has a left lateral displacement of one mile and a dip slip component of movement estimated as 4,000 feet. Faults repeat Quatsino limestone to the east. Northeasterly faults near the mine show small displacements only. Rainier, Merry Widow, South and Marten Creeks are expressions of northeasterly faults. These cut Quatsino limestone and Bonanza rocks as well as those of Coast Copper stock.

CHAPTER III LOCAL GEOLOGY

Magnetite at Empire mine occurs in limestone and volcanic rocks near the margin of the Coast Copper stock. The Merry Widow and Raven deposits are in a small wedge of volcanic rocks, the Kingfisher completely within limestone. All are near the upper contact of Quatsino limestone. Geology at Empire mine area is shown on Map A (in pocket).

Bedded Quatsino limestone strikes northerly and dips westerly at moderate angles toward the stock. Strike generally parallels intrusive contacts. Local variations in attitudes reflect gentle open folds. Most prominent change in strike occurs near a bulge in the Coast Copper stock north of Empire mine. Intensity of deformation increases toward intrusive contact. Near Merry Widow deposit, limestone dips steeply to the east; to the north near the Shamrock and Blackjack showings, limestone dips steeply near intrusive contacts. In Craft Creek limestone in contact with the intrusion is isoclinally folded about a west-northwesterly axis.

Bonanza rocks overlie the limestone and occur as a discontinuous rim around margins of the Coast Copper stock. North of Empire mine, rocks previously mapped as Bonanza volcanics are not considered part of extrusive Bonanza rocks, but rather one of the many greenstone masses found near the mine. If these are Bonanza rocks there is a stratigraphic problem. Limestone at the Merry Widow deposit is nearly 4,000 feet thick, near Blackjack and Shamrock, 3,000 feet. At the bulge in the stock, between the Blackjack and Merry Widow, it is 1,600 feet thick. There is 1,400 feet of Quatsino limestone missing in this section. There is no evidence to suggest that this amount of limestone has been displaced by faulting. It is suggested on this basis that these rocks are part of the many intrusive greenstone masses common near the mine.

Bonanza rocks consist of metamorphosed tuffs, flows and agglomerates. Bedding is poorly preserved but where visible conforms to the generally northerly trend and westerly dip. Massive rocks are fine-grained, dense, medium to dark green in colour, indistinguishable from intrusive greenstone which invade them. On the northwest and westerly wall of the Merry Widow pit, bedding is preserved as colour banding. Banding is due to segregation of light and dark minerals; light bands are predominantly feldspar, dark bands pyroxene. Result is a gneissic texture. Jeffery (1960 p 95) calls this rock a pyroxene-plagioclase gneiss. Colour banding is thought to reflect original bedding in volcanics.

The Coast Copper stock intrudes both limestone and volcanic rocks. Contacts are generally steep, ranging from 70° to almost vertical. Near Merry Widow pit underground development and deep drilling show the contact near surface to dip at about 55°, steepening to near-vertical at a depth of 650 feet below floor of Merry Widow pit. The effect of thermal metamorphism on limestone has been re-crystallization. Volcanic rocks near the intrusive margin are in part hornfelsic and in part "granitized." Rocks referred to as "granitized" are essentially those in which metasomatism has in effect produced a feldspathic rock, in places resembling an altered diorite. Areas of feldspathization are irregular, generally less than 10 feet in diameter and grade out into massive metamorphosed volcanics. This is most noticeable in Merry Widow pit where metasomatism has had its greatest effect.

Intrusive greenstone, commonly regarded, at least in part, as intrusive phases of Bonanza volcanism, form large irregular masses, dykes and sills. They are dense, fine-grained, greyish-green to dark green rocks, mostly andesitic or dacitic in composition. The largest greenstone mass is andesite.

Faulting is prevalent near the mine. East to northeasterly faults are numerous, and bear close spatial relation to ore deposits. These are prominent faults with a steep southerly dip. Movement has been negligible. Most can be traced into intrusive diorite and have post-intrusive movements. Northerly faults, one which follows in part the Merry Widow Creek, another the Benson River, have repeated outcrops of Quatsino limestone to the east.

Movement along bedding planes is recognized in both limestone and volcanic rocks. In the Kingfisher pit, movement along the base of a westerly dipping (20 - 25°) greenstone sill is recognized by gouge and slickensides, indicating reverse movement. Fragments of the skarny greenstone sill, with selvages of magnetite and chlorite are healed by coarsely crystallized calcite. The inference is that the fault is a pre-mineral break in which movement had continued during mineralization, fracturing early formed magnetite which was later healed by coarse crystalline calcite. Magnetite and calcite occur in a similar relation in the footwall. Magnetite has spread out under the sill suggesting that the sill, in part, served as an impounding structure to mineralizing solutions.

Movement has occurred in volcanics along bedding planes (fig. 3, p 13). Angular fragments of volcanic material, healed predominantly by

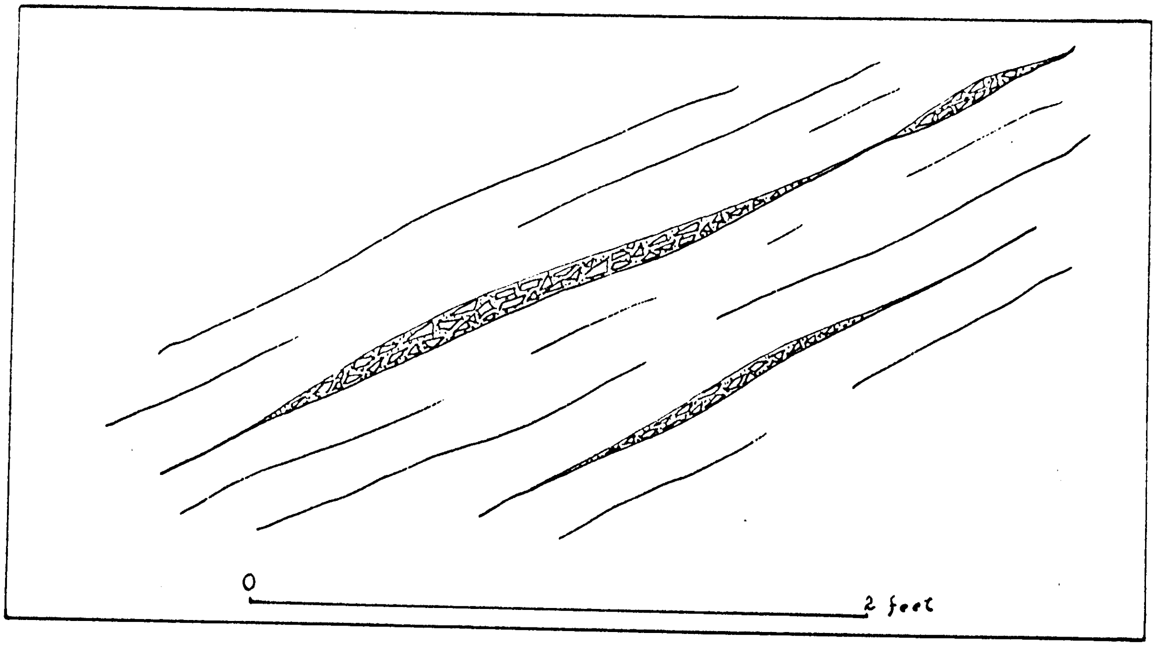
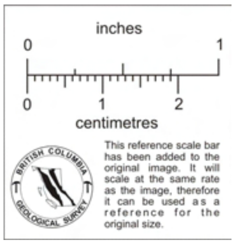


Fig. 3

Sketch to illustrate the nature of brecciation along bedding planes in Bonanza volcanic rocks.



pyroxene, form lenses of breccia along bedding planes. Fragments show a general alignment parallel to bedding.

Petrology

Petrology is based on a study of eighteen thin sections taken from rock types which might have a direct bearing on structural interpretation. Jeffery (1960), Wittur (1961), Sangster (1964) and Eastwood (1965), have ably described common rock types and duplication of this work was not warranted. Four specimens of greenstone, including one from a large irregular mass near Kingfisher pits and three from dykes exposed underground, were examined petrologically to determine the variation in composition. Specimens from spherulitic lava, acidic dykes, breccia, banded volcanics, feldspar porphyry and limestone were also examined. Two sections across contacts between dark siliceous beds and limestone, were examined for any evidence of bedding plane movement. Each of these are described briefly below, supplemented to some extent by descriptions by early workers.

Spherulitic Lavas

A small unit of spherulitic lava outcrops west of Empire mine in a small gully on the south slope of what is known locally as "Little Merry Widow" mountain. The unit, three to six feet thick, crudely banded, is intercalated with thin-banded volcanic rocks, possibly acidic lavas.

The rock is composed of spherical forms that range in size from 1/4 to 1/2 inches in diameter, cemented in a green aphanitic matrix. The spherical forms have a radiating structure. Finely disseminated magnetite is distributed throughout both matrix and spherulites. The ball-like forms weather out like marbles. (Plate I p 44)

Rock consists of radiating masses of albite feldspar with interstitial quartz. Polysynthetic twinning is not common. X-ray powder photographs confirm albite and quartz. Albite is slightly cloudy, crystal boundaries are not distinct. Quartz is clear. Mafic minerals are almost completely lacking, less than 1% chlorite is present as the only mafic mineral. Magnetite is lathlike and short stubby crystals form irregular patterns crossing spherical form boundaries without interruption. Structures along which magnetite crystals have formed may be simultaneous with or later than the formation of spherical forms, depending on which origin of spherulitic lavas is accepted. Possible origins of spherulitic lavas are: (a) immiscible liquids; (b) devitrification of glass; (c) rapid crystallization of a viscous lava. Spherulitic lava near Empire mine is believed formed by devitrification of volcanic glass.

Bonanza Volcanics

Bedded volcanics are best exposed on the northwest rim of the Merry Widow pit where bedding is preserved as colour banding. (Plate II p 45) Rock consists of light and dark alternate bands, some bands coarsely crystalline. Lighter bands consist of predominantly plagioclase, and dark bands pyroxene. Modal analysis is 47% plagioclase, 20% pyroxene with less than 10% K-feldspar. Alteration minerals include ragged amphibole (actinolite) laths, epidote, calcite, chlorite, with accessory sphene. Prehnite forms clear crystals in lighter bands. The rock has been called a pyroxene-plagioclase gneiss by Jeffery (1960).

Diorite-Gabbro

Diorite is a light grey to greenish-grey, medium- to coarse-grained granitic rock. Gabbroic phases are darker in colour and contain a higher percentage of mafic minerals and magnetite than diorite. Analysis by Sangster (1964) shows the basic border zone, to a distance of 800 feet into stock, to contain an average of about 8% iron. Modal analysis of gabbro by Sangster (1964) is 50% plagioclase (An_{53}), 39% augite, 7% actinolite, 2% opacite and 2% accessories.

Breccia

Near the diorite intrusive contact, exposed only in underground workings on the main haulage level, is a breccia zone 120 feet across separating diorite from the limestone. The rock has three distinct textures; (a) fragmental rock composed of dark greenish-grey angular to subrounded rock fragments in a light grey to pinkish groundmass, (b) a less marked fragmental rock with clusters of mafic minerals and knots of garnet in a fine pinkish-grey groundmass, and (c) a "mylonitic" rock with augen-like clusters of pyroxene. The latter rock has a marked lineation (Plate XII p 55).

The first rock type consists of rock fragments composed of anhedral grains of feldspar with 25% equant intergranular pyroxene. Clusters of larger pyroxene occurs in inter-fragment spaces. Epidote, sphene and prehnite fill fractures. Zoisite, clinozoisite (x-ray confirmation) and carbonate also occur as alteration minerals.

The second type consists of 21% albite (An_{9-11}) and 50% K-feldspar with interstitial equant grains of augite. Clusters of larger anhedral augite grains have a tendency to be augen or lense-like. Small equant and irregular yellowish-brown isotropic garnet rarely showing crystal form, bears a close spatial relation to pyroxene. Late minerals filling fractures include calcite, K-feldspar, epidote and prehnite; apatite and chlorite occur sparingly. Fine-grained nature of rocks prohibits accurate determination of feldspars. Etch tests with HF and sodium cobaltinitrate suggest preponderance of K-feldspar. X-ray powder photographs and optical properties confirm pyroxene as augite.

The third type is much the same as the second. Pyroxene forms lense- or augen-shaped clusters with lineation near vertical. Specimen examined came from near light coloured greenstone dyke that cuts the breccia zone.

Intrusive Greenstone

Greenstone masses, dykes and sills are predominantly andesitic in composition. Of the four specimens examined, three were andesite and one was "dacite." All had suffered some alteration, and with the exception of the "dacite," all had selvages of skarn and, in part, magnetite along the contacts.

Andesite:

Most prominent dyke underground is a large andesite dyke 35 - 40 feet in width that has been emplaced or at least lies along the main thrust fault that cuts into the Merry Widow pit. The dyke strikes northerly and dips at about 55° easterly. Closely spaced joints are filled with pink K-feldspar, epidote and brown garnet. Sub-parallel fractures and alteration haloes give the rock a banded appearance. The dyke is referred to as the "West Pipe" dyke.

The specimen consists of a felted mass of feldspar microlites with intergranular equant pyroxene. Occasional untwinned feldspar phenocrysts, considerably altered to sericite and epidote are present. In one instance a feldspar crystal is completely altered and replaced by a mosaic of anhedral epidote grains. Both epidote and feldspar are cut by calcite veinlets. Epidote fills fractures, decreasing outward from the centre.

Modal analysis shows the rock to consist of 43% plagioclase (An_{50}), 15% K-feldspar and 18% pyroxene (augite) with sphene and apatite as accessories. Alteration minerals include K-feldspar, epidote, calcite, diopside, garnet and prehnite. Opaque minerals include a few scattered grains of pyrite, magnetite and chalcopyrite.

Other dykes examined are similar in character to that described above. A 10-inch dyke consisted of large remnant grains of pyroxene cut by laths of plagioclase in subophitic relation. Sericite, epidote and calcite alteration obscures original nature of feldspar. Untwinned anhedral K-feldspar comprises about 20% of the rock, plagioclase 25% and intergranular pyroxene 17%. Ragged laths of amphibole occur sparingly. Calcite prehnite and epidote occur as vein minerals. Texture was likely originally diabasic.

"Dacite":

A greenstone dyke cuts the breccia zone exposed on the 1920 level. It is a fine-grained, grey-green felsitic rock composed of 30% anhedral to subhedral plagioclase, 33% anhedral K-feldspar with 23% interstitial quartz, and 1% intergranular pyroxene. Biotite and amphibole comprise less than 1%. Calcite, epidote and chlorite occur as alteration minerals; accessory minerals are apatite, magnetite and pyrite. Pyroxene, in part, forms clusters of anhedral grains. Quartz and K-feldspar are at least in part introduced or metasomatic, hence original nature of rock is obscured.

The dyke is cut by irregular masses of fine-grained granite which enclose angular fragments of the intruded rock.

Granite Dykes:

In underground workings cutting breccia is a grey to pinkish-grey, fine crystalline igneous rock with a composition of granite. It is composed almost entirely of large anhedral to subhedral K-feldspar and quartz. Modal analysis shows 60% perthitic feldspar, 35% quartz and 4% aegerine-augite with apatite and sphene as accessories. Jeffery (1960) describes an alaskite north of the Kingfisher pit. Near this latter occurrence, greenish-grey, medium-grained andesite is cut and brecciated by fine-grained granite. Edges of brecciated fragments are bleached by granite. Only mineralogical change in the bleached haloes is a reduction in amount of opaque iron minerals.

Feldspar Porphyry:

Sutherland-Brown (1962) has pointed out the ubiquitous relation between feldspar porphyry dykes and contact metasomatic deposits associated with Vancouver group rocks.

North of the Kingfisher pit, cutting brecciated intrusive andesite is a feldspar porphyry dyke which in turn is cut by later granite dykes (alaskite). It is a dark green, fine-grained rock with laths of plagioclase showing a sub-parallel alignment with dyke contacts. Laths range in size from 3mm to 7mm. It consists of large phenocrysts of plagioclase (An_{56}) enclosed in a felted mat of feldspar microlites with intergranular pyroxene. Epidote and calcite occur as alteration minerals along corroded feldspar grain boundaries, cleavage planes and fractures. Some feldspar are zoned, some not; all show undulatory extinction. Few ragged biotite flakes and amphibole laths occur sparingly, biotite is closely associated with pyrite.

Post Ore Basic Dykes:

In the Merry Widow and Raven ore zones, are post-ore green dykes with a coarse, sugary texture. They cut andesite dykes, ore zones and gabbro and are likely one of the latest phases of intrusion. They vary little from andesitic dykes in composition, containing 37% plagioclase, 8% K-feldspar, 25 - 30% pyroxene, 12% chlorite and 3% epidote. Long laths of plagioclase and subhedral pyroxene with interstitial chlorite form most of the slide. Pyroxene is replaced in part by calcite and in part by a brown fibrous mineral exhibiting radiating forms. An undetermined mineral, brownish green in colour, slightly pleochroic, forms radiating masses with striking birefringent colours. It is a minor alteration mineral.

Gunning (1929 p 107A) in reference to acidic, basic and porphyry dykes found near stocks, states " - - - - - - - -they are believed related in origin to main intrusive bodies in that they represent differentiates from the same parent magma".

Metasomatic Vein Rock:

On the north wall of the Merry Widow pit volcanic rocks appear cut by a finely crystalline rock which shows crosscutting relations to bedded volcanics and in many respects is dyke-like. Contacts are relatively sharp and the vein in places includes fragments of wall rock in which bedding in fragments matches that in wall rocks.

The vein rock is light grey, slightly mottled, spotted with small clusters of pyroxene. It consists of large altered feldspar crystals studded with anhedral pyroxene set in a groundmass of equant plagioclase feldspar and granular pyroxene. Plagioclase for the most part does not show multiple twinning and all are unzoned. Determination of feldspars by Michel-Levy method and refractive indecies indicates a composition of at least An_{32}. Pyroxene (augite) forms clusters of clear crystals as well as equant grains which commonly have an alteration halo. Composition of the rock is approximately 70% plagioclase, less than 5% K-feldspar and 25% pyroxene (augite) with less than 3% epidote, sphene and apatite.

Vein is considered to be a metasomatic rock in which metasomatism has occurred along fracture systems and bedding surfaces, producing intrusive-like characteristics (Plate II p 45).

Siliceous Bands in Limestone:

Within Quatsino limestone are thin siliceous bands that range in thickness from a fraction of an inch to three inches. They are extremely fine-grained and finely banded, dark, slightly calcareous rocks with finely disseminated pyrite. Microscopic examination shows the rock to consist of about 15% pyrite with scattered quartz grains in a fine dark brown groundmass. With the exception of pyrite, quartz and occasional carbonate grains most of the groundmass could not be identified. Contacts with limestone are sharp. Adjacent to the contacts limestone has a fine granulated texture in which occasional fragment of coarse calcite is enclosed in the finer material. Relation indicates movement along bedding planes on an extremely fine scale.

Ore Zones

Most of the production from Empire mine came from the Merry Widow and Kingfisher deposits. Approximately 20,000 tons of ore was taken from the Raven zone in 1960 but sulphide content was particularly high and the pit was abandoned. Since then it has been buried by waste. Description of the Raven zone given here is from company reports. Geology of ore zones is shown on Map B (in pocket).

Merry Widow

The Merry Widow orebodies occur as tabular-shaped masses with irregular boundaries within a wedge of meta-volcanics of the Bonanza group. This wedge is bounded to the west by the easterly dipping gabbro and to the east by westerly dipping limestone. Width decreases sharply with depth to 150 feet where it is exposed underground as a severely brecciated skarny rock. It is separated from gabbro by 15 feet of massive garnet-epidote skarn and from limestone by 10 feet of massive skarn. Diamond drill data indicates an irregular volcanic-limestone contact dipping toward the gabbro. Contact curves sharply down toward the gabbro. Intrusive contact in the pit dips easterly at 55°, steepens to 70° or 75° below the 1920 level. Magnetite layers lie parallel to the contact.

Ore occurs as massive magnetite, replacing both skarn and volcanic rocks and partially enclosed by a halo of garnet-epidote skarn. Replacement is incomplete and orebodies may have lenses of low grade to barren skarny rock interlayered with ore-grade material.

The Merry Widow deposit may be divided into three units; an upper, intermediate and a lower unit. The upper unit is a tabular body 340 feet long by 500 feet thick plunging eastward at 30°. Ore terminates abruptly down plunge against limestone. Upper termination grades sharply into skarny volcanic rocks. Lying below and separated from it by about 40 feet of relatively barren mixed skarn and volcanic rocks, is the intermediate unit. It is tabular in shape, has a length of 280 feet, thickness of 30 feet and lies parallel to the upper unit. The main thrust fault extends between these two orebodies, cutting the barren rocks. Footwall rocks have been folded upward against the fault as evidence of reverse movement (fig. 4 p 25). The third and lowermost unit lies along the gabbro contact, separated from it in most places by a cushion of skarn. Down dip extent, defined by limits of exploration, is 540 feet, maximum thickness is 140 feet. It tapers with depth. Where the intrusive contact steepens, ore layers also steepen and at one point ore occupies an enclave in the gabbro, reflecting the close relation between configuration of gabbro contact and orebody. There is little doubt but that the form of the deposit is to some extent controlled by the intrusive contact.

Mineralization consists of massive magnetite with associated pyrrhotite, pyrite and chalcopyrite. Other minerals found include cobaltite, arsenopyrite, sphalerite, erythrite and chalcotrichite. This last group is found in small or trace amounts. X-ray powder photographs confirm chalcotrichite (cuprite). Sulphides are discussed in another section with relation to zoning.

Colloform magnetite from the Merry Widow pit has been described by Stevenson and Jeffery (1964). Formation of botryoidal forms has been ascribed to crystalization from colloidal suspension under relatively low pressures. Curvature of the forms is convex against white calcite and magnetite shows both radiating and concentric growth to botryoidal forms. Sangster (1964) has discussed possible origin of colloform magnetite and concluded that magnetite in Kingfisher deposit was deposited from a colloidal dispersion by re-deposition of earlier magnetite in a post-ore fault now cemented by calcite. The solutions which carried this calcite dissolved some of the crystalline magnetite of the brecciated ore in the

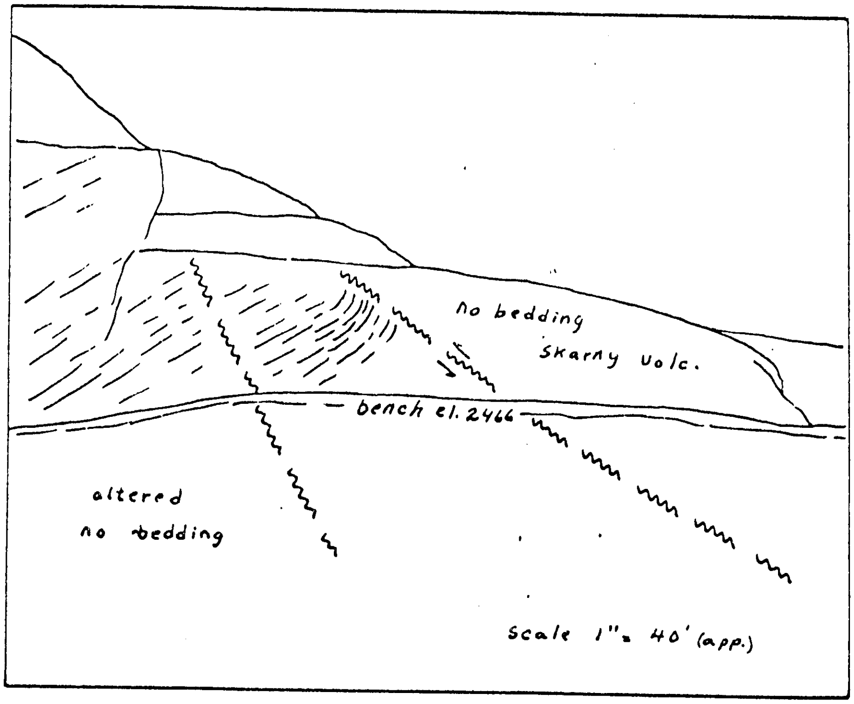
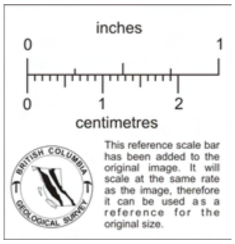


Fig. 4

Sketch showing the drag effect in volcanic rocks as a result of reverse movement on an easterly dipping fault.



fault and this dissolved magnetite was precipitated both as an electrolytic crystalline aggregate and also as a colloid. Skarn minerals include andradite-grossularite garnet, diopside, actinolite, epidote, pink K-feldspar and calcite. Clear calcite rhombs have been found in a partially filled cavity with associated small well formed prisms of ilvaite and cubes of pyrite.

Kingfisher

The Kingfisher has two steeply plunging cylinderical or pipe-like orebodies that merge with depth. Both lie within Quatsino limestone, approximately 1000 feet from the gabbro contact. Maximum vertical extent of the two pipes is 420 feet. They taper and finger out into limestone with depth. Magnetite is massive forming sharp contacts with limestone. Skarn minerals are confined to many greenstone dykes and sills criss-crossing the ore. Skarn forms selvages along greenstone dykes and sill contacts and in part replaces large areas of the original rock. Magnetite penetrates greenstone to some extent but has favoured limestone. Replacement of limestone has been such that original bedding is preserved in magnetite (Plate III p 46).

Limestone has been folded into gentle flexures, nowhere are the rocks intensely deformed. Swarms of greenstone dykes and at least one prominent sill cuts both pipes. The Kingfisher deposit lies between two greenstone masses, one 400 feet to the southeast, the other 800 feet to the northwest, with the swarms of pre-ore dykes between. The sill exposed in the Kingfisher East dips at 25° westerly. Reverse movement has occurred along the base of the sill. Magnetite has moved out along the base of the sill which has acted as a barrier, suggesting that mineralizing solutions were ascending.

The steep northeasterly-trending Kingfisher fault cuts both deposits. The intersection of the Kingfisher fault, with greenstone dykes and sills, is believed to provide favourable sites for deposition.

Raven Zone

The Raven orebody lies at the southwesterly end of a long north-easterly trending zone of mineralized greenstone associated with a north-easterly trending fault. It consists of magnetite with associated sulphides, pyrrhotite, pyrite, sphalerite and chalcopyrite. The orebody occurs as a tabular mass surrounded in part by massive garnet and epidote skarn and plunges steeply to the southeast. High sulphide content made the deposit uneconomic and after extracting about 20,000 tons of ore the deposit was abandoned.

West Pipe

In early exploration, a magnetic high was obtained west of the Kingfisher central deposit and was named the West Pipe. Diamond drilling has indicated the existence of mineralization but not enough to make an orebody. Mineralization consists of massive magnetite as a tabular body immediately overlying the West Pipe dyke. Its occurrence coincides with the intersection of the dyke and the Kingfisher fault. Small lenses of pyrrhotite, pyrite, arsenopyrite and chalcopyrite with associated gold in calcite gangue lie along the hangingwall of the West Pipe dyke.

Within the Merry Widow and particularly in the Raven zone, magnetite has associated with it pyrrhotite, pyrite and chalcopyrite. Sulphides occur as small masses, commonly associated with white calcite and as disseminated grains distributed throughout the massive magnetite. Pyrrhotite is most abundant. Ratio of sulphides to oxides in general increases with increased distance from the gabbro toward the limestone contact. Closely spaced test holes in the Merry Widow pit between elevation 2260 and 2220 were sampled at 10 feet intersections during mining. Copper content of the 10 foot intersections has been plotted on plans for the 2260 and 2220 levels to show relation to magnetite. Results indicate that sulphide concentration is peripheral to massive magnetite. Greatest concentration is along the northeastern margin of the Merry Widow orebody (fig. 5 and 6 pp 29 and 30). Occurrence of sulphides is erratic and a continuous zonal arrangement could not be established.

Greenstone Relation

A significant feature at Empire mine is the presence of irregular masses, dykes and sills of what is known at Empire as "intrusive greenstone." Megascopically and microscopically, these are all similar. With

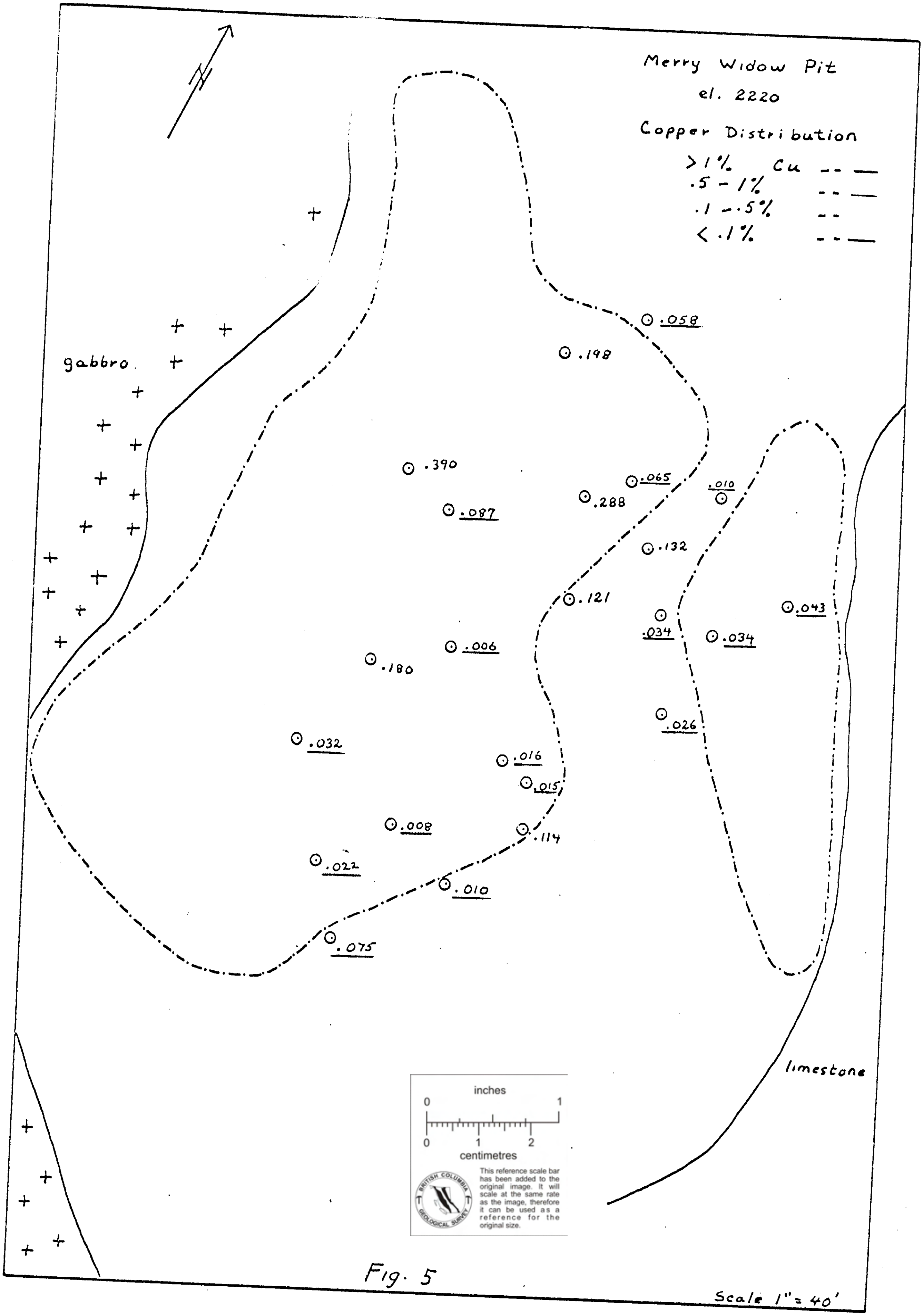

Merry Widow Pit
el. 2220
Copper Distribution
>1% Cu
.5 - 1%
.1 - .5%
< .1%
gabbro
limestone
.058
.198
.390
.087
.288
.065
.010
.132
.121
.034
.034
.043
.006
.180
.026
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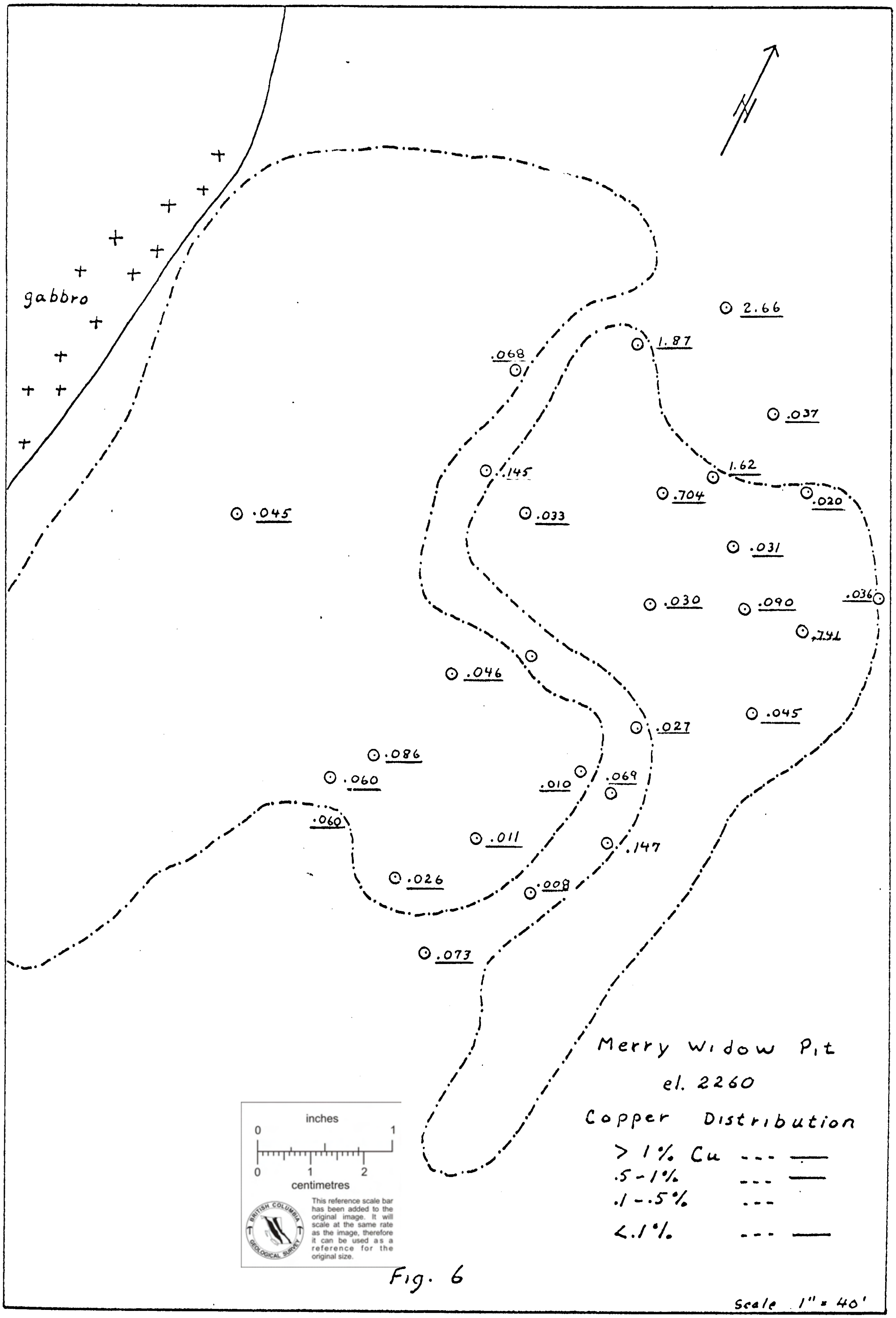
Fig. 5



gabbro
2.66
1.87
.068
.037
1.62
.145
.704
.020
.045
.033
.031
.030
.090
.036
.046
.027
.045
.086
.060
.010
.069
.060
.011
.147
.026
.008
.073
Merry Widow Pit
el. 2260
Copper Distribution
> 1% Cu
.5 - 1%
.1 - .5%
<.1%
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BRITISH COLUMBIA
GEOLOGICAL SURVEY

Fig. 6

some exceptions, most have intergranular texture, in part diabasic, consisting of a felted mass of feldspar microlites with intergranular augite. Feldspar in one dyke showed subophitic relation to pyroxene. Chlorite and epidote alteration is common.

The larger masses shown on Map A (in pocket) are dark green to grey-green aphanitic rocks with little variation in texture. Contacts are generally steep and in places, show fault contacts with limestone. Intrusion has produced some bleaching of limestone, but little evidence of deformation. Commonly associated with these greenstone masses are small deposits of magnetite. Associated with some but not all deposits, are northeasterly trending faults.

Greenstone dykes invariably have selvages of skarn and/or magnetite along margins which may project into limestone. There is little doubt that these dykes are pre-ore and have served, in part, as guides to metasomatizing solutions. Greenstone dykes are cut by granitic rocks thought to be related to the Coast Copper intrusions and are, therefore, probably pre-intrusion.

Relation of greenstone to folding is not so clearly defined. Configuration of some dykes and their relation to limestone suggest possible intrafold emplacement. Some of the relations observed are:

1) A broken dyke with fragments displaced by movement or adjustment within limestone may occur within 10 feet of a similar dyke which remains intact, undeformed (Plate X p 53).

2) A greenstone sill following the crest of a gentle open fold has been cut by a later dyke with a slight displacement on the limestone (Plate XI p 54).

3) A greenstone sill, 3 to 4 inches thick, fragmented with small displacement of fragments, follows crest of a small fold. A similar sill follows over the crest of a small fold unbroken (Plate V p 48).

4) Dykes are commonly emplaced along axial surfaces of open folds.

5) Dykes side by side may have different contact relation. Narrow sill-like projections from larger dyke with ragged contacts are cut by later dyke with clean contacts and chilled margins (Plate VIII p 51).

6) Some small greenstone masses exposed underground have very irregular shapes with arm-like protrusions that suggests both rocks were "- - - - - - highly mobile."

Carlisle and Susuki (1965 p 464) describes similar relations at Open Bay on Quadra Island and conclude that "- - - - - - andesite pods and sheets are intrusive bodies, most of which were emplaced after an initial period of strong folding."

The writer suggests that in the Empire area, greenstone dykes are mostly pre-folding but that intrusion of greenstone continued into early stages of folding prior to or during emplacement of Coast Copper stock.

Structural Geology of Mine

Structural geology does not appear to be particularly complex. Of the thirteen magnetite deposits associated with the Coast Copper stock, eight lie along northeasterly faults. The Kingfisher, Merry Widow, Raven, Shamrock and Blackjack lie in enclaves or re-entrants in the stock. Where these re-entrants have occurred, limestone has been deformed. All lie in or near greenstone masses or are cut by greenstone dykes, and where these intersect northeasterly faults, they provide favourable loci for deposition.

There is little surface indication of folding. The Quatsino limestone is relatively pure and contains no structures which might indicate tops or bottom of beds, hence presence or absence of overturned beds is based on interpretation of data.

Folds

Relict bedding in meta-volcanics near the gabbro contact, has a northerly strike and steep westerly dip. On the headwall of the Merry Widow pit, dip at the contact is from 80° westerly to vertical. The dip decreases with increase distance from the gabbro to a westerly dip of 25 to 30°. Change in dip defines the westerly limb of a northerly trending anticline. Where alteration is intense near the orebody, volcanic rocks have a hornfelsic texture and bedding is obscured by alteration. Poles to bedding, plotted on a Schmidt equal area net, lower hemisphere, form a broad girdle along a great circle defining a fold with axis at 354° and plunge 18° (fig. 7 p 34). Attitudes of beds (100 points) within the

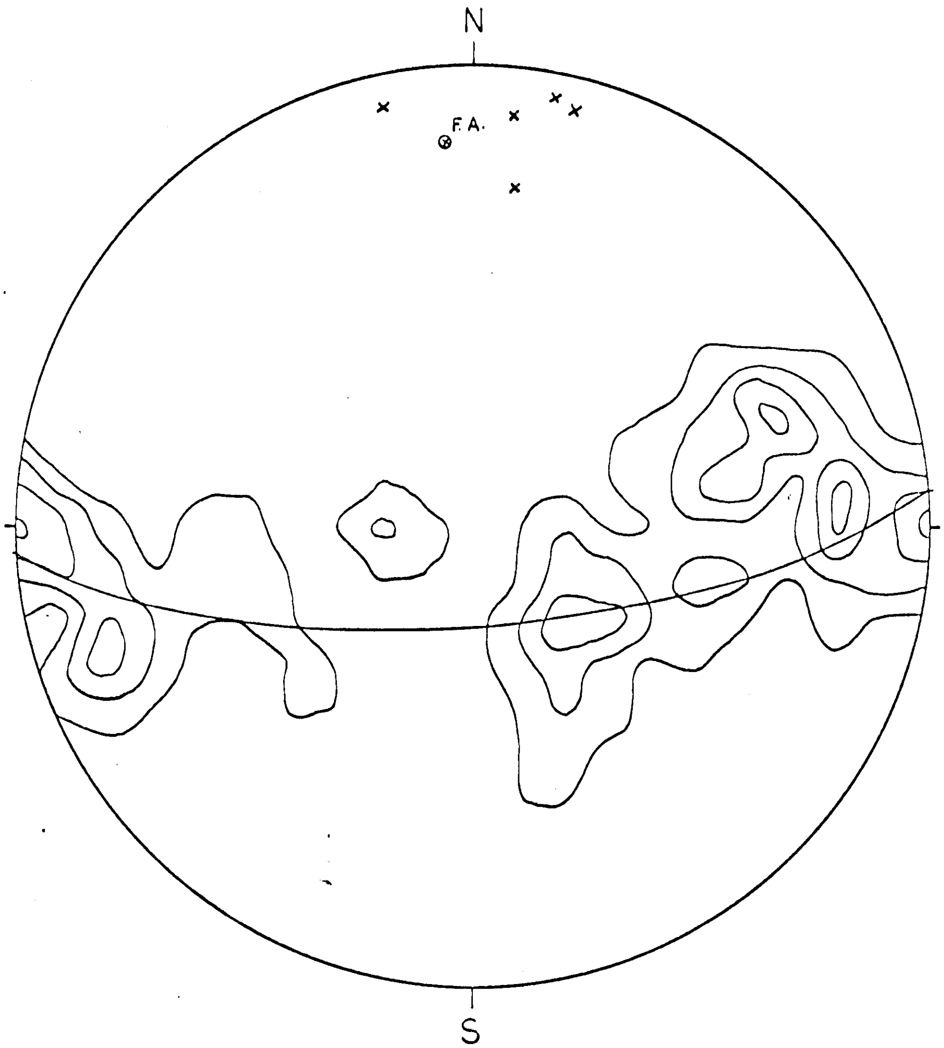


Figure 7

Plot of poles to bedding in the Merry Widow area indicate a north-northwesterly plunging fold. Fold axis of measured folds are indicated by small ×.

Merry Widow area only were used. Trace of the fold axis conforms generally to the gabbro contact. Underground development and diamond drilling outline an irregular but upfolded volcanic limestone contact, dipping westerly, thus supporting the surface evidence for folding (Map C in pocket).

Limestone near the surface expression of the limestone-volcanic contact has a steep easterly dip and north-northwesterly to northeasterly strike. Dips range from 60° to 85° easterly. At the entrance to Merry Widow pit, left wall, the western limb of an overturned fold can be traced. Axial plane strikes east of north and dips 55° easterly. (Plate IV p 47). To the right of the pit entrance limestone folds sharply down to the west. West of this point beds have a steep easterly dip and east of this point dips are 10 to 20° easterly. Axial plane dips easterly at 50 to 57°. In the main haulage level underground, east of the West Pipe dyke, limestone is sharply folded into an overturned anticline with strike of axial plane west of north and dip 57° easterly. West of this fold, limestone dips steeply and is intensely deformed. East of the fold dip of limestone is more gentle, deformation less intense. This fold is an underground expression of the fold indicated on the surface and the projected axial plane between them is sub-parallel to the West Pipe dyke. In the underground, the main thrust lies along the footwall of this dyke. The same stresses which caused the thrust movement also produced the overturned fold. Volcanic rocks were more resistant and small drag folding only occurred. In the Merry Widow pit, bedded volcanics are folded against the fault indicating a reverse movement with hangingwall rocks moving westerly relative to footwall rocks.

A third type of fold, seen only in underground, are folds of small amplitude generally 2 to 10 feet, occurring west of the West Pipe dyke. These are similar type folds with near-vertical to steep easterly dipping axial planes and northerly plunging fold axis (Plate V p 48). Observed relation to larger folds indicate that these occur principally on the western limb of the larger main fold.

Superimposed on bedding in the limestone are minor disharmonic folds with an amplitude of less than one foot. Fold axis may plunge either to the north or south but strikes generally within 10° of north. Axial surfaces are highly irregular, thin beds, inches apart, will have totally different configuration (Plate VIII p 51). Thin, brittle beds within limestone may be folded and broken with fragments displaced (Plate VI p 49).

During emplacement of the Coast Copper stock, limestones and volcanic rocks were locally folded about a northerly axis forming an asymmetric fold with steep easterly dipping axial plane. Superimposed on this main fold is a sharp overturned anticline in limestone folded against the West Pipe dyke. At some stage during this minor folding a break occurred along the base of the West Pipe dyke. Small reverse movement on the fault occurred accompanied by drag folding, both in limestone and volcanic rocks. Limestone responded to stresses by folding, the more brittle volcanic rocks by fracturing. Greenstone sills and dykes broken during deformation, form boudinage structure (Plate VII p 50). Limestone has moved in to fill space between fragments. Greenstone boudin commonly have a thin selvage or rim of skarn clearly showing that boudinage structure was formed prior to mineralization.

There is a close correspondence between attitude of axial planes which would suggest that these are related to one period of deformation. Folds are nearly parallel to the intrusive contact and are confined to a small area within an embayment in the Coast Copper stock. Relatively intense folding associated with orebodies at Empire mine is considered to be a direct response to intrusion of the stock.

Folding in the Kingfisher deposit is less intense than in the Merry Widow. In Kingfisher East, rocks are folded into a gentle north-westerly plunging anticline. In the Kingfisher Central, limestone is relatively undeformed, beds generally strike northeasterly and dip north-westerly.

Faulting

Faults occur in three sets: north trending steep normal faults, east to northeasterly high angle faults and northeasterly reverse faults with moderate easterly dips (50° - 57°). Three of the more prominent faults are discussed in some detail below.

Kingfisher Fault

The Kingfisher fault is not the most prominent fault exposed but is the most persistent, both laterally and vertically. It has been traced in the underground at all levels as a tight break, cutting the orebody. It is a northeasterly-striking fault with a steep southeasterly dip. Where exposed on the headwall, it has a steep southerly dip which decreases sharply at the foot of the wall to about 69°, then increases to 80 or 85° in the bottom of the pit (Plate XV p 57).

The fault makes a broad swing to the northeast, maintaining a steep dip and extends through the Kingfisher Central and Kingfisher East orebodies. Where this fault has been observed underground, it has selvages of magnetite and/or skarn along it. Within the Kingfisher deposits, brecciated magnetite along the fault suggests post-ore movements. Also within the Kingfisher deposit magnetite apparently replacing limestone outward from the fault suggests a pre-ore break. The Kingfisher fault with a persistent lateral and vertical extent, is considered to be one of the more important controls in deposition in both the Kingfisher and Merry Widow deposits.

South Fault

Along the south wall of the Merry Widow pit is a prominent steep, rusty easterly-striking fault (see Plate XVI). Fault surfaces are lined by calcite crystals coated with a brown earthy mineral. Thickness of calcite filling is as much as 8 inches.

Main Thrust

The main thrust exposed in the Merry Widow pit strikes east of north and dips easterly at 50 to 55° (Plate XIII p 56). It shows several subsidiary breaks, some healed with calcite, others showing slickensided skarn. On the north rim of the pit, skarny rocks are thrust on top of less altered volcanics. Footwall rocks, where relict bedding is preserved, are folded upwards. Where this fault occurs underground it lies along the footwall of the easterly dipping West Pipe dyke. Limestone is folded sharply in what is interpreted as an overturned fold, against the greenstone dyke. Whether this fold has been formed as a result of reverse movement on the fault, is not clear. The upper contact of the dyke does not appear to be a fault contact. Selvages of magnetite and skarn occur along the fault where it is exposed underground (Plate V p 48). Aside from the main thrust at least three other faults of this attitude are recognized but do not show the same reverse movement. These cut the Merry Widow zone below and subparallel to the main thrust, less prominent than the latter.

Time Relation Between Geologic Events

The suggestion has been made earlier in this report that greenstone dykes, sills and masses, in part, have been emplaced during folding of limestone. It has further been suggested that folding at Empire mine is related to the Coast Copper intrusion. Hoadley (1953 p 37) has suggested that the pronounced lineation of the Coast intrusions of Northern Vancouver Island -

> "- - - - - - more or less parallel with the general fold structure of the invaded rocks indicates that the intrusions were associated with orgenic disturbances and that they were intruded at about the time the invaded rocks were folded."

Evidently the final stages of Bonanza volcanism, regional folding, intrusion of Coast Copper stock with associated local folding and mineralization, were more or less contemporaneous. The close time relation between intrusion and orogeny may in fact have been a significant factor in the formation of ore deposits associated with Coast Copper stock.

CHAPTER IV SUMMARY AND CONCLUSIONS

The Merry Widow, Kingfisher and Raven ore deposits occur at the contact between Quatsino limestone and overlying Bonanza volcanic rocks near the margins of the Coast Copper stock. The stock is a composite intrusion consisting of a two-phase early system of diorite with gabbroic border phases later cut by a more acidic monzonite intrusion. Deposition of magnetite has occurred within an embayment in the stock where country rocks have been more intensely deformed. Both limestone and volcanic have been locally deformed, the limestone folding in response to stresses; the volcanic rock fracturing.

The Merry Widow deposit occurs as easterly plunging tabular orebodies within a wedge of meta-volcanics that have been folded into a northwesterly-trending anticline. Shape of the orebodies to some extent, reflects the configuration of the fold but also corresponds closely to easterly-dipping intrusive contact along which it lies. Superimposed on the westerly limb of this fold is an overturned fold possibly a drag-fold in limestone trending east of north and dipping easterly. The overturned limb abuts against the upper contact of an easterly-dipping andesite dyke. Along the lower contact of the dyke, is a thrust fault with strike and dip almost parallel that of the axial plane of the fold. Relations suggest that during emplacement of the Coast Copper stock, both volcanic rocks and limestone responded to the stresses produced by forceful intrusion, first by folding, then as stresses increased by fracturing of volcanic rocks. Limestone responded by folding, controlled somewhat by the West Pipe dyke, forming the overturned fold. A break occurred along the base of the dyke and a small reverse movement caused dragfolding on footwall volcanic rocks.

Away from the contact folding is less intense. In the Kingfisher zone, deformation has been mild.

The Kingfisher, Merry Widow and Raven deposits, all lie along northeasterly faults. The Kingfisher fault cuts through both Merry Widow and Kingfisher deposit. I believe this fault has provided the necessary channel for mineralizing solutions. Where it intersects fractured volcanics of the Merry Widow, upper contact of the West Pipe dyke, and crisscrossing greenstone dykes of the Kingfisher, there has been a concentration of magnetite. Structural controls then at Empire mine are: -

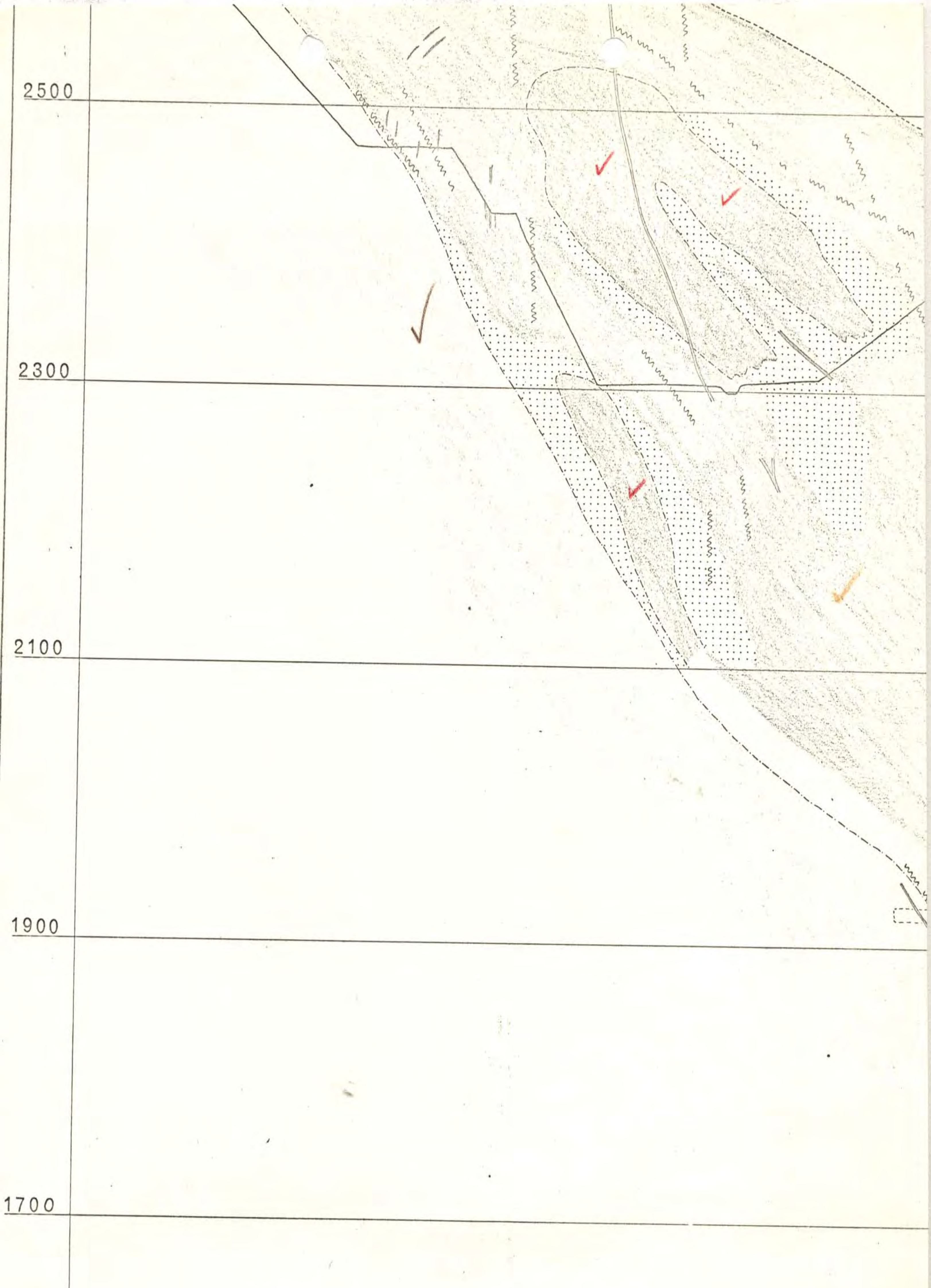
1) Configuration of the intrusive contact. Of thirteen magnetite deposits along or near the margin of the stock productive deposits and those near economic size lie in re-entrants in the stock.

2) Deformation of the country rocks. Fracturing of volcanic rocks during folding provided easy access for mineralizing solutions.

3) Northeast faulting, in particular the Kingfisher fault, provided the main channel-ways for mineralizing solutions.

4) Presence of greenstone dykes and sills in the Kingfisher deposit where these intersect the Kingfisher fault, provide favourable sites for deposition of ore.

Greenstone dykes and faults, where observed underground and in deep drilling, have selvages of magnetite and/or skarn along them. Magnetite occurs along the base of the limestone below the Merry Widow and following the intrusive contact. Mineralizing solutions were, for the most part ascending and where these solutions reached favourable sites deposition occurred.

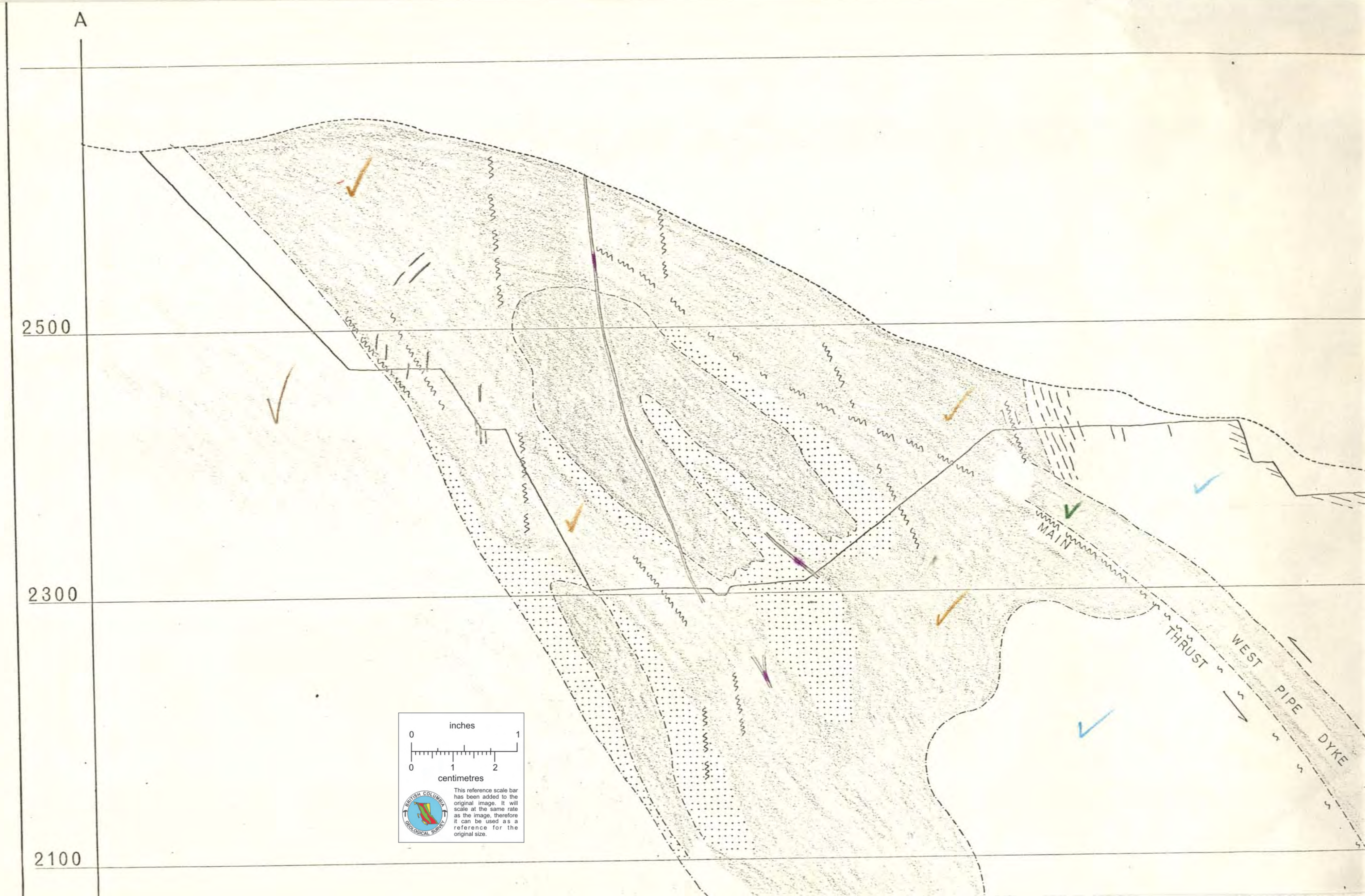


GEOLOGIC SECTION A—B

MERRY WIDOW and KINGFISHER DEPOSIT

EMPIRE DEVELOPMENT CO. LTD.

Scale: 0 40 80 100 Feet



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2500
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MAIN THRUST
WEST PIPE DYKE
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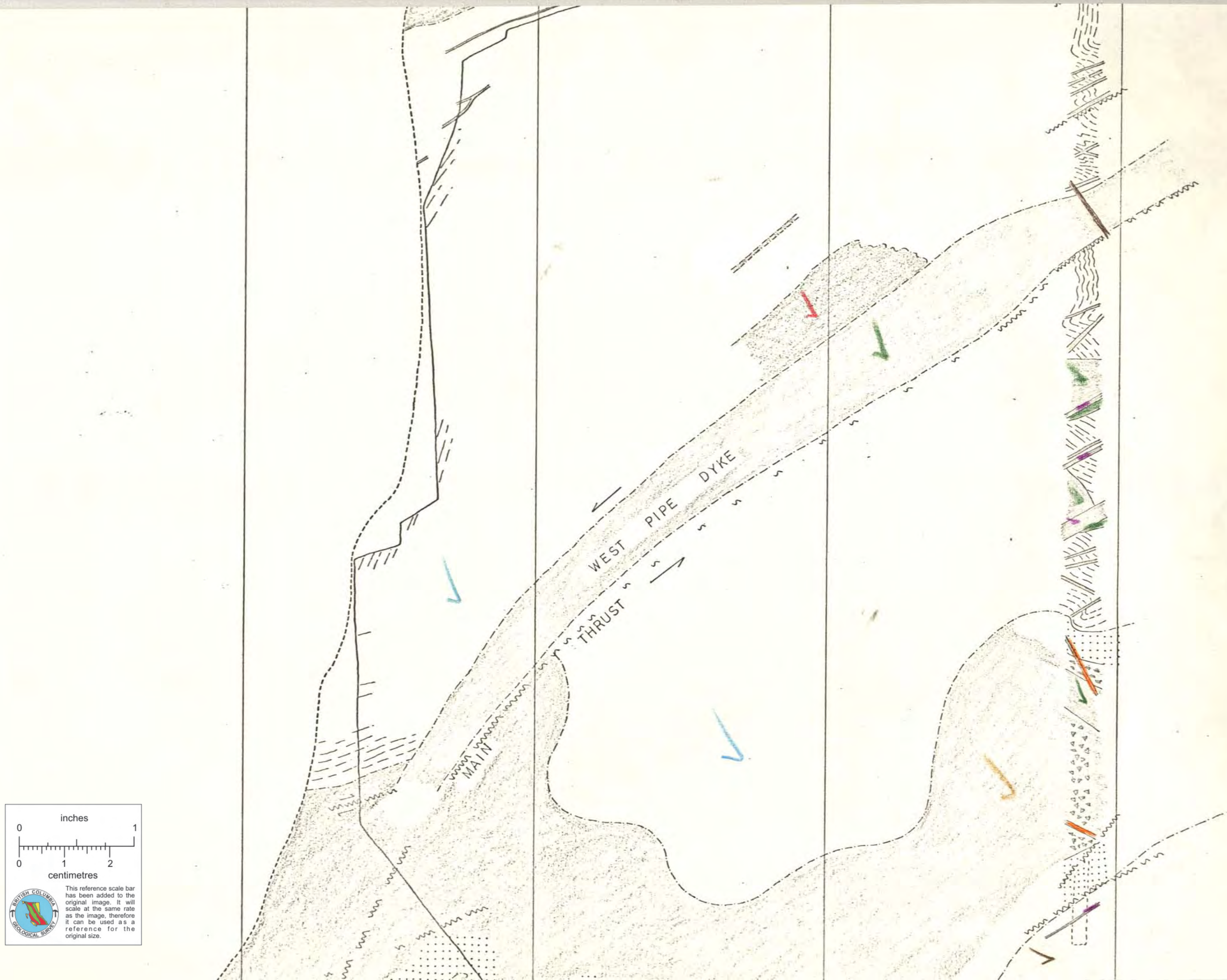
WEST PIPE DYKE
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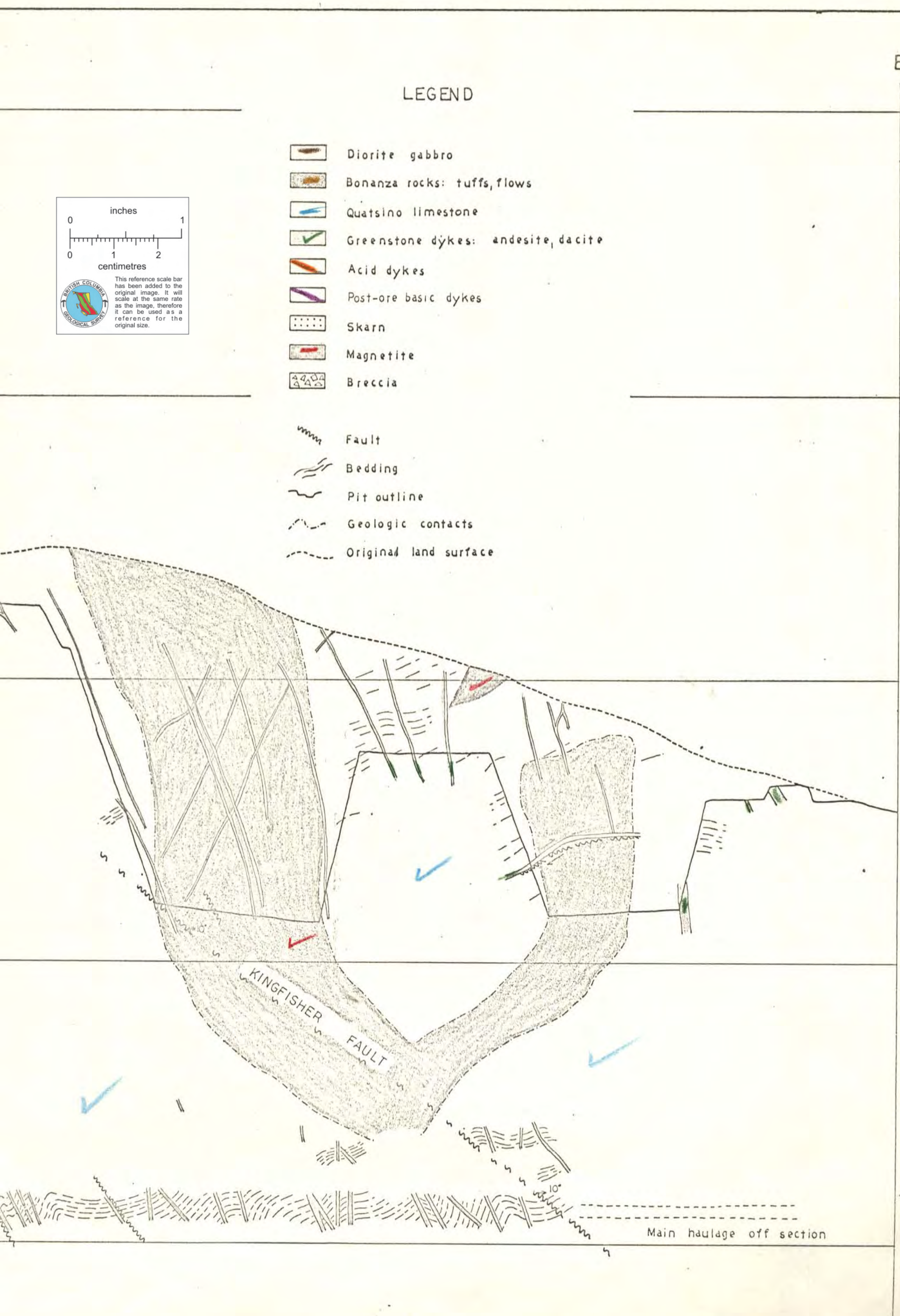
B
LEGEND
Diorite gabbro
Bonanza rocks: tuffs, flows
Quatsino limestone
Greenstone dykes: andesite, dacite
Acid dykes
Post-ore basic dykes
Skarn
Magnetite
Breccia
Fault
Bedding
Pit outline
Geologic contacts
Original land surface
inches
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1
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1
2
centimetres
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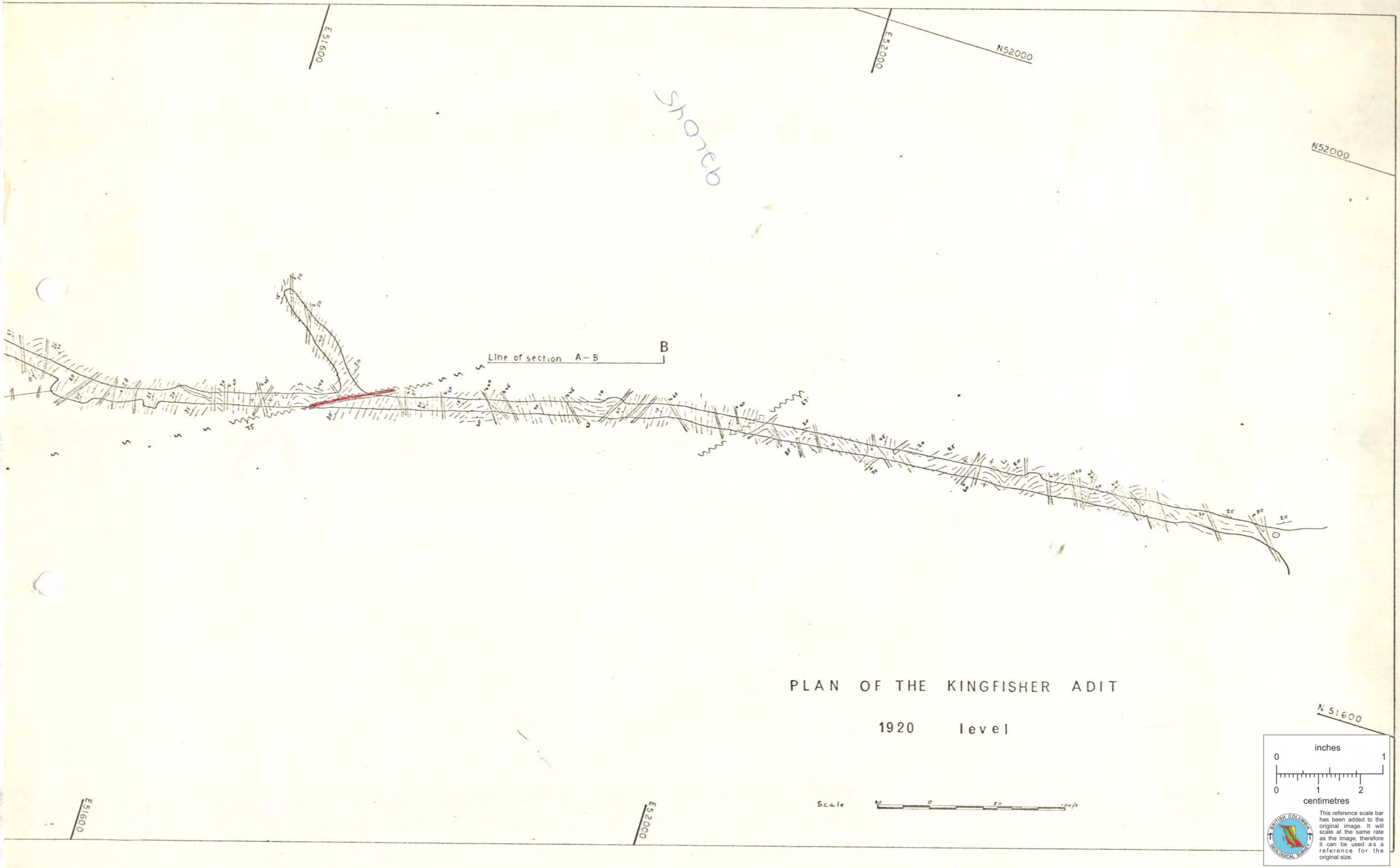
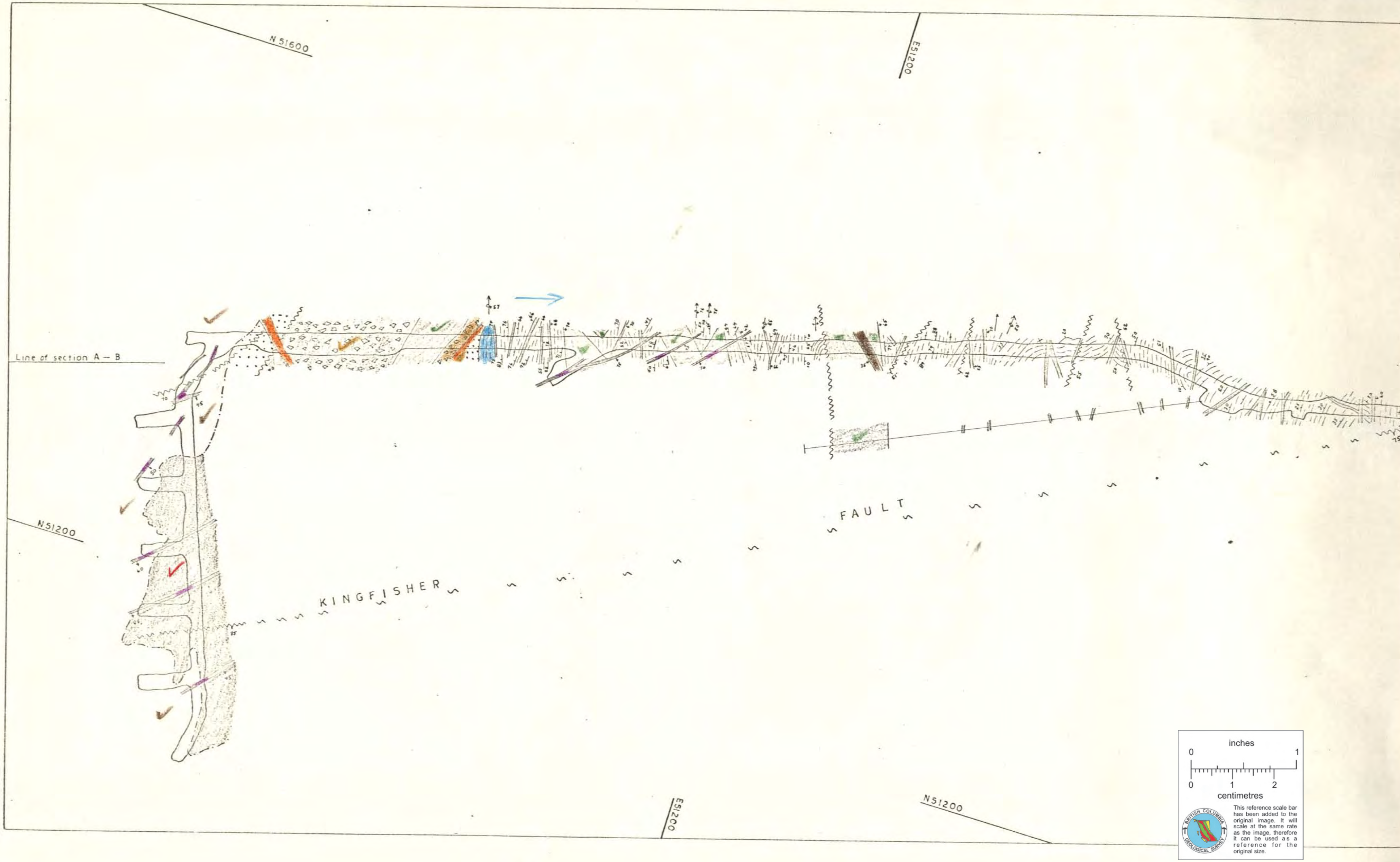
10°
KINGFISHER FAULT
10°
Main haulage off section



PLAN OF THE KINGFISHER ADIT

1920 level


N 51600
E51200
Line of section A – B
N51200
KINGFISHER
FAULT
E51200
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inches
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1961

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EXPLORATION AND GEOLOGY

EMPIRE DEVELOPMENT COMPANY LIMITED

PORT McNEILL, B. C.

STATUS ON JANUARY 1ST, 1961.

INTRODUCTION:-

Exploration commenced early in May. The regular staff, including the writer and P. M. Billwiller, were assisted in the field by the following students from the University of British Columbia:

G. R. Wittur - Third year geology honors.
May 23 to September 25.

M. A. Mitchell - Third year geology.
May 9 to September 16.

D. G. Allen - First year.
May 9 to September 16.

J. A. Coates - Graduate (1960) in Honors Geology
September 26 to December 5.

Below is a list of areas or projects on which exploration was done, with a brief description of each. These will be discussed later in detail.

1. MERRY WIDOW & KINGFISHER

Diamond drilling from May to August and detailed geological mapping.

2. RAVEN

Geological mapping in the pit, mined by Mannix Co. during the summer.

3. KEYSTONE

Dip needle surveys and surface stripping by hand labor.

4. SNOWBIRD

Staking claims and re-locating the old trail from Kathleen Lake.

5. AJAX

Detailed geological mapping and dip needle survey.

6. BLACK JACK AND SHAMROCK

Transit and dip needle surveys, geological mapping and claim staking.

7. GENERAL RECONNAISSANCE

Field Traverses to fill in the geological picture on Empire and Coast Copper ground.

8. BRITISH COLUMBIA DEPARTMENT OF MINES

Three months geological field mapping in the Empire-Coast Copper vicinity by a party of two men.

9. OUTSIDE PROPERTY EXAMINATIONS

During the year a number of copper and iron prospects on both Vancouver Island and the mainland coast were examined and reported on.

PRODUCTION:-

Production commenced in May from the Merry Widow and Kingfisher pits. The Kingfisher was worked out in August while the Merry Widow continued to the end of the season. In addition a small tonnage was mined during the summer from the Raven pit.

To the end of the producing year 418,812 long tons of concentrate were produced from 592,274 long tons of ore milled. Concentrate grade was 59.0% iron, some penalties being incurred by excess sulphur in certain shipments.

Since mining commenced three years ago the following tonnages of concentrate have been produced:

Merry Widow -	767,500	tons
Kingfisher -	366,597	tons
Raven -	10,765	tons

An exact separation of the ore from the above three sources is not possible hence the above figures are only an approximation.

MERRY WIDOW - (Figure 5)

By the year end mining had advanced well down in the deep ore which was found in 1958 by diamond drilling. Much waste rock had been removed from the headwall of the pit and the floor stood at elevation 2,342 feet.

Early in the season seven diamond drill holes totalling 2,996 feet were put down to check previous ore reserve estimates and test all potential ground around the Merry Widow pit. As a result of this work we now know that:

(a) the deep ore projections are substantially as pictured two years ago. Fortunately near the present pit floor a supposed spread of waste rock between two ore bands turned out to be largely ore, meaning that a much higher quantity was mined at this level than was anticipated;

(b) there are no mineable extensions of deep ore layers southward beneath the South pit;

(c) the ore layers with the exception of the lowest one next to the diorite contact, fade away down-dip into low grade skarny rock, or, when they encounter limestone, become restricted to narrow pipe-like zones;

(d) there is a variable sulphide content in the magnetite of the deep ore and it is highest around the north end of the ore bands.

Geology was mapped upon completion of each monthly pit survey. The mapping indicates the chief elements affecting ore deposition to be pronounced folding, strong shearing and intense rock alteration.

A prominent fold can be seen in the trench at the mouth of the pit where limestone beds overturn from a westerly to steep easterly dip and continue below present levels in this attitude. In spite of the alteration in the headwall volcanic rocks, enough bedding remnants have been preserved to indicate a moderate westerly dip. In the centre of the pit the only recognisable structures are the easterly dipping ore bands with their associated slips and shears, the whole sub-parallel to the underlying diorite contact. Based on this evidence the writer sees the overall structure as a large drag fold, overturned westerly (figure 1 opp. page), the strong shearing and the ore bodies lying within its attenuated overturned limb. The fold appears to die out in a short distance accounting for the up and down dip limits of significant mineralisation.

Several recent shipments of ore have exceeded the allowable limit in sulphur content. This fact confirms the statement in last year's report (2), page 5 para 4, where it was stated: "Visibly the magnetite appears to contain more sulphide minerals than formerly.....".

While sulphides, especially chalcopyrite and pyrrhotite have always been present, they appeared to be in large patchy masses rather than in disseminations. Spectacular showings of these minerals are common in the magnetite around the north rim of the pit but in addition there is disseminated sulphide. It is this latter material that is difficult for the present concentrator to separate from the magnetite.

Of academic interest only was a find of beautiful large, glass-clear crystals of calcite in a gougy fault zone, cutting a band of magnetite. This material is probably of secondary origin, post-dating the emplacement of magnetite and probably formed at comparatively shallow depths where confining pressures were low enough to permit the growth of such crystals.

<u>KINGFISHER</u> (Figure 5)

The Kingfisher ore pipes reached their economic open pit limits by mid summer and all mining ceased. The East pipe floor stood at elevation 2,134 and that of the Central pipe at elevation 2,130. Both have since filled with water to a depth of forty feet.

Between May and July, twenty-seven holes totalling 5,683 feet were diamond drilled in the Kingfisher zone. The purpose of the drilling was to -

(a) look for an ore pipe between the Central pit and the Merry Widow,

(b) look for mineralization along the Kingfisher fault zone east of the East pit,

(c) assess the present ore pipes at depth by drilling below the pit floors.

Of the three holes drilled between the Central pit and the Merry Widow, two intersected about 50 feet of low grade ore beneath 250 feet of limestone. It is concluded from these results that there is no mineable ore in this area.

The three holes drilled to the east of the East pit and along the Kingfisher fault zone failed to locate any magnetite mineralization.

Drilling below the pit floors shows that the Central and East ore pipes merge at a depth of 100 feet and continue to at least elevation 2,000 feet, somewhat reduced in size. Calculations indicate that to this elevation, there are approximately 170,000 tons of magnetite in place grading 46.5% iron (without dilution), which is equivalent to 120,000 tons of recoverable concentrate. Open pit extraction of this material is considered to be uneconomic and underground extraction on the borderline.

Evidence from drilling and geological mapping indicates that mineralization in the East pipe changes from an almost vertical downward trend to a westerly plunge at 30 degrees as it passes beneath a prominent greenstone sill which marks the upper surface of a strong healed breccia zone. Movement in this zone spanned the period of introduction of magnetite and probably made it a major channelway for ore solutions in both pipes.

Large masses of clear calcite were found in the Central pipe ore zone embedded in soft greenish mud, which is probably an alteration product of greenstone dikes and sills. Many fine specimens of botryoidal magnetite were found also in this area. Both of these occurrences, while of academic interest, point towards conditions of low pressure at the time of formation of the ore. As pressure is a function of depth it follows that the Kingfisher ore probably formed not far beneath the original ground surface.

The Rambler zone, a few hundred feet east of and below the Kingfisher was examined and a detailed dip needle survey carried out. Neither the anomaly nor the showing is impressive enough to warrant further exploration.

RAVEN

Mannix Co. Ltd. the mining contractors opened up a small pit at the west end of the Raven zone. Diamond drilling in 1959 had indicated a concentration at this point of magnetite containing sulphide minerals (3). The pit was operated only during the summer months, after which it was abandoned and filled with waste from the Merry Widow. Although the mineralisation was not bottomed the pit had become uneconomical to work.

The ore contained more disseminated sulphides than the other two pits. Among these were the usual pyrrhotite and chalcopyrite, some pyrite and even sphalerite (sulphide of zinc). It is the only occurrence of zinc known to the writer on Empire's property.

The magnetite is markedly different than that in the main pits. It is fine grained, bluish-black with a dense texture, forming a much tougher rock to drill and blast. It is associated with a dark brown hard skarny alteration of volcanic greenstone close to a limestone contact.

The mineralized zone trends NNE along a steep fault zone and is about 100 feet in maximum width. The immediate controls localising this small ore body seem to be (a) the junction of the ENE Raven fault with the NNE fault; (b) the contact between greenstone and limestone.

KEYSTONE

The density of dip needle readings was increased from the 50 foot grid pattern of the 1959 survey to a 25 foot pattern this year. This procedure made no significant difference to the anomalous pattern; i.e. it still indicated a number of small, discontinuous anomalies. Hand stripping was done on the largest anomaly just west of the "Mitchell Stock" (greenstone) contact. It revealed discontinuous mineralization in the form of small gently dipping lenses of high grade magnetite.

In summary the Keystone is an interesting mineralized zone but shows little indication of making an ore body.

SNOWBIRD

Work in this area was confined to re-locating and blazing the old trail up to the Snowbird from the east end of Kathleen Lake. Eight new claims and fractions were staked adjacent to and west of the Snowbird crown granted claims, although only seven claims were recorded. This staking had the purpose of covering a greater area along the diorite-limestone contact. The work was performed in October on behalf of Empire by prospectors L. W. Jorgensen and R. Waller.

AJAX (Figure 2, opposite page)

The Ajax zone lies on the Coast Copper claim, old Sport No. 8 (L 1502), approximately 1700 feet north of the head of the tramway.

The showings are situated on a steep, bluffy, easterly facing slope, covered with heavy forest, between elevations 2500 and 2200 feet. The upper showings consist of narrow magnetite bands replacing skarny volcanic rock, with an interlacing of small magnetite veinlets. They outcrop over an area of 200 by 80 feet. The lower showing is a bedded replacement of limestone by magnetite just north of a fault contact between limestone and greenstone. At this point a twenty foot band of massive magnetite dips 30 degrees southwesterly (into the hill). The magnetite is flecked with much green chlorite but appears to be otherwise clean. The outcrop measures about 50 by 40 feet.

Geologically the showings are close to the limestone-volcanic contact, about 500 feet southeast of the main diorite contact. The limestone occupies a northeast facing crotch or angle in the outline of the volcanic rocks and the mineralization is in this vicinity. The volcanics are in part fragmental (resembling the overlying Bonanza formation) and in part fine grained (intrusive greenstone) with an intimate intergradation between these rocks. The writer feels that the lack of conformable relationships between these volcanic rocks and limestone means that the volcanics belong to the intrusive greenstone group rather than to the Bonanza group.

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A transit survey was extended down-hill from the main baseline to tie in the Ajax. Using this survey as control a grid was laid out at 50 foot intervals where topography, geology and dip needle readings were taken. At a later date the geology was re-mapped in more detail on 40 scale.

The Ajax showings in themselves are not impressive, nor do they look promising. The upper ones are scattered and low grade while the lower one seems confined to the immediate fault zone with little hope for expansion. The dip needle survey, however, yielded a moderate to strong anomalous pattern covering an area of 400 by 300 feet, as large as the map (Figure 2). Wide variations from positive to negative readings are present and probably due in part to the very steep slope on which readings were taken. It is obvious from this pattern that magnetite must extend beyond the limits of the present showings.

BLACK JACK AND SHAMROCK (Figure 3)

The 1960 exploration target on Coast Copper ground was the Black Jack, which had been reconnoitred briefly the previous season. It was partly explored during the year but became of secondary importance to the Shamrock zone, the existence of which was unknown until July.

The work was performed in the following manner:

1. A chain and transit traverse was run from the tramway to the far end of the Shamrock, a distance of 1½ miles. The course of the traverse was approximately on the ridge separating the Newt Lake drainage basin from that of the Benson River. At intervals, short spur traverses were run on either side of the baseline, one of which covered the Ajax and another the Black Jack.

The main baseline was an open traverse and could not be balanced for errors in the usual manner. A check was obtained on the survey by a one-mile bearing shot from the Merry Widow area across Newt Lake to Shamrock summit. It revealed a bearing error of seven minutes of arc, well within the allowable limits.

2. Several closed-loop surveys were run within the Black Jack and Shamrock areas to provide closer control.

3. Compass lines were run on either side of the base line at 100 foot intervals to cover the anomalous zones. Topographic details, geology and dip needle readings were recorded at hundred-foot intervals on each line. The results were later plotted on maps. Following an assessment of these results, the field work was repeated at fifty-foot intervals to provide more precise information in the important areas.

4. Based on interpretation of the final results, a program of diamond drilling on the Shamrock was recommended by Empire's staff and by Dr. A. C. Skerl (4), consulting geologist. Equipment was transported by helicopter from the Merry Widow area to a prepared site on the upper Shamrock zone. Drilling commenced on September 7, continuing until November 22, when heavy snowstorms forced a halt. During this time, twelve holes were completed and a thirteenth had been started; the total drilling amounting to 2,995 feet.

The main Black Jack outcrops (Figure 3) are at 2,700 elevation in a narrow precipitous canyon near the northwest corner of L 1499 (Old Sport #6 M.C.). At this point the magnetite is exposed in a 40 foot bluff on the south wall of the canyon for a width of 50 feet. The lower part of the showing is massive clean blue-black magnetite and the upper has a bedded appearance, with alternate limestone and calcite layers which strike northwest and dip 30 degrees to the southwest. The south edge of the magnetite ends abruptly at a contact with a hard greenish-gray altered volcanic complex which occupies the space between the limestone below and the diorite on the ridge above. A small outcrop of magnetite four feet wide lies on the limestone-volcanic contact about 300 feet lower and 300 feet east of the main showing. A small outcrop of magnetite in skarny greenstone lies about 600 feet to the west at elevation 2,940 feet.

The zone of dip needle anomaly trends west-northwest about 300 feet and is 175 feet across. It spans the contact area between limestone, altered volcanic and diorite. Much of the zone is concealed by forest growth or in the canyon by coarse talus blocks. Sink-holes are numerous and pock the surface in areas underlain by limestone.

It is obvious that there must be more magnetite in the Black Jack zone than is indicated by outcrops. Its form and distribution are unknown but it is probably composed of:

(a) layers of magnetite dipping toward the diorite contact and replacing limestone,

(b) stringers and irregular pods of magnetite associated with the thin selvedge of volcanic rocks between limestone and diorite.

The Shamrock outcrops are scattered for 1,200 feet along a narrow belt of skarny, altered volcanic rock bounded on the South by diorite and the North by limestone (Figure 3). In elevation they lie between 2,900 feet and 2,350 feet. They consist of disseminated magnetite in the upper part and more massive outcrops at the lower end. Much of the magnetite is clean but in places considerable pyrite is present.

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The significant dip needle anomaly is about 1,400 feet by 175 feet, following the limestone-diorite contact zone (Figure 3). Within this zone strong positive and negative readings are common, with sudden changes from one to the other within a short distance. These erratic readings are attributed to the effects of underlying magnetite accentuated by steep topography, where the horizontal attraction on a needle is often as strong or stronger than the vertical.

Diamond drilling on the Shamrock covered approximately the area indicated on the map (Figure 3). The hill side in this vicinity is very steep and forested and the drill was moved about with difficulty. The only dependable source of water was the small pond near the southeast corner of the claim, from which the water was pumped against a 150 foot head over the summit of the hill. The drill is now stored for the winter near station EB-73.

The drill program was laid out on the premise that mineralization formed an almost vertical slice along the steep diorite-limestone contact. The holes were to be drilled from the diorite in an easterly direction in vertical fans of two holes each, at -30 and -60 degrees to span the anomalous zone. As the drill picture unfolded the plan was changed to drilling steep holes downward from the actual outcrop area.

Drilling results to date have been disappointing. They indicate a partial replacement of skarny volcanic rock by magnetite in an irregular fashion. No definite pattern or trend of mineralization can be deduced from these results. An almost barren segment of ground 100 feet long was drilled just north of co-ordinate 57400 N (Figure 3). Mineralization is better in either direction from this segment, especially downhill to the North where the most massive outcrops are found. Hole No. 13 near station EB-73 had reached 51 feet when drilling ceased but it had a 36 foot intersection of 51% iron. Most of the intersections in the other holes were of moderate grade and width and were separated by barren stretches of skarny rock.

To date no mineable ore has been located by drilling in the Shamrock zone. Preliminary calculations by P. W. Billwiller show about 200,000 tons of material containing 26% iron, in the zone drilled. This, of course, is not ore, just mineralization.

The limestone-volcanic contact appears from drill hole interpretation to be very irregular. For this reason it is concluded that the volcanic rock is a greenstone, intrusive into limestone, rather than Bonanza rocks lying in conformable contact with limestone.

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GENERAL RECONNAISSANCE:-

During the summer the Staff reconnoitred the country, north, west and south of Empire's claim group, examining the rock types and general structure of the area. Around Merry Widow Peak (two miles southwest of the pits) the area is largely underlain by tuff, agglomerate and flows of the Bonanza group. The large cirque basin east of the peak (headwaters of Merry Widow Creek) is occupied by a small stock of intrusive pink syenitic rock. Its relationship to other rocks or to mineralization is not known.

The easterly contact of the Coast Copper diorite stock was traced from the Whiskey Jack zone north and west to Craft Creek, a distance of two miles (Figure 4) and in most of this distance is believed to be steep. The diorite is in contact with an altered volcanic rock which thins out across the Shamrock claim to a narrow salvedge less than 200 feet wide, finally disappearing on the Don fraction. Limestone lies east of and downhill from the volcanic rock. The volcanic exhibits, over broad areas a definite fragmental texture similar to some Bonanza extrusive rocks on the Bluebird claim (Lot 1538), south of the Merry Widow pit. It does, however, grade imperceptibly into the fine grained type of rock, known locally as intrusive greenstone. On the eastern boundary of Old Sport #6 M.C. (Lot 1499) the fragmental rock is in contact with limestone at elevation 1,600 feet. Below this point the limestone measures 1,600 feet thick down to its base which rests on Karmutsen volcanic rocks. A short distance both to the north and to the south of this point, over 4,000 feet of limestone exists. With these points in mind the writer feels that the contact in question is intrusive, i.e. the volcanic rock has replaced much of the limestone. It follows then that the volcanic rock is not of the Bonanza, rather it is intrusive greenstone. This point illustrates the problem discussed in the 1960 exploration report (2), page 3 under the heading "The Greenstone Problem".

The similarity in form between the eastward bulge in the diorite stock on Lot 1499 and that of the intrusive greenstone in the same area leads to the conclusion that the rocks were emplaced under the same structural control.

THE BRITISH COLUMBIA DEPARTMENT OF MINES:-

As a result of talks early in the year between the writer and officials of the Department it was decided to commence a geological investigation of the district. Dr. W. G. Jeffery and his assistant J. Lund spent several months mapping an area about 6 x 6 miles, centering on Empire's property. They made no attempt to re-map the detail already done by the Empire staff; rather were they concerned with the broader geological framework of the district. The work is unfinished but we hope it will continue next season.

Government mapping such as this can, in the long run, only be of great help to the mining industry. Little work has yet been done on coastal magnetite deposits and it is hoped that this effort will be the beginning of a better understanding of them.

The above mentioned geologists were partly responsible for the discovery of the Shamrock. Traversing beyond Empire's original survey line to the Black Jack, they reported strong dip needle reactions and the presence of magnetite in the area. Following this lead, Empire's staff outlined by mapping and further surveys the whole Shamrock zone.

OUTSIDE PROPERTY EXAMINATIONS AND REVIEWS

Following is a list of mineral properties examined or reviewed during the year. Each of these was reported on under separate cover.

1. IRON HILL

The maps and sections of this abandoned iron mine near Campbell River were reviewed in February by J. Lamb.

2. IRON RIVER

This property near Campbell River was examined by P. W. Billwiller in March.

3. TZARTUS ISLAND AND SARITA RIVER

Near Barkley Sound, Vancouver Island, these properties were examined by P. W. Billwiller and J. Lamb in March.

4. INDIAN CHIEF

On Sidney Inlet, Vancouver Island, this old copper mine was examined by J. Lamb and P. W. Billwiller in May.

5. LUCKY SEVEN AND PROVINCE GROUPS

Situated in the vicinity of Pender Harbor they were examined in July by J. Lamb and P. M. Stiles.

6. STAR OF THE WEST

Located on Tahsis Inlet, Vancouver Island, the maps and drill logs of this property were studied by J. Lamb and M. Mitchell in August, for Alberta Coal Ltd.

7. PRINCETON BENTONITE

This property was examined by Dr. A. P. Fawley in August.

8. TULAMEEN AREA

Literature on the iron deposits of Lodestone Mountain was reviewed in October by J. Lamb.

9. LEHMAN PROPERTY

Near Powell River, this property was examined by J. Lamb in November.

10. PECKO PROPERTY

On Mahatta River, Quatsino district, this property was examined in November by J. A. Coates.

11. HESQUIAT

Review of reports of iron in this part of Vancouver Island was made in November by J. Lamb and E. C. Oates.

12. LITTLE JOE PROPERTY

This property near Port Hardy was examined in November by J. Lamb and F. W. Billwiller.

13. BURMAN RIVER

Following reports of iron in this part of Vancouver Island, an investigation was made in December by J. A. Coates.

14. HEAD BAY IRON SHOWINGS

A study of the maps and sections was made for Mannix Co. Ltd. in October by J. Lamb and P. M. Stiles.

FUTURE EXPLORATION

Exploration this coming season is of prime importance to the Quatsino property of Empire Development Company. New ore must be found if the operation is to continue in 1962. Past exploration located further ore in the Merry Widow and Kingfisher and this ore is now being mined. In addition a number of interesting areas were explored and eliminated as possibilities. The search has been narrowed to a relatively few targets, these being discussed below.

1. MERRY WIDOW

The possibility of finding ore beyond the presently proposed pit limits is remote. Mineralization undoubtedly continues beyond these limits, especially downward, but it is not considered to be economically minable.

Geological mapping should continue as long as the pit is being mined. No other form of exploration is recommended.

2. KINGFISHER

Provided that Mannix Co. mines the bottom of the ore pipes by underground methods, geological mapping should be done and further exploration by drilling from the underground workings should be carried out.

3. AJAX

The anomalous pattern over this zone should again be checked with a good dip needle at an approximate spacing of 25 feet instead of the present 50 feet. If results indicate a favorable anomaly, compatible with the surface outcrops, a few short exploratory diamond drill holes will be justified.

4. SHAMROCK

At least three more holes should be drilled on the good showings near the northwest corner of the Shamrock No. 1 claim before the diamond drill is removed from that area. If these holes are favorable, more drilling will be required.

On the upper Shamrock between stations EN-65 and EB-59, several short holes should be drilled to span the anomalous zone. With favorable results drilling should continue, otherwise further work is not recommended.

5. BLACK JACK

Neither the location nor the appearance of the Black Jack showings is impressive. Were it not for the large area of anomalous readings, the zone might be dismissed as unfavorable. Before the diamond drill on the Shamrock is removed three or four short holes should be drilled, especially under the west end of the zone. Further work would depend upon the results of this drilling.

6. SNOWBIRD

Each year this remote zone has been considered but in the press of other work nothing has ever been done about it. A fly camp should be established by the exploration crew and the whole zone given a detailed survey such as that done last year on the Shamrock. Further exploration will be dependent on the results of this survey.

It is worth repeating that the Snowbird is so located that ore discovered there would mean a whole new mine, not just another ore body to be extracted from the present layout. Certain statements about the

Snowbird have been given much greater importance than they deserve from the available facts, therefore it will be necessary that the exploration be thorough and decisive.

Regardless of the outcome of future exploration at Empire's Quatsino property, the Company has gained invaluable information and experience on magnetite occurrences of this type. Such information and experience should make easier the assessment of other deposits that the Company may consider.

Respectfully submitted,

John Lamb, P. Eng., Geologist

Vancouver, B. C.
January 25, 1961.

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1959

SUMMARY:-

The Quatsino iron property of Empire Development Company is in north central Vancouver Island. It has in the past two years produced 375,000 tons of concentrate and has about three more years' ore reserves, at present extraction rates. All the reserves are contained in the Merry Widow and Kingfisher Zones although several other zones of mineralization are known.

To date 28,000 feet of diamond drilling has been done in addition to considerable geological and geophysical mapping.

The geological environment of the deposits is similar to the other well known iron orebodies on the British Columbia coast. The magnetite ore occurs along contacts between limestone and volcanic rocks in zones of lime silicate alteration.

Continued exploration will be necessary to fully exploit all possibilities for ore and to gain a better understanding of the nature of this type of iron deposit.

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GEOLOGY AND EXPLORATION
OF THE
QUATSINO PROPERTY OF EMPIRE DEVELOPMENT COMPANY LIMITED
VANCOUVER ISLAND, B. C.

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by
JOHN LAMB

FEBRUARY 1959

INTRODUCTION

The iron mining property of Empire Development Company lies in the Quatsino district of north central Vancouver Island (see map, Fig. 1). During the past year and a half, 375,000 long tons of magnetite concentrate were produced at this property and shipped to Japan.

At the close of the nineteenth century the first wave of prospecting flooded the Quatsino district but few records are left of its passing. In 1912 high grade copper ore was found in the Old Sport vein near Benson Lake, this discovery being followed by several years of active prospecting. Many mineralized showings were found and most of the Crown granted claims were located at that time. The magnetite outcrops were well searched for copper, gold and silver. Coast Copper Company, owners of the Old Sport, carried out extensive underground development until about 1932, when operations ceased. Quatsino Gold-Copper Mines Limited was incorporated in 1929 and began to acquire most of the claims that are now in the main group, controlled by Empire. A diamond drill campaign in 1930, to locate copper, was unsuccessful. Increasing interest in iron ore led Quatsino in 1950 to initiate another exploration, which continued until 1952. Diamond drilling, geological mapping and geophysical surveys were completed at this time. Results of the work are contained in the report of H. L. Hill (6).

In 1956 Quatsino Copper-Gold Mines and Mannix Ltd. of Calgary participated in the formation of Empire Development Company, for the purpose of operating the property. Production of concentrates began in September 1957.

The known reserves are approximately 1,700,000 tons of ore at a grade of 44% iron. These reserves are all contained in two zones, the Merry Widow and Kingfisher. Other zones on the property have, at present, only exploration possibilities and no reserves are shown for them.

Ore is mined by an open pit benching method and loaded by power shovels into dump trucks. Hauled about half a mile to a primary jaw crusher, the ore is lowered by inclined surface tramway to the mill where a straight magnetic separation produces a concentrate containing 58% iron. This concentrate is hauled twenty five miles in semi-trailer trucks to the dock near Port McNeill, on the northeast coast of Vancouver Island (see map, Fig. 2).

ACKNOWLEDGMENTS

A number of people have contributed information and ideas for this report and their help is hereby acknowledged. Among them are:

G. C. Lipsey P. W. Billwiller	Empire Development Company
A. Shank P. M. Stiles	Mannix Co. Ltd.
A. C. Skerl	- Consulting Geologist
W. T. Irvine C. L. Unwin	Consolidated Mining & Smelting Co. Ltd.

Several maps and drawings were prepared by Z. Witt and P. Billwiller, their help being much appreciated.

HOLDINGS

The property controlled by Empire Development Company consists of fifty six Crown granted and three located mineral claims situated in the valley of Benson River, Nanaimo Mining Division. Forty five of these claims are in one compact group, while eleven known as the Snowbird group are scattered along the mountain side above Kathleen Lake and separate from the main group about two miles (see map, Fig. 3). Immediately north of the main group are the claims of Coast Copper Company.

A camp accommodating over 100 employees is situated close to Benson River, while a smaller camp is maintained at the loading dock near Port McNeill.

TOPOGRAPHY AND CLIMATE

The district is moderately rugged, with elevations ranging from 500 to 4600 feet above sea level. The main claims cover the steep, lower, easterly face of Merry Widow Mountain. The mine is near the western edge of the property at 2500 elevation, while the concentrator is near the camp in the bottom of the valley.

The climate is mild with a heavy annual precipitation (possibly up to 150 inches). At the higher elevations deep snow accumulates in Winter. As a consequence of the climate, vegetation is profuse, consisting chiefly of dense forests of hemlock, cedar and spruce. Tangled undergrowth on the forest floor renders foot travel difficult. Such conditions are detrimental to good prospecting and mapping.

EXPLORATION TO DATE

DIAMOND DRILLING:

A total of 141 holes have been drilled on Empire's Quatsino holdings, aggregating 28,540 feet. The following table summarises this drilling.

ZONE	1930		1950-1952		1956	
	NUMBER OF HOLES	FOOTAGE	NUMBER OF HOLES	FOOTAGE	NUMBER OF HOLES	FOOTAGE
CAMP AREA	4	3786				
MERRY WIDOW	1	954	46	6729	27	7849
SUMMIT					5	657
WHISKEY JACK					12	1724
RAVEN					5	803
MARTEN					5	729
KINGFISHER			16	2532	18	2630
RAMBLER FR.			2	157		
TOTAL	5	4740	64	9408	72	14392

Of the total footage drilled, 54% was on the Merry Widow and 18% on the Kingfisher.

GEOLOGICAL MAPPING:

In 1952 H. C. Gunning mapped the mine area on a scale of one inch to 100 feet. In 1957 C.L.R. Unwin mapped the main claim group on a scale of one inch to 200 feet, with special emphasis on rock types.

In 1958 the writer did considerable detailed mapping in the Merry Widow and Kingfisher zones on a scale of one inch to 40 feet. Mapping at one inch to 200 feet was completed on the roads and limited reconnaissance was done in the district. Geologists of the Consolidated Mining and Smelting Company completed detailed mapping in the camp area. This work was done in connection with an agreement between Consolidated and Empire.

GEOPHYSICAL SURVEYS:

In 1952 magnetometer and dip-needle surveys were performed in the Merry Widow, Kingfisher and Snowbird areas. Further magnetometer work was done in 1957 by Empire's geological staff on the Summit, Whiskey Jack and Keystone Zones. In addition, much of the mountain side between the camp and mine was covered. A survey was also run across the Contact claims, located at the northeast corner of the main claims.

The British Columbia Department of Mines surveyed a large part of the district in 1957 with an air-borne magnetometer and published a map of the results, on a scale of one inch to half a mile (10).

The chief value of the geophysical surveys was in outlining anomalies over the known zones of mineralization. No important anomalies were indicated elsewhere. The results of the work were qualitative, in that they traced in a general way the trends of mineralization, but could not be used to estimate tonnages of ore. The 1958 drilling on the Merry Widow and Kingfisher Zones proved that the geophysical anomaly outlines were only approximately correct. The earlier assumptions, that these outlines delimited ore boundaries for purposes of mine planning, were corrected when the drilling evidence became available.

REGIONAL GEOLOGY

The Quatsino district has been mapped geologically only in a reconnaissance way by Dolmage (2) and Gunning (5). The Nimpkish-Zeballos area to the east was mapped ten years ago by Hoadley (7) of the Canadian Geological Survey, on a scale of one inch to one mile. Some attempts were made during the years to map geology on local mining properties.

With the above information to draw on and with some original observations, the writer compiled a geological map on the Alice Lake Map Sheet (No. 92-L 6 appended to this report, Fig. 4). It is thought to be a fair approximation of the areal geology, subject to alteration when further information becomes available.

The rocks of the district are composed of volcanic and sedimentary formations trending northwesterly and dipping to the southwest. The eastern half of the Alice Lake Sheet is underlain by the Karmutsen Group, a volcanic assemblage of basaltic and andesitic lavas containing minor breccias and sedimentary layers. These rocks are well exposed on the main road to Port McNeill between Iron Lake and Keogh Lake. Here they consist of massive green to purple flows and pillow lavas. Amygdaloidal structures are common in these rocks.

Conformably above the Karmutsen lies the Quatsino Formation which trends diagonally across the map from southeast to northwest corners. Composed of well defined beds of massive blue-gray and white limestone, this formation underlies most of the surface of Empire's claims, where it appears to be about 3000 feet thick. It is locally quite siliceous and sometimes completely recrystallized to coarse white marble. Well preserved fossils have been found near the lower contact of the Quatsino, on Merry Widow Creek and on the road near Iron Lake. They are believed to be Triassic in age.

The Bonanza Group occupies the western part of the map-area, overlying the Quatsino conformably. It consists of a thin, lower, dominantly sedimentary series of tuffs, argillite and quartzite overlain by thick beds of andesitic lava, tuff and agglomerate. These rocks range in color from green to brown to dark red. The contact between the Bonanza and Quatsino formations is thought to be in the vicinity of the Merry Widow orebody.

Several irregular stock-like bodies of crystalline igneous rocks have been found in the district and doubtless others will be found by thorough mapping. These bodies are made up of medium to coarse grained gray to blackish, granitic textured rocks, with a composition varying from granodiorite to gabbro. One such body, southwest of Benson Lake, is called the "Coast Copper Stock". Its eastern contact, 400 feet behind the Merry Widow pit, dips steeply eastward below the pit.

All the above older rocks are intersected by late volcanic dikes, sills and irregular bodies; fine grained and usually grayish green. Even among these rocks several different types have been observed and probably represent different periods of intrusion.

LOCAL GEOLOGY (map, Fig. 5)

Empire's main claim group is bounded on its western border by the diorite-gabbro of the Coast Copper Stock. Outcropping over most of the ground are the limestones of the Quatsino formation. In the northeast corner of the claim group the contact between Quatsino and the underlying Karmutsen volcanics is poorly exposed.

This contact, running north-northwesterly into Coast Copper property, forms the plane of the Old Sport copper mineralization.

Around the eastern boundary of the property near the Benson River bridge, extensive outcrops of volcanic breccia, agglomerate and minor flows overlie the limestone. These rocks were tentatively correlated with the overlying Bonanza volcanic formations. If this is correct, it means that both the top and bottom of the Quatsino outcrop in the valley a short distance apart. Possible explanations of this occurrence are -

a. the correlation is incorrect;

b. faulting has displaced the upper Quatsino down into the valley.

Many small cross cutting dikes and irregular sills of greenstone outcrop throughout the limestone. Several of the larger bodies form steep rugged bluffs on the mountain side. Their contacts with the limestone are usually sharp, steep dipping and sometimes faulted.

Bedding structures are well developed in the Quatsino formation and partially developed in the volcanic rocks. The bedding invariably dips from flat to gently westward and strikes from northeast to northwest. Cross bedding, observed in several places, indicates the beds to be lying top-side up. At no place was evidence seen of overturned folding. The present feeling is that the whole rock sequence on Empire ground is monoclinal to the west.

Numerous gentle cross folds or warps are indicated by close mapping on the tote road and around the mine. Such folds in gently dipping rocks are responsible for the wide variation in strike. The pronounced northeasterly bedding trends in the limestone at the mine are caused by this type of folding.

The fault pattern is not well understood. A prominent set of steep NNE faults shows on maps and air photographs and controls to some extent the drainage pattern on the hill side. Doubtless there is some displacement on these faults, but it is probably small. In the mine area these faults appear to have little if any displacement.

The valley of the Benson River and that in which Maynard and Iron Lakes lie, form long straight lineaments trending north across the northwesterly striking formations. These features are probably old regional breaks or zones of crustal weakness. Their significance is beyond the scope of this report.

THE OREBODIES AND MINERALIZED ZONES

MERRY WIDOW - (plan, Fig. 6)

The Merry Widow orebody is made up of plates of massive magnetite dipping easterly from 30 to 50 degrees (cross-section 105, Fig. 7). These plates may be from a few feet to over 60 feet thick and are stacked one above the other between bands of low grade skarn (lime silicate) and volcanic rocks. The thickness of the whole zone is about 500 feet from the surface down to the contact of the diorite-gabbro of the Coast Copper Stock, which is sub-parallel to the layers of ore. Beneath the contact mineralization ceases. The prolongation of ore down the dip of the layers is not known. The change into a limestone environment in this direction may affect it. The ore appears to terminate up-dip as shown on the section. Drill holes on other sections indicate this to be the case but it is not yet understood why.

In plan the Merry Widow orebody is 200 feet long, north-south, by 350 feet, east-west, with a local southward extension known as the South pit.

The lime-silicate is more widespread than the magnetite mineralization. It is a hard, heavy, blocky rock, brownish green in color, composed largely of garnet and diopside, with minor amounts of epidote and wollastonite. These minerals are formed by reaction between siliceous fluids and impure limey rocks.

The magnetite is black and massive, varying from coarsely crystalline to a fine steely looking dense rock. Minor amounts of metallic sulphides are associated with the ore in the form of pyrrhotite, pyrite, arsenopyrite and chalcopyrite, usually in small blebs or streaks in the magnetite. The amount of these sulphides does not constitute a problem in maintaining the specifications of the final iron concentrate. The gangue minerals in the ore are lime silicates, chlorite and coarsely crystalline white calcite. This calcite is a late mineral filling a network of fractures in the massive magnetite.

The sequence of mineralisation is thought to be -

a. widespread lime silication, followed by crackling and brecciation;

b. magnetite mineralisation replacing and veining the skarn and wall rocks. This is followed by further brecciation.

c. mineralisation by metallic sulphides and calcite.

The following known elements of Merry Widow structure are:

a. The volcanic-limestone contact passes through the Merry Widow.

b. The easterly dipping diorite contact forms a steep floor beneath the ore zone.

c. Bedded rocks in the pit headwall dip westerly.

d. Magnetite layers dip easterly.

e. Limestone beds trend northeasterly and dip gently to the northwest, but around the ore zone show many anomalous dips.

f. Several prominent ENE faults pass through the ore zone.

Putting together these elements produces the picture shown in plan and section on the opposite page (Fig. 11). It suggests the orebody is involved in a plunging fold structure, open at its northern end and pinching to the south. Such a structure could form a trap for mineralising fluids and explain the location of the orebody at that point.

KINGFISHER - (Figures 6 and 7)

The Kingfisher orebodies, 800 feet easterly from the Merry Widow, are in a different structural setting. The exploration program of 1952 outlined a narrow anomalous zone trending east-northeast for 700 feet, with two nodes of mineralization, one in the centre and the other at the eastern end of the zone. Drilling indicated that the mineralization had a small lateral spread with a much greater vertical extent. Inclined holes, drilled in 1958, succeeded in outlining the shape and trend of the ore. As a result, we now know that the Kingfisher consists of two pipe-like orebodies, roughly elliptical in plan, plunging steeply to the southeast. The larger Central Pipe, outcropping at elevation 2400 feet, has been traced to 2070 elevation and the East Pipe to 2100 elevation. Both are open at the bottom and it is not known how much deeper the mineralization goes.

The orebodies consist of clean, dense, high grade magnetite surrounded by crystalline limestone. Although there are a few steep narrow greenstone dikes in the ore and patches of coarsely crystalline calcite, the boundaries between ore and limestone are sharp. The magnetite is dense, blue-black in color and inclined to be brittle and crumbly. It varies from loosely held aggregations of coarse crystals to fine grained coaly-looking material.

Unlike the Merry Widow, the Kingfisher pattern of alteration is characterized by widespread marbleization of the surrounding limestone with almost no skarny alteration, except around greenstone dikes. In the case of these dikes, the skarn is usually limited to narrow bands along the contacts.

In the Kingfisher area the limestone shows fairly good bedding with a northeasterly trend and a low northwesterly dip. Conforming closely to this pattern is a crude banding of the magnetite in the Central Pipe, consisting of alternate layers of coarse and fine ore. The plunge of the pipe is approximately perpendicular to the plane of this banding.

One can only speculate on the ore controls in the Kingfisher Zone. The facts of the occurrence are:

a. Steep southeasterly plunging pipes;

b. The limestone wall rocks strike northeasterly and dip gently to the northwest;

c. The ENE trending Merry Widow and Kingfisher faults pass through the zone;.

d. Steep northwesterly trending breaks form complementary fractures to those in "c". Narrow greenstone dikes are commonly found along such breaks.

It is possible that the lines of intersection of the above sets of fractures are the localizing agents for the Kingfisher pipes, in that they acted as channelways for the mineralizing fluids or gases. The deposition of the ore may have been partly by replacement and partly by fissure filling. There are probably chemical factors involved in this deposition that are not obvious to the geologist in the field.

<u>MARTEN</u> (Figs. 5 and 6)

This small zone, lying across a steep narrow gulch from the Merry Widow, had five holes drilled into it in 1958. Extensive showings of massive pyrrhotite, with minor chalcopyrite and magnetite, outcrop on a steep wooded ridge and are exposed by old trenches.

The limestone-volcanic contact passes right through the zone, along which are narrow bands of magnetite. The drilling, while not extensive, found only a token amount of mineralization.

<u>RAVEN</u> (Figs. 5 and 6)

This zone, 500 feet north of the Merry Widow pit, was outlined as a narrow anomaly trending ENE. It is parallel to a prominent fault of the same name, which dips steeply to the northwest. The fault is well marked on surface by a line of small gullies and depressions, and is one of the same set to which the Merry Widow and Kingfisher faults belong. On the hangingwall or north side of the fault is an assemblage of intrusive greenstone, breccias and micro diorite, while on the footwall side the rock is all crystalline limestone, cut by a few late dikes. Along the explored length of the Fault there is scattered magnetite and sulphide mineralization.

In 1958 five holes drilled in the Raven zone succeeded in finding narrow widths of skarn, some of it mineralized with magnetite. While no mineable ore was located, there are enough indications to merit further investigation. The whole zone appears to have some of the structure and alteration which is associated with ore in the Merry Widow and Kingfisher.

WHISKEY JACK (Figs. 5 and 8)

Lying astride the main haul road, 600 feet southwest of the crusher, the Whiskey Jack is represented by small scattered outcroppings of mineralized skarn at a place where a residual pod of limestone occurs, almost surrounded by altered intrusive greenstone.

A magnetometer survey in 1957 outlined two small anomalies around which 12 holes totalling 1724 feet were drilled in 1958. A narrow band of mineralized skarn was found between barren white limestone on the east and siliceous altered greenstone on the west. The mineralization appears to trend northeast and dips steeply to the southeast. It is known to be 300 feet long by 150 feet deep (Fig. 8).

While it has not been exhaustively drilled, the Whiskey Jack is so limited that possibilities for more mineralization are not good. The writer believes that no significant tonnage of open-pit ore is available in the first hundred feet of depth.

SUMMIT (Fig. 5)

Lying close to the northern boundary of the claims, the Summit Zone is 400 feet north of the tramway hoist room. Scattered magnetite float lies on a steep forested slope and what appears to be an outcrop (20 by 30 feet) is a mass of high grade magnetite projecting from the ground.

A magnetometer survey in 1957 outlined a small anomalous zone. In 1958 five holes totalling 729 feet were drilled in and around this zone. Core recovery was less than 10% and results were almost negative. To a depth of 100 feet, fragments of greenstone mixed with magnetite form a loose unconsolidated mass of rubble. It is not known whether this material is from a fault zone or a buried talus slide. It is certain, however, that to the depth drilled it is not ore. (Fig. 9).

RAMBLER FRACTION (Fig. 5)

This zone is several hundred feet east of and lower than the Kingfisher. In 1952 geophysical surveys were run in the vicinity of a 30 X 6 feet outcrop of high grade magnetite on the old mine trail. In the same year two short holes were drilled, with negative results. Since that time no work has been performed on the showing.

KEYSTONE (Fig. 5)

Situated on Merry Widow No. 6 claim, the Keystone lies one quarter mile southeast of the Kingfisher orebodies. It consists of a northeasterly trending string of scattered magnetite outcrops on a steep forested slope with characteristic sink hole topography.

During 1957 magnetometer and geological surveys were made across the Keystone showings. This work succeeded in outlining four small anomalies along a contact zone between intrusive greenstone and limestone. Since that time no further work has been done.

SNOWBIRD (Fig. 3)

Apart from a dip-needle survey and visual examination of the Snowbird group in 1952 no work has been done in the area. The showings are located on another mountain two miles northwest of the Merry Widow. The outcrop consists of a band of magnetite mineralization dipping gently southward into the hill. Geological maps suggest it is close to the contact between the Coast Copper Stock and Quatsino limestone.

FUTURE EXPLORATION

REGIONAL -

A study of the known magnetite deposits on the coast of British Columbia indicates they all have certain characteristics in common, that is, their geological environments are similar. They consist of massive magnetite in zones of lime silicate (skarn) alteration which are found along contacts between bands of limestone and volcanic rocks where such contacts are in proximity to bodies of crystalline igneous rocks of granodioritic to gabbroic types.

A thorough explanation of the particular environment would involve a highly theoretical discussion of chemical and physical controls of ore beyond the scope of this report. The following outline suggests the writer's view:

a. The original source of the iron is the volcanic country rocks (Bonanza Group), which have a higher than average content of iron.

b. Processes involving heat and pressure within the earth's crust have, at certain locations, driven the iron out of these rocks, re-worked it into the form of magnetite and concentrated it in favorable traps.

c. Limestone is necessary to allow the chemical reactions in "b" to proceed.

d. Structurally disturbed areas suitable for these reactions are often foci for the formation of crystalline igneous rocks. Therefore, the presence of a body of granodiorite may be a clue to a disturbed area. In addition, the granodiorite body introduces another rock type to the area which further complicates the details of structural control.

From the above knowledge the following approach could be used to search for magnetite deposits:

1. From existing literature and maps build a picture of the regional geology.

2. Outline the belts of limestone-volcanic contacts.

3. Either on maps or in the field try to locate areas where such contacts are close to granitic-type bodies of rock.

4. Conduct detailed field prospecting in these favorable areas. The work should include a close visual inspection of the area, looking for clues, such as skarn alteration or magnetite float. In places where overburden masks the obvious clues, a dip needle or magnetometer should be employed to search for anomalous zones.

5. Follow up promising indications with exploratory diamond drilling.

When one considers the climate, terrain and lines of communication of coastal British Columbia and the present scanty geological information, it will be appreciated that a thorough exploration program would be long and expensive.

LOCAL EXPLORATION -

Economic considerations as to the definition of ore are beyond the scope of this report. It is, however, important to realize that underground mining methods are more expensive than open-pit methods. As some of the Merry Widow and Kingfisher mineralization is now considered to be too deep for open-pit mining, an underground approach may be necessary for any further ore found there. Unless the ore tonnage is much greater and the shape of the orebodies is amenable to low cost underground mining, it is not likely that it will be mineable. In the following discussion on exploration, the chief consideration is for open-pit ore but underground possibilities will be noted, where applicable.

MERRY WIDOW AND KINGFISHER -

a. Both the bottom of the Kingfisher pipes and the downward extension of the Merry Widow ore layers require deep drilling to determine the extent and magnitude of mineralization. Apart from any ore found, which would probably require underground extraction, this drilling would provide vital information on the nature and habit of these magnetite orebodies.

b. Between the Merry Widow and Kingfisher orebodies (cross-section 10S) is a zone in which information is lacking. Drilling penetrated only 100 feet below surface in rubble and caved material but did not reach solid rock.

The Kingfisher geophysical anomaly, superimposed on the Central and East pipes (see Fig. 10), indicates that each pipe occurs at a prominent bulge in the anomalous outline. A third bulge lies directly above the rubble zone, which defeated the first drilling attempt.

Inclined holes, drilled westerly from the wall of the Central open pit, would adequately test the zone for the possible occurrence of another pipe-like deposit of magnetite. Any ore found would probably require an underground approach.

c. Between the Rambler Fraction showings and the Kingfisher east pipe is a zone that requires further detailed geological and geophysical mapping.

d. Diamond drilling below the Merry Widow south pit down to the diorite contact would test this area for any possible southward extension of the deep ore layers.

RAVEN -

The Raven Fault Zone should be mapped in detail and closely surveyed with a dip needle or magnetometer. Sharl (8) was impressed with the appearance of the whole zone.

KEYSTONE -

The anomalous zones should be stripped to reveal the nature of their occurrence. This work could best be accomplished by hand labor or by a bulldozer. If results are encouraging, diamond drilling might be justified.

SNOWBIRD -

Being in a location remote from all present facilities, the Snowbird exploration will be more expensive than in the other zones. It requires a close geological study to determine its structural environment. Further work on the zone would depend on the results of this study.

SOUTHERLY EXTENSION OF CONTACT ZONE -

A relatively unexplored segment of geologically favorable ground extends for over half a mile south of the Merry Widow pit. The limestone-volcanic contact trends in this direction and presumably the diorite body is not far distant. The hill slope is densely forested and outcrops are scarce throughout the area.

Exploration along this contact zone should begin with tight survey control, run westward from the upper leg of the tote road. Based on this survey, close geological mapping and dip-needle traverses should be done. Further exploration would depend on results of the above work (see Fig. 5).

Answers to some of the problems of ore occurrence on the Quatsino claims have already been found. The importance of close geological observation in arriving at these answers cannot be overstressed. To reach a still better understanding, continued work of this nature will be required. Not only will it be useful in searching for ore on the present property but it may also be applied to the search for deposits of iron ore elsewhere.

John Lamb, P.Eng.,
Geologist.

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Inst Const + 1.2 ft

M.W. Sample Traverse

June 12 - sunny

1

Sta	to	HI	Rod	Int	Vert ∠	ΔV	ΔH	El	Dist		Remarks
⊡H4		3.1						2624.2 0			
	⊡H5		5.3					2622.0 -2.2	79.5		
	T1		3.5	0.50	32° 45'	+2.4		2626.2 +2.0	50.		
	⊙1		3.3	0.54	-10° 01' 19° 59'	-9.5		2614.7 -9.5	53		
	⊙2		3.3	0.70	-3° 50' 26° 10'	-4.7		2619.3 -4.9	71		
	⊙3		4.6	1.18	-3° 44' 26° 16'	-7.7		2615.0 -9.2	119		
	⊡1		4.7	2.65	-0° 16' 29° 44'	-1.2		2621.4 -2.8	266		
Δ1		4.3						2621.4 -2.8			
	⊙4		4.3	1.35	-9° 17' 20° 43'	-21.5		2599.9 -24.3	134		
	⊙5		9.0	1.05	-17° 31' 12° 29'	-30.4		2586.3 -37.9	97		water course is 6' lower
	Δ2		6.5	0.83	+ 25° 23' 55° 23'	+32.1		2651.3 +27.1	69		
	Δ3		3.0	1.21	+ 16° 53' 46° 53'	+33.7		2656.4 +32.2	111		
	⊙6		6.2	0.50	+ 24° 37' 54° 37'	+ 19.0		2638.5 +14.3	42		
Δ3		4.7						2656.4 +32.2			
	Δ4		3.5	0.61	+ 22° 47' 52° 47'	+21.4		2679.0 +54.8	52		
	⊙7							2669			on correct line, - measured 14' down from Δ4

June 13 – sun

Sta	to	HI	Rod	Int	Vert ∡	ΔV	El	Dist	Remarks
Δ4		4.3					2679.0		
	⊙8		3.0	0.26	+21°34′, 51 34	+8.8	2689.1	22	
	Δ5		3.0	0.80	+22° 03′, 52° 03′	+27.8	2708.1	69	
Δ5		4.3					2708.1		
	Δ6		3.0	0.55	+21°50 51° 50′	+19.1	2728.5	47	
Δ6		4.2					2728.5		
	Δ7		6.5	0.85	+22°48′ 52°48′	+30.1	2756.3	73	
	⊙9		6.3	0.62	+7° 22′ 37°22′	+7.9	2734.3	62	
Δ7		4.3					2756.3		
	Δ8		3.3	0.58	+18° 19′ 48° 19′	+17.3	2774.6	53	
	⊙10		3.0	0.16	+11° 52′ 41° 52′	+3.2	2760.8	16	
Δ8		4.3					2774.6		
	Δ9		3.3	0.70	+19° 03′ 49° 03′	+21.5	2797.1	63′	
Δ9		4.1					2797.1		
	Δ10		3.5	0.77	+18° 50′ 48° 50′	+23.5	× 2821.2	× 70′	← incorrect – see next page
	⊙11		9.5	0.13	−11° 11′ 18° 49′	−2.3	2786.4	13′	

Sta	to	HI	Rod	Int	Vert ∠	ΔV	El	Dist		
Δ10		4.4					2824.2		El from Δ9	p 3.
	Δ9		3.5	0.87	−20°00' 10°00	−28	2797.1	77'	B.S. − check.	El as on p2 Δ9
	Δ11		6.5	0.73	+18°24' 48°24'	+21.8	2843.9	67'		
							June 14 — sunny, hot			
	⊙12		9.7	0.15	−24°09' 5°51'	−5.5	2813.4	13'		
Δ11		4.1					2843.9			
	Δ10		6.3	0.70	−15°10' 14°50'	−17.4	2824.3 ✓	66' ✓	BS − check ok	
	Δ12		3.5	1.37	+25°20' 55°20'	+52.6	2897.1	114		
	⊙13		9.5	0.73	+19°51' 49°51'	+23.1	2861.6	65		
Δ12		3.8					2897.1			
	Δ11		3.5	1.37	−25°55' 4°05'	−53.5	2843.9 ✓	113 ✓	B.S. check.	
	Δ13		3.2	0.35	+27°41' 57°41'	+14.4	2912.1	27		
	⊙14		3.5	0.22	+10°21' 40°21'	+3.9	2901.3	22		
Δ13		4.1					2912.1			
	Δ12		3.5	0.36	−29°00' 1°00'	−15.4	2897.3 ✓	28 ✓	B.S. − check	
	Δ14		3.3	0.59	+14°29' 44°29'	+14.3	2927.2	56		

Sta	to	HI	Rod	Int	Vert ∡	ΔV	El	Dist	
Δ14		4.2					2927.2		
	Δ13		3.7	0.59	-15° 56′ 14° 04′	-15.6	2912.1	55	B.S. - check
	⊙15					-2-	2925.2	18′	direct measurement.
	Δ15		3.5	1.04	- 4° 13′ 25° 47′	-7.7	2920.2	105	
	T2		3.0	1.10	-17° 07′ 12° 53′	-30.9	2897.5	106	
Δ15		3.9					2920.2		
	Δ14		4.0	1.04	+ 3° 45′ 33° 45′	+6.8	2926.9	105	B.S. - check.
	⊙16		3.3	0.57	+ 4° 36′ 39° 36′	+4.6	.	58	
	Δ16		4.0	0.99	- 19° 35′ 15° 25′	-24.1	2896.0	93	
Δ16		4.0					2896.0		
	Δ15		4.0	1.01	+ 19° 38′ 49° 38′	+32.0	2828.0	91	B.S check
	⊙17						2910.2		Δ19 - Δ15 produced 14′ - 10′ lower than Δ15
	Δ17		4.0	1.41	- 0° 41′ 29° 19′	-1.7	2894.3	142	
	⊙18		9.0	0.30	-17° 56′ 12° 04′	-8.8	2882.2	28	
						June 15 - sunny, hot			
Δ17		4.3					2894.3		
	Δ16		3.0	1.41	+ 0° 06′ 30° 06′	+0.3	2895.9	142	B.S
	Δ18		5.5	1.24	-17° 45′ 12° 15′	-35.9	2857.2	114	

Sta	to	HI	Rod	Int	Vert ∡	ΔV	El	Dist			
△18		4.0					2857.2				
	△17		6.0	1.25	+19° 08' 49° 08'	+38.7	2893.9	113		B.S.	
	△19		9.0	1.65	−29° 20' 0° 40'	−70.3	2781.9	125			
△19		4.6					2781.9				
	△20		8.5	1.00	−26° 58' 3° 02'	−40.2	2737.8	79			
	⊙19	~~7.4~~	7.4	1.40	[illegible] (at +31°30'	+62.0	2841.1	102			
	⊙20		3.6	.78	+6°15' 36°15'	+8.5	2791.4	77			
△20		4.3					2737.8				
	△19		3.5	1.02	+28° 40' 58° 40'	+42.3	2780.9?	79			
	△21		3.3	0.70	−9° 46' 20° 14'	−11.7	2727.1	69			
						June	16 −	sunny			
△21		4.2					2727.1				
	△22		3.0	1.30	−20° 26' 9° 34'	−42.4	2685.9	115			
	⊙21		3.5	0.62	− 6° 58' 23° 02'	−7.5	2720.3	62			
△22		3.8					2685.9				
	△21		3.0	1.30	+19° 28' 49° 28'	+40.7	2727.4	116			
	⊙22		9.0	1.20	+1° 42' 31° 42'	+3.6	2684.3	121			
	⊙23		6.5	0.89	+10° 53' 40° 53'	+16.6	2699.8	87			

M.W. Headwall — June 24 - overcast

Sta	to	HI	Rod	Int	Vert ∡	ΔV	Elev	Dist		
							2624.18			
H4		3.6								
	⊙1		3.3	0.53	−12° 38′ 17° 22′	−11.4	2613.1	52		
	⊙24		3.5	0.86	− 1° 40′ 28° 20′	−2.5	2621.8	87		
	⊙25		3.5	0.97	+ 2° 08′ 32° 08′	+ 3.6	2627.9	98		
	⊙26		3.5	0.87	+ 0° 55′ 30° 55′	+ 1.4	2625.7	88		
	⊙27		3.4	0.74	+ 5° 07′ 35° 07′	+ 6.6	2631.0	74		
	⊙28		8.0	2.90	+ 5° 37′ 35° 37′	+ 28.5	2648.3	289		
	⊙29		3.5	3.28	+ 8° 08′ 38° 08′	+ 45.9	2670.2	322		
	△23		6.0	4.36	+ 5° 53′ 35° 53′	+ 44.8	2666.6	433		
							2666.6			
△23		4.2								
	H4		6.0	4.34	− 5° 21′ 24° 39′	− 40.5	2624.3 ✓	431 ✓	B.S. – ck	
	⊙30		5.0	3.25	− 6° 39′ 23° 21′	− 37.1	2628.7	321		
	⊙31		8.0	3.10	− 5° 35′ 24° 05′	− 31.9	2630.9	308		
	⊙32		2.0	2.17	− 10° 35′ 19° 25′	− 39.1	2629.7	211		
	⊙33		5.0	3.06	− 6° 45′ 23° 15′	− 36.9	2629.9	304		
	⊙34		3.0	1.70	− 13° 26′ 16° 34′	− 38.1	2629.7	162	15′ x 15′	oc.
	⊙35		9.5	0.94	− 13° 12′ 16° 48′	− 20.9	2640.4	90		

Sta	to	HI	Rod	Int	Vert ∡	ΔV	Elev	Dist
Δ23 cont'd	⊙36		9.9	0.38	− 11° 54′ 18° 06′	−7.7	2653.2	38
	⊙37		6.8	0.53	− 7° 52′ 22° 08′	−7.2	2657.3	53
	⊙38		3.3	0.54	+ 5° 23′ 35° 23′	+5.1	2672.6	54
	⊙39		5.5	1.45	+ 3° 41′ 33° 41′	+9.3	2674.6	146
	⊙40		9.0	1.45	+ 0° 53′ 30° 53′	+2.3	2664.1	146
	⊙41		5.5	1.07	+ 7° 34′ 37° 34′	+14.0	2679.3	107
	⊙42		3.5	0.96	+ 9° 50′ 39° 50′	+16.2	2683.5	94
	⊙43		3.5	0.87	+ 5° 47′ 35° 47′	+8.8	2676.1	87
	⊙44		9.0	1.29	− 10° 36′ 19° 24′	−23.4	2638.4	125
	⊙45		9.0	1.83	− 9° 01′ 20° 59′	−28.3	2633.5	178
	⊙46		2.0	2.86	− 8° 06′ 21° 54′	−39.9	2628.9	280

MW & Dumps — July 3 – sunny, hot

Sta	to	H.I.	Rod	Int.	Vert ∡	Δ El.	El	Dist				
H5		3.4					2622.0					
	T5		5.0	2.44	-25° 58′ 4° 02′	-96.0	2524.4	198				
	T6		8.0	2.30	-26° 15′ 3° 45′	-96.0	2521.4	185				
	T7		5.0	3.17	-18° 39′ 11° 26′	-96.0	2524.4	284				
	T8		9.0	1.46	-27° 05′ 2° 55′	-59.0	2557.4	116				
	T9		9.0	1.75	-26° 26′ 3° 34′	-69.8	2546.6	141		intersection roads		
	T10		9.0	1.49	-18° 02′ 11° 58′	-43.9	2572.5	134				
	Δ 24		5.0	~~9.80~~	-10° 05′ 19° 55′	~~-168.0~~	~~2452.4~~	~~950~~				
	T11		5.0	9.35	-12° 24′ 17° 36′	-195.0	2425.4	895				
	T12		6.0	8.80	-14° 26′ 15° 34′	-212.0	2407.4	825		addit		
	T13		6.0	6.35	-18° 10′ 11° 50′	-187.0	2432.4	574				
	T14		6.0	7.13	-16° 44′ 13° 16′	-196.0	2423.4	658				
	T15		5.0	8.12	-16° 05′ 13° 55′	-216	2404.2	750				
	T16		5.0	9.30	-14° 24′ 15° 36′	-223	2397.4	875				
	T17		6.0	8.75	-18° 56′ 11° 04′	-266	2353.4	782				
	T18		6.0	7.40	-20° 07′ 9° 53′	-239	2380.4	652				
	T19		5.0	9.90	-14° 30′ 15° 30′	-239	2381.4	930				
	Δ 25		3.0	6.25	-11° 23′ 18° 37′	-244	2378.4	1210		½ hairs		

	T 20		6.0	4.70	-21° 42′ 8° 18′	-162	2457.4	408				
	T21		6.0	5.00	-20° 01′ 9° 59′	-161	2458.4	441				
	Δ 26		6.0	6.34	-10° 12′ 19° 48′	-110′	2509.4	615				
Δ 26		4.4					2509.4					
	T 22		4.5	2.94	+ 2° 22′ 32° 22′	+ 12.2	2521.5	295				
	T 23		4.5	2.92	+ 1° 58′ 31° 58′	+ 10.1	2519.4	293				
	T 24		5.0	3.72	+ 1° 55′ 31° 55′	+ 12.6	2521.4	373				
	T 25		5.0	3.13	+ 1° 22′ 31° 22′	+ 7.5	2516.3	314				
	T 26		8.0	2.75	- 0° 19′ 29° 41′	- 1.3′	2504.5	276				
	T 27		5.0	2.18	- 1° 58′ 27° 02′	- 7.5	2501.3	218				
	T 28		3.5	0.70	- 9° 13′ 20° 47′	- 11.3	2498.9	69				
	T 29		8.0	2.51	- 0° 02′ 29° 58′	- 0.0	2505.8	252				
	T 30		5.0	2.21	+ 0° 09′ 30° 09′	+ 0.6	2509.4	222				
Δ 24		4.2					~~2452.4~~ 2450.8					
	H 5		5.0	9.00	+ 11° 15′ 41° 15′	+ 172	assume 2622.0	870		B. S.		
	T 31		5.0	3.75	- 3° 00′ 27° 00′	- 19.6	2430.4	375				
	T 32		8.0	4.70	- 2° 51′ 27° 09′	- 23.4	2423.6	470				
	Δ 26		6.0	4.14	+ 8° 10′ 38° 10′	+ 59.8	2508.8	410		B.S.	ok.	(+0.6)

T33		6.0	5.65	+ 3° 35' 33° 35'	+ 35.1	2484.1	564
T34		5.0	2.24	- 7° 10' 22° 50'	- 27.8	2422.2	221
T35		5.0	3.15	- 6° 15' 23° 45'	- 34.0	2416.0	313
T36		8.0	2.00	- 9° 20' 20° 40'	- 31.9	2415.1	197.
T37		4.5	3.00	- 0° 02' 29° 58'	- 0.0	2450.5	301
T38		2.0	2.10	- 0° 11' 29° 49'	- 0.7	2452.3	211

Shamrock Plane Tabling — July 4 - sunny

Sta	to	HI	Rod	Int	Vert ∡	ΔEl	Elev	Dist			
EB 60		3.1					2906.3				
	EB 59		4.0	1.80	+ 6° 35′ 36° 35′	+ 20.6	2926.0	179		Ref elev - assumed 2926	
	⊙84		4.0	1.56	+ 5° 35′ 35° 35′	+ 15.2	2920.6	155			
	⊙85		8.7	0.17	0 30° 00′		2901.1	18			
	⊙86		3.0	0.53	− 16° 20′ 13° 40′	− 14.4	2892.0	49			
	⊙87		9.0	0.28	− 14° 36′ 15° 24′	− 6.8	2893.6	27			
	⊙88		9.0	0.31	− 11° 19′ 18° 41′	− 6.0	2894.4	30			
	⊙89		10.0	0.60	− 9° 48′ 20° 42′	− 9.6	2889.8	59			
	⊙90		3.5	0.94	+ 1° 58′ 31° 58′	+ 3.2	2909.1	95			
	⊙91		4.0	1.30	+ 5° 37′ 35° 37′	+ 12.6	2918.0	129			
	Δ27		4.0	1.40	− 0° 54′ 29° 06′	− 2.2	2903.2	141			
Δ 27		4.0					2903.2				
	Δ28		6.0	1.01	− 21° 42′ 8° 18′	− 34.7	2866.5	88			
	⊙92		9.0	0.50	− 21° 56′ 8° 04′	− 17.4	2880.8	43			
Δ28		4.3					2866.5				
	⊙93		3.5	0.66	− 21° 00′ 9° 00′	− 22.1	2845.2	58			
	⊙94		10.0	0.14	− 15° 15′ 14° 45′	− 3.5	2857.3	13			
	Δ29		9.5	0.83	− 21° 28′ 8° 32′	− 28.3	2833.0	73			

Sta	to	HI	Rod	Int	Vert ∡	ΔEl	Elev	Dist	
△29		4.3					2833.0		
	△30		6.0	0.74	−24° 17′ 5° 43′	−27.8	2803.5	62	
	⊙95		3.0	0.55	−15° 27′ 14° 33′	−14.2	2820.1	51	
	⊙96		3.0	0.28	−15° 49′ 14° 11′	−7.4		26	2 ft from c/c
△30		4.2					2803.5		
	△31		3.5	1.08	−13° 36′ 16° 24′	−24.7	2779.5	102	
△31		4.0					2779.5		
	△32		3.5	0.74	+4° 57′ 34° 53′	+6.3	2786.3	74	
	⊙97		10.0	0.27	+2° 30′ 32° 30′	+1.2	2781.5	28	
EB 59		3.0					2926.0		
	⊙98		15.0	0.12	−12° 18°	−2.4	2912.6	11′	sinkhole – rod on shoulder
	⊙99		10.0	0.58	−6° 39′ 23° 21′	−6.7	2912.3	58	
	△33		3.5	0.55	−9° 19′ 20° 41′	−8.8	2916.7	54	
△33		4.4					2916.7		
	⊙100		3.0	0.45	−22° 02′ 7° 58′	−15.8	2902.3	39	
	△34		8.0	2.30	−17° 42′ 12° 18′	−66.6	2846.5	210	
	⊙101		4.0	0.95	−23° 02′ 6° 58′	−34.2	2882.9	81	

	⊕102		7.0	1.36	−17° 10′ 12° 50′	−38.0	2876.1	124				

2nd Merry Widow Sample Traverse

Aug 1 – sunny

Sta	To	HI	Rod	Int	Vert ∡	ΔEl	Elev	Dist	Remarks
H4		2.8					2624.18		
	Δ35		5.0	3.98	+12° 55' 42° 55'	+85.3	2707.4	382	
Δ35		3.9					2707.9 2707.4		
	H4		5.0	3.91	−12° 27' 17° 33'	−83.0	2623.3	378	0.9' diff ∴ El Δ35 mod to 2707.9
	⊙105		4.5	1.11	+28° 17' 58° 17'	+46.2	2753.5	86	
	⊙106		7.0	1.59	+31° 22 61° 22'	+70.5	2775.3	116	
	Δ36		7.0	2.85	+31° 23' 61° 23'	+126.	2830.8	208	
	⊙107		5.0	2.14	+31° 14' 61° 14'	+95	2801.8	156	
Δ36		4.3					2830.8		
	Δ35		9.0	2.78	−29° 44' 0° 16'	−118	2708.1	209	
	⊙108					−3	2827.9	8'	
	Δ37		6.0	0.50	+29° 41' 59° 41'	+21.5	2850.7	38	
Δ		4.4					2850.7		
	⊙109		3.0	0.32	+19° 45' 49° 45'	+10.2	2862.3	28	
	⊙110		3.0	0.50	+30° 48' 60° 48'	+22.0	2874.1	37	
	⊙111		9.0	0.34	+10° 00' 40° 06'	+5.8	2851.9	34	
	⊙112		9.0	1.25	+30° 00 60° 00	+54.1	2900.2	94	
	Δ38		4.0	1.92	+29° 17' 59° 17'	+81.8	2932.9	145	

Sta	to	HI	Rod	Int	Vert ∡	ΔEl	Elev	Dist		
Δ38		4.7					2932.9			
	⊙113		3.0	0.70	−25° 42′ 4° 18′	−27.2	2907.4	57		
	Δ39		6.0	1.73	+16° 07′ 46° 07′	+46.0	2977.6	160		
Δ39		4.0					2977.6		Aug 2, sunny	
	Δ38		7.0	1.70	−14° 48′ 15° 12′	−42.0	2932.6	158		
	⊙114		7.0	0.45	−9° 47′ 20° 13′	−7.6	2967.0	44		
	⊙115		3.0	0.68	+12° 39′ 42° 39′	+14.6	2993.2	65		
	Δ40		4.0	1.03	+14° 14′ 44° 14′	+24.5	3002.1	97		
	Δ39A		8.0	2.39	−10° 21′ 19° 39′	−42.1 −24.5	2931.5	230		
Δ40		4.2					3002.2 3002.1			
	Δ39		4.0	1.03	−14° 30′ 15° 30′	−25.0	2977.3	97	diff 0.3 ∴ El Δ40 3002.2.	
	Δ41		4.0	0.55	−7° 27′ 22° 33′	−7.1	2995.3	54		
	Δ15		8.0	3.20	−14° 12′ 15° 48′	−76.0	2922.4	300	tie.	2.2 ft ΔEl
Δ41		3.9					2995.3			
	Δ40		4.0	0.55	+7° 22′ 37° 22′	+7.0	3002.2	54		
			4.0	0.88	−12° 54′ 17° 06′	−19.2	2975.0	87		

Plane Table Kie Mine Pit

Aug 18, sunny

Sta	to	HI	Rod	Int	Vert ∡	Δ El.	Elev	Dist	Remarks
61 WF		4.3	8.	1.06			365.50		
	⊙1		3.5	1.06	-22° 21' 7° 39'	-37.0	329.3	91	
	⊙2		3.0	1.60	-13° 49' 16° 11'	-37.1	329.7	151	
	⊙3		9.0	1.66	-14° 33' 15° 27'	-40.3	320.5	155	
	⊙4		2.0	2.08	-11° 52' 18° 08'	-42.1	325.7	201	
	⊙5		5.0	2.61	-9° 16' 20° 44'	-41.5	323.3	255	
	⊙6		2.0	2.50	-11° 28' 18° 32'	-48.1	319.7	241	
	⊙7		8.0	3.15	-11° 33' 18° 27'	-62.0	299.8	304	
	⊙8		8.0	3.10	-13° 51' 16° 09'	-72.8	289.0	292	
	⊙9		8.0	295	-14° 10' 15° 50'	-70.4	291.4	278	
	⊙10		8.0	2.69	-14° 32' 15° 28'	-65.5	296.3	252	
	⊙11		5.0	3.10	-15° 28' 14° 32'	-79.5	285.3	288	
	⊙12		5.0	2.35	-15° 56' 14° 04'	-61.9	302.9	217	
	⊙13		8.0	L95	-15° 43' 14° 17'	-50.9	310.9	181	
	⊙14		4.0	1.82	-19° 51' 10° 09'	-58.0	307.8	161	
	⊙15		5.0	2.40	-8° 17' 21° 43'	-34.2	330.6	236	
	⊙16		5.0	3.35	-5° 10' 24° 50'	-30.1	334.7	330	

Sta	to	HI	Rod	Int	V	ΔEl	El	Dist	
	⊙17		5.0	3.25	−8° 12' 21° 48'	−46.0	320.8	318	
	⊙18		5.0	3.80	−3° 52' 26° 08'	−25.5	339.3	374	
	⊙19		5.0	3.45	−3° 24' 26° 36'	−20.5	344.3	344	
	⊙20		6.0	4.00	−2° 26' 27° 34'	−17.1	346.7	399	
	⊙21		6.0	5.55	−0° 15' 29° 45'	−2.4	361.4	556	
	⊙22		7.0	5.65	−1° 20' 28° 40'	−13.2	349.6	566	
	⊙23		6.0	6.20	−0° 46' 29° 14'	−8.4	355.4	621	
	⊙24		3.0	7.80	−0° 30' 29° 30'	−6.9	359.9	781	
	⊙25		5.0	8.40	+0° 09' 30° 09'	+2.2	367.0	841	
	⊙26		6.0	7.90	+0° 33' 30° 33'	+7.6	~~5~~371.4	791	
	⊙27		9.0	8.30	+0° 26' 30° 26'	+6.3	367.1	831	
	⊙28		5.0	9.30	+1° 49' 31° 49'	+29.5	394.3	930	
	⊙29		4.0	8.70	+0° 57' 30° 57'	+14.5	379.3	871	
	⊙30		5.0	8.15	−0° 16' 29° 44'	−3.8	361.0	816	
61WF		3.6					365.50		Aug 19, sunny
	⊙31		6.0	6.30	+2° 49' 32° 49'	+30.8	394.1	630	
	⊙32		6.0	6.40	+2° 29' 32° 29'	+27.7	390.8	640	

Sta	to	HI	Rod	Int	V	Δ El	El	Dist	Notes
	⊙33		7.0	5.60	− 1° 04′ 28° 56′	−10.4	351.7	560	
	⊙34		6.0	6.28	− 0° 58′ 29° 02′	−10.7	352.4	629	
	⊙35		6.0	6.10	− 1° 07′ 28° 53′	−11.9	351.2	610	
	Δ 1		5.0	9.45	+ 0° 56′ 30° 56′	+ 15.5	379.6	946	
	⊙36		5.0	9.30	+ 2° 21′ 32° 21′	+ 38.0	402.1	930	
	⊙37		6.0	7.90	+ 1° 57′ 31° 57′	+ 26.9	390.0	790	
	⊙38		5.0	8.80	+ 5° 45′ 35° 45′	+ 87.5	449.6	875	
	⊙39		3.0	8.40	+ 5° 37′ 35° 37′	+ 81.8	447.9	835	¼ hour
	⊙40		5.0	9.30	+ 5° 41′ 35° 41′	+ 91.8	455.9	925	
	⊙41		5.0	10.0	+ 7° 13′ 37° 13′	+ 125	489.1	990	
	⊙42		4.0	10.50	+ 6° 07′ 36° 07′	+ 112	477.1	1040	
	⊙43		4.0	1000	+ 4° 30′ 34° 30′	+ 78.0	443.1	992	
	⊙44		4.0	1100	+ 5° 26′ 35° 26′	+ 104	469.1	1090	
	⊙45		4.0	1060	+ 4° 32′ 34° 32′	+ 83.0	448.1	1050	
	⊙46		4.0	1020	+ 3° 20′ 33° 20′	+ 59.0	424.1	1013	
Δ1		4.0					~~379.9~~ 379.6		
	G1 WF		5.0	935	− 0° 50′ 29° 10′	− 13.7	364.9	936	0.6 diff - elev. 379.9 Δ1

Sta	to	HI	Rod	Int	V	Δ El	El	Dist			
	⊙47		5.0	2.64	+ 2° 03′ 32° 03′	+ 9.5	388.4	264			
	⊙48		4.0	2.90	+ 1° 21′ 31° 21′	+ 6.9	386.8	290			
	⊙49		5.0	3.10	+ 1° 25′ 31° 25′	+ 7.7	386.6	310			
	⊙50		5.0	2.11	+ 0° 30′ 30° 30′	+ 1.8	380.7	212		?	
	⊙51		5.0	3.50	+ 6° 29′ 36° 29′	+ 39.4	418.3	348			
	⊙52		6.0	4.15	+ 8° 49′ 38° 49′	+ 69.5	447.4	409			
	⊙53		5.0	4.00	+ 10° 08′ 40° 08′	+ 69.0	447.9	389			
	⊙54		5.0	3.80	+ 2° 05′ 32° 05′	+ 13.9	392.8	380			
	⊙55		5.0	3.55	+ 2° 42′ 32° 42′	+ 15.6	394.5	355			
	⊙56		4.0	1.80	− 2° 50′ 27° 10′	− 8.9	371.0	180			
	⊙57		5.0	2.25	− 2° 17′ 27° 43′	− 9.0	369.9	225			
	⊙58		2.0	2.72	− 2° 19′ 27° 41′	− 11.0	370.9	272			
	⊙59		8.0	3.32	− 0° 32′ 29° 28′	− 3.1	372.8	333			
	⊙60		6.0	4.13	− 0° 11′ 29° 49′	− 1.3	376.6	414			
	⊙61		6.0	4.45	− 0° 36′ 29° 24′	− 4.7	373.2	446			
	⊙62		6.0	4.45	− 0° 50′ 29° 10′	− 6.5	371.4	446			
	⊙63		6.0	5.84	− 1° 06′ 28° 54′	− 11.3	366.6	585			

⊙64		6.0	5.50	− 1° 56′ 28° 09′	−18.6	359.3	550	
⊙65		5.0	4.65	− 2° 14′ 27° 45′	−18.1	360.8	465	
⊙66		4.0	1.93	− 4° 37′ 25° 23′	−15.5	364.4	192	
⊙67		10.0	0.20	−11° 43′ 18° 17′	−3.9	370.0	20	
⊙68		3.0	0.34	−4° 06′ 25° 54′	−2.4	378.5	34	
△1	4.0					379.9		Aug 20, sunny
61 WM		0.0	16.20	− 2° 34′ 27° 26′	−72	311.9	1615	
⊙69		5.0	3.35	−6° 16′ 23° 44	−36.5	342.4	332	
⊙70		4.0	1.12	−7° 58′ 22° 02′	−15.4	364.5	109	
⊙71		5.0	3.90	+ 2° 37′ 32° 37′	+17.9	396.8	390	
⊙72		6.0	4.27	+ 3° 55′ 33° 55′	+27.5	405.4	426	
⊙73		6.0	4.39	+ 2° 28′ 32° 28′	+19.0	396.9	438	
⊙74		5.0	4.96	+ 2° 12′ 32° 12′	+19.1	398.0	495	
⊙75		6.0	5.25	+ 2° 12′ 32° 12′	+20.4	398.3	524	
⊙76		6.0	5.66	+ 2° 01′ 32° 01′	+20.0	397.9	565	
⊙77		9.0	6.10	+ 1° 42′ 31° 42′	+18.2	393.1	610	
⊙78		7.0	6.70	+ 2° 02′ 32° 02′	+23.9	400.8	669	

	⊙79		7.0	5.92	+ 4° 31′ 34° 31′	+46.3	423.2	589	
	⊙80		7.0	5.35	+ 8° 40′ 38° 40′	+ 79.3	456.2	525	
	⊙81		7.0	5.48	+ 7° 56′ 37° 56′	+ 74.5	451.4	540	
	⊙82		6.0	4.60	+ 8° 15′ 38° 15′	+ 65.0	442.9	450	
	Δ2		5.0	3.15	− 7° 41′ 22° 19′	− 41.9	337.0	312	
Δ2		4.3					337.0		
	Δ1		5.0	3.17	+ 7° 58′ 37° 58′	+ 43.1	379.4	314	.5′ diff ∴ El Δ2 337.2
	⊙83		5.0	2.05	+ 1° 55′ 31 55	+ 6.8	343.3	205	
	⊙84		4.0	1.06	+ 0° 51′ 30° 51′	+ 1.6	339.1	107	
	⊙85		3.0	0.94	−0° 30′ 29° 30′	− 0.8	337.7	95	
	⊙86		4.0	1.98	+ 0° 44′ 30° 44′	+ 2.6	340.1	199	
	⊙87		4.0	2.95	+ 0° 37′ 30° 37′	+ 3.2	340.7	296	
WF		3.6					365.5		
	. ?		4.0	~~16.50~~	− 1° 33′ ✓ 28° 27′	~~− 44.5~~	~~320.9~~	~~1645~~	
	⊙88		4.0	10.30	− 4° 24′ 25° 36′	− 79.	286.1	1025	
	⊙89		4.0	11.70	−4° 06′ 25° 54′	− 83	282.1	1165	
	⊙90		5.0	9.40	−6° 10′ 23° 50′	− 100	264.1	935	
	⊙91		5.0	9.90	− 4° 48′ 25° 12′	− 82.5	281.6	985	

	⊙ 92		4.0	11.40	− 4° 43′ 25° 17′	−94	271.1	1135
	⊙ 93		4.0	11.00	− 5° 09′ 24° 51′	−98	267.1	1095
	⊙ 94		5.0	9.70	− 4° 03′ 25° 57′	−68.0	296.1	966.
	⊙ 95		5.0	9.00	− 4° 38′ 25° 22′	−72.1	291.9	896
	⊙ 96		5.0	8.20	− 4° 10′ 25° 50′	−59.1	305.0	817
	⊙ 97		6.0	7.87	− 6° 22′ 23° 38′	−87.0	276.1	780
	⊙ 98		6.0	6.90	− 5° 57′ 24° 03′	−70.5	292.6	687
	⊙ 99		6.0	6.15	− 5° 39′ 24° 21′	−60.0	303.1	612
	⊙ 100		7.0	5.84	− 3° 44′ 26° 16′	−37.6	324.5	583
	⊙ 101		7.0	5.36	− 5° 15′ 24° 45′	−48.4	313.7	534
	⊙ 102		6.0	5.00	− 4° 06′ 25° 54′	−35.5	327.6	498
	⊙ 103		7.0	4.66	− 2° 15′ 27° 45′	−18.4	343.7	465
	⊙ 104		6.0	5.50	− 8° 15′ 21° 45′	−78.0	285.1	539
WJ 61		3.2					336.3	
	WF 61		4.0	10.90	+ 1° 34′ 31° 34′	+30	365.5	1090
	⊙ 105	0.0	4.0	10.50	− 1° 16′ 28° 44′	−23.0	309.3	1050
	⊙ 106.	0.0	5.0	9.30	− 1° 10′ 28° 50′	−19.0	312.3	930

} azimuth is a little out
} dist. is ok.

⊙107	6.0	7.40	−2° 19′	27° 41′	−30.0	303.5	739
⊙108	5.0	8.25	−2° 29′	27° 31′	−35.7	298.8	823
⊙109	5.0	8.30	−2° 20′	27° 40′	−33.8	300.7	828
⊙110	5.0	9.10	−2° 11′	27° 49′	−34.5	300.0	907
⊙111	3.0	12.10	−1° 07′	28° 53′	−23.8	312.7	1210
⊙112	3.0	12.60	−0° 58′	29° 02′	−22.4	314.1	1260
⊙113	5.0	8.25	−3° 36′	26° 24′	−51.0	283.5	823
⊙114	7.0	4.24	+3° 32′	33° 32′	+26.0	358.5	423

Sheet 2 - Draw Ck.

Aug 26 – evening

Sta	to	HI	Rod	Int	Vert ∠	ΔEl.	El	Dist
T3		4.3					357.9	
	61-167		2.0	2.04	−0° 40′ 29° 20′	−2.4	356.8	205
	⊙115		8.0	2.85	+2° 00′ 32° 00′	+10.0	364.2	285
	⊙116		5.0	2.82	+1° 08′ 31° 08′	+5.6	362.8	282
	⊙117		8.0	3.15	+1° 14′ 31° 14′	+6.8	361.0	315
	⊙118		8.0	3.60	+3° 09′ 33° 09′	+19.9	374.1	360
	⊙119		8.0	4.00	+6° 15′ 36° 15′	+43.2	397.4	397
	⊙120		5.0	3.35	+5° 59′ 35° 59′	+34.8	392.0	332
	⊙121		8.0	3.55	+7° 32′ 37° 32′	+47.2	401.4	350
	⊙122		7.0	4.45	+9° 48′ 39° 48′	+74.5	429.7	430
T3		3.8					357.9	
	⊙123		8.0	3.14	−1° 05′ 28° 55′	−6.0	337.7	314
	⊙124		9.0	1.84	−0° 55′ 29° 05′	−3.0	349.7	185
	⊙125		7.0	4.85	+11° 07′ 41° 07′	+91.2	445.9	469
	⊙126		6.0	6.22	+12° 37′ 42° 37′	+133.0	488.7	598
	⊙127		7.0	6.69	+11° 55′ 41° 55′	+134.0	488.7	645

8-5-

Aug 28 – sunny

	⊙128		7.0	5.32	+3° 14′ 33° 14′	+30.0	384.7	530
	⊙129		7.0	5.65	+3° 27′ 33° 27′	+34.0	388.7	563
	⊙130		4.0	11.80	+7° 12′ 37° 12′	+148.	506	1160
	⊙131		3.0	12.20	+6° 31′ 36° 31′	+138	495	1200
	△3		6.0	6.75	-0° 08′ 29° 52′	-1.6	354.1	676
△3		3.6					354.1	
	⊙132		5.0	2.36	+3° 32′ 33° 32′	+14.5	367.2	236
	⊙133		4.0	1.00	-5° 25′ 24° 35′	-9.4	344.3	99
	⊙134		8.0	1.34	+0° 05′ 30° 05′	+.3	350.0	135
	⊙135		7.0	4.36	+0° 45′ 30° 45′	+5.7	356.4	437
61-WF		3.5					365.5	
	⊙136		7.0	5.11	+10° 45′ 40° 45′	+93.0	465.0	498
	⊙137		7.0	4.06	11° 37′ 41° 37′	+81.0	443.0	394

Sheet 3 - Draw Ck.

Aug 29, sunny

- inst. may have moved - Vert ∡ no good
- re-shot on nail of 400-5

61WU		4.2					458.1	
	400-5		3.5	0.67	-6° 20′ 23° 40′	-7.3	450.1	67
	400-5		0.0	0.67	-9° 12′ 20° 48′	-10.6	451.7	
	⊙138		4.0	1.55	-5° 03′ 24° 57′	-13.6	444.7	154
	⊙139		3.0	1.84	-7° 01′ 22° 59′	-22.5	436.8	182
	⊙140		5.0	2.82	-4° 58′ 25° 02′	-24.4	432.9	280
	⊙141		5.0	2.56	-1° 00′ 29° 00′	-4.5	4528	256
	△4		3.0	1.37	-2° 31′ 27° 29′	-6.0	453.3	137
△4		4.3					453.3	
	⊙142		3.0	0.76	-6° 46′ 23° 14′	-8.9	445.7	76
	△5		9.0	1.82	-3° 13′ 26° 47′	-10.3	438.3	182
	⊙143		8.0	2.50	-6° 39′ 23° 21′	-28.9	420.7	248
	⊙144		7.0	5.42	-7° 14′ 22° 46′	-68.0	382.6	532
	⊙145		6.0	6.80	-6° 09′ 23° 51′	-72.5	379.1	670
	⊙146		5.0	8.50	-5° 04′ 24° 56′	-74.5	378.1	842
	⊙147		5.0	3.00	-8° 00′ 22° 00′	-41.2	411.4	294
	⊙148		8.0	2.22	-11° 08′ 18° 52′	-42.1	407.5	213

Sheet 1 - Draw Ck

Sept. 2 / 61

Sta.	to	HI	Rod	Int	Vert ∡	Δ El	Elev	Dist
61-		3.5					365.5	
	Δ 6		6.0	6.78	−1° 38′ 28° 22′	−19.4	343.6	677
	⊙ 149		7.0	5.40	−0° 38′ 29° 22′	−5.7	356.3	541
	⊙ 150		7.0	4.16	−2° 10′ 27° 50′	−15.8	346.2	416
	⊙ 151		5.0	3.45	−4° 19′ 25° 41′	−25.8	338.2	344
	⊙ 152		4.5	2.90	−11° 24′ 18° 36′	−56.0	308.5	279
	⊙ 153		2.0	2.48	−16° 52′ 13° 08′	−69.0	298.0	229
	⊙ 154		6.0	1.92	−22° 56′ 7° 04′	−69.0	294.0	176
	⊙ 155		8.0	2.08	−22° 13′ 7° 47′	−73.0	288.0	178
	⊙ 156		5.0	2.20	−21° 23′ 8° 37′	−74.5	289.5	190
	⊙ 157		8.0	2.08	−19° 09′ 10° 51′	−64.4	297.0	186
	⊙ 158		3.0	2.89	−17° 38′ 12° 22′	−83.0	283.0	262
	⊙ 159		8.0	2.91	−13° 57′ 16° 03′	−68.0	293.0	273
Δ 6		3.0					343.6	
	⊙ 160		5.0	2.15	−11° 38′ 18° 22′	−42.4	299.2	206
	⊙ 161		5.0	2.36	−6° 43′ 23° 17′	−27.5	314.1	234

- overcast morning

- sunny

Sheet 4 - Draw Ck. Sept 8, sunny

Sta	to	HI	Rod	Int	Vert ∡	Δ El	Elev	Dist
61-WF		3.7					365.50	
	Δ 18		5.0	2.63	-4° 20' 25° 40'	-20.0	344.2	262
Δ 18		4.3					344.2	
	⊙ 195		3.0	0.72	-17° 05' 12° 55'	-20.3	325.2	64
	⊙ 196		3.0	2.95	-9° 10 20° 50'	-46.3	299.2	288
	⊙ 197		2.0	2.45	-11° 47' 18° 13'	-48.6	297.9	237
	⊙ 198		5.0	2.05	-9° 59' 20° 01'	-34.7	308.8	198
	⊙ 199		5.0	2.30	-10° 56' 19° 04'	-42.9	300.6	224
	Δ 19		6.0	6.35	+4° 03' 34° 03'	+44.5	387.0	630
Δ 19		4.3					387.0	
	⊙ 200		5.0	4.06	+2° 58' 32° 58'	+20.9	407.2	406
	⊙ 201		6.0	5.25	+2° 57' 32° 57'	+27.0	412.3	525
	⊙ 202		5.0	2.70	+0° 10' 30° 10'	+0.8	387.1	271
	⊙ 203		5.0	3.78	+4° 39' 34° 39'	+30.5	416.8	376
	⊙ 204		5.0	5.89	+7° 56' 37° 56'	+80.0	466.3	578
	⊙ 205		7.0	7.80	+9° 10' 39° 10'	+123.0	507.3	755

344.2
-35.4
308.8

344.2
-43.6
300.6

+44.5
-1.7
+42.8
344.2
387.0

387.0
79.3
466.3

Sta	to	HI	Rod	Int	Vert ∡	Δ El	Elev.	Dist
	⊙162		8.0	3.20	−6° 31′ 23° 29′	−36.0	302.6	315
	⊙163		5.0	3.87	−9° 29′ 20° 31′	−63.0	278.6	375
	⊙164		7.0	5.10	−7° 31′ 22° 29′	−66.4	273.2	505
	⊙165		8.0	3.85	−7° 29′ 22° 31′	−49.5	289.1	380
	⊙166		4.5	1.45	−1° 41′ 28° 19′	−4.3	337.8	146
	⊙167		4.0	1.55	+0° 04′ 30° 04′	+0.2	342.8	156
	⊙168		3.0	0.83	+0° 19′ 30° 19′	+0.4	344.0	84
	⊙169		5.0	2.25	+0° 22′ 30° 22′	+1.5	343.1	226
	⊙170		5.0	2.70	−0° 15′ 29° 45′	−1.2	340.4	271
	⊙171		5.0	2.95	−0° 33′ 29° 27′	−2.9	338.7	296
	⊙172		8.0	3.85	+1° 07′ 31° 07′	+7.6	346.2	386

Sheet 1 - Draw Ck.

Sept 4 - rain

Δ7									
	⊙173		8.0	2.46	−0° 30′ 29° 30′	−2.2.	362.8	247.	
	⊙174		8.0	2.56	−0° 01′ 29° 59′	0.0	365.0.	257.	
	⊙175		7.0	4.10	−0° 31′ 29° 29′	−3.7	362.3	411	
	⊙176.		3.5	0.98	+0° 27′ 30° 27′	+0.8	370.3.	99	
	⊙177		8.0	4.90	+2° 54′ 32° 54′	+24.8	389.8.	490	
	61-WF		0.0	10.23	−0° 25′ 29° 35′	−7.5.	365.5	1024	← using this elev. inst Δ7 = 373.0
	⊙178		8.0	4.59	−0° 25′ 29° 35′	−3.6.	361.4	490	

Sheet 3 - Draw Ck.

Sept 5 - sunny

61-WD		4.8					458.1		
	Δ8		3.0	177	−9° 46′ 20° 14′	−29.6.	430.3	171	
Δ8		4.3					430.3		
	⊙179		3.0	116	−1° 34′ 28° 26′	−3.2	428.9	116	
	⊙180		3.5	91	−13° 27′ 16° 33′	−20.5	410.6.	86	
	⊙181		3.0	175	−11° 39′ 18° 21′	−34.5	397.1	169	
	⊙182		5.0	211	−9° 47′ 20° 13′	−35.4.		206	
	⊙183		7.0	435	−4° 41′ 25° 19′				
	61 WU		0.0	—	+7° 46′ 37° 46′	23.5	458.1	171	B.S. ck ✓
Δ5		4.5					438.3		
	Δ4		4.0	1.84	+4° 30′ 34° 30′	+14.5	453.3	184	B.S. - ck. ✓

Sta	to	HI	Rod	Int	Vert ∡	Δ El	Elev	Dist	Remarks
	Δ 9		4.0	0.58	−16° 03′ 13° 57′	−15.5	423.3	54	
Δ[illegible]		4.2					423.3		
	⊙ 184		3.5	0.91	−7° 47′ 22° 13′	−12.3	411.7	90	
	Δ 10		0.5	0.66	+0° 26′ 30° 26′	+0.5	427.5	67	
Δ 10		2.1					427.5		
	⊙ 185		9.0	0.43	+0° 25′ 30° 25′	+0.3	420.9	44	
	⊙ 186		9.0	0.65	+7° 26′ 37° 26′	+8.4	429.0	66	
	Δ 11		4.0	1.44	−4° 40′ 25° 20′	−11.8	413.8	144	
Δ 11		4.1					413.8		
	Δ 10		3.0	1.48	+4° 57′ 34° 57′	+12.9	427.8	148	∴ dist 146
	Δ 12		5.0	1.27	+3° 39′ 33° 39′	+8.0	420.9	127	
	⊙ 187		6.0	0.75	+5° 27′ 35° 27′	+7.1	419.0	75	
Δ[illegible]		4.0					420.9		
	Δ 13		8.0	1.80	−11° 04′ 18° 56′	−33.9	383.0	174	
Δ 13		4.3					383.0		← Sept 6, sunny
	⊙ 188		7.0	1.13	+6° 45′ 36° 45′	+13.3	393.6	112	
	⊙ 189		8.0	1.66	+1° 25′ 31° 25′	+4.1	383.4	167	
	⊙ 190		3.2	0.58	+0° 45′ 30° 45′	+0.8	384.9	59	

(p 31 over)

	Δ 14		8.0	2.51	− 0° 21′ 29° 39′	−1.6	377.7	252
Δ 14		4.2					377.7	
	Δ 15		6.0	1.15	+ 2° 42′ 32° 42′	+ 5.4	381.3	116
	⊙ 191		10.0	0.72	− 13° 43′ 16° 17′	+16.6	355.3	68
	⊙ 192		4.5	0.90	−22° 21′ 7° 39′	− 31.6	345.8	77
Δ 15		4.2.					381.3	
	⊙ 193		6.0	1.00	+ 4° 22′ 34° 22′	+ 7.6	387.1	100
Δ 14		4.1					377.7	
	Δ 16		4.0	10.10	− 5° 15′ 24° 45′	− 92.0	285.8	1000
Δ 16		3.8					285.8	
	⊙ 194		6.0	6.20	+ 1° 23′ 31° 23′	+ 15.0	298.6	620
	Δ 17		8.0	307	− 2° 19′ 27° 41′	−12.5	269.1	307

5.8
+16.6
377.7
− 22.4
355.3

377.7
− 31.9
345.8

Z 03 S