

PETROLOGICAL STUDY OF THE DYKE ROCKS
OF THE
WHITEWATER CREEK AND LYLE CREEK AREA.
SLOCAN DISTRICT
British Columbia

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by

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I N T R O D U C T I O N

Treatment of this subject has been divided into two parts. Part I includes detail regarding the area under consideration with especial reference to general geological conditions. Part II includes the particular findings of petrological study of the dyke rocks exposed in the area.

P A R T I

Location and Access of the Area.

The Lyle Creek--Whitewater Creek area is situated $2\frac{1}{2}$ to 3 miles slightly eastward of north from the town of Retallack, station on the Kaslo-Sandon and Nakusp branch line of the Canadian Pacific Railroad and on the Kaslo-New Denver highway, 18 miles from Kaslo and 13 miles from New Denver. Access to Lyle Creek Basin is by 3 miles of road from Retallack. Whitewater Basin lies north-westerly from Lyle Creek Basin, separated from it by a steep ridge which rises 1200 feet above the floor of the former and 1800 feet above the floor of the latter. Access to Whitewater Basin is by 1 mile of road and 1 subsequent mile of trail, from the Lyle Creek road at 1 mile from Retallack.

The Highland Surprise camp is on the north-westerly wall of Lyle Creek Basin.

Topography.

The area is one of strong relief. Elevations rise to 9000 feet at the summits of sharply pointed mountains and serrated ridges which are aligned to form ranges of generally north-westward trend. The valleys between the ranges are

deeply incised, primarily as a result of glacial action and latterly by rapid erosion of swiftly running water. The annual spring runoff is heavy and reduced flow is maintained throughout the summer from melting ice which still lies in glacial cirques at the heads of the higher basins. The precipitous slopes of the higher walls of the valleys are reduced at lower elevations by concentrations of talus and moraine material. Surface erosion is so active that development of upland meadows is rare.

Evidences of glaciation are common in the area. Many of the softer rocks have rounded outlines on the surface, from which glacial grooving has been removed by later surface erosion; on more resistant rocks, however, striae are frequently well preserved. One very interesting exposure was observed on the high south-westward rim of the Whitewater Basin where well defined striae trend southward. At this location the wall of the basin is almost vertical for 900 feet and the striae occur at the top, on the very edge of the rim on rock in place which dips at 25 degrees to the southward, that is, away from the rim and Whitewater Basin. The suggestion is that, comparatively recently, movement of ice was from higher ground above the present basin. It is clearly recognized that the serpentine underlying the basin is considerably more subject to erosion than the volcanic members which flank it to the south-westward but this

illustration of the ratio between the two rates of erosion is startling and indicates that local topographic features can be given little weight in consideration of any but very recent events.

Climate.

A combination of topographic and climatic conditions render year-round operation difficult. Heavy snowfall during the winter months produces many slides which frequently make it impossible to travel or work on the surface with safety. Snow lies at higher elevations until July and is seldom gone even from the basins, at a mean altitude of from 5000 to 5500 feet, until late in June. Although in the ordinary year at least three months of clear weather may be expected, rain hampered field work until the end of June during the past season and snow storms prevented work entirely during one week in July.

Timber.

Timber-line is close to 6000 feet and below this elevation there is available adequate timber for all domestic and mining needs, constructional and underground. Fir, pine and cedar are abundant below 5500 feet at locations sheltered from snow-slides and not subject to the effects of active erosion.

Water-Supply.

Available water is subject to seasonal fluctuation and practically all the small creeks which may be of good flow up until July are completely dry by the end of August. The exceptions are Lyle Creek and Whitewater Creek, but even these are greatly reduced by the time seasonal runoff is complete.

General Geology.

The rocks of the area under consideration belong to the Kaslo Series of Triassic age. In Memoir 173, Geological Survey of Canada, C. E. Cairnes divides this series into volcanic rocks, intrusives, serpentine and sediments and sub-divides the volcanic rocks into pyroclastics and flows.

The region has been subjected to metamorphism, dynamic and hydrothermal, which has obscured many of the original characteristics of the rocks and the contacts between the individual members. While it is not possible to be certain, it is probable that much of the volcanic material was originally andesitic in composition. As most of the volcanic rocks are chloritized it has been found convenient to classify the pyroclastic, flow and sedimentary members as greenstones. Strictly, the sediments should probably not be included in this classification but in the area they are not abundant

and scarcely distinguishable from the volcanics. Dioritic intrusives and serpentine are easily identified by the characteristics given below. The remaining rock type in the area is represented by the feldspar porphyry dykes of current interest in this thesis and petrological description of them is deferred to Part II.

Greenstone (includes original flows, pyroclasts and sediments.)

Of the three original constituent members the flows are the only ones which may be identified with any degree of ease. Typically pale-green or light-green on the weathered surface, slightly darker-green or grey on fresh fracture, fine to medium-grained in texture, the diagnostic feature is flow structure which is apparent occasionally on a broad scale. Visible when seen in place, in its entirety, but seldom authoritative in fragmentary hand samples, this structure is generally represented by fine lines or elliptical outlines of colour either lighter or darker than the remainder of the rock. Such flow structure is best seen on the south-westward side of the serpentine. Where flow structure is not available as a guide and the ground mass is fine-grained and homogeneous, as in large areas on the north-eastward side of the serpentine, it is sometimes possible to distinguish the flows by means of isolated fragments of unabsorbed early crust. However, these criteria are unreliable as such isolations may often represent coarse fragmental material

in finely divided pyroclastics.

Of the pyroclasts a few examples were seen, notably underground at the Highland Surprise, where it was possible to define at least small areas with some assurance. Under a hand lens, or occasionally in the hand specimen, these rocks may be seen to be fragmental in origin.

Sediments are apparently rare in this section; none were seen with characteristics as defined by Cairnes. This however is not surprising, as they are prominent nowhere in the Kaslo Series. There may be some sediments exposed underground at the Highland Surprise but the writer saw no rock which could be classified definitely as such although there are several exposures in which bedding appears obvious at first sight. Closer examination of these exposures shows, however, that the illusion is created by a near parallel arrangement of quartz and albite stringers which follow lines of shearing in highly metamorphosed rock which was probably originally pyroclastic.

Serpentine.

The serpentine is the most extensive and best defined member of the Kaslo Series. Of a north-west strike, with a dip steeply to the south-westward it has ex-

posed widths up to 2500 feet.

On weathered surfaces the serpentine is typically black, green of shades from dull to bright, pink or light-brown; the last two colours grade frequently almost to white. The extreme softness and decided greasy feel are easily recognizable characteristics. The greasiness is due to the abundant production of talc as the result of alteration. Fibrous appearance along shear planes is due to the production of serpentine wool.

The whole member probably represents an original ultra-basic injection which has reached its present composition by simple hydration or other more involved metamorphic processes. That it was originally intrusive is emphasized by inclusions of greenstone within it and by the narrow but well defined branches which lead off the main mass. On the accompanying map several of these fingers are indicated to the south-westward of the main body.

Dioritic Intrusives.

With the exception of the feldspar porphyry dykes all the minor intrusives seen in the area are approximately dioritic in composition. Typically dark-green in colour, these rocks are composed essentially of

oligoclase-andesine plagioclase and shreddy amphibole. There is practically no visible quartz. Fine to medium-grained, they may sometimes be distinguished from the volcanics by slightly coarser texture but frequently the exact margin between the two rocks is indeterminate by a gradational relationship and numerous small inclusions of volcanic rock. However, with the fine-grained, homogeneous and massive facies of the diorite it is usually possible to make distinction from the volcanics only on freshly broken, wetted surfaces where the amphibole and plagioclase are apparent. Structurally this member is probably best described as a series of irregular plugs, of no definite form. Younger than the serpentine, the intrusions took particular advantage of structural weaknesses in the greenstone marginal to it, as suggested by a vague line of concentration along the north-eastward contact of the serpentine and some elongation of the individual exposures parallel to its length. On the accompanying map only two areas of diorite are indicated, one on the Gold Quartz property and one above the Highland Surprise workings, and in neither case are the exact boundaries defined. While it is unlikely that there is any genetic relation between the diorite and the mineral deposits in the district, it does appear that mineralized veins may be localized in fractures marginal to the individual bodies and, in one case, a vein was seen within the diorite itself.

Feldspar Porphyry Dykes.

These dykes are apparently the youngest rocks in the area. They are intrusive into fractures in the greenstone marginal and approximately parallel to the serpentine contact. In width they vary from 1 to 10 feet, often with marked variation in width along the strike which tends to produce characteristically lenticular outline. Like that of the serpentine, their strike is generally north-west; the dip is usually north-eastward but it varies radically, even between the two walls. As an example, underground at the Highland Surprise one wall of a dyke dips at 10 degrees to the north-eastward and the other stands vertically.

In colour these rocks are grey on fresh surfaces and shades of pale-pink, light-brown or white on weathered surfaces.

Veins.

Two types of vein occurrence have been exposed at the Highland Surprise. Both are in the fractures of north-west strike in the greenstone marginal to the serpentine. For purposes of identification one type will here be referred to as "vein", the other as "vein-zone". The veins are composed of quartz and calcite gangue which contains gold-bearing sulphides. The sulphides are principally pyrite and

chalcopyrite. No free gold was seen in hand specimens but microscopic examination shows it to occur as blebs in the pyrite. Samples from the Highland Surprise yielded a considerable amount of free gold on the Haultain Super-Panner.

The veins on the north-eastward margin of the serpentine have proved upon development to be sufficiently mineralized by gold-bearing sulphides to warrant serious consideration; those on the south-westward margin, by evidence of surface exposures alone, are almost barren of sulphides. Those on the south-westward contact appear to have been deposited at comparatively low temperatures; drusy structure is common, wall-rock alteration is almost absent in many places and several angular and unaffected inclusions of wall-rock were noted within the vein-quartz.

To date development indicates considerable weakness and irregularity both along the strike and on the dip of the veins. The veins have naturally assumed the habit of the fractures and, like the feldspar porphyry dykes, are variable in width along the strike. However, the veins are even more irregular than the dykes, particularly when the wall-rock is highly sheared, for, while the general occurrence of vein-quartz may continue on strike, individual strands are often highly contorted and irregular in dip as a result of having followed minor local folds and fractures in the greenstone. In other places the width of

vein-quartz may pinch abruptly to a single narrow stringer. Vein widths vary up to $5\frac{1}{2}$ feet; this may be of solid quartz or may be comprised of several strands or lenticular bunches of quartz and included low-grade rock. Where vein and feldspar porphyry dyke occur together in the same fracture the vein gains strength from the competency of the dyke.

The vein-zones may be representative of the veins at locations where vein solutions were not abundant and where fracture of the greenstone was represented by tight shearing rather than by well maintained openings. In at least one case there is apparently a transition on strike from vein-zone to vein. The width of the vein-zones is comprised of very narrow stringers of albite and quartz which strikes north-west. Pyrite is disseminated sparsely in the quartz, in the albite and in the included and marginal greenstone. Highly altered, the marginal greenstone is often dark in colour, homogeneous and compact. To date the gold content in the vein-zones has been found to be small but if there is proved to be transition from them to the veins the zones may be followed as a guide in development.

The veins may prove to be simple shoots within the vein-zones but there is some suggestion that there may be cross-fracturing of the vein-zone shearing and that the intersections of the two sets of fractures permit concentra-

tions of mineralization along the cross-fractures. Nowhere was it possible to see two fracture-systems which actually crossed but at two locations veins which contain commercial values strike north to north-east as against the general vein-zone strike to the north-west. In the course of further exploration particular attention should be given to the possibility that there is such a secondary and less conspicuous fracture-system.

Relative Ages of Veins and Feldspar Porphyry Dykes.

The close areal association of veins and dykes ~~and the common orientation of the dykes~~ naturally suggests that there may be some genetic relation between them.

Structural relations at the Highland Surprise indicate that there the dykes are generally younger than the veins. However, at the Gold Quartz property there is at least one very good exposure in which quartz stringers lead off from a strong vein and fill fractures in a dyke which lies on the vein wall. Thus it appears, ^{from field observations,} that there may be local precedence of either veins or dykes in certain sections of the area but it is probable that on a broad scale vein deposition and dyke intrusion were probably nearly contemporaneous. (Further reference to this subject in Part II.)

Structure.

As described by Cairnes, "the Kaslo rocks form an almost structureless mass". However, in his report he gives such data as are available concerning the thickness of the Kaslo Series and the nature of the contacts with underlying Milford Series and the younger Slocan Series. On the map accompanying this report the contact of the Kaslo and Slocan Series is indicated and, as described by Cairnes in the area farther south-eastward, there is little apparent discordance between the two series. The Kaslo-Milford contact does not occur in the area under consideration but its extension from the location as mapped on Cairnes' sheet is exposed approximately $1\frac{1}{2}$ miles north-eastward from the north-westward limit of this area. At that point the contact crosses the south fork of Cooper Creek and there its general line may be distinguished easily by the marked difference in the weathering of the two formations. The slates, argillites and limestone of the Milford Group weather with characteristically rounded outline in strong contrast to the ruggedness of the Kaslo Series.

On the basis of Cairnes' areal work the strike of the Kaslo Series is taken as north-west, the dip steeply to the south-westward. Heavy shearing coincident with and subsequent to folding has resulted in marked schistosity

parallel to the bedding-planes. Much of this shearing probably occurred just prior to the intrusion of the Nelson Batholith. In unsheared and comparatively unsheared greenstone at least three sets of joints have been developed; one of these strikes north-west, dips steeply south-westward; the second strikes north-west, dips flatly south-westward; the third strikes north-east, dips steeply south-eastward.

By the evidence available to date the veins and feldspar porphyry dykes strike north-west and dip north-eastward or south-westward. One possible explanation of the origin of the fractures through which their solutions passed is that the fractures were formed by the intrusive action of the serpentized sill. If so, there may be a set of conjugate fractures as suggested earlier in discussion of the vein-structure. A second possible explanation of the origin of the fractures is that the serpentine behaved as a structural unit during the folding of the older rocks, with the production of fractures against and nearly paralleling the serpentine contact. A third possible explanation is that the fractures were caused by strains produced in the marginal rocks during change in volume within the sill attendant upon composition changes from the original rock to serpentine.

It should be understood that a generalization

is intended when reference is made to vein and dyke fractures of north-west strike which approximately parallel the serpentine contact. Underground at the Highland Surprise there is variation in strike of as much as 30 degrees between the veins and dykes and the serpentine contact and a definite tendency for the veins to strike slightly farther to the west than the serpentine contact.

Alteration.

The most marked alteration is that of the serpentine to talc and carbonate in the vicinity of the veins on the Highland Surprise property. This effect is so far advanced that where intersected by underground workings walls and back of adits may be held only by considerable effort.

Alteration adjacent to the veins is generally confined to widths which may be as much as 6 feet but which are often considerably less. In the vein-zones alteration has taken place in the greenstone which remains within the limits of the zone as well as in the marginal rock.

Typical of this alteration is the darkened colour of the

rock and the presence of scattered pyrite. At the Highland Surprise it has been found that where marginal to veins such wall-rock, unsilicified, dark in colour and mineralized sparingly by pyrite, will often contain sufficient value in gold to be of milling-grade; marginal to the low-grade vein-zones it has not found to be of value.

There has apparently been little or no active emanation from the feldspar porphyry dykes. The only effect they have had has been to bake the greenstone for a very narrow width at the contact.

Additional detail in these connections is given in Part II.

HIGHLAND SURPRISE PROPERTY

General Geology.

Considerable detail applicable to this particular property has been given already in the general statement. The rocks exposed underground are greenstones, as defined previously, of the Kaslo Series, intruded by irregular masses of diorite and by feldspar porphyry dykes. The underground workings follow the margin of the basic intrusive, now converted to serpentine, and the veins and the dykes both parallel approximately the contact between the serpentine and the greenstone. The greenstone is schistose and largely chloritized; in proximity to the veins it is commonly darkened by hydrothermal alteration.

As detailed in the general statement, distinction is made between two types of vein-structure which are designated as "vein" and "vein-zones" respectively. Further development is required to show whether the veins are merely shoots within the vein-zones or whether the veins are concentrations at the intersections of cross-fractures with the fractures of the vein-zones. The vein-zones strike north-west, dip north-eastward or south-westward; indications are that any cross-fractures strike north or north-east. Sulphide mineralization within the veins consists of pyrite, chalcopyrite and small amounts of galena and sphalerite. Pyrite is usually the only sulphide present in the vein-zones and in the wall-rock.

It is necessary to emphasize the extreme irregularity of the structure of the veins. Due to the incompetency of the wall-rock, widths will pinch from mineable widths to a stringer within a few feet and the dip will change as much as 90 degrees. At the same time, however, the occurrence of quartz will be maintained on the same general line of strike.

Geologic detail and detail of underground development is given on the plan which accompanies this thesis. By the small amount of information available correlation is dangerous between exposures of rock members or

of vein-structure.

GOLD QUARTZ PROPERTY

As at the Highland Surprise, the veins exposed here are in greenstone, on the north-eastward side of the serpentine but here the veins are farther from the serpentine contact than are those at the Highland Surprise. Probably as a result of the greater distance from the serpentine contact the greenstone in which the Gold Quartz veins occur is generally more massive and compact than that exposed underground at the Highland Surprise. Although the greenstone-serpentine contact is covered by overburden toward the eastward end of Whitewater Basin, it may be placed approximately as on the accompanying map. Near the vein-exposures the greenstone is intruded by irregular masses of diorite and by feldspar porphyry dykes. The veins upon which development has been concentrated strike north-west. Thus rock types and strike of the veins at the Gold Quartz duplicate conditions at the Highland Surprise. There are however, two marked points of difference between the two deposits. One is that there are noticeable amounts of galena and sphalerite with the pyrite and chalcopryite in the Gold Quartz veins. The second difference is that at the Gold Quartz there are exposed at least three narrow quartz veins which strike north-east or east.

Practically no work has been done on these veins but they may be of importance as indicators of fractures which intersect the principal fracture-system of north-west strike. At an elevation of 6300 feet, surface-stripping has exposed a vein which strikes north 20 to 25 degrees west, dips 60 to 70 degrees eastward. The vein is exposed over a length of 200 feet. There are usually one or two well maintained bands of quartz which vary in width from 6 to 24 inches. Between these bands, and outside them, quartz stringers occur irregularly in the greenstone. Sulphides are disseminated in the quartz and in the greenstone and the total width of the lode varies from 24 to 84 inches. Within some of the wider bands of quartz there are longitudinal openings which are coated on the walls by milky, crystalline quartz. This evidence, with the presence of noticeable amounts of galena and sphalerite in the vein, suggests there may be some correlation between the present surface and temperature conditions which pertained at the time of vein deposition. No such open structure and little or no galena or sphalerite is present in the veins exposed at the Highland Surprise where the upper adit is 600 to 1300 feet lower than the Gold Quartz exposures.

P A R T IIINTRODUCTION.

Following are detailed reports of microscopic study of thin sections of the feldspar porphyry dykes. The sections represent various surface exposures and underground exposures at the Highland Surprise property. Exact locations at which the specimens were obtained are indicated on the accompanying map and plan of the Highland Surprise workings.

In classifying the rocks represented by the thin sections, unstriated albite has been included with orthoclase and microcline as alkali feldspar. By this usage most of the igneous rocks may be termed microgranites. Those in which the feldspar is predominantly sodic plagioclase are indicated by the addition of "ablite" or "albite-oligoclase" to the rock name.

PETROGRAPHY OF THIN SECTIONSSection 13Microgranite (Albite)

The section consists of subhedral to euhedral feldspar in a microcrystalline ground-mass. The feldspar

is about half albite (Ab. 93, An. 7) and half orthoclase. A very few quartz grains of subhedral to anhedral outline are present; these are of smaller size than the feldspars but are definitely larger than the average grains size in the ground-mass. The ground-mass is essentially subhedral to anhedral quartz.

Alteration of the feldspars has proceeded generally with the production of sericite, muscovite and kaolin.

Chlorite is scattered throughout the ground-mass, usually in small specks which have vague orientation as though drawn out into lines. Some of it is interstitial between the feldspars. It is suggested that the chlorite is due principally to alteration of original biotite, some of which is still present although bleached.

Carbonates are general in the ground-mass and seaming the feldspars. These are probably of supergene origin.

Subhedral to euhedral pyrite is scattered through the ground-mass.

The section illustrates Bowen's reaction series well--early crystallization of feldspars, later biotite, final ground-mass of residual biotite and quartz.

Section 14Contact of microgranite with greenstone

In the microgranite feldspars, 25% \pm albite--oligoclase (Ab. 84, An. 16) and 75% \pm orthoclase, occur in microcrystalline ground-mass of feldspar and quartz. There are a few relatively large anhedral grains of quartz. The feldspars are altered markedly with the production of sericite, muscovite and kaolin.

The ground-mass shows definite lines of flowage around the feldspar growths, indicating the later fluidity of the final siliceous extracts.

The greenstone in contact with the microgranite has been reduced to a mass of chlorite, kaolin and residual quartz. By field observation and from this section it appears unlikely that there has been much hydrothermal alteration of the original rock (now greenstone) by the intrusive. On the other hand, a considerable amount of chlorite in the microgranite is probably derived from the greenstone although some of it results from the alteration of biotite which occurs as a minor original constituent of the igneous rock.

Carbonates are general. Obviously late, as evidenced by the unbroken passage of carbonate veinlets

from ground-mass to greenstone, this mineralization is probably supergene in origin.

Subhedral to euhedral pyrite is scattered through the ground-mass.

Section 31

Microgranite

The principal feldspar is orthoclase. Several large plates are present but most of the section is composed of granophyric intergrowths of smaller fragments of orthoclase and albite (Ab. 89, An. 11) with quartz. There is no defined ground-mass as in sections 13 and 14. Subhedral to euhedral inclusions of plagioclase within the larger plates of orthoclase are common. One hexagonal outline, which appeared to be of quartz, was observed within orthoclase but the occurrence was too small to permit positive identification.

Alteration is advanced, with the production of chlorite from biotite; kaolin and sericite from the feldspars.

Magnetite grains, subhedral to euhedral, are scattered through the section.

Section 35Microgranite

The feldspars in the section consist of large subhedral to anhedral growths of microcline, 80% + and smaller grains of albite-oligoclase (Ab. 86, An. 14) 20% -. These, and a few anhedral grains of quartz lie in a microcrystalline ground-mass of which quartz is the principal constituent. The texture is thus microporphyritic. Although there are inclusions of plagioclase crystals within the microcline they are not numerous enough or of sufficiently distinctive pattern to permit the use of the term poikilitic. There is also definite replacement of albite by microcline. Rotting of the feldspars, with the production of sericite and kaolin, is far advanced in many instances; frequently this process has proceeded outward from the centre of the crystal.

Biotite, anhedral, is scattered through the ground-mass; a small amount of chlorite is probably secondary after the biotite. Two large shreds of biotite, which appears to be lying on top of the section, are apparently secondary.

There is very little carbonate in this section.

Scattered subhedral to euhedral pyrite grains show alteration to hematite.

Section 48Micromonzonite

The section is heavily altered. Euhedral to anhedral crystals of albite-oligoclase (Ab. 83, An. 17) and of anhedral quartz are isolated as individuals and in groups by a microcrystalline ground-mass. Potash feldspar was not identified. The quartz and feldspar grains are interlocked characteristically and/or the quartz occurs as interstitial filling between the feldspar. There is more quartz than in the previous sections and its percentage of total felsic content much more nearly approaches the upper limit (66%) permissible in a granite.

The ground-mass, in the form of veinlets, is now mainly chlorite, sericite and kaolin with some quartz and a little feldspar. Much, or perhaps all, of the chlorite has been derived from biotite, the latter present throughout the section in bleached form.

Alteration of the feldspars has proceeded so far that in some cases the original outline is indicated only by the secondary minerals, of which sericite is the most common. There is little or no development of carbonates.

There are one or two specks of magnetite but no pyrite in the ground-mass.

Section 53Microgranite

Large sub to anhedral plates and smaller sub to euhedral crystals of microcline (80% \pm) and sub to euhedral crystals of albite- oligoclase (20% -) (Ab. 83, An. 17) lie in a microcrystalline ground-mass to produce a microporphyritic texture. In places the ground-mass is almost cryptocrystalline but it appears to be composed principally of quartz with minor amounts of feldspar.

There are definite evidences of replacement between microcline and the plagioclase. While there are examples which might be taken as indicative of a late magmatic concentration of albite, the weight of evidence is in favor of the normal action--replacement of plagioclase by microcline.

Kaolin and sericite are present as alteration products of the feldspars.

Biotite occurs throughout the ground-mass as interstitial filling between the feldspars and at the contacts of ground-mass and feldspars. Chlorite results from the alteration of the biotite. Lines of flowage in the ground-mass are indicated by the arrangement of the biotite and chlorite.

A few larger quartz grains concentrated in the ground-mass or marginally to the feldspar crystals suggest final crystallization of quartz, even after consolidation of the ground-mass proper.

A considerable amount of magnetite but no pyrite occurs in the section.

Section 57

Microsyenite (Albite)

Albite (Ab. 89, An. 11), common hornblende, (20 to 25%) a little quartz, (less than 5%), and probably some orthoclase, constitute most of the section. The texture is almost holocrystalline. A late fracture-system traverses the section, the present filling of which is principally kaolin, sericite and carbonate.

Kaolin and sericite are general, principally as the result of alteration of the feldspars.

Biotite is closely associated with the hornblende. Chlorite results from alteration of the biotite.

There is present a small amount of magnetite and hematite; no pyrite.

Section 60Microsyenite

This section represents intensely altered rock. Albite-oligoclase (Ab. 85, An. 15), orthoclase and a little quartz are probably the only original minerals. The quartz represents less than 5% of the original felsic constituents.

A considerable amount of biotite occurs in streaks, probably as an alteration product of amphibole--of which there are a few residual and badly decomposed plates. Chlorite has resulted from the alteration of biotite. The arrangement of the biotite suggests shearing of the rock subsequent to consolidation, a conclusion borne out by the field evidence. Alteration of the feldspars has produced considerable sericite and kaolin. Carbonates are plentiful and general, probably supergene in origin.

An iron mineral, which is either pyrrhotite or tarnished pyrite, occurs in streaky concentrations paralleling the biotite.

Section 101

Contact. Microgranite (Albite-Oligoclase)
and greenstone

In the microgranite albite-oligoclase (Ab. 85, An. 15), a very small amount of quartz and probably some

orthoclase occur as phenocrysts in a microcrystalline ground-mass which is principally quartz.

Sericite and kaolin are secondary from the alteration of the feldspars. Chlorite is present as alteration product of biotite some of which, bleached, remains in the section. The chlorite defines lines of flowage in the ground-mass. Carbonates, of supergene origin, are plentiful. In the ground-mass there are two large euhedral crystals of pyrite, some smaller grains and some specks of magnetite.

The greenstone is principally chlorite, with kaolin and carbonates. Some quartz and feldspar was probably derived from the microgranite.

Section 9A

Microgranite (Albite)

Phenocrysts of albite (Ab. 93, An. 7) and orthoclase occur in a microcrystalline ground-mass which is essentially quartz. The orthoclase is subhedral to anhedral; the plagioclase subhedral to euhedral.

Bleached biotite, in the process of alteration to chlorite, is disseminated through the ground-mass and defines lines of flowage in it.

A small amount of quartz, crystallized in larger grains than that in the ground-mass, is apparently the result of very late concentration. The form of this quartz is vein-like.

Carbonates are common, generally of close association with the feldspars; in some cases they occur as fracture filling in the feldspars.

Muscovite and sericite are the usual products of alteration of the feldspars.

Anhedral magnetite and sub to euhedral pyrite are disseminated in the ground-mass.

Section 4

Greenstone

This section represents wall-rock 4 feet from the dyke of section 101. Chlorite, kaolin and carbonates are the principal constituents, with minor quantities of residual quartz and feldspar. Biotite occurs in close relationship to the chlorite and is apparently the source of much of it. Pyrite is scattered through the section.

There is a definite tendency for the constituent minerals to be arranged approximately in parallel bands indicative of shearing.

Further consideration is given to this section under the heading "Wall Rock Alteration".

Section 10
(2 sections)

Vein-zone

Section 10-39 RJM is one made for the writer; section 10-39S was made for the B. C. Department of Mines. The latter consists of a feldspathic ground-mass traversed by veinlets of anhedral quartz and sub to anhedral albite (Ab. 91, An. 9). Beside the laths of feldspar the ground-mass contains some anhedral quartz and some biotite in the process of alteration to chlorite. Carbonatization, apparently of supergene origin is general in both the ground-mass and the veinlets. Pyrite and magnetite are scattered through the ground-mass but are not present in the veinlets; in one or two instances magnetite occurs in close relationship to concentrations of biotite-chlorite.

Section 10-39 RJM represents almost the same location as 10-39S but in it the ground-mass and veinlets are predominantly of anhedral quartz. There is some of feldspar present in the ground-mass, but any originally in the veinlets has been replaced to such an extent that exact identification is impossible.

Section 24

This section represents a location where isolations of dyke rock and vein mineralization lie closely together in greenstone. The isolations have resulted from the simultaneous weakening and dispersion of a narrow dyke and a narrow vein which occur closely together and parallel.

The feldspathic ground-mass in the section represents the greenstone wall-rock. Traversing the ground-mass are veinlets of quartz and albite (Ab. 91, An. 9). Both quartz and albite crystals are anhedral; both are comparatively fresh.

The greenstone ground-mass is similar to that in Section 10 and alteration has proceeded similarly.

There is a considerable amount of sub to euhedral pyrite in the ground-mass, apparently earlier than the quartz-albite veinlets.

DISCUSSION

Originally this thesis was to be concerned only with the dyke rocks of the area, to provide simple descriptions of them and to record any variations between the individual intrusions. However, in the course of that recording a little information has been obtained which is other than statistical. This information suggests some points of interest, the chief of which is that there may be a genetic relationship between the dykes and the gold quartz veins. The ensuing discussion is based on these suggestive findings but its value is necessarily limited by the small number of sections studied.

Variations in the dykes

The sections studied are representative of all the dykes in the area and the sections show closely related mineralogical composition. By these facts and from the generally similar physical characteristics of all the dykes, it may be assumed reasonably that all of them belong to one family and all represent one limited period of intrusion. The variations noted are in presence or absence of pyrite and magnetite, in albite content of the plagioclases, in presence or absence of potash feldspar, in amount of quartz, in ground-mass and coarsely crystalline, and in feldspar present. These data may be summarized thus:

Section	Pyrite	Magnetite	FELDSPAR		QUARTZ		Femic
			Plagio- class	Potash Fsp.	Ground- mass	Coarse- ly Cry- stalline	
13	Present	Absent	Ab. 93	Ortho- class	Princi- pally quartz	Slight amount	Biotite- chlorite
14	Present	Absent	Ab. 84	Ortho- class	Felds- par & quartz	Slight amount	Biotite- chlorite
31	Absent	Present	Ab. 89	Ortho- class	None as in Sects. 13 & 14	Consid- erable amount	Biotite- chlorite
35	Present	Absent	Ab. 86	Micro- cline	Princi- pally quartz	Slight amount	Biotite- chlorite
48	Absent	Absent	Ab. 83	None id- entified	A little quartz & feldspar	Consid- erable amount	Biotite- chlorite
53	Absent	Consid- erable amount	Ab. 83	Micro- cline	Princi- pally quartz	Slight amount	Biotite- chlorite
57	Absent	Present	Ab. 89	Ortho- class (?)	None	Slight amount	Biotite- chlorite; hornblende
60	Present (?) or (Pyrrho- tite ?)	Absent	Ab. 85	Ortho- class	Slight- ly over half qu- artz, re- mainder principally altered fsp.	Slight amount	Considerable biotite. A very little amphibole
101	Present	Present	Ab. 85	Ortho- class (?)	Principally quartz	Very Slight amount	Biotite- chlorite
9A	Present	Present	Ab. 93	Ortho- class	Principally quartz	Slight amount (vein ?)	Biotite- chlorite

From such a compilation it was hoped some information might be forthcoming as to the ages of the dykes, relative to the parental magmatic stage. However, due to repeated contradictions within it, the table is of little use in this connection except in the cases of sections 57 and 60. In these two cases the presence of amphibole as a femic constituent suggests that the two dykes thus represented may be more closely related to the original magma and hence slightly older than the others which were studied. The absence of a groundmass rich in quartz in section 57, also lends to this assumption.

Wall Rock Alteration

It has been mentioned in Part I and under Section 14 that it is the writer's opinion that there has been little hydrothermal alteration of the wall rock by the dykes. There is commonly an inch or two of purely thermal alteration but this appears to be the only effect on the wall rock directly attributable to the intrusives.

Casual examination of the area would not support this view as there is frequently a marked darkening of the greenstone marginal to the dykes, as mentioned in Part I and represented by section 4. However, bands of this darkened rock, up to 10 feet wide, may be found where there is no

dyke marginal to them. Further, as exposed to date at the Highland Surprise, wherever this chloritized phase of the greenstone does occur, there is always vein or vein zone within its margins and striking with it. Thus the relationship appears to be between the alteration and the vein mineralization rather than between the alteration and the dykes.

It is possible to explain this metamorphic effect independently of the dykes if it is assumed to be dynamic in origin, contingent upon folding prior to the intrusion of the dykes and facilitated by water as a constituent of the original rock and also perhaps by water of supergene origin carried downward by the folding. There is nothing in section 4 to indicate that the rock could not have reached its present condition from, say, an original andesite, by dynamic metamorphism alone.

Late Magmatic Effects

Section 10 and section 24 indicate that albite and some of the quartz of the vein zones were of simultaneous crystallization. This suggests a transition from magmatic to hydrothermal conditions and possible genetic correlation between the dykes, in which albite is a common constituent, and the vein mineralization.

SUMMARYPart I

1. Field relations show the dyke of section 60 to be older than the quartz vein which lies on its wall.
2. Several of the dykes exposed underground at the Highland Surprise cut through the vein zones and in two cases concentrations of vein mineralization lie on both walls of dykes.
3. The recurrent proximity of dykes and vein structure, particularly on the north-east side of the serpentine, suggests the possibility of genetic relationship between dykes and veins.

Part II

1. Sections 57 and 60 may represent dykes intruded earlier than the others of which thin sections were studied but the relationship between the plagioclases in all the sections is sufficiently close to permit assumption that the total time interval was short during which intrusion took place.
2. Typical darkening of the greenstone in which veins and vein-zones occur is believed to be an effect of dynamic metamorphism, completed prior to the intrusion of the dykes.
3. The presence of albite in the vein zones and the prominence of albite in the dykes further suggests possible genetic relationship between vein mineralization and dykes.

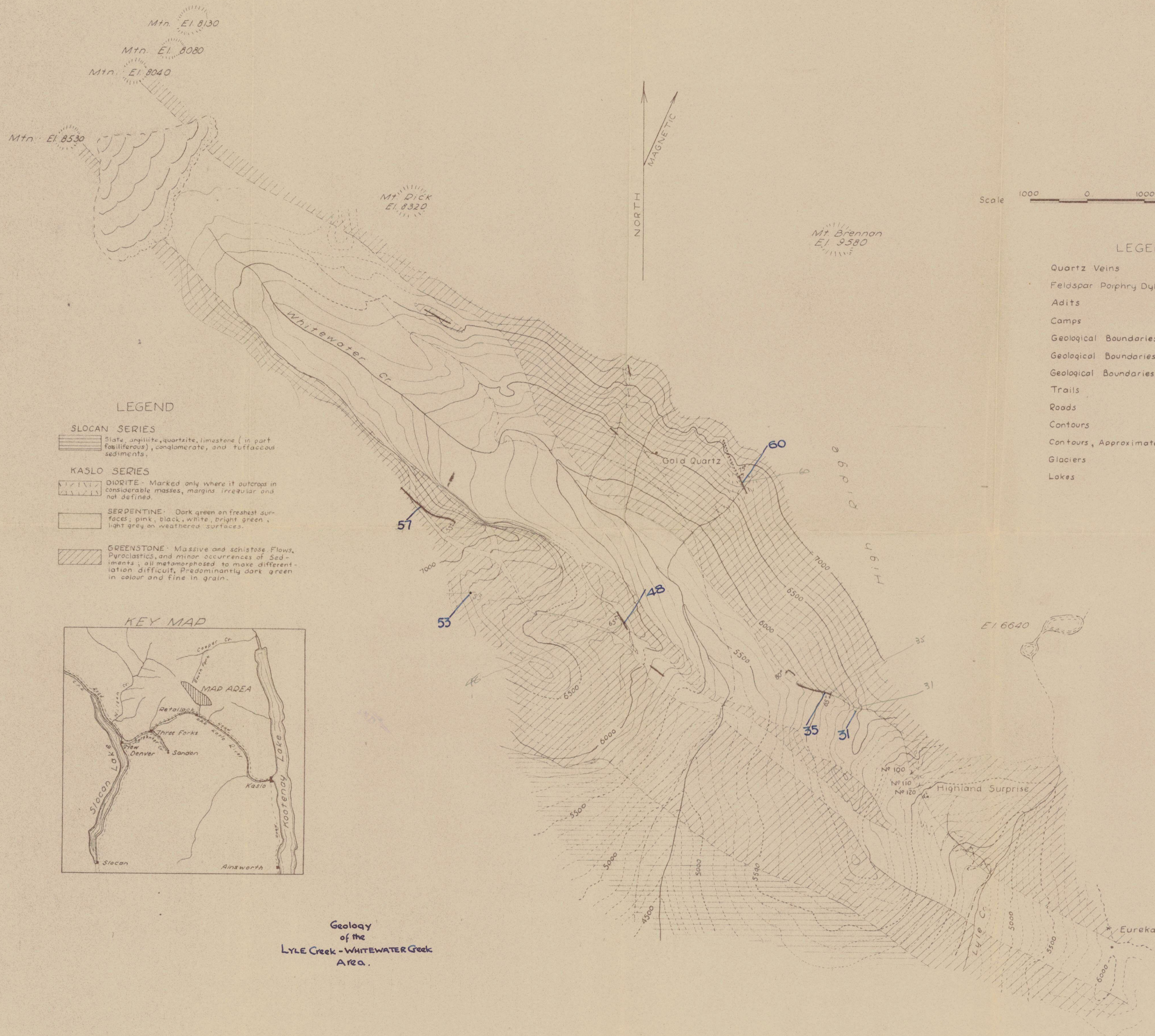
CONCLUSIONS

While field relations indicate general similarities between the dykes and leads to the assumption that they are of close genetic relationship, microscopic study was necessary to show that the relationship is very close indeed. This statement is based on the small compositional range of the plagioclases. The dyke of section 60 is known definitely to be earlier than the vein on its wall and hence it is assumed that the greater part of the intrusive action was complete before vein and vein zone mineralization took place. This must be only an assumption because there is little or no definite evidence of a general transition from magmatic to hydrothermal conditions; the presence of albite and quartz stringers in the vein zones may not be taken as proof; nor can the common presence of pyrite in the dyke rocks.

However, based on this assumption, explanation is possible of the relation between veins, vein-zones and dykes, as exposed at the Highland Surprise. At this property, because the dykes intersect the veins and vein zones, they have been considered to be later than the quartz-sulphide mineralization.

The alternative explanation, based on the foregoing assumption, is that, following stopping intrusion of the dykes into the normal, sheared greenstones, fractures were set up in the relatively competent, regionally metamorphosed bands

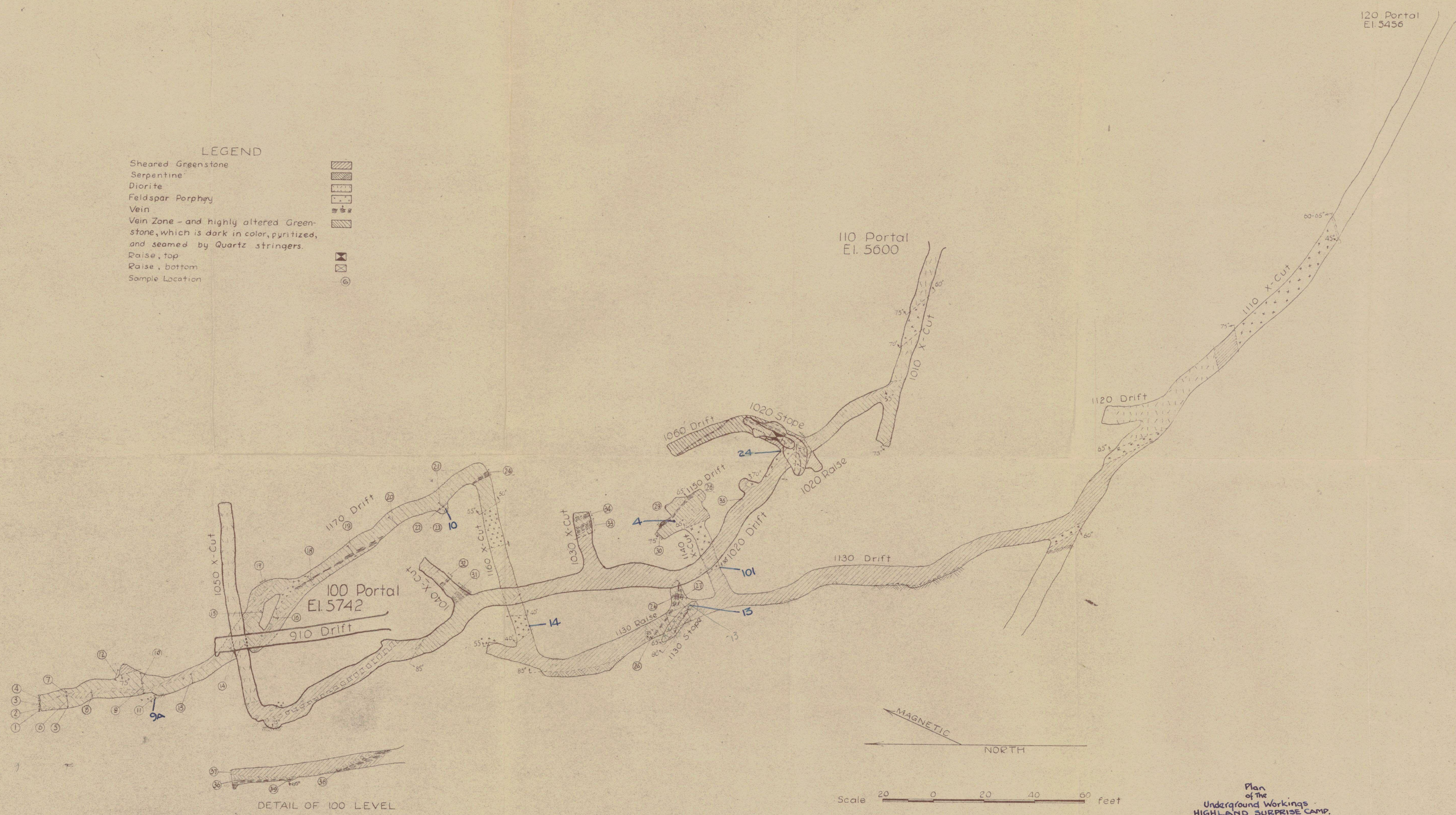
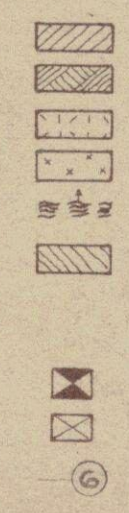
of greenstone. These fractures would result from minor crustal adjustments, probably chiefly tensional. The tendency would be for them to remain in the competent bands and to parallel the length of the dykes. While the metamorphic bands and the dykes are parallel in general, there are cases in which the dykes intersect the bands at flat angles. At these intersections the fracturing would not be of sufficient strength to penetrate the dykes and would tend to be dispersed or change direction toward that of the dyke contact. Upon the entry into the fractures of the mineralizing solutions responsible for vein deposition, the areas which offered the maximum space for filling would be at and near the dyke contacts; by the time of deposition from the final, richest solutions those centres would offer the only remaining openings to permit the present concentrations of high grade ore.



Topography, Geology by Macdonald
 Drafting by J.S. McIntosh.

LEGEND

Sheared Greenstone
 Serpentine
 Diorite
 Feldspar Porphyry
 Vein
 Vein Zone - and highly altered Greenstone, which is dark in color, pyritized, and seamed by Quartz stringers.
 Raise, top
 Raise, bottom
 Sample Location



Plan of the
 Underground Workings
 HIGHLAND SURPRISE CAMP.
 (Survey, Geology by Macgachie.
 Drafting by J.S.M. Inloosh.)