104B General

REGIONAL GEOLOGICAL ASSESSMENT OF THE STEWART-SULPHURETS AREA AND GEOLOGY AND ALTERATION OF THE SULPHURETS PROSPECT AREA

NTS 104B/8E, 8W, 9E, 9W

— Brucejack Lake Area

— Treaty Ck Area

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5.1 RECOMMENDATIONS

Regional exploration of the Sulphurets-Stewart District is strongly recommended. Exposures at the margins of areas of receding ice sheets in areas within and fringing zones identified by Groves (1982) as hornfels (unit 2) or schist (unit 1) are particularly good targets.

Rock samples that are collected for analyses should have their mineralogy positively identified using staining techniques, thin/polished section examination, or X-ray diffraction techniques; half-fist sized sample should be retained for these purposes.

A stratigraphic package that consists of sediment-volcanics-sediment may be a reliable marker 'relation' on a local mapping scale (e.g. Silver Butte, Sulphurets, and Treaty Creek) and perhaps on a regional scale.

Thick sequences of volcanic breccias that could be cauldera or vent related or ring-shaped cauldera related structures might have controlled some of the large-scale alteration features in the region; these features are considered highly prospective for precious metal mineralization.

Detailed mapping/sampling of the area between the Snowfields Gold Zone and the Brucejack Lake Area is strongly recommended. The character of the schistose, widely-leached Zone on Mitchell-Sulphurets Ridge, the character of the Brucejack Fault-linear and subsiduary features and the general area of Kouchkowski's pit should be carefully evaluated. Subtleties of the alteration zonation should be established using the techniques mentioned above on selected samples.

Drilling of the Snowfields Gold Zone to investigate large tonnage disseminated gold potential of the area and the possibility of higher grades with depth is recommended. Ice bound exposures between the Snowfield Gold Zone and Mitchell-Sulphurets Ridge should also be mapped and sampled.

Rapid prospecting or grab sampling of outcrop at the ice margin below the Treaty Creek Property is a lower exploration priority because much of the ice-bound ground is held by E and B Explorations.

Alteration mineralogy across the strike of the recently drilled zones in the Brucejack Lake area should be characterized at several selected sections along strike. Particularly the distributions of sericite and K-feldspar and dolomite-siderite and calcite.

5.2 CONCLUSIONS

Lower to Middle Jurassic volcanics and sediments (Hazelton Group) in the Stewart-Sulphurets district were emplaced in an island-arc-type setting. An early left-lateral strike-slip regime along roughly north-south principal displacement zones and attendant northwest-trending en echelon tension features were avenues for migrating hydrothermal fluids. West-southwest-trending folds that may have accompanied this early strike-slip regime were eventually overprinted by orthogonal north-northwest-trending folds which caused a structural interference pattern that consists of domes and depressions. Renewed left-lateral north-south strike-slip movement controlled more recent fault and dike patterns.

Hypabyssal plutonic rocks and volcanic-sedimentary rocks that represent the lower levels or 'root-zone' of a Lower to Middle Jurassic volcanic edifice are the host-rocks of widely altered and mineralized areas at the Sulphurets Property. Both the compositions and field relations of volcanic and intrusive phases suggest the system evolved from more basic (diorite) to more acid (granite) differentiates. Two major periods of alteration are indicated; they followed construction of the major portion of the volcanic edifice. An early stage, which might have accompanied diorite porphyry and syenodiorite porphyry intrusion, caused the development of early quartz stockworks, some of the widely-distributed pervasive sericitic alteration, and possibly some copper, molybdenum and gold mineralization. The development of a second major period of hydrothermal activity caused the extensive pervasive K-feldspar and sericitic alteration which is intimately associated with economic minerals at the Sulphurets Prospect. This activity may have predated and, in part, certainly accompanied intrusion of the syenite and granite. The high-level alteration products, native sulphur and alunite, occur in a similar system at Treaty Creek, which is located several kilometers to the northeast.

Characteristics of the geology and the alteration and mineralization at the Sulphurets Prospect are similar to those of volcanic-hosted shallow-level (hot-spring or 'epithermal') gold deposits of the United States. Other characteristics are similar to those of the gold-bearing alkaline porphyry copper deposits in British Columbia. These two major types of mineral deposit appear to be genetically related in time and space at the Sulphurets Prospect. The prospect is highly prospective for economic concentrations of both types of mineralization.

5.3 INTRODUCTION

Two major objectives are presented in this report. The first is a regional assessment of the area in which the Sulphurets Prospect is located and is based on two recently published 1:100,000 geology maps (Map 2153-70). The second is a comprehensive compilation of the geology and alteration-mineralization of the property based on several years mapping by many geologists and limited field work completed during the 1982 field season. Traverses, designed to begin in unaltered or weakly altered areas and cross the strike of the alteration-mineralization zones, were completed over a period of about 3 weeks. Raw data was plotted on 1:5,000 orthophoto overlay sheets and interpreted with other data on 1:20,000 sheets (Maps 2153-71 and 2153-72).

Roughly 300 "type" hand specimens were collected and eventually slabbed and stained with Na-cobaltinitrate to establish K-feldspar content. From these hand specimens and drill core, fifty-five samples were selected for polished and thin section examination (Appendix 5.I) and sixty samples were x-ray diffracted (Appendix 5.2).

In addition to descriptions of the lithologies, alteration-mineralization assemblages, and structural features, important functions of this work are the interpretation of temporal and spatial relations and possible target areas and guides for exploration.

For a review of the history of the property to 1981 see Bridge et al. (1981). This report also documents all previous geological knowledge to that point in time, notably a compilation by Kruchkowski and Ostensoe (1975), and presents data on individual mineral occurrences. Recent exploration of the property is documented in Bridge et al. (1983, this volume) which primarily concentrates on the gold-silver-bearing veins of the Brucejack Lake area.

5.4 REGIONAL GEOLOGY

The Sulphurets Prospect is found within a thick succession of Hazelton Group volcano-sedimentary strata at the northern, western edge of the Bowser Basin. In the area of the Prospect Lower Jurassic (Unuk River Formation) to Middle Jurassic rocks (Betty Creek and Salmon River Formations), of the Hazelton Group are bounded to the east by extensive Upper Jurassic (Nass Formation) sediments that cover the central regions of the Bowser Basin (see Map 2153-70). To the west is the Coast Crystalline Belt Complex of Eocene or older (?) age. The Lower to Middle Jurassic Hazelton Group rocks are thought to form part of the "Bear River Uplift" (Groves 1968), a major unit found to extend from Alice Arm to the Iskut and east to include the Oweegee Dome-Ritchie anticline area. Paleozoic rocks are exposed in the Oweegee Dome, but except for recent basalt flows and Quaternary sediments, all other rocks in the region are of Mesozoic age.

The Mesozoic stratigraphy and intrusions in the region surrounding the Sulphurets Prospect will be reviewed using the only recent publication of the area (Groves 1971) although lithologies are apparently similar. The Unuk River and, less frequently, the Salmon River map sheets (Groves 1982) were also consulted in this regard.

5.4.1 Upper Triassic Stratigraphy

Limestone, siltstone, sandstone, and conglomerate, which are commonly volcanolithic and, towards the south, minor volcanic (?) breccia, and crystal and lithic tuff comprise the Upper Triassic Takla Group (?) assemblage. They form a thick wedge about 10 km maximum dimension that tapers toward the north in the Unuk River Basin about 20 km west of the Sulphurets Prospect. At the southern end of this wedge Groves (1982) has distinguished Triassic schist, gniess, cataclasite and mylonite that extends about 30 km to the southeast, towards the Granduc Mine; these may be the altered equivalent of the Takla Group assemblage although definitive paleontological or radiometric age dating is lacking or at least not presented. Overlapping the eastern margin of this altered unit are similarly altered rocks which are apparently younger (Jurassic) but again definitive dating is lacking and major faults are mapped in the area. These altered rocks are of particular interest because they host the Granduc Mine.

5.4.2 Lower to Middle Jurassic Stratigraphy

In his anthology of the Stewart area Groves (1971) states, "No recognizable base of the Hazelton has been located in the Stewart district (Salmon River Map Sheet) on structural evidence, and without fossils it is very doubtful that any separation between the Triassic and Jurassic rocks is possible because of the similarities in lithology." This statement could also be applied to the differentiation of the Lower Jurassic Unuk River Formation and Middle Jurassic Betty Creek Formation which also have similar lithologies and, except locally (i.e. Story Creek), have meager fossil control over wide areas (see Map 2153-70). Both units consist of green, red, and purple volcanic breccia, conglomerate, sandstone and siltstone, crystal and lithic tuff, limestone and chert, in addition to pillow lava and lava which are distinguished as separate units. The only differences are minor coal in the Unuk River Formation and black volcanic breccia in the Betty Creek Formation. According to Groves (1982) the Unuk River Formation is widespread throughout the area of Lower to Middle Jurassic rocks whereas the Betty Creek Formation is confined to the eastern half of the area. In view of their similarities in lithologies, meager fossil control, and the structural complexity of the region differentiation of the Formations in many areas is regarded as very uncertain and exploration models -- especially of syngenetic bias -- should be applied with this uncertainty in mind.

5.4.3 Middle to Upper Jurassic Stratigraphy

Overlying the Unuk River and Betty Creek Formations are the siltstone, greywacke, sandstone calcarenite, and minor limestone, argillite, conglomerate and littoral deposits of the Middle Jurassic Salmon River Formation. It is widespread throughout the region but is particularly common along the eastern margin. Similar lithologies that include minor coal and exclude littoral deposits constitute the Nass River Formation of Upper Jurassic age; they occupy most of the Bowser Basin to the northeast. As is the case with older units, local differentiation of the Salmon River and Nass River Formations is uncertain because of the lithologic similarities and the lack of paleontological control.

5.4.4 Intrusions

Intrusions of Mesozoic and Cenozoic age are common in the general area of the Sulphurets Prospect. Mesozoic intrusions are best exposed in the western sections of the map area. The apparent lack of crosscutting relations, lack of radiometric age determinations and the insertion of "AND YOUNGER?" after each time group indicates that the relative and absolute ages of the various Mesozoic intrusions (and possibly the Cenozoic intrusions) differentiated by Groves (1982) are very uncertain (Map 2153-70).

The Mesozoic intrusions range from diorite to syenite; they are elongate with major axes that are oriented north-northeast in the southeast which change trend to north-northeast in the northwest. Subparallel to en echelon patterns are locally developed and may have useful structural implications (see below). Partial unroofing of small, previously unmapped stocks in the Treaty Creek and Sulphurets areas suggest that the paucity of intrusions in the eastern margin of the region is partially caused by a deeper level of erosion in the western areas relative to the east. These small stocks represent the cupola zones of high-level intrusions.

Cenozoic plutons, that are probably apophyses of the Coast Range Crystalline Complex, are scattered throughout the map area; their range in size, geometry, and general orientations are similar to Mesozoic plutons although trends are somewhat less consistent and vary from northwest to northeast.

A spectacular feature in the Stewart area are predominantly northwest-trending, commonly porphyritic dike swarms. Individual dikes range from a few feet to 450 feet thick and extend for several thousand feet in length and depth. Four major kinds of dikes are recognized (see Groves 1971, Fig. 11 for distribution of dikes) -- the Premier (granodiorite porphyry), diorite (including hornblende diorite) and Portland Canal dikes (quartz monzonite, granodiorite, and quartz diorite) which are all cut by lamprophyre dikes (hornblende diorite and quartz diorite). Age relations between the first three types of dikes are uncertain but they are probably related in time. The Portland Canal swarm appears to be the northwest extension of an elongate quartz monzonite plug. Both the Premier and Portland Canal dike swarms are mainly oriented northwest, diorite dikes are less consistent in trend, whereas lamprophyre dikes are oriented northwest, north and east. Trends of the latter dikes are commonly crosscutting according to Groves (1971) and the dikes "appear to be more or less evenly distributed in all three directions except at the east margin of the area where the northerly direction predominates. Although the dikes are locally mineralized and altered their temporal relation to major alteration/ mineralization is uncertain based on the descriptions of Groves (1971).

5.4.5. Large-Scale Alteration Zones

There are two major belts of large-scale alteration which are assumed to be defined by units 1 and 2 on Grove's (1982) regional geology maps. A relatively narrow southerly one begins south of Stewart and trends north-northwest to Summit Lake. Numerous mines and prospects (see Groves 1968, Fig. 8) including the Pioneer, Silbak-Premier, Big Missouri, Scottie Gold and Esso's Silver Butte are located within this belt. Local alteration patterns are dominated by en echelon northwest trends at the northern end and somewhat similar but more splayed or horsetailed patterns toward the southern end of the belt. (Paul McGuigan suggests the patterns are more north-south.) If prospects to the east, in the American Creek and Bear River drainages are included then the width of the belt doubles. At this stage the characters of these properties are unknown and if only large-scale alteration (mainly sericitic?) zones are used to define the limits of the belt then the American Creek drainage might not be included.

The second, less confined large-scale alteration belt is located nothwest of the first belt; at its southern extremity it is marked by the Granduc Mine on the southwest side of a major fault with unknown magnitude of movement and is cut off by the Coast Crystalline Complex. It trends north-northeast through the Sulphurets Prospect and apparently terminates at the Treaty Creek Prospect. The belt is wedge-shaped apex north-northeast if the Story Creek Prospect is omitted, however, if it is not omitted then the belt is substantially widened and has subparallel boundaries, but encompasses large patches of apparently unaltered rock. Within the belt patterns are dominated by north-northwest en echelon trends. Toward its northern end northeast trends are evident at the Treaty Creek and the Story Creek Prospects and local areas off the western margin of the belt.

Mineralogy of these units are dominated by muscovite (sericitic), plagioclase, chlorite quartz, carbonate and accessory pyrite. Outcrops are common schistose with locally dominant foliation trends. Groves (1968) describes the altered rocks within the southern belt as cataclasites, mylonites and schists (including kakirite, phyllonites and semi-schists). This description is retained on the later maps (Groves 1982) which encompass both the northern and southern belts. Groves (1968) states that processes involving dynamothermal metamorphism, cataclasis, granitization, migrating meteroic waters and later remobilization phase(s) of mineral constituents were major factors in the genesis of the deposits in the Stewart area. He rejects the concept of "a classical simple hydrothermal fluid ejected by cooling magma into dilatant voids" (sic) -- a statement which succinctly describes part of the process thought to have controlled alteration-mineralization at the Sulphurets Prospect and which is suspected as being a major cause of much of the alteration noted in the two large-scale alteration belts.

5.4.6 Structure

The description of structural features in the Stewart area (Groves 1968, pp. 77-89) indicate that lithologies in this region have experienced deformational periods that are both complex and somewhat continuous throughout Phanerozoic time. Only major structural features will be discussed here.

The region is dominated by northwest to north-northwest structural trends that are marked by the elongation directions of Mesozoic and Cenozoic plutons (and dikes) and the en echelon character of alteration/mineralization zones; these could be viewed as major structural features that, except for Cenozoic plutons, were healed by the intrusive and alteration/mineralization episodes. Towards the northern end of the area these plutons change trend and swing toward the northeast.

Fold axes, although locally multi-directional, have similar trends but are generally of uncertain age; some could be younger.

The Sulphurets Prospect is located on what has been called a dome-like structure. Stratigraphic attitudes on nearly all but the eastern, probably fault-bounded side, bear this out although the dome is at the southwest corner of the property. By using similar criteria, in addition to fold hinges that plunge away (dome) or toward (depression) and older units which are exposed at high levels (dome) or younger units which occur at low levels (depression), it is possible to locate obvious dome and depression-like features. Unfortunately, because of unsuitable lithologies, meager mapping, or extensive snow and ice cover there are wide areas in which no data is available. Disruptions, mainly faulting, that post-date the dome-forming causative event have also complicated identification of these structures.

The spatial relations between domes and depressions is best illustrated by Lower Jurassic pillow lava units at the northwest margin of the map area. Three aligned elongate exposures stretch north-nothwest from the Granduc Mine to a point west-southwest of Sulphurets. They represent domes which have a periodicity of about 12 to 20 km. East-northeast of the northern-most exposure of pillow lavas is a depression, marked by low-lying Upper Jurassic units and inward plunging synformal axes. Farther along, slightly off-strike is the dome of the

Sulphurets property. A periodicity of 5 to 10 km is indicated.

The domes and depressions are thought to represent two stages of orthogonal folding whose time relations are unknown although the west-southwest trending set could be related to major north-south left-lateral strike-slip tectonics; this is discussed below.

The absolute timing of this folding is uncertain but, in part, could pre-date episodes of large-scale alteration-mineralization because axial plane cleavage at both Sulphurets and in the Stewart area (Groves 1971) localized sulphide-bearing assemblages. Groves (1971) repeatedly refers to canoe-shaped folds or depressions (sic) -- a phrase that could aptly describe depressions formed at the synclinal intersections of two orthogonal stages of folding which have different axial plane spacings. He later suggests that the Upper Jurassic Bowser Formation was locally deposited in such depressions. The Middle Jurassic is therefore suggested as a major period of folding.

Smaller-scale, disharmonic folds in incompetent stratigraphy, drag folds, en echelon folds caused by strike-slip faulting, and folds marginal to intrusions also occur throughout the map units and, in many cases, post-date the orthogonal sets.

Faults that post-date the large-scale alteration belts are characterized by major north-south orientations and less sizeable but perhaps more numerous northeast and northwest trends. In the Stewart area 1500 feet of left-lateral strike-slip movement has been documented on the north-south Long Lake Fault (Fig. 5.1). Similar displacement has occurred on northeast-trending steep westerly-dipping faults where northwest-trending faults have undergone right-lateral movement. The attitudes and sense of movement of these faults are compatible with major left-lateral shear (Inset, Fig. 5.1). Some of the northwest-trending dike swarms could represent healed tension fractures caused by strike-slip movement. Small west-southwest-trending folds might also be a product of this movement although their steep plunge of about 60° is not ideally compatible with this type of movement.

The mylonite, cataclasite and alteration/mineralization zones in the Stewart area (Groves 1971, 1982) are perhaps the remnants of an earlier strike-slip fault regime that was largely healed by metasomatic processes and later overprinted or refractured by the renewed strike-slip movement discussed above. Northwest-trending en echelon alteration patterns, noted earlier in the southern large-scale alteration belt, might reflect healed tensional features in a north-south left-lateral shear regime that provided major avenues for the migration of hydrothermal fluids. The en echelon pattern could have a similar origin although the overall trend has changed to slightly east of north (Map 2153-70).

The Coast Crystalline Complex is a major feature in the area which undoubtedly has disrupted features along its margins. It truncates most lithologies, including the northern alteration belt. Apophyses of the Complex are found in the southern belt but an older pluton (Middle Jurassic (?) Texas Creek granodiorite) has protected much of the area. Shallow westerly-dipping faults mapped in the Sulphurets area (Kirkham 1963) and Stewart area (Groves 1971) are perhaps related to intrusion of the complex or to later east-directed thrusting.

5.4.7 Summary

Following deposition of Lower to Middle Jurassic volcanics and sediments in an island arc-type setting, an early left-lateral strike-slip regime developed along north-northwest (southern alteration belt) to north-northeast (northern alteration belt) principal displacement zones. Mylonite and cataclastics were products of fault activity which provided major, roughly northwest- trending, en echelon tension features that were avenues for migrating hydrothermal fluids. West-southwest-trending folds may have accompanied this early strike-slip regime that was eventually overprinted by orthogonal north-northwest-trending folds. Deposition of Upper Jurassic Bowser assemblages also occurred during this time. At a later date renewed left-lateral strike-slip movement controlled more recent fault and dike patterns.

5.4.8 Implications for Regional Exploration

Many of the ideas presented in the preceding discussion should be viewed as working hypotheses that are testable in the field and which have important implications for regional (and property-scale) exploration. Because they are working hypotheses, however, their field application should be flexible and alternatives should be continuously reviewed as data bases are enlarged.

In many mineral deposits the intersection of major structural features is a common locus of economic minerals. From a regional perspective it is interesting to note that the Sulphurets Prospect lies near the intersection of the northern and the projected southern alteration belts although no particular importance is attached to this relation based on the available data.

The parallels that can be drawn between the geologic histories of the two alteration belts suggests that simialr densities of mines or prospects (see Fig. 8, Groves 1971) might be expected between them in spite of variation in character or style of alteration and mineralization. Altered zones within the northern belt should therefore be considered priority regional exploration targets.

The Granduc Mine and the Big Missouri Prospect have features that suggest syngenetic emplacement. Exploration for other syngenetic-type deposits requires good stratigraphic control and at least a basic understanding of structural events both in time and space. In this regard Grove's maps should be used, with caution and reliable marker horizons or stratigraphic sequences should be sought. For example, a sedimentary-volcanic-sedimentary stratigraphic sequence has been established in the Silver Butte area (McGuigan, 1983) as well as in the Sulphurets Prospect area (this study) and is inferred in the lower Treaty Creek area. Whether these sequences are of similar age is uncertain at this stage because intervening areas are not well mapped.

The possibility of pre-alteration-mineralization and post-alteration-mineralization regional-scale strike-slip faulting, that not only prepared ground for alteration-mineralization events but also determined the final location of mineral deposits, should not be overlooked. In addition, the sense of movement on individual fault planes might be inferred (first order approximation) once the strike-direction of the principal displacement zone is established.

5.5 GEOLOGY OF THE SULPHURETS PROSPECT

Kirkham (1963) and Ostensoe and Kruchkowski (1975) discussed the geology of the Sulphurets Prospect in a comprehensive fashion. Much of the geological discussion in this report, in particular lithologies, are based on their work and more recent field and laboratory work by the author (see Table 5.1). The work of many other geologists is also included but on a more local scale. Intrusive rock types are classified according to the IUGS system (Streckeisen 1973).

In the area of the Prospect, Lower to Middle Jurassic volcanic and sedimentary rocks are cut by four major types of intrusions, extensive zones of alteration-mineralization, and late dikes and faults (Maps 2153-71 and 72). Intense pervasive alteration and structural disruption has greatly hindered reconstruction of the stratigraphy and the timing of igneous events.

There is an uncertain relation between two major packages of sedimentary rocks which are located on either side of a major shallow-dipping structure -- called the Sulphurets Fault by Ostensoe and Kruchkowski (1975). It appears, however, that east of the fault lower sediments are overlain by volcanolithic sediments and pyroclastics. West of the fault upper sediments consist of black shales that, at least locally, appear to be overlain by epiclastic conglomerates. The stratigraphy can therefore be simply summarized as lower sediments, volcanolithic sediment-pyroclastic sequence and upper sediments (Fig. 5.2). A map that shows the location of main mineralized zones and place names is presented in Figure 5.3 to augment the discussion that follows.

5.5.1 Lower Sediments

A thick sequence of argillite, siltstone and chert surrounds the Sulphurets Glacier in the southern portion of the map area. The argillites are black, pyritic and calcareous; the siltstones are grey siliceous or cherty; the cherts are usually grey and highly fractured. Minor amounts of wackes, arenites, tuffs and trachytes in addition to thin limestone lenses (the latter particularly noted in the upper portion of the lower sediments) occur in the lower sediments.

In general these sediments are thinly bedded, well indurated or weakly hornfelsed and commonly contain chlorite, sericite and epidote. Minimum thickness in the prospect area is about 1500 m.

5.5.2 Volcanolithic Sediments and Pyroclastics

Clastic rocks, that are dominated by volcanolithic greywackes, andesite, trachyandesite and trachyte pyroclastics, overlie the lower sediments east of Sulphurets Fault (see symbols in legend of Maps 2153-71 and 72 for distribution of these and other subdivided rock types). The relative distribution of these units is erratic although in the eastern and southern part of the map area the volcanoclastics are peripheral to a major thickness of pyroclastics.

Ostensoe and Kruchkowski (1975) state:

> lithic greywacke, in which rock-fragments exceed detrital feldspar grains, predominate in the southwestern portion of the property, whereas feldspathic greywacke is most abundant in the eastern and northwestern portion. Chert fragments commonly comprise 10% of the lithic varieties of greywacke. Feldspathic greywacke has about 30% and occasionally up to 60% feldspar both as subangular detrital grains and as phenocrysts in rock fragments. Sorting is poor and particles range from silt and clay size through coarse sand and pebble sizes. Colors vary from green to grey-green and are usually influenced by weak chloritization of the rock-flour "paste" matrix. In addition to chlorite, carbonate and in particuar epiote are common products of alteration.

Ostensoe and Kruchkowski, while agreeing that these are very immature rocks, suggest that they are more traditional rocks and not volcanolithic sediments as suggested by Kirkham (1963). However, the feldspar phenocrysts in rock fragments of the feldspathic greywacke described above could be volcanically derived as could many of the other components, including the "so-called chert". The presence of K-feldspar in greywackes was not mentioned by any of the authors. Greywacke in the South Brucejack Lake area contains up to 20% K-feldspar. The distribution of K-feldspar in these rocks may temporally correlate with K-feldspar-bearing volcanic and plutonic rocks associated wth the Sulphurets system but more work is required before a definite relation can be established. In the southwestern portion of the Sulphurets area a ridge line is capped by greywackes which are tentatively grouped with the volcanics. Nothing is known of this unit except that alteration is widespread throughout the area.

Arenites are widely distributed throughout the Sulphurets Prospect according to Ostensoe and Kruchkowski. However many of the rocks called arenites, especially in the northern half of the map area, are intensely altered zones or are clearly pyroclastic in nature.

In the southern portion of the map area arenites overlie the lower sediments and in Sulphurets Creek they are typically a massive grey, fine-grained, pyritic, quartz-rich rock that contains less than 10% argillaceous matrix and lacks good bedding features. Quartzitic, feldspathic and lithic varieties of arenite were determined from observations of cut surfaces (Ostensoe and Kruchkowski 1975); wackes were also recognized.

Pyroclastic rocks, that range from fine tuff to breccias and contain blocks greater than 1 m in size, occur in a northerly-trending elongate zone through the central regions of the map area. On the west they are normally bounded by volcanolithic sediments; the north, east and southeast boundaries are not adequately resolved. Volcanic breccias or tuff breccias occupy the eastern margin of the pyroclastic belt and are medium to fine-grained grey-green rock that contain mainly feldspar porphyry fragments. They are most extensive and coarsest on the north slope of the Mitchell-Sulphurets Ridge and, to a lesser extent, in the Brucejack Lake area; these may be vent-related or at least vent-proximal breccias. Alternatively they could be breccias related to a cauldera collapse structure.

Andesites comprise the bulk of the pyroclastics except in the central regions of the belt, where trachyte to trachyandesite tuff-breccia was recognized from stained slabs. At the southern end of the belt, in the Brucejack Lake area, the pyroclastics typically contain feldspar-porphyry fragments and are described as monolithic high matrix (up to 10% lapilli and blocks) or monolithic low-matrix tuff-breccia with or without interbedded heterolithic conglomerate sequences (see Bridge _et al_., 1983, this volume). Most units to the north would fall into the low-matrix category.

Quartz phenocrysts that are normally amoeboid and rarely euhedral, average 1 mm in size and constitute 1 to 5% of the rock. They occur in tuff-breccias in the Brucejack Lake area. Similar quartz phenocrysts are found in spatially-related syenodiorite and diorite porphyries; these quartz phenocrysts might provide good evidence of a genetic link between the pyroclastics and porphyritic intrusives.

Tuff units are erratically distributed and are poorly understood because of their susceptibility to alteration. In the least altered areas they are grey to green and consist of plagioclase, chlorite, sericite and lesser quartz and K-feldspar; amphiboles are locally common (Bridge et al. 1981). They are normally lithic-crystal tuffs and contain euhedral phenocrysts and small feldspar porphyry fragments.

5.5.3 Upper Sediments

The upper sediments consist of an extensive sequence of very immature black shales and argillites that are similar in character to lower sediments. Kirkham (1963) noted that rhythmically bedded sections are usually small and disconnected in the map area.

A sequence of conglomerates and finer sediments at the northern end of the Sulphurets Prospect overlie the volcanoclastic-pyroclastic strata. Shales, siltstone and sandstone, which are locally graded and cross-bedded, occur at the northeastern end of the area and sporadically with conglomerates and greywackes in the central-northern (near the Iron Cap) to northwestern end. Conglomerates near the Iron Cap contain abundant porphyritic trachyandesite fragments in addition to fine-grained volcanic fragments. According to Bridge *et al*. (1981) volcanic fragments appear to predominate in this part of the area whereas sedimentary clasts are more common toward the west.

5.5.4 Hornfels

Fine-grained strata on either side of the western end of the Mitchell Glacier has been extensively hornfelsed by intruding syenites and granites. This unit is most likely the stratigraphic equivalent of the lower sediments although it could partially represent tuffaceous units or greywackes associated wth volcanolithic sediments and pyroclastics. Hornfelsing and, in many places, partial assimilation or granitization have considerably altered the rocks to variable colored assemblages of K-feldspar, chlorite and quartz. "Chert and iron formation" reported in Bridge *et al*. (1981) are probably contact metasomatic in origin and represent silicified fine-grained sediments and the local development of skarn, respectively. Although a synsedimentary origin for these rocks cannot be entirely ruled out the central location of the "chert" bodies about the periphery of the granites in particulr and the character of the hornfelsing strongly suggest they are contact metasomatic in origin. The iron formations, which are commonly associated with chlorite and quartz and consist of "ill-defined discontinuous patches and lenses that contain variable mixtures of pyrite, chalcopyrite, and magnetite" (Bridge *et al*. 1981), are very similar in appearance to skarn developed in carbonate-bearing sedimentary rocks in contact aureoles of plutons that host porphyry-type alteration-mineralization. Small limestone lenses do occur in the upper part of the lower sediments that are located at the south end of the Sulphurets Prospect.

5.5.5 Intensely altered undifferentiated rocks

Intense alteration has destroyed original textures to such an extent that positive identification of the host rock is uncertain over wide areas of the prospect; this is especially true of medium or fine-grained clastic or porphyritic rock types. In some areas there are local patches of less intensely altered units which can be identified but positive extrapolation across the more extensively intensely altered zones is difficult without detailed petrologic studies. It is for these reasons that an intensely altered undifferentiated rock type is warranted.

5.5.6 Intrusions

The four major intrusions are differentiated on their mineralogy (see Table 5.2); age relations are commonly uncertain because clear cross-cutting relations have not been established. From the least felsic (and possibly oldest) to the most felsic (and probably youngest) the intrusives are grouped as diorite porphyry, syenodiorite porphyry, syenite and granite. Dikes of several possible varieties or episodes do cross-cut the syenodiorite porphyry but their relations to the syenite or granite are unknown.

Diorite porphyry

A major northerly-trending elongate plug of diorite porphyry is located in the eastern margin of the Prospect area. Phenocryst phases consist of medium to coarse-grained hornblende feldspar; hornblende ranges from $<$ 10 to 20 vol. % and plagioclase (An_{5-20}) about 30 to 50 vol. %. These are set in a dense grey-green groundmass of fine-grained plagioclase and alteration products; apatite, sphene, and magnetite are accessories.

In the Brucejack Lake area the diorites are generally medium-grained hornblende feldspar porphyries and typically occur as small plutons. Kirkham (1963) has identified similar porphyries near the northern end of the Sulphurets Glacier; they are commonly altered. Also included with this rock type in this area are the patches of diorite and andesite dikes and sills of Ostensoe and Kruchkowski (1975). The diorite dikes are essentially hornblende feldspar porphyries whereas the andesites are described as green, dense and holocrystalline.

A patch of strongly foliated (schistose) hornblende feldspar prophyry near the toe of the Mitchell Glacier is grouped with the diorite porphyry and might provide good evidence of cross-cutting relations with the granite.

Syenodiorite Porphyry

Syenodiorite porphyry is very similar to the diorite porphyry in terms of texture, style of intrusion, and areal extent. The presence of abundant groundmass K-feldspar in the syenodiorite porphyry distinguishes it from the diorite porphyry which has mainly plagioclase in its groundmass. The medium to coarse-grained, uncrowded seriate texture of plagioclase phenocrysts in the diorite porphyry is mirrored in the syendiorite porphyry which also contains K-feldspar phenocrysts locally.

Trachytes reported by Ostensoe and Kruchkowski (1975) near the bend in the Sulphurets Glacier are included with this rock type. Feldspars, presumably plagioclase, are euhedral and medium-grained. Hornblende is also present and is set in a dark green aphanitic matrix of unidentified composition but presumably K-feldspar-rich. These rocks are perhpas finer-grained and more crowded than the porphyries to the east. Without staining for K-feldspar using Na-cobaltinitrate categorizing these rocks is difficult; their subdivision in this area is very uncertain.

Syenites

Several varieties of syenite have been distinguished; syenite and quartz syenite (Kirkham 1963), porphyritic syenite and cataclastic syenites (Ostensoe and Kruchkowski 1975), and syenite, hornblende syenite and syenodiorite (Bridge et al. 1981). The diversity in names reflects the mineralogical/compositional variability within the syenite group and the possible hybrids or transitions from syenite to granite and from syenite to syenodiorite.

In this report syenites are defined as rocks that contain K-feldspar both in the groundmass and as phenocryst phases. Plagioclase may also be present but generally constitutes less than one third of the total feldspars.

Irregular stocks of syenite occur on the top of the Mitchell-Sulphurets Ridge and on a steep slope north of the Mitchell Glacier. They vary from fine to medium-grained and commonly have porphyritic to granitic textures; phenocrysts are normally 2 to 5 mm in length and rarely 20 mm. Euhedral and subhedral, pink to red and white microcline microperthite (Kirkham 1963) exhibits oscillatory zoning and frequently has a core of white plagioclase. The less common plagioclase (An 5-25, Kirkham 1963) is generally subhedral or corroded, white to green and occurs as a phenocryst phase and in the groundmass. Mafic minerals, probably hornblende, are commonly altered to chlorite and other secondary minerals; relict, partially resorbed hornblende was noted by Kirkham (1963). These altered mafics rarely constitute more than 70% of the rock and are commonly less than 5%. Quartz, where present, is a groundmass component; apatite, sphene and magnetite are common accessory minerals.

Unlike the diorite and syenodiorite porphyries, which commonly have sharp contacts with host rocks in areas of less intense alteration, syenites normally have gradational and highly complex contacts with the rocks they have intruded. The area of hornfels located both north and south of the Mitchell Glacier is a contact metasomatic aureole to the syenites and granites. The pinkish color that is commonly noted in the hornfels is primarily K-feldspar that was added to the rock by replacement, partial assimilation, and perhaps a process akin to granitization.

Granite

Although spatially related to the syenite, granite is not as common and occurs at or beyond the eastern margin of major syenite intrusions on either side of the Mitchell Glacier. It mainly occurs as large irregular stocks and, to a lesser extent, as small dikes and sills. Kirkham (1963) and Wares (1968) report that the granite crosscuts the syenite although the relation may not be simple because a unit that is very similar to the syenite (possibly a quartz syenite) crosscuts the granite in the Mitchell Zone. This may be the late porphyritic phase of the granite reported in Bridge et al. (1981). In any case the granite and the syenite are thought to be intimately associated with one another temporally (see Kirkham 1963) as well as spatially.

The granite is characterized by a dark red to light purple color, phenocrysts of commonly euhedral quartz and a low content of mafic minerals. It is described as holocrystalline and equigranular although it varies from fine to medium grained in the south to medium to coarse-grained in the north (Bridge et al. 1981). Quartz content also appears to increase towards the north and east (Kirkham 1963). The dominant feldspars, microcline microperthite and perthite, are generally red but may have white cores. In one sample (EV#719) microperthite twinning was partially replaced by another K-feldspar mineral, possibly orthoclase, or microclie and fine-grained blades of albite. Magnetite and apatite are common accessories; sphene has not been reported.

Dikes

Several textural and probable compositional varieties of dikes have been mapped but their age relations are uncertain. The dikes range from less than 1 meter to more than 8 meters in thickness. They are generally straight and can be traced over long distances in some cases. At this point two major varieties are distinguished, keratophyre and lamprophyre dikes and are compositionally identified on the absence or presence of generally groundmass K-feldspar.

Keratophyre dikes range from northwest to west-southwest in strike direction and dip steeply or shallowly north. A low-dipping one, located north of the Sulphurets Glacier, is described as dark green and typically contains 25 to 30% albite, 35 to 40% hornblende, a trace of corroded clinopyroxene, and many secondary minerals. In the Brucejack Lake area amygdules filled with carbonates are commonly noted and on weathered outcrops impart a vesicular texture to the otherwise finely microcrystalline rocks. These dikes range from diorite to perhaps gabbro in composition.

Lamprophyre dikes trend roughly north and normally have subvertical dips. In the Brucejack Lake area they are generally microcrystalline except at chilled margins or if dikes are narrow. Examination of stained slabs indicates a K-feldspar content that varies from less than one third to two thirds of the total feldspars. A range from syenite to diorite is therefore indicated although fine needles of a mafic mineral, possibly hornblende, locally constitute 60% of the rock. K-feldspar is interstitial to the mafic and plagioclase in addition to occurring as discrete fine-grained phenocrysts. Magnetite is a common accessory and the secondary minerals, mainly chlorite and calcite, were also noted but, compared to the keratophyre dikes, the lamprophyres appear relatively fresh.

Dikes that were rarely noted in areas north of the Mitchell-Sulphurets Ridge were identified as diabasic by earlier workers and are grouped with keratophyres dikes in this report. Dikes intersected in the Sulphurets Gold Zone drill holes and others reported by Ostensoe and Kruchkowski (1975) are not dealt with here becase of inadequate information.

5.5.7 Structure

The Sulphurets Prospect area has been subjected to a complex history of structural disruption that controlled the development of the alteration-mineralization zones and the subsequent location and character of these zones. Major fold and fault patterns and regimes noted on the region scale map (2153-70) manifest themselves at the scale of the Sulphurets Prospect (Fig. 5.3).

Folds: A major, relatively open fold is located at the southwest corner of the map area where it plunges to the north-northwest. It forms a depression with a southerly plunging syncline west of the Mitchell Creek-Sulphurets Creek junction (see Map 2153-70). A dome and a depression are suggested by stratigraphic attitudes in the southwestern part of the area and north of Brucejack Lake, respectively. Other minor folds are located in the Brucejack Lake area and in the northwest corner of the map area. These are perhaps related to strike-slip and thrust fault movement respectively. Disharmonic folds located west of the Brucejack Lake area are possibly also related to fault activity, although gravity sliding (Kirkham 1963) or folds caused by intrusion are likely alternatives.

<u>Faults</u>: The Brucejack Fault, which is near vertical and northerly-trending, is located toward the eastern margin of the map area. It extends from the Brucejack Lake area north to bound the eastern margin of the Iron Cap zone. A right-lateral sense of movement is indicated by the offset of a lamprophyre dike and major alteration zone boundaries.

A vertical component to movement on this fault is also implied by the high topographic level at which major plutons are found on the eastern side -- a feature that suggests east side up relative to the west. Thrust faults, which dip westerly 35 to 50^{o} and strike roughly north, are located in the eastern and western (Sulphurets Fault) margins of the property. They appear to have displacements on the order of 100's of meters. Their age relation with the Brucejack Fault is uncertain although they may be younger. A flat-lying fault immediately north of the nose of the Mitchell Glacier could mark a plane of overthrust or gravity sliding. It may be related to the eastern thrust fault and, like the Sulphurets Fault, postdates alteration-mineralization.

Other inferred major faults are thought to exist beneath the ice cover of the Mitchell Glacier, Sulphurets Glacier and possibly the Hanging Glacier. These have roughly east-west trends and are paralleled by a schistose foliation that is widely distributed throughout the prospect area. Northerly trending veins in early quartz stockworks are commonly kinked and have easterly-trending axes to crenulations. Very recent fault activity which has similar trends can be viewed near the base of the slope south of the Mitchell Glacier. This series of step-like normal faults have displacements of 1 to 2 meters, trend about 110°, and dip steeply north.

Many other minor faults have been mapped, notably north and south of the Mitchell Glacier (Fig. 5.3). They are probably related to the major faults.

Bedding Attitudes: Faults and intrusions have locally greatly disrupted stratigraphic attitudes. In the areas of the previously discussed depression and dome attitudes are relatively shallow dipping. Between these features moderate to steep easterly dips are common. In the northern portion of the map area similar northerly dips to stratigraphy are the rule.

Foliation: Schistose styles of foliation commonly have east-west trends and steep northerly dips in the northern half of the map area and southwesterly dips in the southwest corner of the area. Near the Brucejack fault the foliation trends more northwesterly suggesting local fault control.

The foliation is primarily a shear cleavage that is probably related to large-scale fault or fold structures.

Veins: Although there are many types and episodes of veins two major varieties warrant discussion in he context of the prospect-scale geology. Thin (.5 to 1 cm wide) quartz veins are found in scattered localities throughout the prospect but are particularly noticeable in the two stockwork zones located south of the Mitchell Glacier. Meter-wide en echelon veins of quartz are primarily found in an intensely altered zone that trends north to north-northwest and which has been offset by the Brucejack fault (Fig. 5.4). Development of the intensely altered zone might have been controlled by a right-lateral shear regime oriented nearly north-south (see inset Fig. 5.4). The meter-wide en echelon veins could occupy tensional fractures in such a system. If true, then right-lateral faulting probably controlled the development of alteration-mineralization zones in addition to their later fault dislocation.

Tension gash quartz veins were noted over wide areas of the Prospect. At this point they have not been incorporated into the structural picture because of variable and scarce data. Such featurees, however, should be kept in mind when evaluating structurally controlled mineralization.

5.5.8 Alteration-Mineralization

The Sulphurets Prospect is characterized by extensive zones of intense normally pervasive alteration with which significant copper, molybdenum, gold and silver values are locally associated. A major zone extends relatively continuously from the Brucejack Lake area north to the Iron Cap, a distance of nearly 7 km (Fig. 5.4); it is open on both the northern and, to lesser extent, on the southern ends. West of the central regions of this area intense alteration follows an apparent northeast trend in which the Sulphurets Gold Zone is located. Post-alteration movement on the Sulphurets fault may have significantly distorted this apparent trend. Other major zones that apparently trend north-northeast occur in the southwest corner of the map area but their character and mineralogy is unknown. They are not on the ground currently held and called the Sulphurets Prospect.

Within these major zones K-feldspar-dominated assemblages are overprinted by feldspar-destructive sericite-dominated assemblages. Chlorite and carbonates associated with sericitic alteration are locally significant whereas tourmaline and pyrophyllite are of limited extent but are of genetic importance. Less intense propylitic-type assemblages in which feldspar phases are not totally destroyed fringe the pervasive assemblages. They are also overprinted by sericite-dominated assemblages.

Quartz veins and stockworks of major significance are found within the zones of intense pervasive alteration. Early-stage stockworks are commonly structurally disrupted unlike en echelon meter-wide veins which are commonly mineralized and are probably later and more closely related in time to the events that caused much of the intense pervasive alteration.

Early Quartz Stockworks

Two quartz stockwork zones are defined as early because xenoliths of quartz stockworks in hornfels occur in granites of the Mitchell zone. Stockwork characteristics of these xenoliths are similar to those found in the Moly Zone located south of the Mitchell Glacier and another located north of the Snowfields Gold Zone (Fig. 5.4). They are characterized by thin (1 cm wide), generally milky-white, quartz veins which are commonly broken or crenulated as previously mentioned. Two major trends of about 030^{o} and 150^{o} of commonly closely spaced (e.g. 2 cm centers) parallel veins with subvertical dips are found in both stockworks although a 110^{o} trend and a shallow westerly-dipping en echelon set occur in the Moly Zone. The stockwork north of the Snowfields Gold Zone has 030^{o} and 150^{o} trends in its respective southern and northern portions. Although these trends are based on limited observations there is a strong implication that whatever caused the fracture patterns was consistent between the early quartz stockwork zones.

Hornfels

Contact metasomatism around the granite and syenite plutons is discussed in a previous section. The eastern limit of the hornfels merges with intense alteration zone. The western limit is unknown but probably does not penetrate far into the sedimentary pile.

K-feldspar

Criteria that clearly distinguishes primary from secondary K-feldspar is not common. Microcline phenocrysts in granite from the Mitchell Zone exhibit remnant patches of twinning and are largely replaced by orthoclase (?) and exsolved albite blades. Is this replacement caused by a secondary process or is it late magmatic crystallization? Is the fine-grained K-feldspar in the groundmass of intensely altered rocks a secondary alteration product or a remnant primary feature of a syenite, syenodiorite or trachyandesite?

In spite of these uncertainties there is little doubt that K-feldspar-dominated assemblages which occur in the Iron Cap, in a patch south of the Hanging Glacier, and scattered through the Brucejack Lake area are in equilibrium with quartz and pyrite and perhaps locally minor sericite. This assemblage may be more widespread than indicated on Maps 2153-73 and 74 because many areas were not examined or sampled for later mineralogic tests. (Over 300 samples were stained with Na-cobaltinitrate to determine presence or absence of K-feldspar and of these about 70 were X-ray diffracted (see Appendix 5.2). Correlation between the staining and X-ray diffraction techniques was very good).

K-feldspar occupies both groundmass and phenocryst sites in this alteration type. Tabular coarse-grained phenocrysts (0.8 cm long) in one sample from the Iron Cap intensely altered zone may represent a remnant syenite porphyry texture and therefore are largely of primary origin.

At the fringes of the Electrum Zone in the South Brucejack Area a progression from outer chlorite-sericite to a narrow K-feldspar-dominated assemblage to probable overprinting inner sericite-dominated alteration occurs as meter to several meter scale envelopes around an electrum-bearing quartz vein or stockwork. Even though textural criteria confirming the sericite overprint is lacking in the area and the distribution is based on limited sampling the K-feldspar is felt to be at least partially secondary in origin because of its abundance.

Sericitic

Sericitic alteration is subdivided into three major assemblages -- sericite, chlorite-sericite and carbonate-sericite. All are characterized by intense pervasive alteration that includes ubiquitous quartz and pyrite as part of the assemblage and by total or near total destruction of feldspar phases.

A major area of sericitic alteration is bordered to the north by the Mitchell Glacier. It extends in a band roughly 1 km wide to south of the Hanging Glacier where it narrows to about 0.5 km. Between this southern extremity and the Brucejack Lake area there is little information although less regular structurally-controlled patches that are similar to those in the Brucejack Lake area are predicted from helicopter sightings.

Westerly-trending areas of sericitic alteration are located both north and south of the lower end of the Mitchell Glacier. The northerly one is poorly understood whereas the southerly one, which is partially obscured by glacial-fluvial debris, encompasses sericite and chlorite-sericite assemblages and the quartz stockwork of the Moly Zone.

The Sulphurets Gold Zone is shown as mainly sericitic although K-feldspar alteration is also common (Bridge et al. 1982). Very little work was done by the author on this area and like the two broad zones of alteration that lie to the south their definition as sericitic is conjectural.

Chlorite-sericite alteration assemblages could reflect a high mafic content in the host rocks relative to surrounding sericite altered rocks. Alternatively a relatively high Mg and Fe content in the alteration fluids or less intense degree of hydrogen metasomatism might be indicated. In either case changing conditions are suggested and until properly understood differentiation of the chlorite sericite assemblage is desirable. A major zone of this type of alteration occurs in the Snowfields Gold Zone and extends north to the Mitchell Glacier.

Carbonate-sericite alteration mainly occurs within and bordering the K-feldspar-dominated assemblage in the Iron Cap area. Where abundant carbonates extensively replace phenocryst and groundmass constituents the K-feldspar content is radically reduced. Another area where carbonate-sericite alteration is locally dominant is in the Brucejack Lake Peninsula area. X-ray diffraction of several across-strike samples from drill core indicates that wall-rock carbonate alteration does not have a simple relation with the mineralized zone (Fig. 5.5). Calcite is the major carbonate although dolomite is present locally and may be indicative of less strongly altered fringing environments. This type of alteration is probably more common in the Sulphurets region than currently realized.

Tourmaline and pyrophyllite are respectively found with or surrounded by sericite assemblages. Tourmaline is locally found in the southwestern portion of the Sulphurets Gold Zone and above this latter zone on the Mitchell-Sulphurets Ridge. It occurs as rosettes within a mosaic of sericite-quartz-pyrite in the Snowfields Gold Zone. On the Mitchell-Sulphurets Ridge tourmaline replaces phenocrysts or clasts as tabular euhedral crystals with interstitial quartz and a high-relief, semi-isotropic, yellow-brown unidentified mineral. In this case it constitutes more than 10% of the rock and appears to be antitehtic with sericite.

Pyrophyllite has been noted in only one locality between the Snowfields Gold Zone and the quartz stockwork to the north. It is associated with quartz and pyrite and a transparent unknown; sericite is not part of the assemblage. The rock has a white to grey mottled texture caused by the pervasive alteration of phenocrysts or clasts to fine-grained bladed mosaics of pyrophyllite. Because this mineral can only be identified by X-ray diffraction techniques it is probably more common than presently known.

Propylitic-Type

Characteristic features of propylitic-type assemblages are a relatively sudden increase in chlorite and carbonate or epidote contents and preservation of textures and feldspar phases. Although there is considerable variation two major assemblages are indicated and consist of inner chlorite-carbonate and outer chlorite-epidote assemblages; albite and sericite are associated with both.

Chlorite-carbonate is found in wide areas throughout the Brucejack Lake area. It is also found less extensively bounding either side of the sericite alteration on the Mitchell-Sulphurets Ridge; it changes from chlorite-carbonate to chlorite-epidote assemblages from inner to outer zones. Chlorite-epidote is more widespread on the eastern side of the area (see Map 2153-73) and extends south toward Brucejack Lake. Both types of alteration are probably more extensive than shown.

Mineralization

Major features of the mineralized zones are shown in Tables 5.3 a and b. Much of this data are recorded in greater detail in Bridge _et al_. (1981) or in other sections of this report; it will not be repeated here. The discussion which follows relates main element-deposit types to the Prospect-scale picture of alteration. Figure 5.6 shows the approximate distribution of base and precious metals in relation to mineralized areas.

Porphyry copper-type mineralization occurs in the Mitchell and Kirkham Zones at the northwest corner of the Prospect area. The mineralization is found in granite, syenite and hornfels associated with possible secondary K-feldspar. Intense contact metasomatism of fine-grained rocks produced the hornfels which is locally mineralized and contains magnetite. East of the Mitchell Zone molybdenite is erratically distributed with copper. They interface with higher gold contents in intense K-feldspar alteration at the western margin of the gold-bearing quartz veins of the Iron Cap. Northeast of the Kirkham Zone hornfels give way to pervasive chlorite-sericite and the sericite quartz-stockworks of the Moly Zone. Farther east similar assemblages, in addition to local tourmaline and pyrophyllite, are found within and around the Snowfields Gold Zone. Copper minerals are notable for their absence in both of these areas. The gold in the Snowfields

Gold Zone is most likely contained in disseminated pyrite. Except for molybdenite, no other sulphides are found; quartz veins are relatively rare.

The only known significant patch of copper-gold porphyry-style mineralization occurs in the Sulphurets Gold Zone where K-feldspar, sericite, and locally biotite and tourmaline dominate the alteration assemblages (Bridge et al., 1981).

There is a large gap (i.e. not mapped) between the intense sericite alteration on the Mitchell-Sulphurets Ridge where a Ag-bearing quartz vein was noted and the Au-Ag veins of the Brucejack Lake area. Both pervasive K-feldspar and sericite assemblages occur in this gap as they do in the Brucejack Lake area. Base metals, primarily sphalerite, galena and, less commonly, chalcopyrite are intimately associated with the Au-Ag mineralization of the Brucejack Lake Area.

5.5.9 Brucejack Lake Area Mineral Paragenesis

Seventeen samples selected by D. Bridge from trenches and drill holes in the Brucejack Lake area were briefly examined as polished sections. The results are tabulated and described in Appendix 5.1. Paragenetic relations are illustrated in Figure 5.7 and the minerals are discussed below in the order shown from early to later stage.

Pyrite is the most common and widespread mineral followed by sphalerite, galena and chalcopyrite roughly in order of abundance. Tetrahedrite and pyrargyrite are the most common precious-metal bearing minerals observed whereas argentite and electrum are not as common. Less abundant or widespread minerals include arsenopyrite, bornite, enargite, and covellite. Possible botryoidal melnikovite pyrite was noted in one sample from the Brucejack Lake area.

Pyrite

Two major stages or temporal end-members of pyrite are likely although episodic emplacement of this mineral throughout mineralizing events is a strong possibility. It normally occurs as medium to coarse-grained subhedral commonly embayed grains or discrete euhedral crystals; fine-grained crystal aggregates were also noted. The pyrite is disseminated in wallrocks and locally replaces fragments or phenocrysts or fills veins. Later-stage pyrite is mainly vein-controlled.

Very fine-grained to fine-grained blebs of chalcopyrite, bornite and a dark tan unknown in addition to galena and, less commonly, sphalerite and tetrahedrite occur in pyrite. However, coarser-grained varieties of these minerals surround and, in the case of sphalerite, embay the pyrite grains. Similar blebs of the copper sulphides were noted in pyrite grains from the Iron Cap area.

Arsenopyrite

Medium-grained, generally euhedral crystals of arsenopyrite are cemented by pyrite of unknown early or late-stage affinity. It was noted in only one sample (EV 744).

Chalcopyrite

The main habit of chalcopyrite is as fine to medium-grained subhedral to anhedral fillings. Chalcopyrite occurs as emulsion-like very fine-grained exsolution grains in sphalerite in addition to the rounded blebs that occur in pyrite.

Galena

Galena typically occurs as medium to coarse-grained irregular fillings that surround earlier pyrite. While commonly exhibiting mutual boundary textures with tetrahedrite, pyragyrite and the argentite composite it is commonly embayed and shares cuspate boundaries with sphalerite. However, this apparent time relation is not consistent because galena also fills fractures cross-cutting sphalerite.

Tetrahedrite

In addition to the fine to medium-grained anhedral grains and fillings mentioned above, tetrahedrite locally occurs with covellite in a fracture that cross-cuts a sphalerite grain. Generally tetrahedrite is embayed by sphalerite.

Pyrargyrite

Fine to medium-grained anhedral pyrargyrite grains and fillings are commonly associated with galena and tetrahedrite. Although it locally appears to replace sphalerite, like galena and tetrahedrite the bulk of the pyrargyrite probably post-dated early-stage sphalerite and overlapped in time with late-stage sphalerite.

Argentite Composite

Medium to coarse-grained anhedral grains that appear to consist of atoll-like pyrite or gold that are set in a possible tetrahedrite-argentite aggregate is tentatively defined as an argentite composite. The composite does not polish well possibly because of the varying hardness of the constituent minerals. A positive identification of this mineral will be undertaken by Exxon's research group in Houston, U.S.A.

Electrum

Variably colored electrum is more common than indicated by this study. Where noted in polished sections it occurred s fine-grained anhedral grains. In hand specimen coarse hackly textured grains are easily identified and correlate reasonably well with high Au contents.

Sphalerite

Fine to coarse-grained anhedral to subhedral interstitial fillings of sphalerite normally embay pyrite, galena and tetrahedrite. As previously mentioned sphalerite is locally crosscut by galena and tetrahedrite and contains chalcopyrite exsolutions.

Covellite

Typical habits of covellite are fine-grained blebs in tetrahedrite, fracture fillings in sphalerite with tetrahedrite, and discrete anhedral grains. Most of these occurrences are thought to be of primary origin. However, in one sample where galena is partially replaced by covellite and at least two other greyish intermediate products it is probably supergene.

5.5.10 TREATY CREEK

This area is located in an inland of rock that is completely surrounded by glacial ice about 6 km northeast of the Iron Cap. The ground is currently held by E and B Exploration.

Two days were spent mapping the Treaty Creek area during which time no economic mineralization was recognized. The geologic environment is similar to the Sulphurets Prospect in terms of rock types and alteration assemblages although in addition to pervasive K-feldspar and sericitic assemblages advanced argillic alteration minerals were also noted.

Lithologies

Briefly, the geology at Treaty Creek consists of a volcanic-sedimentary pile that is intruded by hornblende feldspar porphyries and fine-grained syenodiorite plutons (Fig. 5.8). Volcanics comprise the majority of the lower parts of the stratigraphy and vary from pillow lava in the north (Kirkham 1963) to tuff breccia, lapilli tuff and fine tuff towards the south. Arkosic wacke and argillites are locally intercalated. In the southeast part of the area fine-grained wacke beds are steeply overturned and intruded; they are probably equivalents of the upper sediments in the Sulphurets Prospect area.

Hornblende feldspar porphyries are generally altered and are of uncertain origin. The fine-grained syenodiorite is fresh or only weakly altered and is probably more common in the area than shown on earlier maps. The southerly pluton occupies the center of a ridge line and it is suggested here than many of the ridges in this and other areas surrounding the Sulphurets Prospect will commonly be found to largely consist of intrusive rocks.

Structure

Inadequate coverage precludes a comprehensive discussion of structure in the area. Stratigraphy dips moderately toward the southeast and steeply northwesterly to northerly in the northern and southern parts of the map area, respectively. One east-northeasterly, steeply dipping fault is spatially related to an occurrence of alunite. Quartz veins that trend northeasterly to north-northwesterly and have moderate to steep dips occur in scattered localities.

Alteration

Pervasive sericitic and K-feldspar-dominated assemblages generally occur at high and low levels in the system, respectively (Fig. 5.9). Chlorite and carbonate-bearing assemblages are scattered throughout the area; two of these assemblages are atypical compared to the Sulphurets Prospect. Structurally-controlled northerly trending patches or circular patches of carbonate +- pyrite (+- sericite +- quartz +- clays?) occur at the northern end of the area. Toward the southern end of the Prospect a broad zone of northwest-trending (?) intense silicification and minor chlorite and carbonate is recognized.

Perhaps the most outstanding feature of this area is the presence of alunite, native sulphur, patches of fine-grained intense silicification and very fine-grained pyrite. These are features of advanced argillic alteration and indicate that the exposed portions of Treaty Creek are higher-level in terms of alteration assemblages relative to the Sulphurets Prospect.

Strongly foliated rocks, that are perhaps verging on a mylonite, are intensely altered to alunite-bearing assemblages and crenulated. Openings caused by this minor folding have localized white to smoky-colored alunite and native sulphur. These textures, in addition to structurally controlled alteration zones, indicate that tectonics at least partially controlled the development of the alteration system.

Exploration

The advanced argillic assemblages suggest that this system is relatively high-level. Rapid prospecting and rock-chip sampling at the lower western margin of the altered zones, particularly near the ice margins, is recommended. This area probably represents the deepest-level of exposure of the hydrothermal system at Treaty Creek. Because of its ice-bounded location more detailed work than this is perhaps not justified.

5.5.11 INTERPRETATIONS

Following deposition of the lower sediments in the Early Jurassic, andesitic volcanics were emplaced in a shallow marine environment (Fig. 5.10a). With continued activity volcanism changed from subaqueous to subaerial conditions as the edifice emerged above sea level. Extrusion into a subaerial environment is indicated by the commonly oxidized nature of the volcanics, the relatively uncommon intercalated sediments, the poor sorting of fragments and the local deposits of channel fill or fluvial conglomerates.

Andesitic volcanism evolved to more felsic trachyandesite, latite, and possibly rhyolite composition (Fig. 5.10b). As epiclastic greywackes and conglomerates were deposited about the fringes of the edifice, diorite porphyry and syenodiorite porphyry successively intruded this, more or less, comagmatic pile. These intrusive events might have caused the development of early quartz stockworks and perhaps some of the widely distributed, pervasive sericitic alteration; some copper, molybdenum and gold mineralization may also have been deposited at this time.

Syenite and granite were successively intruded at a somewhat later date as the volcanic edifice was partially eroded (Fig. 5.10c). It is either during this stage or during the time interval between the emplacement of the syenodiorite porphyry and the syenite that a large hydrothermal system developed and caused the extensive pervasive K-feldspar and sericitic alteration which is intimately associated with the economic minerals at the Sulphurets Prospect.

There are other major points which should be considered as new data is acquired.

1. There might be a fifth major intrusive phase that is intermediate to the syenodiorite porphyry and the syenite both in time and space as well as composition. Some members of this intermediate phase could currently be grouped with the syenodiorite. Textural features of an intensely altered porphyry in the Iron Cap area suggests such a phase might exist and, indeed, be spatially closely related to the pervasive alteration and associated mineralization.
2. Current mapping has concentrated on one locality which overlaps the marginal or epiclastic westerly fringing zone of the volcanic pile. The overall dimensions of this volcanic pile, location of its extrusive center or centers, and the possibility of caldera development that controlled later-stage intrusive, extrusive, or alteration-mineralization events, should be evaluated as mapping progresses in the region.

3. The role that regional structural features, such as the strike-slip regime presented earlier, or more local structural features, such as cauldera collapse or vent facies volcanics, or combinations of several structural features should be evaluated.
4. The relative timing of structural and igneous events. This is particularly important in terms of fold and fault regimes that predate mineralizing events and which might have controlled the emplacement of gold-bearing quartz veins.
5. The two distinct periods of intrusive and alteration proposed above may be the major cause of the east-west assymetry of the alteration-zonation at the Sulphurets Prospect. Alternatives or contributing causative factors include the erosion level or pattern, structural disruption that has caused offset, tilting or folding of the major alteration zones, greater permeability of host rocks in the east relative to the west (whether inherent or tectonic in nature), or differences in the level of intrusions that generated the alteration zonation.

6. The relations in time and space between K-feldspar, sericitic, and carbonate-sericite assemblages and mineralization is probably sequential, at least for the first two. Gold mineralization occurs with all three alteration types; areas where they overprint one another might be considered higher potential on a local scale. The significance of the carbonate assemblage is not understood; the association of carbonates with many other gold deposits indicates it may be an important factor in the localization of ore.

K-feldspar alteration occurs at Steamboat Springs, Nevada (Schoen and White 1967) and the Ohaki-Broadlands hydrothermal area, New Zealand (Browne and Ellis 1970). At these areas loss of CO_2 during steam separation or boiling is a major mechanism proposed to evolve the high K^+/H^+ ratio necessary to precipitate K-feldspar. A similar mechanism probably applies to Tertiary gold deposits (see the model of Buchanan 1981) and possibly to the Sulphurets Prospect. Certainly locally high carbonate contents and boiling conditions are present at both.

7. The Sulphurets Prospect has elements of mineralogy that are comparable to the model Buchanan (1981) proposes for Tertiary gold deposits. It differs in size (the Sulphurets system is comparatively large), the nature of the K-feldspar alteration assemblages, and the lack of advanced argillic assemblages (which could be a function of erosional level). K-feldspar-dominated alteration appears to be widespread at Sulphurets and not fracture- or envelope-controlled as it is on Buchanan's model. It is closely related in space to intrusive bodies which impart porphyry-style features. Both porphyry copper (molybdenum and gold) mineralization and gold veins with epithermal characteristics occur at Sulphurets; the areas of K-feldspar and overprinting sericitic alteration may represent an interface between the two types of mineralization.

8. The early-stage, relatively barren quartz stockworks might represent the central regions of an early hydrothermal system. Barren quartz cores or stockworks are noteably features in some porphyry copper deposits (e.g. Ok Tedi and Yandera, Papua New Guinea). Mineralized zones are found at their periphery. The Snowfields Gold Zone which is located at the southern periphery of one quartz stockwork at Sulphurets represent an analogous situation.

Exploration

The intensely altered region that includes the Snowfields Gold Zone and extends south to the Brucejack Lake area is a prospective area. Gold mineralization is known to exist at both ends, although it is of different tenor and character. Except for the Mitchell-Sulphurets Ridge, the intervening ground has received no attention but is known to contain wide areas of pervasive alteration which probably include both K-feldspar and sericitic assemblages. In addition, this area is higher-level in terms of an epithermal-type system and relative to the Brucejack Lake area.

Several factors suggest that the region between the Snowfields Gold Zone and the Hanging Glacier, which includes the Mitchell-Sulphurets Ridge, warrants more detailed evaluation:

1. The southern exposure of the Mitchell-Sulphurets ridge consists of strongly foliated and fractured rocks that have not been glaciated. A leached cap of iron-oxide stained, strongly sericitized rocks has therefore been preserved and may indicate supergene enrichment at depth although analyses of relatively fresh grab-samples (see Table 5.4) downgrades this possibility.

2. A quartz vein located in the Mitchell-Sulphurets Ridge line that contained a black sooty mineral (argentite) assayed 16.7 oz/t Ag and 0.017 oz/t Au. This was the only economic mineral identified in the area although pyrite was noted over widely scattered areas where supergene leaching was not as severe; analyses of some grab samples containing disseminated pyrite were weakly anomalous in Ag, As and Au (see Table 5.4).
3. At the western margin of the Snowfields Gold Zone quartz veins, molybdenite veins, and ferricrete were noted. The ferricrete appears to be derived from an area within or under the remnant patch of ice that lies between the Snowfields Gold Zone and the Mitchell-Sulphurets Ridge. It is a sign that rocks containing high sulphide contents have been leached.
4. Pyrophyllite and tourmaline are minerals that indicate a high-level alteration environment and proximity to zones of mineralization, respectively. Both were found near the Snowfields Gold Zone. Tourmaline was also seen on the Mitchell-Sulphurets Ridge where it is associated with an unknown mineral and constitutes up to 20% of the rock.

5. As mentioned previously the Mitchell-Sulphurets Ridge line is considered the highest-level expression of the alteration-mineralization system. Significant disseminated or stockwork gold-silver +- molybdenum +- copper grades at depth are certainly a possibility even though surface grab-samples were not strongly anomalous. In this regard a deep diamond drill hole through the Snowfields Gold Zone is warranted; based on the more detailed mapping and rock geochemistry which are recommended here, additional deep holes might be warranted in the general region of the Mitchell-Sulphurets Ridge like and perhaps farther south toward Brucejack Lake.
Glaciers, that cover the large alteration zones in both the Sulphurets Prospect area and other areas in the region, have suffered significant ablation in the last 10 years (in some cases up to 200 meters). Particular attention should be paid to prospecting, sampling, and mapping glacial margins in areas of known alteration or mineralization (or potentially mineralized) because this new terrain has probably never been examined.

Recording good structural data and taking at least representative samples for more detailed examinations are strongly recommended while mapping in the field. The benefits of good structural data (vein attitudes, foliations, bedding attitudes, faults, etc.) are self evident particularly in a region as complex as the Sulphurets Prospect. Representative samples for later slabbing, staining, petrologic or X-ray diffraction work provide information that greatly increase the data base and can help outline the extent and geometry of hydrothermal systems by indicating temperature or composition gradients; this is particularly true of intense pervasive very fine-grained alteration assemblages commonly found in the high-level portions of hydrothermal systems.

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AGE RELATIONS	INTRUSIVE ROCKS	ALTERATION AND MINERALIZATION	SEDIMENTARY AND VOLCANIC ROCKS
Youngest	Keratophyre Dikes (K) Lamprophyre Dikes (L)		
	Granite (G)	Hornfels (H) (Mineralization?)	Upper Sediments (US) Conglomerate (cg) Black shales (bs)
	Syenite (S)		
	Syenodiorite Porphyry (Sp)	Intense (I) Alteration (Mineralization)	Volcanoclastics (V) Tuff Breccia - andesite (Tb-a) - trachyandesite (Tb-t)
	Diorite Porphyry (Dp)	Early Quartz Stockwork	Tuff to lappilli (Tl)
			Greywacke (Gw)
Oldest			Lower Sediments (LS) Argillite Siltstone Chert

TABLE 5.1 Age relations and nomenclature of lithologies at the Sulphurets Prospect.

TABLE 5.2 Mineralogy of intrusive rock types

Rock Type	Pyroxene	Hornblende	Biotite	Quartz		K-Feldspar		Plagioclase	
				Pheno[1]	G.M.[2]	Pheno.	G.M.	Pheno.	G.M.
Granite		±		✓	✓	✓	✓	±	
Syenite		✓		±[3]	✓	✓	✓	✓	✓
Syenodiorite Porphyry	±	✓	±		✓		✓	✓	±?
Diorite Porphyry		✓		±[3]	✓			✓	✓

1 Phenocryst
2 Groundmass
3 Amoeboid Texture

TABLE 5.3 Geochemical analyses (unless noted otherwise analyses are in ppm except Au which is in ppb) of grab samples from the Mitchell-Sulphurets ridge.

Sample #	Alteration	Mo	Cu	Pb	Zn	Ag	Hg	As	Au	Sb
RB 181	Sericite		9	11	6	0.8	100	102	20	2
RB 182	Carbonate-sericite (arkose?)		12	9	28	0.5	50	460	100	22
RB 183	Sericite (remnant K-feldspar)		7	20	5	3.4	45	26	50	5
[1]RB 184	Quartz vein	.001%	.002%			16.70 oz/t		.01%	.017 oz/t	.01%
RB 185	Sericite (tuff?)		10	25	6	0.8	60	5	80	3
RB 186	Sericite		6	9	5	0.3	80	27	5	4
RB 187	Sericite-tourmaline		6	35	6	0.6	150	63	30	10
RB 189	Propylitic-strong chlorite carbonate epidote		13	42	85	0.7	30	96	40	33

[1]Partially leached, black sooty oxide mineral noted.

Area	Vein Type	Vein Mineralogy Non-Sulphide	Vein Mineralogy Sulphide	Structure
Iron Cap	simple qz vein, sharp walls	qz	C-py M-tet, mg T-sph, gn, Mo, cp, specularite	350° to 020°, vertically dipping to steep to the W
Near Shore Zone	complex vein and stockwork, minor vuggy qz w. calcite infilling	qz, calcite, late? barite veins	C-py M-sph, tet, gn, electrum T-cp, argentite	140°, vertical to steep to the SE
Second Zone	stockwork of qz-sulphide veins	qz, calcite	C-py, tet, sph, gn T-cp, argentite, electrum	140°, subvertical
Third Zone	as for Second Zone			
Discovery Vein	pods of qz vein in stockwork	qz, late? barite veins	C-argentite M-electrum, py, tet, sph, gn, pyrargyrite	050°/70 NE
367 Zone	dilatant zone between faults with matrix supported breccia	vuggy quartz matrix and later qz-calcite veins	M-aspy T-gn, sph	050

First page of Table 5.3 a

West Zone	qz-sulphide stockwork, local high-sulphide vein in stockwork	qz	C-py, tet M-sph, gn, pyrargyrite, argentite, electrum	140/90
Stockwork Zone	qz-sulphide sheeted stockwork	qz, minor calcite	C-py, sph M-tet, gn T-electrum, cp, pyrargyrite?	090/-90
Galena	qz vein with halo of qz and qz-electrum stockwork	qz, minor calcite	C-py M-sph, tet T-gn, electrum, cp	090/-70S for main qz vein
Electrum	zone of weak, irregular qz veining	qz	M-py T-tet, electrum	no preferred orientation

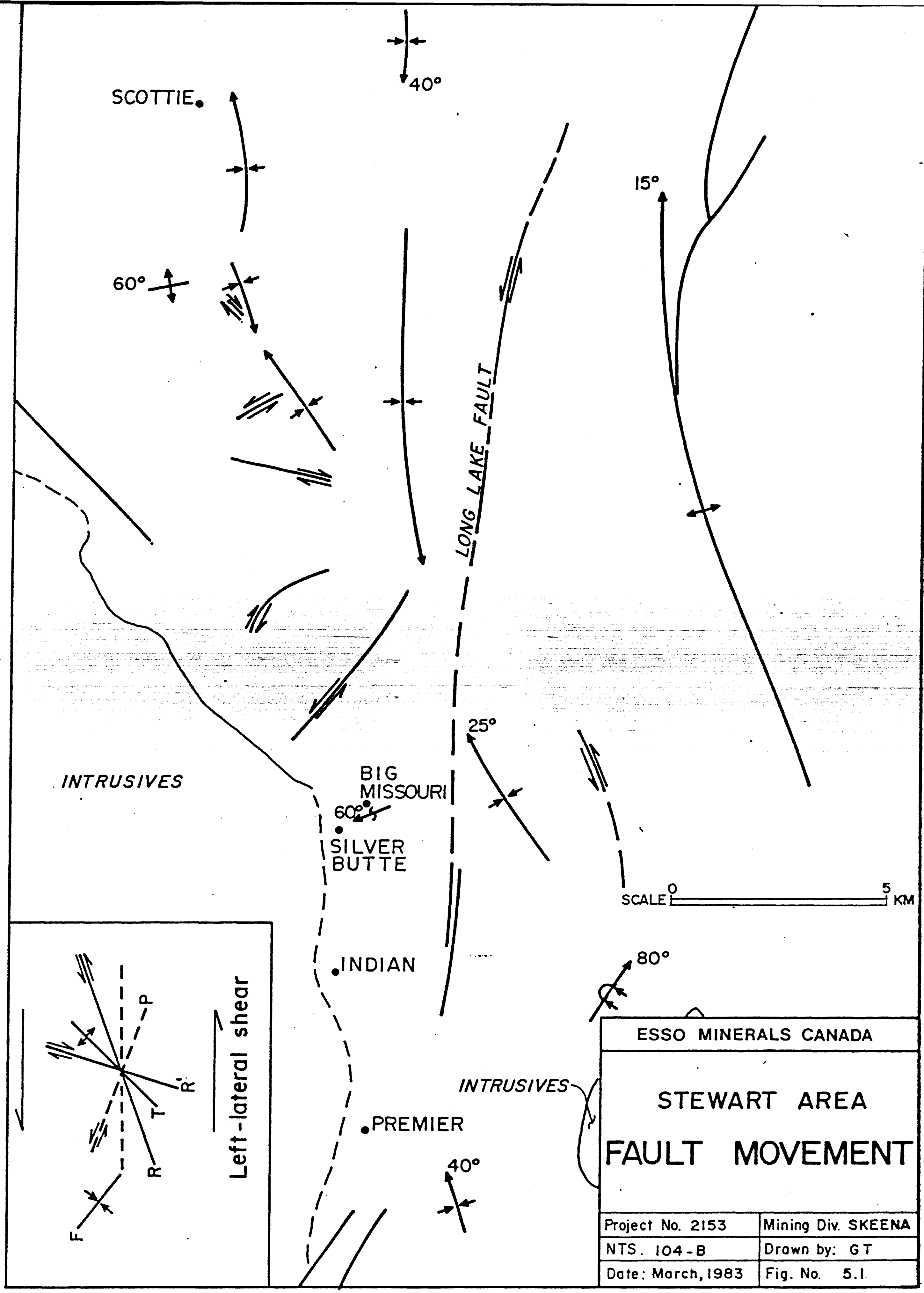
TABLE 4: Characteristics of epithermal vein zones. C = common, M = minor, T = trace. Compare with Table 2 for grade and tonnage comments.

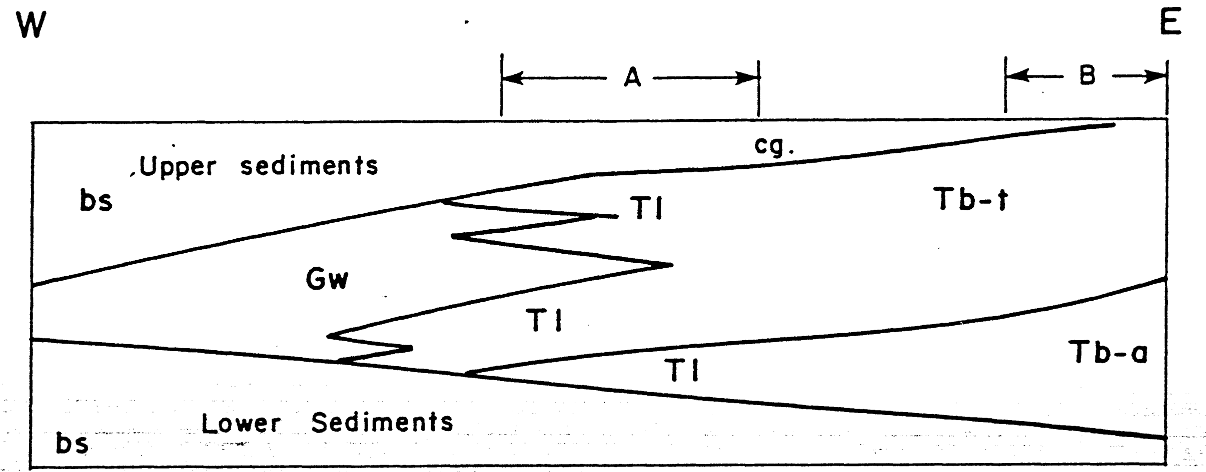
Also Table 5.3 a

Area	Type, Habit	Alteration, Intensity	Rock Type	Structure, Geometry
Kirkham	Cu diss, fract	K-feld, chl, ser, bio, mt, moderate	granite, hornfels, syenite	irregular, with pod-like intrusive masses
Mitchell	Cu diss, fract	K-feld? primary or secondary, silicification	granite, syenite, hornfels	irregular, circular?
Iron Cap	Cu, Mo diss, fract	K-feld? chl, ser, moderate	syenite, hornfels	irregular
Moly	Mo qz stockwork	ser, intense	volcanics undifferen-	consistent vein trends in roughly equidimensional qz stockworks
Gold Zone, Breccia Zone	Au and local Cu-Mo-Au diss, fract	ser, K-feld, local and rare bio, alb, widespread but rare tourmaline	syenites, undiffer-entiated volcanic and sedimentary rocks	sheet-like? gently dipping top of fine-grained syenodiorite body
Snowfield	Au diss + Mo on fract	ser, chl, rare local pyrophyllite and tourmaline	volcanics, mainly tuff-breccia	irregular

TABLE 10: Characteristics of Sulphurets porphyry-type showings. Compare with Table 1 for grades and tonnage comments.

Also Table 5.3 b


SCOTTIE
40°
60°
15°
LONG LAKE FAULT
25°
INTRUSIVES
BIG MISSOURI
60°
SILVER BUTTE
INDIAN
PREMIER
80°
40°
INTRUSIVES
SCALE 0 5 KM
Left-lateral shear
P
R'
T
R
F
ESSO MINERALS CANADA
STEWART AREA
FAULT MOVEMENT
Project No. 2153
Mining Div. SKEENA
NTS. 104-B
Drawn by: GT
Date: March, 1983
Fig. No. 5.1



cg	conglomerate	Tb-a	Tuff breccia-andesite
bs	black shale	Tb-t	Tuff breccia-trachyandesite
Gw	Greywacke	Tl	Tuff to lapilli tuff

SCALE 0 ≈1 ≈2 KM

ESSO MINERALS CANADA	
IDEALIZED ROCK TYPE RELATIONS AT THE SULPHURETS PROSPECT	
Project No. 2153	Mining Div. SKEENA
NTS. 104 - B	Drawn by: GT
Date: March, 1983	Fig. No. 5.2

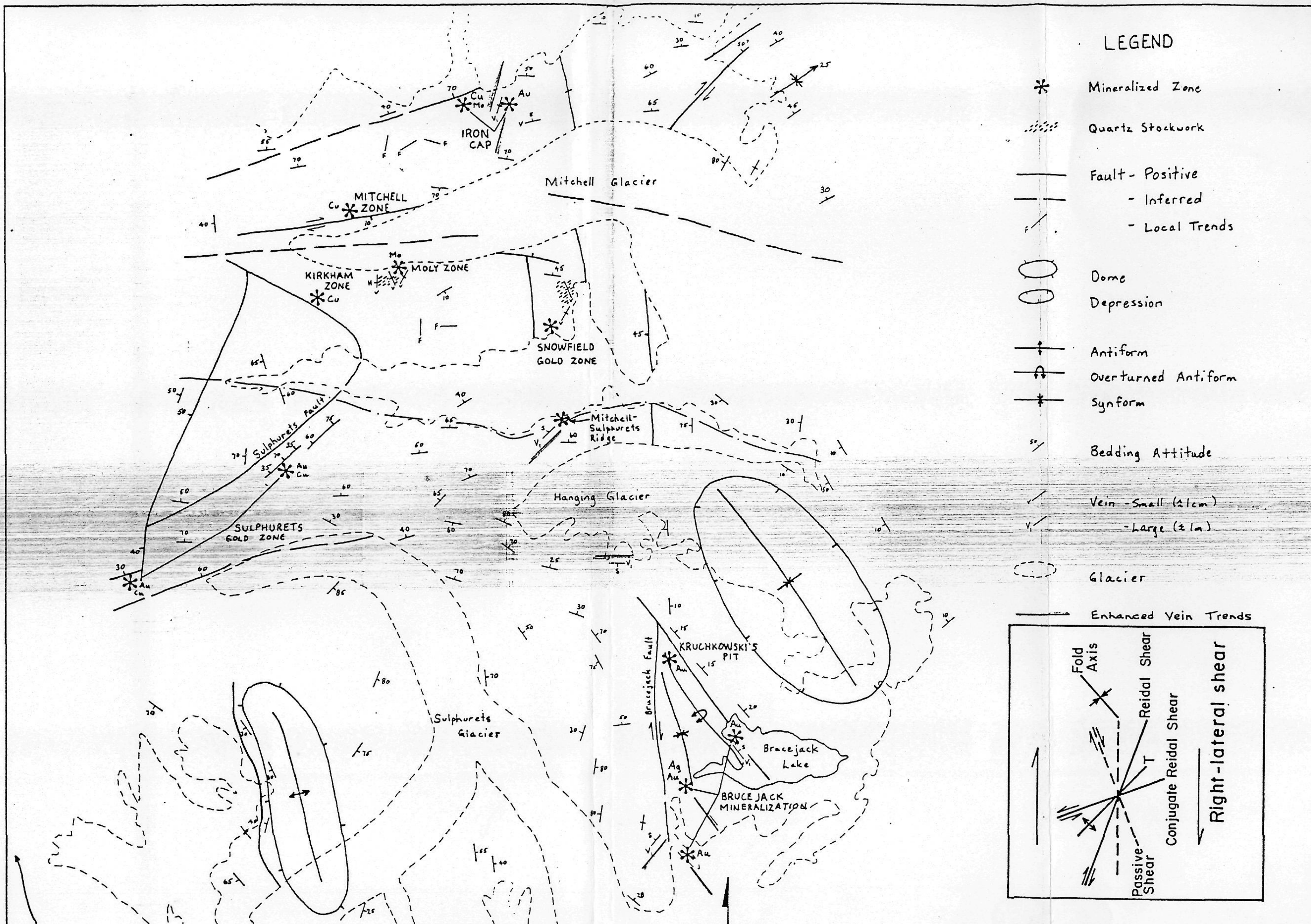


FIG 5.3 Structural features and locations of mineralized zones the Sulphurets Prospect.

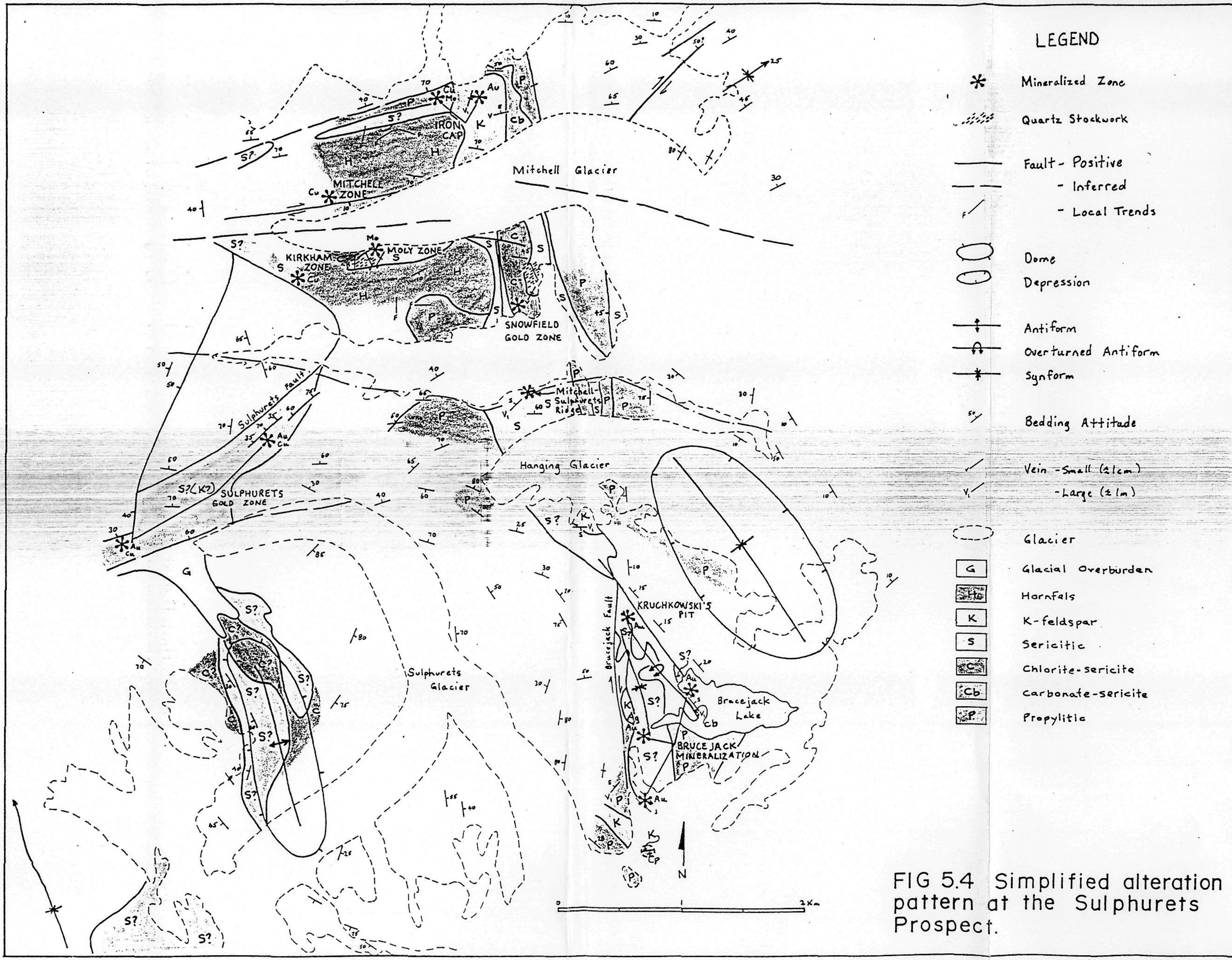


FIG 5.4 Simplified alteration pattern at the Sulphurets Prospect.

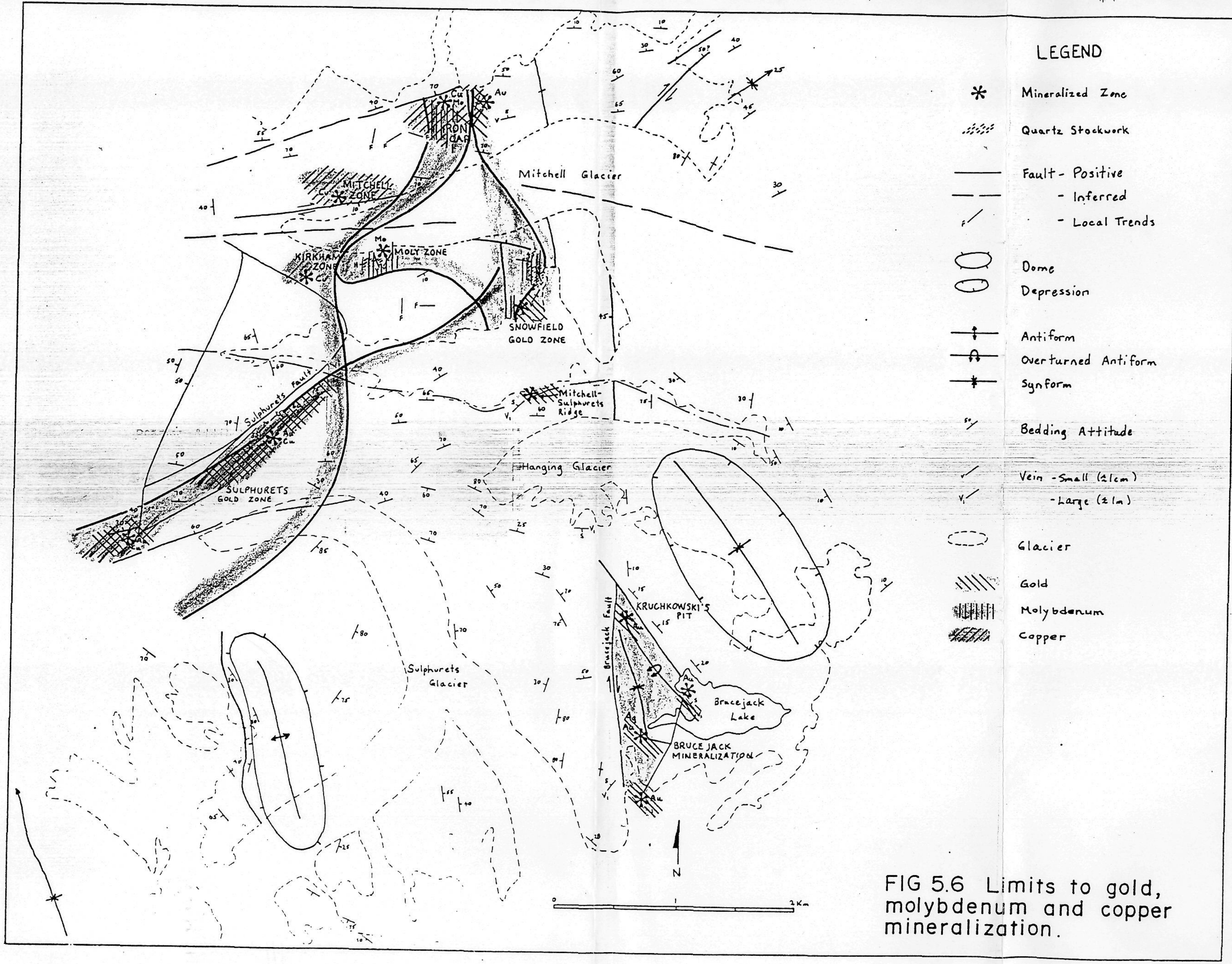
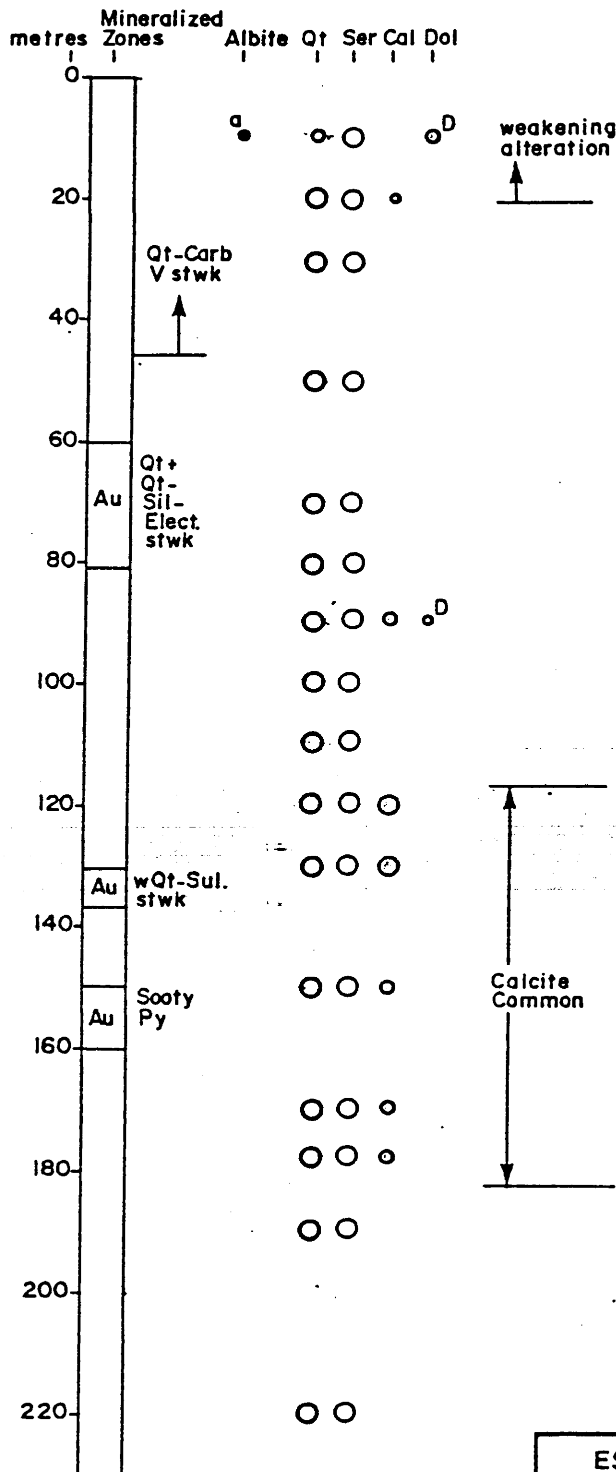


FIG 5.6 Limits to gold, molybdenum and copper mineralization.



NOTE: Qt (quartz), Ser (sericite), Cal (calcite), Dol (dolomite), Carb (carbonate), Sil (silicified), Elect (electrum), stwk (stockwork), Sul (sulphied), Py (Pyrite), ○ strong, ∘ moderate, ◦ weak.

ESSO MINERALS CANADA	
BRUCEJACK PENINSULA DIAMOND DRILL HOLE 63 XRD RESULTS	
Project No. 2153	Mining Div. SKEENA
NTS. 104-B	Drawn by: GT
Date: March, 1983	Fig. No 5.5

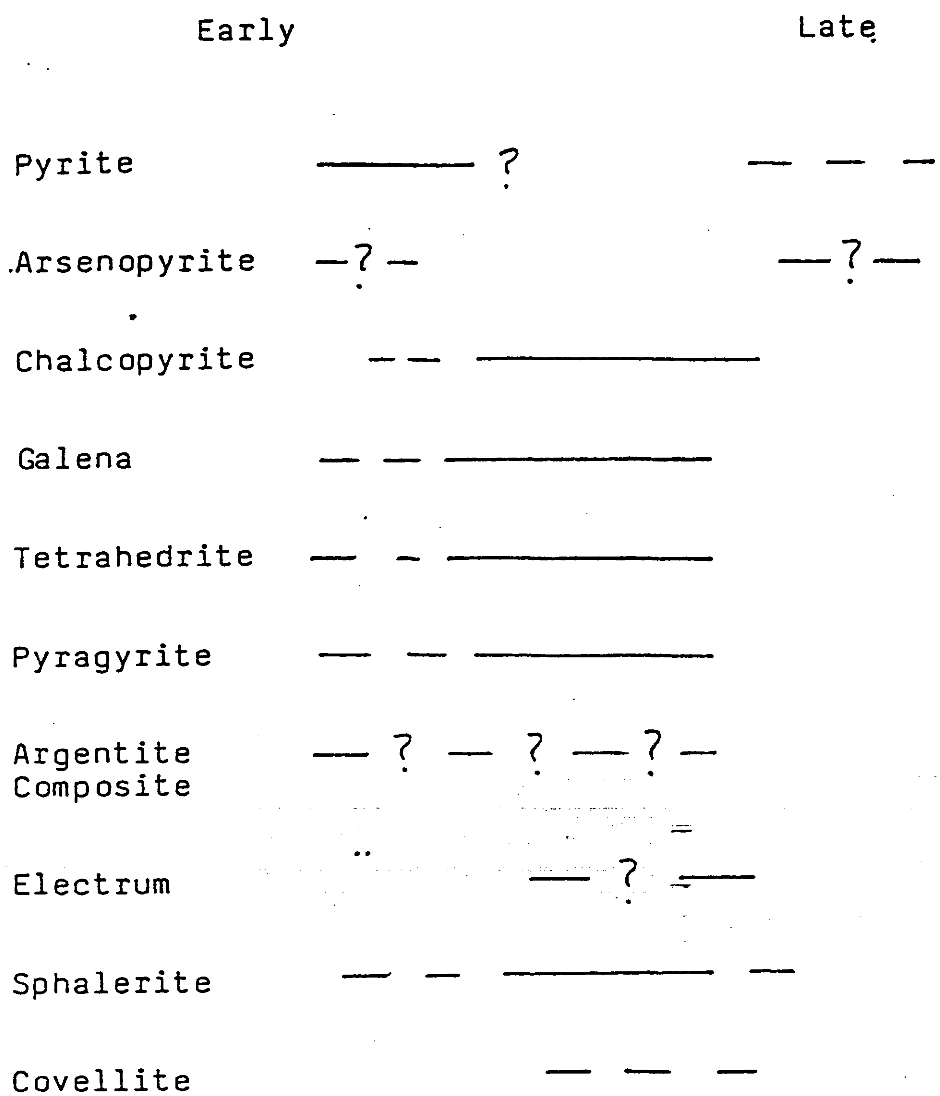
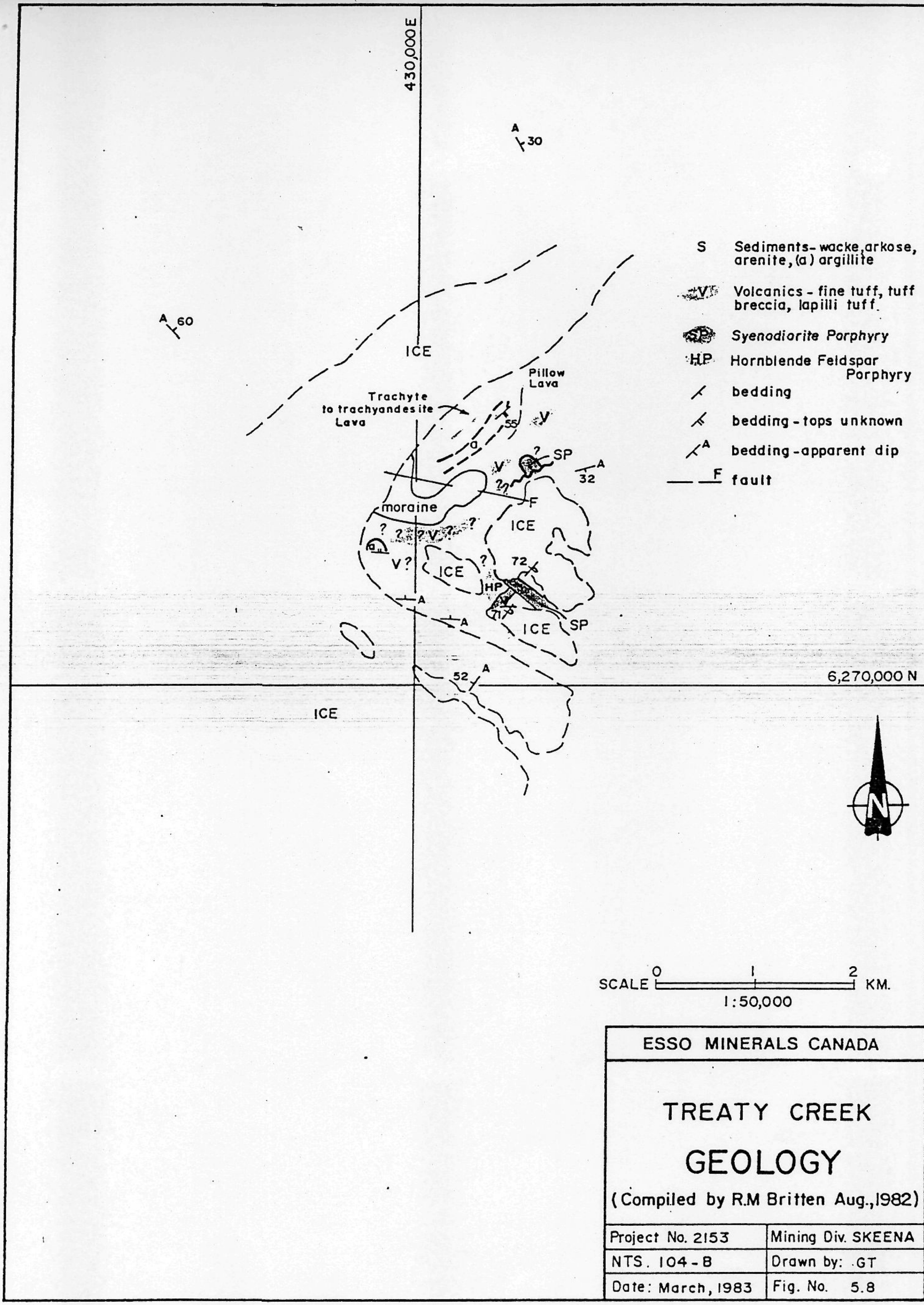


Figure 5.7 Paragenesis of opaque minerals from limited sampling in the Brucejack Lake area.



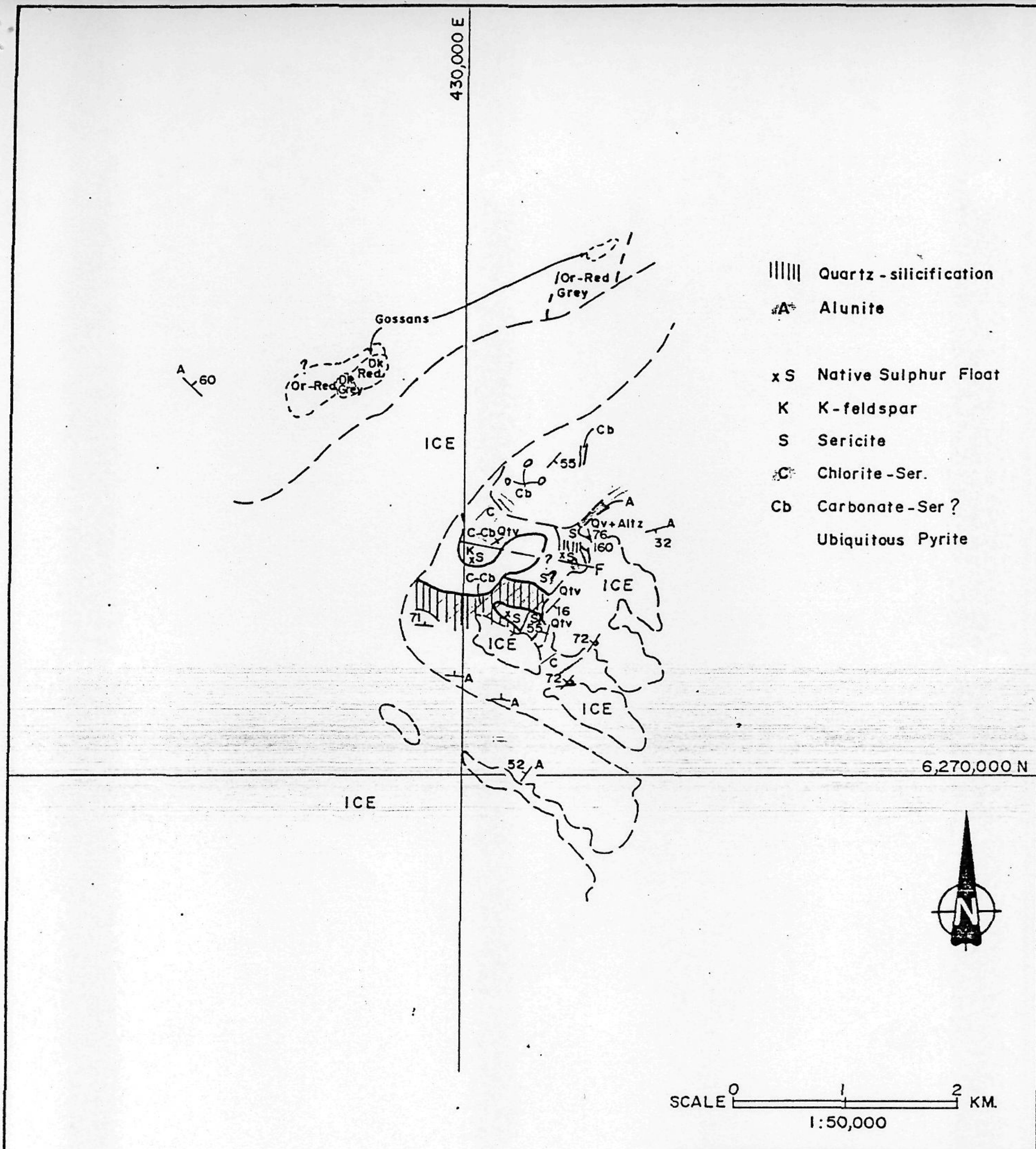
ESSO MINERALS CANADA

TREATY CREEK

GEOLOGY

(Compiled by R.M Britten Aug.,1982)

Project No. 2153	Mining Div. SKEENA
NTS. 104-B	Drawn by: GT
Date: March, 1983	Fig. No. 5.8



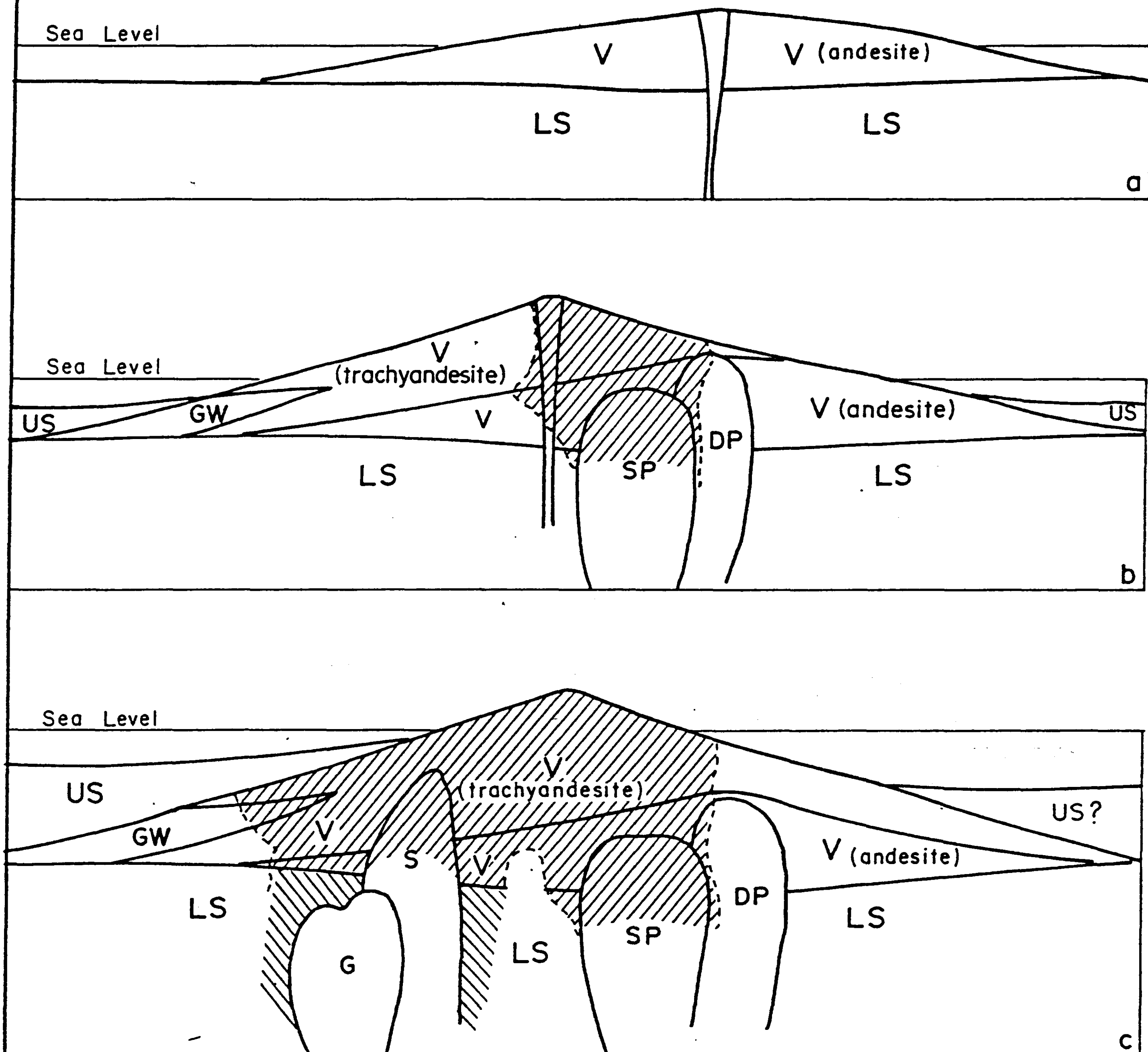
ESSO MINERALS CANADA

TREATY CREEK

ALTERATION

(Compiled by R.M. Britten Aug., 1982)

Project No. 2153	Mining Div. SKEENA
NTS. 104-R	Drawn by: G.T.
Date: March, 1983	Fig. No. 5.9



Hydrothermally Altered Zones

Hornfelsed Zones

DP (diorite porphyry), G (granite), GW (greywacke), LS (lower sediments), S (syenite), SP syeno-diorite porphyry), US (upper sediments, V (volcanics).

ESSO MINERALS CANADA	
GEOLOGICAL EVOLUTION of the SULPHURETS PROSPECT	
Project No. 2153	Mining Div. SKEENA
NTS. 104 - B	Drawn by: GT
Date: March, 1983	Fig. No. 5.10

APPENDIX 5.1

THIN AND POLISHED SECTION OBSERVATIONS

Definition of terms and columns:

1st column - an arbitrary identification number

Field No. - sample number applied in the field and generally noted on maps
D51 35.0 reads as diamond drill hole 51 sampled at 35.0 m
RB64 reads as Ron Britten's sixty-forth sample

EV # - Esso Vancouver sample number under which the thin section, polished section, rock chip etc. is stored.

Most of the remaining columns are self-explanatory except for definition of abbreviations and the column

phenocrysts not in contact
phenocrysts in point contact
phenocrysts in edge contact
crowded edge contact and interstitial grains that are .5 to 1 mm size

ABBREVIATIONS

Alb - albite
Agg - aggregate
Aln - alunite
Aniso - anisotropic
An - anhedral
And - andalusite
Anhy - anhydrite
Ap - apatite
Bio - biotite
Bn - bornite
Bx - breccia
Cal - calcite
Carb - carbonate
Cc - calcocite
C.G. - coarse-grained
Clay - clay minerals
Clvg - cleavage
Cov - covellite
Cpy - chalcopyrite
Diasp - diaspore
Diss - disseminated
Dol - dolomite
En - enargite
Ep - epidote
Eu - euhedral
Feld - feldspar
F.G. - fine-grained
Fr - fracture
Gr - grain
G.M. - groundmass
H - hardness
Hb - hornblende
Ht - hematite
Il - ilmenite
Instit - interstitial
[] - vein selvage
[()] - weak in vein selvage
- fragment
ext - parallel extinction
Luz - luzonite
K-spar - K-feldspar
M - moderate
Marc - marcasite
Mat - matrix
Min - mineral
M.G. - medium-grained
Mt - magnetite
Musc - muscovite
Part - partial
Pl - plagioclase
Poik - poikiolitic
Por - porphyry
Pseudo - pseudomorph
Py - pyrite
Px - pyroxene
Qt - quartz
Rded - rounded
Rem - remnant
R.I. - refractive index
Rut - rutile
S - strong
Sec - secondary
Ser - sericite
Sid - siderite
Sp - sphene
Su - subhedral
T - trace
Text - texture
Tf - tuff
V - vein
Vol - volcanic
W - weak
xtal - crystal
Zr - zircon

The definition of alteration strengths are based on a biotite hornblende diorite to granodiorite mineral composition and at a hand specimen or thin section scale.

*K-spar

W - Partial alteration of groundmass plagioclase sometimes accompanied by microfractures

M - complete alteration of groundmass plagioclase, partial alteration of coarser-grained plagioclase phenocrysts; clear evidence of K-spar overprint

S - substantial (20%) alteration of coarser-grained plagioclase phenocrysts - clear flooding of the unit

*NOTE: primary mineralogy of most rock types includes 5-10% interstitial K-feldspar (this may also include "so-called" diorites); alteration K-feldspar is difficult to recognize or differentiate from primary unless replacement textures are identified. Definition of flooding as secondary as opposed to primary is also uncertain in some cases.

Chlorite

W - partial alteration of biotite and/or hornblende

M - complete alteration of mafics; partial alteration of groundmass or finer-grained constituents

S - substantial alteration of other phenocryst phases in addition to complete alteration of mafics

Sericite

W - partial alteration of biotites and/or dusting through groundmass and plagioclase phenocrysts

M - partial to complte alteration of biotites; partial (50%) alteration of plagioclase

S - complete alteration of biotite and plagioclase

NOTE: Some sericites, which are of comparable grain size to finer-grained biotite (primary), may themselves be primary.

Biotite	W -	partial alteration of hornblende
	M -	complete alteration of hornblende
	S -	mafics complete altered; alteration of some groundmass and phenocryst constituents
Epidote	W -	partial (10%) alteration of mafics and/or plagioclase
	M -	partial to complete alteration of mafics or plagioclase
	S -	near complete alteration of mafics or plagioclase
Calcite	W -	incipient (25%) patches in plagioclase phenocrysts or groundmass
	M -	substantial patches (10-20%) in plagioclase phenocrysts, less common in mafics, common in veins and along grain boundaries
	S -	overall flooding of groundmass; 20% replacement of mafics or plagioclase
Quartz	W -	overgrowths on groundmass quartz grains
	M -	partial replacement of mafics
	S -	flooding of the groundmass and replacement of some phenocryst phases

*NOTE: alteration textures are difficult to recognize - especially in weakly altered zones

Clay	W -	dustings in plagioclase
	M -	10-20% replacement of plagioclase
	S -	partial (20%) to complete replacement of plagioclase

Anhydrite W - 5% in groundmass, plagioclase or mafic psuedomorphs

M - 5-20% of above replaced

S - 20% of above replaced

*Albite W - narrow sutured rims to plagioclase
rare microfractures in plagioclase

M - partial alteration of plagioclase (20% phenocrysts) with sericite and calcite

S - complete alteration of feldspars

*NOTE: difficult to accurately establish - especially M

Opaques - are generally at least an order of magnetite smaller in abundance compared to silicates

T - present

W - present to .1%

M - .1 to 1%

S - 1%

SAMPLE #EV741

S	Pyrite - coarse grained, euhedral to subhedral; anisotropic
T	Chalcopyrite - fine-grained, subhedral to anhedral
M	Galena - remnant grains
M	Sphalerite - medium to coarse grained, anhedral fillings
W-M	Pyrargyrite - anhedral grains and fillings
T	Covellite - blebs in tetrahedrite
S	Tetrahedrite - coarse grained anhedral fillings
W-M	Unknown Mixture of Composite - sphalerite - tetrahedrite-pyrite-native gold-argentite?

SAMPLE #EV742

W	Galena - fine-grained to coarse grained, blebs in pyrite to fillings
M-S	Sphalerite - coarse-grained, subhedral fillings
W-M	Chalcopyrite - fine-grained, subhedral exsolution blebs in sphalerite. Less common in pyrite.
M-S	Pyrite - coarse-grained, subhedral blebs in chalcopyrite and galena; sphalerite embayments
W-M	Tetrahedrite - fine-grained, anhedral fillings in sphalerite with covellite
W	Covellite - fracture filling in sphalerite

NB Classic exsolution texture of chalcopyrite in sphalerite.

SAMPLE #EV745A

M Pyrite - euhedral grains

M Tetrahedrite - fine to medium grained fillings

W-M Argentite composite? - hardness tetrahedrite, medium grained filling. Very fine grained pyrite (?) grains or aggregates. Atoll-like, hackly appearance which is probably due to polishing - could be Gold!

W-M Galena - fine to medium grained filling

W Covellite - fine-grained, replacing tin

T-W Gold-silver? and grey (dark inner and light outer) mineral - mantle galena at covellite and galena replacement inter-face; hackly texture; plumose replacement texture

SAMPLE #EV745B

W-M	Sphalerite - fine to medium grained fillings
W	Galena - fine-grained, associated with sphalerite
W	Tetrahedrite - fine to medium grained fillings disseminated, fine grained, atoll-like pyrite?
W	Argentite composite - medium grained aggregate with galena, tetrahedrite, covellite. Anistropic.
T	Chalcopyrite - blebs in pyrite
T	Covellite - very fine grained aggregate with enstatie aggregate
M	Pyrite - Poikiolitic with sphalerite, enstatile, tetrahedrite, chalcopyrite

SAMPLE #EV747

M	Pyrite - medium grained euhedral. Poikiolitic with galena and chalcopyrite
W	Galena - fine to medium grained fillings
W	Chalcopyrite - fine to medium grained fillings; exsolution in pyrite (?) and sphalerite
S	Sphalerite - fine to coarse grined fillings Embays pyrite and galena phenocrysts

SAMPLE #EV748

M	Pyrite - medium to coarse grained. Subhedral to embayed crystals - fine grained aggregate
W	Galena - fine to medium grained fillings; fine grained exsolution blebs in pyrite
W-T	Chalcopyrite - fine grained fillings and exsolution blebs in pyrite and sphalerite
S	Sphalerite - coarse grained fillings; embays galena

SAMPLE #EV750

Pyrite -	medium grained, subhedral crystalline aggregates
Chalcopyrite -	exsólution in pyrite - very fine grained
Galena -	fine to medium grained anhedral fillings, fracture in pyrite with chalcopyrite
Tetrahedrite -	fine to medium grained with galena. Embayed by sphalerite
Sphalerite -	fillings

SAMPLE #EV751

Pyrite -	Chalcopyrite and galena exsolution
Galena -	fine to medium grained filling
Tetrahedrite -	fine to medium grained filling
Chalcopyrite -	very fine grained exsolution, also some free grains
?	- Isotropic, dull brown color, less than 30% reflectance, hardness less than pyrite, greater than chalcopyrite
Sphalerite -	Chalcopyrite and galena exsolution or inclusions

SAMPLE #EV752

M-S	Pyrite - medium grained, subhedral to irregular. Poikiolitic with galena, chalcopyrite, and sphalerite	
W	Galena - fine grained anhedral fillings	
W	Pyrite aggregate - fine grained with galena	
T	Chalcopyrite - fine grained	
S	Sphalerite - fine to medium grained irregular fillings	

SAMPLE #EV753

Pyrite	- replace hot or fragments. Fine grained, subhedral, poikiolitic - in vein. Subhedral or anhedral, partially resorbed by sphalerite replacement. Poikiolitic
Galena	- fine grained irregular fillings; in pyrite
Tetrahedrite	- fine grained irregular, commonly elongate fillings
Pyrite aggregate	- fine grained irregular, commonly elongate fillings
Sphalerite -	fine to medium grained fillings
Gold -	fine grained sub-angular grains

SAMPLE #EV754

M-S	Pyrite - euhedral to subhedral medium grained; anistropic
M-S	Pyrite aggregate - fine to medium grained fillings, replacing sphalerite
W	Galena - commonly rounded or irregular fragments
W-M	Tetrahedrite - fine to medium grained filling
M	Sphalerite - fine to medium grained filling

APPENDIX 5.2

X-RAY DIFFRACTION WORK

X-ray diffraction work on sixty-nine samples was carried out at the research laboratory of Esso Resources Canada Ltd. in Calgary. Under the tutaledge of Ron Dean, the samples were run on a Rigaku Rotoflex unit outfitted with a Gunier-De Wolf, 4 sample FR502 powder camera. Films were exposed to CuK_x radiation for about 10 minutes; running conditions were 50 kV and 20 mA using 0.5 and 1.0 degree slits.

Results are presented in the following tables. Major points noted include:

1. Monoclinic K-feldspar was identified in all samples that recorded a significant Na-cobaltinitrate stain.
2. Sericite are all well-crystallized $2M_1$ polymorphs, except for one sample from Treaty Creek which appears to be both $2M_1$ and $1M_1$.
3. Chlorite is normally iron-rich although rare iron-poor (30% Fe) does occur.
4. Carbonates are dominated by calcite, dolomite is rare; siderite and ankerite are not present in any samples.
5. Jarosite (largely supergene), alunite, and pyrophyllite are less common constituents.
6. Kaolinite, dickite, and mixed layer clays are conspicuous by their absence although samples likely to carry montmorillonites were not selected for X-ray diffraction work.