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SILVER-GOLD VEIN MINERALIZATION, WEST ZONE, BRUCEJACK LAKE, NORTHWESTERN BRITISH COLUMBIA (104B/8E)

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INTRODUCTION

The West zone is one of over 20 mineralized zones and showings on the Sulphurets property (Newhawk Gold Mines Limited, 60%; Granduc Mines Limited, 40%), located 65 kilometres north of Stewart, British Columbia (Figures 6-2-1). Intial fieldwork was completed by the senior author in 1989 (Roach, 1990), comprising grid mapping of lithologies and alteration assemblages in the West Zone and the recording of structural data (attitudes of veins and principal fabrics). In 1991, the co-author extended mapping to include traverses in the Brucejack Lake area in a 2-kilometre radius around the West zone. In addition, 14 diamond-drill holes on a section through the centre of the West zone were studied and sampled extensively in 1991. This report discusses the geology and structure observed at surface in the West zone. Further objectives of the study are to define:

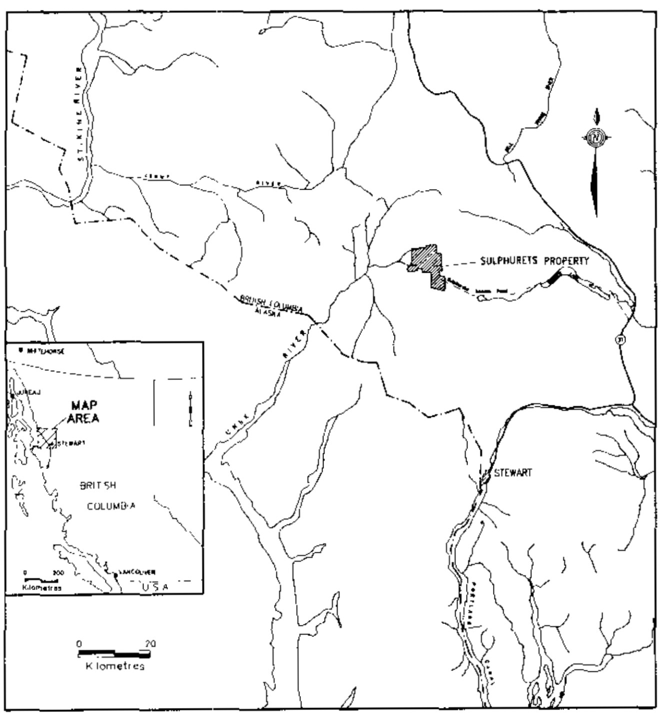

Figure 6-2-1. Location map, Stewart-Iskut River district, northwestern British Columbia.

- Lithostratigraphic relationships between hostrocks to precious metal vein mineralization.
- Alteration mineralogy and chemistry around mineralized zones.
- Hypogene mineralogy of the vein systems in the Brucejack Lake area.
- An examination of vein material to assess applicability for fluid inclusion studies.

HISTORY OF THE SULPHURETS PROPERTY

The Sulphurets property covers approximately 85 square kimometres (Figure 6-2-2). A small fractional claim (500 by 20 m), located 5 kilometres north of the West zone, is owned by a third party. Exploration for placer gold in the Unuk River valley and subsidiary valleys such as that occupied by Sulphurets Creek, was first recorded in the 1880s, although there are no production data. In 1935, prospectors located copper mineralization in the area now referred to as the Main Copper zone (Figure 6-2-2). Prospecting in the Brucejack Lake area continued intermittently until 1959, when gold and silver mineralization was first reported. In 1960, Granduc Mines Ltd. staked most of the area comprising the current property and began an exploration program for porphyry copper mineralization, employing airborne and ground geophysics in addition to reconnaissance geology; as a result copper mineralization was discovered on the ridge between the Mitchell and Sulphurets glaciers and gold and silver mineralization at the base of the Iron Cap area (Bridge *et al.*, 1981). Exploration continued sporadically on the property from 1961 to 1974, with the focus on diamond drilling of anomalies identified by geophysical and geochemical prospecting techniques. During the period 1961-1963 R.V. Kirkham completed an M.Sc. thesis comprising geological mapping of the bulk of the property (Kirkham, 1963). The Brucejack Lake area was prospected in 1975. Relatively little exploration activity occurred at Sulphurets until 1980, when Esso Minerals Ltd. optioned the property from Granduc, conducted detailed and reconnaissance geological mapping and geochemical sampling throughout the property, and diamond drilling, which focused principally on the West and Shore zones (Figure 6-2-2). In 1985, Newhawk Gold Mines Ltd and Lacana Mining Corporation optioned the property from Granduc and continued with intensive exploration on the West zone, driving an exploration decline to the 1150-metre level, approximately 250 metres below surface (Roach, 1990) providing access for extensive underground diamond drilling and reserve delineation.

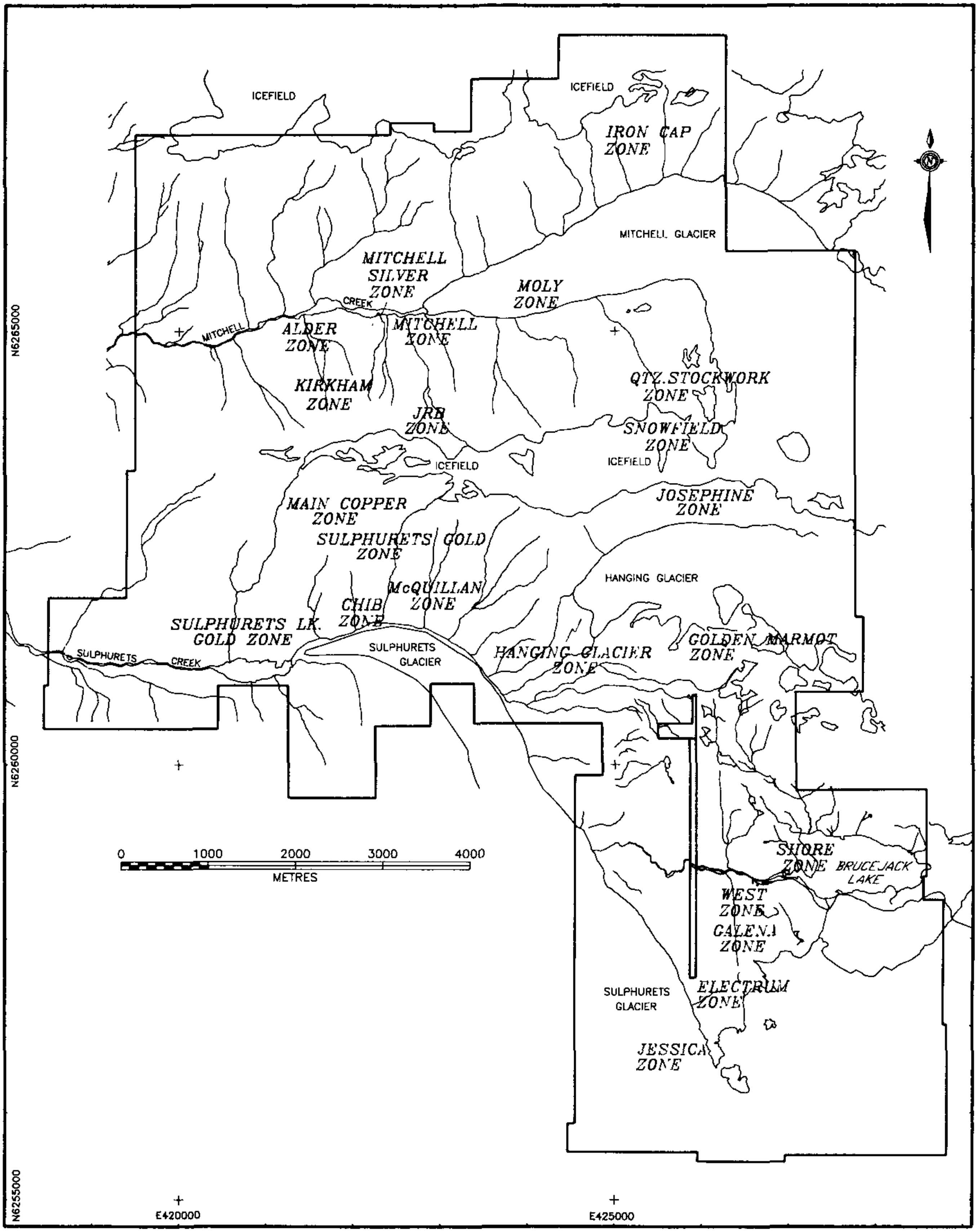

Figure 6-2-2. Sulphurets property, with location of mineralized zones.

In 1989, Newhawk commissioned an independent report of *in situ* ore reserves by Watts, Griffis and McOuat, Consulting Geologists and Engineers of Toronto. Using a cut-off grade of 0.2 ounces per ton (approximately 6.9 g/t Au) and a minimum true width of 5 feet (approximately 1.5 metres), proven and probable reserves were announced (Newhawk Gold Mines, Press Release, February 6, 1990) as 715 400 tons (approximately 650000 tonnes) at a gold grade of 0.431 ounces per ton (14.8 g/t) and a silver grade of 19.7 ounces per ton (675 g/t). Based upon the ore reserve, International Corona Corporation, which holds a 42 per cent interest in Newhawk, conducted a feasibility study for the West zone, concluding that the project was uneconomic under existing conditions (Newhawk Gold Mines, Press Release, October 25, 1990). The decline was allowed to flood in 1990.

REGIONAL GEOLOGY

LITHOSTRATIGRAPHY

The Sulphurets property and surrounding area is within the Stikine Terrane (Wheeler and McFeely, 1987) and is underlain by Upper Triassic and Lower to Middle Jurassic Hazleton Group volcanic, volcaniclastic and sedimentary rocks (Grove, 1986). The lithostratigraphic assemblage in the Sulphurets area has been described by Kirkham (1963), Britton and Alldrick (1988), Alldrick and Britton (1991) and Kirkham *et al.* (in preparation), and comprises a package, from oldest to youngest, of alternating siltstones and conglomerates (lower Unuk River Formation, Norian to Hettangian); alternating intermediate volcanic rocks and siltstones (upper Unuk River Formation, Hettangian to Pliensbachian); alternating conglomerates, sandstones, intermediate and mafic volcanic rocks (Betty Creek Formation, Pliensbachian to Toarcian); felsic pyroclastic rocks and flows, including tuffaceous rocks ranging from dust tuff to tuff breccias and localized welded ash tuffs (Mount Dilworth Formation, Toarcian); and, finally, alternating siltstones and sandstones (Salmon River and Bowser formations, Toarcian to Bajocian). Britton and Alldrick (1988) also describe at least three intrusive episodes in the area: intermediate to felsic plutons that are probably coeval with volcanic and volcaniclastic supracrustal rocks; small stocks related to the Cretaceous Coast Plutonic Complex; minor Tertiary dikes and sills. Regional geological mapping (*e.g.* Britton and Alldrick, 1988; Anderson, 1989) has demonstrated the continuity of lithologies and formations from well-constrained areas, such as the Stewart mining camp to the south (*e.g.* Alldrick *et al.*, 1987) to the Sulphurets area. In the immediate Sulphurets area, however, age constraints are poor at present, although considerable work in progress is addressing this problem, for example, by using high-precision U-Pb and K-Ar geochronometry.

Researchers include Anderson, Kirkham and Bevier (Geological Survey of Canada), Alldrick, Britton and coworkers (British Columbia Geological Survey), Bridge (M.A.Sc. candidate, The University of British Columbia), Margolis (Ph.D. candidate, University of Oregon), and the authors of this study. In addition, Smith and Nadaraju of The University of British Columbia are conducting paleontological studies in the area. It is anticipated that a more tightly constrained framework for the relative and absolute ages of rocks in the Sulphurets area will be forthcoming in the near future.

STRUCTURE

Britton and Alldrick (1988) and Kirkham *et al.* (in preparation) have described the regional structural geology; in brief, the Hazleton Group lithologies display fold styles ranging from gently warped (*e.g.*, a mapped synform to the south and east of Brucejack Lake, Alldrick and Britton, 1988) to tight disharmonic folds in the Salmon River and Bowser formations. Synvolcanic, synsedimentary and synintrusive faults are suspected but are yet to be documented fully (Kirkham *et al.*, in preparation); Britton and Alldrick (1988), however, describe a syndepositional fault to the northeast of the Sulphurets property. Northerly striking, steep normal faults are recognised (*e.g* Britton and Alldrick, 1988), although certain prominent northerly striking lineaments, such as the Brucejack lineament (Kirkham, 1963, 1991), immediately west of the West zone, display evidence for little, if any, motion, at least in the Brucejack Lake area. Kirkham *et al.* (in preparation) note that elsewhere along this linear, hydrothermal alteration zones are truncated. Minor thrust faults, dipping westerly, are common in the region and are important in the northern and western parts of the Sulphurets property in regard to interpretation of mineralized zones. Ongoing research by the Geological Survey of Canada and by Peter Lewis of the Mineral Deposit Research Unit at The University of British Columbia will add significantly to the near-term structural understanding of the area.

During the 1991 field season, an intermediate to felsic flow-dome complex has been defined at the southeast corner of Brucejack Lake, first identified, apparently, by G. Albino and J. Margolis (International Corona Corporation; personal communication, 1990). The rock is flow banded, locally flow folded and intrudes heterogeneous, bedded to massive pyroclastic rocks, locally red, maroon or green coloured, and locally potassium feldspar and plagioclase-hornblende-porphyritic flows, ascribed to the upper Unuk River and Betty Creek formations by Alldrick and Britton (1988). The flow-banded unit has gradational contacts with a voluminous breccia unit, comprising clasts of identical composition to the intrusive phase, in a hematitic, muddy and locally finely laminated matrix. The morphology and geometry of the breccias suggests conformity with enclosing flow rocks, including potassium feldspar and plagioclase-hornblende-phyric flows; the breccias are interpreted as volcanic ejecta, cemented by subaqueous, iron-rich pelitic material. Higher in the section to the south of Brucejack Lake, the flow-banded intermediate to felsic unit rests in apparent stratigraphic contact upon marooon, blocky tuff. These field relationships indicate that the flow-banded unit passes up-section from intrusive at depth, to complex interdigitations with related ejecta at intermediate levels, to extrusive at the highest observed level.

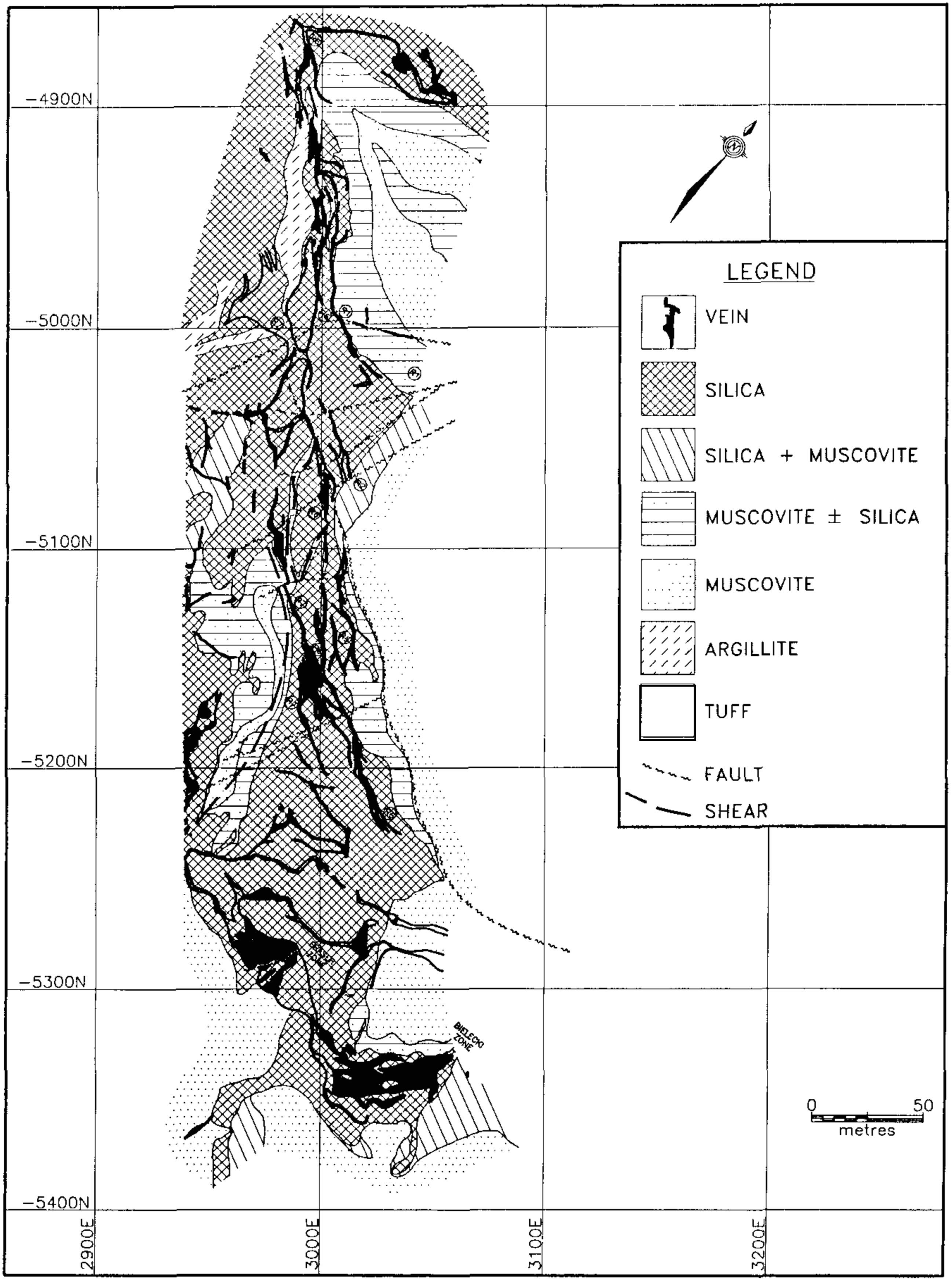

Figure 6-2-3. Map of the West zone (modified from Roach, 1990), showing distribution of mineralized and hydrothermally altered zones.

GEOLOGY OF THE WEST ZONE

Rocks underlying the West zone are considered by Britton and Alldrick (1988), and Alldrick and Britton (1988) to be confined to the Unuk River Formation and consist of a band of generally northwesterly-trending volcanic and sedimentary rocks 400 to 500 metres wide, sandwiched between two plagioclase and hornblende-phyric intrusive bodies (Kirkham, 1991). The hostrocks are dominantly intermediate volcanic (pyroclastic) rocks to the northeast of the zone, and intermediate volcaniclastic rocks and minor argillaceous rocks to the southwest (Roach, 1990; Figure 6-2-3). Geological relationships and original characteristics of the host lithologies are obscured in the vicinity of the mineralized rocks, as a result of intense hydrothermal alteration and the development of penetrative fabric(s).

In the immediate vicinity of the West zone, intermediate tuffs and tuff breccias have been strongly silicified and (?) potassium feldspar altered, brecciated and fractured, with subsequent silica influx into the zones of brecciation and fracturing, resulting in vein and stockwork zones containing up to 20 per cent quartz, over widths to 35 metres on surface (Figure 6-2-3). Roach (1990) has identified a well-developed zonation of hypogene alteration about the mineralized zone, up to 100 metres wide at surface. From the core of the West zone to its mappable outer margins, the alteration assemblages, with the first mineral listed being dominant, are:

1. Quartz±sericite±carbonate
2. Sericite±quartz±carbonate
3. Chlorite±sericite±carbonate
4. Clay

In addition, diamond-drill core reveals the presence of considerable potassium feldspar and at least two carbonate species. Few petrographic and mineralogic data on the alteration mineralogy are currently available, and are a focus of on-going work.

WEST ZONE MINERALIZATION

The West zone comprises at least ten quartz vein and veinlet shoots (Figures 6-2-3 and 4), named R1, R2, R4, R5, R6, R7, R8, UTC, Bielecki and Eraser; the nearby Old Yeller zone is approximately 150 metres to the south-southeast. Some shoots do not outcrop and are known only from underground development and exploration (Figure 6-2-4). Description in this paper is restricted to geological relationships exposed on surface and in diamond-drill core. The R6 shoot is the most extensive within the West zone, exposed along a strike length of 250 metres, and ranges in thickness from 0.3 to 6 metres. Ore shoots tend to have greater down-plunge extent (to the northeast) than in the strike dimension (Kirkham *et al.*, in preparation); the structural geology of various elements of the West zone is described in the next section. With the exception of R7, the other shoots with prefix R are structures that splay off R6; these relationships are amplified later in this paper.

Gangue mineralogy in the veins is dominated by quartz, with accessory potassium feldspar, albite and sericite, and minor carbonate (at least two varieties noted in core: white calcite and an orange, calcium-magnesium carbonate, probably kutnohorite; R.H. Sillitoe, personal communication, 1991), barite, apatite and rutile (Harris, 1989). Sulphides in the veins include, in decreasing order of abundance, pyrite, sphalerite, chalcopyrite and galena; silver is present as tetrahedrite, pyrargyrite, polybasite, electrum and native silver, with rare stephanite and acanthite; native gold has been described, although electrum is the principal auriferous phase (Harris, 1989; Kirkham *et al.*, in preparation). At least six vein and veinlet assemblages have been documented macroscopically in this study based upon crosscutting relationships observed in diamond-drill core; from earliest to latest, they are:

1. Potassium feldspar and quartz microveinlets (1 mm in width)
2. Quartz-carbonate veins and veinlets – generation (i)
3. Pyrite-sphalerite-galena veinlets
4. Quartz-carbonate veins and veinlets – generation (ii)
5. Quartz (alone) veins and veinlets – generation (i)
6. Quartz (alone) veins and veinlets – generation (ii)

This preliminary paragenesis is to be confirmed by petrography and will form the basis for a study of the applicability of the West zone material for microthermometric analysis of fluid inclusions. Petrography and lithogeochemistry will also be used to characterize the hypogene alteration related to West zone mineralization.

STRUCTURE OF WEST ZONE AREA

The West zone has an overall southeasterly strike, approximately 140°, although internal structural elements such as veins, veinlet arrays and associated penetrative fabric(s) are complex and variable (Figures 6-2-3 and 4). Most of the structural data presented in this paper were collected predominantly by the senior author in 1989, during a surface mapping program conducted by Newhawk Gold Mines (Roach, 1990); additional data, collected by the co-author in 1991, are also included. The dominant fabric in the rocks at some distance (100 m) from the West zone dips steeply and strikes to the south-southeast (160°; Figure 6-2-5). Approaching the West zone, the fabric is rotated to between 110° and 130°, throughout a zone approximately 130 metres wide, that correlates spatially with the most altered and highly strained hostrocks. The sense of rotation suggests sinistral shear in the West zone, based upon typical geometries of structural elements in a shear zone (e.g., Tchalenko, 1970). These relationships are, however, complicated by development of a northeasterly (30° to 70°) fabric over a zone 40 metres wide to the northeast of the high-strain rocks (Figure 6-2-5).

The majority of veins observed on surface dip steeply to the northeast and strike approximately parallel to the trend of the zone (*i.e.*, 140°), although locally exhibiting sygmoidal terminations (Figures 6-2-4 and 5). Veins of this geometry are "central shear veins" and "oblique shear veins", using the terminology of Hodgson (1989a, b). Subsidiary, second-order veins branch off the principal veins, and strike between 100° and 130°; again, this vein geometry supports a

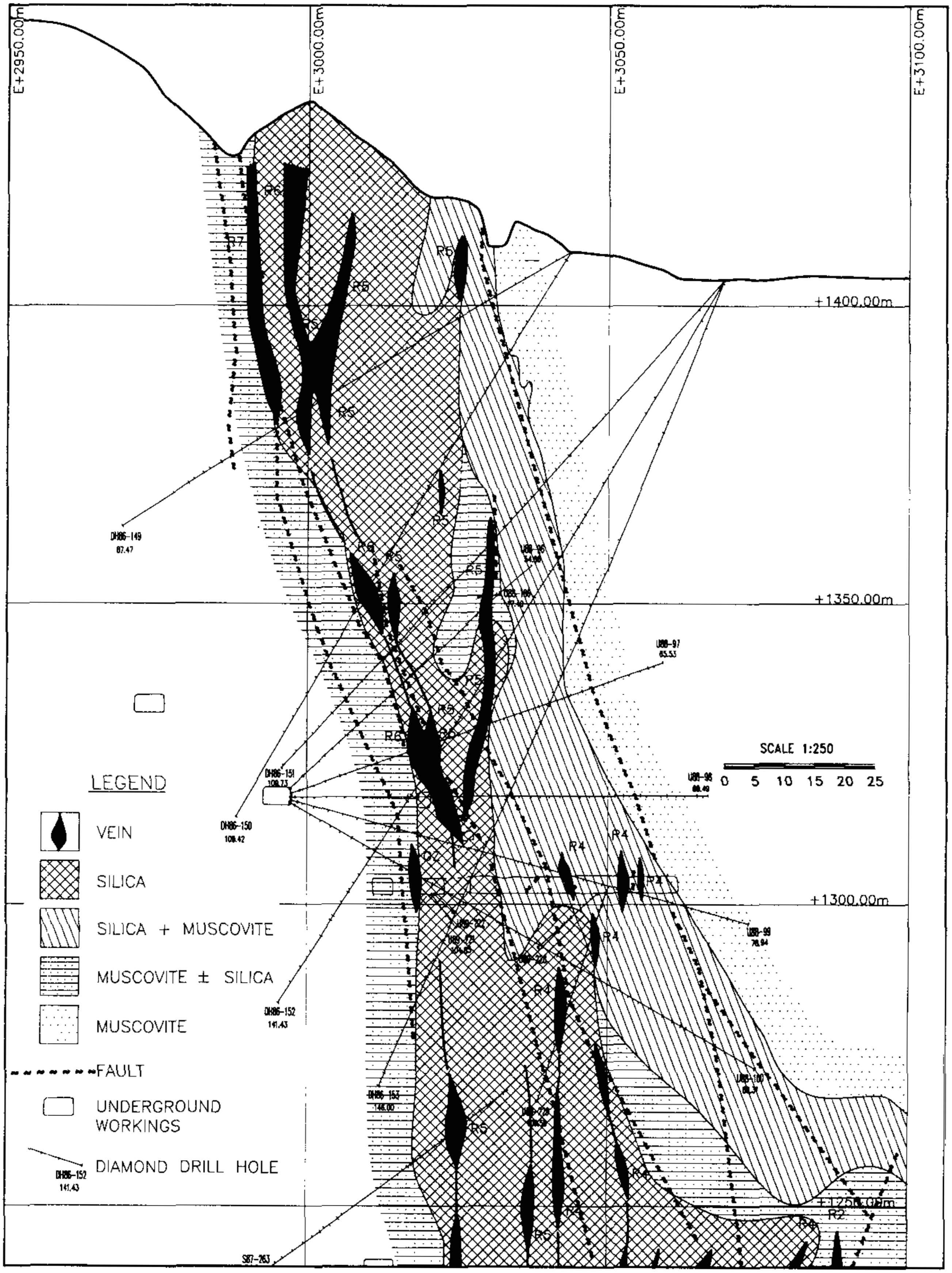

Figure 6-2-4. Cross-section 51+00 S, West zone.

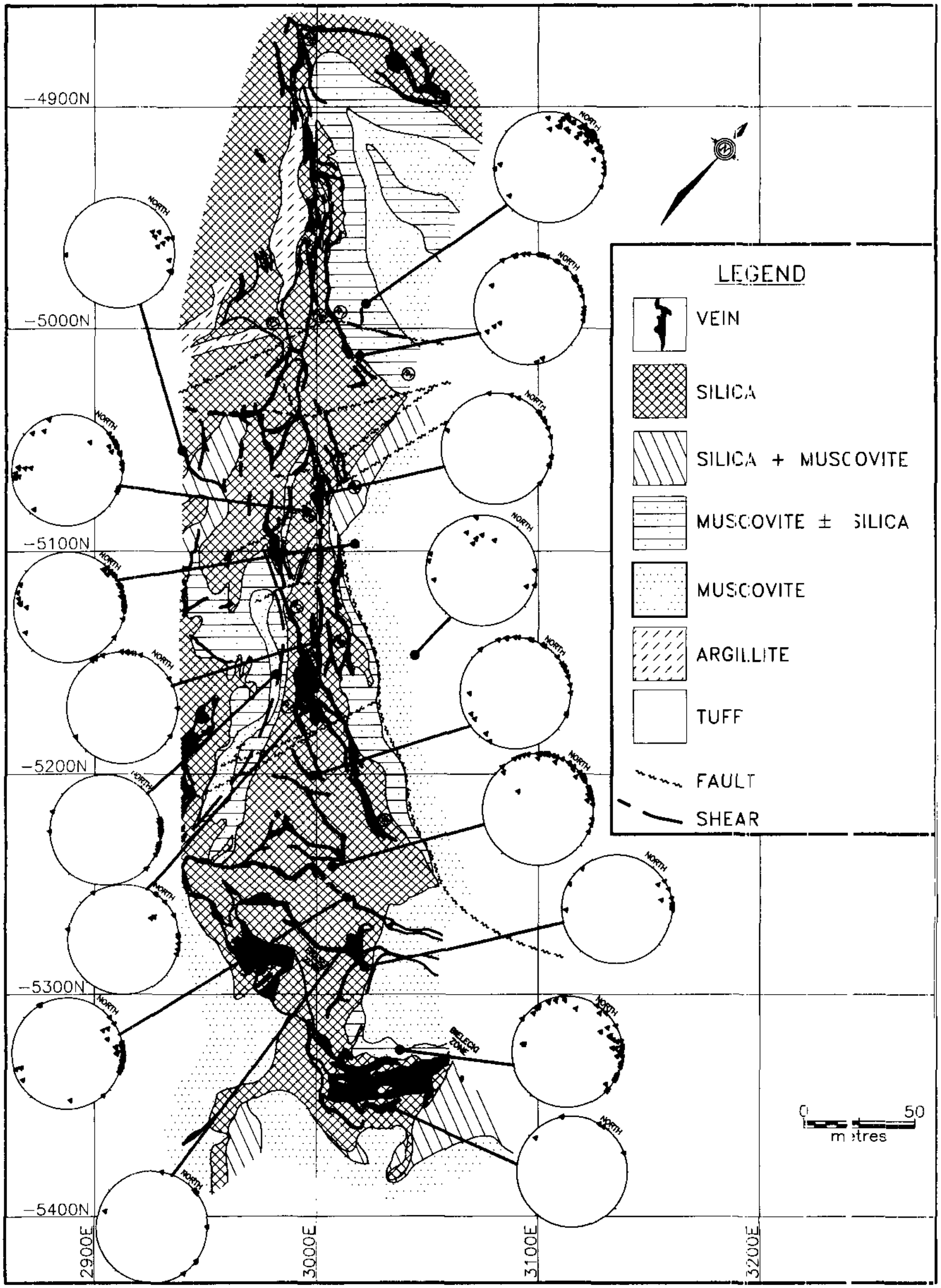

Figure 6-2-5. Lower hemisphere projections of poles to structural elements within and adjacent to the West Zone.

sense of sinistral shear. In addition, a few veins follow northeast structures, oblique to the general trend, and dip steeply to the southeast and northwest (note that attitudes at depth differ from those at surface – the vein system tends to steepen and dip to the southwest; B. Way, Newhawk Gold Mines Ltd., personal communication, 1991). Individual veins and composite vein sets exposed on surface in the West zone exhibit evidence of crack-seal fill with slivers of altered wallrock included within veins; and also vein fill in an extensional environment, subjected to contemporaneous folding and localized brecciation during crystallization of gangue minerals, for example quartz and carbonate (Roach, 1990; Kirkham *et al.*, in preparation; and this study); observed features at surface include (from apparently least strained to most strained): vug fills of quartz with unbroken crystal terminations; vug fills in small-scale (5–10 cm wavelength) folds; extension gash veins; second-order central or oblique veins; sigmoidal central or oblique veins, locally conjugate arrays of sigmoidal veins and veinlets. These geometric relationships between veins are observed on several scales – from hand-specimen to map scale (note, for example, the sigmoidal, enechelon and branching vein geometries in Figures 6-2-3, 6-2-4), and are consistent with fluid influx (and hydrothermal alteration) during predominantly ductile deformation, interrupted periodically by brittle failure in response to a fluctuating fluid pressure (*e.g.*, Sibson *et al.*, 1975).

SUMMARY

Vein-hosted, gold-silver mineralization in the West zone at Brucejack Lake, is contained within a zone of intensely altered and strained volcanic and volcaniclastic rocks. Alteration is zoned about the mineralized veins and veinlet arrays, from a central silicified zone, passing outwards to sericite, to chlorite and finally to clay; accessory sericite and carbonate are found throughout each alteration facies. The geometry of structural elements observed on surface in the West zone described here is compatible with high strain zones, as synthesized by, for example, Hodgson (1989b).

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This paper is dedicated to the memory of Phil Malone.

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NOTES