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VINE - A MIDDLE PROTEROZOIC MASSIVE SULPHIDE VEIN, PURCELL SUPERGROUP, SOUTHEASTERN BRITISH COLUMBIA (82G/5W)

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(Contribution No. 20, Sullivan-Aldridge Project)

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INTRODUCTION

The Vine prospect is a steeply dipping, massive pyrrhotite base and precious metal vein deposit that cuts across gently dipping lower and middle Aldridge siltstones and wackes in the Purcell anticlinorium in southeastern British Columbia. It is owned 90% by Consolidated Ramrod Gold Corporation and 10% by Cominco Ltd.

The deposit is located in the Peavine Creek valley approximately 3 kilometres north of Moyie Lake and 11 kilometres south of Cranbrook (Figure 1). It is readily accessible via a 4.5-kilometre gravel road, the Hidden Valley road, that leaves Highway 3a just east of the Moyie River bridge at the Moyie Lake Provincial Park. The St. Eugene silver vein, worked extensively in the early 1900s, is located on the east shore of Moyie Lake, approximately 12 kilometres farther south.

The initial discovery of the Vine deposit in 1976, by D. Pighin while working for Cominco Ltd., consisted of a number of massive sulphide boulders scattered within a thin layer of glacial till. Subsequent work by Cominco consisted of trenching, which exposed the massive sulphide vein, reconnaissance VLF-EM geophysics to trace a fault structure that controlled the vein, and four diamond-drill holes.

Kokanee Explorations Ltd. (since acquired by Consolidated Ramrod Gold) began an exploration program on the Vine property in May, 1989 that included geophysical and geochemical surveys, geological mapping, trenching and 14 368 metres of diamond drilling (Photo 1). Trenching exposed the vein for over 150 metres along strike, and the geochemical and geophysical surveys indicated that the Vine structure continue for more than 4 kilometres. Subsequent mapping and drilling has more clearly defined this structure and recognized the importance of a gabbro dike that closely follows the fault structure. The drilling indicates that the vein is continuously mineralized along a strike length of at least a kilometre and to a depth of 800 metres; it remains open in both depth and strike.

More detailed fill-in drilling in 1990 outlined three main zones, defined as thicker and higher grade areas within the Vine vein. These include the Upper Trench area, the Vat zone and the "41" area. Drill-indicated reserves in these zones, released by Kokanee Exploration in 1991, are outlined in Table 1:

TABLE 1
RESERVE FIGURES, VINE DEPOSIT (1991)*

	Tonnes (000)	Lead (%)	Zinc (%)	Silver (g/t)	Gold (g/t)
Proven	240	5.20	2.24	6[illegible].23	1.92
Probable	307	4.22	2.51	39.77	1.75
Possible	820				

**diluted to a 2.44-metre mining width*
Source: (Pighin, 1991)

This paper describes the structural and stratigraphic controls of the Vine vein system, its mineralogy and chemistry, and compares it to other hydrothermal systems in the Aldridge Formation. It also describes briefly the stratigraphy of the Sullivan horizon and immediately adjacent units, thus allowing speculation regarding regional facies changes in this important interval.

REGIONAL GEOLOGY

STRATIGRAPHY

The Vine vein is within the Aldridge Formation of the Middle Proterozoic Purcell Supergroup. The formation comprises in excess of 4000 metres of coarse to fine clastic rocks, dominantly turbidites, deposited in a developing extensional basin in an intracratonic setting (Winston *et al.*, 1984). The formation is divided into three divisions (Figure 2). The lower Aldridge consists mainly of rusty weathering, thin-bedded argillaceous siltstone with occassional sections of coarse, more massive turbidite wackes. It is overlain by the middle Aldridge, comprising approximately 3000 metres of grey-weathering, thick to thin-bedded turbidites with some intercalated, well laminated siltstone marker units.

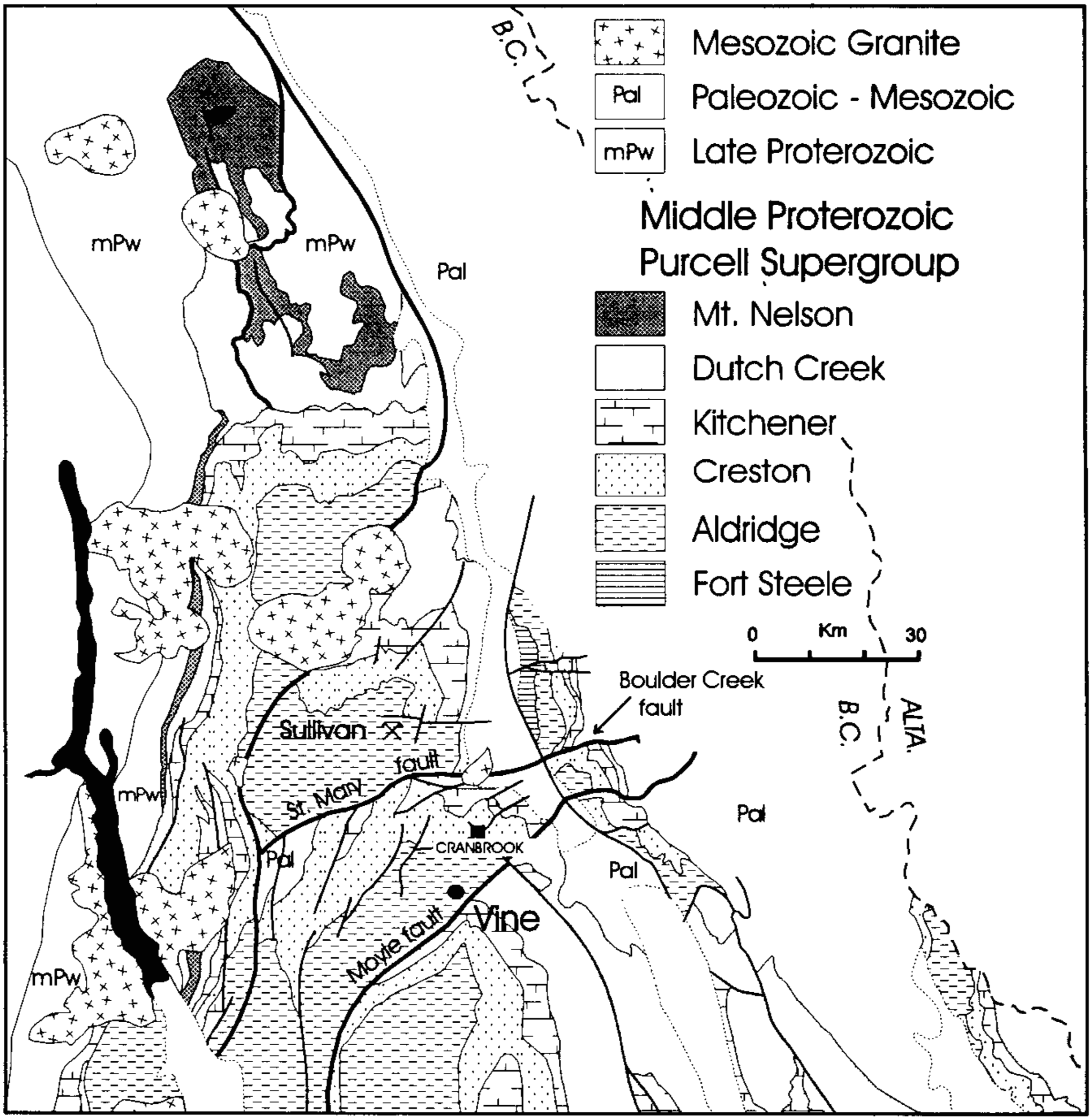

Figure 1. Regional geology map showing the location of the Vine deposit area within the Purcell anticlinorium, southestern British Columbia.

Photo 1. View of trenching, Vine deposit, in July, 1994.

The upper Aldridge comprises 500 metres of massive to faintly laminated argillite and argillaceous siltstone.

A number of thick gabbro sills, the Moyie sills, intrude the upper part of the lower Aldridge and the middle of the middle Aldridge. Contact features indicate that some of these sills were intruded into wet, unconsolidated to partially consolidated sediments, indicating magmatism accompanied extensional tectonics during development of the basin (Höy, 1989, 1993). Uranium-lead dating of these sills (1445±11 Ma, Höy, 1989; 1465 Ma, Anderson and Davis, in preparation) therefore constrain the early age of the Purcell basin and its contained mineral deposits.

The Aldridge Formation is overlain by shallow-water to locally subaerial argillite, siltstone and quartzite of the Creston Formation (Figure 2), interpreted to represent mudflats and alluvial apron deposits that were fed from braided streams in the south, southwest and northeast (Winston and Link, 1993). These latter deposits are recognized in the northern Hughes Range and are characterized by clean white, crossbedded and flat-laminated quartz sands. Overlying carbonate rocks of the Kitchener Formation are dominantly shallow-water deposits; prominent cyclical sedimentation in correlative rocks of the Helena Formation in Montana are interpreted to record periodic expansion and shrinkage of a Purcell (Belt) lake (Winston and Link, 1993).

Upper Purcell rocks include shallow-water carbonate and clastic rocks, deposited in a similar setting to those of the Creston and Kitchener formations and, along the eastern margin of the Purcell-Belt basin, a sequence of dominantly subaerial basalts of the Nicol Creek Formation (McMechan *et al.*, 1980; Höy, 1993). South of the Moyie fault, Purcell Supergroup rocks are overlain unconformably by Devonian carbonates of the Fairholme Group; north of the Moyie fault, Lower Cambrian shale and quartzite overlie the Purcell Supergroup.

STRUCTURE

The Vine deposit lies within the core of the Purcell anticlinorium, a broad north-trending structure cored by Purcell Supergroup rocks and flanked by Late Proterozoic, Early Cambrian or Devonian rocks (Figure). The deposit is in a structural panel that is underlain to the south by the Moyie fault, a right-lateral reverse fault that extends east across the Rocky Mountain Trench as the Dibble Creek fault, and overlain to the north by the St. Mary fault.

These northeast-trending faults, and their extensions east of the Rocky Mountain Trench, have a complex and

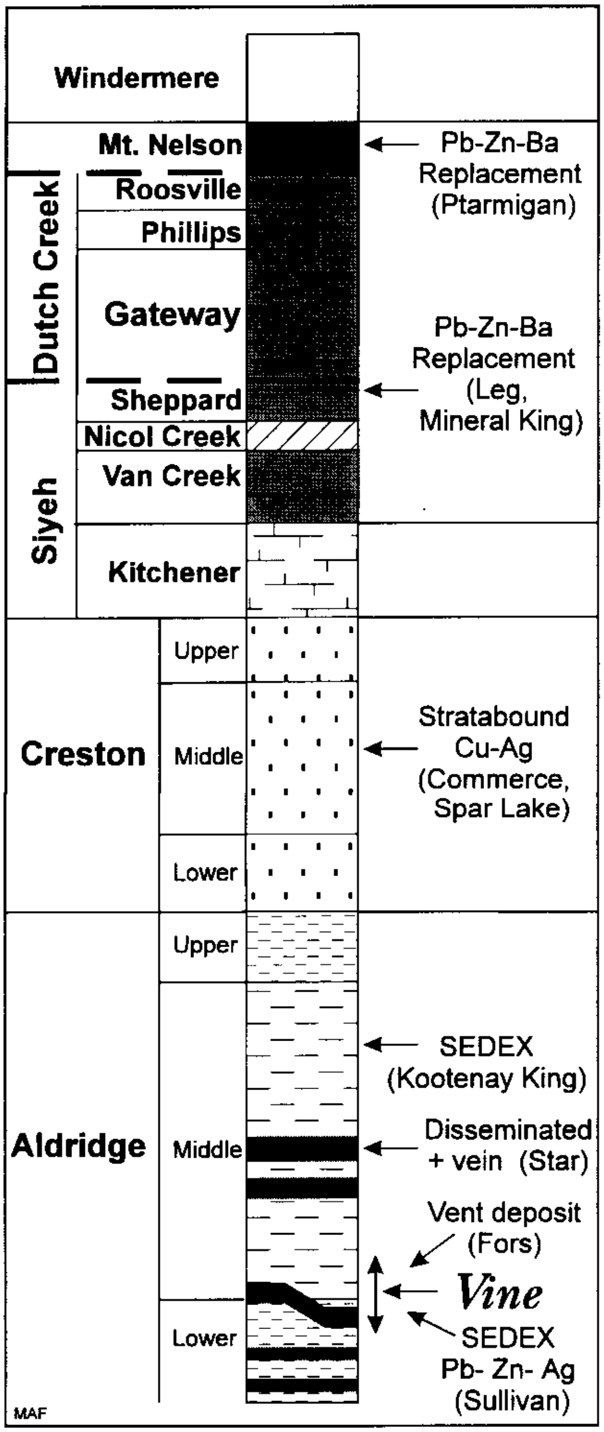

Figure 2. Purcell Supergroup stratigraphic column, showing position of Vine deposit and other important deposits within Purcell Supergroup rocks.

extended history of movement recognized by prominent facies and thickness changes in sedimentary units across them. Prominent facies changes within Aldridge rocks near the Boulder Creek fault, the eastern extension of the St. Mary fault (Figure 1), indicate that it coincides approximately with the faulted eastern margin of the Purcell basin (Höy, 1993). The Moyie fault is the locus of a faulted southern margin of the late Proterozoic Windermere basin (Lis and Price, 1976) and marks the northern margin of a pre-Devonian tectonic high referred to as Montania (Leech, 1962). Evidence for a Middle Proterozoic structure along the antecedent of the Moyie fault is less well documented. However, anomalous thicknesses of Middle Proterozoic Moyie sills, subtle but persistent thickness changes within Aldridge rocks, comparisons with the similarly oriented St. Mary fault, and concentrations of mid-Proterozoic hydrothermal mineralization near the fault, suggest that it may also follow the locus of an earlier Middle Proterozoic structure.

The Moyie anticline, a doubly plunging anticlinal fold, dominates the structure of the Moyie block south of the Moyie fault (Figure 1). Both the Midway and St. Eugene vein deposits occur in Aldridge rocks in the core of the anticline. The fault is locally marked by a zone of intense shearing, up to several hundred metres wide, that dips northwest at 60° to 70° (Figure 3).

Aldridge rocks in the immediate hangingwall of the Moyie fault are locally folded into a series of tight and locally overturned folds with commonly well developed axial planar cleavage. These die out rapidly to the northwest; the Vine deposit, located less than 2 kilometres from the Moyie fault, is in gently north dipping Aldridge metasediments which locally have a weakly developed crosscutting penetrative cleavage.

PROPERTY GEOLOGY

The geological map of the Vine deposit area, shown in Figure 3, shows the northwest trend of the Vine vein structure within northeast-trending lower and middle Aldridge metasediments. It is parallel to a number of northwest trending faults with west-side-down normal displacements of a few tens to a few hundred metres. A late fault within the Vine structure is projected southeastward, cutting across intense shearing and folding in the hangingwall of the Moyie fault.

A more detailed surface plan of the Vine occurrence is shown in Figure 4 and cross-sections in Figures 5 and 6. Figure 4 is developed mainly from trenching and drilling; natural outcrops in the immediate vicinity of the vein are few.

DETAILED STRATIGRAPHY

Stratigraphic sections of the wallrocks of the Vine vein are shown in the cross-sections of Figures 5 and 6. The vein straddles the boundary between the lower and middle Aldridge, the approximate stratigraphic position of the Sullivan sedex deposit. These Aldridge metasediments strike northeast and dip 15° to 20° northwest.

The host succession comprises four main units: a lower quartzite succession, a siltstone succession, a laminated argillite succession, and an upper quartzite succession. Based on detailed correlation of marker units within the upper quartzite unit, the composite host succession can be correlated with Aldridge Formation elsewhere, including that in the vicinity of the Sullivan deposit.

The transition between the lower and the middle Aldridge occurs at the top of the laminated argillite unit;

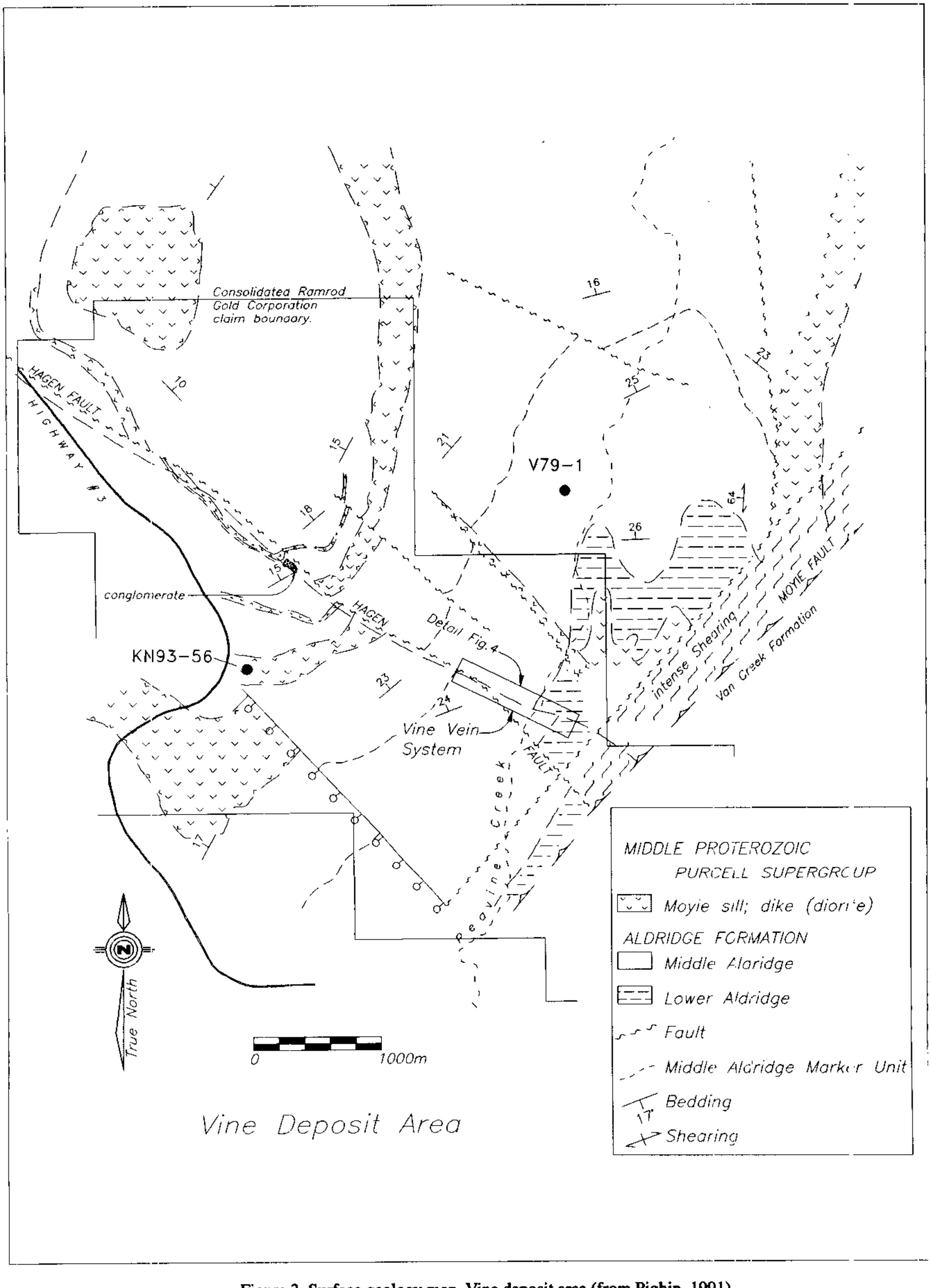

Figure 3. Surface geology map, Vine deposit area (from Pighin, 1991).

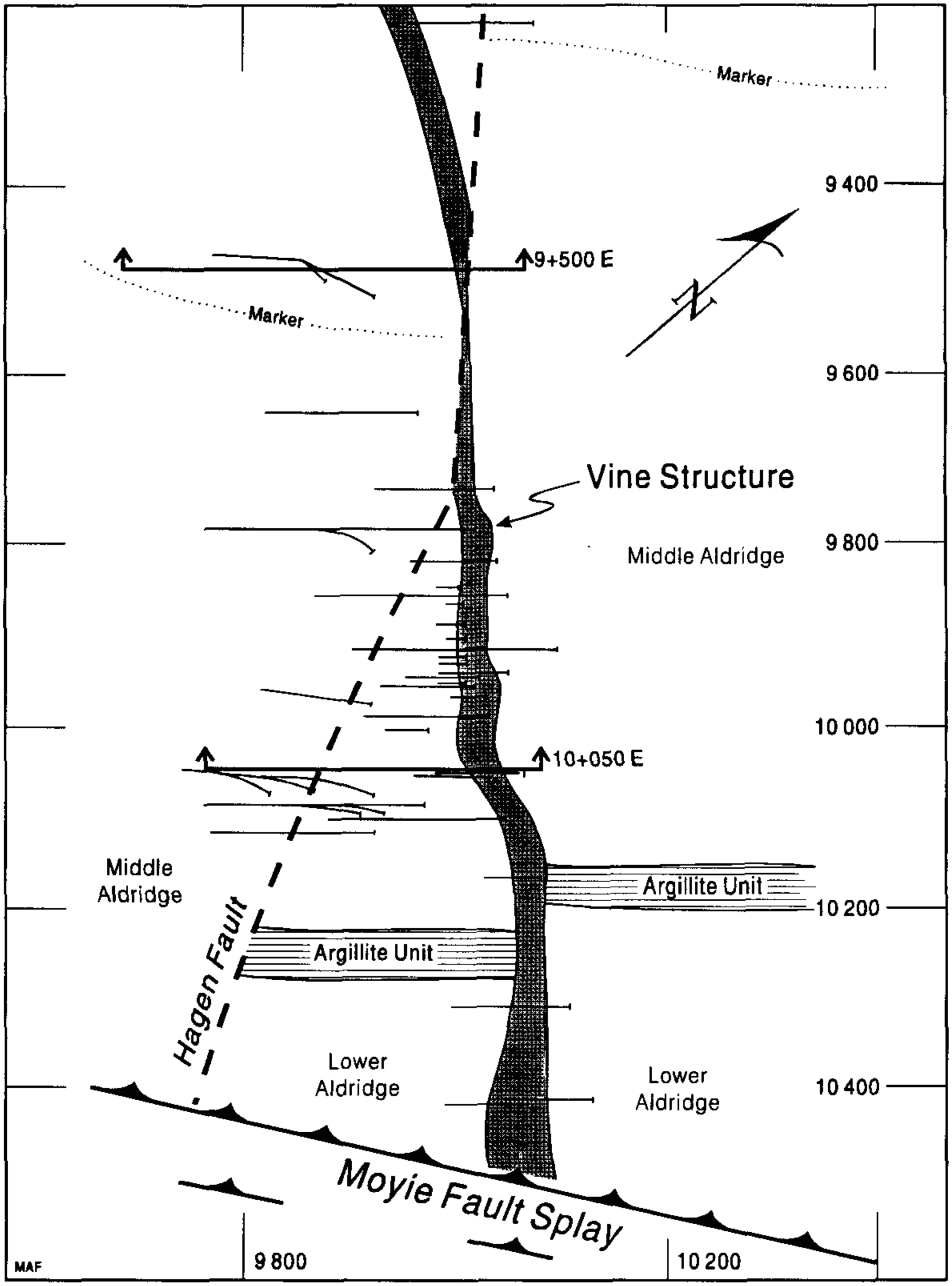

Figure 4. Surface drill plan and simplified surface geology, Vine deposit; *see* Figure 3 for location (after Pighin, 1991).

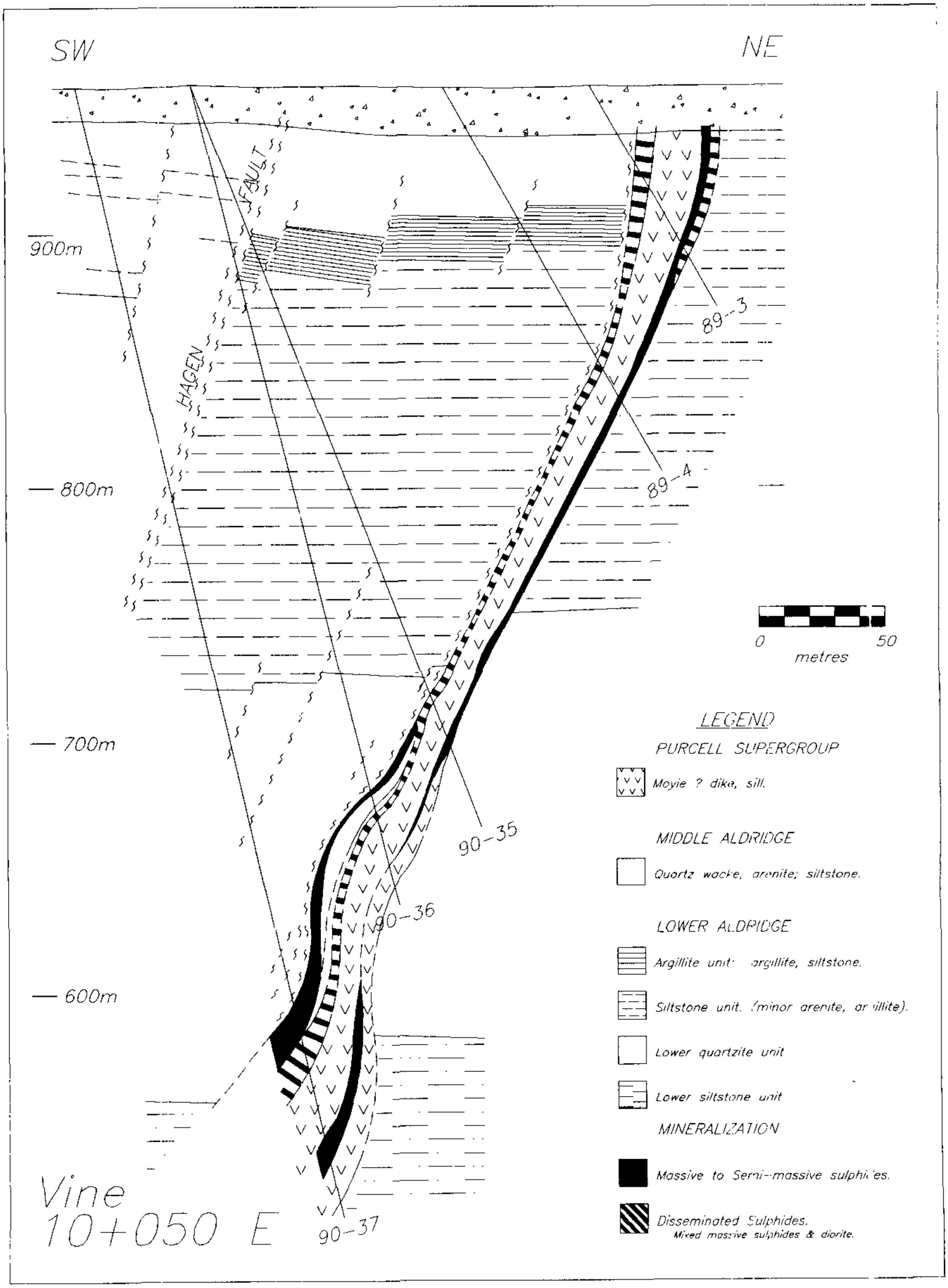

Figure 5. Section 10+050 E Vine deposit; *see* Figure 4 for location (after Pighin, 1991).

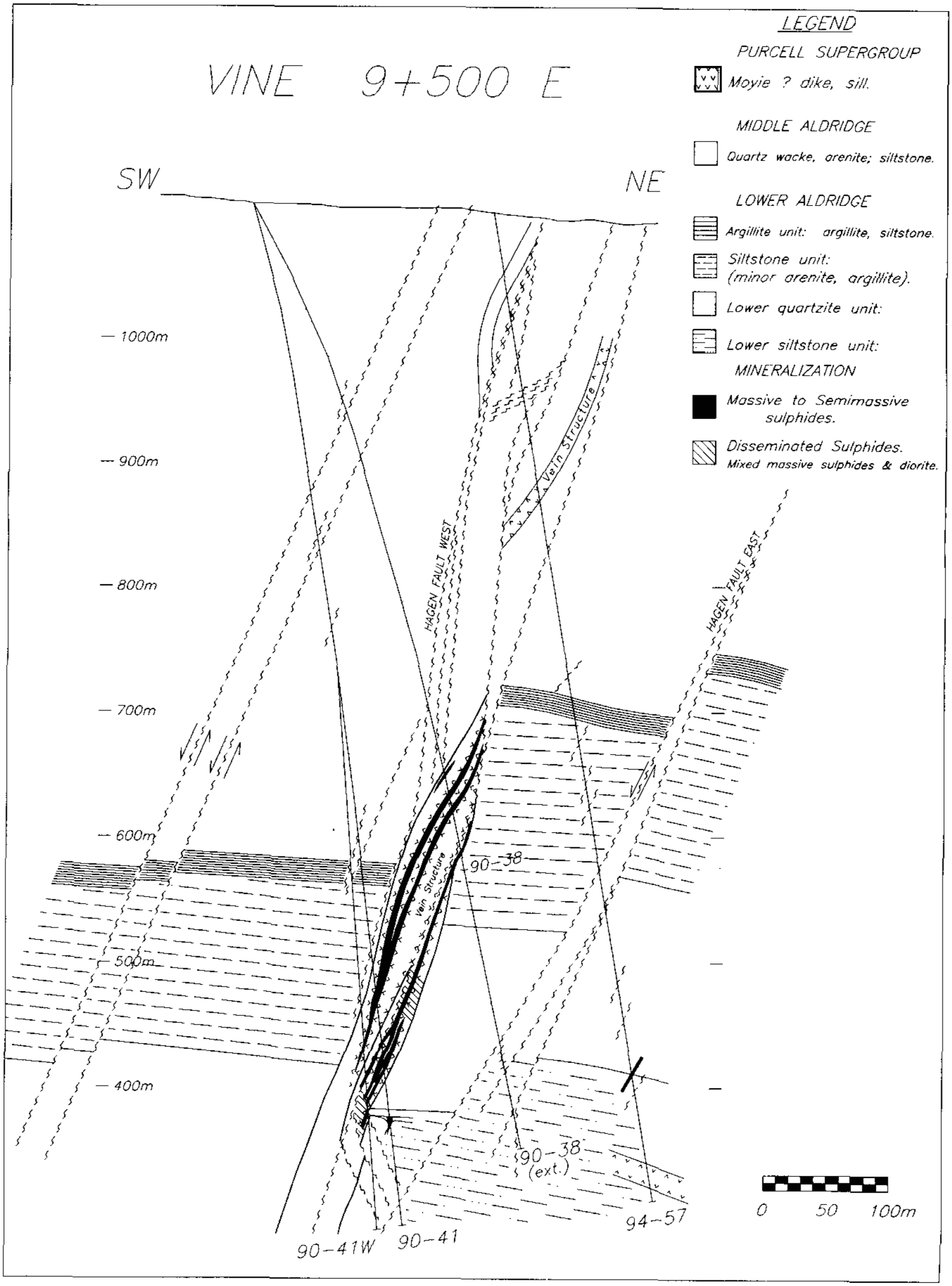

Figure 6. Section 9+500 E, Vine deposit; *see* Figure 4 for location (after Pighin, 1991).

the laminated argillite unit correlates with the Sullivan horizon, and the lower quartzite unit with the footwall quartzites of the Sullivan mine area.

LOWER QUARTZITE UNIT (LOWER ALDRIDGE)

The lower quartzite unit comprises approximately 150 metres of thick to medium-bedded, massive to locally graded quartz wacke and arenite. Argillite partings between beds are uncommon. Thin-bedded siltstone units, generally less than a metre thick, occur locally. The top of the unit is marked by 10 to 15 centimetres of laminated grey siltstone with varying amounts of disseminated to locally laminated pyrite. A similar unit occurs approximately 100 metres below the top of the unit.

SILTSTONE UNIT (LOWER ALDRIDGE)

The lower siltstone unit comprises approximately 150 metres of thin to medium-bedded siltstone and wacke. Individual beds may be massive, poorly graded or vaguely laminated. Beds are typically grey coloured although abundant fine-grained metamorphic biotite produces a purple cast. The siltstone contains more pyrrhotite (3 to 4%) and is generally finer grained and thinner bedded than the underlying quartzite unit or the basal part of the middle Aldridge. It contains occassional thin, laminated silty argillite layers and, in the top 3 to 4 metres, thin fine-grained quartz arenite and wacke units similar to those that characterize the lower quartzite unit.

ARGILLITE UNIT (LOWER ALDRIDGE)

The argillite unit, referred to as the Sullivan horizon in the Sullivan deposit area (Hamilton *et al.*, 1982) is a massive to laminated silty argillite and siltstone succession up to 20 metres thick. Biotite and pyrrhotite are ubiquitous, and particularly abundant in the more argillaceous intervals. They commonly define the parallel-laminated nature of the unit.

Thin, massive to graded, grey siltstone layers occur throughout the unit. Minor crossbedding occurs in some of these layers. Conspicuous dark-light laminations are present in some siltstone units; the bottom 2 metres of the argillite unit in diamond-drill hole 89-4 (Figure 5) is particularly well laminated, with up to 50% pyrrhotite in the darker laminae. This laminated interval is similar to the mineralized horizon on Concentrator Hill just east of Kimberley, which is the distal expression of the Sullivan deposit.

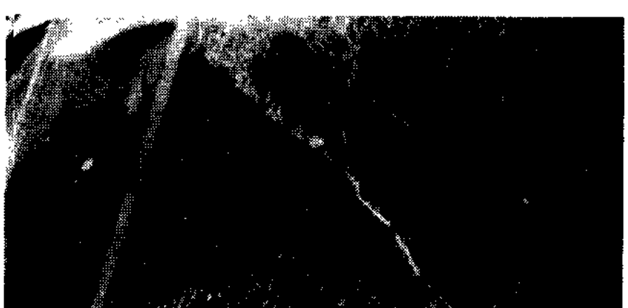

Photo 2. Dispersed pyrrhotite forming vague laminations in otherwise massive argillite, base of argillite unit (Sullivan horizon) (ddh 41, 564.8 m; sample width - 9 cm).

Sulphides, particularly pyrrhotite and minor pyrite, occur throughout as disseminated grains and occasionally in thin millimetre-thick laminations. Rare disseminated grains of sphalerite and galena are recognized in sections where pyrrhotite laminations occur. Highest abundances occur in a 2 to 3-metre section in the lower third of the argillite unit. Within this interval, zinc analyses of 2000 to 3000 ppm and lead analyses of 500 to 1000 ppm are common (in 20 cm intervals). A persistent section, up to 10 centimetres thick near the bottom of the argillite unit, contains up to 20% sulphides, dominantly pyrrhotite and trace sphalerite (Photo 2).

The true thickness of the argillite unit varies from approximately 11 metres to just over 20 metres with a hinge located along the Vine structure. Northeast of Vine, in diamond-drill hole V79-1, the unit is 19.4 metres thick (D. Anderson, personal communication, 1994); to the west, in hole KN93-56, it is also approximately 20 metres thick. However, in drill intersections in the hangingwall of the Vine structure, the argillite unit averages between 15 and 16 metres, in contrast to the more typical 20 metres immediately to the east in the footwall. This suggests that the Vine structure may have had a seafloor topographic expression during Sullivan time, with a high located immediately to the west. As the Vine fault is occupied by a Moyie dike and a small, crudely layered conglomeratic unit occurs adjacent to the structure higher in the Aldridge (Figure 3), the structure is interpreted to be a minor north-northwest trending growth fault during Aldridge deposition.

Approximately 5 kilometres south-southwest of the Vine deposit, near Munroe Lake, numerous drill intersections indicate that the Sullivan horizon is marked by up to 50 metres of fragmentals that define a northeast-trending depression that parallels the Moyie fault. This suggests that the Moyie fault may also be the approximate trace of a Middle Proterozoic fault.

In summary, both thickness and lithologic variations of units deposited at the lower-middle Aldridge transition support a model for increasing structural subsidence to the west during Sullivan time, controlled in part by an antecedent of the Moyie fault, and interrupted by small northwest-trending growth faults such as the Vine structure. The Vine structure was reactivated later in middle Aldridge time, with deposition of the fragmental unit along its northwest extension; it controlled the emplacement of a Moyie dike and the Vine massive sulphide vein.

UPPER QUARTZITE SUCCESSION (MIDDLE ALDRIDGE)

A succession of well bedded quartz wackes that overlies the argillite unit is similar to the base of the middle Aldridge elsewhere in the Purcell Supergroup. It comprises medium-grained quartz arenites, wackes and minor siltstones. Grading is common, vague irregular laminations occur within some beds, and crossbeds are locally recognized. Two laminated siltstone intervals within the basal middle Aldridge are conspicuous marker units that allow correlation of drill intersections. Minor sections within the upper quartzite are similar to the typical thinner bedded siltstone unit of the lower Aldridge.

STRUCTURE

The dominant structure on the property is the Vine vein stucture, now marked by a normal fault that dips 70° to 80° west and has a dip-slip displacement of approximately 80 metres. It contains the Vine vein and a prominent gabbro dike that is mineralogically similar to the Moyie sills. This late fault, referred to as the Vine fault, is a splay of the Hagen fault, also a west-side down normal fault. The Hagen fault cuts at least 1500 metres of Aldridge stratigraphy and can be traced northwest for about 6 kilometres (Figure 3). To the south, both the Vine and the Hagen faults appear to be truncated by the Moyie fault.

The Vine fault is a complex zone, 10 to 60 metres wide, with numerous zones of brecciation and gouge that cut altered gabbro and early sulphide mineralization, and locally leave remnant elongate inclusions of altered Aldridge metasediments within it. It appears to record an extended period of movement beginning before the mineralizing event and continuing after it. Locally, intense shearing is cut by both massive sulphide veining and the gabbro dike. As described below, the veining has a complex history, with early vein material brecciated and sheared, then cut by late sulphide veining and finally, barren, calcite-rich veins. Coarse, angular, vuggy breccia overprints the early Vine structure, recording a late, essentially parallel fault structure with west-side-down normal movement.

The host Aldridge stratigraphy appears to control, in part, both the attitude of the Vine structure and the thickness of sulphide veins. The structure is commonly refracted to steeper dips within the more competent lower quartzite unit, where dips are locally near vertical. Massive sulphide vein mineralization is commonly considerably thicker within these more steeply dipping zones.

MINERALIZATION

The dominant and most conspicuous mineralization on the Vine property is the Vine vein. However, disseminated sulphides and elevated base metal and silver values in the argillite unit at the top of the lower Aldridge, the same stratigraphic level as the Sullivan deposit, and recognized growth faulting in the area, suggest the potential for local massive sulphide deposition. The Fors deposit, located 7 kilometres southwest of the Vine, is a small high-grade lead-zinc-silver vein and sedex deposit in the overlying middle Aldridge Formation (Britton and Pighin, 1995, this volume). Evidence of mineralization is not apparant at this stratigraphic level in the immediate Vine area.

VINE VEIN SYSTEM

The Vine vein system comprises a number of massive to semimassive sulphide-calcite-quartz veins within the Vine structure. These are largely concentrated in the hangingwall and footwall, with generally thinner and less discontinous veins in gabbro closer to the centre of the structure (Figures 5 and 6). Locally, it appears that faulting within the Vine structure has repeated the mineralized system, producing an anomalously thick mineralized interval (DDH 90-41, Figure 6).

The dominant sulphides are pyrrhotite, sphalerite, galena, arsenopyrite and pyrite in a quartz-calcite and minor chlorite gangue. Alteration is generally intense, though typically confined to a few tens of metres from the Vine structure. The following sections describe sulphide mineralogy and alteration in detail.

MINERALOGY

Pyrrhotite is the dominant sulphide within the massive sulphide vein system. It occurs intimately intergrown with brown sphalerite and, less commonly, galena in a quartz-calcite gangue (Photos 3 and 4). The massive sulphides range from coarse grained to mylonitized, with numerous floating, rounded to elongate quartz eyes. In thin section, massive pyrrhotite typically contains many small inclusions of sphalerite, galena, chalcopyrite and rarely pyrite. Pyrrhotite may also occur as veins, with quartz and dark chlorite gangue, that cut earlier massive sulphides; thin, late pyrrhotite veinlets commonly have dark chlorite envelopes.

Pyrite is generally not abundant. Minor pyrite occurs intergrown with the massive sulphides, suggesting early development. However, most pyrite occurs as isolated subhedral grains within the massive sulphides or in late crosscutting, thin to relatively massive veins a centimetre

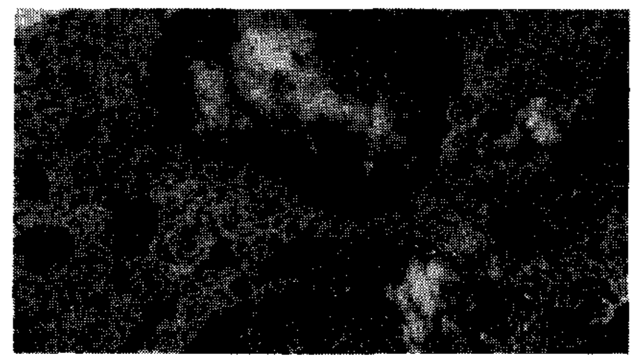

Photo 3. Vine massive sulphide; dominantly pyrrhotite swirled around rounded quartz inclusions. Pyrrhotite contains minor arsenopyrite grains and chalcopyrite occurs along margins of quartz. Lower quartz clasts contains abundant, disseminated subhedral arsenopyrite (ddh 36, 290.7 m; sample width - 9 cm).

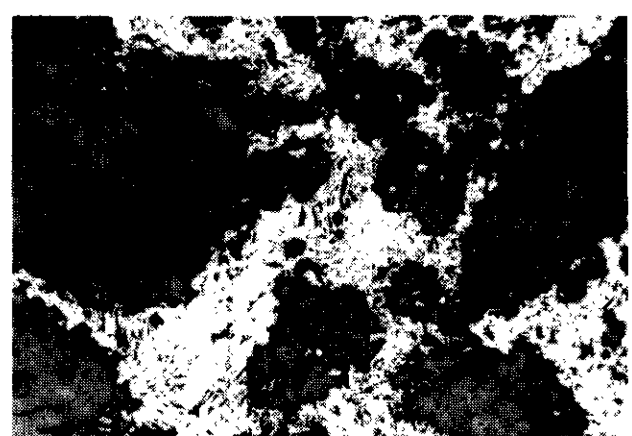

Photo 4. Photomicrograph (reflected light) of intergrown pyrrhotite and galena in a quartz (dark) matrix (ddh 41, 659.3 m; field of view: 5 mm).

thick, commonly with calcite and occassionally with chalcopyrite. Vein margins tend to be diffuse with pyrrhotite, suggesting replacement of the pyrrhotite, but sharp with other sulphides (Photos 5 and 6).

Arsenopyrite is locally a common and abundant sulphide. It occurs as small disseminated euhedral grains within quartz eyes (Photo 7) and within sheared siliceous (quartz) material. It also found occassionaly as floating isolated grains within massive pyrrhotite or pyrite; in thin section, arsenopyrite grains commonly have corroded margins

Photo 5. Late calcite-pyrite±pyrrhotite vein cutting sericite-altered metasediment with disseminated and vein pyrrhotite (ddh 41, 658 m; sample width - 10 cm).

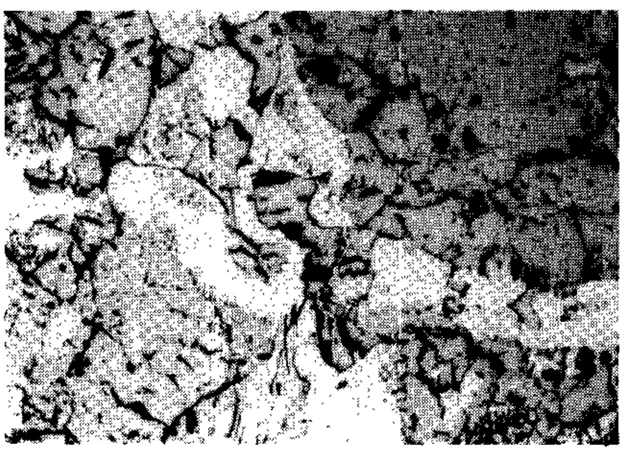

Photo 6. Photomicrograph (reflected light) of pyrite vein cutting massive pyrrhotite; note reaction between pyrrhotite and pyrite and angular broken galena within pyrite vein (ddh 41, 720.8 m; field of view: 5 mm).

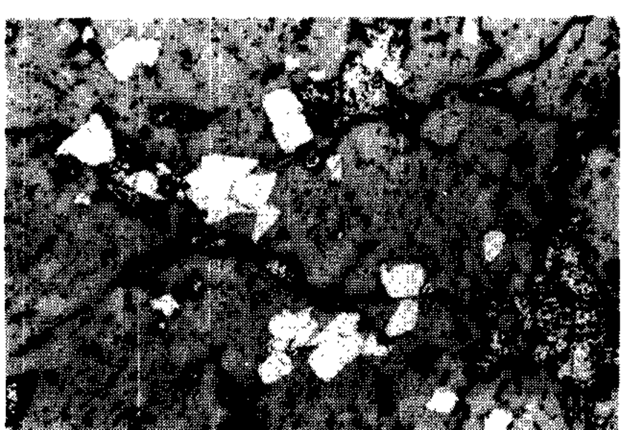

Photo 7. Photomicrograph (reflected light) of subhedral arsenopyrite (light) in quartz; note later veining of pyrrhotite (ddh 37, 368.8 m; field of view: 5 mm).

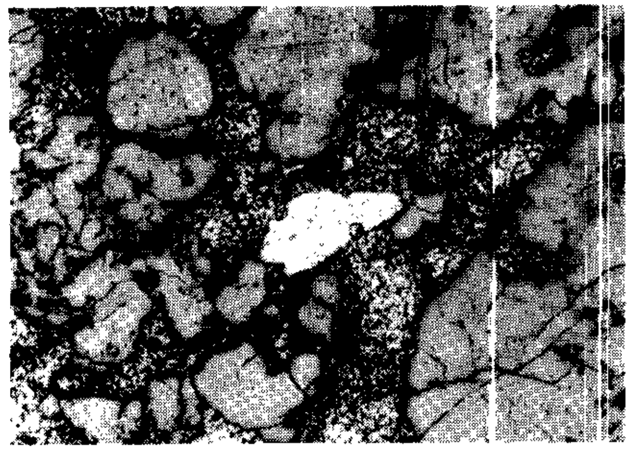

Photo 8. Photomicrograph (reflected light) of corroded arsenopyrite grain in massive pyrrhotite; note subrounded grains of quartz (ddh 41, 659.3 m; field of view: 5 mm).

suggesting early growth (Photo 8). Arsenopyrite is also noted rarely in massive, brecciated veins. These have not been observed cutting other massive sulphides. These relationships are consistent with arsenopyrite being one of the early formed sulphides. Occurrences in quartz eyes may be the remnants of early quartz-arsenopyrite veins that were subsequently broken, sheared and incorporated into the massive sulphides forming durchbewegung textures.

Chalcopyrite occurs as a minor constituent in the massive sulphide vein, commonly closely intergrown with pyrrhotite and other sulphides. It also occurs in the pressure shadows of enclosed silicate fragments and in many thin, wispy crosscutting hairline fractures.

ALTERATION

The dominant alteration minerals within and adjacent to the Vine vein system include sericite, calcite, chlorite, quartz and minor albite. Biotite is a regional metamorphic mineral, reflecting regional greenschist metamorphism. It is not present in alteration assemblages within or immediately adjacent to the vein. Sericite, with or without chlorite, carbonate and silicate alteration are associated with sulphide mineralization; alteration envelopes are cut by late calcite±pyrite veins.

Biotite is ubiquitous in all argillaceous siltstone units, locally forming a penetrative cleavage, or in more competent quartzitic units, giving a purple cast to the rock. In metasediments adjacent to the Vine vein, biotite occurs as fine disseminated, randomly oriented grains. Closer to the vein, it is intergrown with and finally replaced by sericite.

Sericite occurs in a number of different habits. A minor amount is present as fine-grained euhedral grains with the regional metamorphic biotite. This may record regional potassium alteration, related to the Vine vein system, as has been documunted in the Sullivan - North Star Hill area (Leitch *et al.*, 1991). Immediately adjacent to the Vine vein, patchy, white "bleaching" of Aldridge metasediments is due to intense sericitization. Similar pale green to white coloration around microfractures is due to fine-grained

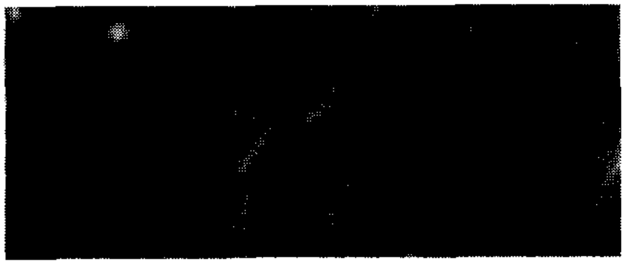

Photo 9. Early "bleached" sericite±pale green chlorite envelopes surrounding a network of microfractures that cut biotite siltstone (ddh 38, 488 m; sample width - 9 cm).

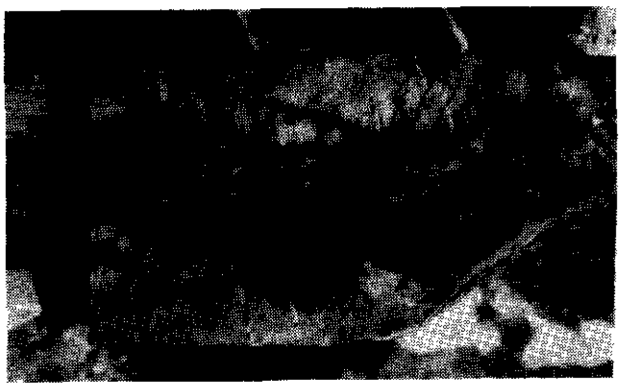

Photo 10. Pyrrhotite-galena-quartz vein cutting sericite altered siltstone; note dark chlorite alteration envelope around sulphide vein and early "bleached" sericite fractures (ddh39, 558.4 m; sample width - 8 cm).

sericite±pale chlorite alteration (Photo 9). This sericite± chlorite alteration is commonly cut by sulphide veins.

Early chlorite, associated with sericite, is a high-magnesium variety. In thin section, it occurs as small, pale green to colourless anhedral grains, interstitial to quartz, with moderate to high relief and anomalous blue birefringence. It commonly forms envelopes around early sulphide veins (Photo 10). Minor dark green chlorite occurs as gangue within the massive sulphides and in late chlorite±pyrrhotite veins that cut other massive sulphides. One sulphide-quartz vein has a distinctive zoned envelope: it comprises massive sulphide, quartz and chlorite, with a pale green chloritic envelope surrounded by a thick, intensely sericitized envelope. These relationships suggest early magnesium chlorite-sericite alteration, followed by more iron-rich chlorite alteration associated with sulphide mineralization.

Quartz occurs as gangue within massive sulphide veins, as included quartz eyes, and in late veins. Disseminated arsenopyrite in the quartz eyes, the abraded nature of many of these eyes, and common undulose extinction and possible deformation lamellae of the quartz grains, suggest that they are broken, rounded fragments of early vein mineralization. The most abundant gangue mineral in much of the massive sulphide vein system is clear to white, coarse-grained quartz. It is also often sheared and recrystallized. Minor quartz also occurs in small, late sulphide-free veins that are locally intensely brecciated.

Calcite typically occurs intergrown with quartz as a minor to locally dominant gangue in the massive sulphide veins. It also occurs with pyrite in late crosscutting veinlets, and barren, vuggy calcite forms the matrix to late fault breccias.

Albite occurs as a white, fine-grained granular alteration, recognized in both drill core and on surface. It is possibly related to Moyie dike emplacement as suggested by Turner and Leitch (1992). It is similar to albitic alteration recognized elsewhere in Aldridge rocks, in thin section characterized by untwinned crystals (C.H.B. Leitch, personal communication, 1994).

SUMMARY

Mineral and alteration assemblages indicate that the Vine vein is a complex system that is both spatially and temporally associated with movements on the Vine structure. An early, premineralization, growth fault that became the locus for gabbro dike emplacement, Vine mineralization and finally, late normal faulting, is suggested by the occurrence of a small bedded conglomerate that lies on the northwest extension of the Vine fault (Figure 3).

Early alteration, related to the Vine vein, included sericitization, locally intense and pervasive immediately adjacent to the vein and as thin bleached hairline stringers farther away. This appears to overprint biotite metamorphism, suggesting that the vein formed in the waning stages of regional metamorphism or possibly later. However, Leitch et al., (1991) argue that the regional disappearance of biotite in the Sullivan area reflects premetamorphic alteration producing a rock composition conducive to sericite rather than biotite growth during regional metamorphism.

The earliest recognized sulphide mineralization includes arsenopyrite with quartz, now preserved as remnant eyes within later massive sulphide mineralization as well as in isolated veins. Massive sulphide vein mineralization, dominantly pyrrhotite, sphalerite and galena with minor chalcopyrite and arsenopyrite, in a quartz-calcite and iron chlorite gangue, and locally with dark chlorite envelopes has a multistage development. Earlier massive sulphide veins are commonly cut by similar late veins. Many have a mylonitic fabric with durchbewegung textures, while others are massive and clearly cut sheared hostrocks, indicating late syntectonic deposition.

Late pyrite veins, with calcite and quartz, cut the massive sulphide veins. Associated faulting commonly produces a vuggy, angular breccia suggesting that these veins, and possibly late pyrite overgrowths, record remobilization of sulphides during late normal faulting. Coarse, sparry calcite matrix and barren calcite±quartz veins are also associated with this late faulting.

DISCUSSION

The Vine vein is an unusual massive sulphide base and precious metal vein system that cuts Middle Proterozoic turbidites and argillites of the Aldridge Formation. It comprises massive pyrrhotite, sphalerite and galena with minor arsenopyrite and chalcopyrite in a quartz-carbonate-chlorite gangue. It appears to overprint regional biotite metamorphism as well as sericite - magnesium chlorite alteration and early quartz-arsenopyrite veining, and is cut by late brecciation associated with pyrite, calcite and minor quartz.

The absolute age of the Vine vein is not known. Lead-lead isotope data from galena are similar to that of other Middle Proterozoic deposits (Cominco Ltd., unpublished internal report). However, the main sulphide mineralization appears to cut a regional metamorphic fabric that is related to the *ca.* 1350 Ma East Kootenay orogeny (McMechan and Price, 1982; Höy, 1993). Magmatic activity - intrusion of the Hellroaring Creek stock and other alkaline stocks - and folds with a penetrative axial planar cleavage are associated with this event in the St. Mary Lake area west of Kimberley. We suggest, therefore, that the Vine vein, and possibly other base and precious metal veins such as the St. Eugene, with Middle Proterozoic Pb-Pb isotopic signatures and possible late to post-tectonic emplacement, may record a hydrothermal event related to the East Kootenay orogeny.

The Vine vein system follows a northwest-trending structure that appears to have been active since Aldridge time, forming the locus for intrusion of a Middle Proterozoic Moyie dike, sulphide mineralization and both syn and post-mineralization faulting. This Middle Proterozoic structure trends northwest, at high angles to well documented northeast-trending Proterozoic structures, recognized as the antecedents of the Moyie and St. Mary faults. It parallels other mineralized northwest-trending structures, including those at the St. Eugene and Midway deposits, and numerous northwest-trending faults. Furthermore, this trend parallels approximately both the Aldridge basin margin and basin axis (Höy, 1993) as well as the axis of Moyie sill intrusions (Cressman, 1989). North of the St. Mary fault, however, regional structures strike more northerly, as do most Middle Proterozoic mineralizing trends, including the Sullivan - North star corridor (Höy, 1984; Turner *et al.*, 1993) and vein deposits such as Estella.

In conclusion, we suggest that some early northwest-trending extensional faults, initially developed during opening of the Purcell (Belt) basin, were reactivated as late faults and became the locus for base and precious metal vein mineralization such as the Vine deposit. Prominent northeast-trending structures reflect basement anisotropy that locally and markedly modified distribution of Aldridge sediments and, on a regional scale, controlled distribution of middle Proterozoic sulphide deposits (Höy, 1982).

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