GEOLOGICAL INVESTIGATIONS OF THE HIDDEN CREEK DEPOSIT, ANYOX, WEST-CENTRAL BRITISH COLUMBIA (103/P5)

By R.W.J. Macdonald, T.J Barrett and R.L. Sherlock

Mineral Deposit Research Unit, U.B.C.

(MDRU contribution 061)

KEYWORDS: Economic geology, Anyox, massive sulphide, pyrite, pyrrhotite, chalcopyrite, metavolcanic, chert, turbidites, hydrothermal alteration, lithogeochemistry

INTRODUCTION

The Hidden Creek deposit constitutes the largest accumulation of known sulphide mineralization in the Anyox pendant, a volcanic-sedimentary succession preserved as a roof pendant along the eastern margin of the Coast Plutonic Complex, approximately 160 kilometres north of Prince Rupert, British Columbia (Figure 1). The deposit was discovered in 1901 and was operated between 1914 and 1935 by Granby Consolidated Mining and Smelting Company. During this period over 21 million tonnes of ore grading 1.5 % Cu, 9.25 g/t Ag and 0.17 g/t Au was mined. The mine was closed on August 1, 1935 and purchased by The Consolidated Mining and Smelting Company of Canada, Limited, now Cominco Ltd., on October 25, 1935 (Davis *et al.*, 1992). From 1936 to 1989 a number of exploration programs were carried out by Cominco and various joint venture partners. The property is now held by TVI Pacific; a 1990 economic assessment of the property indicated a geological reserve of 10.8 to 13.6 million tonnes grading 0.7% to 0.75% Cu (Davis *et al.* 1992).

This study is in the final year of a two-year program designed to examine the geological and geochemical relationships associated with sulphide mineralization in the Anyox pendant. Over the past two years, 24 drillholes totalling over 5300 metres were sampled for lithogeochemistry, petrography and fluid inclusion studies. Detailed mapping on 1:1200 and 1:2400 scales was carried out with special attention given to the ore zones and volcanic-sedimentary contact. Fieldwork this year focused on mineralization styles in the ore zones and associated stockwork zones, and on the extent, spatial distribution and paragenesis of the main alteration facies associated with the ore.

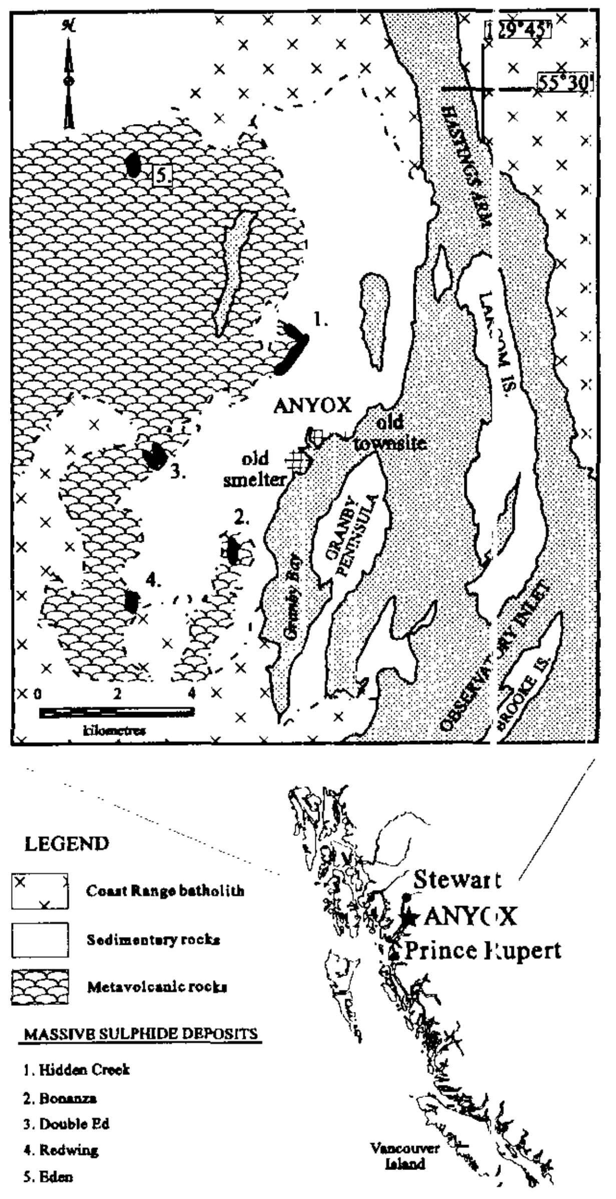

Figure 1. Location and general geology of the east Anyox pendent (after Aldrick, 1986).

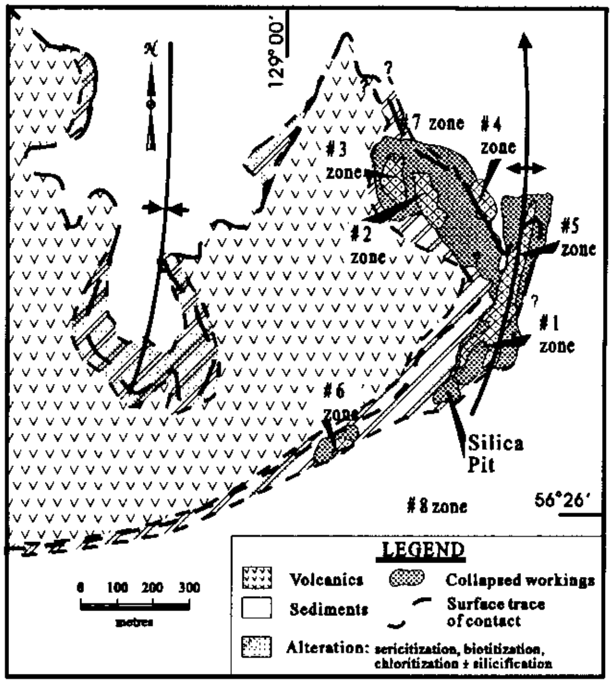

Figure 2. Generalized geology of the Hidden Creek mine area showing the distribution of ore zones and major structures. The Nos. 7 and 8 ore zones are small subsurface deposits indicated by drilling (after Davis, 1993).

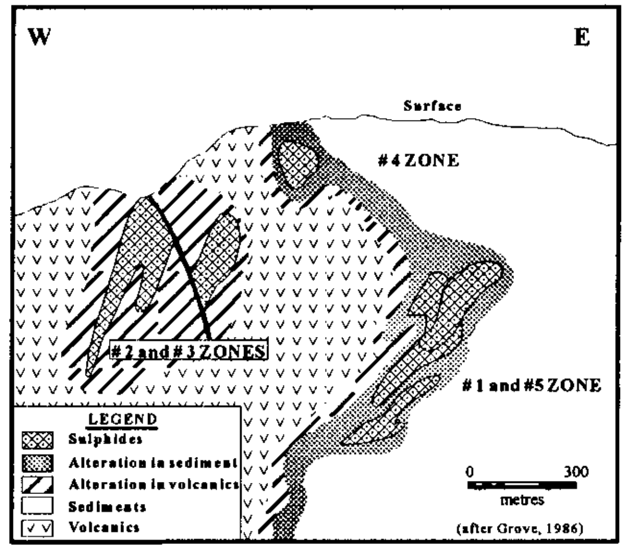

Figure 3. Schematic cross-section from west to east through the Hidden Creek mine showing the distribution of the major ore lenses in the folded volcanic-sedimentary sequence.

REGIONAL GEOLOGY

Recent regional geological mapping in the Anyox pendant by Sharp (1980), Grove (1986), Alldrick (1986) and Macdonald *et al.* (1994) indicates that a thick volcanic sequence of tholeiitic basalt to basaltic andesite with subordinate volcaniclastic layers is overlain by a sequence of siltstone, greywacke and sandstone with minor calcareous and conglomeratic beds. Chert outcrops discontinuously along the volcanic-sedimentary contact. Mafic plutonic rocks occur in several localities in the pendant and may represent the basement to the volcanic sequence. Most recently the geochemistry of volcanic rocks in the pendant has been described by Smith (1993).

GEOLOGY OF THE HIDDEN CREEK AREA

The stratigraphy at the mine site consists of a basal metavolcanic unit overlain by exhalative chert and carbonate lenses of variable thickness, which in turn are capped by a thick turbiditic sedimentary sequence. Rocks in the volcanic-sedimentary sucession are variably altered with mineralogies dominated by chlorite, biotite, sericite and actinolite. Alteration is most intense adjacent to the contact between the volcanic and sedimentary rocks, extending from the footwall volcanic rocks through the exhalative zone and for tens of metres into the hangingwall sedimentary sequence

The Hidden Creek deposit consists of eight distinct sulphide lenses all occurring at or within tens of metres of the sedimentary-volcanic contact (Figure 2). Sharp (1980) reports that the No. 2 and 3 orebodies are located within the footwall metavolcanic rocks; the Nos. 1, 4 and 5 orebodies are located at the volcanic-sedimentary contact and are intimately associated with cherty and carbonate chemical sediments; and the Nos. 6, 7 and 8 orebodies occur stratigraphically above the contact in hangingwall turbiditic sedimentary rocks. Lithogeochemical results presented in this paper show that the Nos. 1, 4 and probably the No. 5 deposits are actually sediment hosted and that further investigation is required to confirm the stratigraphic position of the Nos. 2 and 3 orebodies.

The orebodies are within the hinge zone and the overturned limb of the Hidden Creek anticline (Figure 3), a northerly trending, south and easterly verging structure. The arcuate shape of the contact at surface appears to be the result superposition of at least two phases of deformation and the rotation of the axis of the anticline to a moderate northerly plunge. Deformation in the sedimentary sequence is expressed as open to tight, upright to recumbent folds with wavelengths on a scale of metres to tens of metres. Strong planar and crenulated fabrics in the alteration assemblages, and shear fabrics in the metavolcanic rocks, are the dominant expressions of deformation in these lithologies. The orientation of these structures varies from mainly northtrending throughout most of the map area to westtrending along the southern

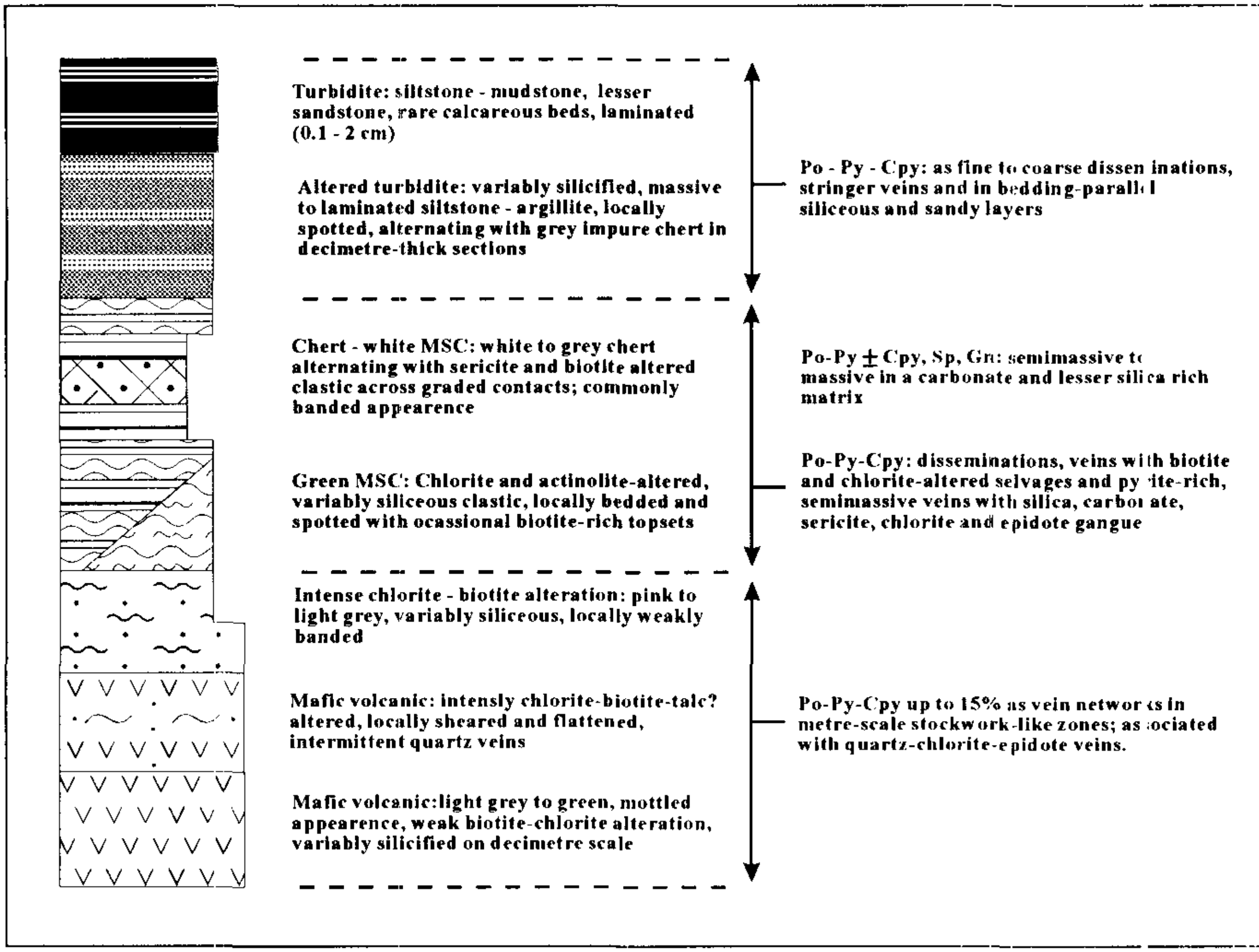

Figure 4. A composite stratigraphic section of the Hidden Creek mine. The section is schematic and represents the gross spacial distribution of the dominant lithological units and alteration assembleges from the basal volcanic sequence *through the contact zone and into the overlying, unaltered sedimentary cap of the ore zones*

edge of the map where structures are subparallel to the contact.

STRATIGRAPHY

Massive to pillowed flows and fragmental metavolcanic rocks form part of the footwall to the Hidden Creek sulphide lenses. These rocks are fine grained to porphyritic and have been altered to assemblages of chlorite, actinolite, biotite, sericite, clinozoisite and zoisite. Pillows, where observed, range from 10 centimetres to 1 metre in longest dimension and typically have length to width ratios of 2:1. Pillow selvages are 1 to 2 centimetres thick, aphanitic and darker than the pillow cores. The interpillow fill consists of aphanitic to fine-grained, black to dark green to reddish coloured rock of predominately chlorite and biotite. In mineralized zones, the pillow selvages and interpillow fill are locally silicified and suphide bearing.

Fragmental rocks crop out in several localities throughout the map area and are commonly recognized in drill core. The rocks consist of subangular to tear-shaped, actinolite-rich mafic clasts, 5 to 30 centimetres long, separated by an anastomosing network of 0.2 to 1-centimetre, aphanitic and fine-grained quartz veins and granular volcanic rock. Individual clasts are flattened and vein networks have consistent trends over tens of metres, imparting a banded appearance to these outcrops. The origin of these rocks is enigmatic as they have a similar appearance, on a small scale, to the silicified pillowed sequences that locally grade into fragmental rocks across zones of more intense deformation.

Thin to thickly bedded saccharoidal chert and carbonate occur along the volcanic-sedimentary contact at the Hidden Creek mine. The chert varies in colour from bone-white to grey, reddish or pale green. Individual beds vary from less than a centimetre to several centimetres in thickness and are separated by sericitic laminae. In drill core, chert intervals vary in thickness from less than a metre to a maximum of about 30 metres. White, coarsely crystalline carbonate occurs as the matrix to the massive pyrrhotite and pyrite, and as discontinuous bands up to 1 centimetre thick where it forms up to 50% of the sulphide intervals. It is closely associated with chert and locally alternates with silica as the matrix to the massive sulphide lenses. Microfossils have not been identified in either the chert or carbonate horizons. The variable thickness of the units and close association with the sulphide lenses suggest that the chert, carbonate and sulphide may have a hydrothermal origin.

An unaltered siltstone-mudstone turbidite sequence forms the hangingwall of the deposit. These rocks consist of laminated to interbedded siltstone, argillite and fine sandstone. Individual beds range from less than a centimetre to tens of centimetres thick; they are commonly massive with thinly laminated tops and rarely display good grading. Flame and load structures mark the boundaries of beds, with crosslaminations preserved in finer layers. Small, discontinuous limestone lenses are common near the base of the sequence immediately overlying the metavolcanics. The lenses are less than a metre thick and occur as boudins within disrupted sedimentary layers.

ALTERATION FACIES

Hydrothermal alteration in the volcanic and sedimentary sequences is most intense and extensive in the vicinity of the Nos. 1 and 5 orebodies where it affects a zone up to 150 metres wide; it decreases in width and intensity laterally along the contact away from the ore zones. Alteration is divisible into three main types: chlorite-biotite-altered volcanic and sedimentary rocks; chlorite and actinolite-altered sedimentary rocks and sericite-biotite-altered sedimentary rocks (Figure 4). Petrography indicates that biotite and actinolite formed later in the paragenetic sequence than the sericite and chlorite assemblages and are probably a metamorphic overprint of hydrothermally altered rocks.

Alteration in the volcanic rocks is dominated by an assemblege of biotite, chlorite and epidote found as discrete veins, in altered selvages to siliceous veins, and as penetrative alteration of the entire hostrock. Alteration increases in intensity toward sulphide and quartz-vein stockwork zones, and stratigraphically up-section toward the sedimentary contact.

Hydrothermally altered and metamorphosed, variably siliceous clastic sedimentary rocks (MSC) overlie the volcanic sequence and form the footwall to the Nos. 1, 4 and 6 ore zones. The basal sedimentary package consists of intensely altered chlorite and biotite-rich rocks. These rocks are commonly associated with an increase in silica and locally grade into pink chert. Rocks at the volcanic-sedimentary contact are commonly so intensely chloritized and biotitized that lithologies can only be identified using lithogeochemical data.

The chlorite-biotite-altered volcanic and sedimentary rocks grade into overlying white to red, sericite biotite-rich clastic sediment (white MSC) and olive-green, chlorite-actinolite-rich clastic sediment (green MSC). These rocks are variably siliceous and range from silica-poor phyllosilicate schists to silica-rich inpure cherts. Transitions between silica-rich and silica-poor zones have a banded or fragmented appearance. Normal-graded bedding and porphyroblasts that are recognized in the green and the white MSC facies may be equivalent to structures in the hangingwall turbidite.

Green MSC stratigraphically overlies biotite-chlorite-altered volcanic rocks in several drillholes that intersect the footwall of the No. 1 ore zone. To the south and north of the No. 1 orebody, the chlorite-biotite sediments grade stratigraphically upward into white MSC which alternates in decimetre to decametre intervals with exhalative carbonate, chert and sulphides, and intervals of unaltered turbidites. Transitions between these intervals are gradational. Where observed, green MSC grades stratigraphically upward into white MSC and then to unaltered turbidite. The presence of chert, white MSC and green MSC in a drillhole along the southern margin of the No. 1 ore zone appears to reflect the lateral zoning from an exhalitive and sericite-dominated hydrothermal system in the vicinity of the silica pit to a chlorite-dominated system underlying the No. 1 ore zone.

LITHOGEOCHEMISTRY

Major and trace element data clearly distinguish between the volcanic, sedimentary and intrusive rocks underlying the Hidden Creek area and provide a chemical basis for characterizing the nature of hydrothermal alteration. Chemically, the least altered mafic volcanic footwall rocks are tholeiitic basalts to basaltic andesites in composition. Sedimentary rocks, including both clastic and exhalative components, are distinguished from the volcanic rocks by higher SiO_2 and lower TiO_2 contents.

Binary immobile element plots can be used to show primary fractionation trends within the volcanic rocks, as well as the effects of alteration on all the rocks. In the TiO_2 *versus* Zr plot (Figure 5a), least altered mafic volcanic rocks plot in two clusters that may be related through fractionation. Similarly, altered mafic volcanic rocks also appear to form two clusters, although the clusters are less distinct, presumably as a result of alteration. The immobile element plot clearly indicates that the sedimentary rocks are not derived from the mafic volcanic rocks, and the mafic dikes are not related to the mafic volcanic rocks. Sedimentary rocks including chert, green MSC, white MSC and turbidites lie along alteration lines emanating from the origin. Displacement of altered samples from their precursor trends reflects a combination of mass loss or gain, dilution by mixing with exhalative silica and carbonate, or high quartz contents in the precursor sediment.

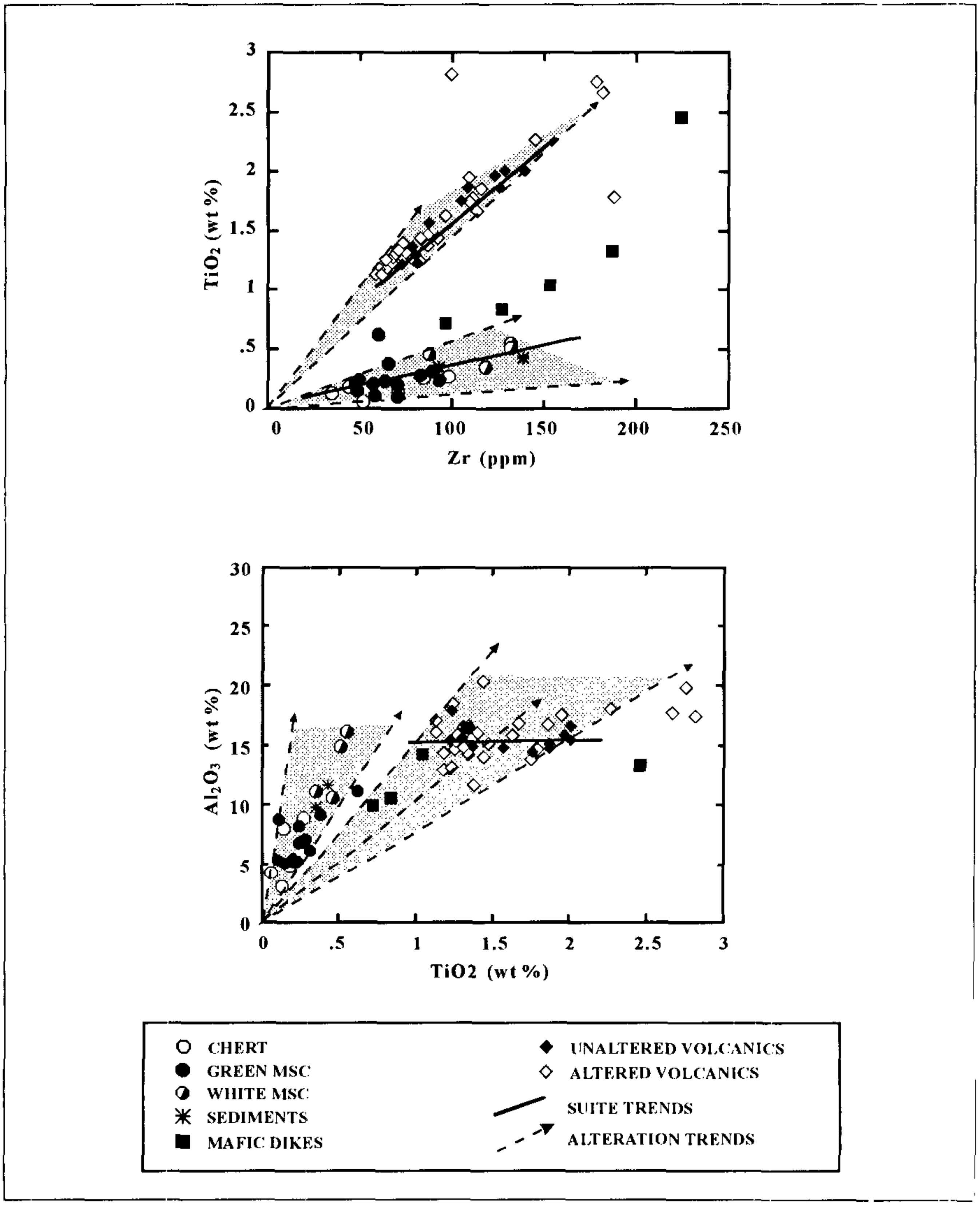

Figure 5. Plots of a) TiO_2 *verus* Al_2O_3 and b) Al_2O_3 *verus* TiO_2 for volcanic rocks, sedimentary rocks and mafic dikes from the Hidden Creek area.

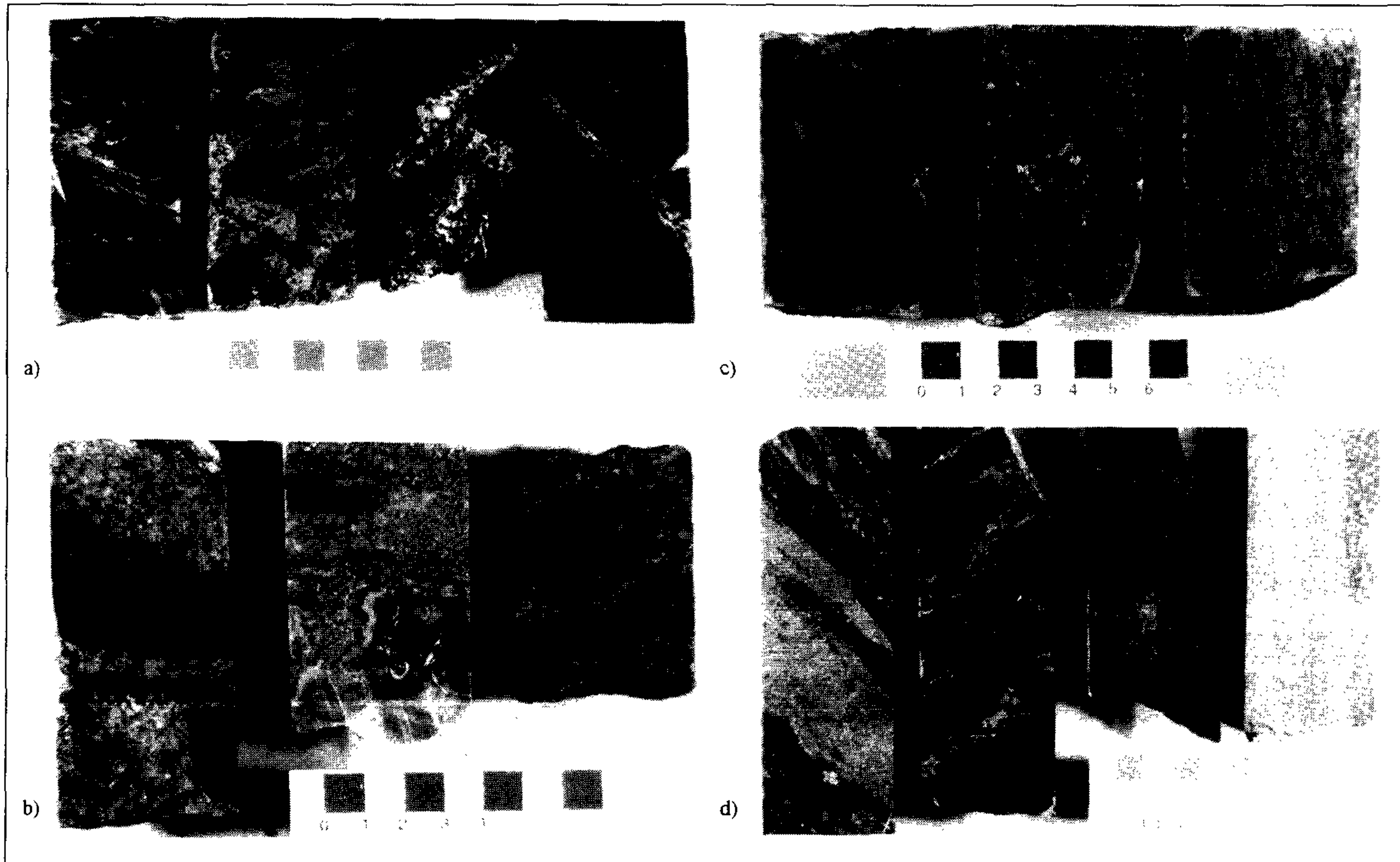

Photo 1. a) Quartz-sulphide veins with darkened chloritized selvages in volcanic rocks b) Carbonate-chlorite-silica-sulphide veins in the metaclastics; c) Pyrrhotite, pyrite and calcopyrite-rich massive sulphides in carbonate matrix; d) Mineralized layers in turbidites

A plot of Al_2O_3 *versus* TiO_2 (Figure 5b) makes a clearer distinction between fractionation processes and alteration processes than the TiO_2 *versus* Zr plot. In Figure 5b, fractionation trends in the volcanic rocks run obliquely to potential alteration trends. As in the previous graph, unaltered volcanic samples plot in two clusters and lie along a potential fractionation trend. Altered volcanic rocks are dispersed around the trend, along alteration lines emanating from the origin for reasons outlined above. The dispersed pattern in the sedimentary rocks appears to represent some combination of primary clastic source variations, and alteration-related mass gains or losses.

Previous authors have never clearly identified the origin or extent of the green MSC unit but have tended to simply associate it with silicified volcanic or volcaniclastic rocks within the contact alteration zone. The green MSC unit has a clastic sedimentary affinity and major and trace element ratios comparable to those in unaltered turbiditic sediments. The green MSC may therefore represent a chlorite-actinolite-altered equivalent to the turbidites, with little or no silicification involved in the alteration. Green MSC rocks are found in drillholes intersecting the footwall of the No. 1 orebody, which indicates that this orebody, the largest in the Hidden Creek mine, is entirely sediment hosted and does not occur at the contact between the volcanic and sedimentary rocks.

MINERALIZATION AND SULPHIDE MORPHOLOGY

Quartz-pyrite-pyrrhotite-chalcopyrite veins occurring in chert, MSC and metavolcanic units stratigraphically below the sulphide lenses probably represent footwall stockwork mineralization. These veins range from less than 0.2 to several centimetres wide and commonly contain quartz. Within intensely chloritzed volcanic rocks, sulphides form feathery textured, braided networks, whereas in siliceous clastic rocks and cherts, sulphides occur as discrete veins with well defined chlorite and biotite-altered selvages (Photos 1 a and b).

Thick intervals of chemical sediments and sulphides occur in several diamond-drill holes and are also exposed in the No. 1, Nos. 2/3 and No. 6 pits. These appear to be lateral equivalents of the mined-out ore zones which Grove (1986) has described as tabular to sheet-like and consisting mainly of pyrite, pyrrhotite and chalcopyrite, with minor sphalerite, galena and magnetite (Photo 1 c). There is a strong association between chalcopyrite and pyrrhotite in the sulphide lenses and underlying vein networks. Pyrite-dominated lenses are copper poor. Semimassive to massive pyrite with minor sphalerite and galena in a matrix of silica and carbonate dominates the stratigraphically lower intervals, in the ore zones. Pyrrhotite, chalcopyrite and pyrite with minor sphalerite occur in stratigraphically higher intervals and form more discrete and massive layers in a carbonate-dominated matrix. In diamond-drill hole 93 D-9, the transition between the two types of massive sulphide interval is characterized by large euhedral pyrite crystals within a finer grained pyrrhotite-chalcopyrite matrix. In the No. 6 pit, the two sulphide intervals are seperated by 1.5 metres of argillite. In the No. 1 pit, a thick pyrite lens occurs within altered turbidite and chemical sediments. It may stratigraphically underlie a pyrrhotite-chalcopyrite-pyrite interval that was intersected in diamond-drill hole 93 D-2, although the transition between the two is not observed.

The clastic and exhalative sequences contain ubiquitous fine to medium-grained disseminated pyrite, pyrrhotite and lesser chalcopyrite. Sulphides also occur in coarse sandstone layers as discrete, bedding-parallel siliceous layers, typically less than 2 centimetres thick, and in more diffuse layers that coalesce into thick semimassive bands (Photo 1 d). Gangue minerals associated with the sulphide bands most commonly include silica, carbonate and sericite, except in the sedimentary footwall of the No. 1 ore zone where carbonate, chlorite and epidote comprise the most common assemblage.

Chloritized turbidites underlie the largest orebodies. Sericitized clastic sediments with asociated exhalites flank and cap the chlorite zone and host much of the mineralization (Figure 4). Soft-sediment deformation is observed in association with coarse disseminated sulphides. Together with the lithogeochemical data, this suggests that mineral deposition was at least partly contemporaneous with early turbidite-mudstone deposition; some of the sulphide lenses were formed after mafic volcanism had ceased, but at the same time as the associated chert and carbonate exhalites.

SUMMARY

A preliminary interpretation of the geological history of the Hidden Creek mine area is: 1) Accumulation of a thick mafic volcanic sequence composed of basaltic to basaltic andesite flows, pillowed flows and lesser fragmental components.

2) Deposition of a basal turbidite siltstone-mudstone sequence (the turbidites are not related to the mafic volcanics).
3) Precipitation of exhalative chert, carbonate and sulphides contemporaneous with sediment deposition.
4) Contemporaneous hydrothermal fluid circulation resulting in the development of stockwork mineralization and intense sericite and chlorite alteration in the volcanic, clastic and exhalative sedimentary rocks underlying the ore zones.
5) Continued accumulation of a thick turbiditic siltstone-mudstone sequence on the cessation of hydrothermal activity;
6) Deformation and regional metamorphism resulting in biotite-actinolite alteration assemblages.
7) Intrusion of calcalkaline mafic dikes.

ACKNOWLEDGMENTS

The authors would like to thank Cliff James and TVI Pacific Inc. for permission to work on the Anyox property, and for making available historical geological material for the study. We would also like to thank John Thompson, Dick Chase, Peter Lewis and Claude Aussant for their contributions to the project during and after the field season. Thanks to Bob Beck for cheerful and capable field assistence. And finally a special thanks to Teddy, Jesse and Fud for all the help and friendly banter during our stay at Anyox.

This research forms part of the Mineral Deposit Research Unit project on Volcanogenic Massive Sulphide Deposits of the Cordillera, supported by the Natural Sciences and Engineering Research Council of Canada, the Science Council of British Columbia and eleven mining and exploration member companies.

REFERENCES

Alldrick, D.J. (1986): Stratigraphy and Structure of the Anyox Area (103P/5); *in* Geological Fieldwork 1985, *B.C. Ministry of Energy, Mines and Petroleum Resources,* Paper 1986-1, pages 211 - 216.

Davis, J.W., Aussant, C.H. and Chisholm, R.E. (1992): Geological, Geochemical and Geophysical Report on the Anyox Property, Skeena Mining Division; *TVI Copper Inc.*, private company report.

Grove, E.W. (1986): Geology and Mineral Deposits of the Unuk River - Salmon River - Anyox Area; *B.C. Ministry of Energy, Mines and Petroleum Resources,* Bulletin 63

Macdonald, R.W.J., Barrett, T.J., Sherlock, R.L., Chase R.L., Lewis, P. and Alldrick, D.J. (1994): Geological Investigations of the Hidden Creek Deposit, Anyox, Northwestern British Columbia; *in* Geological Fieldwork 1993, Grant, B. and Newell, J.M., Editors, *B.C. Ministry ofEnergy Mines and Petroleum Resources*, Paper 1994-1, pages 351 356.

Sharp, R.J. (1980): The Geology, Geochemistry and Sulphur Isotopes of the Anyox Massive Sulphide Deposits; unpublished M. Sc. thesis, *University of Alberta,* 211 pages.

Smith, A.D., (1993): Geochemistry and Tectonic Setting of Volcanics from the Anyox Mining Camp, British Columbia; *Canadian Journal of Earth Sciences*, Volume 30, pages 48-59.