Structure and alteration related to gold-silver veins at the Skukum Creek deposit, southern Yukon

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ABSTRACT

A detailed evaluation of structure and alteration related to gold- and silver-rich, base metal-bearing veins was completed at the Skukum property as part of the 2002 mineral exploration program.

The structural setting is an east-trending sinistral strike-slip system bounded by the Berney Creek and Goddell faults to the south and north, respectively. The deposit comprises northeast-trending quartz-sulphide mineral shear veins that formed during syn-tectonic intrusion of rhyolite and andesite dykes related to the Eocene Mount Skukum caldera complex. A genetic relationship between mineralization and certain rhyolite dykes is indicated by patterns of alteration and mineralization. Dilational, northeast-trending structures interconnect and splay off the controlling faults, and host extensional quartz-sulphide mineral veins.

At Skukum Creek the main gold-silver-bearing minerals are electrum and freibergite, which precipitated with late galena-stibnite mineralization, whereas refractory gold in arsenopyrite is the main style at Goddell. A geological model is proposed that facilitates identification of prospective structures within the property.

RÉSUMÉ

Dans le cadre d'un programme d'exploration minière réalisé en 2002, on a terminé l'évaluation détaillée de la structure et de l'altération associées aux filons de métaux communs riches en argent et en or sur la propriété de Skukum.

Le cadre structural est un jeu de décrochements senestres à direction est qui est limité par les failles de Berney Creek et de Goddell au sud et au nord, respectivement. Le gisement est formé de filons de cisaillement à quartz-sulfures à direction nord-est mis en place au cours d'une intrusion syntectonique de dykes de rhyolite et d'andésite associés à l'ensemble de caldéras éocènes de Mount Skukum. Il ressort clairement qu'il existe un lien génétique entre la minéralisation et certains dykes de rhyolite. Les structures de dilatation à direction nord-est relient les failles de contrôle et s'en éloignent en divergeant; ces stuctures logent des filons de distension à quartz-sulfures.

Au gisement de Skukum Creek, les principaux minéraux aurifères-argentifères sont l'électrum et la freibergite qui ont précipité avec la minéralisation tardive de galène-stibnite, alors que c'est de l'or réfractaire dans de l'arsénopyrite qui caractérise le gisement de Goddell. Un modèle géologique est proposé pour faciliter l'identification des structures prometteuses dans cette propriété.

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INTRODUCTION

The Skukum Creek gold–silver deposit is located within the Skukum property, 60 km southwest of Whitehorse in the Wheaton River mining district. The 171.1 km^2 property also encompasses the Mt. Skukum gold mine, which produced 77 790 ounces (2419 kg) of gold from 233 440 tonnes of ore between 1986 and 1988 (McDonald, 1987 and 1990), the Goddell gold deposit (Hart, 1992a), the Becker-Cochran antimony deposit (Hylands, 1966), and additional gold, silver and copper prospects.

This paper describes a detailed field and petrographic examination of structure and alteration at Skukum Creek. Work included a review of published geological reports, and unpublished exploration reports and data; examination of underground workings and drill core; optical petrography on 63 polished thin sections; and scanning electron microscopy on 26 sections. The paper first summarizes regional and local geology, followed by a review of exploration history and results from drilling in 2002. Structure, alteration and mineralization at Skukum Creek are then described, and the paper concludes with a district-scale geological model.

REGIONAL AND LOCAL GEOLOGICAL SETTING

The regional geological setting of the Skukum project area is described in Wheeler (1961), Doherty and Hart (1988),

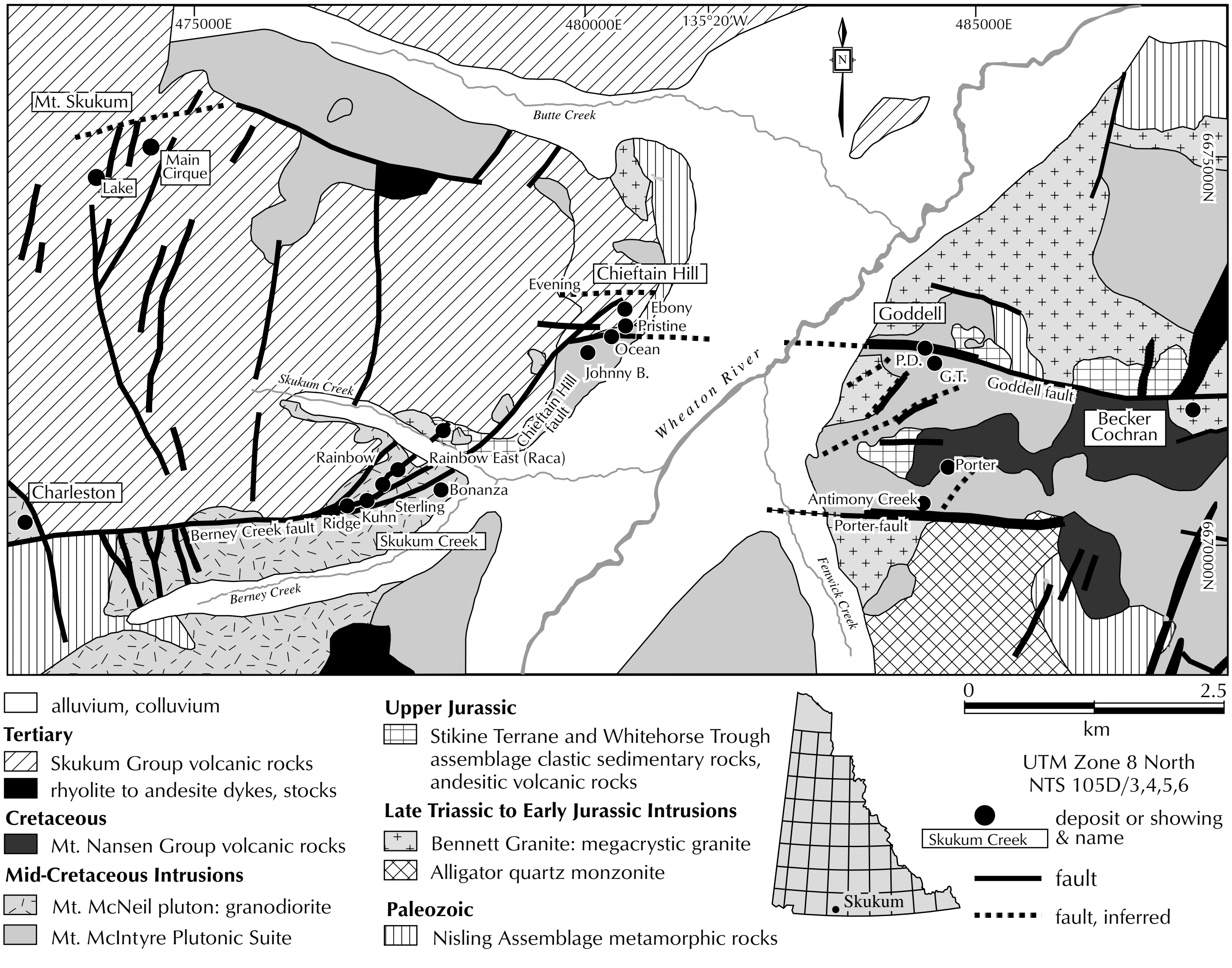

Figure 1. *Geology of the Skukum project area. Data compiled from Hart and Radloff (1990) and unpublished company maps.*

and Hart and Radloff (1990), from which most of the following is summarized. The oldest rocks in the area comprise gneiss of probable Paleozoic age, assigned to the Nisling Terrane by Hart and Radloff (1990), and Jurassic andesitic volcanic and siliciclastic sedimentary rocks of the Stikine Terrane and Whitehorse Trough overlap assemblage, respectively (Fig. 1).

Mesozoic plutonic rocks underlie much of the project area and separate the Jurassic units and Nisling Assemblage into isolated domains (Fig. 1). The most abundant rock types in the region (Hart and Radloff, 1990) are metaluminous Cretaceous intrusions of the Coast Plutonic Complex that comprise the Mt. McIntyre Plutonic Suite (96-119 Ma), which includes the Mt. Ward granite and Carbon Hill quartz monzonite, and the Whitehorse Plutonic Suite (116-119 Ma), locally represented by the Mt. McNeil granodiorite (Fig. 1). Intermediate Cretaceous volcanic rocks of the Mt. Nansen Group are present regionally, and in the project area occur east of the Wheaton River (Fig. 1). Jurassic plutonic rocks, such as the Bennett Granite (regional U-Pb ages around 175 Ma; J.K. Mortensen, pers. comm., 2002), are also widely distributed through the district.

The early Eocene Mount Skukum volcanic complex, part of widespread late Paleocene to early Eocene felsic to intermediate volcanism of the Skukum Group (Smith, 1982 and 1983; Pride, 1986), is a caldera sequence that underlies the western portion of the study area (Fig. 1). The Mount Skukum complex consists of up to 800 m of mainly porphyritic andesitic flows and tuff exposed over an area of approximately 200 km^2 (Fig. 1; B.W. McDonald et al., unpublished company report for Total Energold, 1990). These volcanic rocks are locally separated from pre-Tertiary rocks by curved, east- to northeast-trending structures such as the Berney Creek fault (Fig. 1) and Wheaton lineament (coincident with the Wheaton River valley on Fig. 1) that have been inferred to be syn-volcanic, caldera-bounding faults (Hart and Radloff, 1990). These and parallel structures host or control gold-silver mineralization in the district.

The structural history of the region that is most relevant to the Skukum Creek deposits began in the early Mesozoic. Strata of the Whitehorse Trough are affected by open to tight, northwest-trending folds that probably formed in the Late Jurassic to Early Cretaceous. The folds are superimposed on probable pre-Triassic metamorphic fabrics and the northwest-trending Tally-Ho shear zone, a major Late Triassic structure 15 km northeast of the project area that defines the eastern limit of Nisling Terrane exposures. The brittle, dextral Llewellyn fault system reflects Late Cretaceous and early Paleocene reactivation of the Triassic Tally-Ho shear zone (Hart and Radloff, 1990), and caldera-bounding structures may be reactivated subsidiary faults related to the Llewellyn Fault.

Known mineralization in the district occurs at the Mount Skukum mine, and in the Skukum Creek, Chieftain Hill, Goddell, Becker-Cochran and Charleston zones (Fig. 1). Skukum Creek has received the most exploration attention and comprises the Ridge, Kuhn, Sterling, Rainbow, Rainbow East (formerly Raca) and Taxi zones (Fig. 2). At Goddell, mineralization exposed on surface and intersected by drilling from underground has been called the Golden Tusk and PD zones (G.T. and P.D. on Fig. 1), respectively, but these are separated by a gap in drilling and may be continuous. Host rocks at Mount Skukum and the Charleston zone are Eocene volcanic rocks (Fig. 1). Intrusions are the main hosts at Skukum Creek (Cretaceous Mt. McNeil granodiorite), Goddell (Cretaceous Carbon Hill pluton), Becker-Cochran (Jurassic Bennett Granite) and Chieftain Hill (Cretaceous Mount Ward granite); intermediate volcanic rocks of probable Jurassic age host some veins on Chieftain Hill, and also at the Rainbow East vein where Jurassic Bennett Granite is also present (Fig. 1). Minor rock types at Skukum Creek include dykes or small, irregular bodies of biotite granite, monzodiorite, monzonite, and pegmatite and aplite that mostly appear to crosscut the main Mt. McNeil pluton; they did not substantially influence structure or hydrothermal activity and are not discussed further. A small volume of conglomerate lies beneath cover between the Rainbow and Rainbow East zones and is considered part of the Jurassic Tantalus formation.

EXPLORATION HISTORY

The Skukum Creek area was originally staked in 1922 to cover anomalous gold and antimony showings. Between 1964 and 1967, Yukon Antimony Corporation staked claims, including ground covering the veins at Skukum Creek, for copper and antimony potential. The company completed road access and several bulldozer trenches. Claims at Skukum Creek were again staked in 1973 by W. Kuhn, and were transferred, first to E. Bergvinson in 1980, and then from Bergvinson to Omni Resources Ltd. in 1984. The area was explored intermittently on surface during this period.

Systematic exploration at Skukum Creek began in 1985, and included geological mapping, trenching, soil sampling, and diamond and reverse circulation drilling. The work outlined 10 zones anomalous in gold, including Rainbow, Kuhn and Sterling, which were the focus of additional mapping and 8301 m of diamond drilling in 53 holes in 1986. A production-sized adit was collared at 1300-m elevation in 1987 and 823 m of underground work was completed along and across the Rainbow and Kuhn zones, followed by 7446 m of diamond drilling in 80 surface and underground holes.

In 1988, Skukum Gold Inc. and Omni Resources formed a joint venture to bring Skukum Creek to production. Surface mapping and geophysical surveys were completed in the Taxi zone. Additional underground development included a 1571-m decline to the 1218-level, a new adit on the 1350-level at Rainbow, and a raise to the 1350-level at Kuhn; 6581 m of underground and surface drilling in 37 holes further tested the Kuhn, Rainbow and Sterling zones.

The property reverted to Omni in 1991, when the joint venture failed to put the property into production. Later that year, Wheaton River Minerals Ltd. purchased the assets of Mt Skukum Gold Mining Corp., which included the Mount Skukum property and mill, and penned an agreement with Omni to purchase the Skukum Creek property. Wheaton declined to proceed, and in 1994 the Skukum Creek claims and the Mount Skukum claims and mill were transferred to Omni. In 1995 Omni acquired a 70% interest in the Goddell property from Arkona Resources, and consolidated three gold deposits and numerous showings into the Skukum property. During 1996 Omni drifted 100 m off the 1225-m level and drilled 1647 m in 15 holes that extended Rainbow zone mineralization to the 1050-level. In 1996 Trumpeter Yukon Gold Inc. negotiated an option, exercised in 1997, that gave them a 50% interest in the Skukum property. In that year, 2739 m of diamond drilling in seven surface

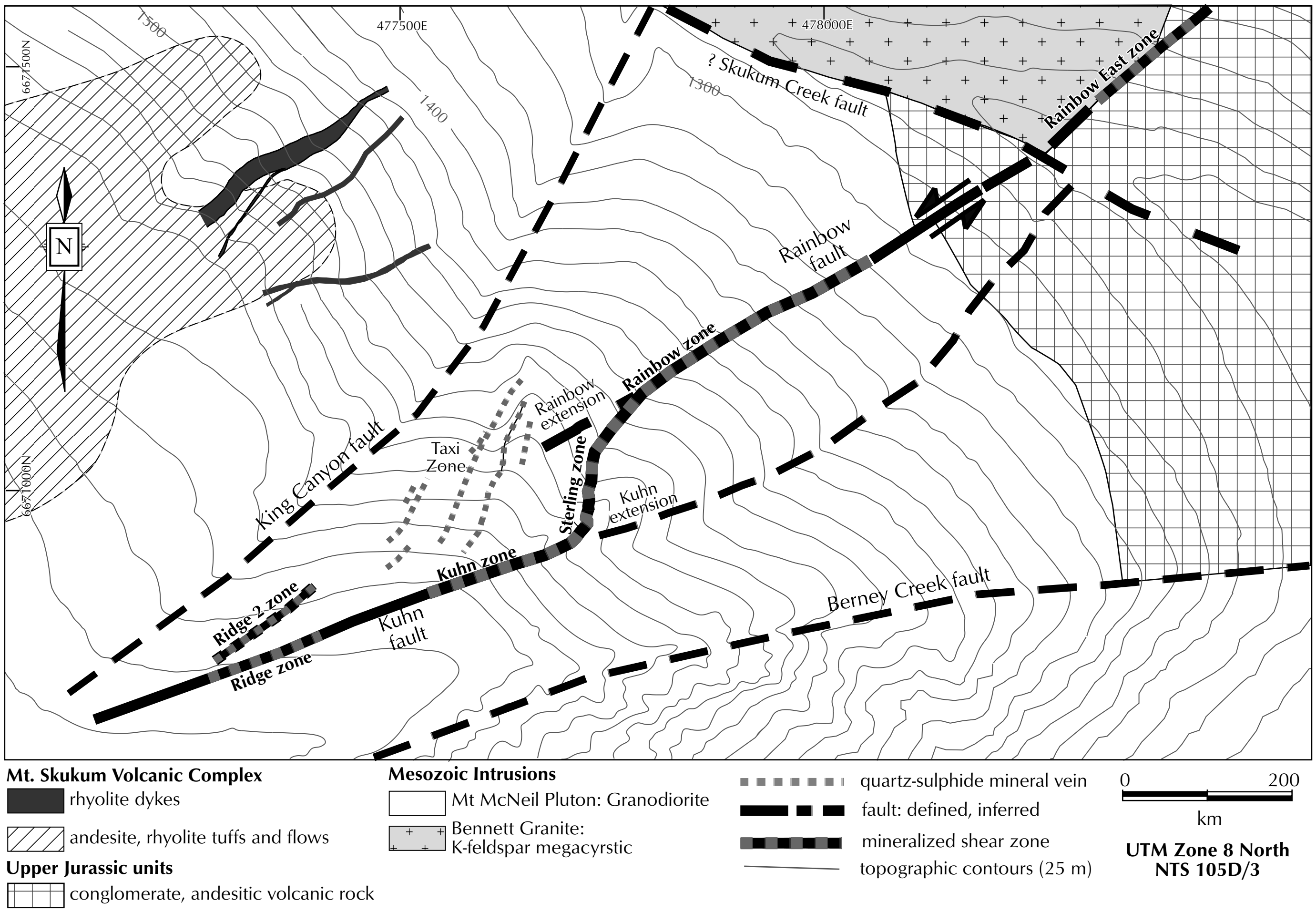

Figure 2. *Geological map of the Skukum Creek zone, compiled from company maps.*

holes tested the Ridge and Rainbow East zones, and led to discovery of the Ridge 2 zone in the footwall to the Ridge zone. Mineralization similar to that at Rainbow was encountered at Rainbow East. In 2000, Trumpeter Yukon Gold and Omni amalgamated into Tagish Lake Gold Corp. The Ridge and Ridge 2 zones were further tested in 2001 by 1502 m of drill core in four holes.

2002 EXPLORATION RESULTS

Drilling continued at Skukum Creek in 2002, with 2502 m in 15 underground holes (Fig. 3) designed to increase and improve the resource base estimate. Mineralization was intersected in each drill hole with results from the Rainbow zone of 3.9-33.5 g/t Au and 62-1627 g/t Ag across widths of 0.6 to 13.6 m; these are comparable to most historical intersections of the mineralized zones. The drilling had three other important results. The first was the determination of the geometry of the Portal dyke, which had historically been considered to intrude along a fault that terminated mineralization at the east end of the Rainbow zone. The recognition that the dyke crosscuts the mineralized zone at a low angle, combined with the similarity of mineralization at Rainbow East, now suggests the potential for mineralization in the footwall of the dyke. Second, one drill hole documented mineralization in the Sterling zone; this supports the structural model outlined in the following discussion, and indicates additional potential at depth in this area. Finally, drilling in the Kuhn zone intersected mineralization and confirmed continuation of the known, steeply northeast-raking ore shoot that is related to the junction of the Kuhn and Sterling zones, thereby confirming the exploration potential of this area.

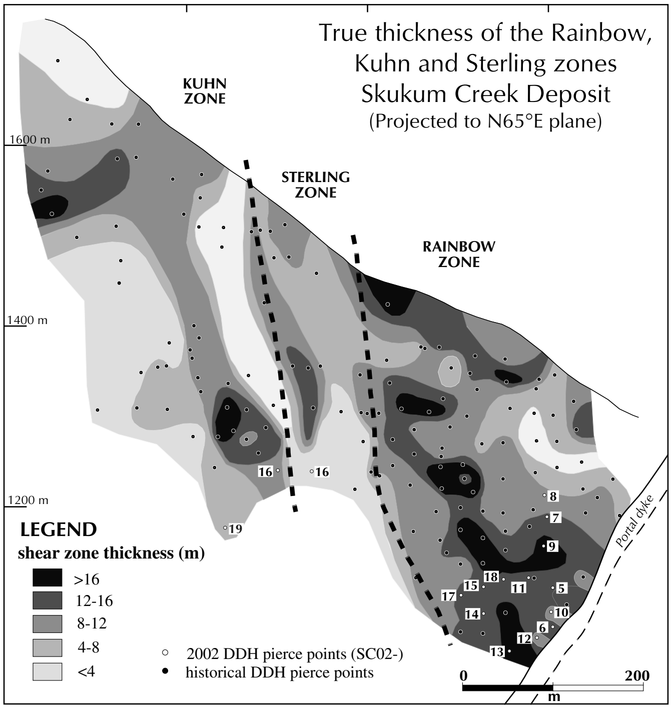

Figure 3. *Long-section through the Skukum Creek zone showing total zone thickness and location of drill holes. Data are projected onto a 065° plane.*

GEOLOGY

The Skukum Creek zone includes the Rainbow East, Rainbow, Sterling, Kuhn and Ridge zones (Fig. 2). These occur along a 1.3-km segment of a fault system that comprises the parallel, northeast-trending and southeast-dipping Rainbow and Kuhn semi-brittle shear zones and the north-trending, steeply east-dipping Sterling zone that structurally connects them (Fig. 2). The King Canyon fault, a northeast-trending splay off the Kuhn fault, and the Skukum Creek fault, postulated to underlie the Skukum Creek drainage (Fig. 2), are not known to host mineralization. Mineralized extension veins with northeast trend occur in the Taxi zone, north of the Kuhn shear zone.

GENERAL FORM OF MINERALIZED ZONES

The Skukum Creek zones lie within a semi-brittle shear zone that comprises rhyolite and andesite dykes, monolithic rhyolite and polylithic phreatomagmatic breccias; second-order semi-brittle shear zones that include cataclasites and stylolitic pressure solution surfaces and quartz-sulphide mineral veins; and late, brittle, gouge-filled faults (Fig. 4). The formation of these features during a protracted, syn-tectonic igneous and hydrothermal event, except perhaps for the latest brittle faults, is supported by 1) mineralized vein fragments in phreatomagmatic breccias; 2) deformed veins as well as veins that cut shear fabrics; 3) a quartz-sulphide mineral matrix to some hydrothermal breccias; 4) a spatial relationship among veins, alteration, shear zones and dykes; and 5) kinematically compatible orientations of veins and second-order faults/shears with shear sense on first-order faults.

RHYOLITE AND ANDESITE DYKES

Rhyolite and andesite dykes form the greatest proportion of the Rainbow and Kuhn zones (Fig. 4). Single or multiple bodies of either or both types of dyke may be present along a given zone segment. Dykes are typically lenticular and extend tens of metres along strike, but are possibly more continuous down-dip; terminations are commonly abrupt and reflect dismemberment by the main shear or later, brittle faults.

MONOLITHIC AND POLYLITHIC BRECCIAS

Both monolithic and polylithic breccias are spatially related to dykes. Monolithic breccias contain rhyolite fragments of highly variable size (mostly <5 cm) and rounding in a sericite-chlorite matrix. Matrix- and clast-supported breccias locally occur in the same body. The thickness of breccia bodies ranges from <10 cm to several metres. Monolithic breccias locally grade into unbrecciated rhyolite dykes, but contacts with other rock types are sharp. They are most abundant between the 1200- and 1350-levels in the Rainbow zone, and are more sporadic in the Kuhn and Sterling zones. Although most breccias are foliated, altered and cut by veins, a syn-mineral timing for some is indicated by rare sulphide mineral-rich vein fragments.

Polylithic breccias mostly contain <30% angular to rounded fragments 0.1 to 10 cm in size that can include any combination of altered granodiorite, rhyolite, andesite, monzonite, and lesser quartz-sulphide mineral vein material in a sericite-chlorite-quartz ± pyrite matrix. Contacts are generally sharp with host rocks, but are locally gradational with monolithic rhyolite breccias. They are largest and most common between the 1000- and 1200-levels at Rainbow, and many are 2 to 10 m thick and extend for at least 40 m along strike; at Kuhn they occur mostly below the 1400-level. The local, weak deformation, and restriction of mineralization to vein fragments indicate late to post-mineral timing.

QUARTZ-SULPHIDE MINERAL VEINS AND BRECCIAS

Most mineralization occurs in quartz veins that formed within and parallel to the main shear zones along slip surfaces and dyke margins. The veins are variably deformed, and the mostly fine-grained sulphide minerals occur in fractures, along pressure solution seams, and in breccia matrices. Initial formation in open space is indicated by prismatic quartz bands; and multiple episodes of vein re-opening are suggested by alternating sulphide-mineral and quartz-rich bands. The Rainbow and

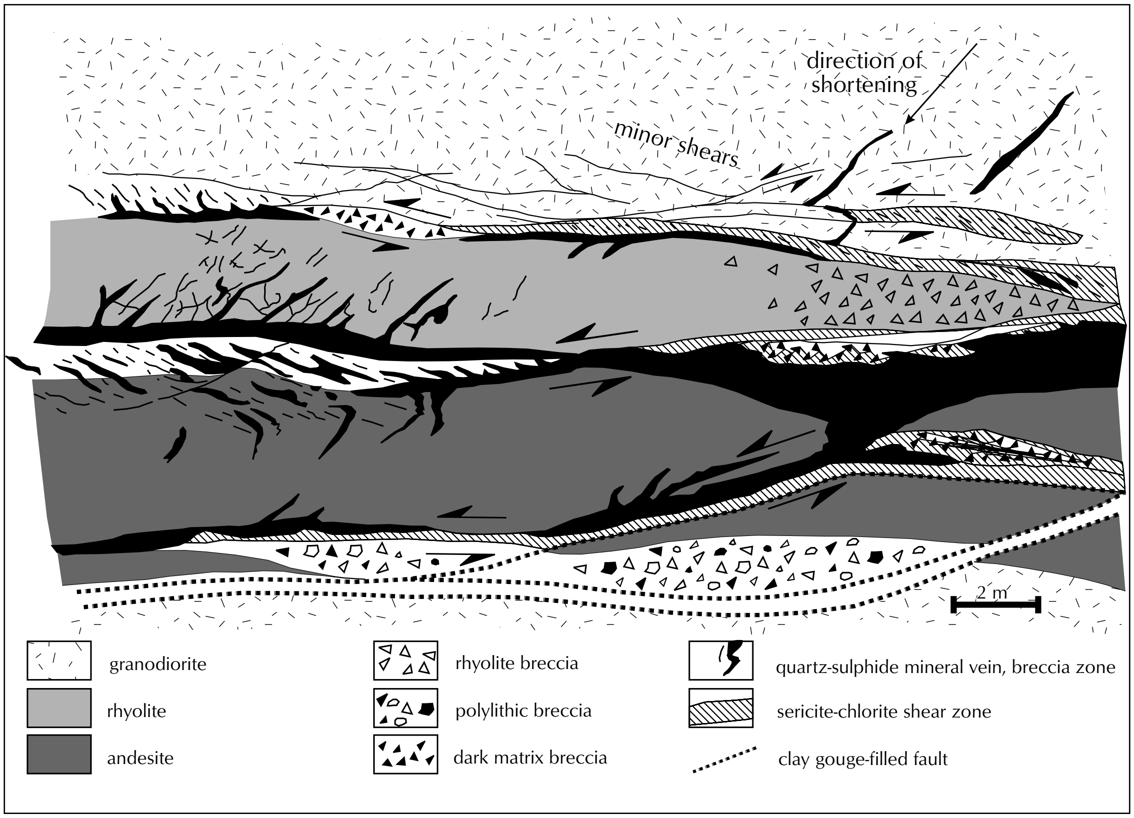

Figure 4. *Schematic plan view of typical features and relationships in the Rainbow zone. The zone is a well layered, heterogeneous zone of andesite and rhyolite dykes, hydrothermal and phreatic breccias, shear zones, quartz-sulphide mineral veins and late brittle faults filled with clay gouge. See text for discussion.*

Kuhn zones contain multiple veins and single veins. Individual veins are commonly lenticular, range up to >5 m thick and extend for tens of metres along strike. Greater continuity down-dip is suggested by steep easterly plunges in the thickest parts of the veins and of the shear zone overall; and a shallow, second-order easterly plunge may reflect modification of ore shoot geometry in the slip direction of late, brittle faults (Fig. 3).

The main quartz-sulphide mineral veins are commonly brecciated and textures indicate formation by both cataclastic and hydrothermal processes. Breccias are mostly composed of quartz-sulphide mineral vein and altered wallrock fragments in a grey matrix. The matrices of cataclastic breccias range from primarily deformed quartz-sulphide mineral veins, to mostly phyllosilicate-rich, sulphide mineral-bearing, non-vein material. Some breccias have a hydrothermal quartz-sulphide mineral matrix with fragments of deformed quartz-sulphide material. These breccia styles can grade laterally into one another, and reflect varying tectonic intermixing of shear zone matrix and brecciated quartz vein material. Shear zones and cataclasites can also grade laterally into quartz-sulphide mineral veins through transitional zones of brecciation (Fig. 4).

Volumetrically minor mineralization is found in quartz-sulphide mineral extension veins that occur as sheeted sets partially transposed into foliation within the main shear zones, and as discrete, north- to northeast-trending veins outside the main shear zones (e.g., Taxi zone; Fig. 2). In the workings, quartz-sulphide mineral extension veins are generally spaced >5 m apart, lack alteration envelopes, are mostly 0.5 to 5 cm in thickness and commonly at least 4 m in length; and generally have a northeast strike and northwest dip (Fig. 5b). They are cut by late-mineral, narrow, commonly vuggy carbonate veinlets.

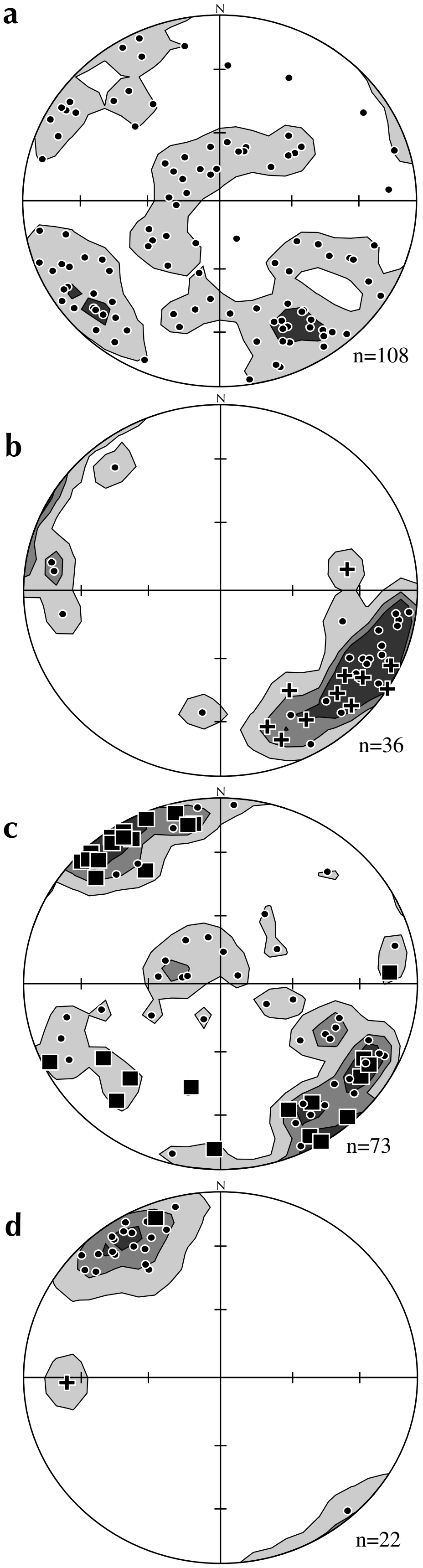

Figure 5. *Contoured equal area (Schmidt) projections of poles to major and minor structures and vein types.* ***(a)*** *Minor shear zones outside the Rainbow and Kuhn zones.* ***(b)*** *Quartz-sulphide mineral extension veins. Contouring peak 209/75. Pluses measured from maps of Taxi zone; circles from measurements underground in the Rainbow zone.* ***(c)*** *Poles to brittle, gouge-filled faults in Rainbow underground workings. Squares are faults with >1 cm of gouge.* ***(d)*** *Poles to Rainbow zone slip surfaces (shear zones). Contouring peak is 056/79. The plus and square indicate the average trend of the Sterling and Kuhn zones, respectively, as determined from historical maps.*

STRUCTURE

DISTRICT-SCALE FAULTS

The structural history of the Skukum Creek deposit is inferred to be related to district-scale faults which include the east to northeast-trending Berney Creek, Chieftain Hill, Goddell and Porter faults (Fig. 1). These faults probably form a single, anastomosing and bifurcating system, and each fault contains Eocene dykes and gold-silver ± antimony mineralization. General descriptions of these structures are available in Hart and Radloff (1990), McDonald et al. (unpublished company report for Total Energold, 1990) and Hart (1992a,b,c,d).

RAINBOW, KUHN AND STERLING ZONES

The Rainbow zone is oriented 050-070°, dips 65-85° to the southeast, and extends 400 m along strike and down dip. The Rainbow East zone may be the eastern continuation of the Rainbow zone (Fig. 2). The Kuhn zone is a 200-m-long mineralized segment of the Kuhn shear zone, which has slightly more easterly (065-080°) trend and steeper southeast dip than the Rainbow zone. Kuhn and Rainbow are linked by the north-trending, steeply east-dipping Sterling zone (Fig. 2). The Sterling zone is 180 m long and has characteristics similar to the Rainbow and Kuhn zones. The juncture between the three zones defines a continuous, S-shaped bend with steep, east-plunging inflection points. Most dykes and shear zones in the Rainbow and Kuhn zones bend into the Sterling zone, but some extend beyond the juncture along the strike of the main shear zones where they form the Rainbow Extension and Kuhn Extension zones.

Shear zones at Skukum Creek form a braided network commonly developed on the margins of, or between, andesite dykes, rhyolite dykes, and associated monolithic and polylithic breccias. They locally cut across the dykes to form lenticular, discontinuous lozenges of dyke rock separated by thin slivers of shear zone material (Fig. 4). Multiple shear zones are commonly present across the width of the zones, and typically vary from <1-cm-thick slip surfaces to broader zones of foliated cataclasite (intensely fractured rock) up to several metres in width. Shear fabrics are strongest in altered granodiorite within and adjacent to the zones, and weakest in rhyolite dykes, which behaved as comparatively rigid blocks.

The main shear zones consist of sericite-chlorite phyllite and foliated cataclasite interlayered with foliated wallrock and quartz-sulphide veins (Fig. 4). Shear zones are commonly cored by lithified, foliated, fine-grained cataclasite with a matrix of sericite-carbonate-quartz ± chlorite ± sulphide minerals. Angular to subrounded fragments of quartz, rhyolite, quartz-sulphide mineral vein and/or altered granodiorite are abundant, are generally <1 cm in diameter, and typically form <30% of cataclasites which are mostly matrix-supported. Internal strain in quartz fragments is typified by undulose extinction without evidence for crystal plastic deformation (i.e., dynamic recrystallization). Cataclasites commonly grade outward into foliated wallrocks with well developed spaced stylolitic pressure solution surfaces defined by sericite-chlorite and/or sulphide minerals. Pressure solution fabrics overprint, and are found in fragments within, the cataclasites, thereby demonstrating that pressure solution and cataclasis operated synchronously.

The main shear zones are surrounded by structural damage zones 5 to 10 m in width that are defined by minor shears that formed mostly in the footwall. More widely spaced minor shears extend up to at least 150 m from the main shear zones. Three orientations of shears and veins were measured (Fig. 5a,b): 1) northwest strike, steep northeast dip and normal, northeast-side-down displacement; 2) east to northeast strike with steep south to southeast dips, parallel to the main zones; and 3) shallow structures with mostly south to southwest dips. A sinistral shear sense is indicated by foliation oriented 10-30° to narrow cataclasites and slip surfaces.

Kinematic indicators in sheared veins suggest a left-lateral shear sense with a reverse (southeast-side-up) component, compatible with formation during left-lateral displacement along the Rainbow and Kuhn shear zones. The orientations of extension veins are also compatible with sinistral displacement on these shear zones. The slip direction on the main Rainbow shear zone, calculated from measurements of oblique cleavage and shear bands (Fig. 5d), indicates a shallow westerly plunge. This plunge is approximately orthogonal to the steep plunge of the thickest parts of the shear zones (Fig. 3), a pattern that would develop if dilation occurred at bends and steps during displacement on the controlling structures.

LATE BRITTLE FAULTS

Brittle, gouge-filled faults are the youngest structures in the mineralized zones. They exploit shear zones, veins and dyke contacts, and exhibit the same three orientations recognized in minor shears and veins (Fig. 5c). The larger faults occur within the main zones as single seams or braided networks. Kinematic indicators consistently suggest left lateral/normal shear sense, but magnitude of displacement could not be determined. Brittle faults commonly cross the main shear zones and displace dykes, shears and quartz-sulphide mineral veins; given their sinistral movement, tectonic thickening of the zones results where brittle faults pass, from east to west, from hanging wall to footwall.

STRUCTURAL MODEL

A simplified structural model for the Skukum Creek zone is shown on Figure 6. The main structures are the Rainbow and Kuhn faults, which represent probable splays off the Berney Creek fault to the south. Kinematic indicators suggest that deformation reflects northeast-directed shortening with 1) left lateral displacement on shear zones; and 2) formation of northeast-trending, steeply-dipping extension veins at a high angle to σ_3. Most mineralization thus far identified occurs on the Rainbow and Kuhn faults near the Sterling zone step-over, a classic dilational jog setting.

ALTERATION AND MINERALIZATION

Alteration at Skukum Creek occurs as pervasive and fracture-controlled K-feldspar, chlorite-sericite-carbonate, and epidote assemblages within and adjacent to the main shear zones. Most alteration formed during a single, protracted hydrothermal event likely related to Eocene volcanism, but a few effects may be older and related to cooling of Cretaceous intrusions. Argillic alteration occurs only within late, brittle faults and is not discussed further.

PRE-SHEAR VEINS

These comprise barren quartz and magnetite-pyrite-chalcopyrite veins hosted primarily by the Mt. McNeil granodiorite. Both types are rare, sinuous to planar and mostly <2 cm in width. The magnetite veins have weak albitic alteration envelopes, and molybdenite was found in one quartz vein. Both vein types are cut by shear-related veins, have characteristics compatible with formation at high temperature, and are interpreted to be related to cooling of Cretaceous intrusions.

EPIDOTE-K-FELDSPAR VEINS

These veins are abundant throughout the Cretaceous intrusions at Skukum Creek. They are planar and are mostly <5 mm in width. They are dominated by epidote with trace to minor calcite and quartz, and locally contain hematite and/or chlorite. They have K-feldspar envelopes from <1 to several centimetres in width that also contain epidote, calcite and rare pyrite; and igneous magnetite remained partly stable. Their timing is unclear. They are

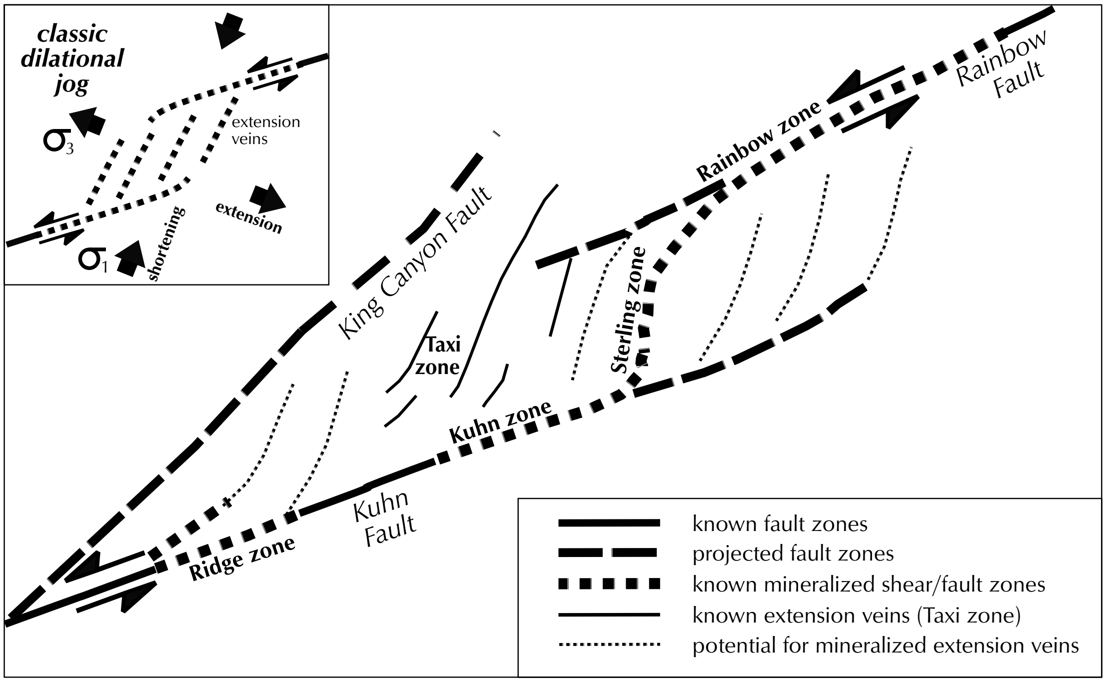

Figure 6. *Structural model for the Skukum Creek zone during mineralization and sinistral displacement on the controlling shear/fault zones. The sinistral shear sense interpreted from underground relationships is opposite the dextral sense suggested by Hart (1992b), who interpreted kinematics on general vein morphology and orientation.*

found in unsheared sets without preferred orientation, and at the scale of observation have no spatial relationship to the main shear zones. They crosscut magnetite veins, but are cut by veins related to the main shear zones. They are provisionally considered intrinsic to the Cretaceous intrusive complex, but they may be related to sheared epidote veins that are part of the main hydrothermal event (see below).

K-FELDSPAR ALTERATION

K-feldspar alteration is the earliest assemblage related to mineralization. It is minor and found mostly in the Ridge and Taxi zones. It is only evident in stained specimens, and consists of narrow K-feldspar envelopes to fractures and irregular chlorite veinlets. In one case K-feldspar was found in a dilatant veinlet accompanied by calcite, and cut by mineralized veinlets.

SERICITE-CHLORITE-CARBONATE ALTERATION

Sericite, chlorite and carbonate are the main alteration minerals at Skukum Creek. They are centred upon the main shear zones, and both pervasive and fracture-controlled alteration have been observed. Individual veinlets can be dominated by either sericite or chlorite, and typically contain abundant carbonate. Veinlets dominated by each of the three minerals have mutual crosscutting relationships that indicate coeval precipitation.

Alteration observed farthest from the main shear zones is dominated by green, Mg-rich chlorite (all compositional information is qualitative and based upon SEM spectra) that replaces hornblende and biotite. It is accompanied by trace to minor calcite, rutile, apatite and rare epidote, partially hematized magnetite, and weak sericite after feldspar. This low intensity chlorite alteration may be a deuteric effect related to cooling of the Cretaceous intrusions, or a wide alteration envelope around the main shear zones.

Fracture density and intensity of chlorite, sericite, pyrite and carbonate alteration increase markedly toward the main shear zones. The strongest chlorite alteration is related to numerous, narrow, irregular to planar veinlets filled with chlorite, lesser quartz, carbonate and sericite, and minor to trace epidote, pyrite, chalcopyrite and galena. Veinlets peripheral to the main shear zones occur individually or in swarms surrounded by sericite-quartz-(pyrite) envelopes and separated by less-altered granodiorite. Similar envelopes form around rare quartz-carbonate ± sulphide veinlets. This style of alteration is best developed in the hanging wall up to 200 m from the main shear zones. Sericite increasingly overprints chlorite as the main shear zones are approached, but veins dominated by each phase continue to crosscut one another. Strong pervasive sericite alteration within the main shear zones commonly bleaches andesite dykes to a tan colour that makes them difficult to distinguish from rhyolite dykes. Minerals that accompany proximal sericite alteration include quartz, chlorite, pyrite, carbonate (variable and commonly paragenetically later), rutile, and trace chalcopyrite, arsenopyrite, hematite and/or galena. Pyrite can exceed 10%, but is typically much less abundant. Igneous K-feldspar is locally preserved. Chlorite proximal to the main shear zones is black and is Fe-rich. A similar assemblage forms the matrices to cataclastic, polylithic and monolithic breccias.

Higher concentrations of pyrite and other sulphide minerals are commonly related to carbonate that replaces chlorite-sericite. Carbonate also occurs in narrow, barren, post-mineralization veinlets. Most carbonate is calcite (± trace Mn), with minor, typically younger ferroan dolomite or ankerite. Carbonate in late veinlets and surrounding brecciated quartz-sulphide mineral vein material includes manganosiderite (enriched in Fe-Mn) and Fe-Mg compositions, both accompanied by Fe-rich chlorite.

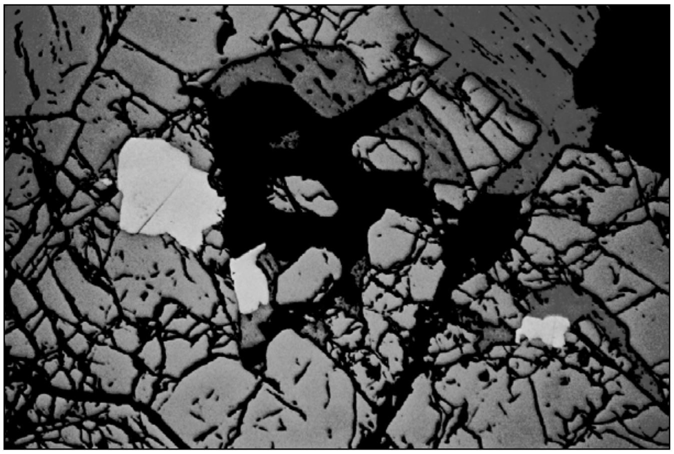

Figure 7. *Photomicrograph that illustrates the paragenetic relationship between electrum (white) and late galena (darkest grey with larger black pits). Both minerals replace early, coarse-grained pyrite (medium grey) in a quartz-sulphide mineral extension vein. The largest electrum grain is about 200 microns across. Sample is from the 1300-level in the Rainbow zone. Reflected light, field of view 0.16 mm.*

SHEARED EPIDOTE VEINS

Sheared epidote-rich veinlets up to 1 cm in width occur within a few tens of metres of the footwall to the main shear zones. Their formation overlapped in time, but extended beyond, sericite-chlorite alteration. They contain minor sericite, calcite and pyrite, and rarely hematite. They lack alteration envelopes and adjacent K-feldspar is stable. They may, at least in part, be sheared equivalents of the epidote-K-feldspar veins, although crosscutting relationships demonstrate that some of them are also younger.

MINERALIZATION

Mineral assemblages are similar in deformed and undeformed quartz-sulphide mineral veins, but paragenetic relationships are much clearer in the latter. Quartz-sulphide mineral extension veins have an early stage of coarse-grained, commonly euhedral quartz, accompanied by several percent coarse-grained pyrite and/or arsenopyrite, and lesser, temporally overlapping to slightly younger sphalerite. Precious metals are texturally related to a younger stage of fine-grained quartz that replaces the early, coarse-grained quartz and sulphide minerals along grain boundaries. Other minerals in the main ore stage include calcite, sericite and rare epidote, chlorite, pyrite, arsenopyrite, sphalerite and galena, and trace to minor freibergite, chalcopyrite, electrum, argentite and stibnite. Rare minerals include barite (in one vein from the Ridge zone), native silver and gold, specular hematite and molybdenite (in one galena-rich vein from the Taxi zone).

Gold occurs mostly as electrum that is paragenetically related to galena and/or stibnite that replace early sphalerite, pyrite and arsenopyrite (Fig. 7). Freibergite occupies the same paragenetic position as electrum (Fig. 8) and is the main host for silver; chalcopyrite, galena, stibnite and sphalerite can exhibit silver peaks on SEM

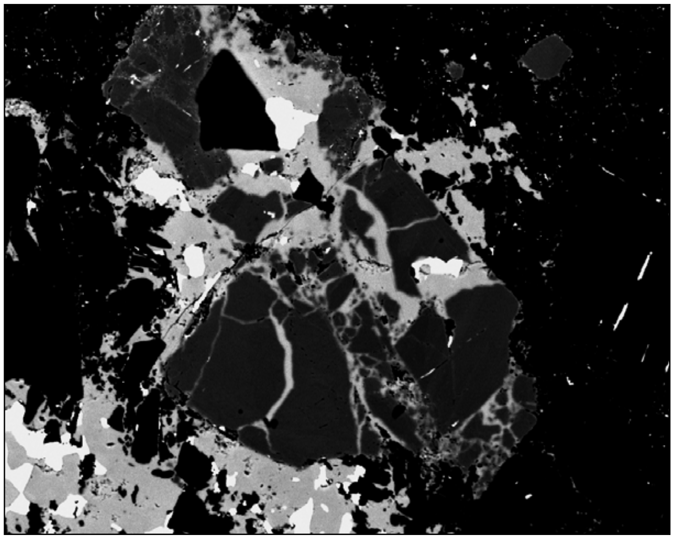

Figure 8. *Backscatter electron image showing freibergite (medium grey) and galena (white) replacing early, coarse-grained, fractured arsenopyrite (dark grey) and pyrite (in black areas to right and left) in a quartz-sulphide mineral extension vein. Matrix to brecciated pyrite also includes fine-grained quartz and minor carbonate. Sample from the Ocean vein; field of view 170 microns.*

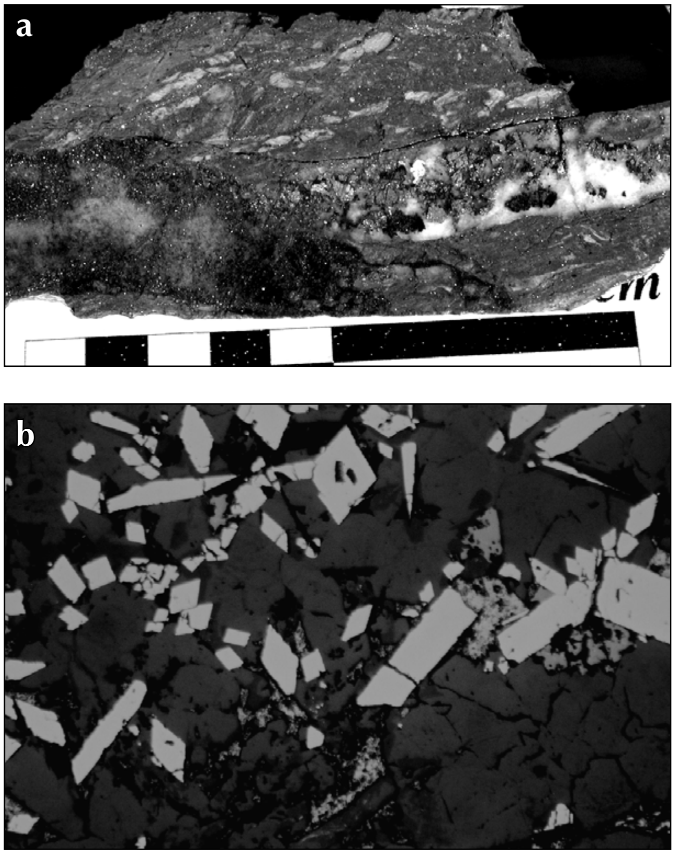

Figure 9. (a) *Timing of different mineralization styles in the Rainbow East vein. A pyrite-rich cataclastic breccia is first cut along foliation by a quartz-sulphide mineral extension vein (right-centre), and both are replaced by quartz with disseminated acicular arsenopyrite (lower left). Field of view about 10 cm.* ***(b)*** *Photomicrograph showing detail of the late quartz-acicular arsenopyrite mineralization stage. Dark gangue is quartz. Bright diamond-shaped crystals are arsenopyrite. Irregular, medium grey grains are stibnite and lesser sphalerite. Reflected light, field of view 0.64 mm.*

spectra, but this occurrence is insignificant in the overall silver budget. An increase in Ag/Au ratios in quartz-sulphide mineral extension veins peripheral to the main shear zones reflects a paucity of electrum, as freibergite abundance and silver grades remain high.

Acicular arsenopyrite, which at Goddell is the principal style of mineralization and contains refractory gold (G.L. Wesa and T.M. Elliott, unpublished company report for Omni Resources Inc./Arkona Resources Inc., 1999), was observed as a very minor, late hydrothermal stage at Rainbow and Rainbow East zones (Fig. 9) but is absent from Ridge zone. In one case from Rainbow, acicular arsenopyrite was found in rounded fragments of quartz vein that preceded the main stage of gold-silver mineralization.

DISCUSSION

A provisional structural model for mineralization in the Skukum project area is shown in Figure 10. The model hinges on the interpretation of oblique left-lateral - reverse kinematic indicators in the Rainbow zone, and reported apparent left-lateral displacements on faults and shear zones at Chieftain Hill and south of the Goddell fault (G.L. Wesa, unpublished company report for Omni Resources Inc./Arkona Resources Inc., 1998; G.L. Wesa and T.M. Elliott, unpublished company report for Omni Resources Inc./Arkona Resources Inc., 1999). The inferred setting of the district is a left-lateral strike-slip fault system with a reverse, south-side-up component. Master structures are the Berney Creek, Goddell and Porter faults. Mineralization occurs in dilational zones where displacement on the Goddell fault is transferred on northeast-trending structures to the Berney Creek and Porter faults, and more locally along the master structures near northeast-trending splays. In the Skukum Creek zone, mineralization occurs in areas of second-order dilational stepovers and bifurcations in the northeast-trending faults, as represented by the Sterling zone. The left-lateral shear sense and overall structural geometry are compatible with relationships between northeast-trending veins and east-trending faults at the Mount Skukum mine (McDonald, 1987 and B.W. McDonald et al., unpublished company report for Total Energold, 1990). Structural features at Skukum Creek formed during a protracted, syn-tectonic igneous and hydrothermal event, except for late brittle faults, which could be much younger.

The hydrothermal fluids have a direct genetic relationship to some rhyolite dykes. Monolithic rhyolite breccias plausibly formed by interaction of rhyolite magmas with fluids in the controlling structures. Several rhyolite dykes in the Taxi zone, however, lack such breccias, yet they contain disseminated sulphide minerals and quartz-sulphide mineral veinlets anomalous in base and precious metals, and have envelopes of alteration identical to those that encompass the main shear zones. A genetic link is further supported by relationships at Goddell (C.R. Robertson, unpublished company report for Berglynn Resources Inc., 1987), and by the consistent background enrichment of gold in rhyolite intrusions at the Mount Skukum mine (B.W. McDonald et al., unpublished company report for Total Energold, 1990). It can be concluded that one or more stages of rhyolite, or their parental magmas, contributed to the fluid and metal budget of the district.

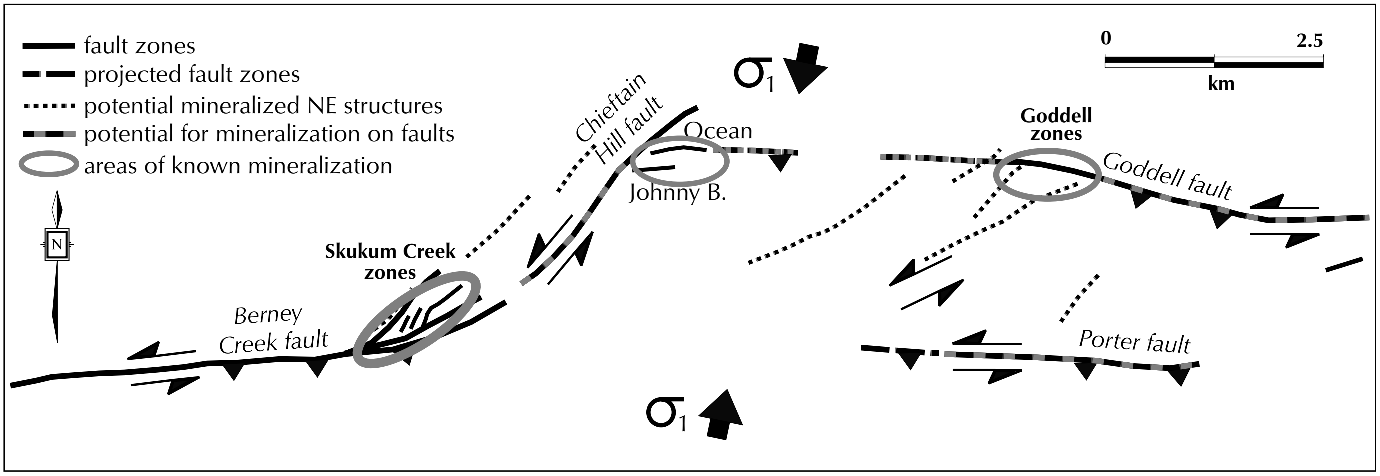

Figure 10. *Provisional syn-hydrothermal structural model for the Skukum project area. Areas with exploration potential are also indicated by shaded ellipses. See Figure 1 for location of mineralized zones. See text for details.*

Timing of deformation and hydrothermal activity with respect to the Skukum Creek caldera complex could not be fully assessed during this study. Hart (1992b) reports a ~58 Ma whole rock K-Ar date on a rhyolite dyke from the Rainbow zone, which is 5-7 Ma older than 51-53 Ma Rb-Sr ages from the Skukum Creek volcanic complex (Pride and Clark, 1985; McDonald and Godwin, 1986). This discrepancy has significant implications for the timing and nature of the faults that control mineralization, and suggests that some might not be caldera-bounding structures. A more plausible alternative is that the dates, which are based on methods of relatively low precision, are not representative. Precise U-Pb dates would more accurately determine if mineralization, shear zones and dykes exploit older, caldera-bounding structures.

Finally, the study highlights a significant potential for discovery of additional mineralization in diverse structural settings in the project area. In addition to continued exploration of known mineralized zones, most of which remain open in at least two directions, other potential areas are 1) northeast-trending extensions of shear zones at Skukum Creek; 2) splays, junctions and extension veins at stepovers of mineralized shear zones at Skukum Creek, such as the junction between the Kuhn and King Canyon faults; 3) the northeast-trending Chieftain Hill fault system; 4) near fault splays and bends along the Goddell and Porter faults; and 5) northeast-trending, locally exposed and mineralized structures between the Goddell and Porter faults. These highly prospective environments clearly warrant additional exploration.

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