PROPERTY DESCRIPTION

Sediment-hosted disseminated gold occurrence, northeast Mayo Lake area

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ABSTRACT

Low to moderate levels of gold are widely distributed within a distinct member of the Mississippian Keno Hill Quartzite northeast of Mayo Lake, demonstrating characteristics of sediment-hosted disseminated gold deposits. Alteration is pervasively developed within a 20-m-thick, moderately dipping quartzite interval that can be traced along strike for 4 km. The unit is distinct in texture and appearance due to the effects of hydrothermal alteration. The altered sandstone is highly porous due to secondary leaching (decalcification), producing a friable unit. Also striking is the bleached white appearance (decarbonatization), which contrasts with the dark grey to black of unaltered graphitic quartzite. Sericite and illite are widespread secondary products of the alteration, and trace amounts of pyrite have been largely oxidized into rusty streaks. Abundant, regular, steep, northeast-striking, vuggy quartz veins are stratabound to the porous interval along its entire length — likely resulting from *in-situ* hydrofracturing due to elevated pore fluid pressure.

RÉSUMÉ

Des concentrations en or faibles à modérées sont largement répandues à l'intérieur d'un membre distinct du Quartzite de Keno Hill du Mississipien, au nord-est du lac Mayo, qui présente des propriétés propres à des dépôts d'or disséminés dans des sédiments. L'altération est répandue à l'intérieur d'une couche de quartzite modérément inclinée d'une épaisseur de 20 m qui peut être suivie sur une distance de 4 km. L'unité est distincte en texture et en apparence en raison des effets de l'altération hydrothermale. Le grès altéré est hautement perméable en raison d'un lessivage secondaire (décalcification), résultant en une unité friable. L'aspect blanc décoloré (décarbonatation) est frappant et contraste avec la couleur gris-sombre à noire du quartzite graphitique inaltéré. La séricite et l'illite, issues de l'altération, sont des produits secondaires largement répandus, et des quantités traces de pyrite ont été en grande partie oxydées en traînées rouillées. D'abondantes et régulières veines de quartz vacuolaire fortement inclinées au nord-est sont stratiformes dans l'intervalle perméable sur toute sa longueur – découlant vraisemblablement de la fracturation hydraulique *in situ* due à la pression interstitielle élevée des fluides.

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INTRODUCTION

The study area is situated 20 km southeast of the Keno Hill mining district (Fig. 1), along the northern fringe of the Selwyn Basin, within map sheet 105 M/15 (Green, 1971). Distinct gold-bearing altered members of the Mississippian Keno Hill Quartzite unit are the subject of this investigation. Mapping and sampling were conducted northeast of Mayo Lake (105 M/15) at a scale of 1:10 000 in order to trace the key altered units along 4 km of strike of exposed bedrock. Two detailed maps are presented. Samples of both altered host rock and vein material were taken; assay results are tabulated and discussed within the paper. Although the gold assays returned modest results, the values are distinctly anomalous.

Recently, in considering the regional setting of the Selwyn Basin and its associated plutonic rocks, it has been suggested that sediment-hosted disseminated gold deposits may be prospective in this area of the Yukon (Poulsen et al., 1997; Roots, 1997). However, an important class of gold vein deposits has now been defined for this region which relate to Cretaceous granitic bodies, comprising the Tombstone Gold Belt (Stephens et al., 2004). In addition, zoned, large-scale polymetallic hydrothermal vein systems, such as at Keno Hill and Dublin Gulch, occur within the district (Boyle, 1965; Lynch, 1989a,b).

Sediment-hosted disseminated gold deposits comprise a diverse class of deposits whose characteristics continue to be refined world-wide as research and exploration progress (Bagby and Berger, 1985; Arehart, 1996; Ilchick and Barton, 1997; Peters, 2004). Most famously, in the Carlin district of Nevada, deposits are typically hosted within Paleozoic-aged impure silty carbonaceous carbonates and feature discrete clay mineral and silica alteration patterns. These rocks contain disseminated gold deposits which are amenable to bulk mining (Bagby and Berger, 1985). However, host rock types are known to be variable and can include carbonaceous sandstone and chert, among others. Regional lineaments and structure,

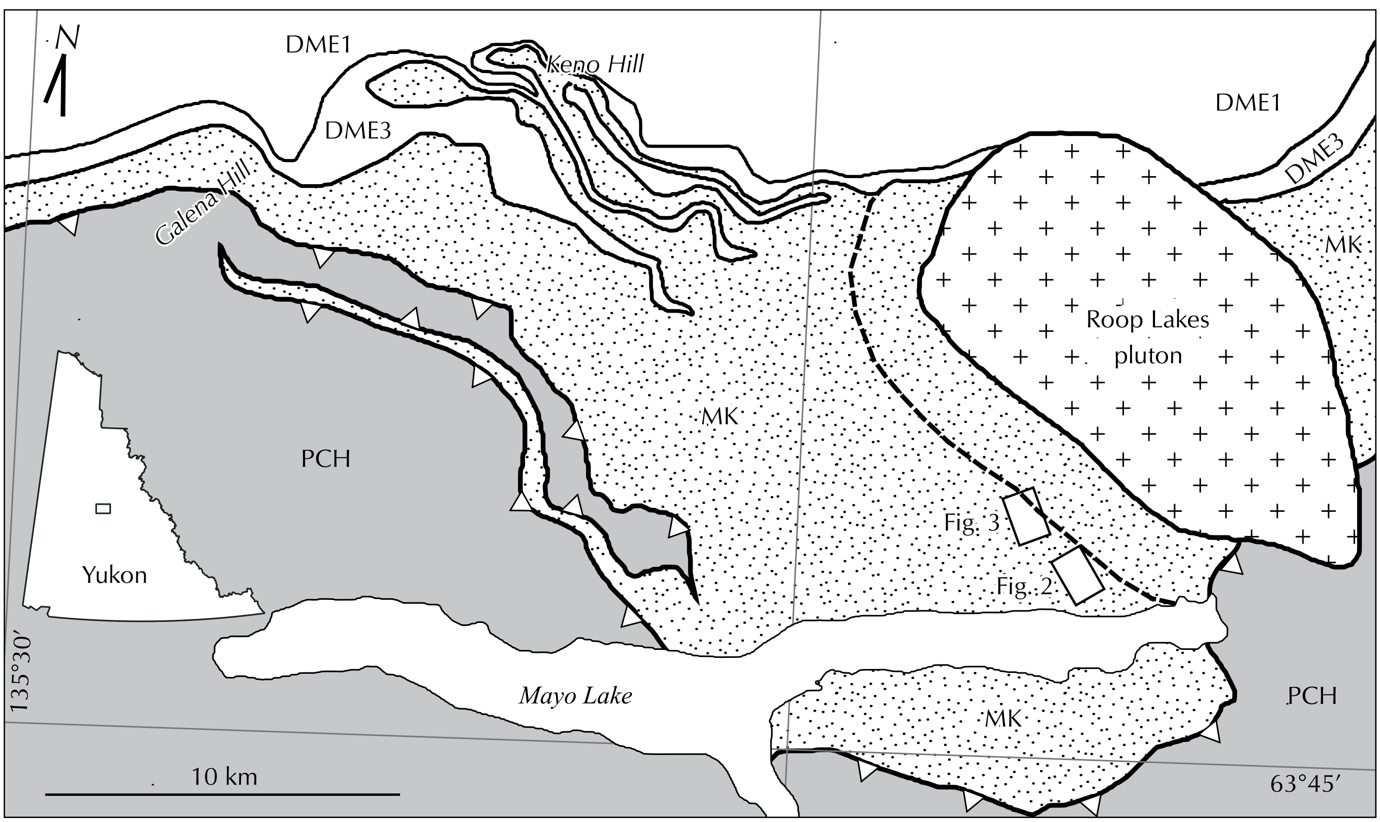

Figure 1. *Location map of study areas displaying map sites of Figures 2 and 3 southeast of Keno Hill mining district and immediately west of the Roop Lakes pluton. Map and units are taken from Yukon Geological Survey website; DME1 corresponds to Devono-Mississippian Earn Group unit 1, DME3 to Earn Group unit 3, MK is Mississippian Keno Hill Quartzite, and PCH refers to Neoproterozoic Hyland Group. Unit descriptions can be found in Roots (1997). Dashed line is the outer limit of contact metamorphic halo adjacent to the Roop Lakes pluton.*

large-scale hydrothermal circulation, as well as proximity to granitic bodies are also thought to be key (Bagby and Berger, 1985; Arehart, 1996; Lefebure et al., 1999).

Nonetheless, reports of sediment-hosted disseminated gold occurrences remain rare for the Selwyn Basin, owing possibly to the often subtle nature of this type of mineralization, or to difficulties and ambiguities related to classification. This report describes an altered member of the Keno Hill Quartzite unit displaying stratabound alteration and veining with associated disseminated gold values. From a descriptive standpoint, designation for this unit as a sediment-hosted disseminated gold occurrence seems reasonable. However, the example presented here displays mesothermal characteristics, whereas those from type areas tend to be more commonly, though not uniquely, epithermal in character. This paper will identify and characterize a new type of mineralization for the area, which may ultimately help guide further exploration and research.

GEOLOGICAL SETTING

The Mississippian Keno Hill Quartzite (Tempelman-Kluit, 1970; Mortenson and Thompson, 1990; Roots and Murphy, 1992; Roots, 1997) is contained within the ancient continental margin succession of the Paleoproterozoic to Paleozoic western North American miogeocline, near the northern edge of the Selwyn Basin (Abbott et al., 1986; Gordey and Anderson, 1993). The region forms the northern extension of the Omenica Crystalline Belt (Monger et al., 1982) and has been affected by late Jurassic to middle Cretaceous deformation, metamorphism and igneous activity (Roots, 1997). The Keno Hill Quartzite extends continuously along strike for 220 km, from the Tintina Fault in the west, to central Yukon in the east (Tempelman-Kluit, 1970). Strata dip generally south as a result of northerly thrusting; the quartzite may be as much as 1 km thick where affected by imbrication and structural thickening. The southern flank of the quartzite is bound by the Robert Service thrust which juxtaposes Neoproterozoic to Cambrian units of the Hyland Group onto the Mississippian Keno Hill Quartzite (Roots and Murphy, 1992; Thompson, 1995; Roots, 1997). Regional considerations constrain the thrusting between the deformed middle Jurassic strata and Late Cretaceous granitoid magmatism, which postdates deformation. Middle Triassic gabbro and diorite sills are dispersed within the Keno Hill Quartzite and underlying units (Mortensen and Thompson, 1990) and have been strongly affected by shearing during thrusting.

The deformed sedimentary rocks of the region are cross-cut by a northwest-trending belt of Cretaceous granitic plutons and dykes termed the Tombstone plutonic suite (Anderson, 1987; Poulsen et al., 1997), which was dated by U-Pb zircon geochronology at 90-95 Ma (Mortensen et al., 1996). The Tombstone plutonic suite includes the large Roop Lakes pluton, dated at 92.8 ± 0.5 Ma (Roots, 1997), which intrudes the quartzite east of the Keno Hill mining district. The Keno Hill Quartzite unit comprises a number of lithologies, including dark grey to black, graphitic quartzite containing variable amounts of muscovite, chlorite, tourmaline, carbonate and detrital zircon. Calcareous quartzite also occurs (Roots, 1997), though thin limestone beds are minor to rare. Interbedded schist and graphitic phyllite are common. Tuffaceous metavolcanic rocks are contained within the Keno Hill Quartzite succession (Roots, 1997).

A contact metamorphic halo within the Keno Hill Quartzite extends as much as 4 km away from exposures of the Roop Lakes pluton (Lynch, 1989a,b). Sillimanite schist at the contact passes outwards to garnet-staurolite-plagioclase-biotite-muscovite schist, whereas the outermost halo is characterized by graphite-andalusite schist, or locally biotite-muscovite schist. Porphyroblasts within the metamorphic halo typically overgrow earlier deformation fabrics. Mineral assemblages within the halo permit characterization of pressure and temperature conditions during emplacement of the Roop Lakes pluton. Microprobe analyses for coexisting garnet-staurolite-plagioclase-biotite-muscovite-quartz returned pressure-temperature determinations, based on the intersection point of three independent reactions (Berman, 1991) near 3500 bar and 530°C (Lynch, unpublished data). As a lithostatic pressure determination, 3500 bar reflects a similar crustal depth to the 1500 bar pressure determination for hydrostatic conditions recorded in the veins of the Keno Hill mining district (Lynch, 1989b; Lynch et al., 1990).

Fault- and fracture-controlled hydrothermal veins within the quartzite extend from the margin of the metamorphic halo toward the west into the Keno Hill mining district, forming a vein system distributed across 40 km. Hydrothermal alteration along the veins in the mining district has been dated at 84 Ma by K-Ar analysis of wallrock alteration (Sinclair et al., 1980). Typically, veins are coarse-grained, vuggy, with euhedral to subhedral crystals displaying banding textures, are structurally discordant, and locally may have well developed alteration haloes. Much of the vein material is unstrained, but parts of some veins contain sheared and deformed crystals, whereas other portions display cyclical brecciation and cementation, indicating contemporaneity between veining, hydrothermal circulation and brittle faulting.

In the study area, the Roop Lakes pluton (Roots, 1997) dominates the centre of map 105 M/15, and is the largest granitic body within the Tombstone plutonic suite. From east to west, veining is zoned away from the pluton, with changing hydrothermal assemblages interpreted to reflect evolving physical-chemical conditions in the fluids (Lynch et al., 1990). Seven mineralogical zones have been defined, which are described in Lynch (1989a,b). Quartz-feldspar-tourmaline veins occur immediately west of this intrusive body, whereas a tungsten skarn is found at its southeastern contact. Outward from the quartz-feldspar veins are vuggy quartz-calcite veins. Further west still, this family of veins transitions into the sulphide-rich, quartz-siderite veins of the Keno Hill silver-lead-zinc mining district. The regional zoning pattern suggests that gold may be found between the Roop Lakes pluton and the Keno Hill district (Lynch, 1986). District-scale zoning in the Keno Hill system is also reflected in the tetrahedrite-freibergite solid solution, with tetrahedrite occurring in the east and changing gradually to freibergite in the west (Lynch, 1989a; Sack et al., 2003). Veins in the mining district display a regular paragenetic association by their growth textures and cross-cutting relationships. These are characterized mainly by early, coarse-grained quartz, followed by siderite and sulphides, and at the western end of the system, a late, fine-grained quartz stage overgrows the middle siderite stage. Furthermore, tetrahedrite has been shown to be a useful petrogenetic indicator; compositions of this mineral in the Keno Hill veins indicate hydrothermal mineralization occurred predominantly within the range of 250° to 310°C, although some analyses indicate that temperatures in the veins may have reached up to approximately 400°C (Sack et al., 2003).

SUGAR MEMBER: GEOLOGY, ALTERATION AND MINERALIZATION

Two detailed maps (1:10 000 scale) of the adjacent study areas are presented in Figures 2 and 3; these maps include the areas surrounding the Sugar and Honey claim groups respectively. The first map (Fig. 2) covers an area along a stream gully situated at the northeast end of Mayo Lake. At this location, the sloping ridge face above the lake provides adequate outcrop exposure from 3000-4500 ft (914.4-1372.6 m) asl. Five mapable units from within the Keno Hill Quartzite unit can be defined at the present scale of work. These are in ascending order: (1) interbedded, grey-black quartzite, graphitic schist and phyllite, with minor greenstone; (2) a unit of thinly bedded, competent, dark green, tuffaceous volcanic rocks and trachytic andesite; (3) pervasively altered, porous, white sandstone; (4) interbedded, silver-grey and brown-coloured schist and phyllite; and (5) foliated to massive, feldspathic greenstone or metadiorite. Because of deformation and lack of top indicators, the true stratigraphic position of these units remains uncertain, and the sequence of 1-5 above represents the present relative positions of the layered sequence. All, except unit five above, are thought to be subdivisions of the Mississippian Keno Hill Quartzite unit. The greenstone-metadiorite is likely Triassic in age (Mortensen and Thompson, 1990). The principal unit of interest is the pervasively altered, porous, white sandstone which was informally labelled the Sugar member during the course of fieldwork, because in places it has the appearance of granulated white sugar.

Bedding strikes north-northwest and dips moderately east-northeast (Figs. 2, 4, 5). Two penetrative fabrics are generally preserved within the micaceous units, and to varying degrees within the more competent rocks. The earliest and strongest foliation is parallel, or sub-parallel to bedding, and is characterized by aligned mica and locally a schistose fabric. The fabric is axial planar to isoclinal folds, which are sometimes observed at hand sample or outcrop scales. Highly sheared, detached, intrafolial folds, boudins, and fault rock were observed at a contact along a series of outcrops in the centre of the map area (Fig. 2), which has been interpreted as a thrust fault. This fault was extended to a mylonitized greenstone outcrop in the north-centre part of the map area. The second fabric comprises an upright-spaced cleavage which strikes northwest-southeast, and is axial planar to open folds which plunge moderately to the southeast. The two stages of deformation are well known in the district and can be related, in succession, to early thrusting in association with the Robert Service Thrust, followed by later upright folding in association with the Mayo Lake anticline.

The Sugar member stands out as a distinct white sandstone band (Fig. 5, 6) within the layered sequence, represented by a number of outcrops exposed along the slope and obliquely across the stream gully (Fig. 2, 5). The unit is approximately 20 m thick and is underlain by a competent, well bedded, dark-coloured volcanic lapilli and ash tuff, or locally trachytic andesite. A number of characteristics make the Sugar member unique. The rock is porous, white, and has been almost entirely bleached of graphite or dark organic matter. Rare, remnant patches of grey-black graphite are present in some outcrops, indicating hints of the protolith, but the graphite is entirely absent in proximity of quartz veins, as well as along alteration haloes which affect most of the unit. The rock has clearly been decarbonatized. The porous nature of the rock is also peculiar; the intergranular porosity is

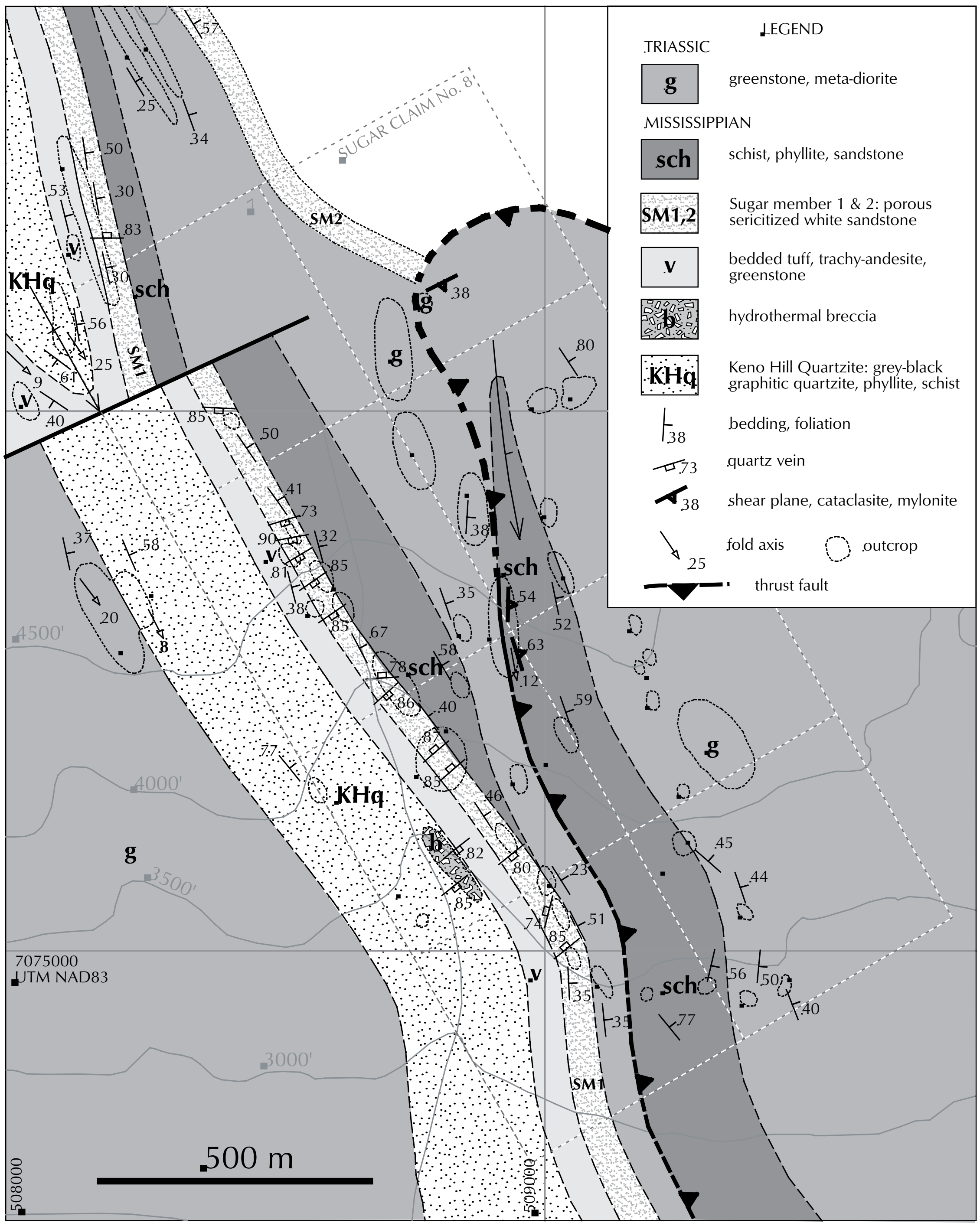

Figure 2. *Geological map of area surrounding Sugar claim group.*

estimated to be up to 10% and greater. When water is poured onto the rock, it is readily absorbed by the unit. It should be emphasized that sandstone which has been deformed and metamorphosed to the degree that these rocks have, cannot retain any primary porosity. A lack of flattening or annealing gives rise to the distinct high porosity of this unit. It should be noted however, that irregularly oriented stylolites with black organic-rich seams are sometimes observed, indicating some degree of flattening. All porosity is likely the effect of secondary leaching and postdates penetrative deformation. Removal of organic matter would have contributed to only a small portion of the porosity. Leaching of a cement such as calcite (decalcification) likely contributed to most of the

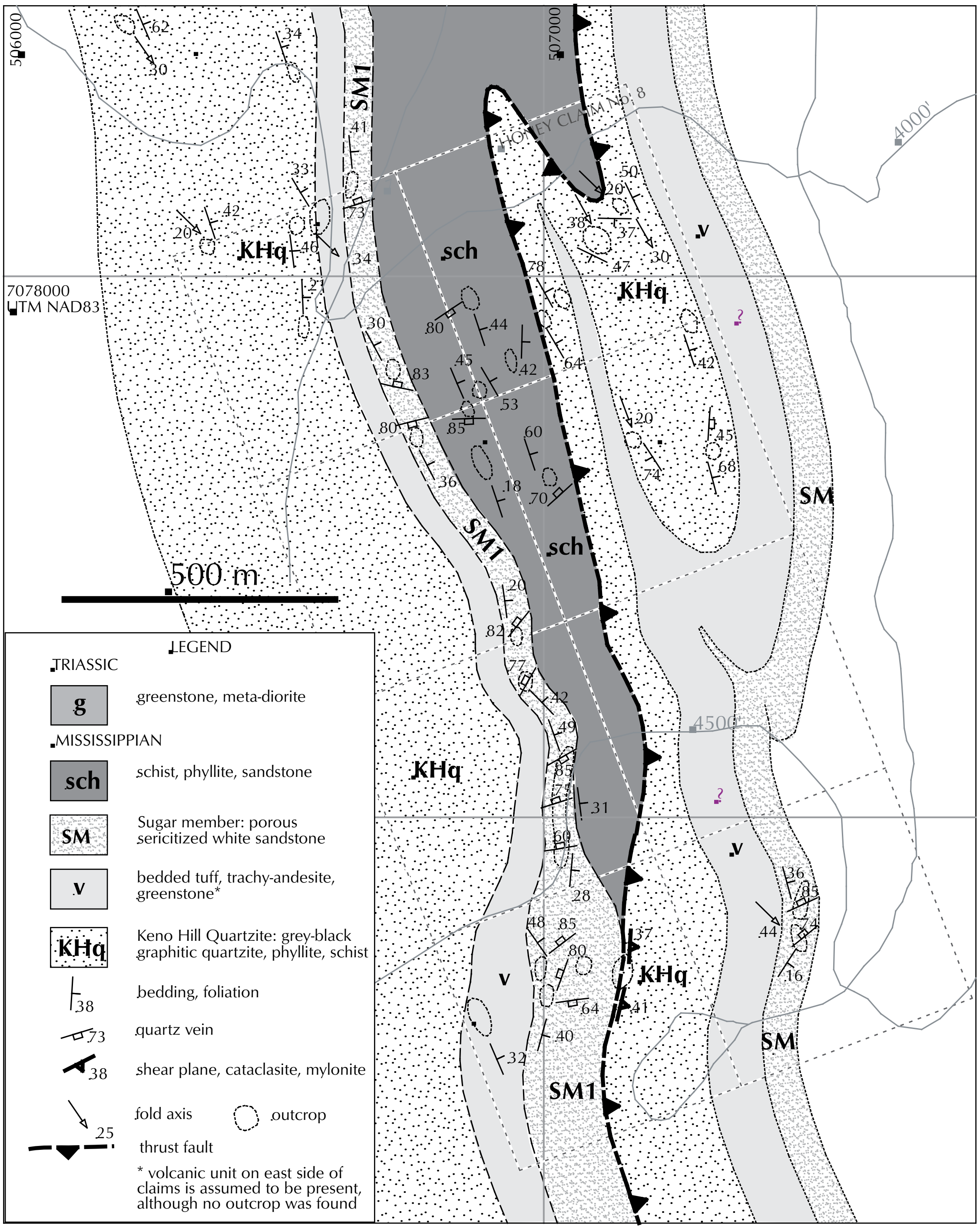

Figure 3. *Geological map of area surrounding Honey claim group.*

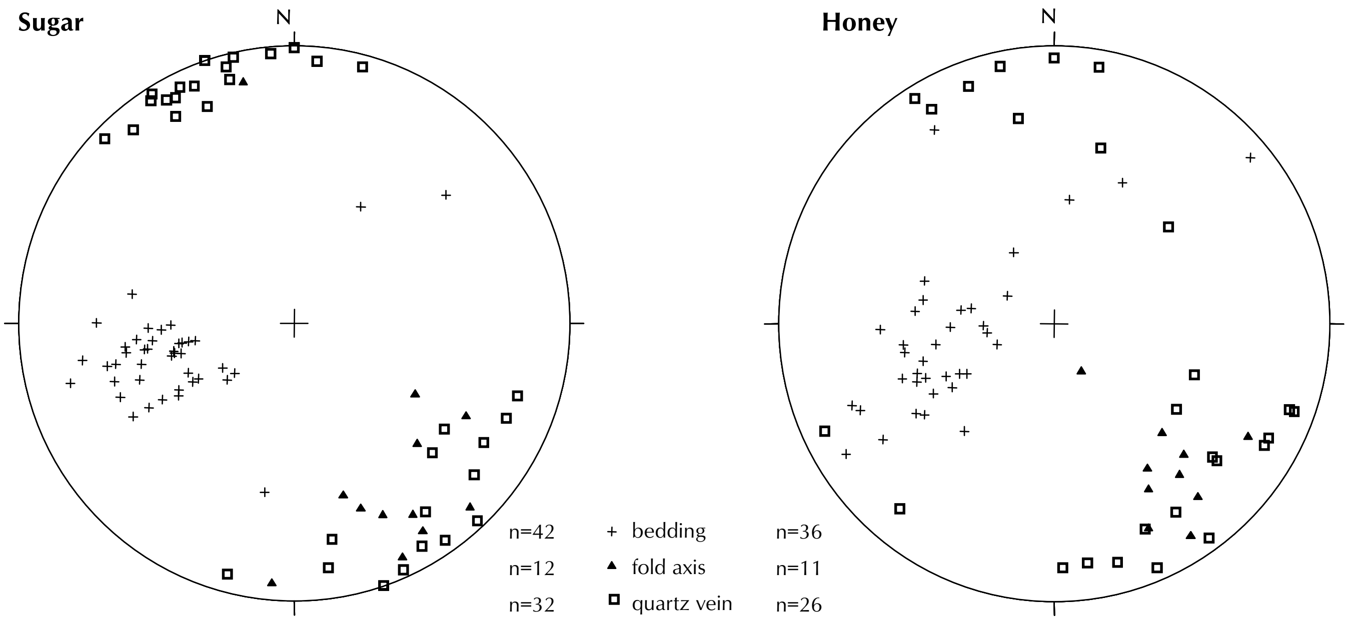

Figure 4. *Lower hemisphere equal area stereonet plots of poles to bedding, poles to quartz veins, as well as trend and plunge of late stage fold axes, for areas covering Sugar claim group (Fig. 2) and Honey claim group (Fig. 3).*

porosity; calcite is locally an important component of the Keno Hill Quartzite (Green, 1971; Roots, 1997). A further consequence of the secondary porosity is the generally friable nature of the rock, which crumbles between the hands in the case of some samples. Outcrops have rounded, as opposed to angular weathering profiles. Rock competency is variable due to widespread sericitization and patchy silicification, however, overall outcrop exposure is good. Small flakes of satin-white to transparent muscovite/sericite are disseminated throughout the Sugar member. Locally, apple green flakes of Cr-muscovite, or fuchsite are observed, which is consistent with the generally high chromium assay values recorded throughout the unit (Fig. 7). A very light brown to buff colouration is common from the weathering of small quantities of disseminated pyrite. This unit is thought to be equivalent to the hydrothermally altered 'powdery sandstone' of Roots (1997) described from a locality near Mount Albert, and the 'crush breccias' of Green (1971).

Quartz veins are abundant along the entire strike of the Sugar member. The veins are often vuggy with comb texture (Fig. 6), and are very regularly oriented as near-vertical, northeast-southwest-striking, fracture-controlled, planar features (Fig. 4, 6). Fractures and joints which control the veins are oriented approximately perpendicular to late-stage, southeast-plunging fold axes (Fig. 4). Folding appears to have influenced fracture orientations. Veins terminate at the upper and lower contacts of the Sugar member. Overlying and underlying units are almost entirely barren of veins. One exception is an irregular quartz vein breccia body hosted in the underlying grey-black Keno Hill Quartzite beneath the Sugar member at the south end of the map (Fig. 2). It is clear that the intense vein system is largely stratabound to the Sugar member. Mineralogically, subhedral to euhedral quartz is the dominant mineral in the veins, however, grey-brown botryoidal crusts occur along the walls of some veins, and white clay minerals have been observed as a late vug filling. A black mineral, possibly tourmaline, was observed, but remains to be confirmed.

It is noteworthy that a second occurrence of the Sugar member was mapped (Fig. 2) and is located at an outcrop situated on the upper ridge at the margin of the map area and to the north. It is uncertain if this is a second independent occurrence of the same facies in the normal stratigraphic succession, or if it is a structural repetition of a single unit. The available outcrop distribution does not allow for a clear distinction to be made. Nonetheless, the unit shows the same attributes of alteration and veining as the Sugar member elsewhere in the map area.

Figure 3 is a map of the Sugar member extending northwest from Figure 2. The area covers a portion of the ridge top to the north of Mayo Lake where the topography is flatter. In this area, outcrops are more

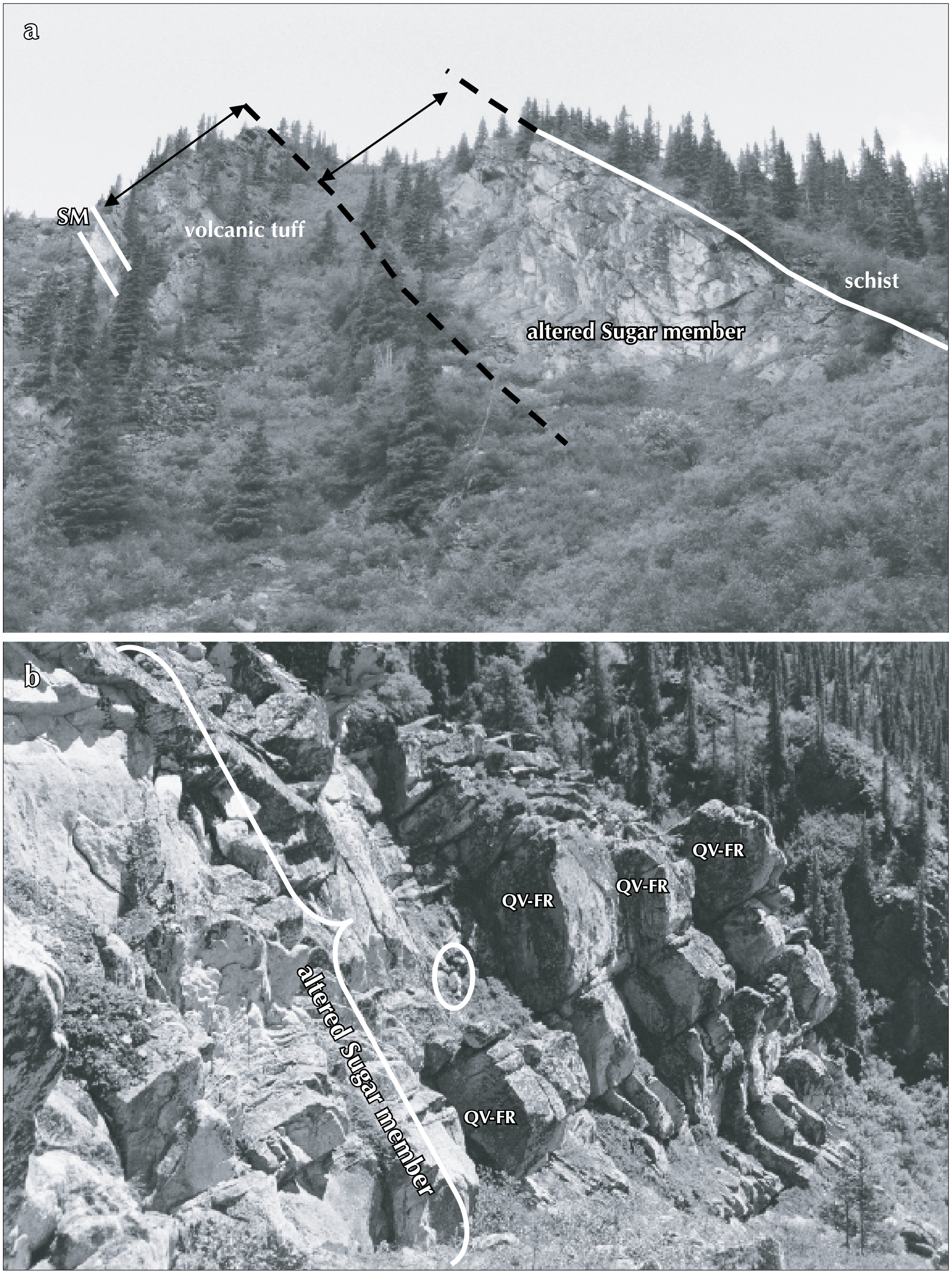

Figure 5. (a) *View looking northwest of Sugar member outcrop profile, sandwiched between overlying schist and underlying volcanic tuff units. Light-coloured Sugar member is highly altered and crosscut by numerous fractures and quartz veins. SM refers to a 3-m-thick band of Sugar member contained within bedded volcanic interval below main outcrop.* ***(b)*** *Variably altered white Sugar member with regular set of quartz vein fractures (QV-FR). Note person standing in middle of outcrop (circled) for scale, where Sugar member is at least 20 m thick.*

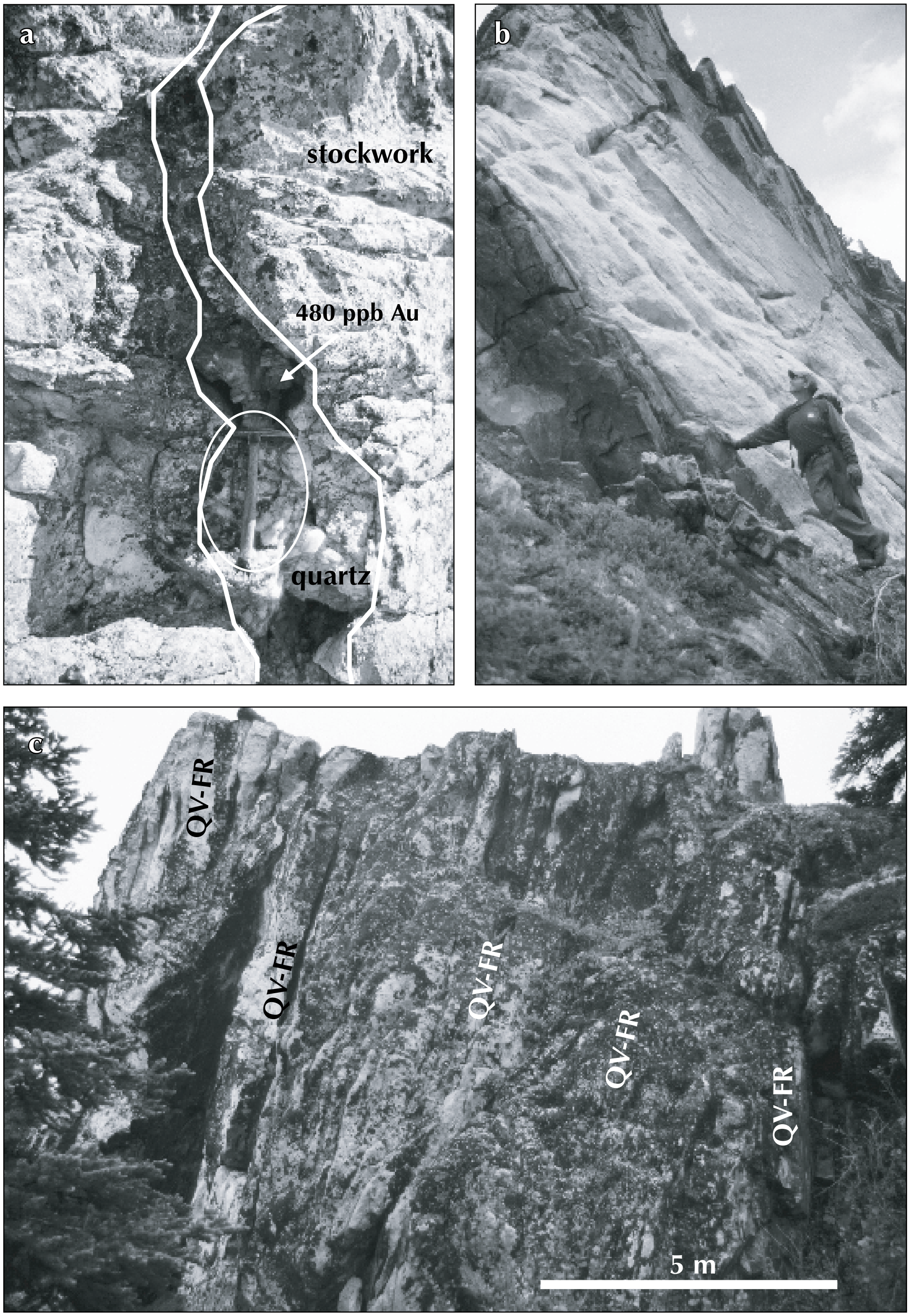

Figure 6. (a) *Close up of coarse, vuggy quartz vein within highly altered Sugar member cross-cut by quartz vein stockwork. Composite sample of quartz vein, host rock, and limonite rim returned a value of 480 ppb Au. Circled hammer used for scale.* ***(b)*** *Three-metre-thick subunit of Sugar member within volcanic tuff unit below main Sugar member interval (see SM on Figure 5a). Note rounded weathering profile of porous, crumbly, altered rock compared to brittle, resistant, tight volcanic unit.* ***(c)*** *Parallel, high-density quartz vein fracture (QV-FR) set within altered Sugar member.*

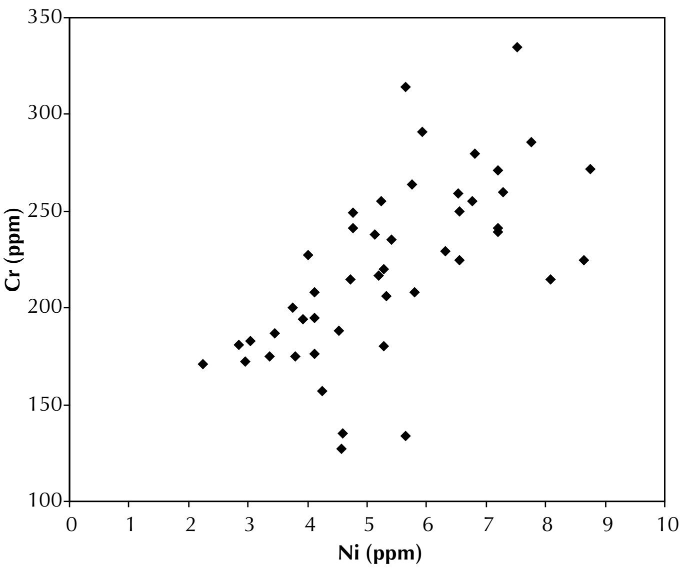

Figure 7. Cross-plot of Cr versus Ni for all samples collected from the study area.

scattered, however, the Sugar member is well exposed in a series of outcrops located along the west side of the map area. In a large outcrop which is continuous for at least 100 m, the unit was measured to be 15 m thick, though this is a minimum since upper and lower contacts are not exposed. Underlying rocks consist of green metavolcanic and greenstone units, which are above grey-black quartzite and phyllite. Overlying rocks are dominated by metasedimentary lithologies consisting of graphitic quartzite, schist and phyllite, as well as one occurrence of sandstone-pebble conglomerate. In contrast to the mapped area to the southeast, a broad continuous unit of greenstone above the Sugar member does not occur in this part of the study area. However, a second unit of the porous, altered and bleached Sugar member is mapped in both the southeast and northwest portions of the study area (Figs. 2 and 3). Structurally, the rocks dip moderately to the east-northeast (Fig. 3, 4). An early, micaceous, bedding-parallel fabric is also recorded. A sheared contact at the top of the Sugar member with detached isoclinal intrafolial folds is found in the southwest portion of the map area and is interpreted to be an early deformation-stage thrust fault. Later, upright, southeast-plunging, open folds are observed in outcrop overprinting the earlier fabrics, and locally have an associated upright-spaced cleavage. A map-scale fold has been interpreted from outcrop exposures. Alteration of the Sugar member is pervasive throughout the southwest portion of the map area and displays a bleached white appearance, sericite alteration and crumbly texture with intense quartz veining within a porous sandstone. Planar, sub-vertical, northeast-southwest-striking, vuggy quartz veins are abundant and stratabound to the member (Fig. 4). The orientation of the veins in the northwest is remarkably consistent with the veins in the area to the southeast. Disseminated pyrite has been largely oxidized to rust streaks in the rock, or occurs along vein margins.

Interestingly, one occurrence of andalusite within black graphitic schist has been found at the northeast corner of the map area of Figure 3. Andalusite is characteristic of the outer contact metamorphic halo to the Roop Lakes pluton (Lynch, 1989b), and indicates a certain proximity to, and influence from, the underlying pluton.

GEOCHEMISTRY AND ASSAY RESULTS

A total of 45 samples were analysed by inductively coupled plasma mass spectrometry (ICP-MS) for 31 elements; gold was analysed separately by fire assay. Fist-sized samples were collected from the altered Sugar member, including altered hostrock and mixed vein/hostrock materials. Samples were collected in order to cover the entire mapped length of the unit. Within the detection limits, gold ranges from 5 to 50 ppb, with one

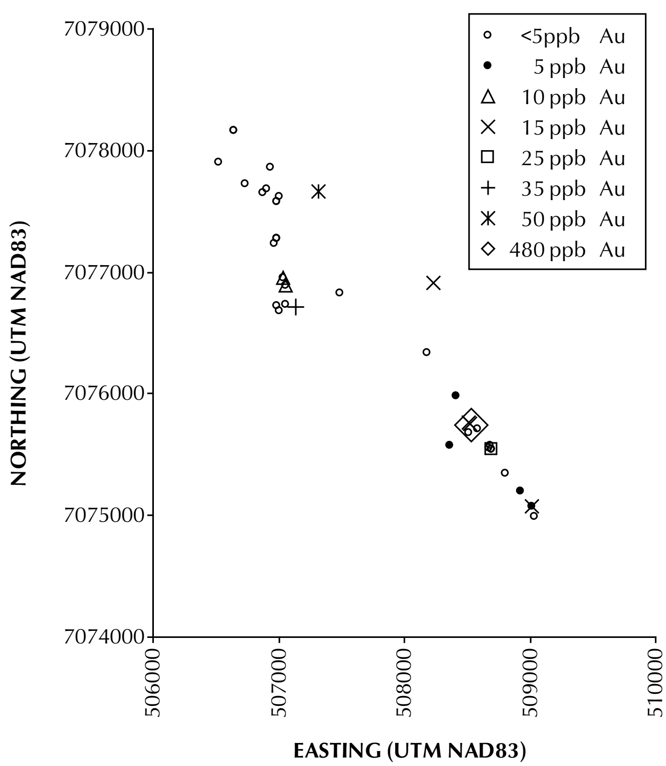

Figure 8. Grid map (UTM NAD83 grid) displaying gold assay results across the two map areas.

outlier that returned a value of 480 ppb (Fig. 8). In total, 14 samples returned gold values distributed along much of the 4-km-long strike length of the unit, although the northwest end appears to be barren. The anomalous value of 480 ppb is from a distinct sample which consists of quartz vein material, altered host rock, and a 1-cm-thick, grey-brown botryoidal goethite rim along the vein margin. None of the other samples include the botryoidal goethite, though this material was noted in the field at other localities such as within the hydrothermal breccia underlying the southernmost end of the Sugar member (Fig. 3); further sampling of this site is necessary now that it has been established that the goethite is gold bearing. Sampling was originally conducted to test for the possibility of widespread, low-grade gold values, in order to determine the potential for bulk mining.

Positive correlations were not established between gold and the other elements. Most of the other metals occur in very low concentrations in the samples. An exception is chromium, which is typically high and correlates positively with nickel (Fig. 7). Values for chromium range up to 335 ppm, well above any concentrations which may arise from contamination by the chromium-molybdenum crusher and are above background values from control samples. Furthermore, the crusher used does not contain nickel, and so the positive correlation between nickel and chromium indicates a natural trend. The likely source of chromium in the rocks is from muscovite, which is known to contain up to 6% naturally occurring Cr_2O_3. Muscovite is also reported to be chromium-bearing in metasedimentary rocks elsewhere in the Rockies (Heinrich, 1965). High chromium mica, termed fuchsite, is a common alteration product in certain gold districts. However, further mineralogical work is needed to confirm the composition of the muscovite.

In considering the geochemical results and assays, it is important to take into account the particular nature of the host rock. The Sugar member is abnormally porous and susceptible to the effects of surface waters, as well as groundwater. Water is readily absorbed into the unit which has undoubtedly been thoroughly flushed over the years. Samples taken from surface outcrops are largely representative of the present day vadose zone where strong geochemical gradients and element remobilization are common. Consequently, a representative evaluation of the Sugar member would require sampling in drill core from below the water table. Gold associated with pyrite, such as is typical in sediment-hosted disseminated deposits, is largely remobilized in surface exposures, while most of the pyrite has oxidized to rust streaks. A higher gold content in association with the botryoidal limonite crust for one sample indicates that gold was indeed remobilized in the low-temperature oxidizing environment; refractory ore is postulated at depth.

DISCUSSION AND SUMMARY

This paper describes a new type of gold occurrence east of the Keno Hill mining district, along the northern fringe of the Selwyn Basin. The occurrence may be classified as a sediment-hosted disseminated gold deposit, on the basis of the stratabound nature of the alteration and veining, the disseminated low-grade gold values, as well as on the basis of the observed decarbonatization and apparent decalcification. However, characteristics suggest that the hydrothermal activity occurred within the mesothermal regime by virtue of the coarse-grained, euhedral morphology of quartz crystals within veins, and predominance of sericite-pyrite (phyllic) alteration. This contrasts with the more epithermal character of well established, sediment-hosted disseminated gold deposits, whereby fine-grained cherty quartz and clay (argillic) alteration are more prevalent (Bagby and Berger, 1985; Lefebure et al., 1999), though characteristics of deeper-seated deposits are also known (Peters, 2004).

The exact timing of hydrothermal activity is uncertain, however, alteration and veining post-date stages of penetrative deformation. Furthermore, the porous nature of the altered rock precludes flattening which was observed in the surrounding units. These relationships roughly place a Jurassic age as the lower limit on the timing of events. It is more likely that the hydrothermal circulation is coincident with the adjacent Roop Lakes pluton of mid-Cretaceous age, which also post-dates deformation. Consequently, the veins and altered host rocks may be linked to the Tombstone Gold Belt.

It is also worth considering the position of the altered Sugar member relative to the zoned Keno Hill hydrothermal system (Lynch, 1989 a,b). The site occupies a position at the outer fringe of the contact metamorphic halo which surrounds the Roop Lakes pluton (Fig. 1), a position inboard of quartz-calcite veins which are widespread immediately to the west of the present study area and overlap with the veins of the Keno Hill silver-lead-zinc district. It is noteworthy that calcite veins typically form a halo surrounding sediment-hosted disseminated gold deposits in the Carlin district, which have been affected by decalcification (Bagby and Berger, 1985).

From a mass balance perspective, decalcification in the orebodies is matched by calcite precipitation in veins adjacent to the deposits. This principle may also apply here where delcalcification of the Sugar member and surrounding rocks is countered with calcite veining immediately west of the study area, and points toward the possible scale of the system to which alteration in the Sugar member is linked. As a porous hydrothermal aquifer, the Sugar member and similar units may have acted as important conduits for regional hydrothermal circulation. The regular set of fractures, as well as the confined stratabound nature of associated quartz veins within the Sugar member, suggest that the interparticle porosity was present during hydrothermal circulation, creating elevated pore fluid pressures which promoted *in situ* fracturing (e.g., Sibson, 2004). Very high, lateral permeability within the unit would be expected from the presence of such a fracture system. In contrast, the immediately overlying and underlying stratigraphy are not fractured and veined because of their lack of associated porosity and very low pore fluid pressures; alternatively they acted as seals and aquicludes. Such a stratified flow system may have created the underlying feeder network to discordant fault-controlled veins in the region.

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