GEOCHEMICAL STUDIES OF GOLD MINERALIZING EVENTS IN THE DISCOVERY-ORMSBY AND CLAN LAKE AREAS OF THE YELLOWKNIFE GREENSTONE BELT, NORTHWEST TERRITORIES, CANADA

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GEOCHEMICAL STUDIES OF GOLD MINERALIZING EVENTS IN THE DISCOVERY-ORMSBY AND CLAN LAKE AREAS OF THE YELLOWKNIFE GREENSTONE BELT, NORTHWEST TERRITORIES, CANADA

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Geochemical Studies of Gold Mineralizing Events in the Discovery-Ormsby and Clan Lake Areas of the Yellowknife Greenstone Belt, Northwest Territories, Canada

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ABSTRACT

Discovery-Ormsby and Clan Lake are areas of active gold exploration in the north end of the Yellowknife Greenstone Belt, Northwest Territories, Canada. Gold occurs principally within silicified and sulfidized metavolcanic rocks of the Archean Banting Group (2.69-2.66 Ga). Discovery-Ormsby is hosted within a narrow and elongate mafic unit, which is surrounded by voluminous metasedimentary rocks. Clan Lake is hosted in a larger, intermediate to felsic, metavolcanic-volcaniclastic complex. Mineralization in both areas is characterized by arsenopyrite followed by pyrrhotite ± native gold. The deposits occur along a N-NE trend associated with regional faulting and present an opportunity to determine if their ores are related to similar hydrothermal systems whose chemistries differ as a function of host lithology, or are instead the result of chemically distinct hydrothermal systems.

Quartz veins from Ormsby have $\delta^{18}O$ values of 13.0-15.2‰ V-SMOW, which are interpreted to reflect dominance of metasedimentary-derived fluids that reacted with the mafic metavolcanic host rocks. In contrast, Clan Lake's quartz veins have $\delta^{18}O$ values of 11.3-15.2‰, which are interpreted to indicate both metavolcanic and metasedimentary sources. Similar influence of both metavolcanic and metasedimentary fluid sources has been documented previously for the hydrothermal system responsible for the world-class gold deposits of the Giant mine at the southern end of the greenstone belt. Wall rock

$\delta^{18}O$ values are 8.5-12.3‰ for the Discovery-Ormsby area and 7.7-12.8‰ for the Clan Lake area.

Tyhee Gold Corporation's large lithogeochemical data set for 150 drill cores from Clan Lake permits us to link $\delta^{18}O$ values with host rock chemistry. 3-D modeling of $\delta^{18}O$ values defines a volume of rock with higher $\delta^{18}O$ values that coincides with elevated gold concentrations. This suggests that $\delta^{18}O$ values may be useful in defining the size of the Clan Lake mineralizing system and may be helpful as an exploration tool and ore guide. Based on this reasoning and drilling to date, a northern edge of an economically mineralized portion of the alteration zone has been defined. To the south-southwest, the high-$\delta^{18}O$, high-gold trend appears to continue, indicating a potential vector for future exploration efforts.

Lithogeochemical data were also used to reconstruct volcanic protoliths at Clan Lake and to determine if there is a preferred ore-hosting chemistry or lithology. Immobile element ratios (Zr/Ti and Cr/Al) of altered rocks at Clan Lake reflect dominantly intermediate composition protoliths, with a minor felsic component. Samples that were initially suspected to be mafic have immobile element ratios more consistent with intermediate rock protoliths. A plot of gold grade versus Zr/Ti ratios suggests that there is a preferred chemistry of intermediate rocks associated with gold deposition, with Zr (ppm)/Ti (%) ratios between 350 and 560. 3-D modeling of lithogeochemistry indicates that geochemical trends crosscut lithological boundaries. This suggests that the favored gold-hosting chemistry likely corresponds to rocks with enhanced porosity and permeability that were more reactive with the ore fluids during the gold mineralizing event, rather than to a particular lithologic unit.

CHAPTER 1: INTRODUCTION

History

Archean terranes in Canada are estimated to contain ~ 8125 t of gold, including contributions from fourteen world-class (> 100 t Au) hydrothermal gold deposits (Robert and Poulsen, 1997). The majority of these Canadian gold deposits are found in the Slave (Fig. 1) and Superior provinces. The Slave Province is well known for its former world-class Giant and Con mines, hosted in metavolcanic rocks of the Yellowknife Greenstone Belt (YGB) of the Northwest Territories (Anglin et al., 2006).

The first reported discovery of gold in the Yellowknife area was in 1898 (Henderson, 1985). The mid-1930's was the start of serious gold exploration efforts, leading to the discovery of high-grade quartz-vein-hosted gold deposits in metasedimentary rocks (e.g. Discovery, Tom, and Ptarmigan mines) and shear-zone-hosted gold deposits in mafic metavolcanic rocks (Con and Giant mines) (Bullen and Robb, 2006). Major deposits of the YGB (Con, Giant, and Discovery mines) have produced approximately 13.5 M toz of gold since 1938 (Bullen and Robb, 2006).

Although there are few areas of active exploration in the northern end of the YGB, two of the more promising areas are Discovery-Ormsby and Clan Lake, where Tyhee Gold Corporation has mounted a substantial exploration effort (Plate 1; Figs. 2-3).

Exploration History of the Discovery-Ormsby area

The Discovery-Ormsby area (Fig. 2) is known for its former gold production from the Discovery Mine. The Discovery Mine was operated from 1950-1968 and produced approximately 1 M toz of gold from 1 M tonnes of ore, from quartz veins hosted in

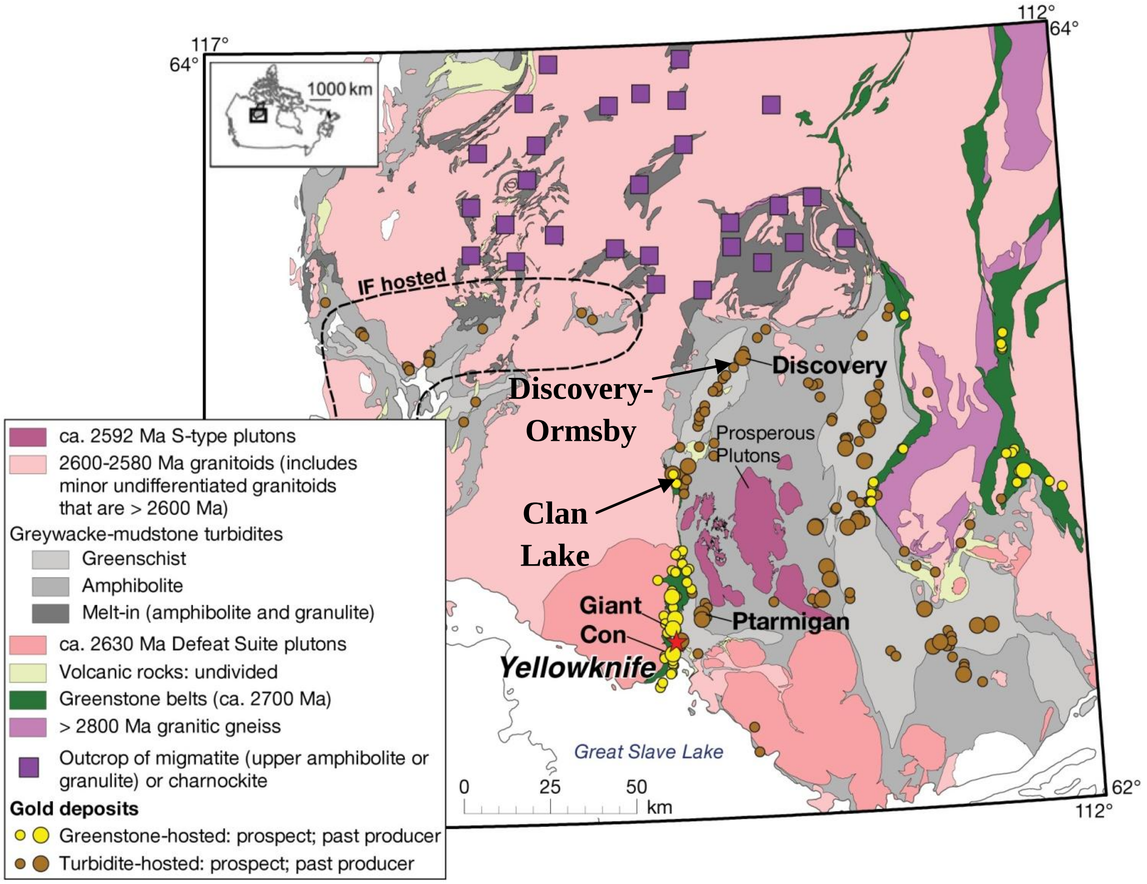

Fig. 1. Geological map of the Slave Province of western Canada, highlighting gold deposits of the Yellowknife greenstone belt (after Ootes et al., 2011). Note the locations of the Giant, Con, and Discovery mines. Arrows indicate the locations of the two study areas, Discovery-Ormsby and Clan Lake.

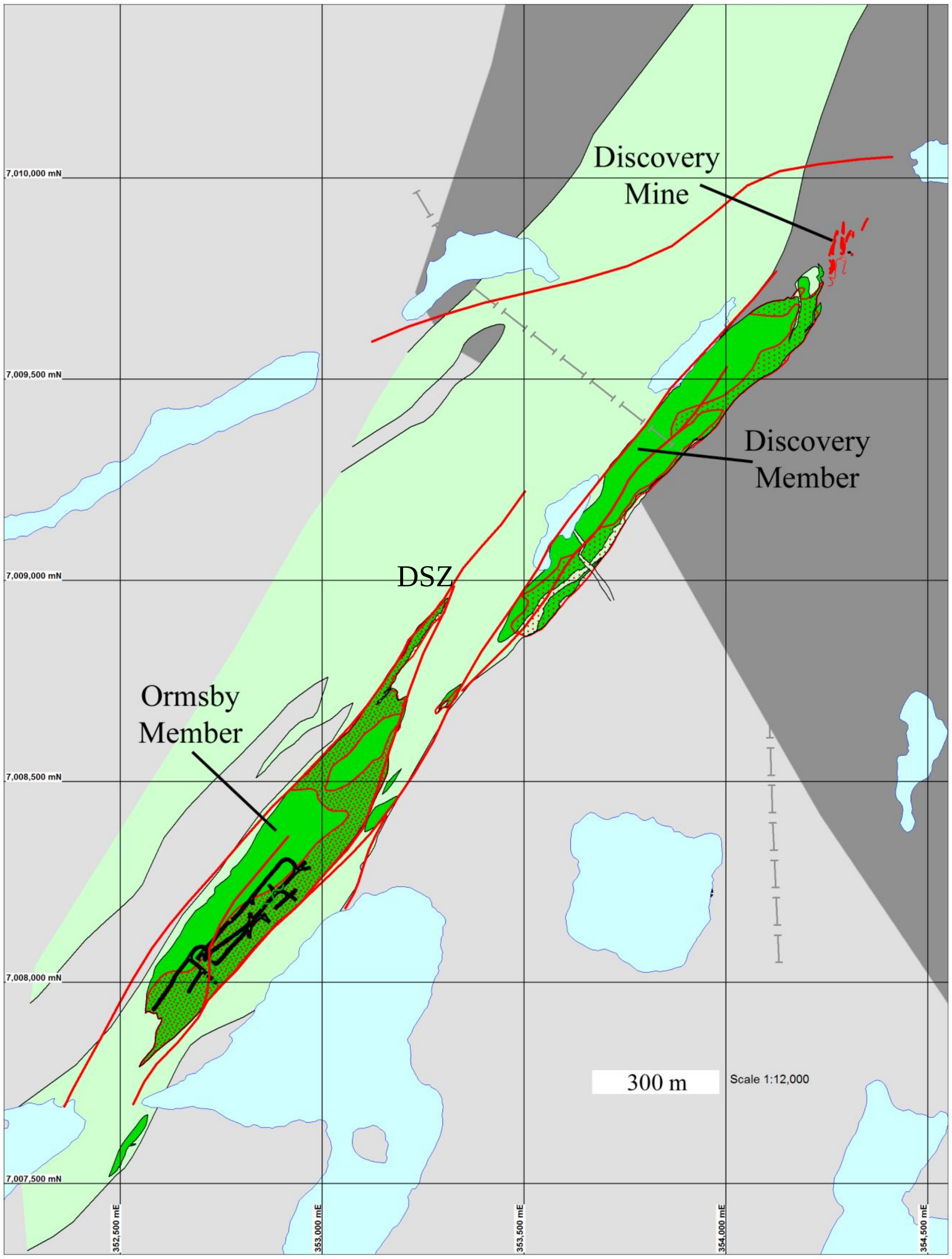

Fig. 2. Generalized geological map of the Discovery-Ormsby area (after Pratico, 2009b). Green indicates mafic metavolcanic rocks of the Giauque Formation and gray indicates metasedimentary rocks of the Burwash Formation. Medium metamorphic grade of the metasedimentary rocks is shown by the dark gray whereas the light gray indicates low metamorphic grade metasedimentary rocks. Quartz veins of the Discovery mine are indicated by irregular red lines. Stippled pattern represents gossan; dashed line indicates the cordierite-in isograd; longer red lines are faults, including the left-lateral Discovery Shear Zone (DSZ) (Stubley, 1997).

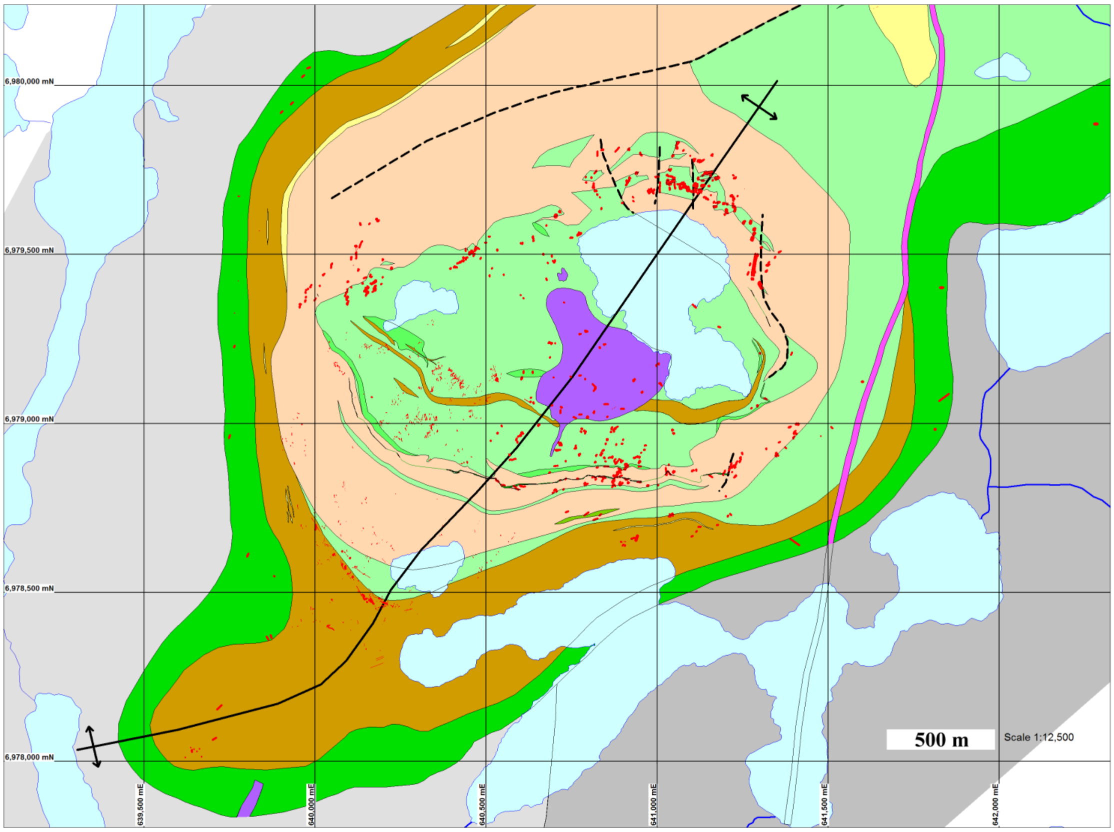

Fig. 3. Generalized geological map of the Clan Lake area (Pratico, 2009c). Gray indicates Burwash Formation metasedimentary rocks. The dark gray shows medium metamorphic grade metasedimentary rocks whereas the light gray indicates low metamorphic grade metasedimentary rocks of the Burwash Formation. Metavolcanic lithologies of the Banting Group include: mafic flows (dark green); inter-volcanic sediments (brown); felsic volcanic flows (yellow); intermediate flows and tuffs (light green); pyroclastic intermediate rocks (peach); garnetiferous mafic tuffs (medium green). The complex is cored by a younger gabbro (purple) and crosscut by a younger diabase dike (fuchsia). Quartz veins are indicated in red. Dashed lines represent faults.

metasedimentary rocks of the Archean Burwash Formation (Padgham, 1992; Bullen and Robb, 2006; Pratico, 2009a).

Current plans for the Discovery-Ormsby area are focused on mining gold ore hosted principally within metavolcanic rocks of the Archean Banting Group (Pratico, 2009a). Gold deposits in the Ormsby Member of the Giauque Lake Formation are undergoing environmental permitting, with mining anticipated to begin in 2014. Resource estimations are an approximate 1.2 M toz gold with an average gold grade of 3.42 g/t (0.11 toz/t) (Pratico, 2009a).

Exploration History of the Clan Lake Area

The Clan Lake area (Fig. 3) was first explored and prospected for gold in the mid-1960's. Its history has been presented by Pratico (2009a) and is summarized below. An early claimholder processed a 1150 ton bulk sample in 1967 and reported a head gold grade of 14.5 g/t (0.47 toz/t). The area's claims were transferred between companies until Tyhee Gold Corporation acquired the area through contiguous staking from 2006-2009. Clan Lake is now considered an active exploration target. Resource estimations of the Main Zone of the Clan Lake area are approximately 350,000 toz gold with an average gold grade of 3.64 g/t (0.12 toz/t).

Rationale for Study

The ore production from the former Discovery Mine and the pending mine status of Ormsby indicate that significant economic gold mineralization exists in the northern YGB. They represent hope that other gold showings in the north end may also prove to be economic targets. This potential is being tested at the Clan Lake area, 38 km south-southwest of Discovery-Ormsby, where active drilling has documented significant gold mineralization. The principal difference between the Discovery-Ormsby and Clan Lake areas is host rock lithology (mafic versus intermediate-felsic, respectively). This presents an opportunity to determine if their ores are related to similar hydrothermal systems whose chemistries differ as a function of host lithology, or if they are instead products of chemically distinct hydrothermal systems.

Comparisons to the deposits of the southern YGB will help to develop a conceptual model for the YGB, which may be applicable to other greenstone belts that have similarly high proportions of metasedimentary rocks relative to their metavolcanic rocks.

This study employs extensive microscopy (transmitted light/petrographic, reflected light/ore, cathodoluminescent, scanning electron), oxygen isotope analysis of quartz veins and wall rocks, analysis of large lithogeochemical data sets from exploration drill core, and 3-D modeling to determine the source(s) of ore-bearing fluid(s), their pathways, and the degree(s) of host rock interaction in the two areas.

Study Questions

The primary questions addressed in this study include:

1) What is the nature of the ore mineralization (mineralogy, paragenesis) in each area?

2) Where did the fluids responsible for gold mineralization originate? Were the fluids responsible for ore deposition derived from a metasedimentary reservoir, a

metavolcanic reservoir, or an interplay of both metasedimentary and metavolcanic fluid sources?

3) What factors controlled the spatial distribution of gold? Is there a preferred host rock lithology/chemistry that determines where gold mineralization occurs or is ore associated preferentially with enhanced permeability and porosity during the gold mineralizing event, regardless of lithology? Does a combination of both factors contribute to the spatial distribution of gold?

4) Can a conceptual model for resource potential be constructed for the entire YGB from comparisons of these study areas to deposits of the southern YGB? If so, what are its implications for future exploration efforts in the YGB?

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CHAPTER 2: GEOCHEMICAL STUDIES OF GOLD MINERALIZING EVENTS IN THE DISCOVERY-ORMSBY AND CLAN LAKE AREAS OF THE YELLOWKNIFE GREENSTONE BELT, NORTHWEST TERRITORIES, CANADA

Introduction

The Slave Province of northern Canada has produced approximately 16 M ozt of gold, mined primarily from the world-class Yellowknife Greenstone Belt (YGB) of the Northwest Territories (Fig. 1) (Goldfarb et al., 2001; Bullen and Robb, 2006; Goodwin et al., 2006). The Giant and Con mines of the southern YGB produced approximately 12.5 M ozt of gold (7.0 M ozt and 5.5 M ozt, respectively) from Archean metavolcanic rocks (Bullen and Robb, 2006). The Slave Province hosts many prospective gold showings. Although there are few areas of active exploration in the northern end of the YGB, two of the more promising are the Discovery-Ormsby and Clan Lake areas, where Tyhee Gold Corporation has mounted a substantial exploration effort (Plate 1; Figs. 2-3).

The Discovery-Ormsby area contains the former Discovery Mine, known for past production of approximately 1 M ozt gold from one M tonnes of ore, mined from quartz veins hosted in metasedimentary rocks (Padgham, 1992; Bullen and Robb, 2006; Pratico, 2009a). Current resource estimations for the nearby mafic metavolcanic Ormsby Member of the Giauque Lake Formation include approximately 1.2 M toz gold at a grade of 3.42 g/t (0.11 toz/t) (Pratico, 2009a). Thirty-eight km to the south-southwest, intermediate-felsic metavolcanic rocks of the Clan Lake area are estimated to contain approximately 350,000 toz gold at a grade of 3.64 g/t (0.12 toz/t) (Pratico, 2009a).

The main objectives of this study are to document the nature of gold ores in the Discovery-Ormsby and Clan Lake areas and to determine whether they are related to similar hydrothermal systems whose chemistries differed as a function of host lithology, or if they were instead products of chemically distinct hydrothermal systems. If the ores are related to chemically similar systems, what factors controlled the spatial distribution of gold? Is there a preferred host rock lithology/chemistry that determined where gold mineralization occurs or is ore associated preferentially with zones of enhanced permeability and porosity during the gold mineralizing event, regardless of lithology? Or, does a combination of both factors contribute to the spatial distribution of gold?

To answer these questions, this study employs oxygen isotope analysis of quartz veins and wall rocks, analysis of large lithogeochemical data sets of exploration drill core, and 3-D modeling to determine the ore-bearing fluid source(s), pathways, and degree(s) of host rock interaction in the two areas.

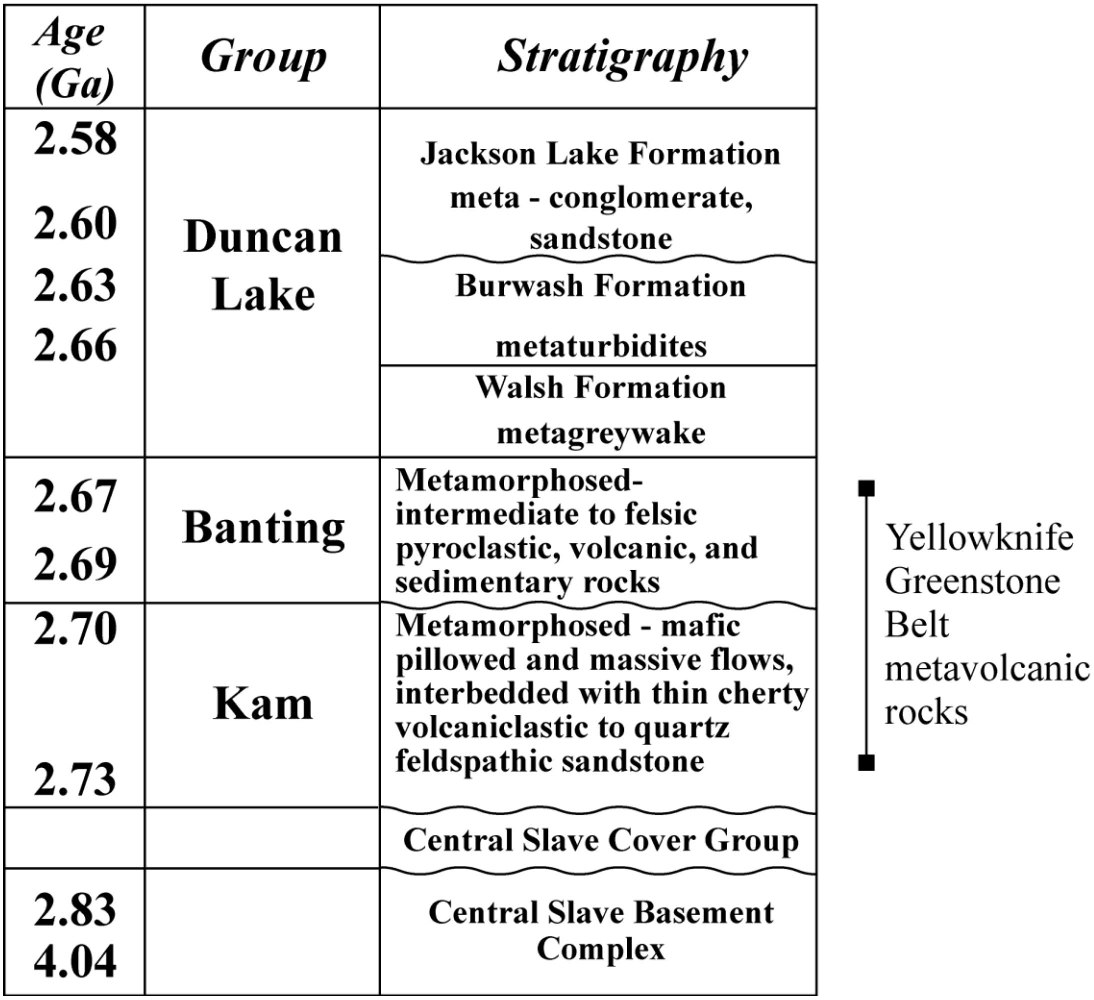
Regional Geology

The Archean Slave craton is a well-exposed portion of the northwestern Canadian Shield (Stern and Bleeker, 1998; Bleeker and Hall, 1999; Bowring and Williams, 1999) and contains some of the oldest intact rocks on the planet (e.g. the 3962 ± 3 Ma Acasta Gneiss; Bowring et al., 1989). The Slave craton is unusual compared to other Archean cratons due to its high proportion of metasedimentary rocks relative to metavolcanic rocks (Helmstaedt and Padgham, 1986; Padgham and Fyson, 1992; Isachsen and Bowring, 1994; Ferguson et al., 2005).

Basement rocks of the craton range in age from > 2.8 to ~ 4.0 Ga (Bleeker et al., 1999, 2000; Sircombe et al., 2001; Ketchum et al., 2004). Rocks of the Central Slave Basement are poly-metamorphosed gneisses with local migmatization, ranging from tonalite to granodiorite in composition (Henderson, 1985; Bowring et al., 1989; Stern and Bleeker, 1998; Bowring and Williams, 1999; Cousens et al., 2002). The Central Slave Cover Sequence unconformably overlies the Central Slave Basement and contains quartzite, chert-magnetite iron formation and felsic to intermediate metavolcanic rocks (Covello et al., 1988; Roscoe et al., 1989; Bleeker et al., 1999, 2000; Cousens et al., 2002; Bleeker and Hall, 2007).

Supracrustal Rocks

The Yellowknife Supergroup unconformably overlies rocks of the basement and cover sequence (Fig. 4) (Henderson, 1985; Bleeker et al., 1999). [For clarity, the following descriptions of these supracrustal rocks reflect their protoliths rather than their metamorphic equivalents.] The oldest rocks of the supergroup belong to the 2.73-2.70 Ga Kam Group, which is characterized by widespread ($\geq$ 100,000 km^2) and voluminous mafic pillows and flows (1-6 km thick) interbedded with volcaniclastic to quartz feldspathic sandstones (Henderson, 1985; Helmstaedt and Padgham, 1986; Goodwin, 1988; Cousens et al., 2002; Ernst and Buchan, 2004). Unconformably overlying the Kam Group are the 2.69-2.66 Ga, intermediate to felsic, pyroclastic volcanic rocks of the Banting Group, which are intercalated with tholeiitic to calc-alkaline basaltic rocks and volcanogenic sedimentary rocks (Helmstaedt and Padgham, 1986; Goodwin, 1988; Bleeker and Hall, 2007).



Age (Ga)	*Group*	*Stratigraphy*
2.58 2.60 2.63 2.66	Duncan Lake	Jackson Lake Formation meta - conglomerate, sandstone
		Burwash Formation metaturbidites
		Walsh Formation metagreywake
2.67 2.69	Banting	Metamorphosed- intermediate to felsic pyroclastic, volcanic, and sedimentary rocks
2.70 2.73	Kam	Metamorphosed - mafic pillowed and massive flows, interbedded with thin cherty volcaniclastic to quartz feldspathic sandstone
		Central Slave Cover Group
2.83 4.04		Central Slave Basement Complex

Fig. 4. Simplified stratigraphic column of basement and supracrustal rocks of the Yellowknife greenstone belt (after Whitty, 2007).

The youngest rocks of the Yellowknife Supergroup are the Duncan Lake Group, which conformably overlies the Banting Group (Henderson, 1972; Helmstaedt and Padgham, 1986; Ferguson et al., 2005; Martel and Lin, 2006). The sedimentary rocks of the Duncan Lake Group are subdivided into the Walsh, Burwash, and Jackson Lake formations. The Walsh Formation is composed of graphitic argillite, mudstone, and turbidite deposits and is similar lithologically to the overlying Burwash Formation (Henderson, 1985; Helmstaedt and Padgham, 1986; Martel and Lin, 2006).

Development of the Burwash Basin (2.68-2.66 Ga) resulted in sedimentation of immature greywackes, mudstones, sandstones and turbidites of the voluminous Burwash Formation (Henderson, 1985; Helmstaedt and Padgham, 1986; Ferguson et al., 2005). The Kam and Banting groups are considered the primary sources of sediment for the Burwash Basin (Henderson, 1972, 1985; Ferguson, 2005). These sedimentary rocks are interbedded with rarer felsic tuffs (Bleeker and Villeneuve, 1995; Ferguson et al., 2005). The youngest rocks of the Duncan Lake Group, and therefore of the Yellowknife Supergroup, belong to the Jackson Lake Formation (< 2.605 Ga) (Isachsen and Bowring, 1994). These rocks are polymict conglomerates and sandstones that often obscure the contact between the Kam and Banting groups (Helmstaedt and Padgham, 1986; Falck, 1990; Davis and Bleeker, 1999).

Closure of the Burwash Basin (2.65-2.63 Ga) resulted in northeast-southwest folding and marked the initiation of pluton emplacement (2.63-2.59 Ga) (Bleeker and Hall, 2007). A later regional structural overprint occurred from 2.60 to 2.58 Ga, resulting in a north-south to northwest-southeast folding and faulting trend (Davis and Bleeker, 1999).

Numerous post-Burwash Formation plutons have intruded the Yellowknife Supergroup (from 2.63 to 2.59 Ga), varying temporally from earlier metaluminous to later, distinctly peraluminous granitic rocks (see Henderson, 1985; van Breemen et al., 1992). Major pluton emplacement concluded with the ~2.59 Ga “granite bloom” (i.e. Prosperous granites) (Kusky, 1993; Davis and Bleeker, 1999). Numerous Proterozoic (ca. 2.2 Ga) diabase dikes and faults crosscut rocks of the Yellowknife Supergroup and some plutons (Boyle, 1961; Green and Baadsgaard, 1968; LeCheminant and Heaman, 1989; LeCheminant et al., 1997).

Peak regional metamorphism and deformation coincided with peak magmatism (Thompson, 1989; van Breemen et al., 1992; Davis and Bleeker, 1999). Metamorphic aureoles are found frequently surrounding plutonic complexes, which overprint regional metamorphic trends and may coalesce with nearby aureoles (Henderson, 1985; Thompson, 2006). Peak metamorphic conditions reached upper greenschist-amphibolite grade (Henderson, 1985; Helmstaedt and Padgham, 1986; Isachsen and Bowring, 1994). The transition zone between greenschist and amphibolite facies may be used as a crude guide to gold deposit types in the YGB (Fig. 1; Plate 1). Within the amphibolite facies, gold deposits are typically auriferous quartz veins crosscutting metasedimentary rocks. Upper greenschist facies rocks may contain wall-rock-hosted gold deposits in addition to mineralized quartz veins.

Shear zones have been observed that both pre-date and postdate pluton emplacement and peak metamorphism (Helmstaedt and Padgham, 1986; Siddorn, 2011). Shear zones that transect the metavolcanic rocks are more frequently mineralized compared to those that are adjacent to the metavolcanic rocks (Boyle, 1961; Henderson, 1985). Deformation within the metasedimentary rocks consists of complex folding and faulting, with degrees of shear frequently concentrated along zones of rock competency contrast (i.e. argillite, bedding planes) (Boyle, 1961).

These features were critical in the formation of large, wall-rock hosted gold deposits in the southern YGB. Faults and shear zones may serve as fluid conduits (Boyle, 1961), allowing auriferous fluids from metasedimentary reservoirs to reach highly reactive metavolcanic host rocks (van Hees et al., 1999, 2006; Shelton et al., 2004). Conversely, faults and shear zones may also act as barriers, hindering fluid flow (Hill et al., 2010).

Gold in the YGB

Creating economic gold mineralization requires auriferous fluid source(s), structural conduits, and, for wall-rock hosted deposits, highly reactive host rocks. Previous investigators have found it difficult to reconcile the substantial gold mineralization in the southern YGB if the gold were assumed to have originated solely from within metavolcanic source rocks (van Hees et al., 1999). Compared to other Archean greenstone belts, the YGB is dominated by voluminous metasedimentary rocks rather than metavolcanic rocks. Since these metasedimentary rocks are derived, in part, from the pre-metamorphic volcanic rocks, it is reasonable that these metasedimentary rocks are an equally viable source of gold as their volcanic precursors.

The presence of vein-hosted gold deposits within metaturbidites of the Burwash Formation, such as the Discovery, Tom and Ptarmigan mines near Yellowknife, demonstrates that economic concentration of gold is possible solely within metasedimentary rocks (Fig. 1) (Padgham and Fyson, 1992; Bullen and Robb, 2006). Therefore, a metasedimentary fluid reservoir is not only possible, it is probable. Recent investigations have suggested that metasedimentary-derived fluids overprinting metavolcanic rocks may have been a necessary condition for the development of world-class gold deposits in the southern YGB (van Hees et al., 1999, 2006). The important roles of both metasedimentary and metavolcanic fluid reservoirs may explain how smaller greenstone belts, with limited volumes of metavolcanic host rocks, may contain substantial economic gold mineralization (Shelton et al., 2004).

Shear zones and faults are critical conduits for auriferous metasedimentary fluids and allowed these fluids to reach highly reactive metavoclanic rocks of the YGB. In the southern YGB, previous investigations have invoked the Yellowknife River Fault Zone (YRFZ) to accomplish this fluid link (van Hees et al., 1999, 2006; Shelton et al., 2004; Martel and Lin, 2006). In the northern YGB, in addition to an inferred extension of the YRFZ, there are other regional faults that may also have served as conduits for auriferous metasedimentary fluids to reach reactive metavolcanic rocks (Plate 1).

Gold mineralization has been documented in all lithologies of the Yellowknife Supergroup (Martel and Lin, 2006); however economic wall-rock-hosted gold mineralization favors highly reactive host rocks that have experienced metamorphism near the greenschist-amphibolite grade transition (Fig. 1; Plate 1). In the Giant Mine of the southern YGB, van Hees et al. (1999) documented that high-Ti, Fe-tholeiitic metabasalts were the favored ore-hosting lithology for refractory sulfide ores. The mafic metavolcanic rocks of the Discovery-Ormsby area are an iron-rich anomaly compared to the surrounding metasedimentary rocks of the Burwash Formation, and are an obvious potential host rock for sulfidized ores. In the Clan Lake area, the intermediate-felsic host rocks' ore-hosting potentials are less obvious due to their lower iron content. The difference in host rock composition at the Discovery-Ormsby and Clan Lake areas is intriguing and serves as the foundation for comparison between the two gold exploration areas.

Discovery-Ormsby

The Discovery-Ormsby area is located approximately 90 km north of Yellowknife. This area contains two narrow (~ 225 m), elongate (~ 1400 m) metamorphosed mafic rock bodies of the Giauque Lake Formation (Discovery Member to the north and Ormsby Member to the south) surrounded by a sea of metasedimentary rocks of the Burwash Formation (Fig. 2). The mafic metavolcanic rocks have been correlated to the Archean Banting Group using U-Pb geochronology (2661 ± 5 Ma; Whitty, 2007).

These metamorphosed mafic bodies have been described as metabasalts or amphibolites (i.e. Whitty, 2007; Pratico, 2009a). Major prograde minerals are almandine garnet, biotite, quartz, plagioclase and amphiboles, including ferro-tschermakite, ferro-hornblende, and actinolite (Whitty, 2007). The Discovery-Ormsby area has been subject to conditions near the upper greenschist-amphibolite grade transition, as indicated by the cordierite-in isograd within the metasedimentary rocks, which is inferred to crosscut the Discovery Member (Fig. 2) (Pratico, 2009a). Retrograde metamorphism dominates host rock mineralogy, with development of overlapping chlorite, chlorite intergrown with biotite (Fig. 5), sericite, and carbonate.

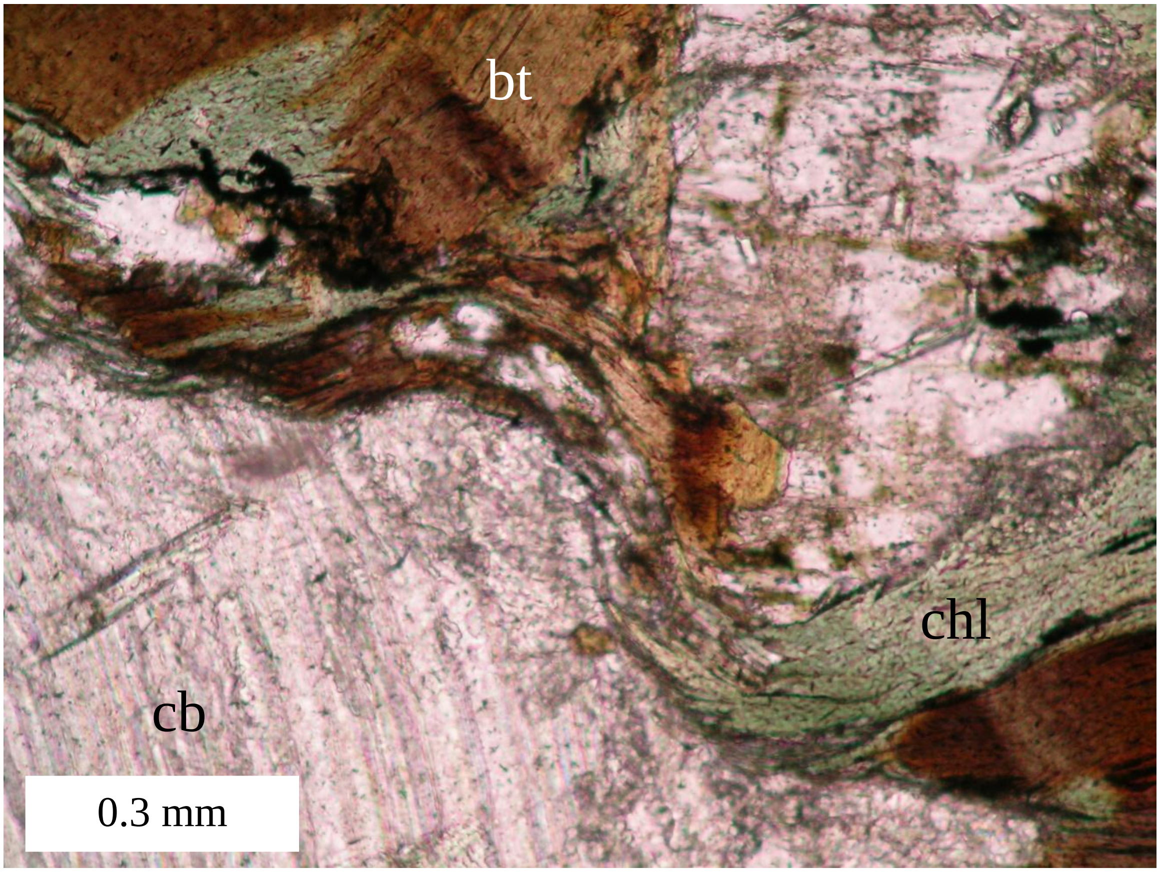


Fig. 5. Plane polarized light (PPL) photomicrograph of retrograde minerals in an amphibolite rock sample from the Discovery-Ormsby area, carbonate (cb) and biotite (bt) intergrown with chlorite (chl).

The metavolcanic rocks of the Discovery-Ormsby area are surrounded by voluminous, more ductile metasedimentary rocks of the Burwash Formation. This competency contrast is analogous to porphyroblasts in a more ductile matrix, where the more rigid metavolcanic rocks are more resistant to deformation (Whitty, 2007). This scenario of competing competencies between rigid bodies enveloped by less competent rocks is a typical setting for Archean orogenic gold deposits (e.g. Yilgarn block, Australia and Abitibi belt, Ontario; Groves et al., 2000).

A ductile shear zone is not readily observed at Discovery-Ormsby, but is thought to be overprinted by retrograde metamorphism and brittle faults (Whitty, 2007). A linear zone of higher strain, termed the Discovery shear zone, is interpreted by Tyhee Gold Corporation to exist on the immediate western margin of the metavolcanic members. This shear zone may have provided the extensional stress regime that permitted movement of hydrothermal fluids and the deposition of gold mineralization (Pratico, 2009a).

A strong, near-vertical lineation can be observed across the Discovery-Ormsby area. Within the deformed mafic metavolcanic rocks, it is easily apparent in outcrop, especially within relict pillows and fragmental rocks (Fig. 6). In thin section, it is defined by alignment of amphibole crystals (Whitty, 2007). The linear fabric is not as easily detected in the metasedimentary rocks in outcrop, but is well defined in thin section (Whitty, 2007). Extensive microscopy in the current study, utilizing seventy-six polished thin sections, indicates that shear deformation may be concomitant with metamorphism, as evidenced by peak metamorphic mineral assemblages that are concordant to

Fig. 6. Vertical elongation deformation of fragmental mafic metavolcanic rocks from the Ormsby Member of the Giauque Lake Formation. Note the 6 cm pocket knife for scale.

deformation fabrics. Overprinting, discordant retrograde minerals indicate that retrograde metamorphism is post-shear deformation (Figs. 5, 7).

Deformation, at least in part, is synchronous with some sulfide mineralization, as shearing caused rotation, recrystallization and deformation in early arsenopyrite, and to a lesser extent in early pyrrhotite (Fig. 8). Sulfide mineralization associated with gold occurred after shear deformation, as these sulfides (later pyrrhotite, arsenopyrite, and base metal sulfides) are discordant to deformational fabrics (Fig. 9). Sulfide mineralization pre-dates retrograde metamorphism, as evidenced by elongated and deformed sulfide grains trapped within late chlorite (Fig. 10).

Ore Mineralization

The Ormsby orebody is a silicified, sulfidized, structurally deformed mafic body (Pratico, 2009a). It has also been described as a disseminated stockwork style within highly altered wall rock (Whitty, 2007). Gold occurs as native gold associated with pyrrhotite within quartz veins and altered wall work. At surface, oxidation of sulfides has formed a recognizable iron staining that is mapped as a gossan zone by Tyhee Gold Corporation (Fig. 2). This zone is used as a primary guide for drilling. Gold mineralization is found typically within foliated and brecciated rocks containing 1-10% pyrrhotite (Pratico, 2009a), especially within those that also contain abundant arsenopyrite (this study).

Two styles of quartz veins have been observed at the Discovery-Ormsby area and are described in detail by Whitty (2007) and Pratico (2009a), as summarized below. The more common style strikes sub-parallel to the dominant deformational fabric of the rock

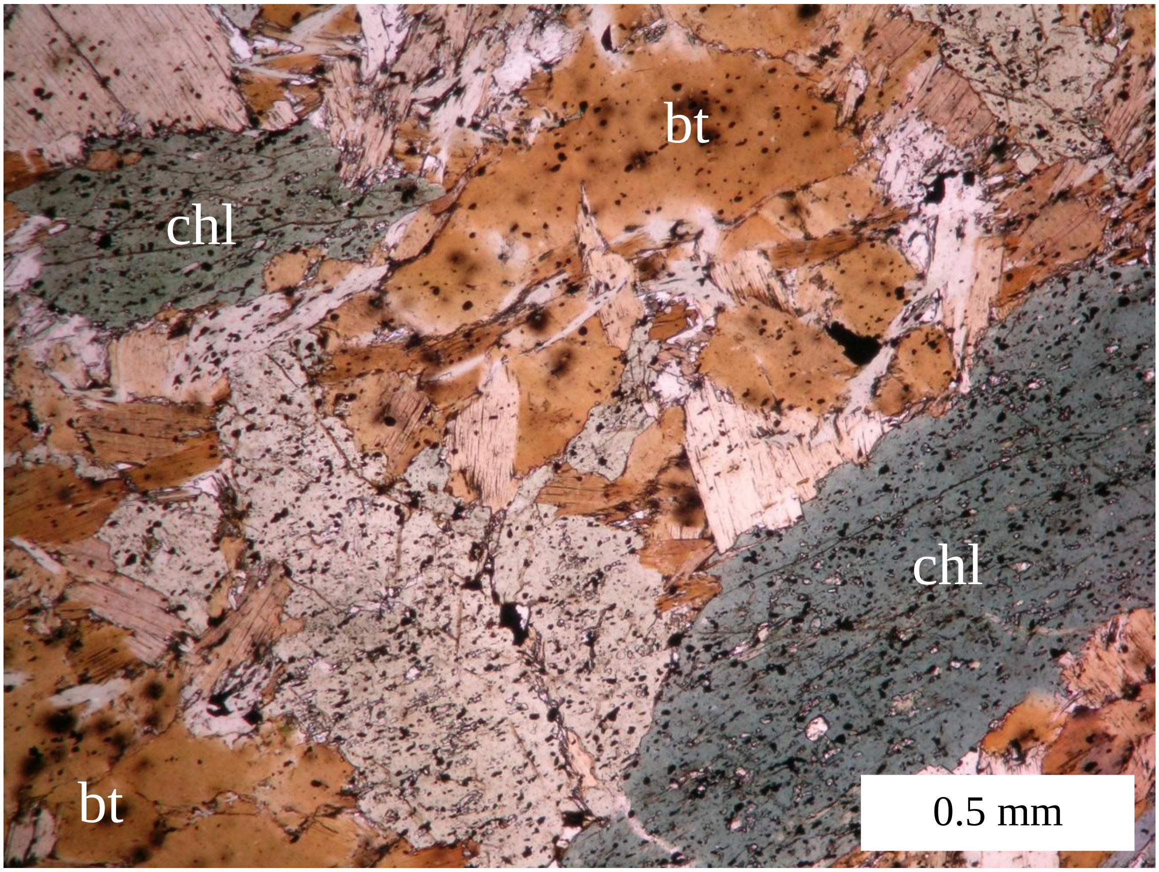


Fig. 7. Photomicrograph (PPL) of overprinting, retrograde minerals, biotite (bt) and chlorite (chl), in an amphibolite rock sample from the Discovery-Ormsby area.

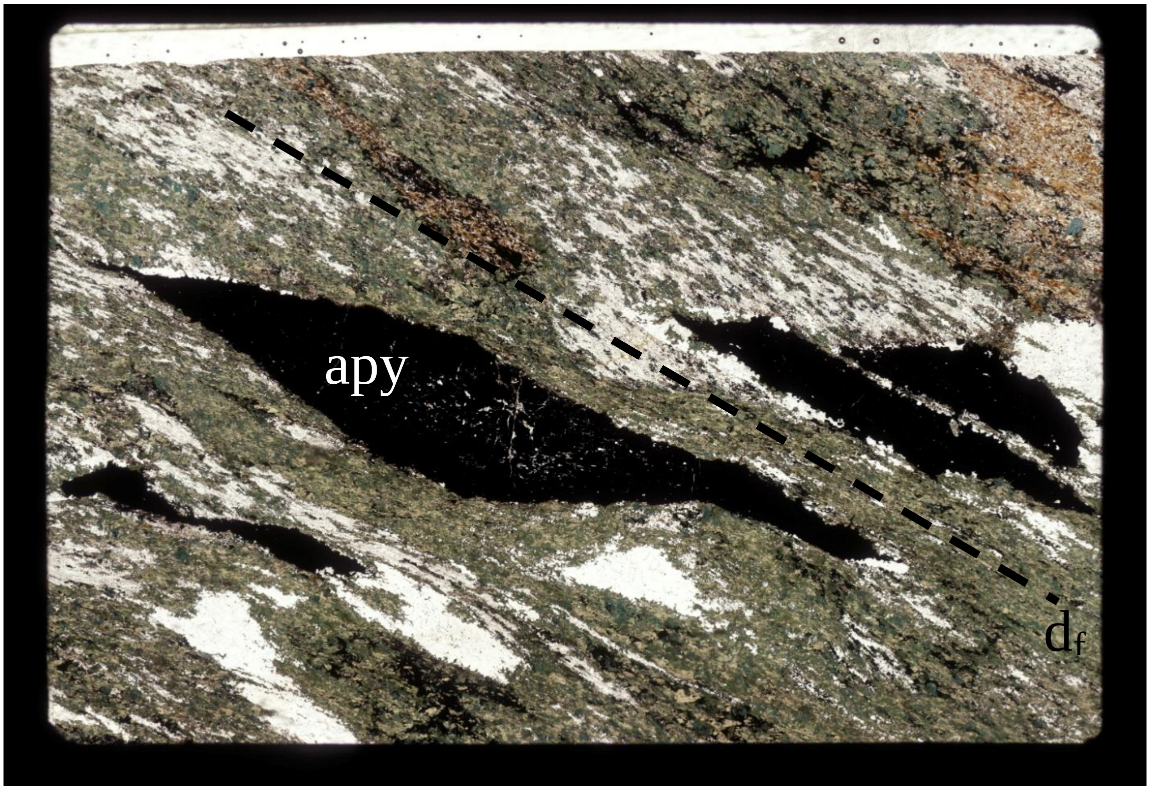


Fig. 8. Scanned image (PPL) of polished thin section of an amphibolite rock sample showing the left-lateral shear-induced deformation and recrystallization of arsenopyrite (apy) concordant to silicate minerals (chlorite = green; biotite = brown; carbonate and quartz = white) forming the deformational fabric (dashed line, d_f) of the wall rock. Width of field is approximately 41 mm.

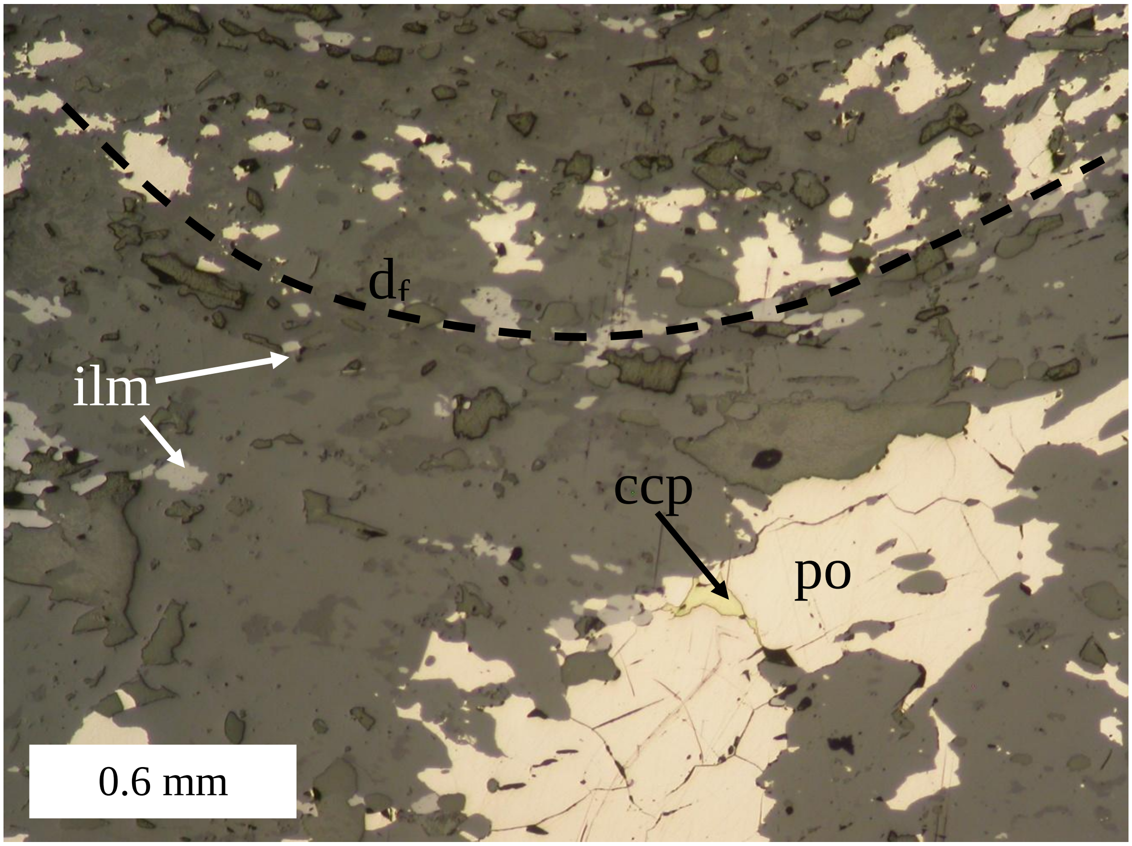


Fig. 9. Reflected light (RL) PPL photomicrograph of an amphibolite rock sample showing a late generation of pyrrhotite (po) and chalcopyrite (ccp) discordant to deformational fabric (dashed line, d_f), defined by elongated earlier pyrrhotite (po) and ilmenite (ilm).

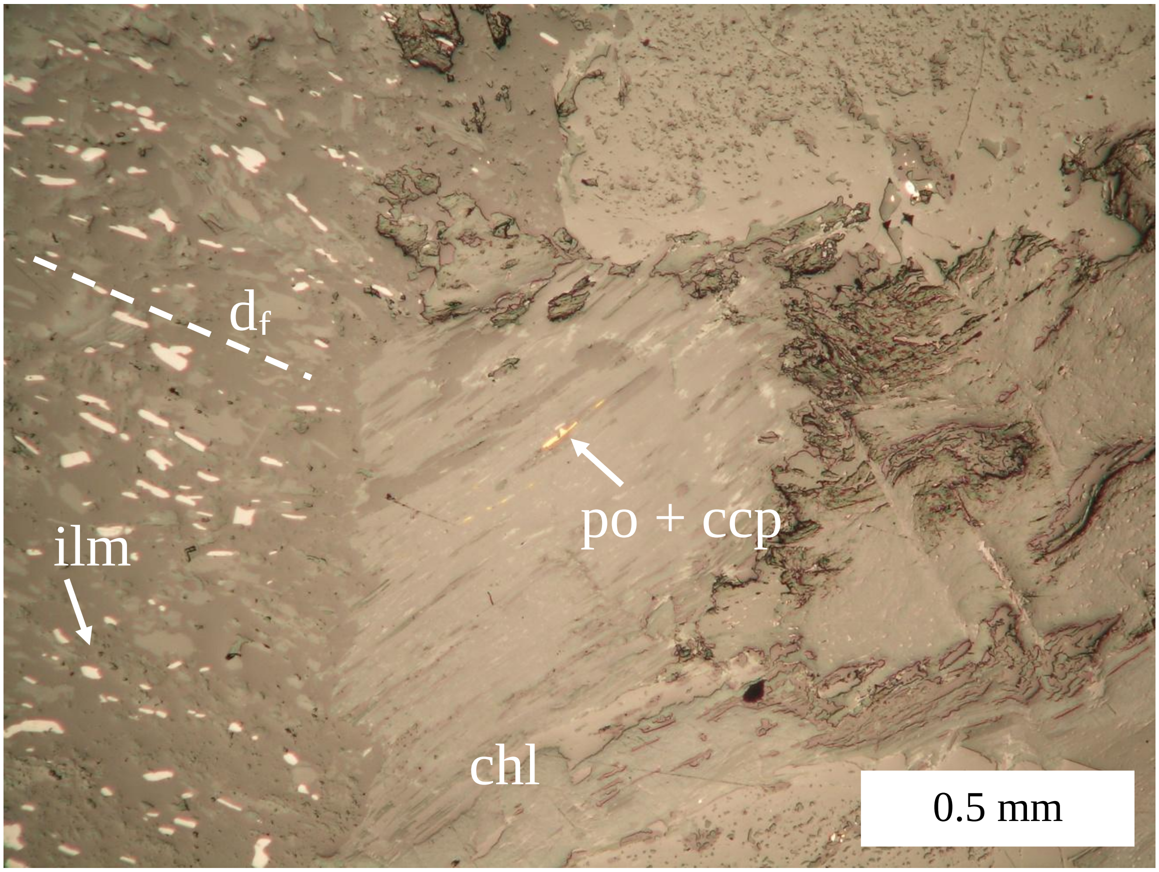


Fig. 10. Photomicrograph (RL, PPL) of an amphibolite rock sample with retrograde chlorite containing pyrrhotite and chalcopyrite, discordant to deformational fabric of the rock (dashed line, d_f) shown by alignment of ilmenite

and dips nearly vertical. These veins are commonly folded, and are less frequently gold bearing. The other style is more frequently gold bearing, and is most prevalent in the coherent meta-pillows (amphibolite) of the Ormsby Member. This silicification occurs as discrete, discontinuous, light to dark gray quartz veins, pods, or disseminations that crosscut foliated and brecciated amphibolite. Quartz veins are typically only a few cm wide and have variable orientations, striking typically 320° to 340° and dipping 10° to 50° SW. Quartz veins have sharp but irregular wall-rock contacts and exhibit changes of orientation over short distances (Pratico, 2009a).

Ore Paragenesis and Alteration

The ore mineral paragenesis for the Discovery-Ormsby area (Fig. 11) is based on observations from hand/drill core samples (n = 74) and polished ore/thin sections (n = 76) (see Appendix 4). Gold occurs as native gold within highly silicified and sulfidized wall rocks and in quartz veins.

Arsenopyrite is the earliest sulfide recognized in this study and pre-dates gold deposition. It is more abundant than documented previously (Whitty, 2007) (Figs. 12a, b). Arsenopyrite is typically euhedral and is frequently a host for later fracture-filling sulfides ± gold. The early timing of arsenopyrite deposition is confirmed by its concordance with the alignment of host-rock minerals including chlorite, biotite, and relict amphiboles that form the deformational fabric of the rock. Arsenopyrite may pre-date shear deformation, as shown by recrystallization and rotation of arsenopyrite, which resulted in the formation of pressure shadows where calcite (and less frequently, quartz or biotite) filled adjacent void space (Figs. 8, 13).

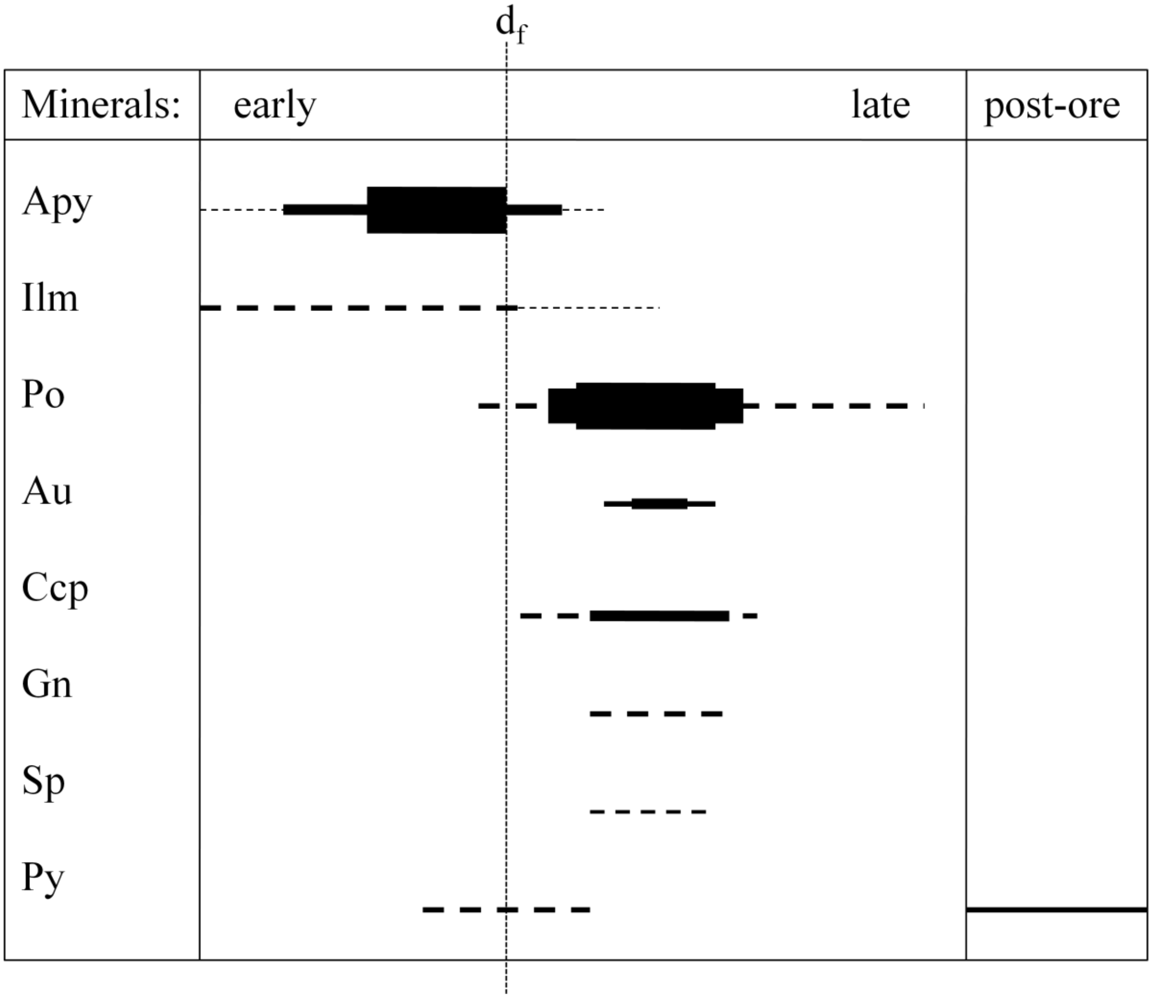


Fig. 11. Simplified ore mineral paragenesis for the Discovery-Ormsby area. . Minerals include arsenopyrite (apy), ilmenite (ilm), gold (Au), pyrrhotite (po), chalcopyrite (ccp), galena (gn), sphalerite (sp), and pyrite (py). Wall rock deformation fabric development (d_f). Note the similarities with Fig. 21.

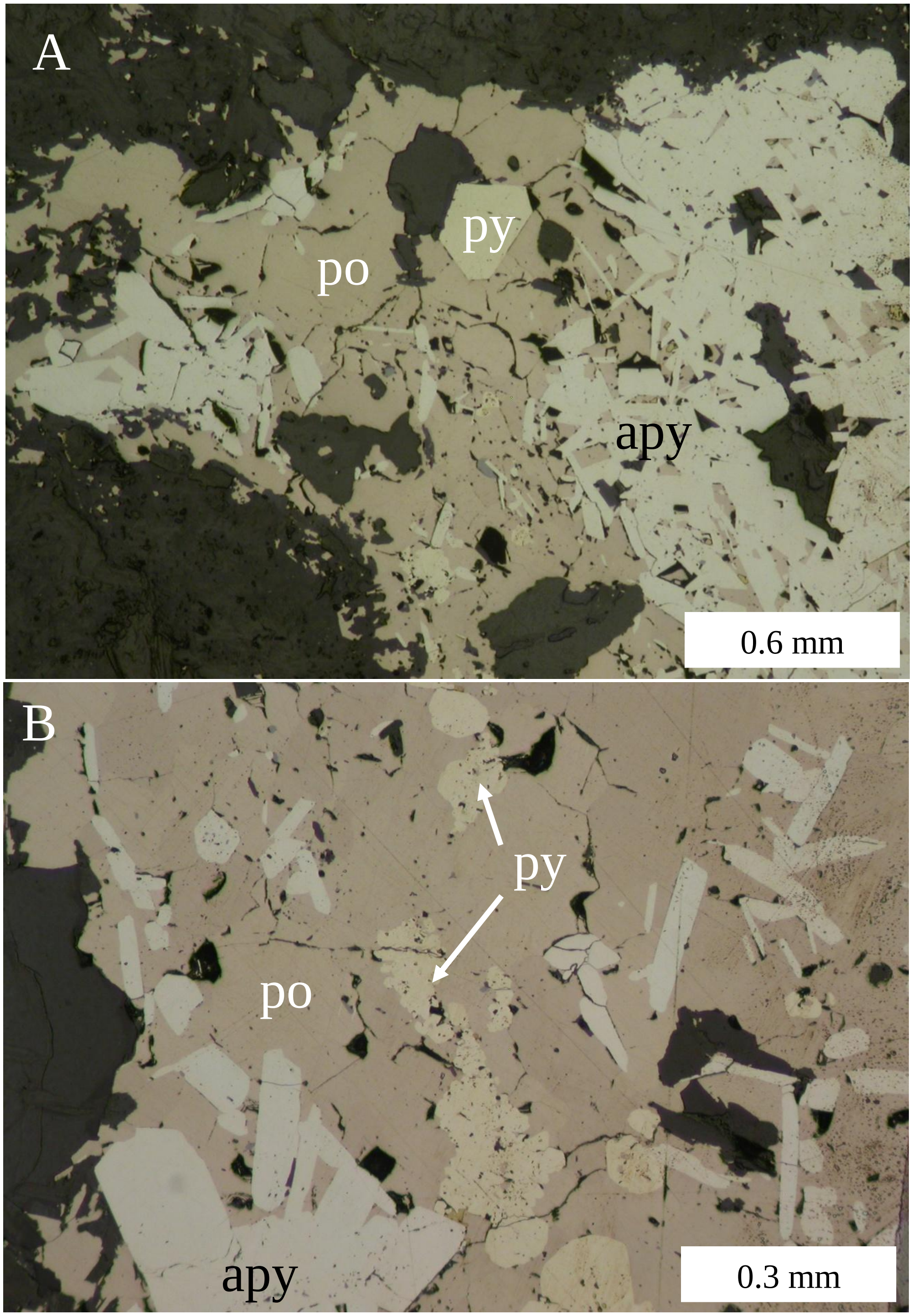


Fig. 12. Photomicrographs (RL, PPL) of sulfides from the Ormsby Member. A. Early arsenopyrite, followed by pyrite (py), overgrown and filled by later pyrrhotite.
B. Euhedral, arsenopyrite overgrown by pyrrhotite, which consumes pyrite.

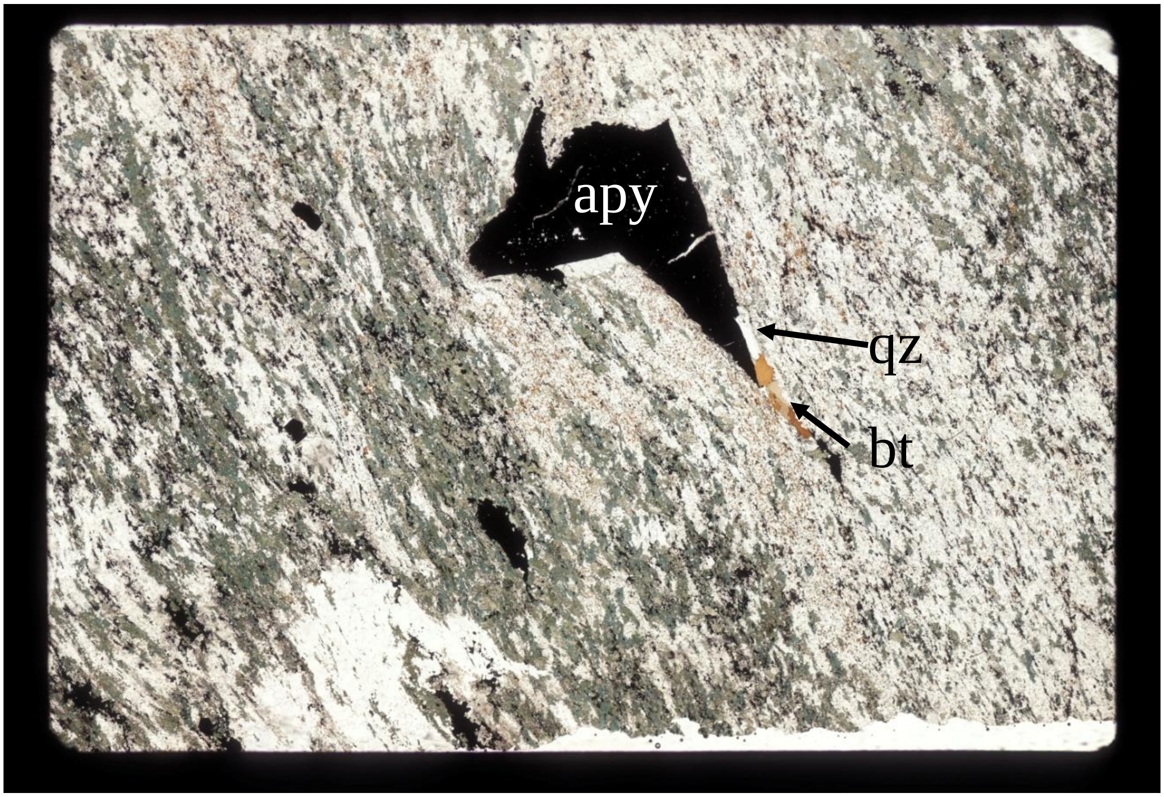


Fig. 13. Scanned image of polished thin-section (PPL) showing recrystallization of arsenopyrite and subsequent pressure shadow development (filled by biotite, bt and quartz, qz) within deformed amphibolite wall rock. The shear-induced recrystallization of arsenopyrite resulted in a concordance with other host rock minerals. The competency contrast between the rigid arsenopyrite and more ductile host rock minerals is analogous to the macro-scale deformation observed at the Discovery-Ormsby area, where the metavolcanic rocks are like the rigid arsenopyrite relative to the more ductile metasedimentary rocks of the Burwash Formation. Field of view (width) is approximately 41 mm.

Pyrite is less abundant and post-dates arsenopyrite deposition. Pyrite is found overgrowing euhedral arsenopyrite or filling fractures in highly deformed arsenopyrite. Pyrite is typically euhedral, especially where it grew as isolated crystals in quartz veinlets or in open space that has been filled subsequently by pyrrhotite. Where pyrite occurs in contact with vein walls in fractured arsenopyrite, later deformation has created fractures in pyrite that are preferred locations for its replacement by later pyrrhotite (Figs. 12a, b). Where dissolution and replacement of pyrite by pyrrhotite is more intense, pyrite is rounded and anhedral, and exhibits a pronounced tarnish.

Later sulfides and gold are discordant to the deformational fabric created by alignment of silicate and early sulfide minerals or fill fractures in the early mineral phases. Gold is associated intimately with pyrrhotite ± base-metal sulfides (chalcopyrite, galena and sphalerite) (Figs. 14a-d). Within the metavolcanic host rock, early arsenopyrite is fractured and filled typically by pyrrhotite, gold and rarer base-metal sulfides (Fig. 14a). Gold ± pyrrhotite also occurs in silicified wall rock as clots discordant to the deformational fabric of the rock (Fig. 14b). In quartz veins, gold may occur independently or intergrown with pyrrhotite (Fig. 14c). In veins containing wall-rock fragments, gold ± pyrrhotite has been observed adjacent to fragments in which plagioclase is altered to biotite (Fig. 14d).

Numerous and overlapping alterations have been observed in the Discovery-Ormsby area, including dominant sulfidation and silicification, as well as potassic (biotite) and carbonate alteration. Pyrrhotite formation is extensive throughout the iron-rich (up to 17.5 wt. % Fe), highly reactive mafic metavolcanic rocks of the Discovery-Ormsby area. Iron-liberating reactions associated with sulfidation have been observed in

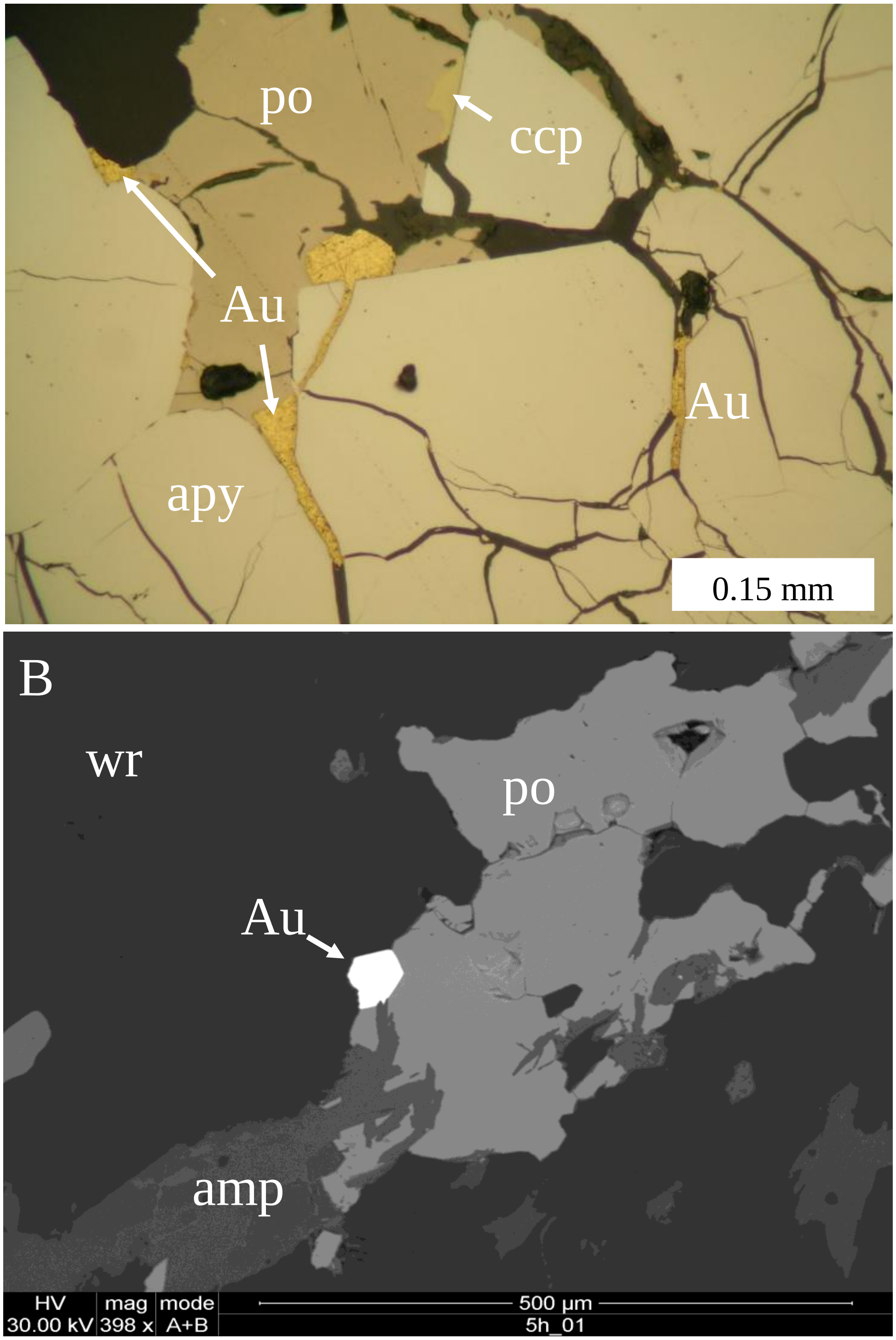


Fig. 14. Photomicrographs of gold-bearing mineralization of the Ormsby Member. A. RL-PPL image of fractured arsenopyrite, filled by pyrrhotite, chalcopyrite, and native gold (Au). B. Scanning electron microscopy (SEM) image utilizing the backscatter detector (BSD) of a highly silicified wall-rock (wr) sample. Gold is intergrown with pyrrhotite (po) adjacent to amphibole (amp).

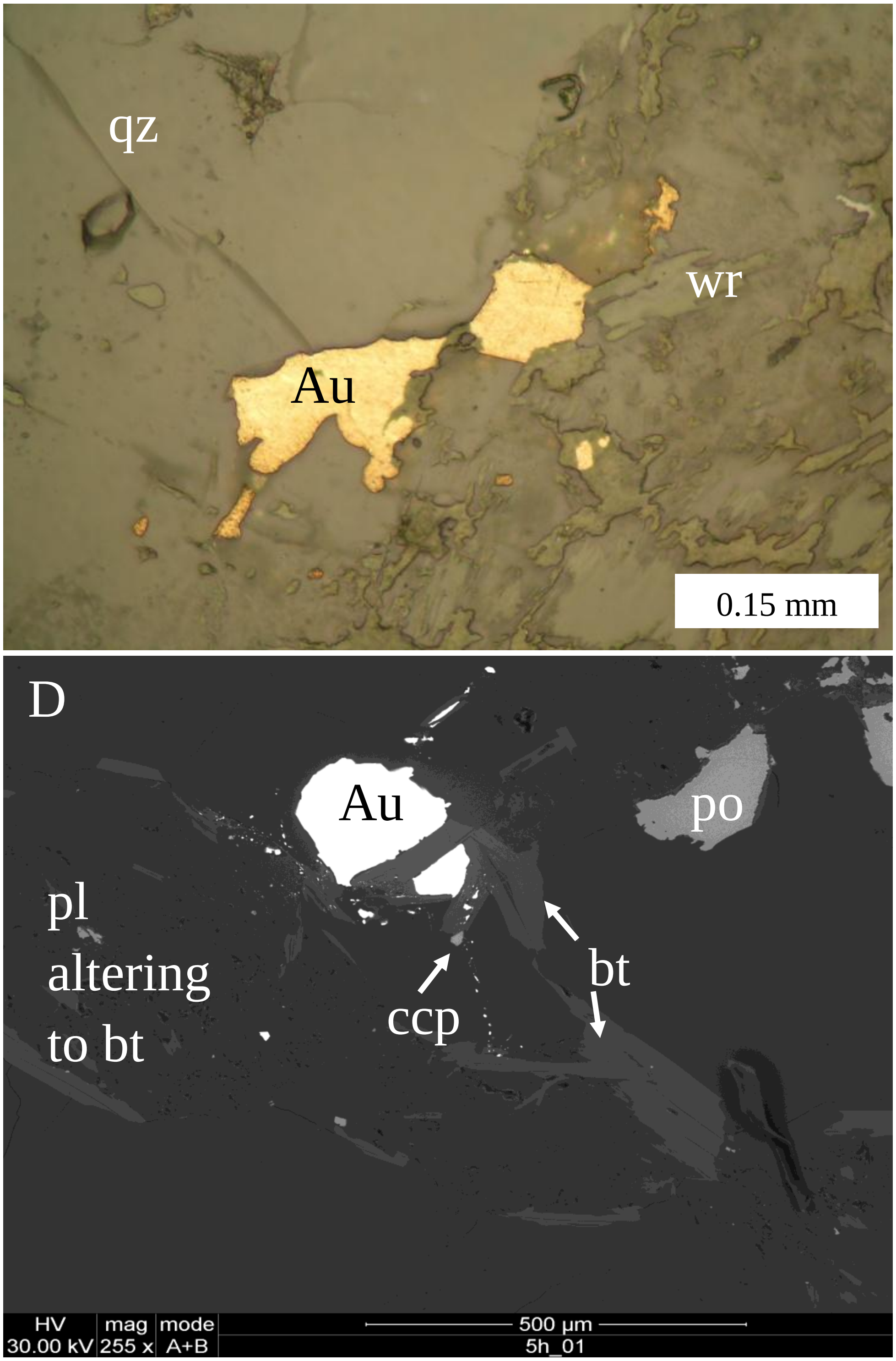


Fig. 14 (continued). C. RL-PPL image of native gold adjacent to a wall-rock fragment, extending into a quartz vein. D. SEM-BSD image of a wall-rock fragment undergoing potassic alteration (conversion of plagioclase (pl) to biotite (bt)) within a quartz vein. Gold is associated with pyrrhotite and chalcopyrite.

wall rocks using transmitted light, ore, and scanning electron microscopy. These include conversion of ilmenite ($FeTiO_3$) to titanite ($CaTiSiO_5$), alteration of amphiboles to chlorite, and recrystallization of early, iron-bearing chlorite to later iron-poor chlorite.

An additional complexity in the alteration history of the mafic rocks is a felsic component, possibly related to syn-peak metamorphism, granitic intrusions, like those found < 7 km north-northeast of the Discovery Mine (Plate 1). This felsic component is denoted by the presence of apatite, scheelite, and biotite (with zircon). Apatite was observed commonly in wall rocks, in quartz veins and in alteration selvedges of veins using cathodoluminescent microscopy (Fig. 15). Scheelite was found within early (pre-gold) ilmenite crystals, using scanning electron microscopy with a backscatter detector (Fig. 16). Additional evidence for a felsic influence may be seen in potassic alteration. Potassic alteration of wall rock fragments is observed within the host rocks adjacent to quartz veins and within quartz veins. This potassic alteration forms biotite from the breakdown of plagioclase. The resulting biotite may be intergrown with pyrrhotite and gold (Fig. 14d). In quartz veins, zircon was detected within biotite adjacent to wall rock fragments (Fig. 17).

The association of Ormsby zone mineralization with biotite alteration and with northwest-striking quartz veinlets that cut both the dominant northeast-striking foliation and earlier foliation-parallel quartz veinlets supports an interpretation that gold mineralization and associated hydrothermal alteration at Ormsby post-dates peak amphibolite facies metamorphism (Stubley, 1997).

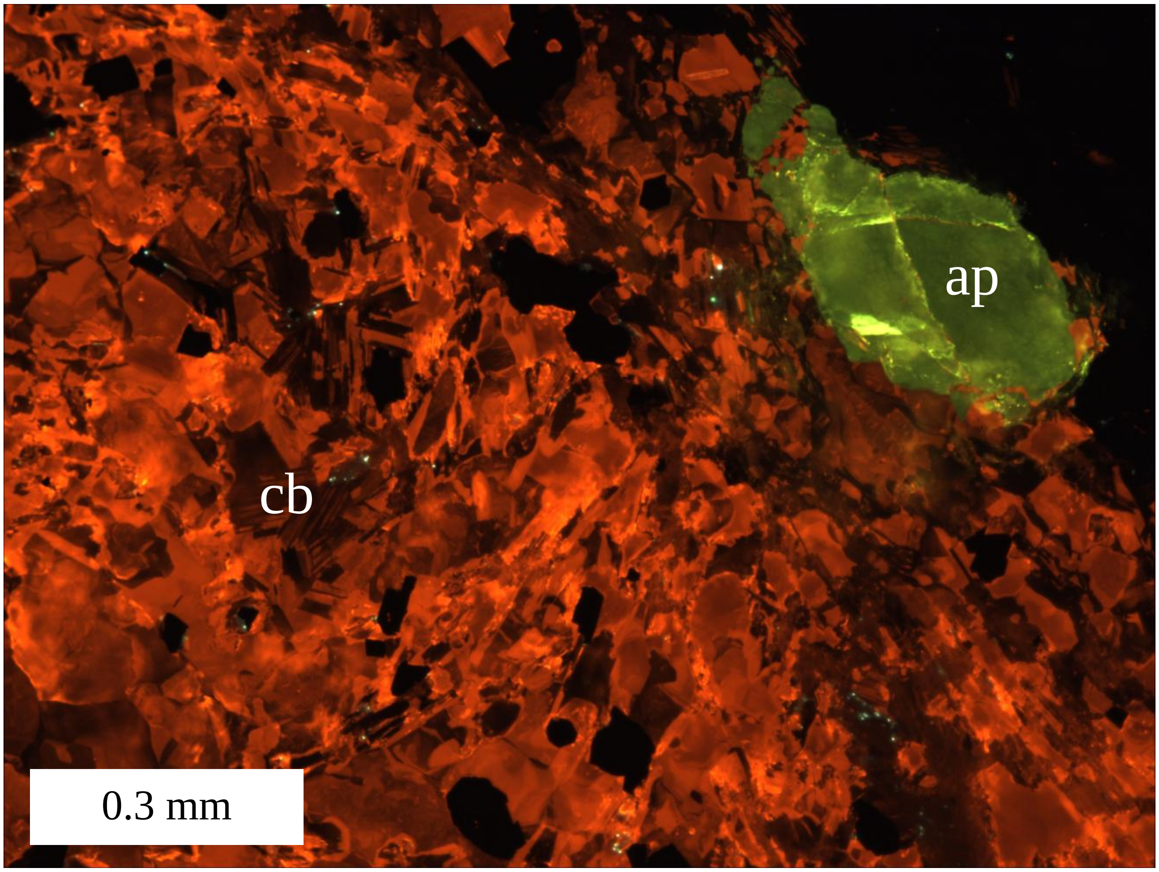


Fig. 15. Cathodoluminescent (CL) photomicrograph showing carbonate (cb) and apatite (ap), within a mafic metavolcanic wall rock of the Discovery-Ormsby area.

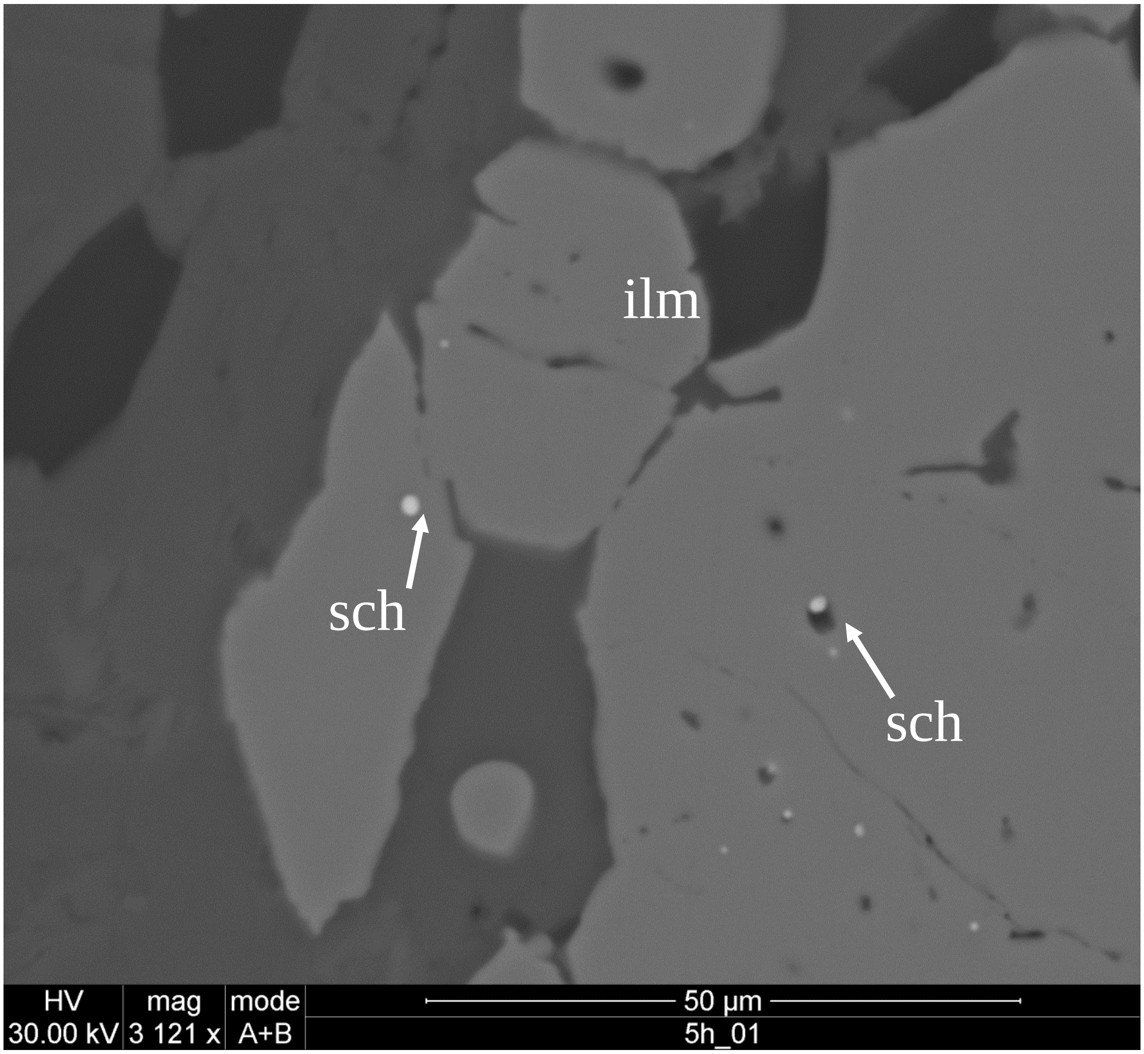


Fig. 16. SEM photomicrograph using a backscatter detector (BSD) showing scheelite (sch) within ilmenite in mafic metavolcanic rocks at the Discovery-Ormsby area.

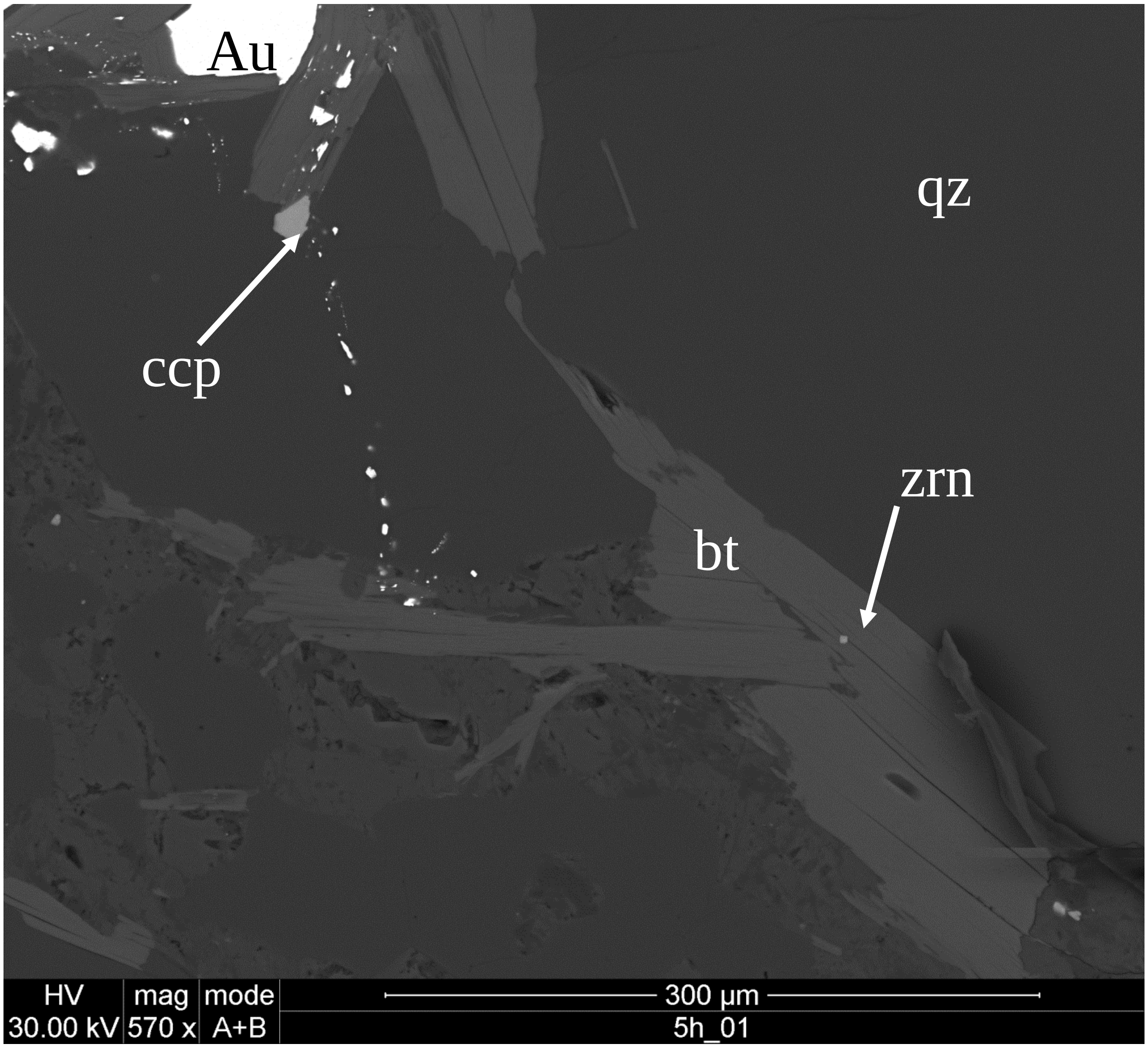


Fig. 17. SEM-BSD photomicrograph (close-up of Fig. 14d) of biotite containing a zircon (zrn) within a gold-bearing quartz vein in the Discovery-Ormsby area.

Clan Lake

The Clan Lake area is located approximately 38 km south-southwest of the Discovery-Ormsby area. It contains a larger, intermediate to felsic, metavolcanic-volcaniclastic complex (~ 1.5 wide and 6.5 km long) surrounded by vast metasedimentary rocks of the Burwash Formation (Fig. 3). Metavolcanic rocks of the Clan Lake area are classified into four lithological units: mafic to intermediate volcanic rocks; intermediate to felsic volcanic rocks; pyroclastic rocks; and crosscutting mafic intrusions (a central gabbro body and diabase dikes) (Pratico, 2009a). The first three units are interpreted to be Banting Group age (~2.7 Ga) (Cousens et al., 2002).

The lithologies at Clan Lake have a minor mafic component and become more intermediate toward the center of the complex, which is cored by a crosscutting, nearly unmineralized gabbro body. The outermost lithology has been described as a mafic volcanic flow with inter-volcanic sediments. The next inward lithology has been described as intermediate flows and tuffs, followed by pyroclastic intermediate rocks. Near the center, rocks are dominantly intermediate flows and tuffs with local inter-volcanic sediments and garnetiferous mafic rocks (Pratico, 2009a).

Extensive and overlapping alteration (described later) has complicated protolith identification by visual inspection, but immobile element plots have been utilized by other studies to look through alteration and metamorphism to determine protoliths in similarly highly altered greenstone belts (Sugitani et al., 2006). A plot of Cr/Al ratios versus Zr/Ti ratios shows that the majority of rocks at Clan Lake have intermediate to felsic protoliths (Fig. 18). Some samples that were suspected to be mafic also have intermediate composition protoliths.

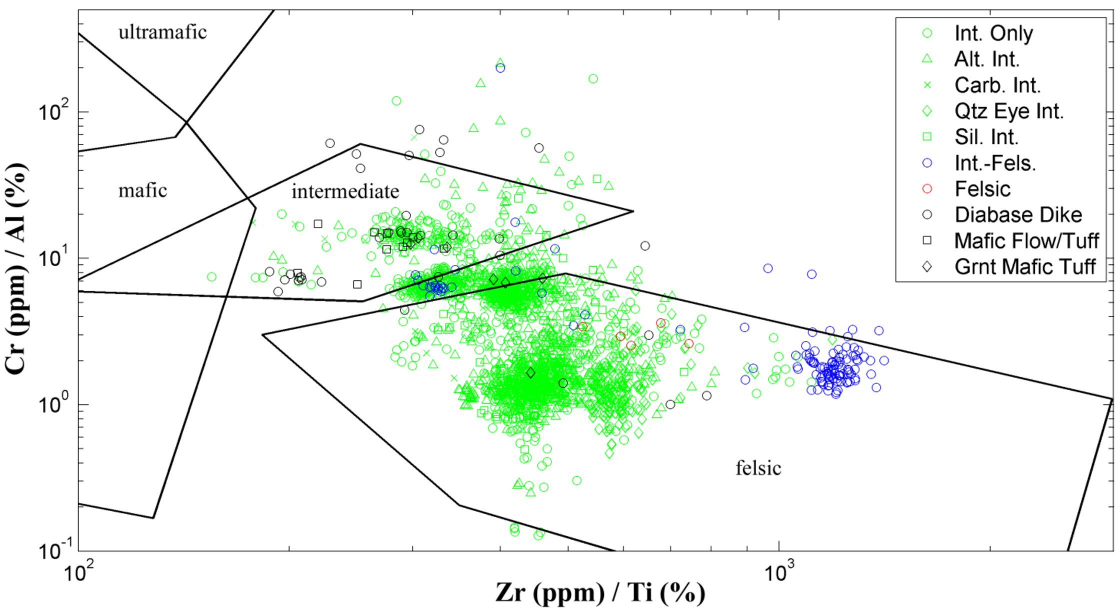


Fig. 18. Immobile element plot of Cr/Al vs. Zr/Ti for altered metavolcanic rocks at Clan Lake. Polygons are from Sugitani (2006) and indicate protoliths for highly altered Archean rocks. Symbols represent rock descriptions as logged by Tyhee Gold Corporation personnel. Abbreviations: Int. Only, intermediate rocks; Alt. Int., altered intermediate rocks; Carb. Int., intermediate rocks with carbonate alteration; Qtz Eye Int., quartz eye intermediate tuff; Sil. Int., intermediate rocks with extensive silicification; Int.-Fels., intermediate to felsic rocks; Grnt Mafic Tuff, garnetiferous mafic tuff.

Wall-rock alteration is so pervasive that we were not able to find a recognizable edge to the alteration zone. This makes it is a challenge to define the size of the Clan Lake hydrothermal system. Other techniques employed in this study (oxygen isotopes, lithogeochemical analysis, and 3-D modeling) may help to determine the extent of the Clan Lake hydrothermal system.

Deformation fabrics are heterogeneous throughout Clan Lake. Degrees of deformation are indicated by the presence or absence of shear fabric(s) and the extent of wall-rock quartz recrystallization (annealing). A sinistral strike-slip fault, ~1.75 km to the west of Clan Lake (Plate 1), is interpreted to be associated with an inferred extension of the Yellowknife River Fault Zone, and may be the key structural component responsible for deformation fabrics, as other observed structural features appear to postdate gold mineralization (Pratico, 2009a).

Major rock-forming minerals affected by deformation and metamorphism include chlorite, biotite, quartz, and hornblende with relict plagioclase (Fig. 19). Metamorphism of Clan Lake is interpreted to have approached lower amphibolite grade as evidenced by garnets in tuffs (Fig. 20) of the Clan Lake complex and cordierite in the surrounding metaturbidites of the Burwash Formation (Pratico, 2009a). Samples displaying shear deformation appear to integrate peak metamorphic minerals into the deformational fabric with minor retrograde overprint, suggesting that deformation and metamorphism were coincident.

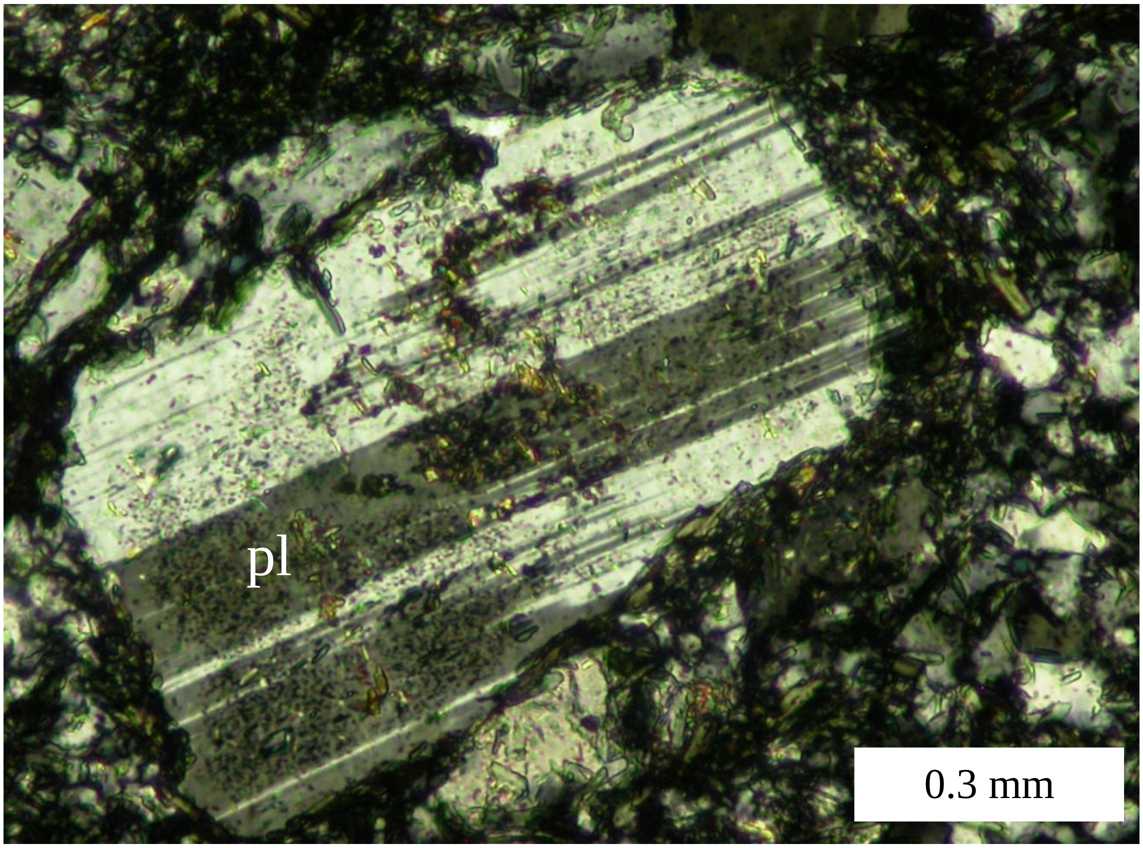


Fig. 19. Photomicrograph (crossed-polarized transmitted light, XPL) showing altered plagioclase (pl) in an inter-volcanic metasedimentary rock in the Clan Lake area. Groundmass includes quartz, sericite, and carbonate.

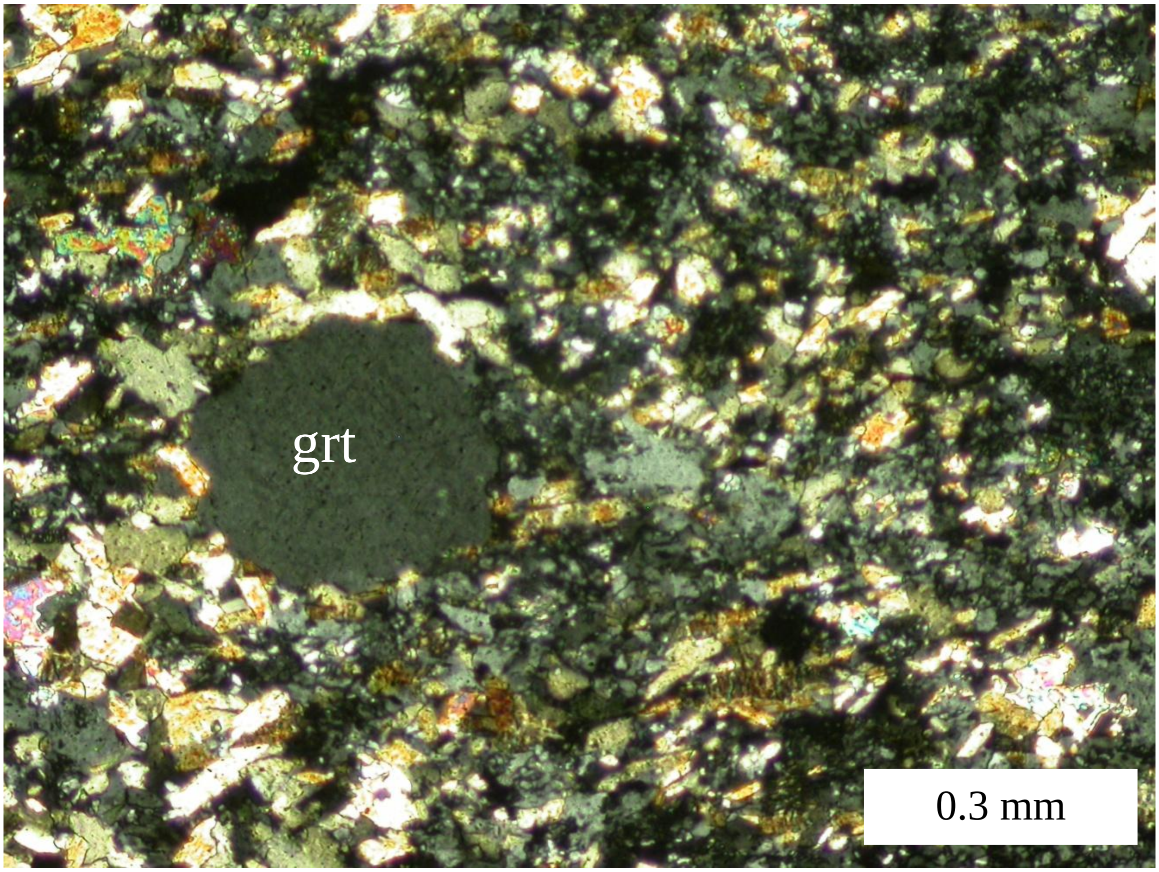


Fig. 20. Photomicrograph (XPL) of altered garnet (grt) within a groundmass of dominantly chlorite, hornblende, quartz, and biotite in an intermediate flow/tuff in the Clan Lake area.

Ore Mineralization

Clan Lake's gold ore mineralization is constrained largely to a 6.5 km long, 900 m wide, north-northeast striking domain. Mineralization consists of altered, silicified, and sulfidized rocks that strike generally to the northwest and that individually may exceed 100 m in width. Six zones of mineralization have been identified by mapping and prospecting within the domain (Pratico, 2009a).

Host rocks in the Main Zone of Clan Lake, the primary drilling target of the area, are intermediate volcanic rocks with extensive silicification, sulfidation and sericite alteration. Potassic (biotite) alteration also occurs in bands and irregular patches with variable intensity (Pratico, 2009a).

Gold mineralization occurs as native gold, principally within quartz veins and in altered rocks adjacent to veins. Mineralized quartz veins vary in color from white to smoky gray to blue gray, in width from < 5 cm to ~ 2 m, and in length from approximately 8 to 12 m with some veins exceeding 25 m locally. Quartz veins recognized in core samples have widths between 5 and 300 cm (Pratico, 2009a). Quartz veins frequently contain sulfide and gangue minerals (chlorite, amphibole, biotite, carbonates). Vein geometries are irregular and are deformed locally into sinuous or boudinage patterns (Pratico, 2009a).

Ore Paragenesis and Alteration

Observations from hand/drill core samples (n = 80) and polished thin/ore sections (n = 69) were used to determine the ore mineral paragenesis in the Clan Lake area (Fig. 21). Gold occurs as native gold in silicified and sulfidized wall rock and in quartz veins,

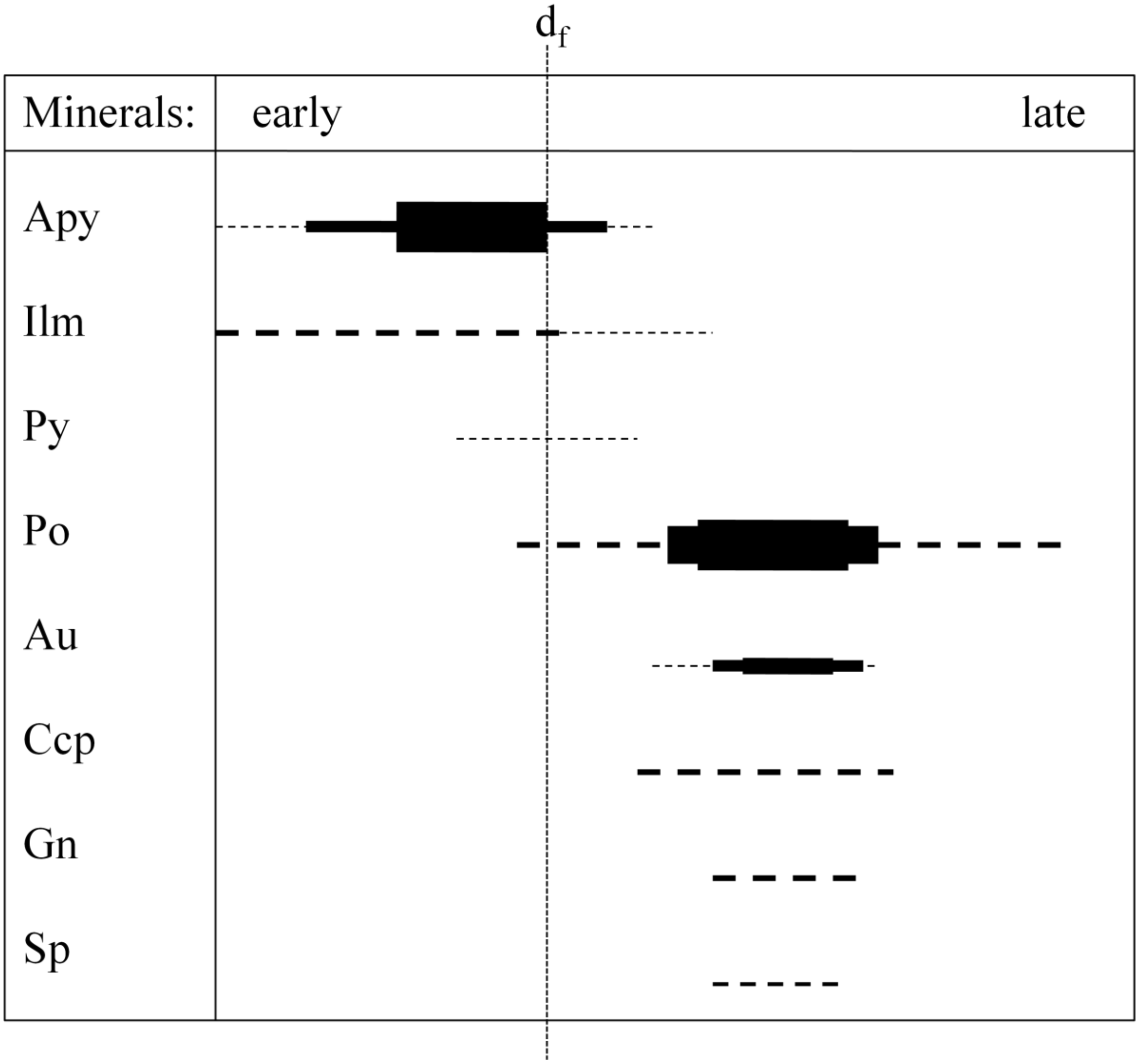


Fig. 21. Simplified ore mineral paragenesis for the Clan Lake area. Minerals include arsenopyrite (apy), ilmenite (ilm), pyrite (py), gold (Au), pyrrhotite (po), chalcopyrite (ccp), galena (gn), and sphalerite (sp). Wall rock deformation fabric development (d_f). Note the similarities with the Discovery-Ormsby area's paragenesis in Fig. 11.

associated with pyrrhotite and infrequently with base-metal sulfides (i.e. chalcopyrite, galena and sphalerite) (Figs. 23a-f). Arsenopyrite and a rare early generation of pyrrhotite have been observed to pre-date the gold mineralizing event. Arsenopyrite is abundant, euhedral, and extensively fractured. Early pyrrhotite exhibits an uneven, dark brown and striated tarnish, particularly along grain boundaries (Fig. 23a). Pyrite is rare, typically euhedral, and tarnishes easily. It is observed overgrowing euhedral arsenopyrite. Fractures within arsenopyrite terminate at grain boundaries with pyrite, indicating that pyrite is later than arsenopyrite. Fractures are less frequent within pyrite, but when present, may be filled by pyrrhotite (Fig. 22). This later pyrrhotite is uniform in its light brown, untarnished appearance and postdates both arsenopyrite and pyrite.

Gold is found frequently filling fractures in arsenopyrite. These fractures are also filled by second generation pyrrhotite (± base-metal sulfides) (Fig. 23b, c). Gold within wall rocks is found less frequently in isolation, without any nearby sulfides. In quartz veins, gold is accompanied frequently by pyrrhotite ± base-metal sulfides (Fig. 23d), or with only base-metal sulfides (Fig. 23e), or less frequently adjacent to wall rock fragments without any associated sulfides (Fig. 23f).

Numerous and overlapping alterations have been observed in the Clan Lake area. The alteration is so extensive that there does not appear to be a recognizable edge to the zone. Host rocks are extensively silicified and exhibit sericite alteration, particularly as quartz vein selvedges, carbonate alteration, and locally, irregular patchy potassic alteration (Pratico, 2009a). Extensive sulfidation is associated with gold mineralization, in spite of the fact that the host rocks at Clan Lake contain less iron (majority of samples

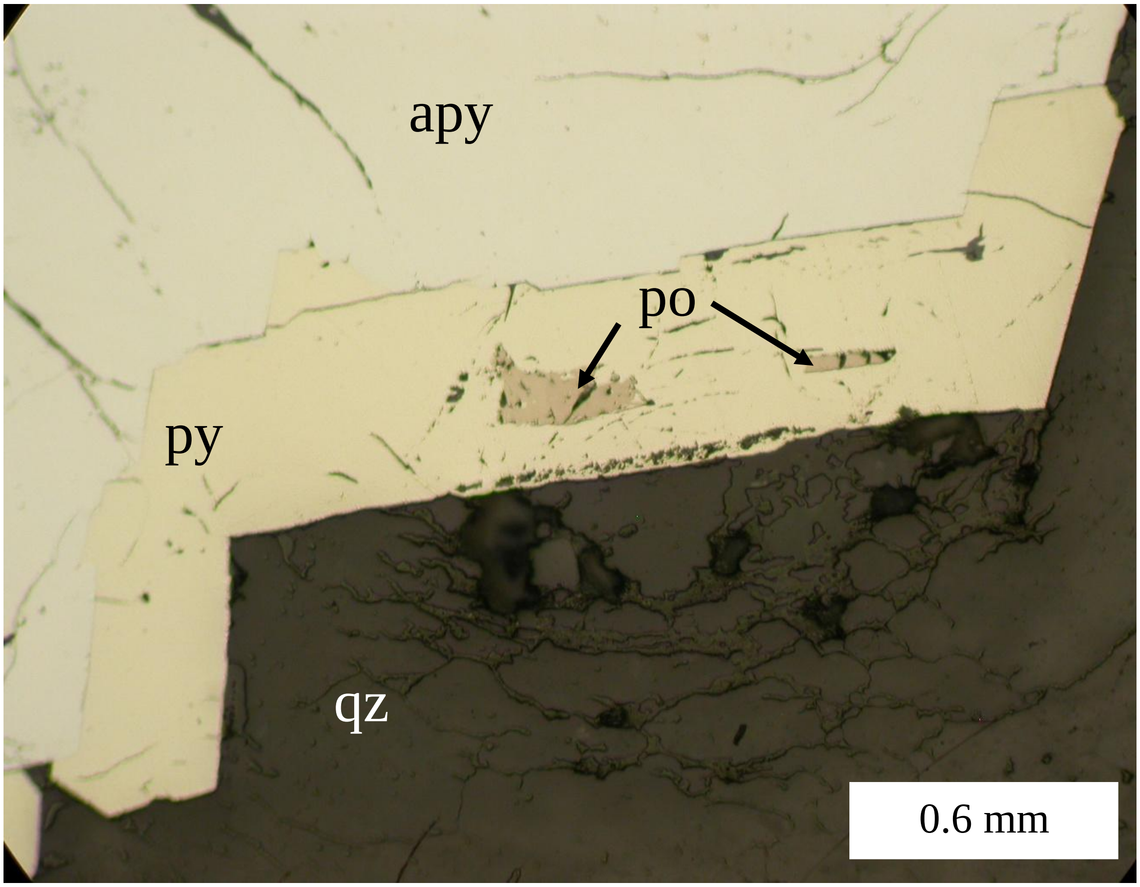


Fig. 22. Photomicrograph (RL, PPL) of early arsenopyrite overgrown by pyrite from the Clan Lake area in a quartz eye tuff rock sample. Pyrrhotite preferentially replaces pyrite where it is most fractured.

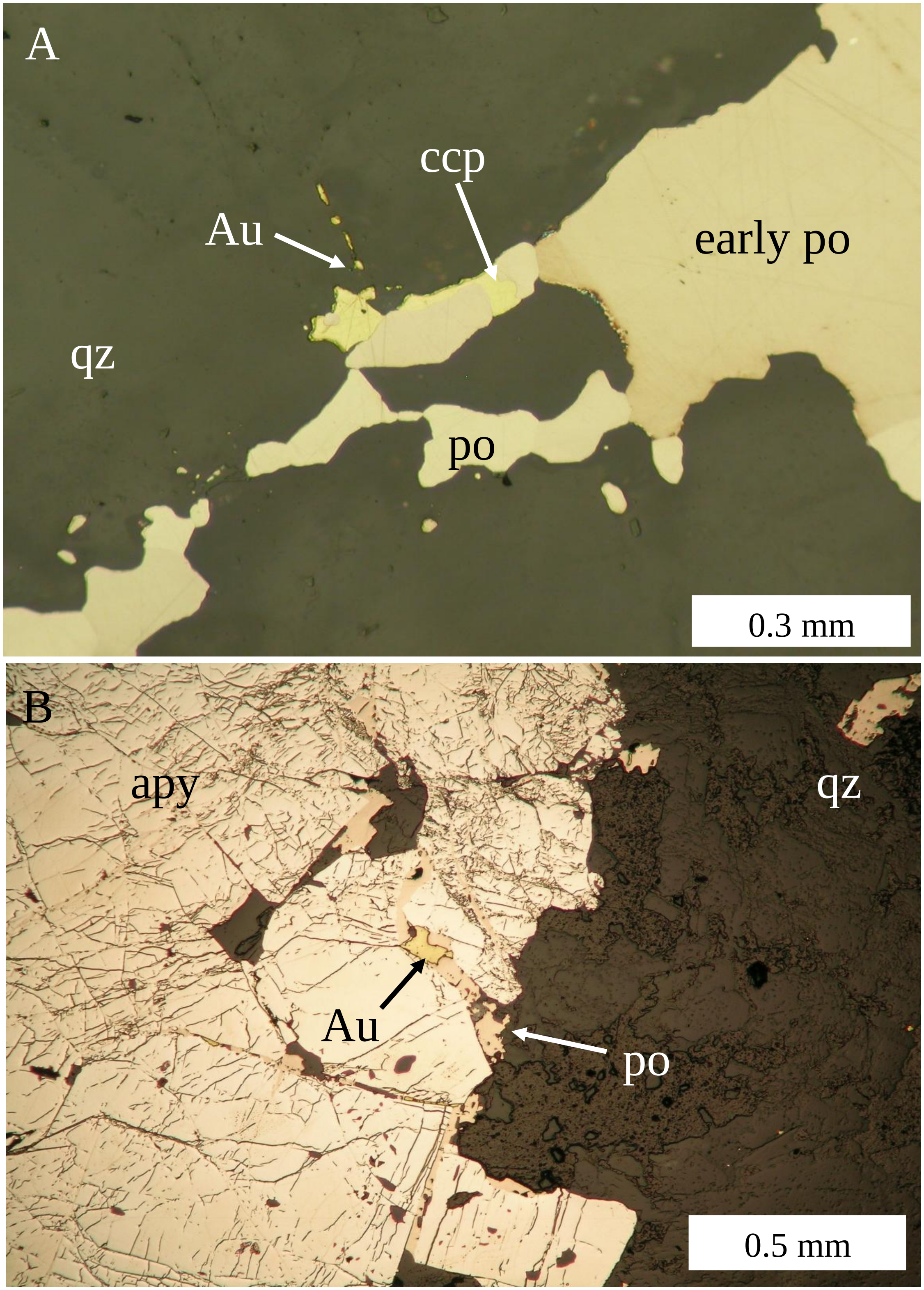


Fig. 23. Photomicrographs of gold-bearing mineralization in the Clan Lake area. A. Two generations of pyrrhotite associated with chalcopyrite and gold in highly silicified wall-rock (RL, PPL). B. Gold and pyrrhotite filling fractures in arsenopyrite within highly silicified wall-rock (RL-PPL).

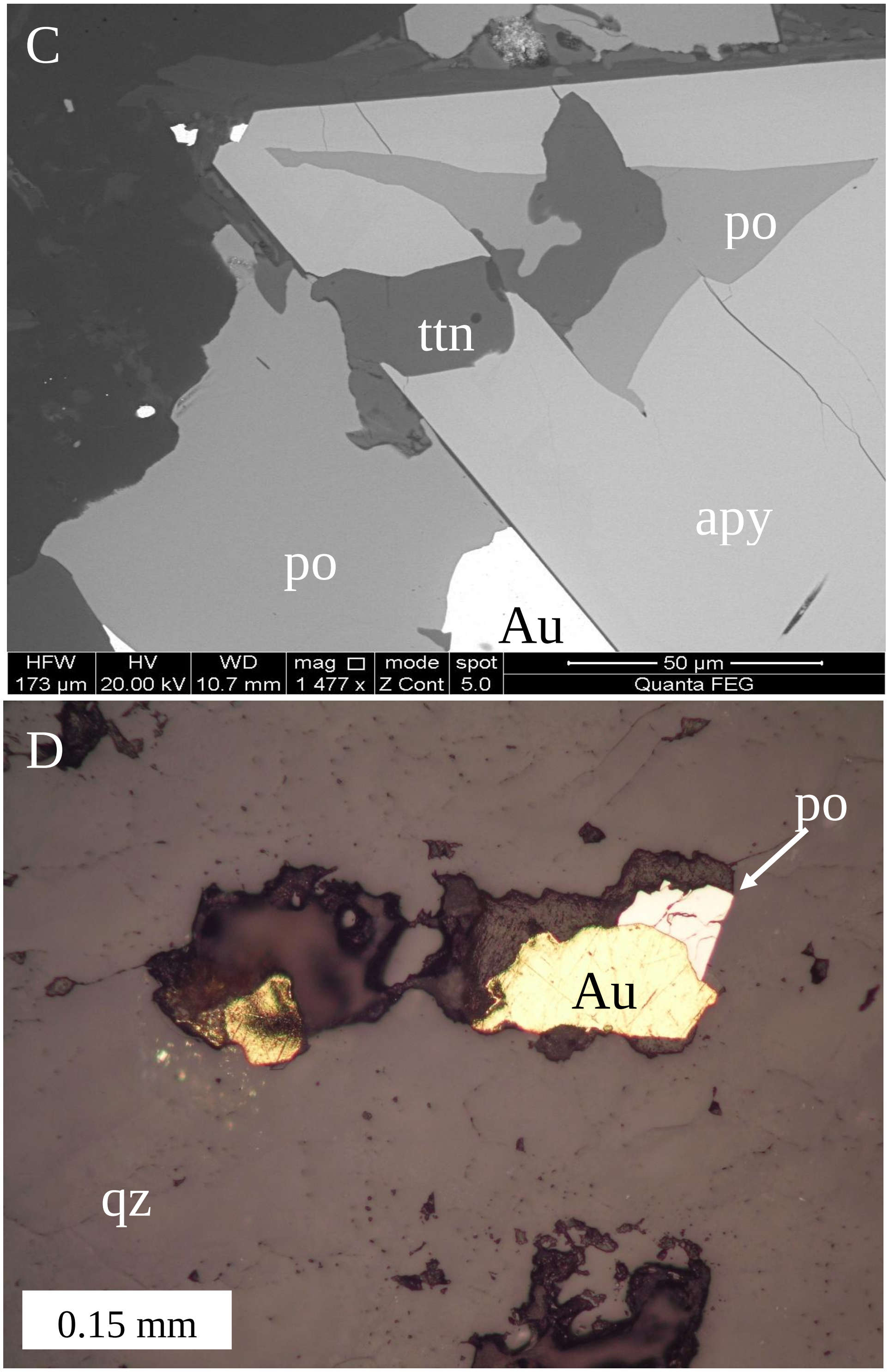


Fig. 23 (continued). C. SEM-BSD image of pyrrhotite, titanite (ttn) and gold filling fractures in arsenopyrite. D. Gold intergrown with pyrrhotite in a quartz vein (RL, PPL).

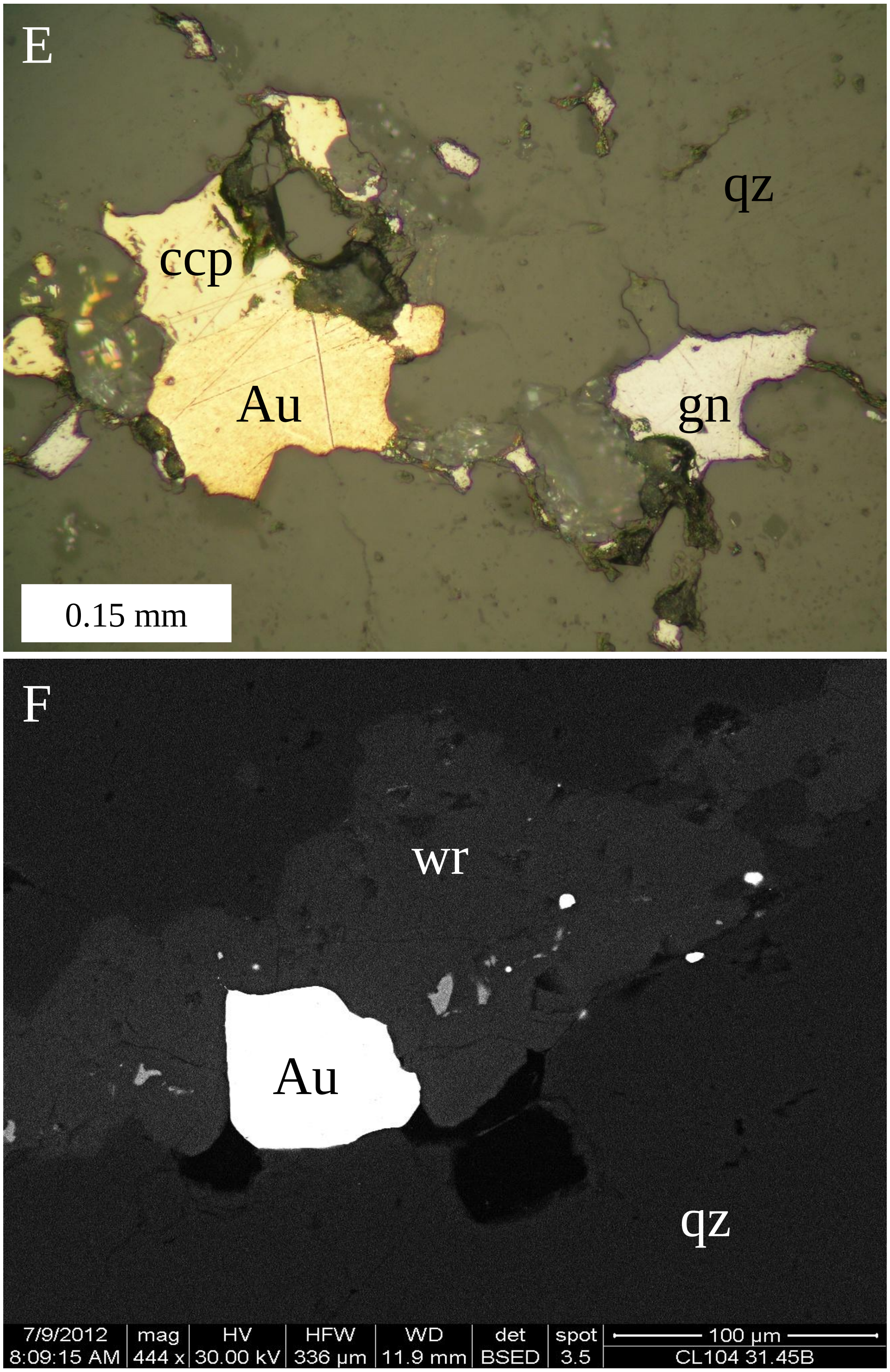


Fig. 23 (continued). E. Gold associated with base-metal sulfides, chalcopyrite and galena (gn), within a quartz vein (RL, PPL). F. Gold associated with an intermediate tuff wall-rock fragment within a quartz vein (SEM, BSD).

≤ 6.5 wt. % Fe) than those at the mafic metavolcanic Discovery-Ormsby area (up to 17.5 wt. % Fe).

Petrographic and scanning electron microscopy have allowed me to determine one example of iron-liberating sulfidation reactions that resulted locally in the formation of pyrrhotite ($Fe_{(1-x)}S$) and gold, the conversion ilmenite ($FeTiO_3$) to titanite ($CaTiSiO_5$) (Fig. 23c):

$$FeTiO_3 + Ca^{+2} + SiO_{2(aq)} \leftrightarrow CaTiSiO_5 + Fe^{+2}$$

$$4\ Fe^{+2} + 4\ Au(HS)_2^{-} + O_2 \leftrightarrow 4\ Fe_{(1-x)}S + 4\ Au^0 + 2\ H_2O + 4\ H^+$$

Other sulfidation reactions likely occurred, though overprinting alterations have made it difficult to determine the specific reactions.

A plot of gold versus iron (Fig. 24) shows that samples with the highest iron concentration (≥ 5 wt. % Fe) do not correlate strongly with gold concentration, in spite of the necessity of iron for the destabilization of the gold bisulfide complex (see second reaction above). The bulk of gold and the highest gold values are found within samples with lower (1-5 wt. % Fe) iron contents. This is interpreted to indicate that fluid-rock interactions along the fluid pathway must have been very efficient in liberating iron to accomplish the observed sulfidation of the gold-bearing host rocks.

Oxygen Isotope Studies

The Discovery-Ormsby and Clan Lake areas exhibit similar ore mineralogy and parageneses (early arsenopyrite followed by gold + pyrrhotite ± base-metal sulfides) and present an opportunity to determine if their ores are related to similar hydrothermal systems whose chemistries differ as a function of host rock lithology, or instead indicate chemically distinct hydrothermal systems. Oxygen isotope studies were employed to

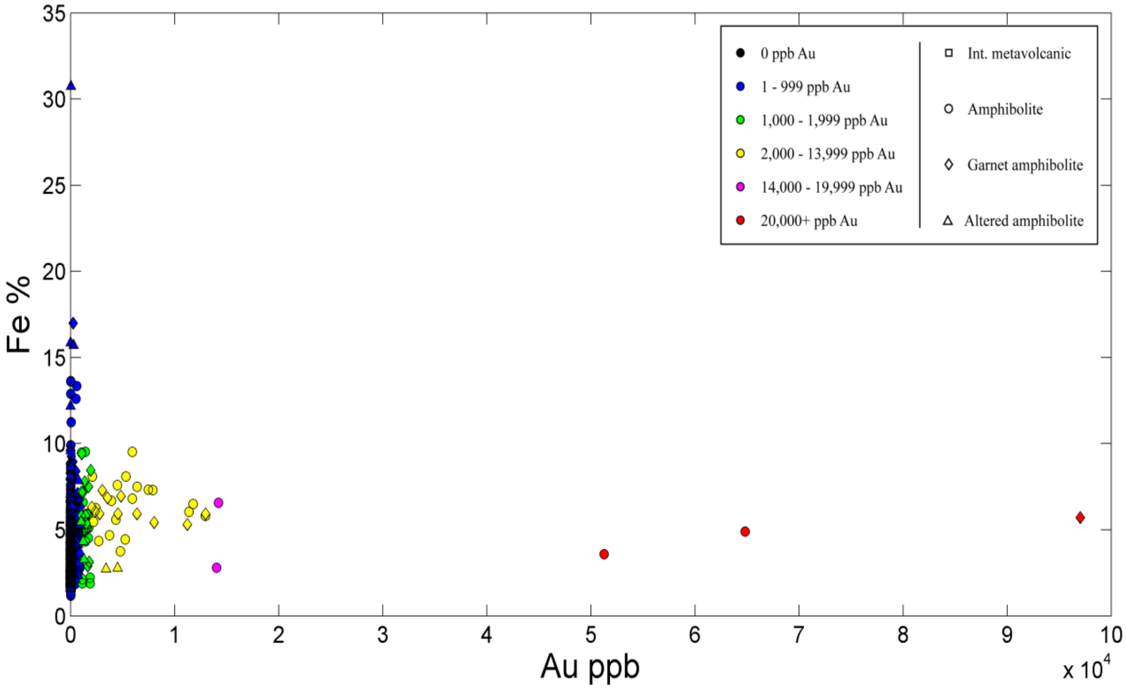


Fig. 24. Iron (wt. %) versus gold (ppb X 10^4) diagram for the Ormsby Member. Higher gold values do not correlate with iron content.

determine the fluid source(s), pathways, and degree of interaction with host rocks in both areas.

Previous Oxygen Isotope Studies in the YGB

Several investigations of gold deposits in the southern portion of the YGB have utilized oxygen isotope analysis to help determine the source(s) of ore-forming fluids and degree of fluid interaction with ore-hosting wall rocks (Kerrich and Fyfe, 1988a, b; van Hees et al., 1999; Shelton et al., 2004; Hill et al., 2010). Figure 25 shows a frequency diagram for $\delta^{18}O$ values of quartz veins from gold deposits throughout the southern YGB. These veins display a wide range of values, from ~ 8 to 18‰. Within this distribution, quartz veins from metasedimentary rock-hosted gold deposits have $\delta^{18}O$ values > 13.0‰, whereas those hosted in metavolcanic rocks tend to have lower $\delta^{18}O$ values, frequently ≤ 11.5‰. However, some metavolcanic-hosted deposits, notably the world-class Giant mine in Yellowknife, display values that span nearly the entire range for the YGB.

Detailed oxygen isotope and lithogeochemical studies of the Giant Mine concluded that its refractory wall rock-hosted ores were the result of metasedimentary-derived fluids reacting with the metavolcanic host rocks, whereas its vein-hosted ores reflected both metavolcanic and metasedimentary fluid sources (van Hees et al., 1999, 2006; Shelton et al., 2004). In contrast, oxygen isotope studies of gold showings hosted in Kam and Banting Group rocks ~ 30 km north of Yellowknife (Smith et al., 2010) found that metavolcanic-rock-hosted and metasedimentary-rock-hosted ores had distinct ranges of $\delta^{18}O_{\text{quartz vein}}$ values. This was interpreted to indicate a lack of fluid

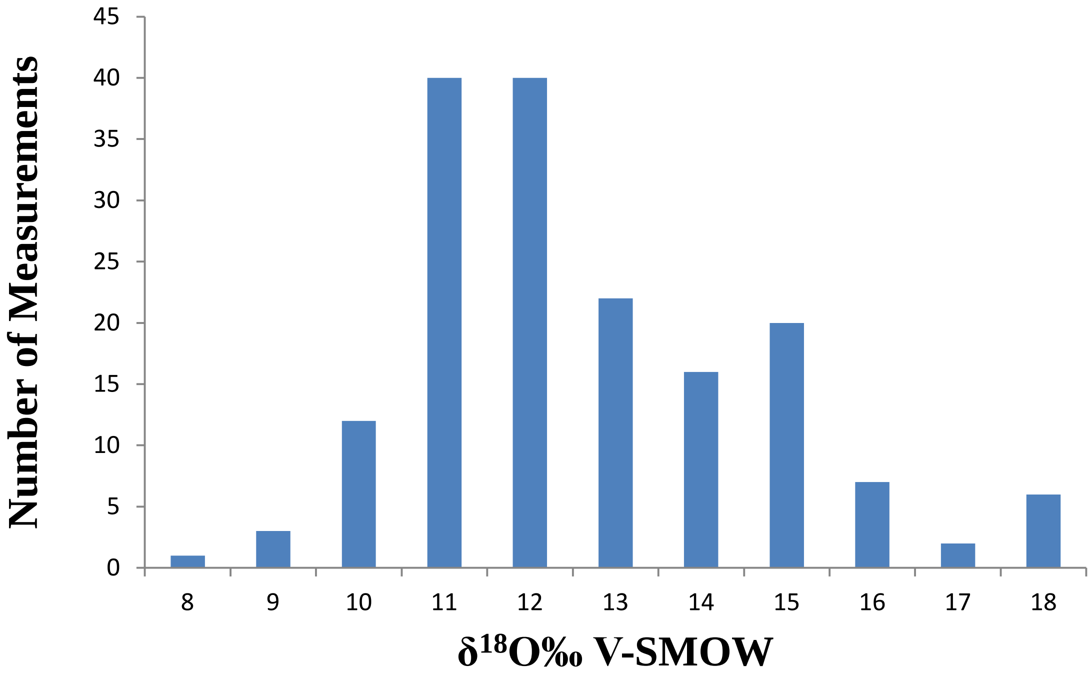


Fig. 25. Frequency diagram of δ^{18}O values of quartz vein from gold deposits of the Yellowknife area (Kerrich and Fyfe, 1988a, b; van Hees et al., 1999; Shelton et al. 2004). Values ≤ 11.5‰ have been interpreted by previous investigations to reflect a metavolcanic influence, whereas those > 13.0‰ have been interpreted to reflect a metasedimentary influence.

communication between metasedimentary and metavolcanic reservoirs during the gold mineralizing events.

These two contrasting scenarios for gold mineralization in the southern YGB form a direct basis for comparison to studies of areas in the north end of the YGB, as metavolcanic rocks that host these gold ores are also in close proximity to voluminous metasedimentary rocks.

Oxygen Isotope Studies of the Discovery-Ormsby and Clan Lake Areas

Samples collected in summer 2011 were analyzed by laser fluorination at Washington State University. A smaller set of samples collected in summer 2010 were analyzed by conventional fluorination at New Mexico Institute of Mining and Technology. Results are reported in standard δ notation relative to V-SMOW (Table 1). The standard error for each sample is ± 0.2‰. Nineteen samples were analyzed from the Discovery-Ormsby area (11 quartz veins; 8 wall rocks) and thirty-five samples from the Clan Lake area (20 quartz veins; 15 wall rocks) (Figs. 26-27). The $\delta^{18}O_{\text{quartz vein}}$ values will be used to assess fluid source(s). The $\delta^{18}O_{\text{whole-rock}}$ values will be used in 3-D modeling to determine likely fluid pathways and the degree of fluid-rock interaction along flow paths.

Results

The Discovery-Ormsby area has quartz veins with $\delta^{18}O$ values of 13.0 to 15.2‰, regardless of host rock lithology (metavolcanic or metasedimentary). Notably, a gold-

Table 1. Results of oxygen isotope studies for the Discovery-Ormsby and Clan Lake areas.

Sample	**Depth in core (m)**	**$\delta^{18}O_{\text{quartz vein}}$ (‰) V-SMOW**	**$\delta^{18}O_{\text{whole-rock}}$ (‰) V-SMOW**	**Host rock**
Discovery Mine				
DISC-1	0.0	13.1		Metaturbidite
Discovery-Ormsby area				
NDM 341	246.7	15.1		Metagreywacke
NDM 341	40.2		11.8 12.3	Metagreywacke
NDM 410	448.9		10.3	Metagreywacke
NDM 424	147.7		11.7	Amphibolite
NDM 424	395.7		11.3	Metagreywacke
NDM 514	115.05	14.0 14.1		Amphibolite
NDM 514	12.2		10.3 11.0	Graphitic meta-argillite
NDM 514	229.5		9.8	Metagreywacke
NDM 532	41.1	14.4 15.2		Amphibolite
NDM 533	270.8	13.4		Amphibolite
NDM 533	276.3	13.7 15.1		Amphibolite
NDM 533	276.4	13.7		Amphibolite
NDM 533	51.5		8.5 9.1	Amphibolite
OR 11-6	0.0	13.7		Amphibolite
ORMS 2	0.0	13.2		Amphibolite
ORMS 5	0.0	14.0		Amphibolite
ORMS 6-1	0.0	13.0		Amphibolite
ORMS 6-2	0.0		9.3	Amphibolite

Sample	Depth in core (m)	$\delta^{18}O_{\text{quartz vein}}$ (‰) V-SMOW	$\delta^{18}O_{\text{whole-rock}}$ (‰) V-SMOW	Host rock
Clan Lake area				
CL 101	25.75	12.2		Altered intermediate tuff
CL 101	111.5	13.3		Intermediate tuff
CL 101	180.45	11.9		Tuffaceous metasediment
CL 104	31.45	13.4		Intermediate tuff
CL 104	34.15	12.2		Intermediate tuff
CL 104	42.0	12.7		Intermediate tuff
CL 104	158.5		10.1 11.4	Mafic tuff
CL 109	76.2	11.3		Intermediate tuff
CL 124	91.8	12.5		Intermediate tuff
CL 129	166.5	12.0		Intermediate tuff
CL 160	132.0		10.6	Intermediate lapilli tuff - pyroclastic
CL 160	236.8		9.8 10.1	Mafic volcanic flow
CL 160	252.8		9.3	Mafic lapilli pyroclastic tuff
CL 164	167.7	12.5 13.5		Intermediate porphyritic flow
CL 168	13.3	7.5		Intermediate porphyritic flow & tuff
CL 168	95.1	14.1		Altered intermediate flow
CL 168	109.0	13.6		Altered intermediate flow
CL 168	110.3		8.7	Altered intermediate flow
CL 168	211.97	13.6		Fragmented intermediate flow & tuff
CL 171	60.0	13.6		Coarse intermediate pyroclastic tuff

Sample	**Depth in core (m)**	**$\delta^{18}O_{quartz\ vein}$ (‰) V-SMOW**	**$\delta^{18}O_{whole\text{-}rock}$ (‰) V-SMOW**	**Host rock**
CL 173	201.8		11.4 12.1	Pillowed mafic volcanic flow & tuff
CL 184	50.9		11.4	Coarse pyroclastic tuff
CL 184	105.9		12.8	Argillaceous metasediment
CL 184	131.5	15.2		Tuffaceous metasediment
CL 184	137.8	15.0		Tuffaceous metasediment
CL 187	320.25		11.8	Garnetiferous mafic tuff
CL 11-2	0.0		10.8 12.5	Garnetiferous mafic tuff
CL 11-3	0.0		9.9	Tuffaceous metasediment
CL 11-4	0.0	13.5 14.4		Quartz vein
CL 11-5	0.0		10.7	Pillows (less altered)
CL 11-6	0.0		10.5	Pillows (more altered)
CL 11-8	0.0		8.2	Gabbro (less altered)
CL 11-9	0.0		7.7	Gabbro, coarse grained
CL 11-10	0.0	11.3 13.0		Gabbro
CL 11-12.2	0.0	13.5		Quartz vein

Note samples reporting a depth of zero meters are surface samples.

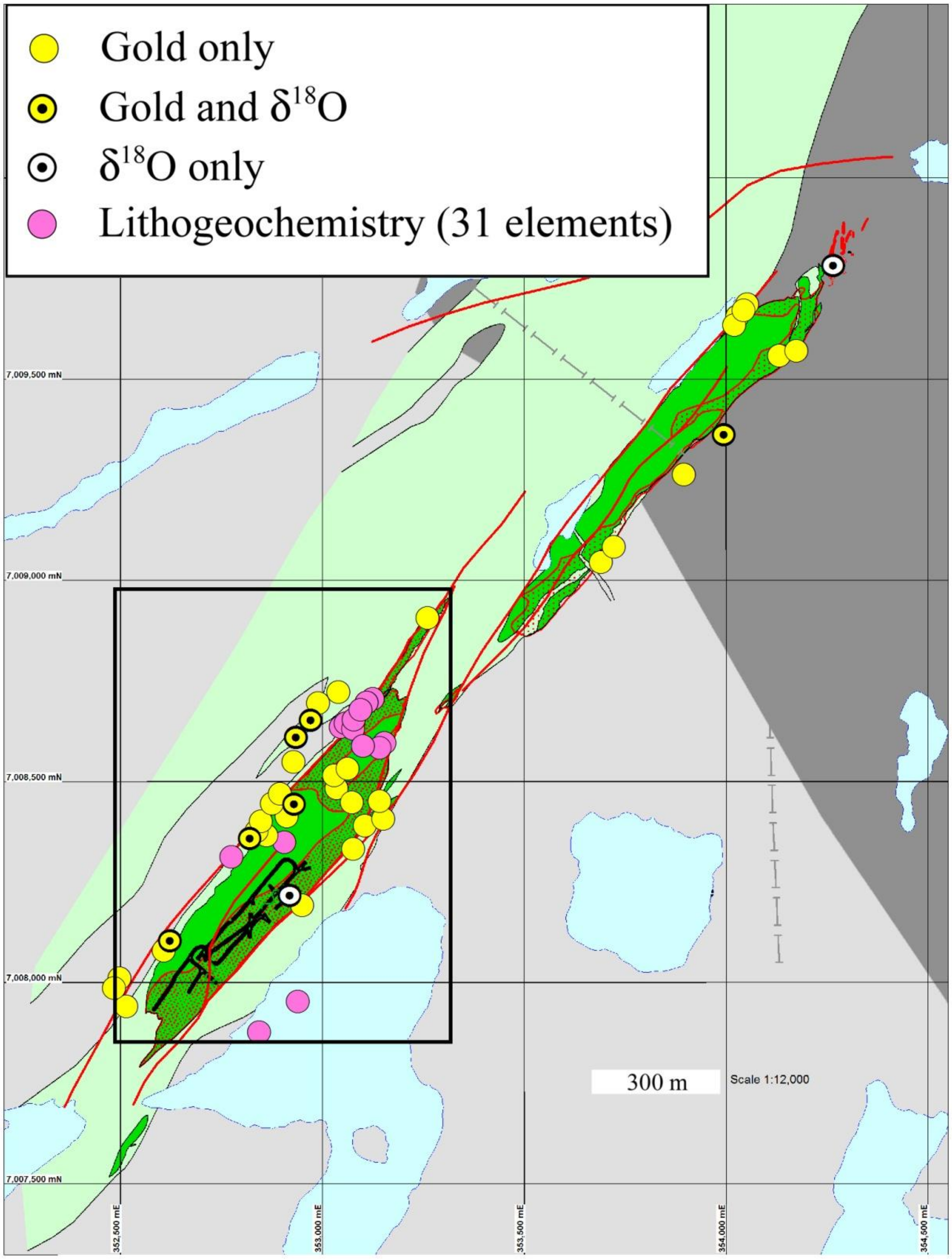


Fig. 26. Geological map of the Discovery-Ormsby area showing sample localities and their uses (after Pratico, 2009b). The outlined rectangle indicates approximate dimensions of the top of the 3-D block models.

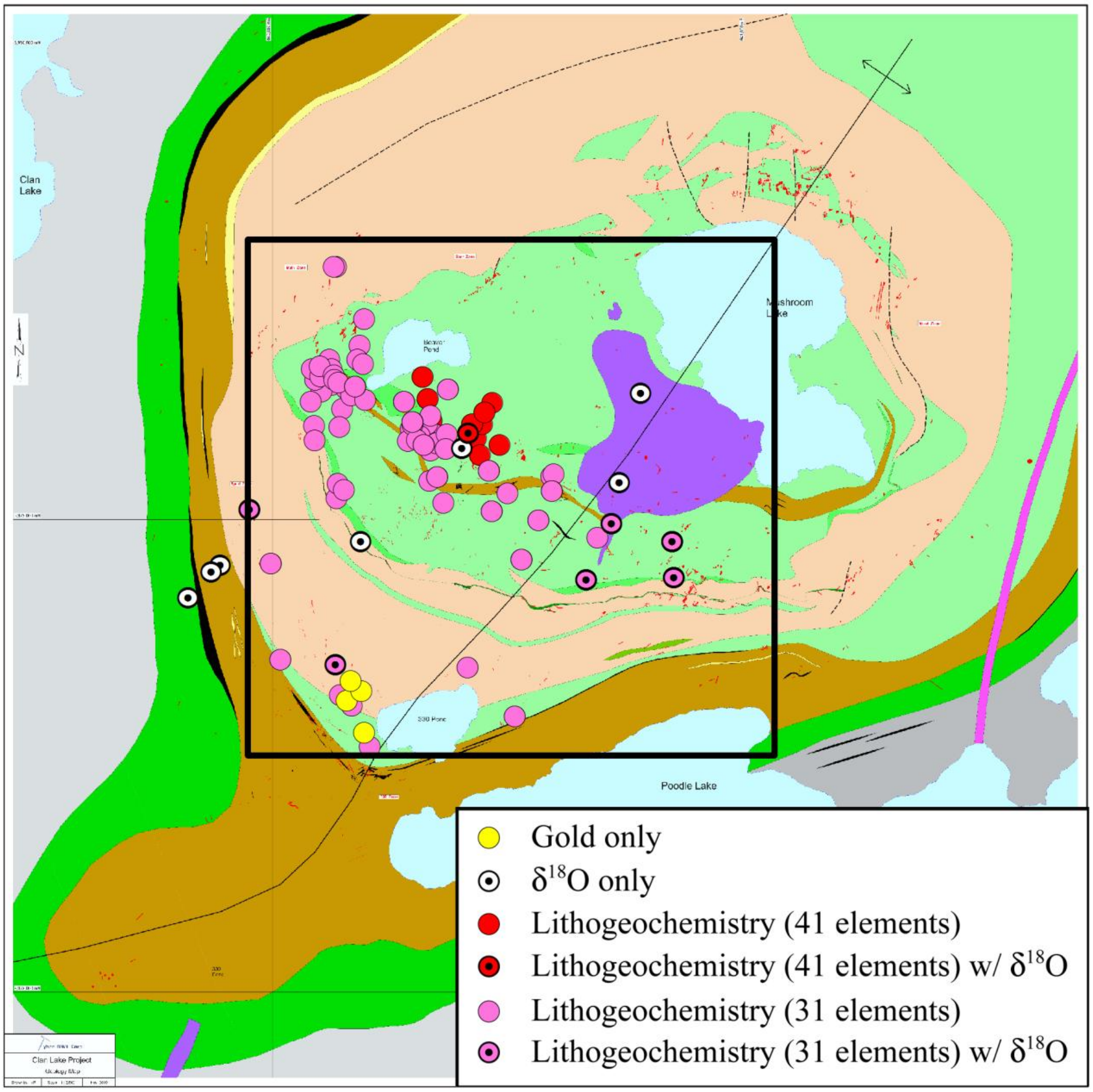


Fig. 27. Geological map of the Clan Lake area showing sample localities and their uses (after Pratico, 2009c). The outlined box indicates approximate dimensions of the top of the 3-D block models.

bearing quartz vein from the metasedimentary-hosted Discovery Mine has a $\delta^{18}O$ value of 13.1‰. Wall rocks display a larger range of $\delta^{18}O_{\text{whole-rock}}$ values of 8.5 to 12.3‰.

The Clan Lake area has quartz veins with $\delta^{18}O$ values of 11.3 to 15.2‰. Its wall rocks have $\delta^{18}O_{\text{whole-rock}}$ values of 7.7 to 12.8‰.

Frequency diagrams for $\delta^{18}O$ values of quartz veins from the two study areas (Fig. 28) show that, although there is some overlap of the ranges of data, quartz veins from the Discovery-Ormsby area define a single population, whereas those from Clan Lake indicate two populations. These distributions of $\delta^{18}O_{\text{quartz vein}}$ values, when compared to the pattern for the southern YBG (Fig. 25), permit me to suggest sources of auriferous fluids in each area. Quartz veins from the Discovery-Ormsby area are interpreted to reflect a dominance of metasedimentary-derived fluid, whereas quartz veins from the Clan Lake area are interpreted to reflect fluids in equilibrium with both metasedimentary and metavolcanic rock reservoirs.

Spatial Distribution of $\delta^{18}O$ values

The $\delta^{18}O$ values from quartz veins have enabled interpretation of fluid source(s). Spatial analysis of $\delta^{18}O$ patterns may be used to propose possible fluid pathways and degree of water-rock interaction along these paths. Spatial analysis and 3-D modeling of $\delta^{18}O$ values utilizes Rockworks™ by Rockware® with modeling parameters described in more detail later.

3-D Modeling: Discovery-Ormsby area

The 3-D block model for the Ormsby Member is 880 m by 1060 m and reaches a total depth of 340 m below surface. This block incorporates the Ormsby Member and surrounding Burwash Formation metasedimentary rocks (Fig. 26). The spatial control is

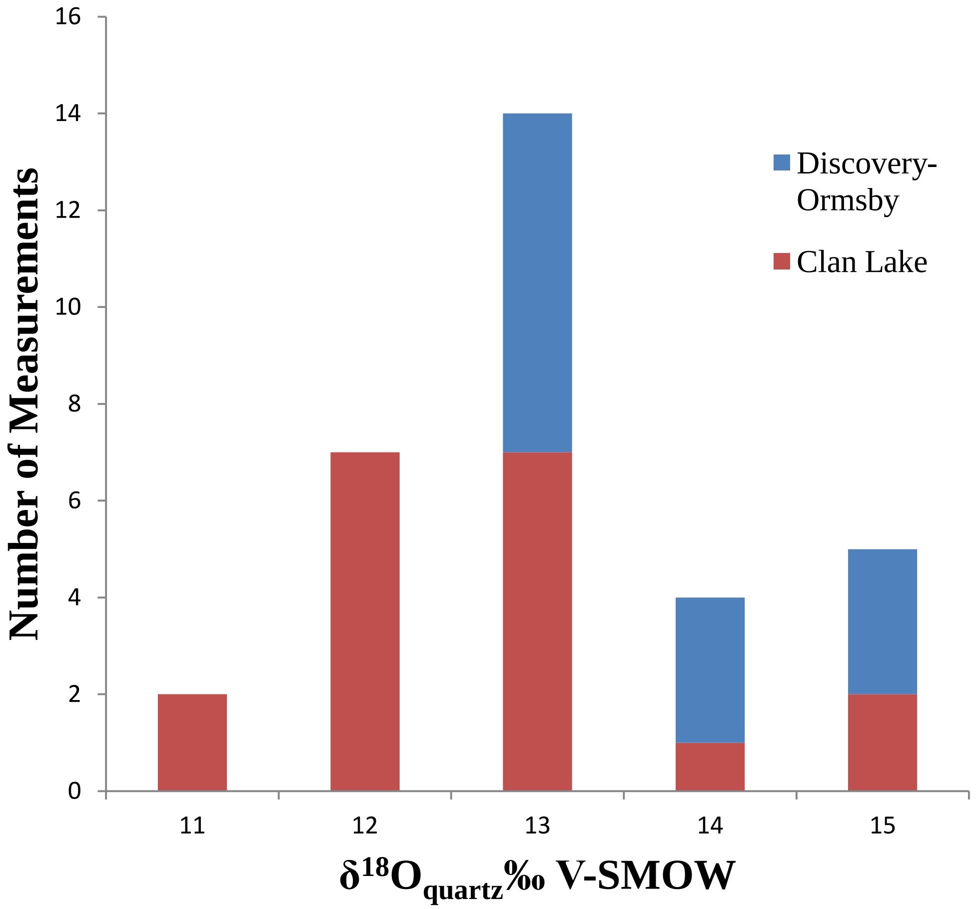


Fig. 28. Frequency diagram of $\delta^{18}O$ values of quartz veins from the study areas.

well established along the Ormsby Member, which lies diagonally within the block, from the southwest to the northeast.

The block model shows higher $\delta^{18}O_{\text{quartz vein}}$ values to the north-northwest (Fig. 29a) and lower $\delta^{18}O_{\text{quartz vein}}$ values to the south-southeast (Fig. 29b). However, it is important to note that the small range in $\delta^{18}O_{\text{quartz vein}}$ values (from 13.0 to 15.2‰) implies that the entire Ormsby Member has been overwhelmed by metasedimentary-derived fluids. The $\delta^{18}O_{\text{quartz}}$ pattern will be compared to a 3-D block model of gold concentrations in a following section.

3-D Modeling: Clan Lake area

Two 3-D block models were constructed for the Clan Lake area, one for $\delta^{18}O_{\text{quartz vein}}$ values and the second for $\delta^{18}O_{\text{whole-rock}}$ values. Both block models are 1175 m by 1050 m with a total depth beneath surface of 540 m. The geology and sample localities (based on all drilling to date) represented by the block model are outlined in Figure 27. All metavolcanic lithologies mapped at the Clan Lake area are represented, at least in part, within the block model.

Modeling of $\delta^{18}O$ values for both quartz veins and wall rocks in the Clan Lake area shows that the southwestern corner of the block model has the highest $\delta^{18}O$ values (11.3 to 15.2‰ for quartz veins; 7.7 to 12.8‰ for wall rocks). These elevated $\delta^{18}O$ values are interpolated from the base of the model (540 m depth) to the surface and crosscut lithologies (Figs. 30a-b, 31a-b). The elevated $\delta^{18}O$ values are shown to widen and form a wedge shape which broadens with shallower depths. The $\delta^{18}O$ values gradually decrease towards the north-northeastern portion of the block model. If we view

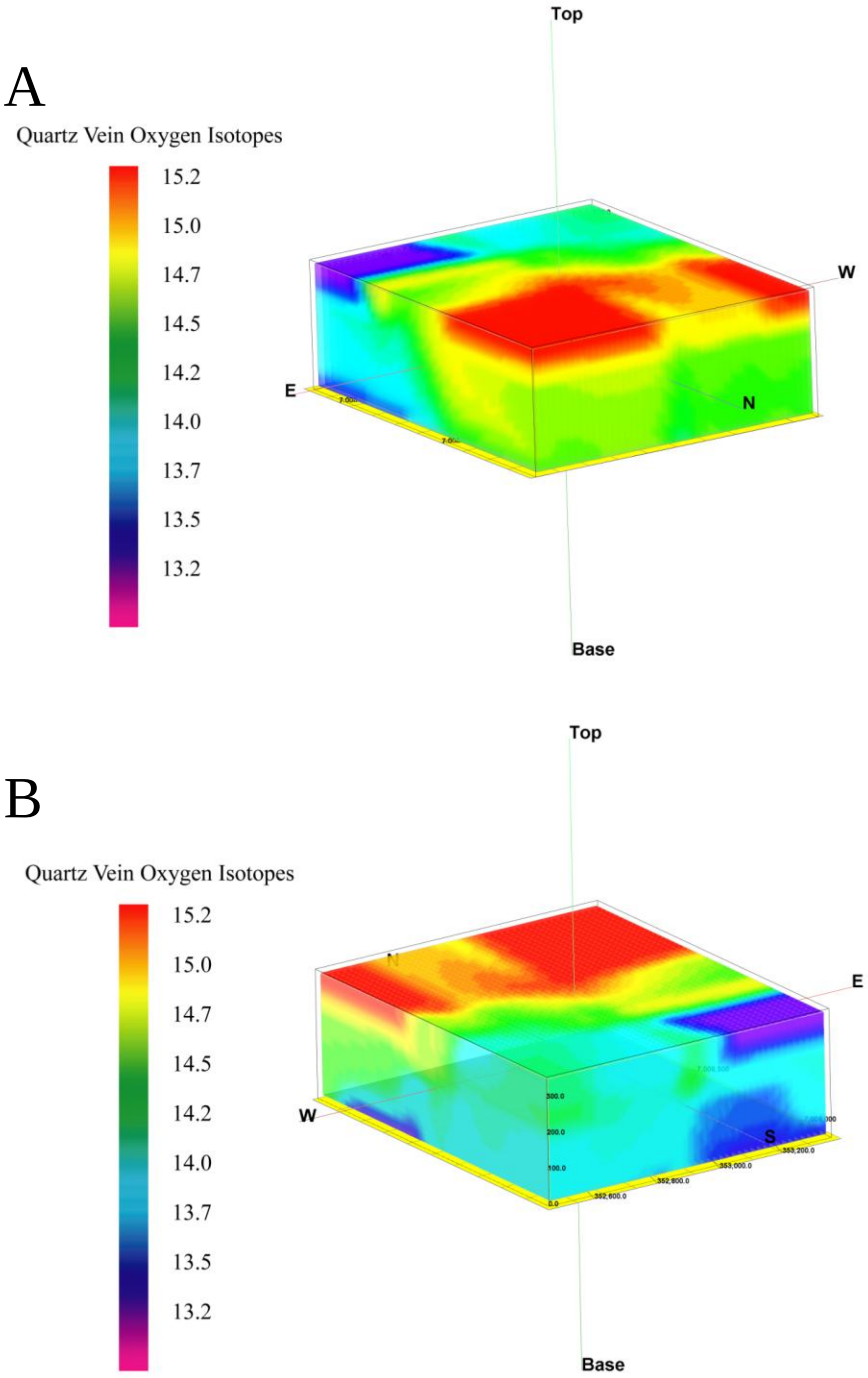


Fig. 29. 3-D block models for $\delta^{18}O$ values of quartz veins (‰)from the Ormsby Member. A. View from the northeast looking towards the southwest. Note that the highest values are located in the northeastern portion of the block model. B. View from the southwest looking towards the northeast.

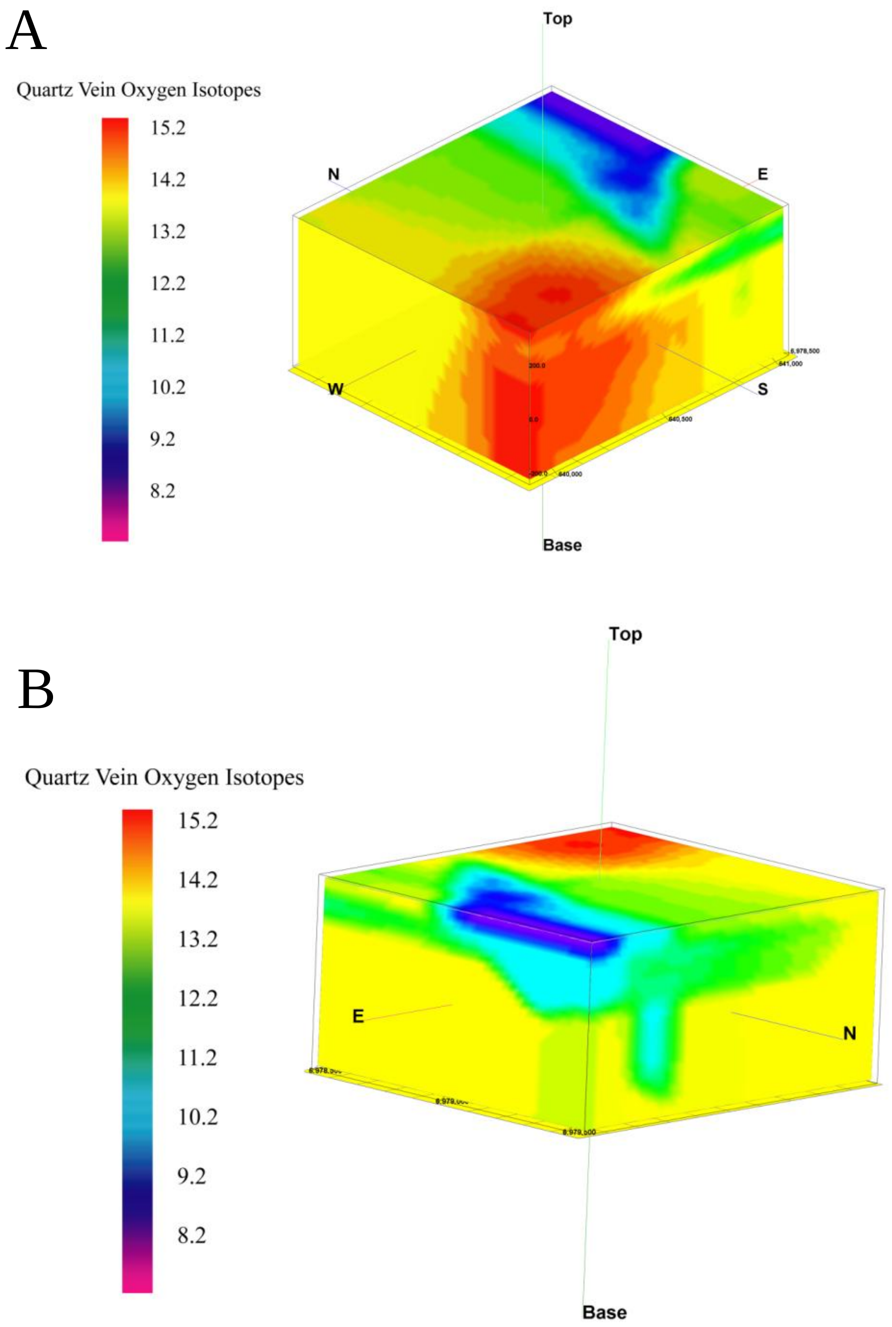


Fig.30. 3-D block model of δ^{18}O values (‰) of quartz veins from the Clan Lake area. A. View from the southwest towards the northeast. Note the wedge-shape of the highest values, located in the southwestern portion of the block model. B. View from the northeast towards the southwest. Note the lower values located at surface, and to shallow depths, of the northeastern corner compared to those at depth.

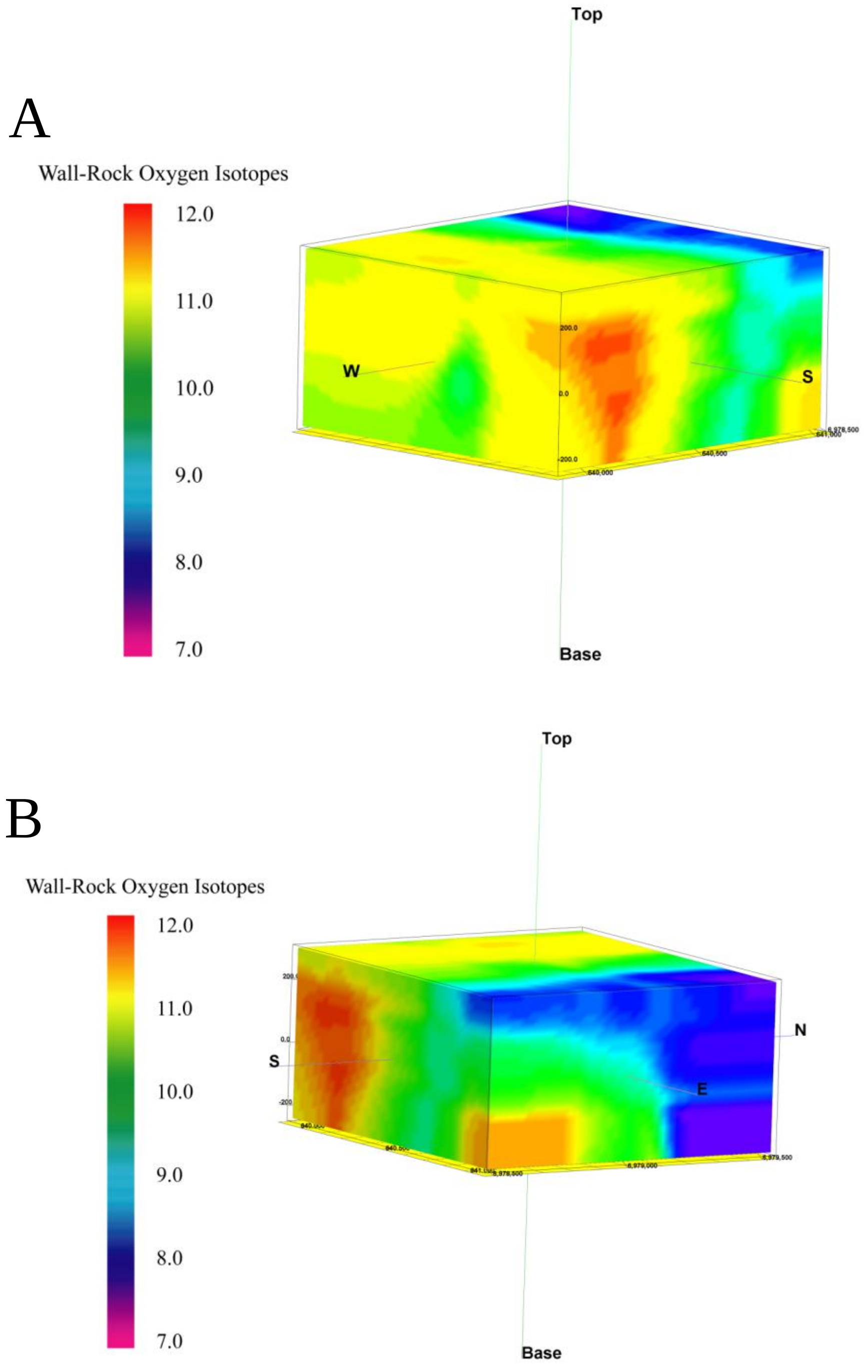


Fig. 31. 3-D block model for $\delta^{18}O$ values (‰) of wall rocks from the Clan Lake area. A. View from the southwest towards the northeast. Note the wedge-shape of the highest values, located in the southwestern portion of the block model. This wedge is consistent with that seen in the quartz vein block model (Fig. 30a). B. View from the southeast towards the northwest. Note the low values located at surface, and to shallow depths, of the northeastern corner and eastern face of the block model compared to values at depth. This is consistent with observations from Fig. 30b.

the block models from the opposite perspective, from the northeast corner looking towards the southwest, we can see that the north-northeastern low- $\delta^{18}O$ edge exists only at and near surface. The $\delta^{18}O$ values below ~ 230 m appear to be similar to $\delta^{18}O$ values in the center of the block, within a range of ~ 12 to 13‰ (Fig. 30b, 31b).

Lithogeochemistry: Modeling and Analyses

Tyhee Gold Corporation provided geological and geochemical data for all cores drilled to date for both study areas. These data are used for lithogeochemical modeling and analysis, permitting us to link oxygen isotope results to host rock chemistry and gold mineralization. Some of Discovery-Ormsby's geochemical data is limited to only gold assay results, but other cores have been analyzed for thirty-one elements (Fig. 26). Clan Lake's geochemical data includes results for thirty-one elements, with some cores having data for forty-one elements (Table 2). Only samples located within the outlined box at Clan Lake (Fig. 27) are included in the 3-D modeling to maintain consistent model dimensions for ease of comparison between different block models.

Data and Methods

Tyhee Gold Corporation contracted Acme Analytical Laboratories, Ltd. to analyze whole rock chemistry using fire assay and inductively coupled plasma emission spectrometry (ICP-ES). Results have standard errors of ~ 1% of the measured concentrations. Additional filtering was applied for analysis of the lithogeochemical data to set any element concentration that was below detection level to a value of zero.

Table 2. List of elements used within lithogeochemical analysis.

Suite of 31 elements:

Ag; Al; As; Au; B; Ba; Bi; Ca; Cd; Co; Cr; Cu; Fe; K; La; Mg; Mn; Mo; Na; Ni; P; Pb; S; Sb; Sr; Th; Ti; U; V; W; Zn

Suite of 41 elements:

In addition to the suite of 31 elements:

Ce; Hf; Li; Nb; Rb; Sc; Sn; Ta; Y; Zr

Although rare, numbers exceeding measureable detection for an element (i.e. >10,000 ppm) were assigned the saturation limit value.

A single lithogeochemical data set exists for Discovery-Ormsby. This set includes data from 65 drill cores to be used for modeling of the Ormsby Member. Spatial control is well developed on the mafic metavolcanic Ormsby Member (Fig. 26).

Two lithogeochemical data sets exist for Clan Lake (Fig. 27). The first, used for lithogeochemical modeling, incorporates 150 drill cores (representing > 30,000 individual samples) to ensure well-developed spatial and vertical control. The second data set consists of 19 cores (total 2,455 samples) that were also analyzed for ten additional elements (Zr, Ce, Sn, Y, Nb, Ta, Sc, Li, Rb, Hf). This data set was used in plotting lithogeochemical analyses and immobile element ratios (Zr/Ti vs Cr/Al) to determine volcanic protoliths, as discussed earlier. Cores have been correlated with geological descriptions. Sample intervals that represent metasedimentary rocks have been removed from the data set. This correlation step is critical for ensuring that immobile element ratios reflect only metavolcanic rocks for protolith identification and are not skewed by metasedimentary rocks and their inherited chemistries. These 19 cores are clustered northwest of the center of the block (see red symbols, Fig. 27), which limits sample variety. This clustering biases protolith identification to rocks present within these cores. Some mapped lithologies could not have their protolith identified because they were not analyzed for Zr, a critical immobile element used for the protolith identification ratios used in this study.

Lithogeochemical models were constructed to visualize spatial distribution of elements and breadth of spatial control using Rockworks™ by Rockware®. The inverse distance weighting (anisotropic) algorithm was chosen for interpolation and model construction because of its applicability to data that are clustered spatially, but that are considerably more detailed with depth. Two iterations of a low-pass smoothing filter were applied to all models. In order to detect artifacts of the modeling process, cross-sections were generated to compare with the box models (see Appendix 6). This allowed for the identification and avoidance of edge effects where the software may have interpolated values erroneously due to a lack of data near the boundaries of the block model.

Lithogeochemical Models

Discovery-Ormsby Area

Models for the Ormsby Member of the Giauque Formation utilize a 3-D block that is 880 m by 1060 m and that totals 340 m in depth. Figure 26 outlines the lithologies and samples used in these blocks. Modeling of gold concentrations shows that the high-gold anomalies occur towards the southern end of the member and crosscut lithologies (Fig. 32). A 3-D oxygen isotope model for the same block (Fig. 29) shows that the highest $\delta^{18}O$ values of quartz veins are in the northern portions of the Ormsby Member. The model shows what appears to be a decrease in $\delta^{18}O_{\text{quartz vein}}$ values from the northern to the southern portion of the Ormsby Member, even though the total range of $\delta^{18}O_{\text{quartz vein}}$ values is only from 13.0 to 15.2‰.

Elevated $\delta^{18}O$ values of quartz veins are indicative of a large movement of metasedimentary fluid through the entire metavolcanic Ormsby Member, which could imply that any area within the member is as viable a location for gold mineralization as

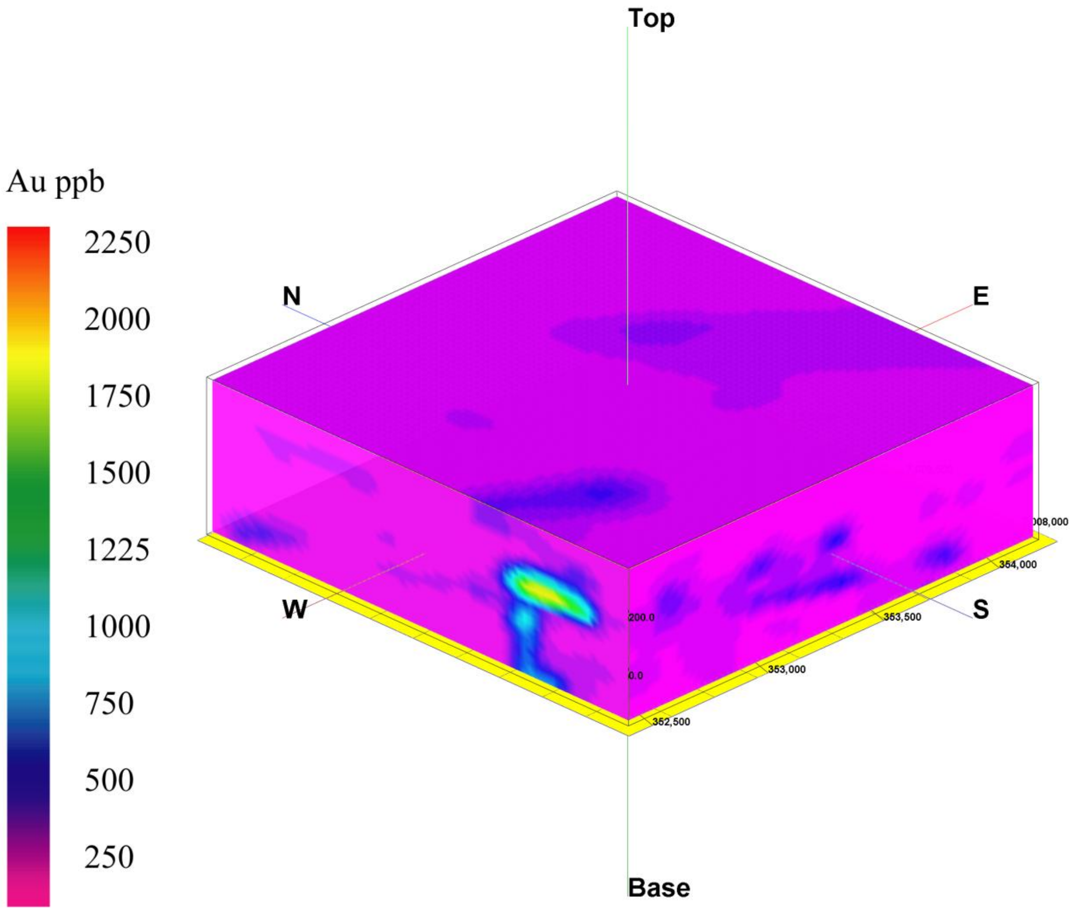


Fig. 32 3-D block model showing the spatial distribution of gold in the Ormsby Member. Note the high gold anomaly in the southwestern corner.

any other. However, that is not the case, as the most notable gold anomaly occurs in the southern portion of the Ormsby Member, where $\delta^{18}O$ values approach somewhat lower values of ~ 13‰.

The spatial relationship of $\delta^{18}O_{\text{quartz vein}}$ values with gold mineralization in the Ormsby Member is similar to that documented for the Giant gold mine in the southern YGB (van Hees et al., 1999). In the Giant mine area, $\delta^{18}O$ values of quartz veins in adjacent metasedimentary rocks are > 15‰ and decrease gradually as the mafic metavolcanic host rocks are approached. Over a broad zone of metavolcanic rock that includes all of the wall-rock-hosted ore mineralization, $\delta^{18}O_{\text{quartz vein}}$ values have a nearly constant value of ~ 12‰. Shelton et al. (2004) interpreted this pattern to reflect extensive reaction of metasedimentary-derived fluids with metavolcanic host rocks at moderate water/rock ratios, conditions in which reaction with the mafic metavolcanic rocks buffered the $\delta^{18}O_{\text{quartz vein}}$ values to a nearly constant value while causing gold deposition via sulfidation. Where insufficient amounts of metasedimentary-derived fluids reacted with the metavolcanic rocks (low water/rock ratios), quartz veins were barren of gold and had lower $\delta^{18}O$ values of ~ 9 to 10‰, approaching values for unmineralized metabasalts throughout the southern YGB (~ 7 to 8‰, Kerrich and Fyfe, 1981). Conversely, where abundant metasedimentary-derived fluids passed through fracture systems and did not react extensively with the host metavolcanic rock, quartz veins were also barren, but had $\delta^{18}O$ values > 13‰.

Similarly, portions of the Ormsby Member's $\delta^{18}O_{\text{quartz vein}}$ block model (Fig. 29) that have values approaching 15‰, indicating that metasedimentary-derived fluids passed through fracture systems in the mafic metavolcanic rock, also have low gold grades. This implies that these fluids did not react extensively with the host metavolcanic rocks along their pathways. If we utilize the Shelton et al. (2004) model in which metasedimentary-derived fluids reacting extensively with metavolcanic host rocks is a prerequisite for development of economic gold mineralization, this would suggest that permeability and porosity of the host metavolcanic rock exert a strong influence over the spatial distribution of gold. In the Ormsby Member, both the narrow range of $\delta^{18}O_{\text{quartz vein}}$ values near 13‰ and the highest gold anomaly occur proximal to the Discovery shear zone and to rocks with extreme vertical elongation (Fig. 6). The shear zone and observed deformation may have provided enhanced permeability and porosity during the gold mineralizing event (Pratico, 2009a), allowing metasedimentary-derived fluids to react extensively with the adjacent metavolcanic rock, resulting in sulfidation and gold deposition.

Clan Lake Area

Models for the Clan Lake area utilize a 3-D block that is 1175 m by 1050 m and has a total of 540 m in depth. Modeling of $\delta^{18}O$ values for both quartz veins and wall rocks shows that the southwestern corner of the block model has the highest $\delta^{18}O$ values, which crosscut lithologies and create a wedge shape (Fig. 30a, 31a). Elevated $\delta^{18}O$ values gradually decrease towards the north-northeastern portions of the block models, where the lowest $\delta^{18}O$ values define an apparent edge to the metasedimentary-derived fluid overprint. If we view the block model from the northeast corner looking towards the southwest corner, we can see that this apparent north-northeastern edge exists only at and near surface. The $\delta^{18}O$ values below ~ 230 m are shown to be similar to $\delta^{18}O$ values in the center of the block, within a range of ~ 12 to 13‰ (Fig. 30b, 31b).

A block model for gold was constructed for comparison with the $\delta^{18}O$ patterns (Figs. 33a-b). The gold model shows a wedge-shaped high-gold anomaly in the southwestern corner, two smaller lens-shaped gold anomalies on the western face of the model, and five small, dispersed anomalies on the southern face. The eastern face of the block model has numerous lens-shaped gold anomalies that crosscut lithologies and trend toward surface when profiled from north to south (Fig. 33b). The highest gold concentrations on the eastern face of the block model are nearest the center of the face. [The northern face of the block model has numerous scattered and minor gold anomalies, relative to those described previously.]

Comparing the $\delta^{18}O$ and gold block models for the Clan Lake area shows that elevated $\delta^{18}O$ values and high-gold anomalies coincide. The gold anomaly in the southwestern corner of the block model is within the large volume of rock denoted by the highest $\delta^{18}O$ values at the Clan Lake area. Gold anomalies on the western and southern block model faces reside within volumes of rock that also show elevated $\delta^{18}O$ values. Conversely, areas with lower $\delta^{18}O$ values (quartz vein or wall rock), such as the north-northeastern edge, are devoid of positive gold anomalies. As described previously, $\delta^{18}O$ values demonstrate higher values at depth beneath the north-northeastern edge. This also coincides with the lens-like gold anomalies which are seen only at depth beneath the north-northeastern edge (Fig. 33b).

The 3-D block modeling of $\delta^{18}O$ values and gold for both the Discovery-Ormsby and Clan Lake areas reveal a relationship between the spatial distribution of gold and

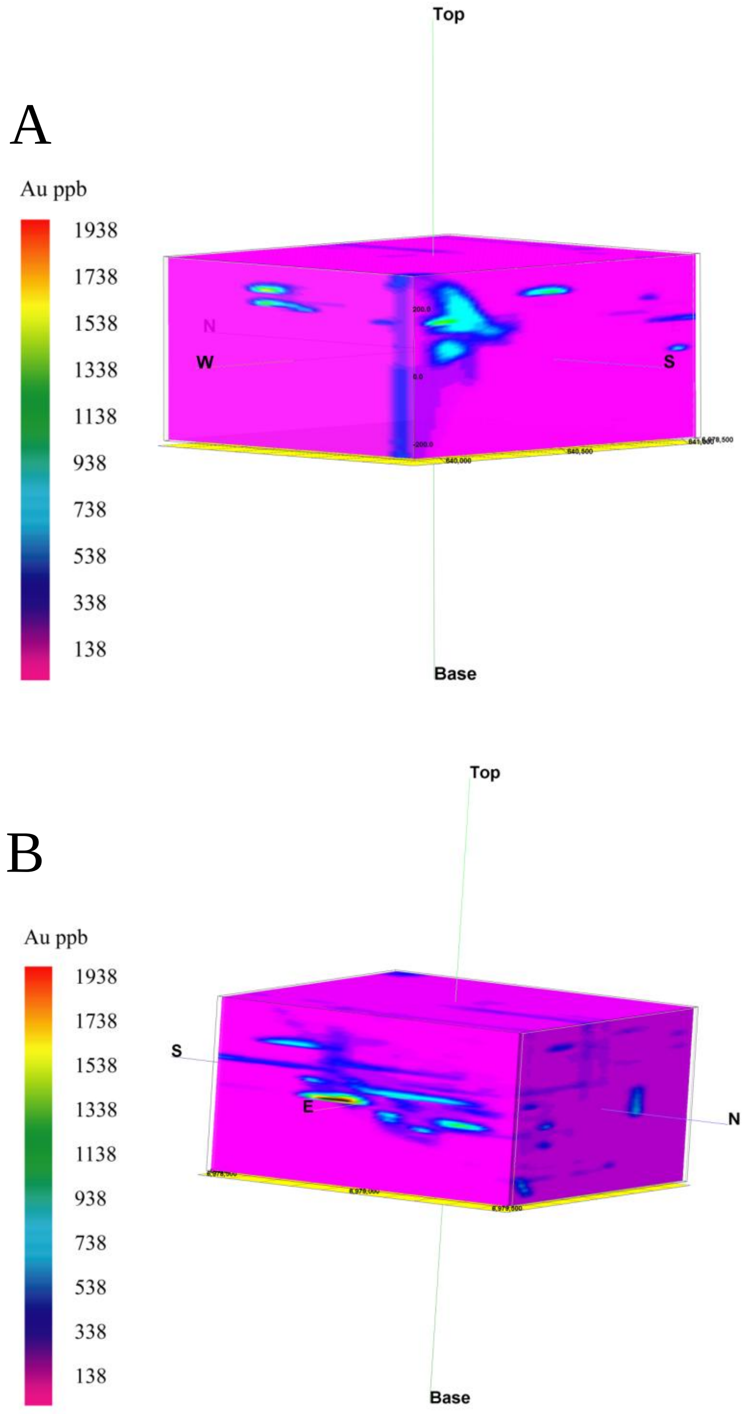


Fig. 33. 3-D block model showing the spatial distribution of gold in the Clan Lake area. A. View from the southwest looking towards the northeast. Note the high gold anomalies in the southwestern corner and on the southern and western faces of the block model. B. View from the east. Note the high gold anomalies (and their depths) on the eastern face of the block model.

volumes of rock with elevated $\delta^{18}O$ values. The $\delta^{18}O$ values and gold anomalies each crosscut lithologies in both study areas.

At the Discovery-Ormsby area, the highest $\delta^{18}O$ values are in the northern portion of the member, although $\delta^{18}O$ values are elevated throughout the entire narrow and elongate, mafic metavolcanic Ormsby Member. Gold values are highest in the southern portion of the Ormsby Member. The highest gold values crosscut lithologies and coincide with $\delta^{18}O$ values of ~ 13‰.

At the Clan Lake area, gold anomalies are found with elevated $\delta^{18}O$ values on all faces of the block model. However, the largest volume of rock with both elevated $\delta^{18}O$ values and high gold concentrations is found in the southwestern corner of the block model, crosscutting lithologies.

Preferred Host Rock Chemistry

Modeling has shown that anomalies of $\delta^{18}O$ values and gold concentrations crosscut lithologies in both the Discovery-Ormsby and Clan Lake areas. The next question investigates the controls on the spatial distribution of gold. Is gold mineralization a function of host rock chemistry (since lithologies are crosscut), enhanced permeability and porosity, or a combination of both? A preferred host rock chemistry could also crosscut lithologies and would serve as a chemical trap for gold deposition. Alternatively, gold deposition may be a function of enhanced permeability and porosity, during the gold mineralizing event, which allowed for a greater degree of interaction between the auriferous fluids and host rocks, regardless of lithology.

Discovery-Ormsby Area

The $\delta^{18}O_{\text{quartz vein}}$ values are elevated throughout the entire Ormsby Member, as seen in 3-D modeling. In the field, extensive silicification and sulfidation of the metavolcanic rocks was observed. Together, these observations indicate that fluid(s) reacted extensively with the entire Ormsby Member. The Ormsby Member is an iron-rich, mafic metavolcanic rock which ought to be an ideal candidate for gold deposition associated with wall-rock sulfidation. However, modeling of gold concentrations shows that the southern portion of the Ormsby Member contains the most notable gold anomaly.

Because gold and pyrrhotite are often associated intimately within sulfidized wall rocks in the Discovery-Ormsby area, iron was anticipated to correlate positively with gold. However, a plot of iron versus gold concentrations (using lithogeochemical data from drill core) does not show that relationship (Fig. 24). Likewise, because arsenopyrite is frequently fractured and filled by pyrrhotite and gold, arsenic was plotted versus gold and it also failed to show a positive correlation.

The lack of correlation of gold to elements relevant to wall rock sulfidation (Fe and As) raised the question: Do any other elements have positive correlations with gold, particularly those related to other observed types of alteration (e.g. sericitic and potassic alteration, and conversion of ilmenite to titanite)? These alteration types involve a variety of elements (Fe, Ti, K, Ca, Na,) that might be correlated with gold. These elements were plotted versus all other elements analyzed within the lithogeochemical data set, while at the same time noting the sample’s gold concentration (see Appendix 5).

If potassic alteration of the host rock were a dominant cause of gold deposition, potassium concentration might be expected to increase with increasing gold concentration, while sodium and calcium concentrations should decrease, as these latter elements should be removed from the rock. However, potassium showed no recognizable correlation with gold (Fig. 34). Instead, sodium and calcium showed an unexpected relationship with gold. Both the majority of gold mineralization and the higher gold concentrations (> 14,000 ppb) occur in rocks with 1.0 to 5.5 wt. % Ca and ≤ 0.25 wt. % Na (Fig. 35). These parameters are not particularly helpful in determining a preferred host rock chemistry, considering the overall ranges of Ca and Na concentrations of the Ormsby Member's metavolcanic rocks are rather limited.

The lack of anticipated correlations of gold with iron or potassium and its unexpected relationship with calcium and sodium imply that a factor(s) other than host rock chemistry is influencing gold enrichment. One possible factor is enhanced permeability and porosity due to structural features such as faults and shear zones. The Discovery shear zone is a likely fluid conduit that allowed metasedimentary-derived auriferous fluids to gain access the metavolcanic host rocks. Additionally, the vertical elongation and fragmental texture of the rocks caused by shear deformation may have created zones of enhanced permeability and porosity necessary for focusing fluid flow. This scenario could explain why only certain portions of the iron-rich metavolcanic Ormsby Member are gold mineralized.

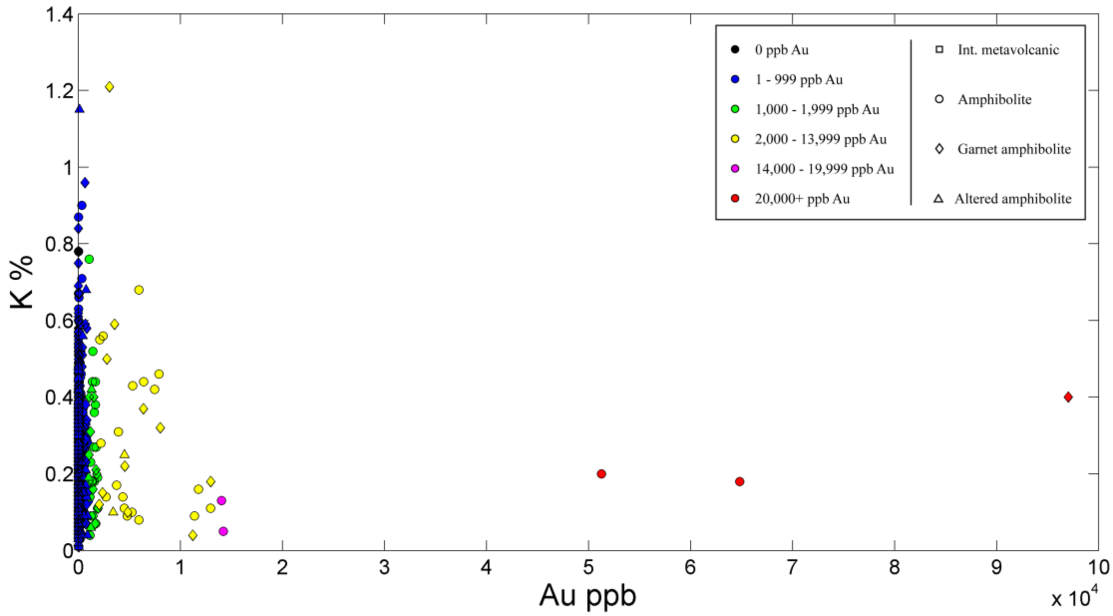


Fig. 34. Potassium (wt. % K) versus gold (Au ppb) diagram for rocks of the Ormsby Member. Rocks with high gold concentrations do not correlate to a particular range of potassium.

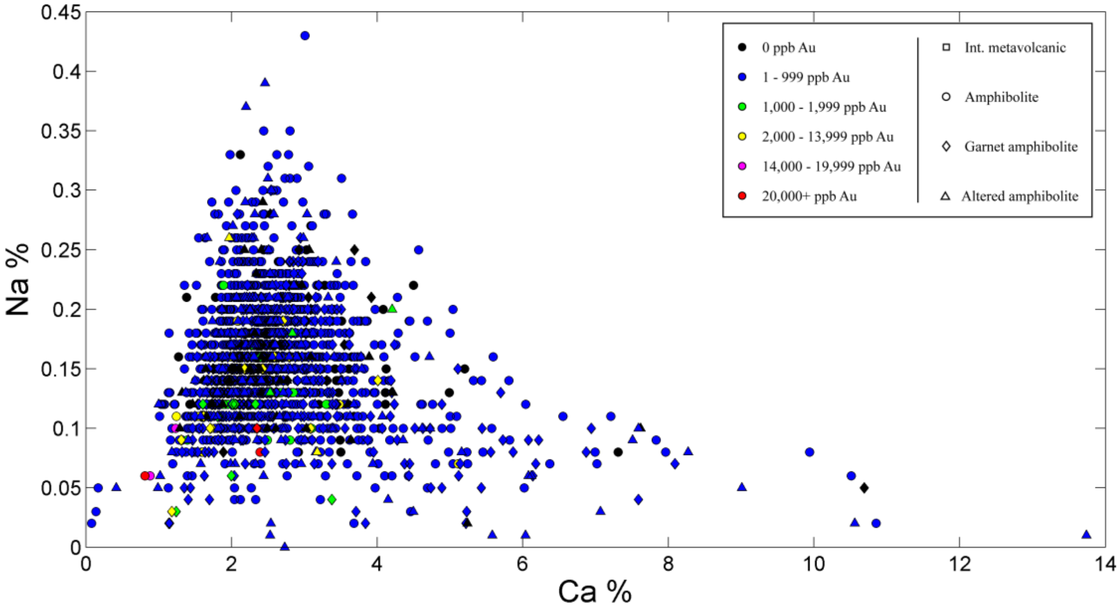


Fig. 35. Sodium (wt. % Na) versus calcium (wt. % Ca) for the Ormsby Member. Symbols represent both logged lithology and gold grade.

Clan Lake Area

For the Clan Lake area, elements involved in wall rock alteration and sulfide deposition (Fe, Ti, As, K, Ca, Na) were plotted versus all elements of the lithogeochemical data set, including gold, to investigate any possible correlations. These elements did not correlate strongly with any measured elements, including gold (see Appendix 5).

Because Zr/Ti ratios proved useful in differentiating pre-metamorphic protoliths at Clan Lake (Fig. 18), an additional plot of gold grade versus Zr/Ti ratios (ppm/percent) was constructed (Fig. 36). This diagram shows (by symbol) the various lithologies of the samples, as logged by Tyhee Gold Corporation personnel. The majority of gold, including higher gold values, coincides with a range of Zr/Ti ratios between 350 and 560 (Fig. 36). Rocks within this range of Zr/Ti ratios have been logged dominantly as a variety of intermediate lithologies (intermediate, altered intermediate, carbonate altered intermediate, quartz eye intermediate, and silicified intermediate). Protoliths of these rocks, using immobile element ratios, are intermediate to felsic, depending upon their Cr/Al ratio.

It appears that the most favorable gold-hosting metavolcanic rocks in the Clan Lake area (based on Zr/Ti ratios) do not belong to one particular lithology. Therefore these rocks must be preferred hosts for gold ore because of some other attribute. One possibility is that the Zr/Ti ratios correspond to a more highly reactive metavolcanic rock chemistry. However, no other elements or combination of elements in these rocks reveal a direct relationship with alteration type or gold content.

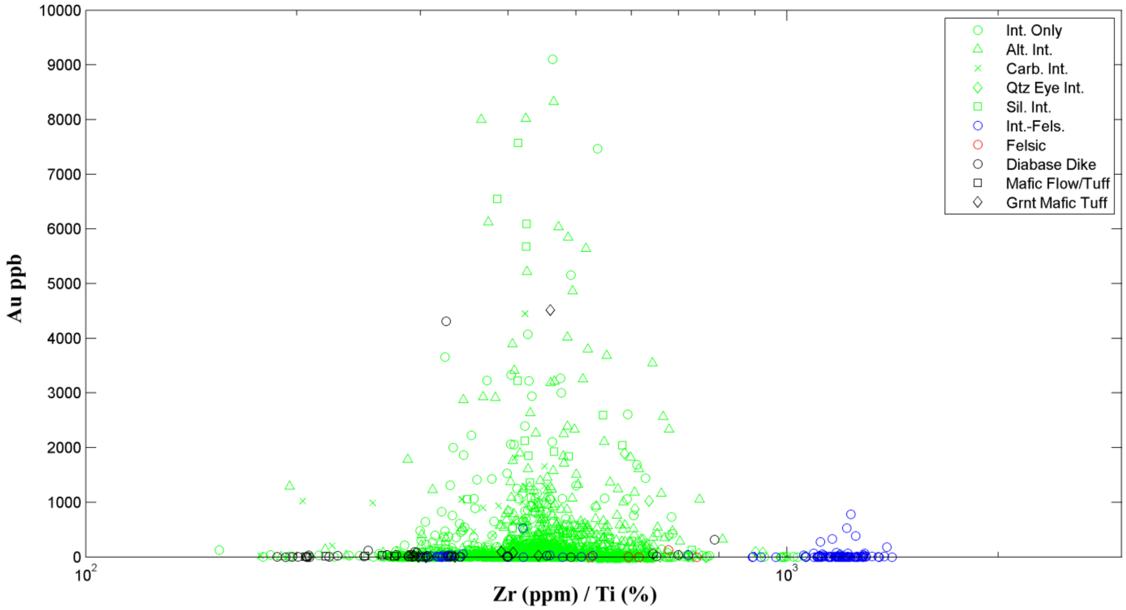


Fig. 36. Gold concentration (Au ppb) versus Zr/Ti ratios for the Clan Lake area. Symbols represent lithological descriptions logged by Tyhee Gold Corporation personnel. Note that a narrow range of Zr/Ti ratio values corresponds to the bulk of gold mineralization and the higher concentrations of gold. Rocks with these ratios represent a wide array of lithologies. Abbreviations: Int. Only, intermediate rocks; Alt. Int., altered intermediate rocks; Carb. Int., intermediate rocks with carbonate alteration; Qtz Eye Int., quartz eye intermediate tuff; Sil. Int., intermediate rocks with extensive silicification; Int.-Fels., intermediate to felsic rocks; Grnt Mafic Tuff, garnetiferous mafic tuff.

Because the Zr/Ti ratios of high gold-bearing rocks do not correlate exclusively with a particular lithology or with a particular alteration chemistry, they may additionally reflect a physical aspect of the rock. Perhaps rocks with the favorable range of Zr/Ti ratios were more susceptible to structural deformation, resulting in enhanced porosity and permeability that made them more accessible for gold-bearing fluids. This supposition is based on observed shear-induced fabric(s) and fragmental rock textures.

Discussion

The Discovery-Ormsby and Clan Lake areas are comparable for many reasons: similar ore mineralogy and paragenesis (early arsenopyrite, fractured and filled by pyrrhotite and gold, ± base metal sulfides); similar metamorphic conditions (upper greenschist-amphibolite transition); association with regional faulting; proximity to voluminous metasedimentary rocks (Plate 1). The primary difference between the two areas is host rock lithology; the metavolcanic host rocks of the Ormsby Member are mafic, whereas those in Clan Lake area are intermediate to felsic. Oxygen isotope studies and lithogeochemistry have shown that the two areas are related to similar hydrothermal systems involving metasedimentary fluid reservoirs. Modeling shows that inferred fluid pathways and positive gold anomalies typically coincide and crosscut lithologies.

Discovery-Ormsby Area

Spatial distribution of gold in the Discovery-Ormsby area must be strongly influenced by other factors, such as enhanced permeability and porosity during the gold mineralizing event because gold anomalies and preferred host rock chemistries crosscut lithologies. The iron-rich and highly reactive mineralogy of the entire Ormsby Member is favorable for gold deposition, yet positive gold anomalies are found preferentially in the southern portions of the member where $\delta^{18}O$ values (~ 13‰) reflect influence of both metasedimentary and metavolcanic influence (Figs. 29a-b; 32).

Whitty (2007) proposed a structural model in which the Discovery and Ormsby members of the Giauque Formation deformed more rigidly during shearing than the encompassing more ductile metasedimentary rocks of the Burwash Formation. This rigid deformation would be comparable to boudinage, causing narrowing and elongation of the mafic bodies. Vertical elongation and deformation (Fig. 6), a likely result of shear deformation, has been observed within rock fragments in the Ormsby Member, and may have provided enhanced permeability and porosity during the gold mineralizing event. The competency contrast and differential deformation between rigid metavolcanic rocks and more ductile metasedimentary rocks has been documented as a favorable structural setting for gold deposits in other Archean greenstone belts (e.g. Yilgarn block, Australia and Abitibi belt, Ontario; Groves et al., 2000).

This structural model may aid in the understanding of the spatial distribution of gold in the Ormsby Member. Shear deformation may have caused fragmentation and elongation of rock fragments, thus enhancing permeability and porosity. I speculate that the Discovery shear zone preferentially directed auriferous fluids toward the southern, fragmented portions of the Ormsby Member. The vertical foliation and elongation of rock fragments could have created local fluid pathways for auriferous fluid supplied by the shear zone conduit. This conceptual model for the Ormsby Member would accommodate the observed vertical patterns of $\delta^{18}O$ values and gold anomalies (Figs. 29a-b; 32).

Clan Lake Area

Unlike the Discovery-Ormsby area, the Clan Lake area does not have an obvious fault that can be invoked as a potential fluid conduit. A sinistral shear zone is noted ~1.75 km to the west of the Clan Lake area, and may have permitted fluids access to the intermediate-felsic complex (Plate 1). The 3-D models of $\delta^{18}O$ values of wall rock and quartz veins cut across lithologies and the preferred gold-hosting rock chemistry (based on Zr/Ti ratios) encompasses several different lithologies. This suggests that local, structurally controlled pathways focused ore-fluid flow in the Clan Lake area.

Modeling has shown that the highest $\delta^{18}O$ and gold values form a wedge shape in the southwestern corner of the Clan Lake area. The vertical nature of this pattern suggests upward movement of metasedimentary-derived ore fluids from the southwestern corner of the block model and lateral movement across the area towards the northeast. The $\delta^{18}O$ values decrease gradually towards the north-northeast, where an edge of the Clan Lake hydrothermal system is proposed to exist. This suggests that $\delta^{18}O$ values may be useful in defining the size of the Clan Lake mineralizing system and may be helpful as an exploration tool and ore guide.

Comparisons to the southern YGB

World-class gold deposits of the Giant and Con mines in the southern YGB exhibit similarities to deposits at the north end of the YGB. They each contain quartz vein and wall rock ores hosted in metavolcanic rocks, in which gold is associated intimately with pyrrhotite. Their rocks experienced similar metamorphic conditions (near the upper greenschist-amphibolite transition). Ore mineralization is associated with regional faulting and shear zones. And, they occur in relatively narrow metavolcanic units proximal to voluminous metasedimentary rocks, which themselves contain vein-hosted gold deposits.

Detailed oxygen isotope and lithogeochemical studies of the Giant mine have suggested that metasedimentary-derived fluids overprinting metavolcanic rocks may have been a necessary condition for the development of substantial economic gold mineralization (van Hees et al., 1999; Shelton et al., 2004). Refractory, metavolcanic rock-hosted orebodies are connected to metasedimentary rocks east of the mine by an east-dipping alteration zone characterized by depletion in Na and enrichments in K, Ag, As, S, and Sb. This zone has been interpreted as a shallow-dipping fault zone connected with the YRFZ that permitted gold-bearing fluids from the metasedimentary rocks to reach the highly reactive metabasalts (Falck, 1990; Martel and Lin, 2006; van Hees et al., 2006).

The Discovery-Ormsby and Clan Lake Areas

The Discovery-Ormsby area contains quartz vein and wall-rock-hosted gold ores hosted within silicified and sulfidized mafic metavolcanic rocks. The elevated $\delta^{18}O$ values of quartz veins and wall rocks reflect the dominance of metasedimentary-derived ore fluids. The entire Ormsby Member of the Giauque Lake Formation is iron-rich and overprinted by metasedimentary fluids (as seen by $\delta^{18}O_{\text{quartz vein}}$ patterns), however the most notable positive gold anomaly is found in the southern portions of the member. The Discovery shear zone is suspected to have served as the main conduit for ore fluids, with local deformation enhancing permeability and porosity, creating more local fluid pathways for auriferous fluid flow.

In the Clan Lake intermediate-felsic metavolcanic complex, gold mineralization occurs as native gold, principally within quartz veins and in altered rocks adjacent to veins. The elevated $\delta^{18}O$ values of quartz veins and wall rocks show the importance of a metasedimentary fluid component during gold ore deposition. Modeling of $\delta^{18}O$ patterns indicates that metasedimentary-derived fluids moved upward through the southwestern portion of the area, broadening and expanding toward the north-northeast. A potential conduit for ore fluid access may be related to the sinistral fault located approximately 1.75 km to the west of the Clan Lake area, which may be associated with the inferred extension of the YRFZ. In spite of lower iron contents of the rocks at Clan Lake relative to those of the Discovery-Ormsby area, there was sufficient iron to promote the observed sulfidation and associated gold deposition. The bulk of gold and highest gold values are found within samples with lower iron contents (1-5 wt. % Fe). This is interpreted to indicate that structural deformation of the host rocks created zones of enhanced porosity and permeability that made them more accessible for gold-bearing fluids within which fluid-rock interactions must have been very efficient in liberating iron to accomplish the observed sulfidation of the gold-bearing host rocks.

The Walsh and Banting Lake Area

A complex variety of gold-mineralization styles is recognized in the Walsh and

Banting Lake area of the YGB, ~ 30 km north of Yellowknife. These include volcanogenic massive sulfides, sulfide zones at intersections of shear zones, and quartz veins cutting metavolcanic and intrusive rocks (Hill et al., 2010). Gold-mineralized areas are hosted in metavolcanic rocks of the Kam Group and in metavolcanic and metasedimentary rocks of the Banting Group, which are older and younger, respectively, than rocks hosting the major ore bodies in Yellowknife. Quartz veins in metavolcanic rocks have $\delta^{18}O$ values of ~ 10 to 12‰, whereas those from Banting Group rocks have $\delta^{18}O$ values of ~ 13 to 15‰, reflecting the influence of metasedimentary rocks in this group (Smith et al., 2010). These data were interpreted to indicate that gold mineralization in the Kam and Banting Groups formed from distinct fluid-rock reservoirs with no evidence of fluid communication/interaction between them. If overprinting of metasedimentary hydrothermal fluids on metavolcanic rocks is a prerequisite for formation of large gold deposits in the YGB, this may explain why no large economic deposits have been found in the Walsh and Banting Lake area (Smith et al., 2010). The lack of fluid communication between the Kam and Banting groups is not due to an absence of faults in the area. Rather, it may be due to improper (near-vertical) fault geometries that did not allow the faults to serve as fluid conduits, but instead prevented flow (Martel and Lin, 2006).

Conceptual model for substantial economic gold deposits in the YGB

A conceptual model for the formation of substantial economic wall-rock-hosted gold deposits in the YGB requires three principal components: ore fluid source(s); conduits for fluid flow (on both regional and local scales); and reactive metavolcanic host rocks. Large accumulations of economic gold mineralization in the YGB are difficult to justify solely from a metavolcanic rock source, and are thought to require an additional contribution of gold from the volumetrically more abundant metasedimentary rocks of the belt (van Hees et al., 1999). The important roles of both metavolcanic and metasedimentary source rocks may explain why some greenstone belts, with limited volumes of metavolcanic rocks, can host substantial economic gold mineralization and has important implications for regional resource evaluation and exploration for gold deposits (Shelton et al., 2004).

Fluid conduits are also critical for the development of economic gold deposits in the YGB. At the Giant Mine, the regionally extensive YRFZ and a proximal shear zone permitted metasedimentary-derived fluids to reach highly reactive metavolcanic host rocks (Falck, 1990; Martel and Lin, 2006; van Hees et al., 2006). The Discovery shear zone may have been the auriferous fluid conduit at the Discovery-Ormsby area. A sinistral fault to the west of the Clan Lake area may have served as the main auriferous fluid conduit. In the Walsh and Banting Lake area of the middle YGB, the lack of proper fault geometries may not have allowed faults to serve as fluid conduits, but instead prevented flow. If overprinting of metasedimentary hydrothermal fluids on metavolcanic rocks is a prerequisite for formation of large gold deposits in the YGB, this may explain why no large economic deposits have been found in the Walsh and Banting Lake area.

Lastly, reactive metavolcanic host rocks are essential for developing substantial economic gold mineralization in the YGB. Areas in both the southern and northern ends of the YGB have similar ore mineralogy, paragenesis, and alteration (i.e. extensive silicification and sulfidation) in spite of contrasting host rock lithologies (felsic-intermediate to mafic) and chemistries (iron contents). As long as there is sufficient iron to accomplish wall-rock sulfidation, gold deposition can occur regardless of host rock lithology. This suggests that efficient reaction between ore fluids and host rocks must have occurred along zones of structurally enhanced permeability in order to deposit large economic concentrations of gold.

Conclusions

Ore petrology, oxygen isotope studies, lithogeochemical analysis, and 3-D modeling permit me to conclude:

1. Similar ore mineralogies and parageneses exist in the Discovery-Ormsby and Clan Lake areas, in spite of significantly different host rock lithologies. Early arsenopyrite is followed by pyrrhotite and gold (± base-metal sulfides) within silicified and sulfidized wall rocks.

2. The $\delta^{18}O$ values of quartz veins allow determination of the sources of gold-bearing fluids. The $\delta^{18}O_{\text{quartz vein}}$ values from the Discovery-Ormsby area range from 13.0 to 15.2‰ and indicate that the mafic metavolcanic rocks have been inundated by fluids from a metasedimentary reservoir. The $\delta^{18}O_{\text{quartz vein}}$ values from the Clan Lake area range from 11.3 to 15.2‰ and reflect the influence of both metasedimentary and metavolcanic sources.

3. 3-D modeling of $\delta^{18}O$ values has defined volumes of rock that correspond to likely fluid pathways. In the Discovery-Ormsby area, a narrow range of $\delta^{18}O_{\text{quartz vein}}$ values between ~ 13 and 14‰ occurs in the southern portion of the Ormsby Member and may implicate the Discovery shear zone is the main ore fluid conduit. In the Clan Lake

area, the southwestern corner contains a near-vertical wedge of elevated $\delta^{18}O$ values, which expands towards the surface, which is interpreted as the principal ore fluid conduit for the area. Modeling also revealed a low-$\delta^{18}O$ edge to the north-northeast, which suggests that $\delta^{18}O$ values may be useful in defining the size of the Clan Lake mineralizing system.

4. Comparison of 3-D models of $\delta^{18}O$ values to those for gold concentrations of Clan Lake indicates that high-$\delta^{18}O$ and high-gold anomalies coincide, indicating the potential use of $\delta^{18}O$ values as an exploration tool. The high-$\delta^{18}O$, high-gold trend appears to continue to the south-southwest, indicating a potential vector for future exploration efforts. High-$\delta^{18}O$, high-gold trends also appear to cut across lithologies. This suggests that factors other than simply host rock type, such as enhanced permeability and porosity during the gold mineralizing event, controlled the spatial distribution of gold.

5. In spite of the availability of iron in the highly silicified and sulfidized host rocks at the Discovery-Ormsby area, gold anomalies are found primarily in the southwestern portion of the member implying that other factors, such as enhanced permeability and porosity, have significant control on the spatial distribution of gold rather than simply host rock chemistry. At the Clan Lake area, a gold concentration versus Zr/Ti ratio plot showed a narrow range of Zr/Ti values which host both the bulk of gold concentration and highest gold values. This range encompassed rocks with a variety of logged lithologies. Perhaps these rocks also have attributes, such as structurally enhanced permeability, that are favorable for gold deposition.

6. A conceptual model for the formation of large wall-rock-hosted gold deposits in metavolcanic rocks of the YGB has three main requirements: an auriferous fluid source(s); structural conduits that permit fluid flow; highly reactive host rocks. Metasedimentary rocks, like those of the Burwash Formation have been shown to be a major ore fluid reservoir throughout the YGB. Fault conduits for fluids are critical in allowing gold-bearing metasedimentary-derived fluids access to highly reactive metavolcanic host rocks in the southern and northern YGB. The geometry of these faults in the central YGB (where no large gold deposits have been found) may have prevented fluid communication between metasedimentary and metavolcanic reservoirs. While metavolcanic host rocks may vary greatly in composition (from felsic-intermediate to mafic), there is typically enough iron to accomplish wall-rock sulfidation and precipitation of gold deposition, provided that zones of enhanced permeability exist. Throughout the YGB, such zones may occur where faults or shear zones encounter create dilatant zones within deformed metavolcanic rocks.

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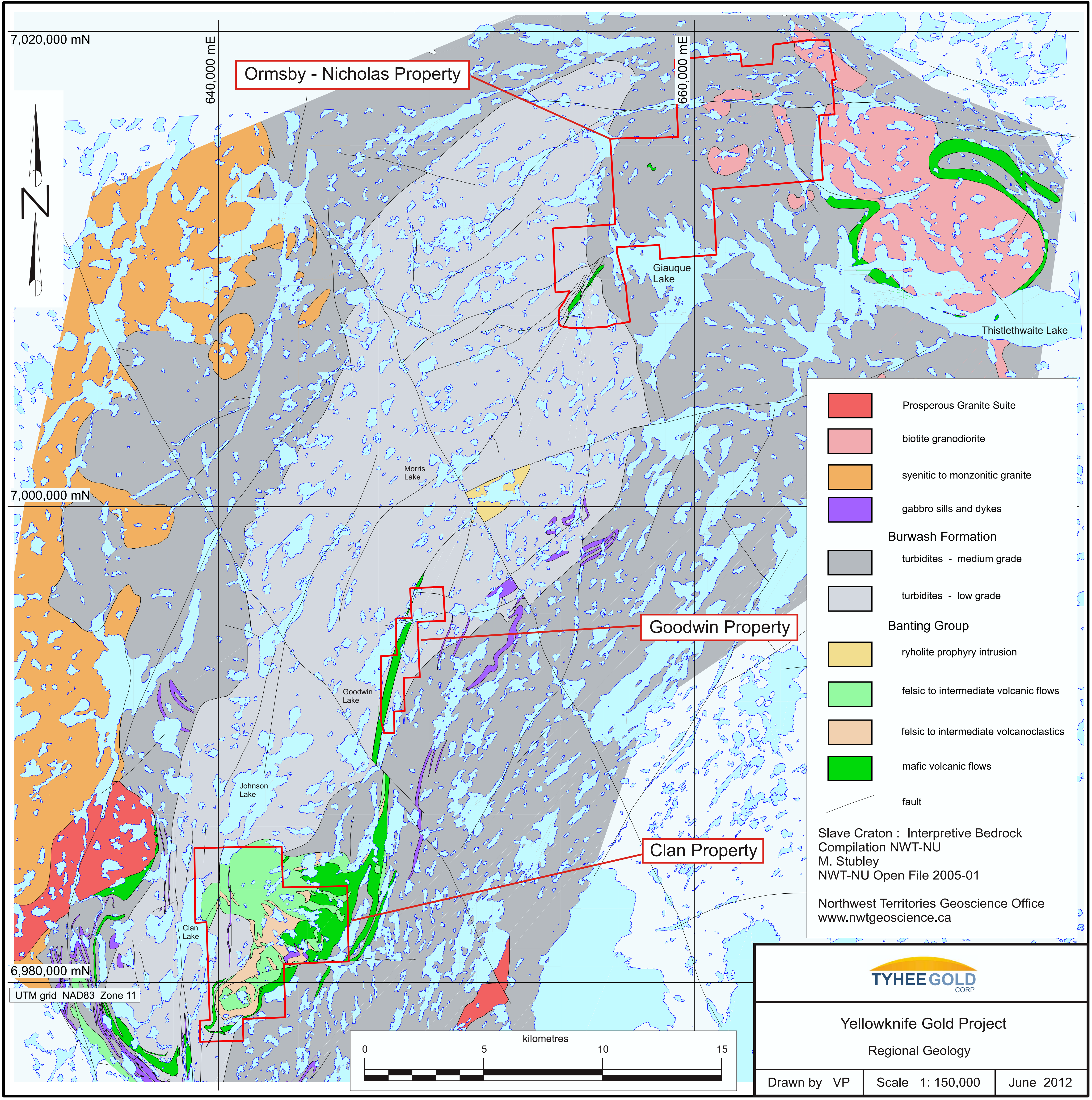
Appendix 1: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Burwash Formation
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Banting Group
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Slave Craton : Interpretive Bedrock Compilation NWT-NU
M. Stubley
NWT-NU Open File 2005-01
Northwest Territories Geoscience Office
www.nwtgeoscience.ca
TYHEE GOLD CORP
Yellowknife Gold Project
Regional Geology
Drawn by VP
Scale 1: 150,000
June 2012

Appendix 2:

Methods: Scanning Electron Microscopy

The scanning electron microscope (SEM) used in this study is a FEI Quanta 600F SEM™, housed in the University of Missouri Electron Microscopy Core Facility. The electron source for this tool is a Schottky thermionic field emission gun.

Microscope Operating Parameters

This microscope has variable pressure capabilities and this study utilized the low vacuum mode with an operating chamber pressure of approximately 130 Pa (~0.98 torr). Flat polished samples were not conductive and exhibited charging under high vacuum. The low vacuum mode was successful in eliminating or significantly reducing the charging of samples. Samples with residual charging effects were grounded to the microscope stage with carbon tape. The pressure parameter of 130 Pa was chosen initially because it ought to be the optimal mean free path for electrons. Given the clarity of images, this working pressure parameter did not need to be changed.

An accelerating voltage of 20 keV was the most frequently used, however this study did utilize a range spanning 15 keV to 30 keV. Spot size also incorporated a wide range of values (3.0 - 6.0), dependent on the accelerating voltage. Working distance varied from 10-12 mm.

Imaging and Mineral Identification

Using analytical information obtained by both imaging with backscattered electrons (BSE) and X-ray energy dispersive spectroscopy (EDS) combined with light microscopy facilitated mineral identification. The details of BSE and EDS are described below.

BSE images were obtained using two modes: Z contrast and A+B mode. Z contrast images are a function of the atomic number of elements within minerals. Heavier elements, such as gold, appear brighter than lighter elements. This mode is particularly useful in locating fracture-filling native gold and sulfides. EDS could then determine whether the bright mineral was native gold or a heavy sulfide such as galena (PbS). A+B mode accentuates relative contrast between mineral phases that contain elements within a narrow range of atomic numbers. This BSE mode has been beneficial in imaging wall-rock fragments which contain chlorite, biotite, and plagioclase feldspar. These minerals have similar cations within their structure, but slight variations are detected using A+B mode. It is important to note that contrast is reconfigured with each image when utilizing this mode based on the minerals present within that frame. Therefore, images may not be directly compared on the basis of contrast even if taken within the same sample.

X-ray energy dispersive spectroscopic data were collected on a Thermo Fisher Scientific, Inc. NORAN System SIX™ Lithium-drifted Silicon (SiLi) solid state detector cooled by liquid nitrogen and analyzed by accompanying NSS (v 2.3) software. The manganese $K\alpha_1$ X-ray (C.M. Taylor Company 51 hexagonal standard) was used for calibrating the detector. X-ray take-off angle to the detector was 35^o. Dead time for pulse processing of signals was set between 20-30% and spectra were collected for 60-120 s with average count ranges in the thousands to tens of thousands.

Appendix 3: Description of Clan Lake's Geological Units

Descriptions compiled by Tyhee Gold Corporation

Intermediate Volcanics:

Medium to dark gray, fine grained to locally medium grained, gray weathering, generally plagioclase porphyritic and locally quartz porphyritic massive to weakly laminated and weakly foliated intermediate massive flows, pillow flows with interlayered laminated to massive tuff. Alteration is sericitic near mineralization and quartz veining. Localized areas described as fiamme tuff, Pillowed flows contain very large up to 2 m pillows. Pillow forms suggest tops are west to southwest away from the gabbro core.

Intermediate Pyroclastic Tuff:

Light gray to pale tan, medium grained to very course grained, tan to orange-pink weathering, subrounded clastic to ash clastic intermediate tuff with clasts of intermediate to more felsic volcanic towards the top of the sequence. Typically matrix supported with variable fine intermediate tuff clast sizes supporting pebble to boulder (bomb) size intermediate to felsic volcanic clasts, possible lahars deposited locally.

Mafic Volcanics:

Medium to dark green, fine grained, dark gray to black weathering, locally plagioclase porphyritic and amygdaloidal, massive to pillowed mafic flows with very minor mafic tuff component. Pillow sizes are typically < 1 m with radiating vesicular textures from core centers. Pillow tops again suggest up direction is away from gabbro core.

Mafic/Gabbro Intrusive:

Medium to dark greenish-gray, dark gray to orange weathering, fine to medium grained, locally weakly plagioclase porphyritic, massive to weakly foliated along contacts, mafic intrusive.

Felsic Volcanics:

Pale pink or white, whitish or pinkish weathering, fine grained, locally plagioclase porphyritic, massive felsic flows. The pinkish equivalent occurs directly on top of the Intermediate Pyroclastic Tuff unit while the white equivalent occurs as lenses within the major tuffaceous metasediment horizon between pyroclastic tuff and mafic volcanics.

Intravolcanic Tuffaceous Metasediments:

Medium to dark gray to black, dark gray to orange weathering, very fine to medium grained, variably laminated and deformed, variably tuffaceous and/or argillaceous marine wackes, tuffs and pelites. Units vary from < 1 m thick to 200 m thick and have a variable tuff and argillite component along their extents. These units are typically situated along contacts between major units or as discrete horizons within the major units. Thinner units are folded and/or boudinaged along their lateral extent.

The thickest sequence, between Intermediate Pyroclastics/ volcanics and the outlying mafic volcanics, suggest an extended period of volcanic dormancy. This thick unit is abundantly argillaceous near the 330 zone and suggested fold nose and becomes more tuffaceous and/or wacke along its lateral extent. The base of the unit is more argillaceous with upper portions becoming more massive orange weathering wacke. Locally where grain size becomes courser the unit has been termed epiclastic.

The thinner horizons tend to be more argillaceous with numerous soft sediment deformation features and very fine laminations. One of these horizons has a number of < 2m thick garnetiferous mafic tuff lenses along its extent.

Mafic Dikes:

There are at least two generations of late dike emplacement across the property. The largest dike is up to 18m thick and occurs east of Mushroom Lake and runs crudely north-south abutting then cutting across the Outer mafic volcanic member. The other set of dikes are generally < 1 m thick and occur as broken fragments again trending crudely north-south across most areas of the property. All dikes cross-cut geological units, contacts, clasts, laminated horizons and veining.

Appendix 4: Sample Images

All samples have been photographed (field and core) and are reported within the file containing the sample locality and depth. "CL" indicates samples taken from the Clan Lake area whereas "OR," "ORMS," "Texture Samples," or "NDM" were taken from the Discovery-Ormsby area. The digital hierarchy of files begins with sample area (Discovery-Ormsby or Clan Lake) and progresses to particular sample localities/cores, is further subdivided by sample depth, and lastly by image type. Photomicrographs may be taken from a variety of microscopes; therefore subfolders indicate the types of microscopy used to acquire images.

Subfolders labeled "Sample Pictures" include images of the rocks before microscope sections were processed. If sections were made, they were scanned using both plane polarized (ppl) and cross-polarized (xpl) light to show the entire microscope section. The field of view (width) for all slide scans is approximately 41 mm.

The subfolder labeled "Microscopy Images" contains images acquired using either plane polarized reflected light (RL) or transmitted light (TL; ppl or xpl).

Photomicrographs within the "CL" subfolder are images from cathodoluminescence (CL). Certain CL images also used a plane polarized transmitted light component which is noted in the description section, if applicable. Exposure time for CL images is also noted along with magnification.

Lastly, images acquired during scanning electron microscopy (SEM) investigation are within the "SEM" subfolder. These images were acquired using either secondary electrons (SE) or backscattered electrons (BSE), as noted in the description.

Appendix 5: Lithogeochemistry Analysis

Cross-plots were generated from assay data provided by Tyhee Gold Corporation. Filtering was applied for analysis of the lithogeochemical data to set any element concentration that was below detection level to a value of zero. Although rare, numbers exceeding measureable detection (i.e. >10,000 ppm) were assigned the saturation limit value. These filters were emplaced because special characters cannot be read into or properly graphed using MatLab. Graphs have been grouped based on the X-axis variable and by study area.

Appendix 6: 3-D Block Modeling

3-D block models of $\delta^{18}O$ values and lithogeochemistry were constructed for the Discovery-Ormsby and Clan Lake areas using Rockworks™ by Rockware®. This program permits the visualization of data within a spatial context by interpolating between data points. An inverse distance weighting (anisotropic) algorithm was chosen for interpolation and model construction because of its applicability to data that are clustered spatially, but that are considerably more detailed with depth. Two iterations of a low-pass smoothing filter were applied to all models.

Multiple views of the block models and cross-sections are included within this appendix. Cross-sections were used to identify and avoid edge effects where the software may have interpolated values erroneously due to a lack of data near the boundaries of the block model.

Block models for the Ormsby Member of the Discovery-Ormsby area are 880 m by 1060 m with a total depth of 340 m. Block models for the Clan Lake area are 1175 m by 1050 m with a total depth of 540 m.