A-type granite plutons and tin skarns in southeast Yukon: Mindy prospect and surrounding granites of 105C/9

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ABSTRACT

In the southeast Yukon, immediately southwest of the mid-Cretaceous Cassiar suite plutons,is a northwest-trending suite of anorogenic one-mica granites called the Seagull suite. This suite is comprised of the Seagull and Hake batholiths, Ork and Thirtymile stocks and an un-named intrusion to the northwest. These B and F enriched granites are associated with various forms of tin mineralization, including skarns. The Mindy prospect in the Thirtymile Range contains a variety of metasomatic silicate and borate and fluoride minerals. Tin (Sn) mineralization is found as cassiterite and borate mineral phases. Mapping has shown that faulting active during metamorphism-metsomatism controlled the distribution of the skarn mineralization. Both mineral chemistry and structural control of mineralization have a significant effect on the economic potential of the Mindy prospect.

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INTRODUCTION

A northwest-trending line of mid-Cretaceous granite plutons in southeast Yukon (Seagull and Hake batholiths, Ork stock, Thirtymile stock and one un-named stock) have been recognized as being distinct from the larger Cassiar suite of intrusions that are immediately to the east of the Seagull suite trend. They are one-mica monzo to alkali feldspar granites which have similar to A-type plutons in chemistry, texture (occasional rapakivi texture) and fluorine-boron-tin (F-B-Sn) mineralization. Tin-rich skarns, greisens and tin±niobium (Nb)±tantalum (Ta) sheeted vein stockworks are associated with the Seagull batholith but the Thirtymile and Ork stocks have peripheral tin or tungsten (W) skarns.

The Mindy prospect (Fig. 1), tested with shallow diamond drilling by Newmont Mining Corp. in 1981, is a greisen-altered skarn characterized by primary, high temperature calc-silicate assemblages that have been formed in, and peripheral to, extensional faults above a buried stock and have been replaced by iron-rich greisenized B-F-Sn skarn mineral assemblages.

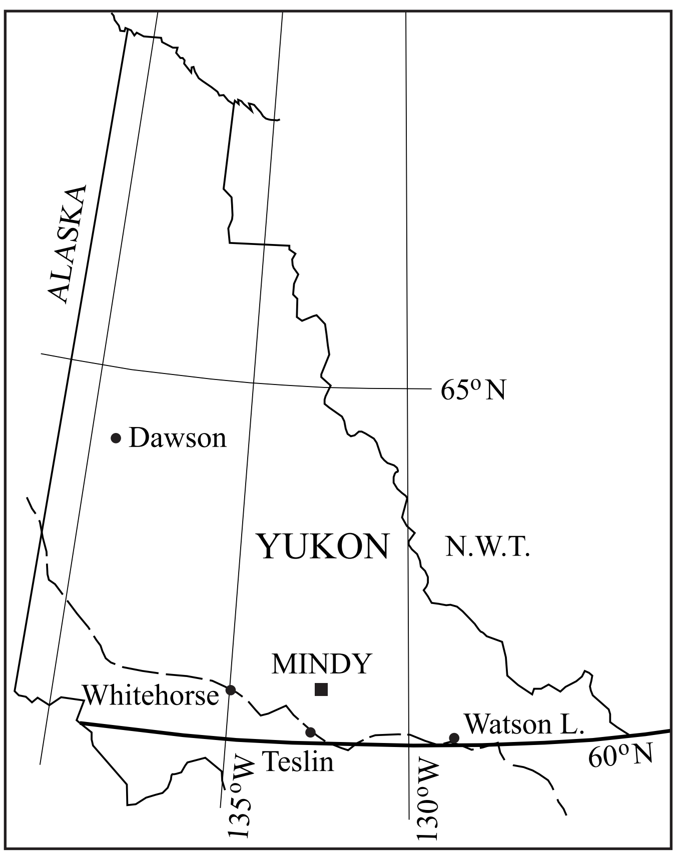

Figure 1. *Location of the Mindy prospect.*

Skarn mineralization may have a variety of tin minerals: cassiterite, vonsenite [$3(Fe,Mg)O{\cdot}2Fe_2O_3{\cdot}SnO_2{\cdot}3B_2O_3$], hulsite [$(Fe^{2+},Mg)_2{\cdot}(Fe^{3+},Sn)BO_5$], nordenskiöldine [$CaSn(BO_3)_2$] and malayaite [$CaSn(SiO_5)$] associated with fluoborite [$Mg_3(F,OH)_3BO_3$]. The borates and silicates are metallurgically refractory and only the cassiterite is of economic interest; as a result, a total Sn analysis may give a misleading result for evaluation of a prospect. The proportion of oxide tin (as cassiterite) to tin borates and fluorides in the Mindy prospect is estimated to be somewhat greater than 50%.

This paper discusses some of the 1992 work plus a re-evaluation of Sn mineralogy through examination of original thin sections and 23 new thin and polished sections cut from drill core stored in the H.S. Bostock Core Library.

GRANITES

The Thirtymile Range contains mid-Cretaceous (101 Ma; Liverton, 1992; Liverton *et al.*, 2001) stocks of monzogranite to alkali feldspar granite according to the Streckeisen classification (LeMaitre, 2004). Two lithofacies of biotite-only granite make up the bulk of the outcropping Thirtymile stock to the northwest of the Mindy prospect (Fig. 2). A volumetrically minor hornblende-bearing porphyry forms a disaggregated syn-plutonic dike within the Thirtymile stock and is the only amphibole-bearing lithofacies seen in the pluton and the Seagull suite. A lithium-mica topaz leucogranite crops out at the southeast corner of the Thirtymile stock and forms ladder dikes in the biotite-bearing 'even-grained' lithofacies. The leucogranite also forms 1-5 m dikes and three sills that contain spectacular concentrations of topaz. The leucogranite may be classified as an alkali feldspar granite *sensu stricto* since the plagioclase is at least 95% albite. A similar lithofacies forms the just-exposed Ork stock and adjacent dikes that are 2.5 km southeast of the Mindy prospect. The Thirtymile and Ork leucogranites consist of a quartz-albite-orthoclase-zinnwaldite-topaz-fluorite mineral assemblage contianing accessory fergusonite.

The Thirtymile and Ork stocks, together with the Seagull and Hake batholiths, were considered as a sub-suite of the Cassiar intrusions by Liverton (1992), called the Seagull-Thirtymile suite and identified as having A-type affinity (Liverton and Alderton, 1994; Liverton and Botelho, 2001; Liverton *et al.*, 2005). Subsequent work on the Cretaceous granites of the Northern Cordillera added a further pluton to the NW as being part of this suite, renamed

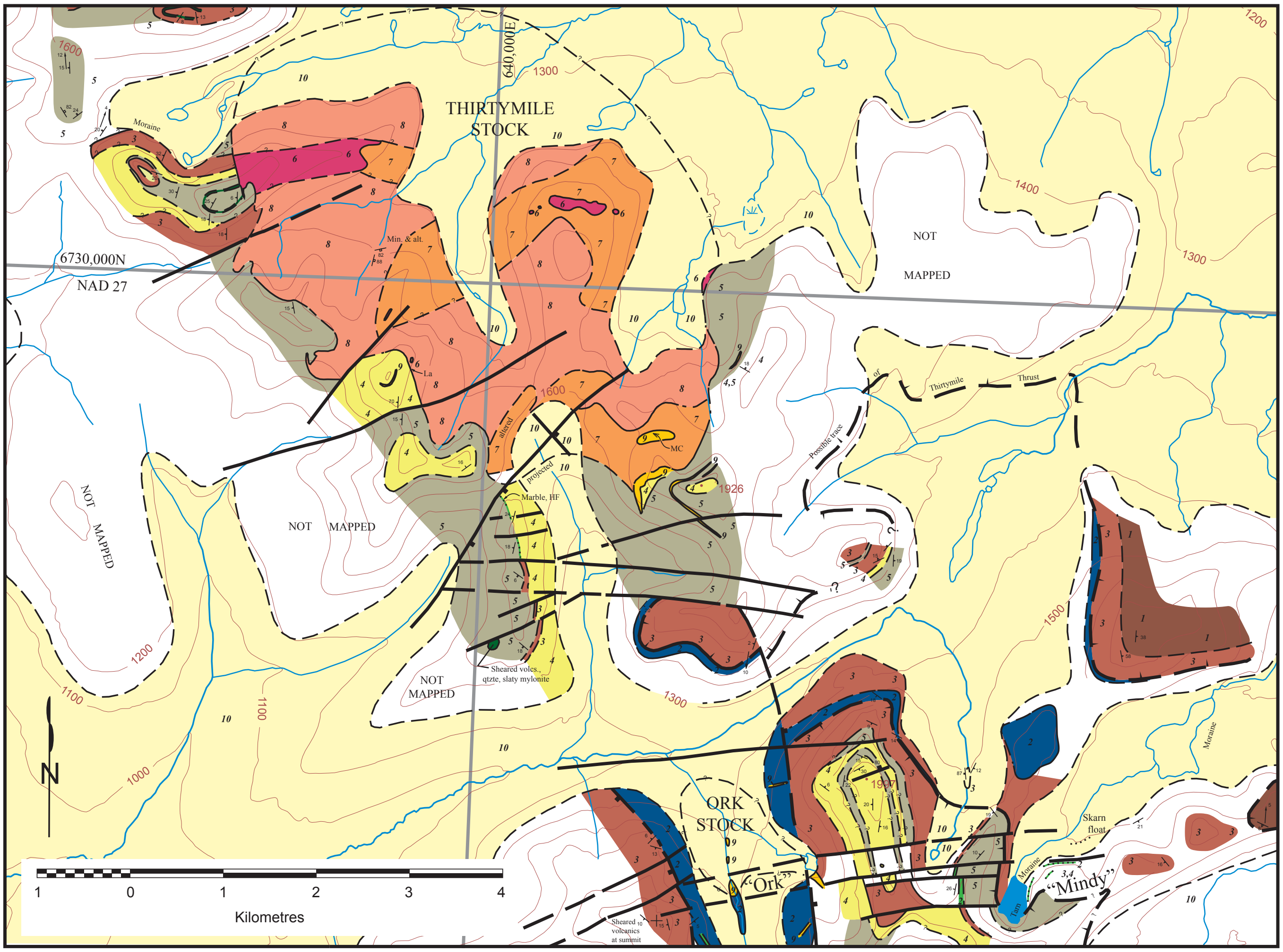

Figure 2. *Geology of the Thirtymile Range. Mapping 1987-1988, by T. Liverton.*

them as simply the Seagull suite, which is recognized as distinct from the Cassiar intrusions, and confirmed their anorogenic nature (Rasmussen, 2013). They are metaluminous to weakly peraluminous and conform to type A_1 of Eby (1992), *i.e.*, they are anorogenic (Fig. 3; Liverton and Botelho, 2001).

The Thirtymile and Ork leucogranites are the most chemically evolved (*i.e.*, fractionated) granites in the Northern Cordillera (Rasmussen, 2013), having Rb/Sr contents exceeding 3000. They might be considered the plutonic analogue to the topaz rhyolites, such as found from Colorado to New Mexico (Christianson *et al.*, 1986). They form the apical portion of batholiths which were emplaced at shallow depth (no more than 2 km), as indicated by common miarolitic cavities and pod pegmatites. These magmas were highly enriched in alkalis, Rb, Li, with B and anions (F^-, Cl^-). This B and halogen enrichment would have allowed the granitic magma to remain as a melt to <650°C, producing a compositional trend different to the 'normal' quartz enrichment process (Fig. 4a). Halogen-enriched granites fractionate to albite-enriched compositions, and due to protracted melt/aqueous fluid and fluid/vapour fractionation, as well as their reduced nature, are able to concentrate high field strength elements (HFSE) into the hydrothermal phase: notably Sn, Nb, Ta (Lehman 1990). Shallow depth of emplacement of the pluton, and being located in the apical part of a batholith, is essential for the development of the F-B mineralization. An 'inheritance' of those metals (*i.e.*, that the source rocks were anomalous in HFSE) might be possible (Lehmann, 1990) but fractionation processes in low-temperature reduced melts are most important for mineralization. In the Seagull suite, halogen enrichment is reflected in the unusual mineralogy at the Mindy and Ork prospects, these are greisenized skarn in the classification of Kwak (1987).

Analyses of Fe-Li micas ranging from siderophyllite to zinnwaldite from the Seagull suite granites indicate a sequence of Li-enrichment in the micas displaying progressive fractionation from the least evolved lithofacies, the Thirtymile porphyry, through the Hake granite, Seagull granite, and the Thirtymile biotite granite, to the zinnwaldite of the leucogranite (leucogranite and biotite-bearing lithofacies of the Thirtymile plutons are shown in Figure 4b,c). Biotite compositions indicate that these granites were distinctly reduced (Fig. 4c): biotite $\{Fe^{2+}/(Fe^{2+}+Fe^{3+})\}$ = 0.811-0.965, magma $fO_2 \leq$ NNO buffer (Liverton and Botelho, 2001). The progression to extremely Li-rich micas (trioctahedral 1M zinnwaldite) may be a particular trait of the anorogenic granite.

The Li-mica leucogranite of the Mindy stock exhibits three forms of hydrothermal mineralization at its southern contact: rare cm-scale beryl pegmatite, cm-scale lepidolite-topaz greisen veins and, presumably the last event, mm-scale joints that carry hematite. It is remarkable that a granite carrying very little total iron is capable of exsolving Fe-rich hydrothermal fluid, but this is evident in the retrograde/greisen stage skarn mineralization at the Mindy prospect.

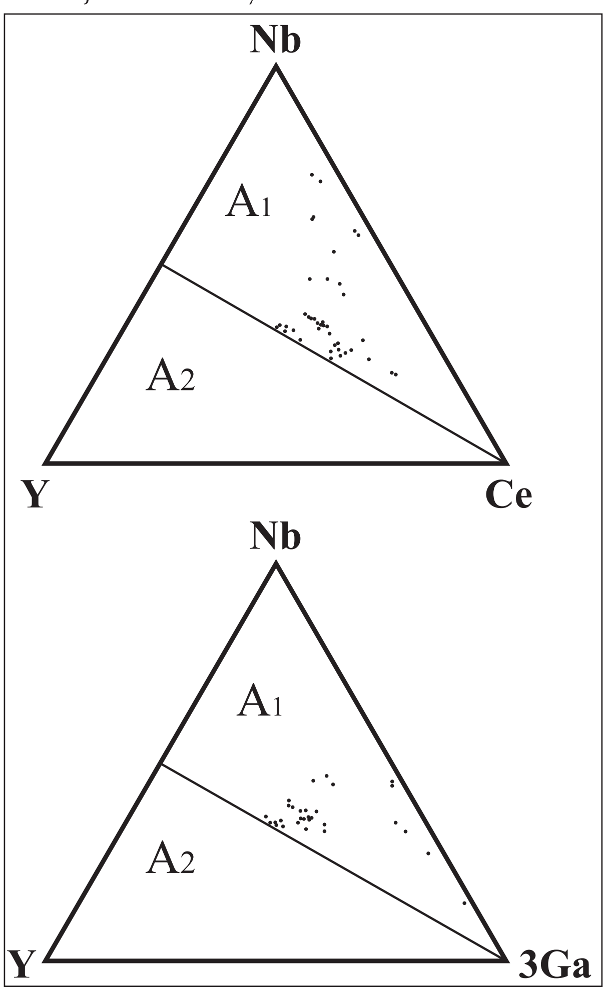

Figure 3. Eby discriminant plots for anorogenic granites showing compositions of the Thirtymile and Ork stocks (Eby, 1992).

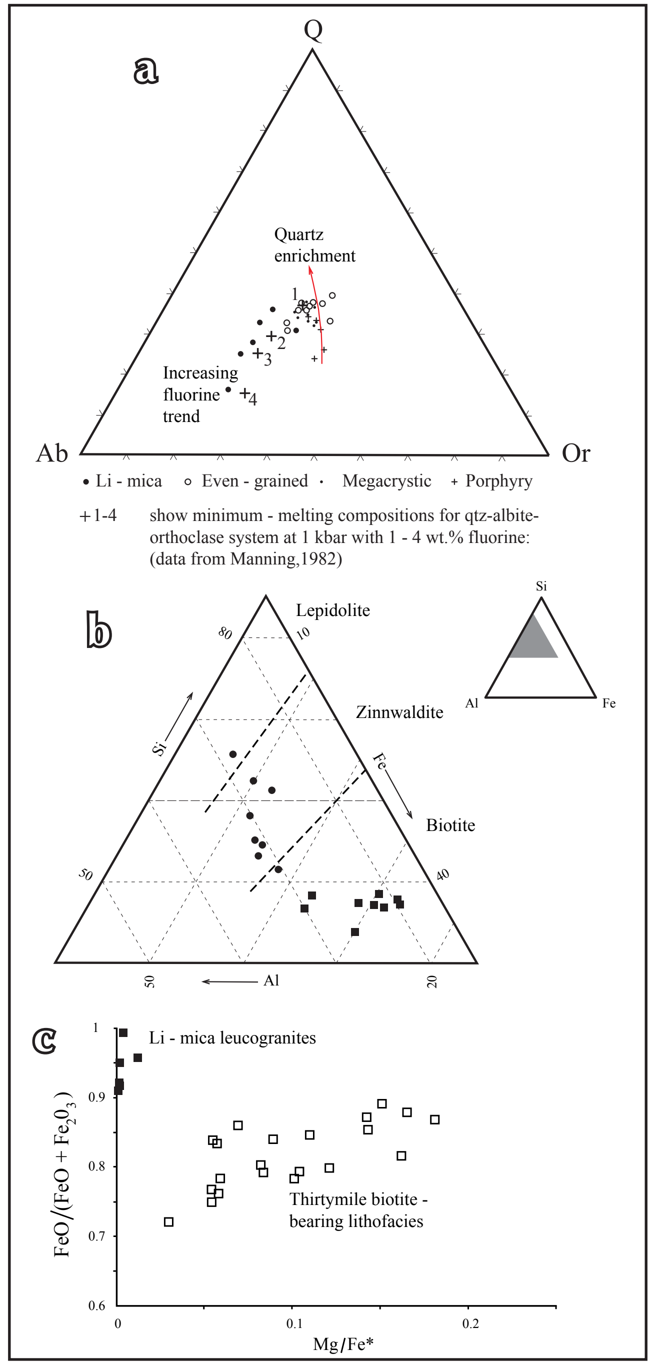

Figure 4. (a) Proportions of quartz-albite-orthoclase for the various lithofacies of the Thirtymile and Ork stocks compared to experimental data for a fluorine-bearing system. (b) Chemical data for Thirtymile and Ork micas. Cation proportions of Al-Si-Fe for Fe-Li micas from Thirtymile granites. (c) Chemical data for Thirtymile and Ork micas. Ferrous iron proportion to Mg/Fe ratio of micas ($FeO/(FeO + Fe_2O_3)$ vs. Mg/Fe* plot).

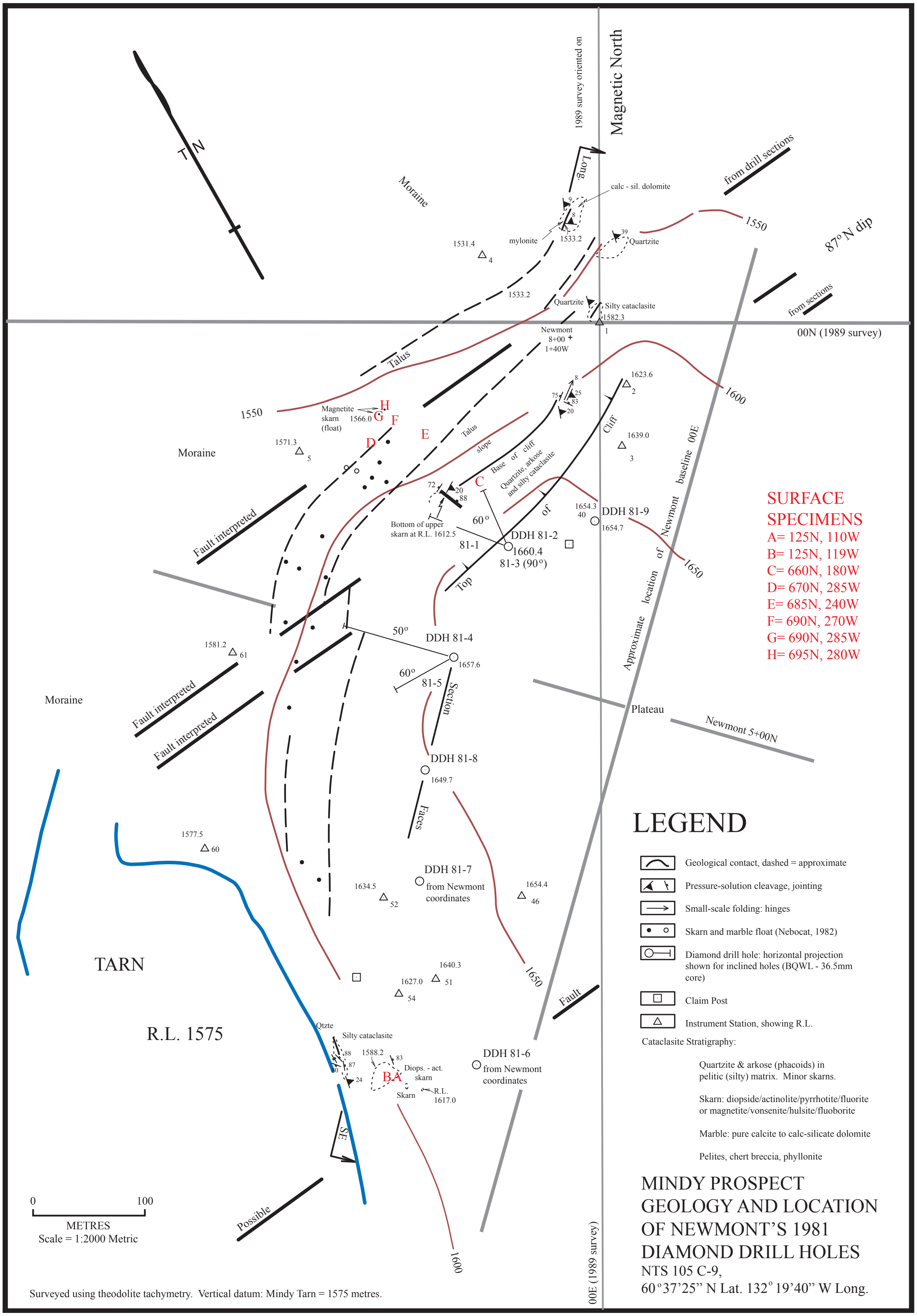

Figure 5. *Detailed map of the Mindy prospect showing trend of the lower skarn horizon and location of diamond drill holes.*

MINDY PROSPECT

The Mindy prospect (Fig. 5) consists of sparse exposure and frequent float of two marble-skarn horizons within siliciclastic rocks that are similar to Proterozoic to lower Paleozoic continental assemblages, probably the rifted continental basement for the Yukon-Tanana terrane. Imbrication of the siliciclastic sequence is likely, and a phacoidal fabric predominates throughout the Range. Mapping (Liverton, 1992) indicated the presence of at least three east-striking extensional faults that transect the property and which have been interpreted to be the principal 'plumbing' for the introduction of hydrothermal fluids into the carbonates. These faults have little obvious displacement and likely were associated with granite intrusion. This is best shown to the west of Mindy where a scheelite-bearing diopside skarn is developed alongside one such fault (Figs. 2 and 5), which projects through the mineralized portion of the Mindy prospect. An interpretation of diamond drill sections (Liverton, 1990) indicates that the lower carbonate-skarn unit, the only potentially economic horizon, is boudinaged (Fig. 6). Away from the extensional faults it consists of pure calcite marble. On the Mindy property the carbonates locally dip from 9° to 25° to the east. Two skarn horizons crop out at the Mindy prospect.

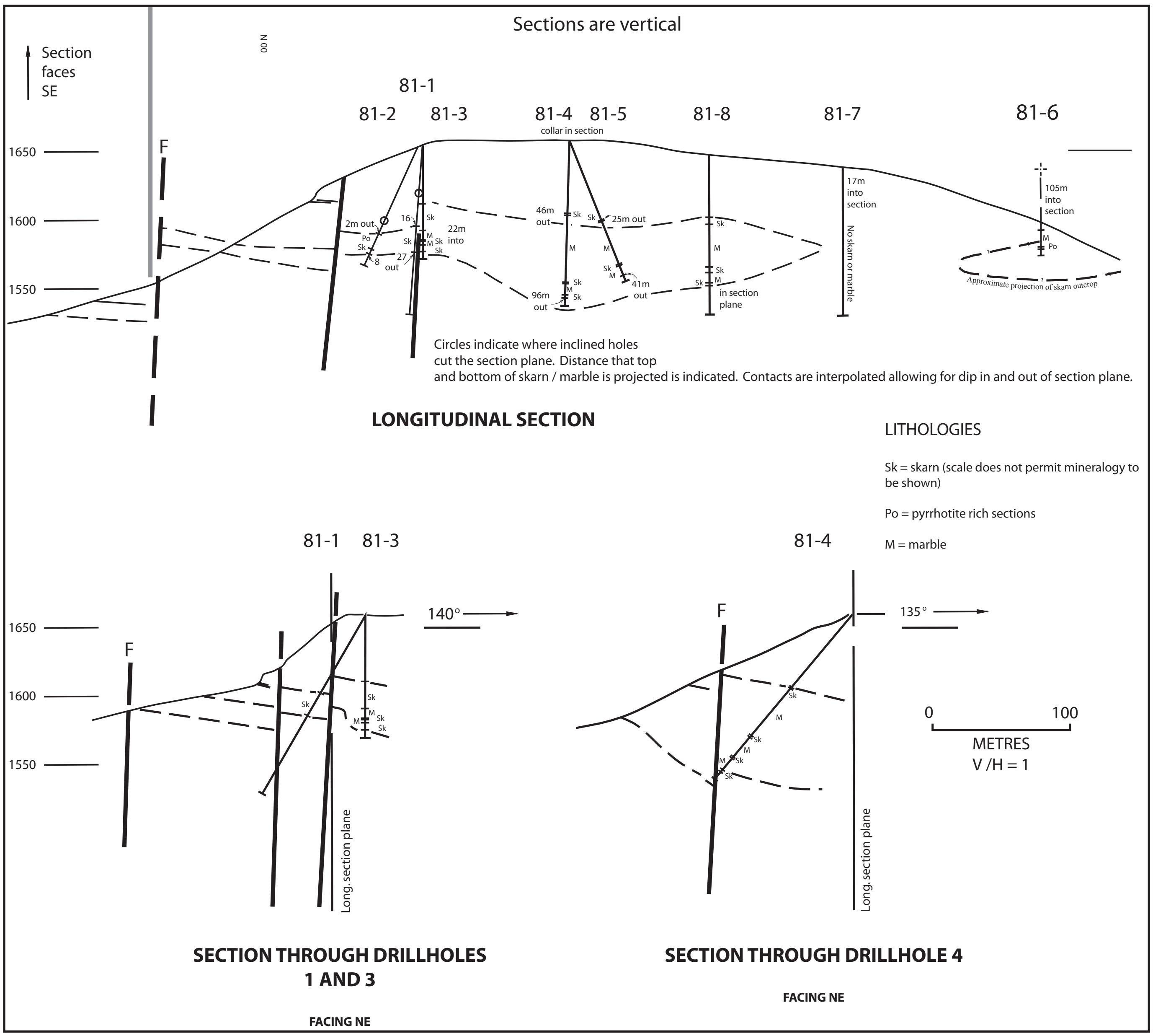

Figure 6. *Longitudinal and cross sections through drillholes 81-1 to 8, of the 1981 Newmont diamond drilling at Mindy prospect.*

The upper skarn consists of vesuvianite-grossular-calcite skarn with acicular vesuvianite crystals up to 40 mm long. No tin mineralization has been noted from this horizon. The margins of the coarse skarn grade into aphanitic ‘calc-silicate hornfels’ (diopside-hedenbergite) in contact with siliciclastic metsediments, that corresponds to the bimetasomatic skarn type of Kwak (1987). The garnet of this horizon (approximately 21% andradite) is significantly more aluminous than that of the lower skarn, presumably reflecting separate protoliths of different chemistry.

The skarn of the lower horizon developed in the major marble unit adjacent to the extensional faults. Textural evidence indicates that the original protolith controlled much of the skarn mineralogy, and that migration of many chemical components during contact metamorphism and metasomatism was limited. The fine-grained hornfels S-C fabric that developed during imbrication is preserved in calc-silicate mineralogy.

The process of skarn formation has had an obvious structural control. Development of successive retrograde and greisenized skarn assemblages has each accompanied fracturing of earlier skarn. Cataclasis of pyroxene, that has a range of compositions from salite to ferrosalite, indicates continued early brecciation. Disequilibrium in composition over the scale of a thin section is common in the central mineralized part of the skarns (Fig. 7).

The most striking texture of later greisenized skarn is the intricately banded ‘wrigglite’ (*c.f.*, Kwak and Askins, 1981; Kwak, 1987). Wrigglite texture displays contorted layers of magnetite and sulphides with phengite or talc, lesser amounts of fluorite, fluoborite and corroded relicts of chondrodite and vesuvianite. The wrigglite zones are discordant to host-rock bedding, hence representing fracture systems and the wrigglite layers themselves may be cut by several generations of microfractures, <1 mm to 3 mm wide that carry phengite, talc and scarcer ferrophengite or serpentine.

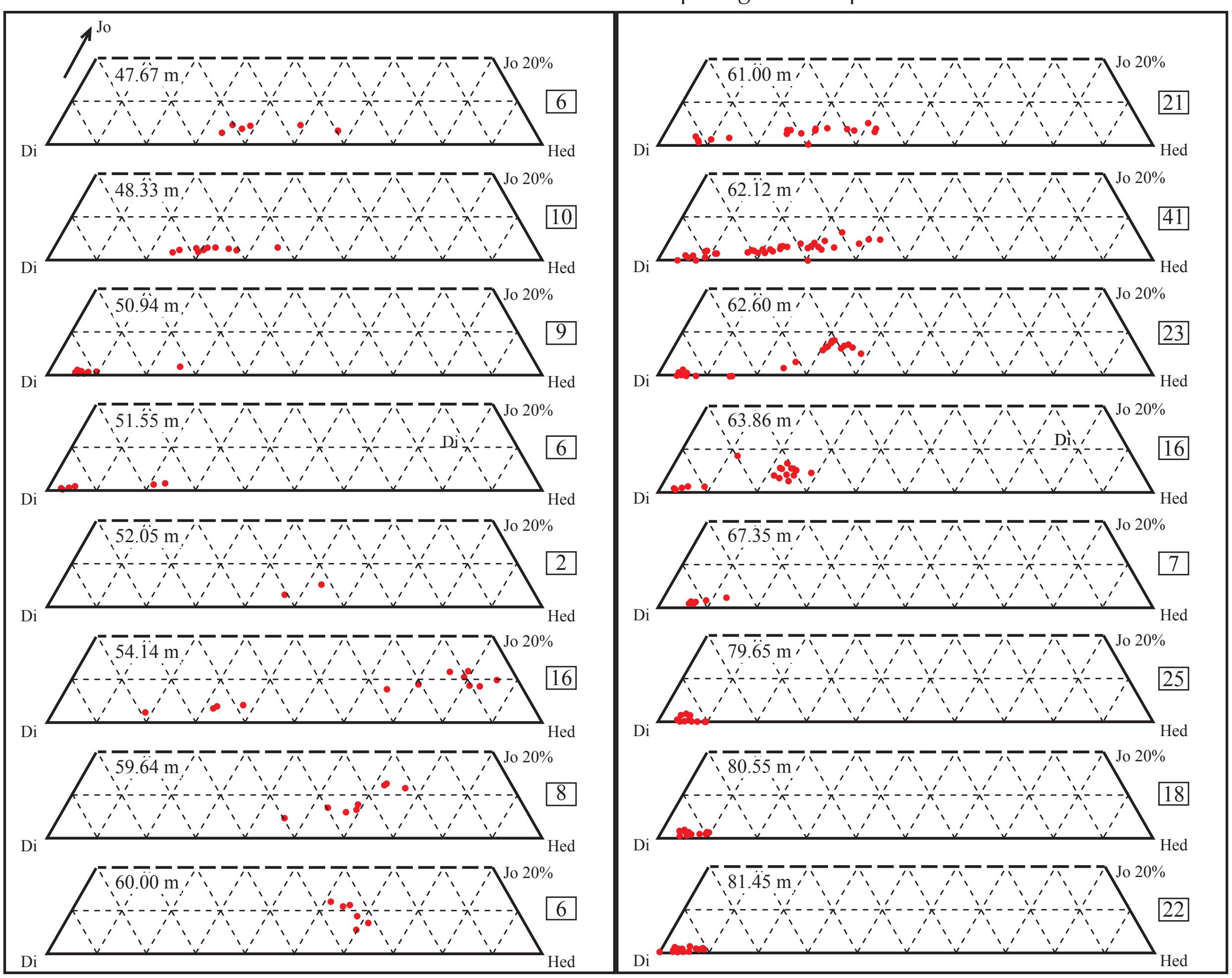

Figure 7. *Proportions of diopside-johannsenite-hedenbergite in skarn pyroxenes from drill hole 81-3, from electron microprobe analyses. Each diagram shows the range of compositions across one thin section. Numbers of analyses are shown in boxes to the right.*

Figure 8 gives a graphical log of DDH 2 to illustrate skarn distribution through the marble horizon and Figures 9-13 illustrate mineralogy, structure and texture of the skarn units.

The various stages of skarn mineralization are as follows:

- *Primary skarn:* garnet-vesuvianite, diopside ± larnite, wollastonite in calcite marble. Increasing Fe content from pyroxene to hedenbergite. Vein skarns of garnet ± arsenopyrite in pure marble. First fluorine mineralization as chondrodite.
- *Early Fe-F-Sn mineralization:* replacement of marble by magnetite-fluorite-cassiterite.
- *Retrograde alteration:* tremolite to actinolite along fractures altering garnet and pyroxene.
- *Greisen alteration and mineralization:* fluoborite alteration of pyroxene skarns, later (?) alteration to massive magnetite-vonsenite-hulsite-fluoborite (often containing relict chondrodite); pyroxene skarn replaced by fluoborite-vonsenite; voluminous wrigglite skarn.
- *Late retrograde alteration:* serpentine growth along fractures and grain boundaries.

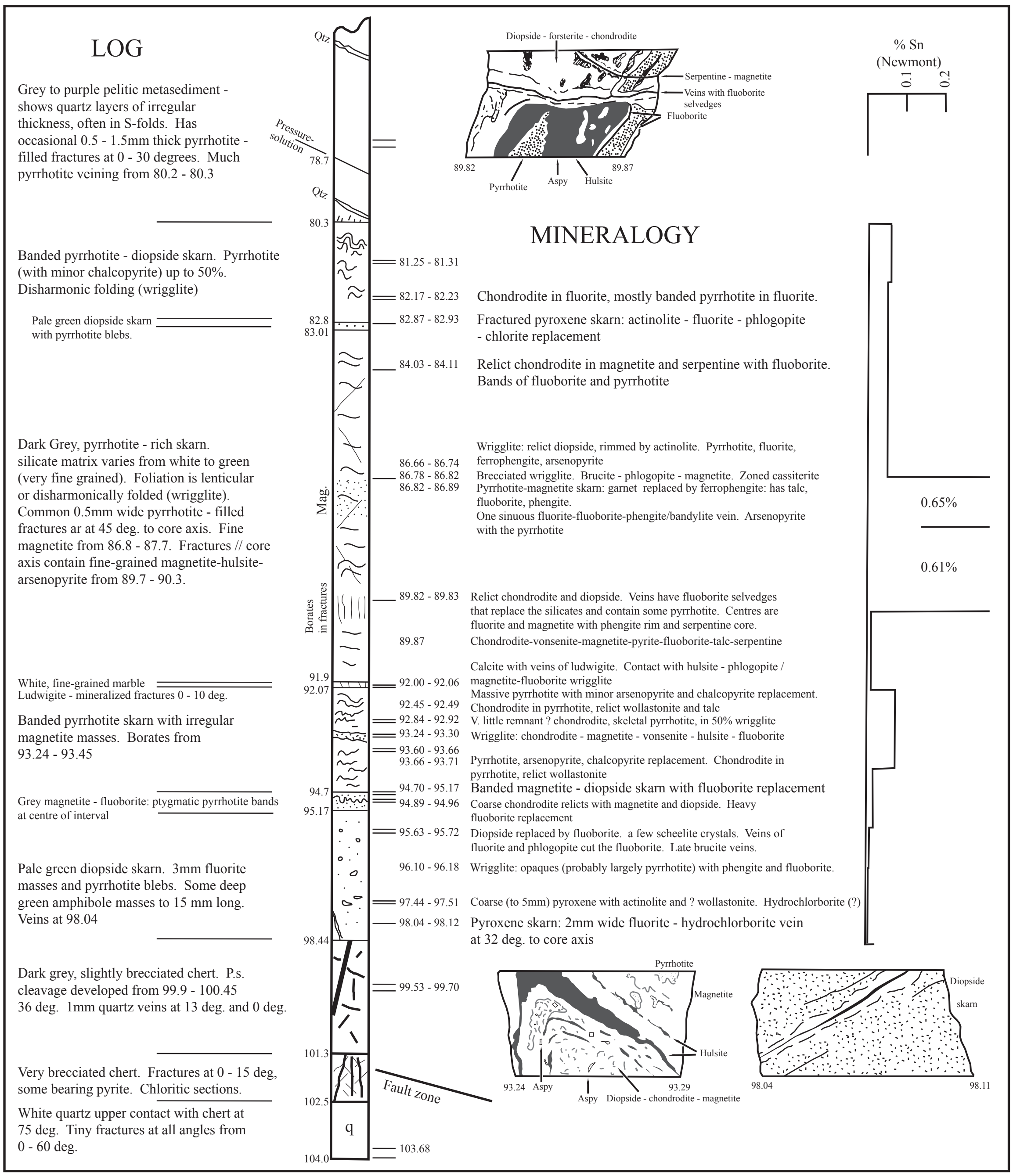

Figure 8. *Log of skarn horizon from Mindy DDH 81-2: dip -60°; Az 006°; Collar R.L. 1660.4 m.*

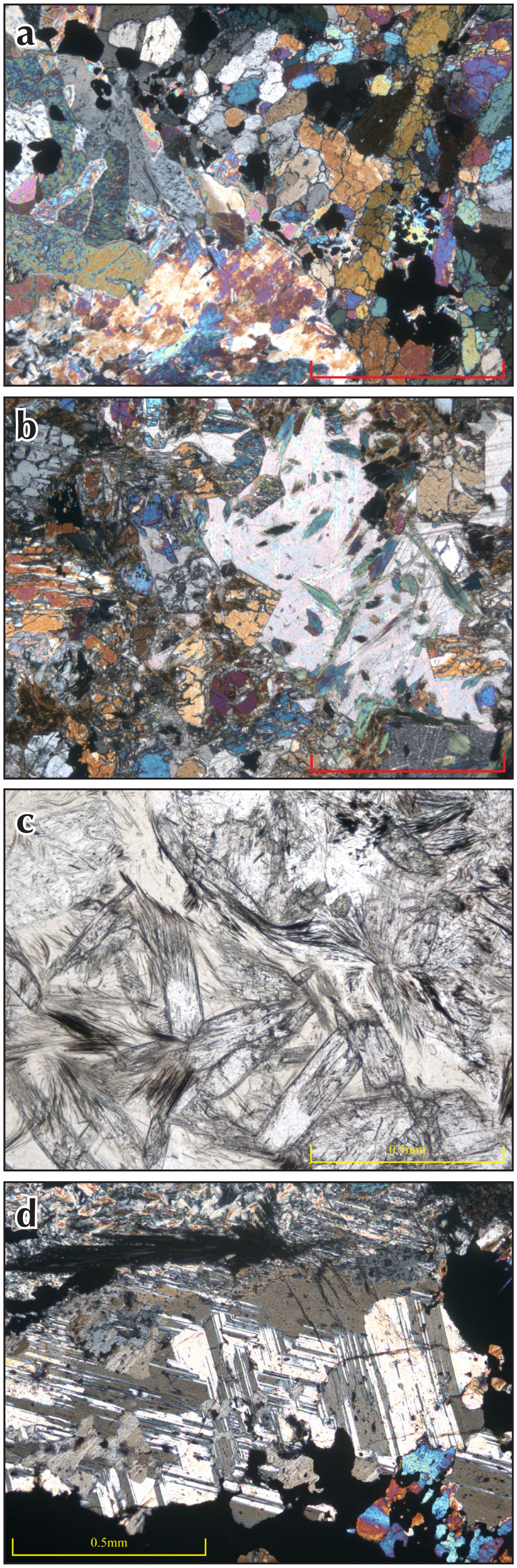

Figure 9. (a) Surface sample (670N, 285W): diopside skarn replaced by fluoborite (SW half of the image). Transmitted light, crossed polarizers, 1 mm scale bar. (b) Surface sample (125N, 110W): diopside skarn with remnant carbonate containing actinolite and crystals of (?) larnite. Serpentine alteration has followed cleavages and gain boundaries in the pyroxene. Transmitted light, crossed polarizers, scale bar 1 mm. (c) Surface sample (670N, 285W): detail of the fluoborite field in (9a). Acicular inclusions are vonsenite and the irregular SE-NW vein is serpentine. Plane polarized transmitted light, 0.5 mm scale bar. (d) DDH 81-2 sample (92.45 m): chondrodite in sulphide. Transmitted light, crossed polarizers, scale bar 0.5 mm.

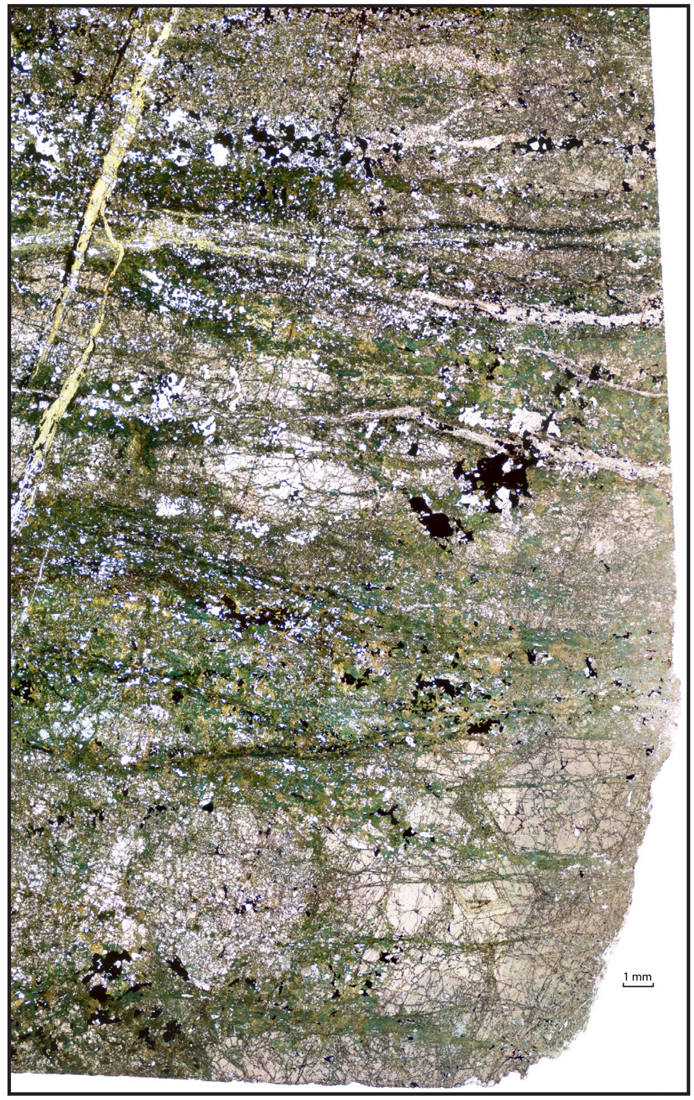

Figure 10. Drillhole 81-4, 149.72 m. Plane polarized transmitted light on: 'stitched' mosaic of 60 photomicrographs. Sheared and retrograde altered skarn. Garnet in the bottom-right corner and centre, showing some zoning. Diopside is in the bottom-left corner and upper part of the image. Actinolite alteration has followed horizontal fractures which carry fluorite and some serpentine. Three en-echelon tension gashes in the top-left corner are filled with serpentine and quartz. These show evidence of at least six crack-seal events. Scale bar 1 mm.

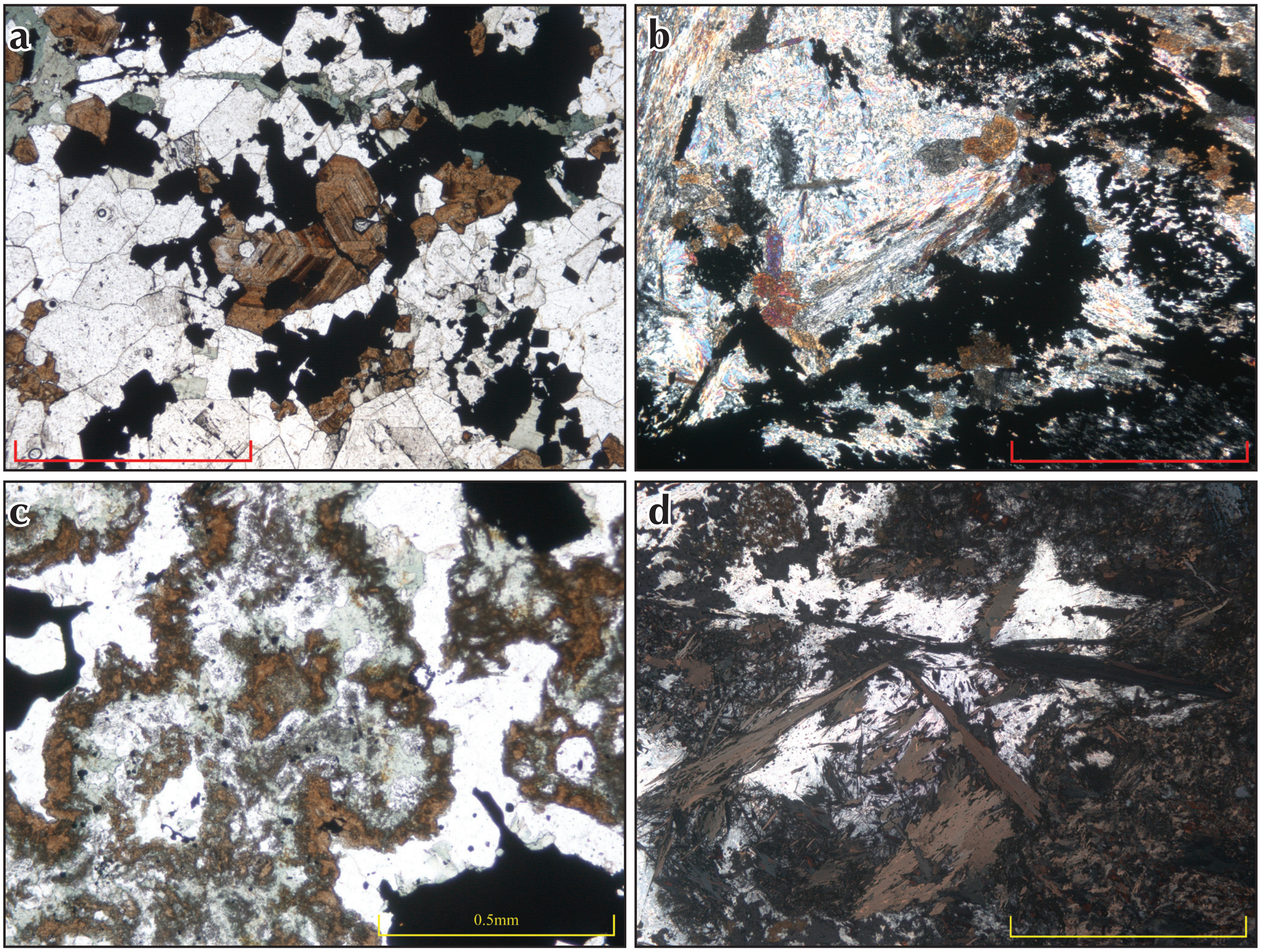

Figure 11. *(a) DDH 81-5B (109.06 m): cassiterite in fluorite with magnetite. The section has cut the cassiterite through a geniculate twin. Plane polarized transmitted light, 1 mm scale bar. (b) DDH 81-8 (49.0 m): wrigglite with cassiterite. Pyrite forms the wrigglite texture and the cassiterite is in a matrix of talc and possibly some phengite. Transmitted light, crossed polarizers, scale bar 1 mm. (c) DDH 81-5B (106.75 m): wrigglite texture shown by cassiterite (brown). Fluoborite and fluorite fill the atoll-like structure. The opaques are sulphides. Plane polarized transmitted light, 1 mm scale bar. (d) DDH 81-8 (48.92 m). Borates: vonsenite (acicular) and hulsite (curved). Incident (reflected) light with polarizers at 85°. Scale bar 1 mm.*

SKARN CHEMISTRY

Compositions of pyroxenes, amphiboles, garnets and vesuvianite were determined using energy dispersive X-ray analysis with a Jeol electron microprobe on polished thin sections and block specimens taken from diamond drill core. The most complete section of pyroxene analyses through the lower (main) skarn was obtained from drill core of DDH 81-3. Two populations of pyroxene are evident: a tight group of 0-12% hedenbergite (interpreted as the 'primary' pyroxene) and a group defined by a wide variation of compositions from the same stratigraphic intervals, interpreted as being formed by successively iron-rich metasomatic fluid events (Fig. 7). The garnet of the main skarn horizon is andradite-grossular, composed of <4% spessartine and <6% almandine components (the method of Droop (1987) was used to estimate Fe^{3+}). The main skarn varies from 58-99% andradite, with the exception of the garnet found with vesuvianite of DDH 81-3, 81.45 m (andradite ≈ 18%).

Chemical evolution of the skarn metsomatism is interpreted to have begun as a high temperature alteration of the carbonate host rock by mostly silica introduction to produce the larnite high temperature (800°C) calcic skarn. Subsequent garnet-vesuvianite skarns, followed by diopside-rich primary skarns, and then successive Fe-enrichment of the hydrothermal fluid resulted in a range of pyroxene, from salite to hedenbergite; retrograde alteration produced amphibole assemblages. Late introduction of HF produced the fluorite/chondrodite which was followed by the greisenized magnetite-phengite-talc wrigglite skarns that contain the bulk of the tin. Cassiterite was probably first to crystallize in the F-rich massive magnetite stage, and the crystallization of borate-fluoride minerals accompanied the later greisen alteration. The latest retrograde stage is represented by serpentine formation and occasional bandylite [CuB(OH)4Cl] (Fig. 12d). Prominent bleached zones as selvages to fractures in the siliciclastic unit above the lower skarn, which have been attributed elsewhere to $CaCl_2$ 'exhaust solutions' from metasomatism, indicate that abundant chloride was present with the boron to form this unusual mineral, bandylite.

TIN MINERALIZATION

Although no quantitative analysis for tin was performed on the silicate phases, the spectra from electron microprobe energy-dispersive analyses were frequently examined qualitatively for tin peaks. None were found, and tin levels in the garnet, pyroxene, amphiboles and vesuvianite are expected to be significantly less than 0.5%. Tin mineralization does not obviously occur until the early greisenized skarn stage, appearing first as cassiterite in magnetite-phlogopite altered marble, and later as fluoride-borate minerals accompanying magnetite-fluorite-fluoborite in the wrigglite skarn. The visible tin mineralization, as cassiterite, vonsenite or hulsite phases (Fig. 12), accompanies a massive introduction of iron as magnetite and often lesser amounts of pyrrhotite and

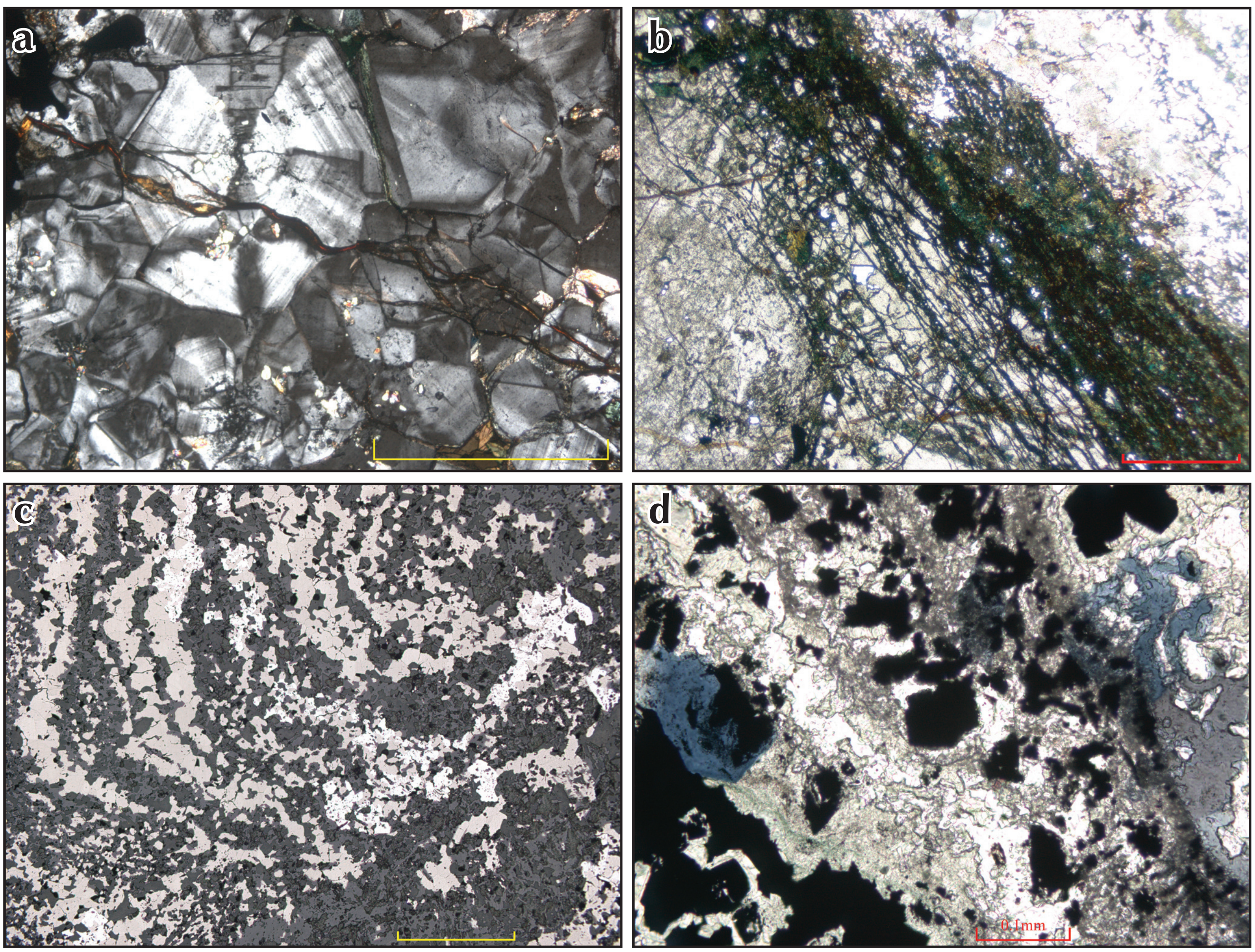

Figure 12. *(a) DDH 81-4 (150.0 m): birefringent, sector-twinned andradite. Transmitted light, crossed polarizers, scale bar 1 mm. (b) DDH 81-5B (105.08 m): microfaulting in skarn. Garnet at the bottom-left, vesuvianite at the top-right and actinolite retrograde alteration along the shear zone. Transmitted light, crossed polarizers, scale bar 1 mm. (c) DDH 81-2 (86.66 m): wrigglite comprised of magnetite and pyrrhotite (pale yellow) in fluorite and fluoborite. Incident (reflected) light with crossed polarizers. Scale bar 1 mm. (d) DDH 81-4 (148.4 m): bandylite (blue, hexagonal) in fluorite and serpentine. Plane polarized transmitted light, 0.1 mm scale bar.*

pyrite into the skarn. In one specimen, pyrite alone has been observed to form wrigglite texture with the fluorides and phengite (Fig. 12c). Nordenskiöldine was indicated by SEM scan from the sample collected at 685N, 290W (Fig. 5). A summary of skarn mineralogies (tin minerals in bold) can be found in Tables 1 and 2.

DISCUSSION

The approximately 100 Ma Seagull suite has peripheral Sn ± Ta ± Nb mineralization that is particular to southeast Yukon, and is consistent with the anorogenic nature of the intrusions. At the Mindy prospect, B-F rich magma with a low solidus temperature and shallow depth of emplacement allowed protracted melt-aqueous fluid interaction and development of a tin-enriched hydrothermal fluid. This fluorine and boron-rich nature of the A-type granite magma is reflected in greisenized skarn mineralization at the Mindy prospect. Tin mineralization as cassiterite was introduced into the granite aureole with the first massive amounts of iron and fluorine. Subsequent greisenization produced exotic minerals such as vonsenite, hulsite and rare nordenskiöldine. At the Mindy prospect, the mineralization has a structural control: skarns are found within and adjacent to extensional faults that presumably formed the 'plumbing' for hydrothermal fluids released by a shallowly emplaced Li-mica leucogranite stock.

Only cassiterite is viable as a tin ore, and at the Mindy prospect only slightly more than half the tin minerals present are cassiterite which reduces any potential grade. The structural control by faulting active during mineralization has also reduced tonnage potential of the prospect by limiting the areal extent of the skarns. It is possible that the greater tin target at Mindy was never tested by drilling during the 1981 Newmont program: greisens would have been developed in the apical part of the underlying granite, and these might be the larger tin target which is likely to be dominated by cassiterite and possibly contain wolframite.

The Seagull batholith (105B/3) has nine tin skarns recorded in the Yukon MINFILE database. Of these, the JC and Val prospects have recorded the presence of borate or silicate tin minerals. Similar skarn prospects are likely to contain borates, but if only total tin is determined during assay, they would have an exaggerated estimate made of economic potential. An accompanying assay of oxide tin is needed to distinguish economically viable minerals (cassiterite) from total tin. Recognition of the structural control on the skarns (which was not emphasized during the 1981 work at Mindy) is also vital.

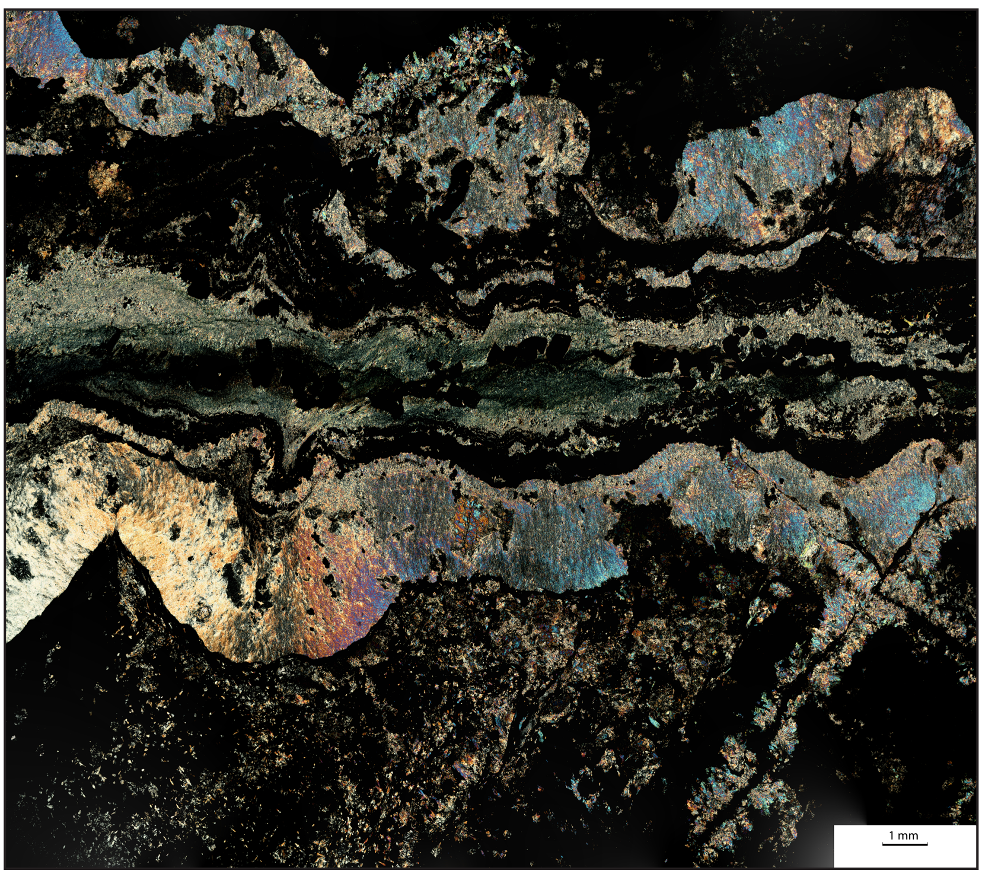

Figure 13. *Transmitted light with crossed polarizers: 'stitched' mosaic of approximately 45 photomicrographs, Massive magnetite-vonsenite mineralization, containing some chondrodite relicts, that has been cut by various generations of veins. The somewhat ptygmatic horizontal vein has fluoborite along its outer margins and euhedral magnetite in serpentine in the centre. A broad intermediate margin of talc contains corroded chondrodite. Magnetite, talc and fluoborite form the diagonal veins. Scale bar 1 mm.*

Table 1. *Mineralogy of the skarn samples from 1981 Newmont diamond drilling.*

Drill hole	Interval/Depth (m)	Mineralogy
81-1	65.2-65.3	Rock is a quartzite, contains diopside, actinolite
81-1	67.0-67.08	diopside, carbonate, serpentine
81-1	69.55-69.62	diopside, actinolite, serpentine
81-1	73.4-73.49	**cassiterite,** magnetite, talc
81-1	75.42-75.49	wollastonite, fluoborite, **vonsenite**
81-1	76.52-76.56 *pts*	diopside, **hulsite,** pyrrhotite. magnetite
81-1	76.60-76.67	diopside, carbonate, scapolite, magnetite, **cassiterite,** sulphide, phengite.
81-1	77.88-77.92 *pts*	magnetite, wollastonite, fluoborite, **cassiterite.**
81-1	88.0-88.90	vesuvianite, diopside, serpentine
81-1	83.9-84.02	vesuvianite, diopside
81-1	88.4-88.61	Rock is a quartzite, contains biotite, cordierite
81-2	89.87 *lts*	chondrodite, **vonsenite,** magnetite, pyrite, fluoborite, talc, serpentine
81-2	86.66-86.74 *pts*	diopside, actinolite, pyrrhotite, fluorite, ferrophengite, pyrite, chalcopyrite
81-2	86.82-86.89 *lts*	pyrrhotite, ferrophengite, talc, fluoborite, bandylite, arsenopyrite
81-2	89.87 *lts*	chondrodite, **vonsenite,** magnetite, pyrite, fluoborite, talc, serpentine
81-2	92.45-92.49 *pts*	pyrrhotite, arsenopyrite, chalcopyrite, chondrodite, wollastonite, diopside, talc
81-2	93.66-93.71 *pts*	fluoborite, fluorite, pyrrhotite, arsenopyrite
81-2	96.10-96.18	pyrrhotite, phengite, fluoborite, serpentine.
81-4	70.17-70.25 *pts*	diopside, magnetite, pyrrhotite, arsenopyrite, garnet
81-4	142.50	magnetite, sphalerite, talc, fluoborite, bandylite, phengite
81-4	148.30 *pts*	magnetite, pyrrhotite, fluoborite, fluorite, arsenopyrite
81-4	148.40-148.5 *pts*	ferrophengite, magnetite, pyrrhotite, arsenopyrite, chalcopyrite, bandylite, serpentine
81-4	149.72-149.82 *lpts*	garnet, salite, ferroactinolite, pyrrhotite, fluorite
81-4	150.00 *pts*	garnet, hedenbergite, actinolite, pyrrhotite
81-4	151.15-151.23 *pts*	diopside, pyrrhotite
81-5B	66.72 *pts*	garnet, salite, actinolite, pyrite
81-5B	103.47-103.51	andradite, diopside
81-5B	104.85-104.92 *pts*	actinolite, fluorite, **cassiterite,** ferrophengite
81-5B	105.08	garnet, vesuvianite, actinolite
81-5B	106.75 *pts*	magnetite, pyrrhotite, chalcopyrite, ferrophengite, **cassiterite**
81-5B	108.87 *pts*	magnetite, pyrrhotite, arsenopyrite, fluorite, talc, **cassiterite**
81-5B	109.06-109.11	**cassiterite,** phengite, quartz, pyrrhotite
81-5B	111.25-111.34 *pts*	fluorite, phengite, fluoborite, quartz, amphibole, pyrrhotite, **cassiterite**
81-8	48.92-49.0 *lpts*	magnetite, **hulsite, vonsenite**
81-8	49.00 *pts*	pyrrhotite, **vonsenite, hulsite,** fluoborite, serpentine
81-8	66.8 *pts*	garnet, diopside

Note: *pts* indicates a polished thin section of 25 x 50 mm, *lts* a 50 x 75 mm covered thin section, *lpts* a large polished thin section on a 50 x 75 mm slide. Tin minerals are shown in bold.

Grid location*	Mineralogy
125N 110W – 1.5 m	diopside, larnite, actinolite, fluorite
125N 110W – 4 m	diopside, serpentine, fluorite, actinolite, carbonate
125N 119W – 1.5 m	diopside, larnite, calcite, actinolite
660N 180W	rock is a quartzite with phacoidal garnet and diopside
660N 180W (2nd slide)	diopside, vesuvianite, garnet.
670N 285W	diopside, magnetite, garnet, vesuvianite, epidote, **borates**
685N 240W	Rock is a quartzite with a little plagioclase, carbonate layers
690N 270W	chlorite, carbonate in siliciclastics, diopside, epidote
690N 285W	garnet, vesuvianite, carbonate, pyroxene, sphene, epidote
695N 280W	**vonsenite**

*Coordinates refer to the original Newmont grid (Fig.5). Distances (*e.g.*, 1.5 m) give depth from top of a near vertical face. Tin minerals in bold.

Table 2. *Mineralogy of the skarn hand samples.*

REFERENCES

Christiansen, E.H., Sheridan, M.F. and Burt, D.M. 1986. The geology and geochemistry of Cenozoic topaz rhyolites from the Western United States. Geological Society of America Special Paper 205, p. 82.

Droop, G.T.R. 1987. A general equation for estimating Fe^{3+} concentrations in ferromagnesian silicates and oxides from microprobe analyses, using stoichiometric criteria. Mineralogical Magazine, vol. 51, p. 431-435.

Eby, G.N., 1992. Chemical subdivision of the A-type granitoids: Petrogenetic and tectonic implications. Geology, vol. 20, p. 641-644.

Kwak, T.A.P., 1987. W-Sn skarn deposits and related meteamorphic skarns and granitoids. Developments in Economic Geology, Elsevier, vol. 24, p. 451.

Kwak, T.A.P. and Askins, P.W., 1981. Geology and genesis of the F-Sn-W (-Be-Zn) skarn (wrigglite) at Moina Tasmania. Economic Geology, vol. 76, p. 439-467.

Lehmann, B., 1990. Metallogeny of tin. Lecture Notes in Earth Sciences 32, Springer-Verlag, Berlin, p. 211.

LeMaitre, R.W. (ed.), Strekeisen, A., Zanettin, B., Le Bas, M.J., Bonin, B., Bateman, P., Bellieni, G., Dudek, A., Efremova, S., Keller, J., Lameyre, J., Sabine, P.A., Schmid, R., Sørensen, H. and Woolley, A.R., 2004. A classification of igneous rocks and glossary of terms, 2nd edition. Cambridge University Press, p. 236.

Liverton, T. 1990. Tin-bearing skarns of the Thirtymile Range, NTS Sheet 105 C/9: a progress report. *In:* Yukon Geology Volume 3, T.J. Bremner (ed.), Exploration and Geological Services Division, Indian and Northern Affairs Canada, p. 52-70.

Liverton, T. 1992. Tectonics and metallogeny of the Thirtymile Range, Yukon Territory, Canada. PhD thesis, Royal Holloway, University of London.

Liverton, T. and Alderton, D.H.M., 1994. Plutonic rocks of the Thirtymile Range, Dorsey Terrane: ultrafractionated tin granites in the Yukon. Canadian Journal of Earth Sciences, vol. 31, p. 1557-1568

Liverton, T. and Botelho, N.F., 2001. Fractionated alkaline rare-metal granites: two examples. Journal of Asian Earth Sciences, vol. 19, p. 399-412.

Liverton, T., Mortensen, J.K. and Roots, C.F., 2005. Character and metallogeny of Permian, Jurassic and Cretaceous plutons in the southern Yukon-Tanana Terrane. *In:* Yukon Exploration and Geology 2004. D.S. Emond, L.L. Lewis and G.D. Bradshaw L.H. (eds.). Yukon Geological Survey, p. 147-165.

Liverton, T., Mortensen, J.K. and Roots, C.F., 2005. Character and metallogeny of Permian, Jurassic and Cretaceous plutons in the southern Yukon-Tanana Terrane. *In:* Yukon Exploration and Geology 2004, D.S. Emond, L.L. Lewis and G.D. Bradshaw (eds.), Yukon Geological Survey, p. 147-165.

Manning, D.A.C., 1982. An experimental study of the effects of fluorine on the crystallisation of granitic melts. *In:* Metallization associated with acid magmatism, A.M. Evans (ed.), p. 191-203.

Rasmussen, K., 2013. Mid-Cretaceous magmatism and mineralization in the southwestern Northwest Territories and southern Yukon: a geochronological, geochemical, and isotopic approach towards a model for the Cretaceous tectonic, magmatic, and metallogenic evolution of the northern Cordillera. PhD thesis, University of British Columbia.