Report on the Minto Exploration Drilling Program
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APEX Geoscience

Overview

This report deals with the geology peripheral to the Minto deposit proper, predominately from what is referred to as 'Area 2'. Its only purpose is to catalogue the primary lithologies and secondary alteration/mineralization styles as seen in drillcore from this area along with some discussion concerning the genesis of these features. It is the authors opinion that the most important tasks at Minto involve detailed and consistent logging of primary lithologies to better aid in correlation of units and rigorous documentation of alteration and mineralization styles/mineralogies to understand existing areas of mineralization and to target new ones.

Lithologies

The various lithotyes encountered during the authors stay are described briefly below. This list and the accompanying descriptions are by no means complete, but may serve as a useful guide for incoming logging geologists.

Unfoliated granodiorite: Unfoliated granodiorite typically consists of quartz phenocrysts (apx 1 cm) and large (2-5 cm) K-spar megacrysts in a groundmass of medium grained plagioclase, K-spar, biotite and amphibole. The origin of the large concentrically zoned K-spar crystals is rather complex and will be dealt with in a later section. The presence/absence and abundance of quartz & K-spar crystals are useful for separating out subphases of this unit. More often than not there is a distinct abundance of one of the mafics over the other. Thus, *amphibole dominant* and *biotite dominant* granodiorites are also useful terms to differentiate different subphases. The percent megacrysts can vary from zero (equigranular phase) to as much as 80% of the rock. This series of granodiorite postdates the regional deformation (or is very late) but seems to predate mineralization. Some have suggested that the foliated and unfoliated granodiotites are the same unit with strain partitioning playing a strong role.

Foliated +/- banded granodiorite: Foliated granodiorite differs quite significantly from unfoliated granodiorite in a number of ways. While the two are compositionally similar, the foliated variety typically exhibits much stronger alteration, mineralization and deformation characteristics. One of the most obvious changes at the boundary between the two (besides the appearance of a fabric) is the disappearance of quartz phenocrysts. This may be because they never developed (different lithotype) or that they have been deformed and recrystallized beyond recognition. Variations in the degree of deformation results in a spectrum of foliation intensities and styles from weakly aligned anastomosing wavy biotite segregations (weak) to well defined parallel bands of biotite-magnetite-chlorite-sulphides separated by sugary recrystallized quartz-feldspar bands (strong). Alteration intensities and styles as well as sulphidization vary linearly with deformation intensities where the more intensely deformed (foliated and banded) sections are preferentially silicified and sulphidized. Outward of the very strongly silicified zones Si decreases, eventually to weak/nonexistent in the weakly foliated sections. The very strongly silicified banded+foliated sections tend to occur at the boundary between the foliated and unfoliated granodiorite indicating that the contact was used by migrating mineralizing fluids. This suggests at least a late if not post deformation mineralizing event. In some cases weak deformation often in the form of mylonitic textures can be seen within the "undeformed" granodiorite at the contact. Garnet, in the form of mm to cm sized crystals in chlorite/biotite bands is a common accessory phase within this unit suggesting it is alteration related.

Pegmatitic veins: Late undeformed coarse grained quartz-plagioclase-Kspar-biotite bearing pegmatitic veins occur indiscriminately throughout the Minto area. Quartz & K-spar (graphitic to graphic) and quartz-plagioclase (myrmekitic) intergrowths are common. Sulphides are quite rare, but when present, occur as coarse chalcopyrite-bornite blebs between grains and rare flecks of fine grained molybdenite. Magnetite is a common accessory phase, occurring as fine to coarse grained euhedral crystals over a small area. Coarse gold hosted by pegmatitic veins has been reported in at least one instance.

Saccharoidal veins: Sugary textured pinky-grey-white aplitic veins are typically associated with the pegmatitic veins and may core them. They are composed of quartz, feldspar, fine grained biotite +/- muscovite. Oriented mafics are the either result of flow banding or fabric development during deformation. Similarly textured but slightly darker coloured (more biotite?) intervals may be better described as microgranites.

Mafic dykes: Fine grained mafic (basaltic to andesitic) dykes are rather uncommon. They crosscut the mineralization and are generally quite thin (up to a few meters). Several variations exist based on colour and phenocryst assemblage.

Porphyry dykes: Feldspar-(amphibole?) phyric felsic dykes occur intermittently throughout the area. Aligned mafic minerals suggest they pre/syn date deformation.

Deformation

The Minto area is situated at the hinge of a regional N-S trending synform. As a result, foliations in the area tend to be flat lying, however, in drillcore they may have any particular orientation (Cavey *et al*., 2004). In drillcore and in outcrop the main foliation is folded into small scale open to ptigmatic folds, apparently with an associated AP cleavage that has only been recognized at surface. Folding is particularly common in the foliated + banded intervals and can end abruptly at the contact with foliated non banded granodiorite. This suggests that the more deformed banded units were preferentially deformed during this later event. Foliations commonly vary significantly in intensity and attitude (relative to core axis) over short intervals. It is expressed as a somewhat spaced fabric defined by thin wavy segregations of biotite +/- amphibole, magnetite and sulphides separated by thicker bands of coarser quartz-feldspar. With increased deformation the banding/foliation becomes better defined (felsic-mafic bands more segregated – gneissic layering), and more parallel (less wavy). There is still a question as to whether the foliated and banded units are ortho or paragneissic in origin.

In the main Minto deposit mineralization only occurs in (typically strongly) foliated granodiorite. Although this mostly holds true outside the main deposit, there are a number of examples of mineralized undeformed granodiorite. Here, mineralization is seemingly controlled by vugs. This style of mineralization is interpreted as late (high level) dissolution of biotite which left behind the previously formed biotite-replacing sulphides.

Debate over the timing of mineralization ranges from syn to post peak deformation. While some have suggested that mineralization is strung out (deformed) along the foliation (syn kinematic) others have proposed that mineralization is preferentially replacing mafics (predominately biotite) along a previously formed foliation (late to post kinematic). Several observations to support the latter theory are described: 1) Sulphide minerals do not appear to be particularly deformed or smeared along this foliation; 2) examples of sulphide stringers crosscutting the foliation or completely ignoring the foliation (well disseminated sulphides in strongly deformed rock) are rather common; 3) Garnet porphyroblasts appear to overgrow the foliation (late) but are replaced/infilled/pseudomorphed by chalcopyrite; 4) The contact between unfoliated and foliated granodiorite has in part controlled the distribution of silica alteration and the mineralization style. Away from the contacts Si alteration changes from strong to moderate to weak. Sulphide textures evolve from blebby + net textures to stringer style. This suggests a late to post deformation mineralizing event; and 5) chalcopyrite-bornite mineralization in unfoliated granodiorite adjacent to foliated and mineralized units. It is possible, however, that this represents remobilization post mainstage mineralization.

Alteration

A number of alteration styles and intensities were noted in drillcore and are described below. Well mineralized intervals are characterized by strong silicification, chloritization and (possibly) albitization which overprints foliated, banded and often folded rock.

Epidote/chlorite: Both epidote and chlorite occur with biotite and amphibole in various amounts. Late epidote is also associated with chalcopyrite or pyrite stringers and patches. Chlorite alteration typically accompanies pinkified zones (combination of K-metasomatism and Fe-staining?) marginal to faults/fractures in the rock. Much of the epidote is likely primary as it often exhibits sharp euhedral boundaries with the mafic minerals. Both chlorite and epidote may form along/in late fractures and faults. The common association of epidote-pyrite +/- chalcopyrite along with calcite and magnetite is indicative of cogenetic Ca metasomatism and sulphidization. Both chlorite and epidote are most abundant outside the mineralized zones although chlorite persists rather strongly in the magnetite-sulphide bands of well mineralized units.

Potassic: Potassic alteration comes in two forms: potassium feldspar and biotite. K-spar alteration occurs as patchy to pervasive pink coloured zones and also along and bordering fractures/faults in the rock. The actual amount of K alteration in these zones is difficult to judge as much of it may be Fe staining. Cm-scale pink crystals in foliated and unfoliated rock have been interpreted as either phenocrysts or porphyroblasts and are discussed below. Biotite alteration is more difficult to identify as most of the granitic rocks contain primary biotite. Secondary biotite tends to occur as fine unoriented flecks in patches that are not chloritized. In the main Minto deposit (and less commonly in Area 2) it occurs as ragged/shredded coarse grained flakes intergrown with sulphides.

Large megacrysts of concentrically zones K-spar are strongly reminiscent of the granites in the Sn-clay districts of Cornwall (e.g. Land's End). There, the K-spars are interpreted to be a late magmatic feature formed near the end of crystallization and segregation of a hydrothermal fluid phase which ultimately gives rise to pegmatitic and aplitic veins as well as Sn mineralization. The zoning is a result of changing Na/K ratios in the magma/fluid and variable concentrations of Ba and other misfit elements (F, B, P, Li, Cs etc) that were not sequestered during main-stage mineralization. Thus, the K-spars are late but not metasomatic in origin (ie. K is not being added). Several other characteristics are reminiscent of the Sn granites of Cornwall. Late Li-mica (related to fluid segregation stage) is commonplace in the granitoids of Cornwall and seems to also occur at Minto (light green phyllosilicate with chlorite - verify with EMPA). The Sn granites of parts of Cornwall are also of the one mica (biotitic) variety in contrast to the more common two-mica tin granites.

Silicification: Silicification is reportedly rare within the Minto deposit proper (Mercer, personal communication), however, it is quite common within the mineralized intervals of Area 2. Moderate to very strong silicification is common in foliated and banded chalcopyrite-bornite-garnet bearing horizons and less common in foliated granodiorite without banding. Silicified sections are accompanied by some potassic alteration (K-spar) as well as weakly pink to cloudy grey zones which is believed to be albitic alteration. Mineralization tends to be weak to non existent in the strongly potassic zones and more significant in silicified albitized intervals. This may be recording a fluid temperature difference between the two types of alteration (i.e. K is higher temperature).

Carbonate: Carbonate alteration is quite rare both in the deposit and outside of it. Most commonly it occurs as thin spiderweb style veins and along fractures. Dolomitic and sideritic veining/patchy alteration was rarely encountered. A significant carbonate alteration zone was intercepted in drillhole 06SWC-080 consisting of rosey coloured calcite, quartz and sulphides.

Sericite-pyrite: Several good intervals of quartz-muscovite-pyrite +/- biotite and chlorite alteration were noted at Area 2. In every instance they occurred above the main mineralized horizon separated by a few 10's of meters. It is possible that these zones represent phyllic alteration.

Amphibole: Amphibole is a very common primary and probably secondary mineral in the Minto granitoids. Amphibole has been noted in silica + K-spar flooded zones (or veins) as coarse (up to 1cm) euhedral crystals. It may also occur as very coarse (up to 5cm) grains associated with magnetite (e.g. top of hole 06SWC-081). There has been some dispute as to whether pyroxene is also present, and this should be followed up with some petrography to determine what variety(s) of amp/px are actually present. Amphibole has also been seen cored by coarse euhedral magnetite. This may be a primary igneous texture.

Other: Other alteration phases observed in core include leucoxene (late mineral altering biotite), hematite (late, along fractures), serpentine-talc (also late and along fractures), Fe staining (along crystal margins and a component of pinkification?) and various zeolites (Fleming, personal communication).

Mineralization

Ore Mineralogy: The primary ore minerals found at Minto are chalcopyrite and bornite. Euhedral coarse grained cuprite and sooty films to dendritic coatings of chalcosite were also observed. Tennantite and hessite (a Ag telluride) have also been reported in past drill logs. As Bi values seem to correlate decently with Cu-Au-Ag, it may be present in telluride form as well. It has been suggested that visible gold may be spatially (and paragenetically?) linked to magnetite and has been noted to be associated with chloritic fractures/faults. It has also been found on occasion as coarse blobs in the late pegmatitic veins. Malachite, azurite and chalcocite occur at and near the surface overlying the main deposit. Each of these minerals occur almost exclusively along fractures and mineral surfaces in the rock as thin coatings. Any sulphides that were once present have since been destroyed with the exception of rare preserved bornite and chalcopyrite. The sulphide source for these oxide minerals may have been the host rock in which they now sit, or, more likely, remobilized (supergene?) from the underlying sulphide zones.

Ore Textures and Paragenesis: Both chalcopyrite and bornite replace pyrite in every instance these minerals are observed together. In turn, bornite is always seen to replace/occur later than chalcopyrite. Magnetite appears to be earlier than chalcopyrite and bornite, but its relationship with pyrite is unknown. The default style of mineralization involves sulphides along the foliation plane overprinting fabric defining biotite +/- amphibole and magnetite. As previously stated a late post kinematic mineralizing event is the preferred interpretation. A number of other mineralization styles have also been observed and are briefly documented below:
1) Medium grained chalcopyrite+ bornite stringers and blebs in chlorite+magnetite bands. This style of mineralization is spatially associated with the style described below.
2) Fine blebby textured chalcopyrite and bornite evenly disseminated throughout highly silicified zones. Such strongly silicified zones tend to be most common at (lithological/deformation) contacts and are always in foliated + banded intervals.
3) Net textured ore, where chalcopyrite or bornite are interconnected between existing quartz-feldspar grains in a honeycomb-style network. In some cases these zones may be cored by chalcopyrite and rimmed by bornite. This style is often associated with the above two.
4) Vein-associated chalcopyrite. The types of veins vary from quartz + epidote + pyrite + chalcopyrite to nearly pure gypsum + lesser Cu-sulphide veins.
5) Fine to coarse chalcopyrite + bornite in vugs within unfoliated granodiorite. This may represent early sulphide replacement of biotite followed by late dissolution of biotite or late mineralization (remobilization?) after the vugs had already formed. This style of mineralization is quite rare.

A structural control over fluid migration and associated alteration and mineralization is suggested by: 1) the occurrence of mineralization almost exclusively within the foliated sections. Presumably the foliated units are more permeable to fluid movement. Sulphides also tend to occur along the foliation within the biotite/chlorite segregations. This may relate to preferential replacement of biotite by sulphides (i.e. some sort of chemical trap), but more likely has to do with sites of dilatency along these planes allowing for fluid movement; 2) An approximate zonation away from lithological/deformation contacts from (a) very strong silicification + destruction of deformation related textures (banding) + occurrence of evenly disseminated globular sulphides to (b) well banded (magnetite + chlorite + Cu-sulphide bands separated by recrystallized quartz-feldspar bands) foliated and folded sections to (c) less sulphidized foliated but non banded granodiorite. In each case it is the region most proximal to the contact between the foliated and unfoliated granodiorite that becomes the most altered, deformed and mineralized.

A note on the Borro Pit: Hole 06SWC-081 was drilled to test a strong magnetic anomaly at the Borro Pit. Mineralization in this area is substantially different from any of the other areas, characterized by a relatively flat lying zone comprised of coarse grained magnetite, pyroxene and biotite with interstitial sulphides (chalcopyrite, pyrite and bornite). The possibility that this is skarn style mineralization is quite real.

Geochemistry

A short time was spent looking at the ICP data from past drillholes from the Minto deposit proper. A number of reasonable correlations exist between Cu, Au, Bi, Fe, as can be seen in the figures below. Precious little can be said about this data as a number of important elements (Zr, Y, Al and Ti) are not included in the dataset. A judicious whole rock program would greatly improve the understanding of the deposits geochemistry. As most of the parent host rock is quite geochemically homogenous, a mass balance exercise (e.g. Barrett and McLean) would be a very simple task and could improve the current exploration strategy. It would also aid in distinguishing between different deposit types (porphyry vs. IOCG vs. skarn).

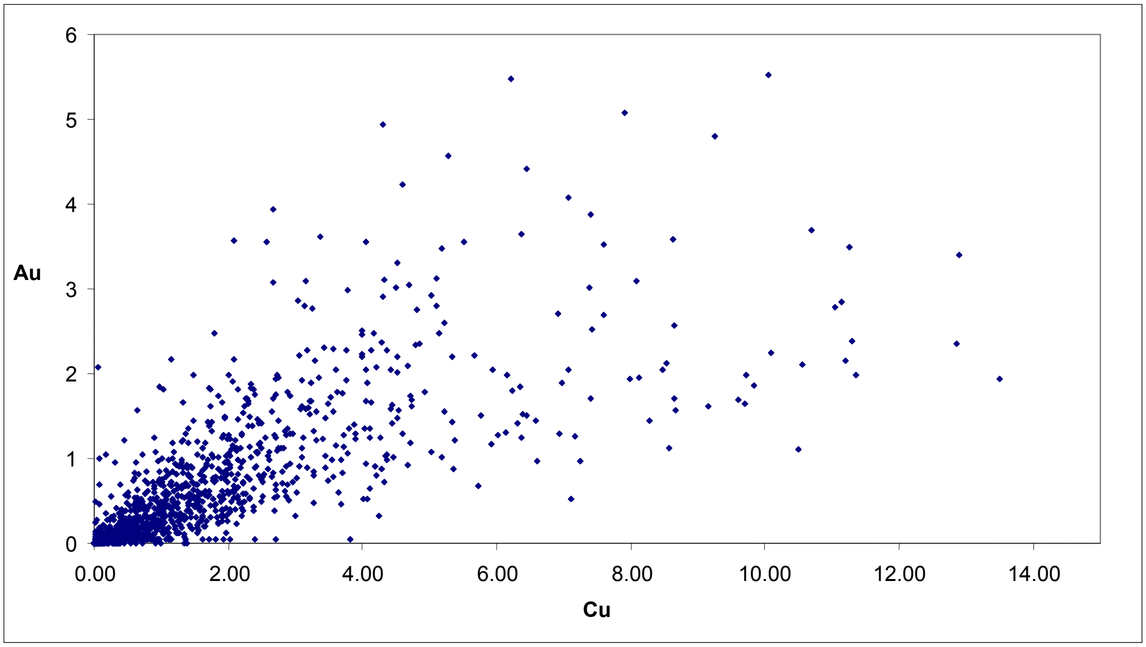

Fig. 1: Au versus Cu binary showing good correlation between the two elements.

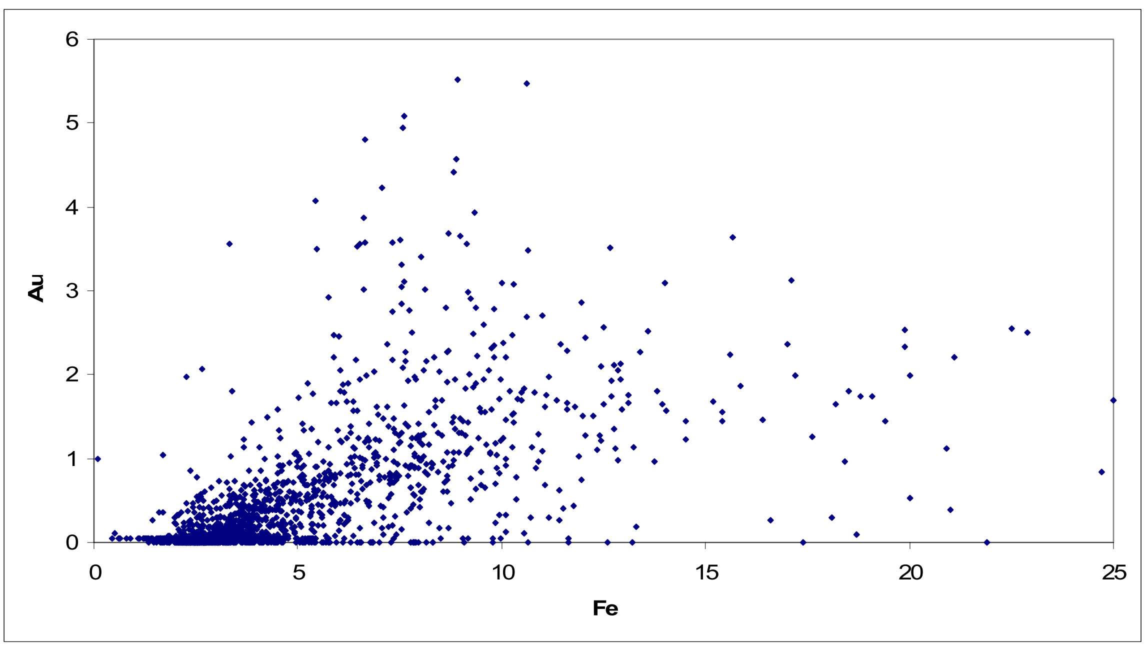

Fig. 2: Au versus Fe binary showing moderate correlation between the two elements. This may relate to addition of Fe during Au mineralization (magnetite?) or removal of other elements (e.g. alkalis) during alteration and Au precipitation.

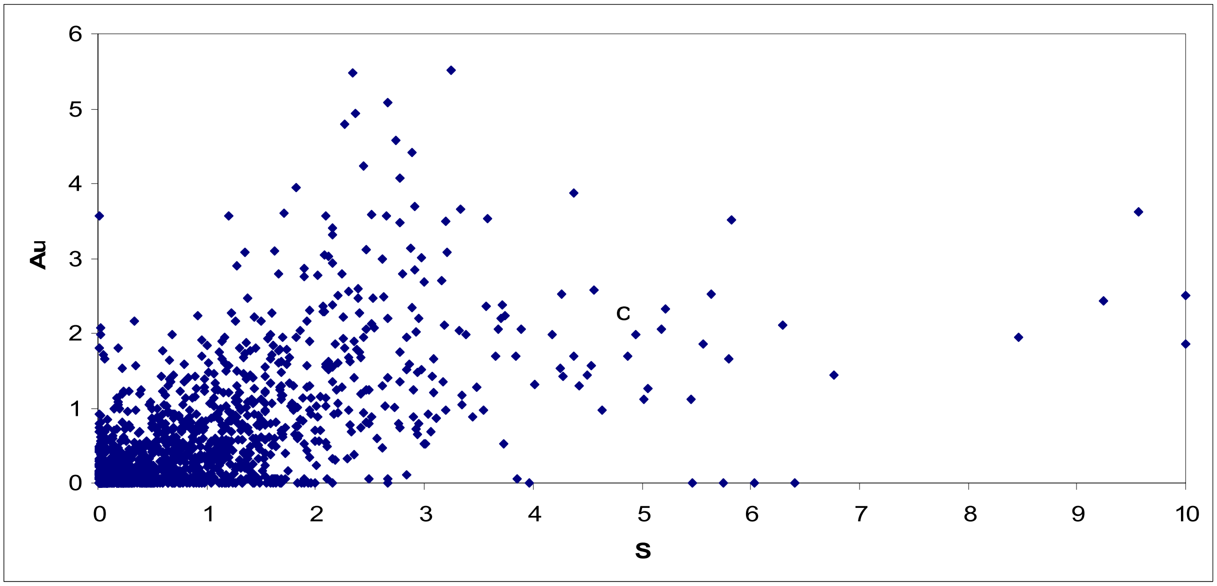

Fig. 3: Binary diagram showing a weak moderate correlation between Au and S.

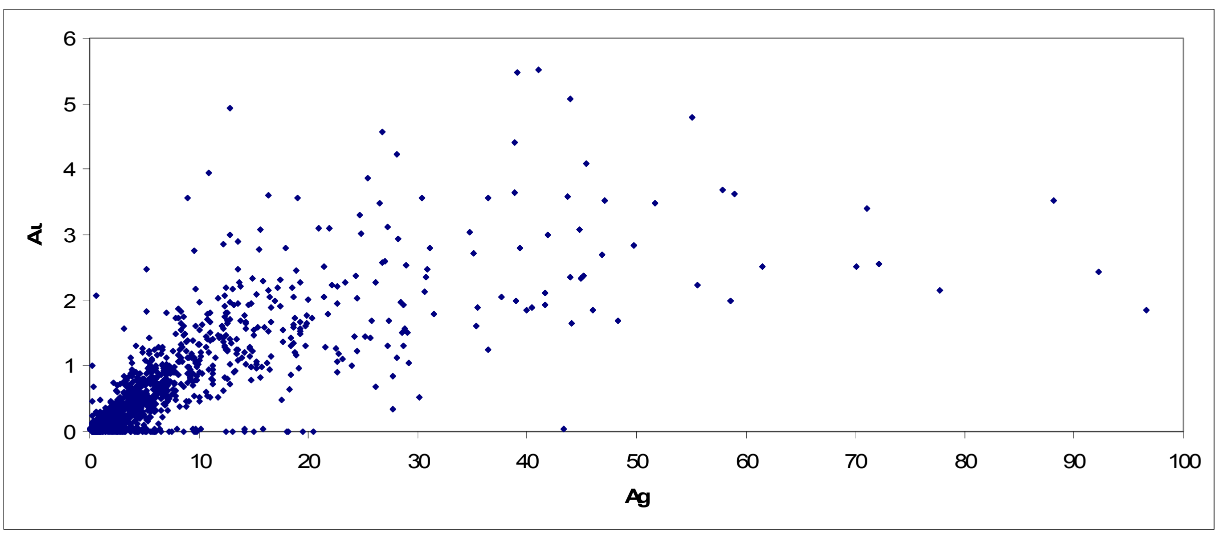

Fig. 4: Binary diagram showing strong correlation between Au and Ag.

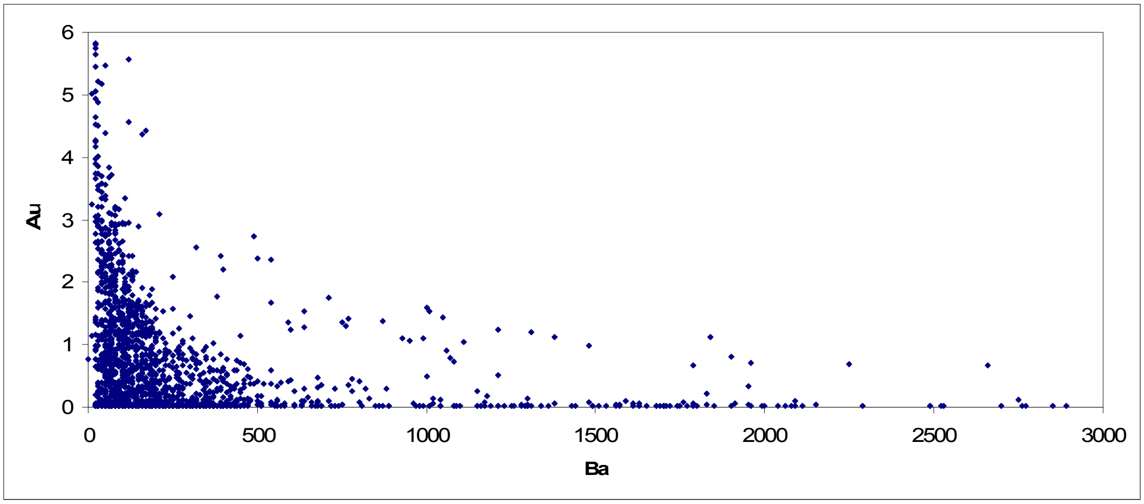

Fig 5: Relationship between Au and Ba. Higher Au values tend to have lower Ba contents. This probably corresponds to the progressive removal of Ba from the breakdown of feldspars during alteration and Au mineralization. Alternatively it may correspond to the addition of other elements (e.g. Si) and the dilution of Ba in the rock during mineralization.

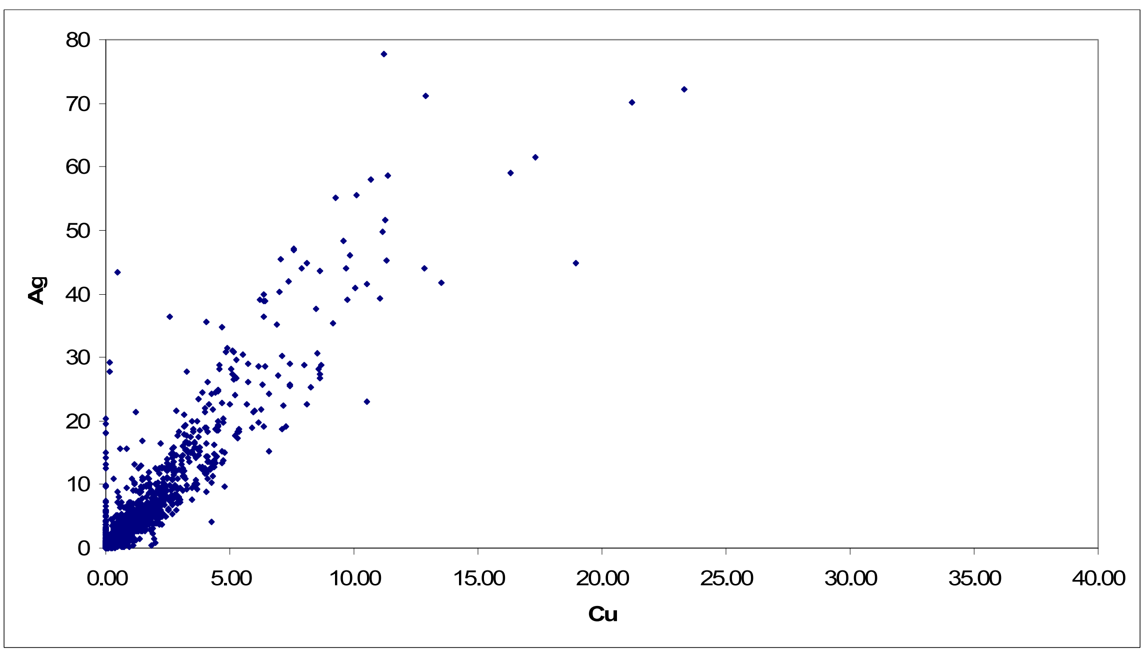

Fig. 6: Cu versus Ag binary showing strong linear relationship between the two elements.

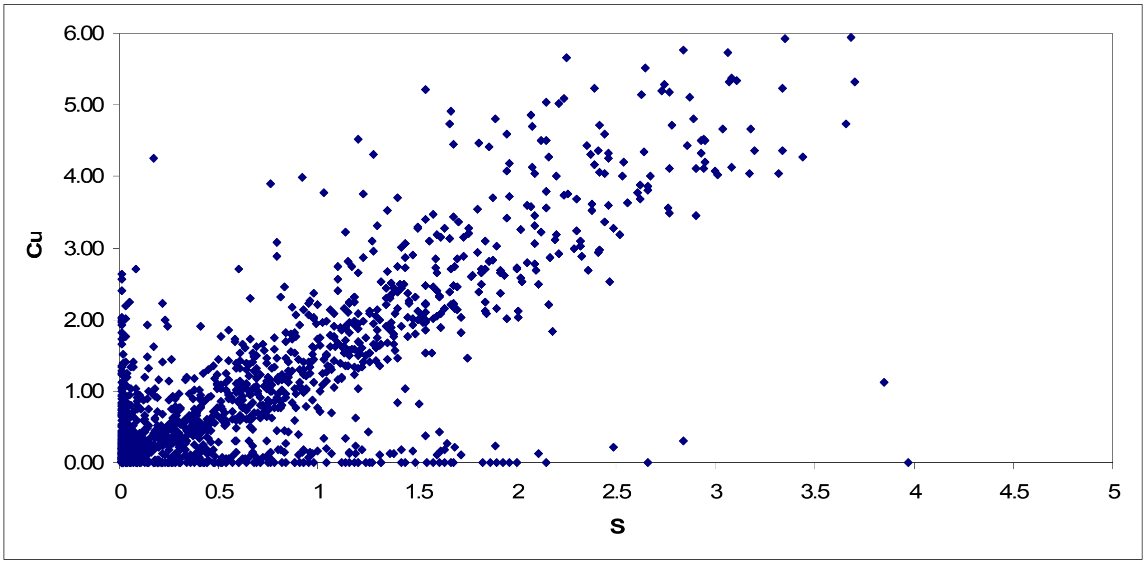

Fig. 7: Cu versus S binary diagram. High Cu low S likely represent carbonate (malachite + azurite) samples while high S low Cu are probably pyritic. The linear trend is produced by Cu sulphides.

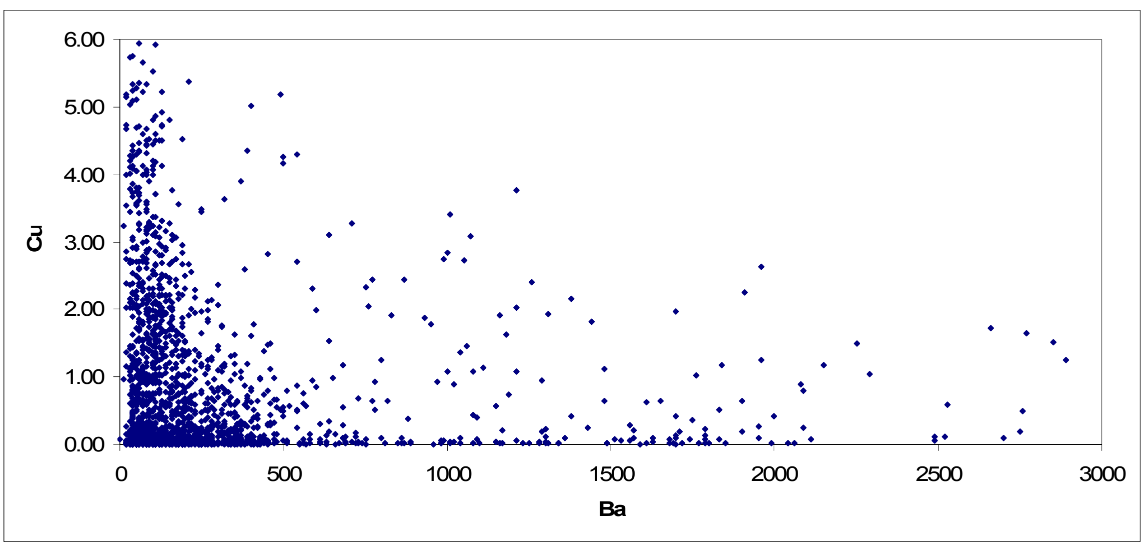

Fig. 8: Cu versus Ba binary. Low Ba values correspond to elevated Cu for the same reasons explained in Fig. 5.

Recommendations

1) A light salmon pink to grey coloured minerall is common in the ore zone in silicious veins/recrystallized bands and flooded zones. This may be albite, and thus there may be a Na anomaly associated with the Cu-Au. Thin sections, geochemistry and mass balance may be useful. A well defined Na anomaly with mineralization may prove to be a useful exploration target.
2) Addition of a veining column to the logging template may be a good idea. Although veining is not common, much of the pyrite and some of the chalcopyrite/bornite can be related to veins. Pyrite is common in thin quartz-epidote-magnetite veins outside the main mineralized zone while chalcopyrite/bornite can occur in quartz-potassium feldspar veins and veinlettes. Rare examples of gypsum veins with high concentrations of chalcopyrite and bornite have also been noted during logging
*3) Thin section analysis of the K-spar crystals and pinkified rock should be completed to determine how much of this material is actually K-spar and how much of it is primary/secondary. Without this information the actual amount of K metasomatism is very difficult to estimate during logging.
4) Initiation of a whole rock program particularly for the purposes of elemental gains/losses calculations. Only a limited number of samples are required to do this and will undoubtedly be very useful in future exploration. Clearly identifying alteration types and associations will also allow for the ICP-MS data to be used more effectively. Subtle separations of the different granodiorite phases may prove useful for correlation purposes.
5) Several similarities exist between the granitoids of Minto and the one-mica Sn-bearing granites of Cornwall and other districts. This may be merely a curiosity or may prove to be more than that.

Representative Samples ***(photos available upon request)***

The samples listed below have been taken by the author from exploration holes drilled in May-June of 2006. They are intended to represent some of the more common lithologies, alteration types and mineralization styles encountered in these drill holes. As the Minto deposit proper is significantly different from its satellite deposits, these samples are probably not representative of the entire region. Plates not included.

Lithology (L=lithology; hole number and depth)

L1 06SWC083-220.2: Unfoliated quartz-plag-amphibole-biotite granodiorite with quartz phenocrysts and K-spar phenos/porphyroblasts. Amphibole dominant. Weak epidote overprints the mafics.

L2 06SWC083-223.75: Coarse grained pegmatitic vein with quartz-plagioclase-K-spar and thin elongate biotite, chloritized.

L3 06SWC080-66.12: Saccharoidal quartz-feldspar (plag and K?)-biotite vein, cores pegmatitic vein.

L4 06SWC081-339: Quartz-plagioclase-biotite-amphibole granodiorite, undeformed, nonmagnetic. Weak epidote overprint.

L5 06SWC082-305.50: Foliated granodiorite – quartz-plagioclase-biotite (defining foliation). Weak K-spar alteration. Amphibole alteration on margin of sample. Weak disseminated chalcopyrite overprints biotite. Weak epidote.

L6 06SWC080-237.5: See also under deformation. Foliation and folding defined by oriented biotite segregations. Biotite folia separate sugary textured quartz-feldspar-albite? Bands defined in part by a few somewhat preserved porphyroblasts/clasts in upper right. Fine grained non-retrograded garnet grows out of biotite foliation and less commonly in felsic bands. Ill defined stringers of cpy preferentially in the mafics. Crosscutting unfoliated/folded fibrosic gypsum veinlette. Minor secondary fine grained unoriented biotite?

L7 06SWC 078-370: Feldspar-(biotite/hornblende?) phyric felsic dyke. Weak foliation. Epidote overprinting mafics.

L8 06SWC091-80.3: Fine grained feldspar-(biotite?) phyric mafic dyke.

Alteration

A1 06SWC082-327.75: Epidote-chlorite-Kspar-leucoxene: Weak-moderate epidote overprints mafics (biotite and amphibole). Chlorite overprints mafics on margin of sample. Very weak K alteration (pink areas). Light coloured mineral overprinting mafics is likely leucoxene.

A2 06SWC078-338: Garnite-biotite-amphibole-Kspar altered granodiorite. Biotite defined weak-moderate foliation and rinds small crushed garnets – retrograded? Larger deep green amphibole grains throughout sample, some of which contain fine magnetite inclusions. K-spar as medium grained simple twinned elongate chalky white to light orange (stained?) crystals and coarse grained pink blasts. Very weak chlorite-epidote. Plagioclase abundant, but can be difficult to separate from K-spar.

A3 06SWC081 87: Strong muscovite + biotite + quartz + pyrite alteration, presumably after granodiorite. Minor K-spar in what may be veins. Pyrite predominately in with muscovite-biotite zones. Foliated and folded.

A4 06SWC094-78: Contact between an unfoliated quartz phyric K-spar crystic granodiorite with saccharoidal biotitic vein. Contact appears to be overgrown by K-spar blast suggesting the K-spars in the unfoliated granodiorite are in fact blasts that postdate the unfoliated granodiorite rather than igneous megacrysts. The alternative is that this represents the uneven surface of the granodiorite before vein emplacement. Considering the rest of the contact is extremely smooth and straight the former explanation is preferred.

Epidote, chlorite, Kspar, biotite, quartz, amphibole, sericite/muscovite+pyrite, carbonate, Amp with mag cores.

Mineralization

M1 06SWC091-34.5: Well banded and foliated unit with bands of mafics (predominately magnetite) separated by sugary quartz-feldspar felsic bands. Bands either tightly crenulated or stylolitic. Oxidized fine grained sulphides evenly disseminated in sample. Non to weakly oxidized chalcopyrite and bornite occur in one of the mafic bands – bo>cpy. Malachite exclusively on fracture surfaces and mineral boundaries proximal to fractures.

M2 06SWC088-311 Banded and foliated mineralized section. Bands of saccharoidal quartz-feldspar, some with amphibole, separated by thinner bands of biotite +/- amphibole – no significant magnetite. Medium grained chalcopyrite preferentially within thin mafic bands, while bornite occurs in much smaller amounts on the borders of chalcopyrite. Several flecks of molybdenite occur toward/within a mafic bands interior to a larger felsic band. Its relationship with the other two sulphides suggests it was the last sulphide to form. Silicification not strong. On the opposite edge what appears to be quite pervasive gypsum flooding occurs with amphibole and fine secondary biotite as well as cpy+bo.

M3 06SWC-090-285: Chalcopyrite-bornite mineralized crowded porphyry textured granodiorite. Light coloured plagioclase phenocrysts, some showing a subophitic texture with quartz. Have been lightly pinkified with some showing chalky rims Matrix has been chloritized. The chlorite has a light green-silver colour and may be interstratified chlorite+(Li?V?Cr?)-mica. As V does show elevations in mineralized zones, this may be what it is. Sulphides occur in the chlorite-mica matrix often with sharp boundaries against the feldspars. Chalcopyrite slightly greater than bornite, with bornite being a later phase replacing the margins of chalcoprite. Couple of late fibrosic gypsum veins. A few poorly formed K-spar porpyroblasts can also be seen.

M4 06SWC081-12.75: Example of mineralization from the Borro Pt. Abundant magnetite with biotite and pyroxene/amphibole. Bluey coloured feldspars. Chalcopyrite occurs mainly with magnetite as fine-medium grains.

M5 093SWC093: Very strongly silicified section. On one side poorly preserved bands of magnetite + chlorite are separated by vague bands of sugary textured quartz + albite? Bands. Mineralization is bornite dominant and occurs as quite evenly disseminated medium grained blebs and rims on less abundant but similarly textured chalcopyrite. This style of mineralization invariable associated with well banded/foliated sections, but typically show quite sharp boundaries between one another. The degree of silicification and preservation of banding seems to be the main control over how sulphides are distributed.

Deformation

D1 06SWC080-237.5: Banded, foliated and folded. Foliation predates folding. No observable AP cleavage in sample.