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AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

"A report on 61 thin sections from the Home of Bullion area east of Barrow Creek, Northern Territory"

by L.A.I. Wyborn

Division of Regional Geology and Minerals

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Professional Opinion

GEOSCIENCE FOR AUSTRALIA'S FUTURE

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Report on 61 thin sections from the Home of Bullion area, east of Barrow Creek Northern Territory.

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Executive Summary

I was asked to examine 61 thin sections from the Home of Bullion mine area east of Barrow Creek, Northern Territory. The thin sections were of rocks from an area believed to be prospective for Au ± Cu mineralisation of early Proterozoic age and possibly analogous to mineralisation styles similar to that found in other Proterozoic belts such as Cloncurry, Tennant Creek and the Granites/Tanami.

The primary rocks present were of four types: metamorphosed schists/gneisses, S-type granites, I-type granites, and mafic intrusives. In the last two types, primary igneous textures and minerals were frequently preserved, including hornblende (olive green), biotite, magnetite and ilmenite. It was common to observe in these magnetites, exsolution lamellae of ilmenite.

All four types had evidence of a metamorphic overprint of at least upper greenschist, if not lower amphibolite facies. Many thin sections also had a metasomatic overprint characterised by an intense blue-green hornblende. This amphibole was controlled by veins and appeared to be closely related to sulphides, biotite (possibly phlogopite ?), magnetite, and some carbonate. This intense blue-green amphibole is commonly found in other Proterozoic areas affected by iron-rich, chlorine-bearing metasomatic fluids: it is atypical of those found elsewhere where mafic intrusives have been metamorphosed to amphibolite facies in the presence of a neutral fluid.

This metasomatic alteration is believed to be related to oxidised, Fe-rich, potassic, possibly high-Cl rich fluids. The association of the blue-green amphibole with the sulphides suggests it may be an indicator of economic potential.

Of all of the granite related systems, I feel that this alteration is more similar to that found in the Cloncurry area rather than the talc-chlorite alteration found in the Tennant Creek area. Amphibole alteration is more common with the former than the latter, reflecting in part the higher temperature of the granites related to the Cloncurry system.

The presence of ilmenite exsolution lamellae in magnetites some of the magnetite and the coarse grain size of the ilmenites are features more commonly associated with igneous rocks. However, it is more than likely that in the presence of oxidised alteration fluids these opaque minerals have survived, whilst the silicate phases have been extensively modified. The preservation of ilmenite, rather than its conversion to sphene (as is more common in the Cloncurry area) and the lack of hematite might suggests that the alteration fluids which affected this suite of thin sections are not as oxidised as in the Cloncurry area.

In conclusion, I do not believe that the rocks in this suite are simply igneous rocks that have been metamorphosed to amphibolite facies. They have also been affected by a relatively high temperature metasomatic fluid, which also has an association with sulphide, but in most cases has failed to alter the existing oxide phases.

Introduction

I was asked to examine 61 thin sections from the Home of Bullion mine area east of Barrow Creek, Northern Territory. The thin sections were of rocks from an area believed to be prospective for Au ± Cu mineralisation of early Proterozoic age and possibly analogous to mineralisation styles similar to that found in other Proterozoic belts such as Cloncurry, Tennant Creek and the Granites/Tanami.

This report is divided into 3 sections. Section 1 comprises a synthesis of the thin sections examined, Section 2 contains a discussion of the regional factors, whilst Section 3 discusses some implications for mineralisation. Appendix 1 contains brief petrographic descriptions of the thin sections supplied.

In preparing this report, I have consulted with Dr Gladys Warren (because of her experience with granitic and metamorphic rocks of the Arunta Region, and her experience in the Barrow Creek area) and Dr Dean Hoatson (because of his experience with Precambrian layered intrusions including the Munni Munni Complex of the Pilbara Block and various Palaeoproterozoic mafic intrusions of the Halls Creek Inlier).

However, all interpretations presented in this report are my own.

Section 1 - a synthesis of the thin sections examined

The primary rock types

The primary rocks present were of four types: metamorphosed schists/gneisses, S-type granites, I-type granites, and mafic intrusives.

Type 1. Metamorphosed schists/gneisses

There are some schists and gneisses which contain biotite, muscovite and K-feldspar. All of these have been metamorphosed to at least upper greenschist, if not amphibolite facies.

Type 2. S-Type granites

There are some S-type granites which contain biotite, muscovite and K-feldspar. All of these have also been metamorphosed to at least upper greenschist, if not amphibolite facies.

Type 3. I-type monzonites, diorites etc.

These are characterised by hornblende, biotite, some clinopyroxene cores to the amphiboles, opaques (ilmenite, magnetite, sulphide). One characteristic of the plagioclases is that when fresh, they do not have distinctive cores. This is characteristic of plagioclases which have crystallised form a melt, and is indicative that the melt does not contain restite (See Figure 2 in Chappell *et al.* 1987). Granites associated with mineralisation are inevitably restite poor (White *et al.*, 1991).

Type 4. The gabbros, pyroxenites, norites etc.

Some of these are normal igneous mafic intrusives which have igneous textures preserved. One common feature is the presence of biotite, indicating that these gabbros are high in K_2O. Igneous hornblende (α= yellow, β = brownish green and γ = olive green) and biotite (α= yellow-brown, $\beta = \gamma$ very dark brown) are preserved in these rocks and are very distinctive in colour from those associated

with the metasomatic fluid. Magnetite and ilmenite in these rocks have characteristic forms. The magnetite frequently contains typical herringbone patterns of exsolution lamellae of ilmenite, and these grains also abut coarse ilmenite crystals.

The overprints:

Type 1: metamorphic overprint.

Almost all rocks show signs of metamorphism to at least upper greenschist facies, if not lower amphibolite grade. In the peraluminous granites and schists this is reflected in the development red brown decussate biotite aggregates.

Type 2: metasomatic overprint.

This is characterised by a specific intense blue green hornblende, (α = straw yellow, β = deep bluish green and γ = green, ?ferrohastingsite) which is present in almost all of the mafic samples, including the igneous gabbros, pyroxenites and norites. Its colour is distinct from the green-brown igneous hornblende present in the mafic intrusives as well as the diorites and monzonites. This distinct amphibole also occurs in association with tourmaline in one of the biotite granites (Hole PD5, 383.6m, sample 771745)

This intense blue green hornblende is characterised optically by a distinctive optical interference figure which is unique for hornblendes in that it has a low $2V_{\alpha}$, with very strong dispersion. As the $2V_{\alpha}$ decreases with increasing Fe content, the suggestion is that this amphibole has crystallised from an Fe rich fluid. I have seen this amphibole in Mount Isa, and it is also present in the Arunta (R.G. Warren pers comm) and other Proterozoic terrains affected by metasomatism. Whenever probed this intense blue green hornblende has a high chlorine content (e.g., Wyborn and Page, 1983). The biotite associated with this amphibole is also a different colour to the relict igneous biotite, in that β and γ are a lighter, more honey brown colour.

Magnetites developed in association with this metasomatic event do not show the exsolution lamellae of ilmenite shown by the relict igneous magnetites. Some may have some exsolution with hematite. In general there was not much hematite present, and one slide had magnetite and possibly pyrrhotite. If this is so, then it is important as hematite and pyrrhotite are supposed to be mutually exclusive, as is found in the high grade ore bodies at Eloise and the eastern zone at Osborne (Williams and Blake, 1993).

The association of this amphibole with magnetite and carbonate suggests that the three minerals have precipitated from chlorine-rich oxidised brines which have associated carbonate. The abundance of biotite and amphibole indicates the alteration fluids were also high in K. Sphene was present in some slides, but was not all that abundant when compared to the Cloncurry area. This could suggest that the oxygen fugacity of the fluid was such that the oxide phase magnetite and ilmenite were stable and did not convert to hematite and sphene. If this were so then it is quite possible that the primary silicate phases were destroyed by the alteration, but that the oxides remained stable, retaining their 'igneous' characteristics. This has also been observed in mafic intrusions in the Halls Creek area (D. Hoatson, pers comm.). Although Buddington and Lindsley (1964) have argued it is possible also to have exsolution lamellae of ilmenite develop in

magnetite during metamorphism in the presence of a water-rich fluid, these authors appear to be discussing higher temperature metamorphic events than have occurred in the Home of Bullion area.

I prefer the interpretation that the exsolved magnetites in the alteration assemblages are igneous relicts as it is possible to observe a complete transition from dominantly igneous assemblages, through samples which have with some vein-controlled alteration with igneous biotite, hornblende and opaques present, to samples which only have relict igneous oxides, to those that have complete replacement.

Section 3 - Regional Factors

The occurrence of S-type granites in the suite of samples examined is not surprising as the granite centred on Barrow Creek is an S-type (R.G. Warren, pers comm) with exceptionally high U and Li. Biotite-muscovite bearing granites occur on the Barrow Creek 1:250 000 Sheet area (Warren, 1989; Haines et al., 1991). Gabbros similar to those in this selection of thin sections are widespread in the northeast Arunta from the Attutra Metagabbro (Freeman, 1986), in plugs in the Cackleberry Metamorphics, and also as plugs in N central Alcoota (R.G. Warren pers comm.).

The monzonites and tonalites are a little harder to place and the rocks in these sections do not match with any of the granite descriptions from the Barrow Creek 1:250 000 sheet area (Haines *et al.,* 1991) with the exception of a hornblende bearing granodiorite which occurs near the Mulbanga copper mine. However, the samples are similar to I-type granites from the Cullen Batholith (Pine Creek) and also the Williams Batholith (Mount Isa). The presence of clinopyroxene cores to the amphiboles is perhaps more common in the Williams Batholith.

It is worth noting that lead model ages in the Home of Bullion Mine, have come out to be very young at 1600 Ma (Warren, in prep). Warren (1994) also inferred that granites in the northern Arunta Block, south west of Barrow Creek (the Enuggan Mountains Granite) was ~1600 Ma on the basis of its similarity to a 1567 ± 6 Ma granite on northern Mount Doreen, the Yarunganyi Granite (Young *et al.*, in press).

Section 3 - Implications for Mineralisation.

The main request for this work was to address the issue as to whether there was a possibly that there was potential for mineralisation analogous to mineralisation styles similar to that found in other Proterozoic belts such as Cloncurry, Tennant Creek and the Granites/Tanami.

Firstly, I would argue that the Tennant Creek and Granites/Tanami areas represent one class of Proterozoic granite-related mineralisation, whilst the Cloncurry area represents the other (Wyborn, 1994). In the Tennant Creek class, the associated

granite is of lower temperature and dominated by a lower temperature hornblende bearing I-type granites. The Cloncurry-Olympic Dam Group are associated with a second type of higher temperature I-type granite which is probably dominated by pyroxene. The difference in primary granite type and temperature could also influence the type of alteration present, with talc-chlorite-magnetite assemblages occurring at Tennant Creek (e.g. Large, 1975), whilst in the Cloncurry area, hematite/magnetite/albite alteration is ubiquitous. McClean and Benjamin (1993) report an alteration skarn of hornblende and biotite in which intrusive textures are preserved at Mount Elliot. At Osborne and Eloise amphibolite alteration/metamorphism appears to be overprinted by sulphide mineralisation (Baker, 1994, Adshead, 1993).

I feel that the presence of an alteration assemblage in the Home of Bullion area dominated by magnetite/amphibole/biotite is more a variation on the alteration assemblages found in the Cloncurry area, rather than in the adjacent Tennant Creek area to the north.

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APPENDIX 1 Brief petrographic notes

SAMPLES FORM HOLE PD3

57m - 771768: granite gneiss. The sample contains biotite, muscovite, K feldspar and quartz phenocrysts, and is deformed. The sample is of 'granitic' composition, and may be a meta-volcanic.

73m - 771769: quartz monzonite. This sample is an igneous I-type granite. It contains quartz, plagioclase, brown-green hornblende (primary), allanite, biotite and some clinopyroxenes which are rimmed by a blue-green amphiboles. Some actinolite is present as an alteration product. Opaque oxides are present as primary and alteration minerals.

105.7m - 771726: adamellite. This sample is a foliated S-type granite metamorphosed to at least upper greenschist facies. The sample has abundant biotite and muscovite and possibly some cordierite.

116.4m - 771725: adamellite. This is also an S-type granite, but is finer grained, with biotite, chlorite and muscovite.

145.3m - 771724 tonalite gneiss. This sample is highly altered I-type granite with sericitised plagioclases, relict allanite, sphene. The alteration is at least upper greenschist, with biotite, chlorite and epidote present, possibly replacing hornblende.

SAMPLES FROM HOLE PD5

74m - 771761 tonalite gneiss. This sample is an altered I-type tonalite, although it does appear weathered. The alteration is at least biotite grade, involving chlorite, epidote, biotite, and sericitisation of plagioclases

76m - 771762 hornblende schist. Hornblende-biotite schist with sulphide (pyrite, chalcopyrite) and ilmenite. The hornblende is a blue green secondary hornblende and the sample is probably amphibolite grade. The hornblendes appear to grow around and along side the opaques phases.

85m - 771763 microdiorite. I am not sure why this sample is called a diorite. In one fragment alteration overprint is biotite + calcite, with some chlorite, whilst the other fragment is highly chloritised with less biotite. In both the feldspars highly sericitised.

105.3m - 771727 micrograbbro. Blue green hornblende is secondary after clinopyroxene, with some sulphide present. The plagioclases are strongly sericitised. Carbonate is also present. Opaques appear to be part of the assemblage.

106.1m - 771728 quartz gabbro. This sample contains the blue-green hornblende, biotite, magnetite, and the plagioclase grains are in part sericitised.

108.4m - 771729 Shear zone. This is an altered mafic rock, with blue green hornblende and biotite, and some sericitisation of feldspars. The rock has been cut

by a vein of chlorite, blue green hornblende, biotite, tremolite (?) and sulphide. This amphibole is part of the alteration assemblage and is intimately associated with the sulphide phase. One good interference figure obtained. It has a $2V_{\alpha}$ of about 50°, it is positive and dispersion is weak, with r > v. This amphibole associated with this alteration vein is similar to the one seen elsewhere as an alteration/metamorphic product. The sample appears to have both magnetite and ilmenite, pyrite and chalcopyrite.

110.6m - 771730 Mafic diorite. This sample contains intense blue green hornblende, biotite, ilmenite, magnetite and some sphene. It appears to have been metamorphosed to amphibolite grade. The amphibole may be ferrohastingsite as the dispersion in the interference figure is very strong and the $2V_{\alpha}$ is around 50°. Although the texture of this rock is 'igneous' most of the mafic silicate phases are replacement. There is some igneous biotite present. Pontifex has I > M. The ilmenite appears as exsolved lamellae in magnetite, but there are also slivers of magnetite only in the alteration amphibole.

113.1m - 771731 mafic diorite. This sample has intensely blue-green hornblende, biotite, ilmenite, magnetite, ilmenite, apatite and some sphene. This sample has also been metamorphosed to amphibolite grade.

130.7m - 771732 biotite granite. This is another S-type biotite granite with muscovite and tourmaline. It has also been metamorphosed.

138.6m - 771733 mafic diorite This is an igneous hornblende pyroxene diorite with biotite and opaques. Notice the browner-green colour of the amphibole and in the interference figure the dispersion appears to be r<v. Note also that the plagioclases do not have distinct cores, indicating that they have precipitated from a melt and do not contain restite. Most of this rock is igneous and Pontifex has I>M. Exsolution lamellae of ilmenite are common in the magnetites.

146.7m - 771734 mafic diorite as above but more altered, with the plagioclases sericitised. Notice that you have the igneous brown green amphibole present, but that the pyroxenes are fringed by an intense blue green amphibole. Pontifex has I>M. Exsolution lamellae of ilmenite are common in the magnetites

159.1m - 771735 quartz micromonzonite. This is a fine grained, I-type diorite with biotite, and metamorphic (?) hornblende. It has also been metamorphosed possibly to amphibolite grade. As the decussate biotite grains are intimately grown with the blue green amphibole, it suggests that both area metamorphic feature.

224.06m - 771736 gabbro + diorite. This is highly altered with biotite, blue green hornblende, actinolite (?) and some carbonate. The primary gabbroic texture is still preserved as is some igneous biotite and hornblende.

225.9m - 771737 micrograbbro This has a chlorite carbonate alteration overprint with biotite and apatite. There is sulphide present whilst the oxicde phases appears to be ilmenite. If the identification of ilmenite is correct, it appears part to be of the alteration sequence, and consists of small composite grains as opposed to the large

grains that occur in the rocks dominated by igneous textures. Importantly, note that there no sphene.

265.7m - 771738 micronorite Plagioclase, orthopyroxene with alteration of yellow brown biotite, tourmaline and the blue green hornblende. This is an important slide, as it shows the amphibole coming in as an alteration vein in association with biotite, sericite and possibly carbonate and opaques. Most of this slide is igneous, and Pontifex has I>M.

278.3m - 771739 dolerite This sample is highly altered with intense blue green hornblende and yellow brown biotite overprinting a dolerite texture. Plagioclases are sericitised and opaques are part of the alteration assemblage. Note: Pontifex has said that M>I. The rock contains pyrite, chalcopyrite, with ilmenite adjacent to magnetites.

280.1m - 771740 gabbronorite Most of this sample is igneous and contains clinopyroxene, orthopyroxene, igneous biotite (brown yellow) and igneous hornblende (yellow green). There are veins and fracture through this rock which contain the alteration blue-green hornblende, yellowish biotite and some opaques. . Pontifex has I>M, which is feasible as most of the rock is igneous, and the magnetites have exsolution lamellae of ilmenite.

293.5m - 771741 mafic diorite This sample contains orthopyroxene (exsolved pigeonite) and the opaques occurs in large igneous biotites. Again this one is fractured and the blue green amphibole occurs along these fractures. Pontifex has I>M, which is again is feasible as most of the rock is igneous, the magnetites have exsolution lamellae of ilmenite, and the ilmenite grains form large clean grains.

298.5m - 771742 mafic diorite This sample has an alteration overprint of intense blue green hornblende and decussate biotite. Some of this decussate biotite surrounds the opaques, but other opaques look stable in large igneous biotites. Some clinopyroxene and primary igneous hornblende (yellow green) are preserved. Pontifex has I=M, the magnetites have exsolution lamellae of ilmenite, and the ilmenite grains form large clean grains.

370.35m - 771743 mafic hornfels This sample contains clinopyroxene and magnetite with some sulphide. Note that along the main sulphide vein the sulphides appear to be rimmed with very fine grained blue green amphibole. The yellow brown alteration biotite is also common in this rock. Most of this is alteration, and again Pontifex has M>I. The sulphide appears to be pyrrhotite, and the adjacent magnetite has fine exsolution lamellae which do not form the typical herringbone pattern of the illuminates. These lamellae may be hematite.

372.9m - 771744 mafic hornfels This is similar to 771743 with a vein of the blue green hornblende. Some of the sulphides again have rims of the blue green hornblende, and some have inclusions of it. Th alteration biotite is again present. Most of this is sample is alteration, and again Pontifex has M>I.

383.6m - 771745 biotite granite This biotite granite has a retrogressive overprint of epidote and sphene. Note a small vein of blue green hornblende and biotite running through it (at the sample number end).

387.5m - 771746 mafic hornfels This sample looks like amphibolitised version of the preceding samples ones. Alteration overprint contains blue green hornblende and chlorite. This was originally a clinopyroxene rock like 771743 at 370.35m and has been overprinted heavily by the blue green amphibole alteration.

395.3m - 771747 ?mafic hornfels This is a more altered version of other hornfelses with actinolite. The blue green hornblende is associated with the opaques, and possibly originally overprinted clinopyroxene. Chlorite appears to be overprinting the blue green amphibole. There may be some actinolite with this alteration. The coarse magnetites have ilmenite exsolution, and there are some coarse ilmenite grains present.

395.8m - 771748 ? pyroxenite This sample has blue green hornblende and the alteration biotite. The clear amphibole is possibly actinolite as it has $2v_{\alpha}$ positive and about 80° The alteration overprint dominant and Pontifex has M>I.

417.2m - 771749 gabbro-pyroxenite Although this sample contains the green/brown hornblende with igneous biotite, the dominant amphibole is the blue green one. The development of this amphibole is contained by veins. Again the alteration overprint is dominant and Pontifex has M>I. However, some of the magnetites present do have exsolution lamellae of ilmenite. There are sulphides present.

419.2m - 771750 mafic diorite. This sample contains huge sphenes in a vein with quartz (very reminiscent of the Cloncurry area) with a biotite and blue green hornblende overprint. There is some sericite carbonate alteration of the plagioclase. There are large numbers of large igneous yellow green hornblendes and biotites and Pontifex has ?I>M.

421.5m - 772751 mafic diorite. This sample is similar to the preceding one, only with actinolite alteration in addition to the blue green hornblende and the yellow decussate biotite.

429.3m - 771752 mafic diorite As above with more sericite and actinolite alteration but still the blue green hornblende yellow biotite alteration.

440.0m - 771753 mafic diorite back to normal gabbro with igneous hornblende and biotite. Alteration consists of some sericitisation of the plagioclases, and the blue green hornblende is virtually non existent.

Samples prefixed 'Pros#'

771770 Pros #2 pyroxenite. Weathered, with magnetite, sphene and clinopyroxene. Pontifex has M>I. There si blue green hornblende with the magnetite, which in places is also associated with sphene.

771771 Pros #3 quartzite This appears to be a fine grained hornfels, with chlorite muscovite.

771773 Pros #3 cordierite hornfels fine grained with cordierite, spinel and possibly corundum.

771774 Pros #3 skarn chlorite magnetite

771775 Pros #3 quartz biotite schist This contains biotite and chlorite an is in upper greenschist.

SAMPLES FROM HOLE RP-1

50m 771775 Amphibolite This sample contains intense blue green metamorphic amphibole with plagioclase sphene and opaques

SAMPLES FROM HOLE RP-4

57m 771764 Quartz Monzonite This contains igneous amphibole, biotite, plagioclase, quartz and opaques. There are traces of the blue green amphibole near veins.

72m 771765 Quartz Syenite This sample has igneous amphibole, biotite, plagioclase, quartz and opaques There is some of the intense blue green amphibole near some veins, or rimming some clinopyroxene ??

106m - 771766 Quartz Monzonite This is contains plagioclases which don't have cores, clinopyroxene, green yellow hornblende, biotite and quartz. There are some traces of the blue green hornblende.

127m 771767 Granodiorite Gneiss back to the S-type, with biotite, muscovite and heavily sericitised plagioclases.

SAMPLES FROM HOLE RP-6

16m 771754 Pyroxenite Some of the pyroxenes have actinolite cores, there is the distinctive blue green hornblende present. The sample appears weathered so the identification of biotite is difficult. The opaques are intimately associated with the hornblende. Pontifex has ?M,I.
28m 771755 Pyroxenite This also contains a pale amphibole (tremolite) as well as the blue green hornblende. Pontifex has ?M,I.

39m 771756 Gabbro Intense abundant blue green hornblende and sericitised plagioclases. The magnetite is part of the alteration. There are some large igneous biotites still present, one of which is cores by an opaque mineral. Apatite is part of this assemblage, again reminiscent of Cloncurry. Pontifex has I>>M, but the magnetites do not have exsolution lamellae.

47m 771757 Magnetite Pyroxenite This sample has pyroxene with magnetite as the matrix, and although the igneous textures are well preserved, there is a strong overprint of the intense blue green hornblende. Pontifex has M>1, although the magnetites do have exsolution lamellae of ilmenite.

49m 771758 Gabbronorite. This sample has a strong sericite overprint on plagioclases. The rock also contains orthopyroxene, clinopyroxene and opaques. The clinopyroxene looks like a skarn overprint on a gabbro. Pontifex has ?M,1

63m 771759 Pyroxenite This sample is highly altered, and the magnetite is interstitial to the relict pyroxene grains which appear to be now actinolite. There are patches of the intense blue green amphibole an yellow brown decussate biotite. There are also some relict igneous biotite and yellow green hornblende. Pontifex has M>1, and the magnetites have exsolution lamellae of ilmenite.

115m 771760 Magnetite Pyroxenite as above but not as altered. There are veins of the intense blue green amphibole. Pontifex has M>1

EXTRA SAMPLES

Pet 1 metagreywacke with muscovite, biotite and possibly cordierite

Pet 2 Amphibolite with epidote, hornblende, garnet, sphene and albite

Pet 3 sulphides

Pet 4 sulphides + quartz

Pet 5 amphibole + sulphide + chlorite

Pet 6 weathered cordierite schist which contains biotite, muscovite + late chlorite, possibly some altered cordierite

Pet 7 Chlorite-muscovite-quartz schist with late chlorite

Pet 8 muscovite-quartz schist

Pet 9 amphibolite like one in drill core.

Pet 10 chlorite epidote zoisite rock.