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GEOLOGICAL SETTING OF IRON OXIDE RELATED MINERALISATION IN THE SOUTHERN MOUNT WOODS DOMAIN, SOUTH AUSTRALIA

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Abstract - The Prominent Hill iron oxide copper-gold deposit (278.8 Mt @ 0.98% Cu, 0.75 g/t Au) is located on the southern margin of the Mount Woods Domain in South Australia's Gawler craton. It is hosted by a sequence of unmetamorphosed lithic quartz sandstone, conglomerate, argillite and dolomite, and mafic to felsic volcanic rocks. The age of the sedimentary rocks remains unresolved. Basalt, andesite, dacite and rhyolite are possible correlatives of the lower Gawler Range Volcanics. Mineralisation comprises disseminated chalcocite, bornite and chalcopyrite in the matrix and clasts of hematite-rich breccias. A large portion of the mineralisation is strata-bound, occurring parallel to stratigraphy within steeply dipping fragmental sedimentary rock units that have undergone extensive hydrothermal alteration and brecciation. Upper greenschist to mid amphibolite facies metamorphic rocks north of the Prominent Hill deposit consist of intercalated iron and calcium-rich chemical sediments, possible meta-evaporites and pelites. They may be correlatives of the Palaeoproterozoic Wallaroo Group of Yorke Peninsula, and have been intruded by felsic magmas and layered sequences of mafic and ultra-mafic cumulate rocks. Drillholes 30 km east of Prominent Hill have intersected a bimodal suite of tholeiitic volcanic rocks, geochemically distinct from the Gawler Range Volcanics and probably Archaean or Palaeoproterozoic in age. Pre- and post-discovery exploration drilling has highlighted the occurrence of numerous iron-oxide (±copper ±gold) systems within both the metamorphosed and unmetamorphosed domains that make up the southern Mount Woods Domain. These include a full spectrum of magnetite, magnetite-hematite and hematite rich prospects and deposits with variable copper and gold tenor.

Introduction

The Gawler craton hosts widespread iron-oxide copper-gold (IOCG) alteration and mineralisation, including the economic Olympic Dam and Prominent Hill orebodies along with numerous other prospects including Carapateena, Acropolis, Wirrda Well, Emmie Bluff and Oak Dam (Gow *et al.* 1993; Gow *et al.* 1994; Davidson and Paterson 1993; Gow 1996; Vella 1997; Ferris *et al.* 2002; Skirrow *et al.* 2002; Bastrakov *et al.* 2007; Davidson *et al.* 2007). The Mount Woods Domain (MWD) is a region of Palaeo- and Mesoproterozoic metamorphic and igneous rocks having a well defined aeromagnetic signature, located in the northeast of the Gawler craton, South Australia (Fig. 1). It is characterised by high magnetic and gravity signatures, caused by multiple iron-oxide and mafic rock sources, and its boundaries are sharp and structurally controlled. Outcrop is sparse and unconsolidated, with flat lying Phanerozoic cover reaching thicknesses of up to 400 m in places, although it is generally less than 200 m.

The Prominent Hill IOCG deposit was discovered through diamond drilling of a gravity anomaly in 2001 (Carter *et al.*, 2003). It is located approximately 650 km northwest of Adelaide, midway between Olympic Dam and Coober Pedy, on the southern margin of the Mt Woods Domain (Fig. 1). Current total resources, including the recently discovered Western Copper deposit, stand at 278.8 Mt @ 0.98% Cu and 0.75 g/t Au, which comprises a copper-gold resource of 200 Mt @ 1.35% Cu and 0.49 g/t Au, and a gold-only resource of 78.8 Mt @ 1.4 g/t Au (OZ Minerals Prominent Hill Resource statements, June 2009 and May 2010). The discovery of the deposit led to renewed interest in mineral exploration in the MWD and the acquisition of high quality data from oriented diamond drill core and detailed geophysical surveys, including 100 m line spaced aeromagnetics and highly detailed ground gravity, especially around Prominent Hill itself.

Based largely on recently acquired data, this paper provides new insights into the geological setting of the southern MWD which hosts numerous large iron oxide occurrences. It has implications for understanding the lithologies, stratigraphy, tectonics, intrusion history and iron-oxide mineralisation of the MWD.

Previous Investigations

Detailed geological investigations in the Mount Woods area were first carried out by Flint and Benbow (1977), and Ambrose and Flint (1981), who described the outcropping Palaeo- to Mesoproterozoic metasediments. Working prior to the major phase of IOCG exploration, and with relatively poor data, these authors grouped the rocks exposed in the MWD into three units; the Mount Woods Metamorphics, the Engenina Adamellite, and the Balta Granite Suite.

The Mount Woods Metamorphics encompass a large range of medium to high grade metamorphic rocks of sedimentary and igneous provenance, further subdivided into: metaconglomerate, leucocratic gneiss, porphyroblastic garnet gneiss, "banded iron formation", and cordierite rich "granofels" and gneiss. The recognition of a metaconglomerate overlying the gneisses of the Mount Woods Metamorphics at one locality has implications for the presence of unconformities within the metasedimentary sequences of the MWD (Chalmers 2007).

Peak metamorphism of the basal metasediments reached upper amphibolite to lower granulite facies (Ambrose and Flint 1981; Betts *et al.* 2003). U-Pb SHRIMP dates on a migmatitic segregation related to this event suggests a melting age of 1736±14 Ma (Finlay 1993; Daly *et al.* 1998). U-Pb zircon analyses on cordierite+garnet-bearing pelite and magnetite psammite surface samples from the

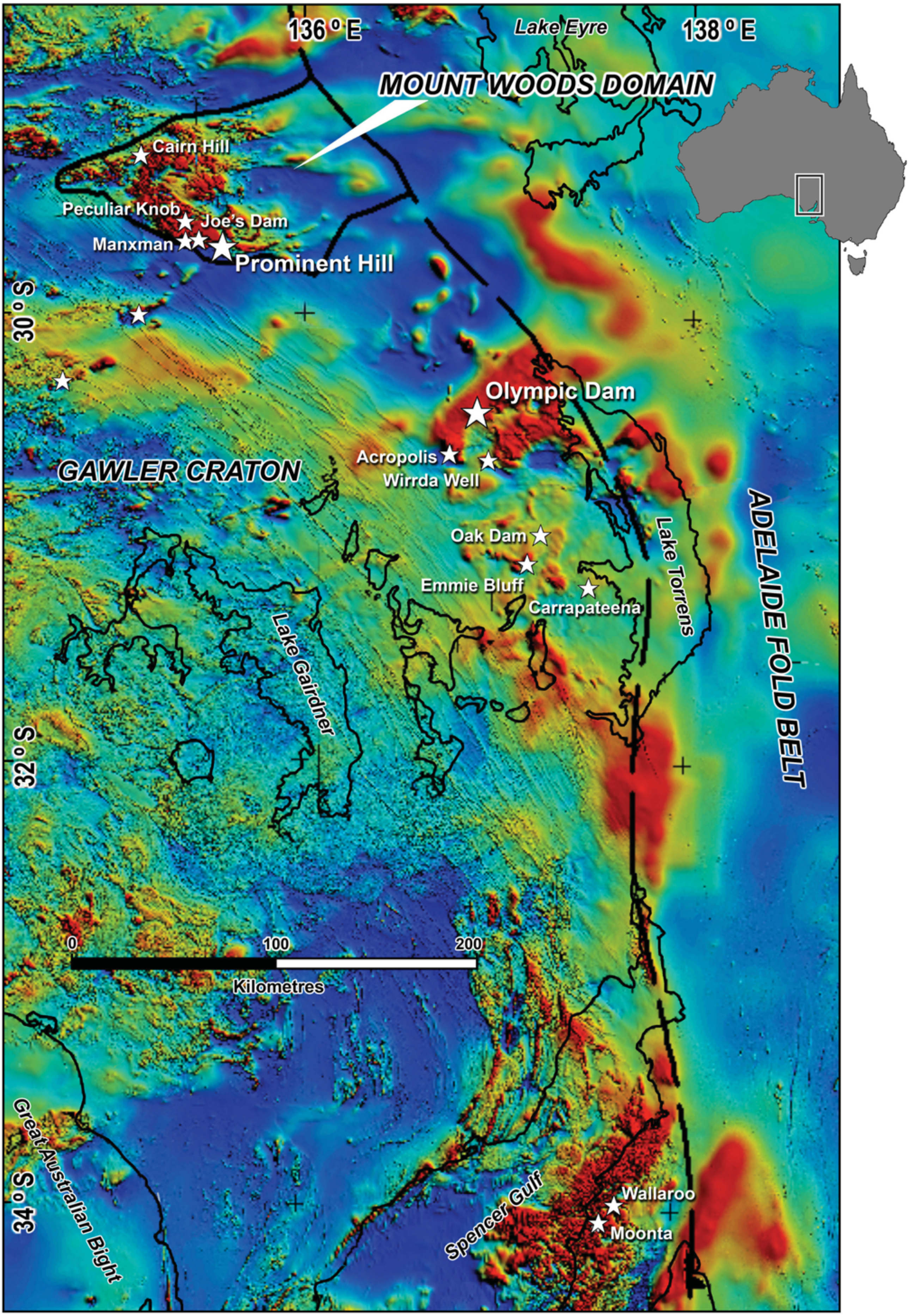


Figure 1: Total magnetic intensity image of the eastern Gawler craton showing locations of major IOCG deposits and iron-alteration systems. Dashed black line represents the approximate current craton margin. Solid black line is an outline of the Mount Woods Domain. TMI data provided by Primary Industries and Resources of South Australia (PIRSA).

Skylark Dam area suggest maximum depositional ages of 1751±6 Ma and 1752±6 Ma respectively (Jagodzinski *et al.* 2007). These metasediments were intruded by the syn-metamorphic Engenina Adamellite (ca. 1691±25 Ma; Finlay 1993; Daly *et al.* 1998), which is characterised by aligned, very coarse feldspar phenocrysts and a weak to moderate, near vertical, biotite-defined foliation which shares a similar orientation to the metamorphic fabric in surrounding metasediments (Chalmers, 2007). U-Pb zircon data also indicate that the unmetamorphosed Balta Granite crystallised at 1584±18 Ma (Fanning 1997), which is indistinguishable from the age of the Roxby Downs granite which hosts Olympic Dam (1588±4 Ma; Johnson and Cross, 1995) and a plethora of published ages for the Hiltaba Granite Suite throughout the Gawler Craton (Daly *et al.*, 1998). More recent geochronological studies have further reinforced the importance of 1590 to 1580 Ma felsic and mafic magmatism (e.g., Holm 2004, Jagodzinski *et. al.*, 2007) in the MWD. Belperio *et al.* (2007) report the first U-Pb zircon date from Prominent Hill, for intrusive dacitic porphyry from the northern hanging wall sequence which yielded a crystallisation age of 1585±8 Ma.

Betts *et al.* (2003), utilising relatively high resolution aeromagnetic data, and from structural mapping of the limited outcrop, attempted a first pass structural and domainal analysis of the MWD. The outcrops indicated a relatively straightforward deformation history for the northern portion of the inlier. D_1 produced an early layer (bedding) parallel foliation (S_1) followed by a tight to isoclinal folding event (D_2). The Engenina Adamellite displays an S_2 fabric that is not as well developed in the granite as in the surrounding metasediments. Based on this evidence, intrusion of the Engenina Adamellite post dates the M_1/D_1 event. Post-D_2 folding was localised and tight to isoclinal in nature. In addition, a series of ductile to ductile-brittle shear and fault zones which post-date S_2 were mapped from outcrop, including: (1) the Spire Shear Zone, which trends eastsoutheast, dips between 60°S and 85°N, and cuts the Engenina Adamellite; (2) small scale, northnortheast-trending, predominantly strike-slip shear zones between Skylark and Spire Hills; and (3) the Moonlight Shear Zone, a large, poorly exposed north-east orientated structure on the Moonlight Hills outcrop.

Based largely on geophysics, Betts *et al.* (2003) divided the MWD into four "geophysical zones", each separated by a major structural discontinuity. The Prominent Hill orebody lies outside the area interpreted in detail by Betts *et al.* (2003). The deposit and its host stratigraphic package are to the south of a major fault, within a separate, previously unnamed domain that exhibits a relatively smooth-textured magnetic signature, in what is interpreted as dominantly Archaean crust.

Prior to the Prominent Hill discovery, sporadic mineral exploration was undertaken in the Mount Woods area over a period of 40 years. This work had primarily focussed on IOCG systems similar to Olympic Dam, BIF-hosted and metasomatic iron ore, and to a lesser degree zinc-lead-silver deposits of similar style to those at Broken Hill in New South Wales or at Cannington in Queensland, and kimberlitic diamonds. Low-grade copper-gold mineralisation associated with abundant magnetite alteration was discovered in the Mount Woods region by explorers in the 1980s and 1990s (Manxman and Joe's Dam prospects; Hampton 1997; Carter *et al*., 2003). Early geological descriptions and interpretation of the Prominent Hill deposit itself are presented in Belperio and Freeman (2004a, 2004b) and Belperio *et al.* (2007).

Geology of the Southern Mount Woods Domain

In the southern portion of the MWD there are no outcrops of crystalline basement rocks and any geological interpretation has to be based largely on potential field data and information from drilling. As is usually the case, drillhole data is scattered and highly localised close to known mineral occurrences. In the southern portion of the MWD, the largest component of drilling has been at the Prominent Hill deposit, the Joe's Dam, Manxman A1 and Taurus magnetite ±copper ±gold occurrences, and the Peculiar Knob hematite deposit (Fig. 2b). Other areas of sparse but important drilling lie within and along the northern edge of the White Hill sub-domain, at prospects to the south, west and east of Prominent Hill, and in the Torch-Danae Hill area approximately 30 km further to the east (Figs. 2a and 2b). Data used to constrain the geological analysis include: (1) High resolution aeromagnetic data collected on 100 m spaced lines and 50 m elevation over the southern MWD. Images have been processed (i.e., reduced to pole and first vertical derivative); (2) Merged South Australian government and open file aeromagnetic data provided on a 200 m cell size grid; (3) Detailed ground gravity surveys collected in the Prominent Hill, White Hill and Danae Hill areas; and (4) Open file and confidential reports detailing exploration drilling in the area.

Major problems can arise when interpreting data from terrains which contain little or no outcrop, sparse and clustered drillhole information, and only aeromagnetic or gravity data. This largely results from the inability to ground truth interpretations, except in localised areas with dense drilling data. The geologic sub-domains in the southern MWD, as outlined in this paper, are characterised by the presence of large, structurally separated terrains displaying variations in folding of lithotypes and overprinting by areas of magnetite development, or destruction, related to intrusions or to structures. These domains are separated by linear breaks in magnetic trends or patterns, interpreted to reflect structures. The domains represent crystalline basement that has undergone differing degrees of metamorphism, deformation, intrusion and hydrothermal activity. The interpretations herein are consistent with the rock types and structures intersected in exploration drill holes.

The Mount Woods Domain comprises at least two separate sedimentary successions that have been subjected to one or more amphibolite to granulite facies metamorphic events, three periods of deformation, and two (probably three) episodes of magmatism, as well as a pulse of Neoproterozoic mafic dyke intrusion. The aeromagnetic signatures of these rocks are highly variable, while those of the overlying cover sequences are poorly understood. In particular, the presence of grabens filled with early Neoproterozoic basalts, magnetite-bearing volcanic rocks and associated red beds, and very late stage palaeo-channels filled with magnetic debris all appear to be developed within and in the vicinity of the southern MWD. All may confuse interpretation of the data. Palaeo-topographic effects dominate the gravity data along the southern and central portions of the MWD. Depth-to-basement information is far too sparse to allow any form of detailed correction to be made for the palaeo-topography which may be pre-Neoproterozoic to Cenozoic in age. In addition, the distribution of dense mafic rocks within the crystalline basement is poorly constrained, and it has been demonstrated that at least

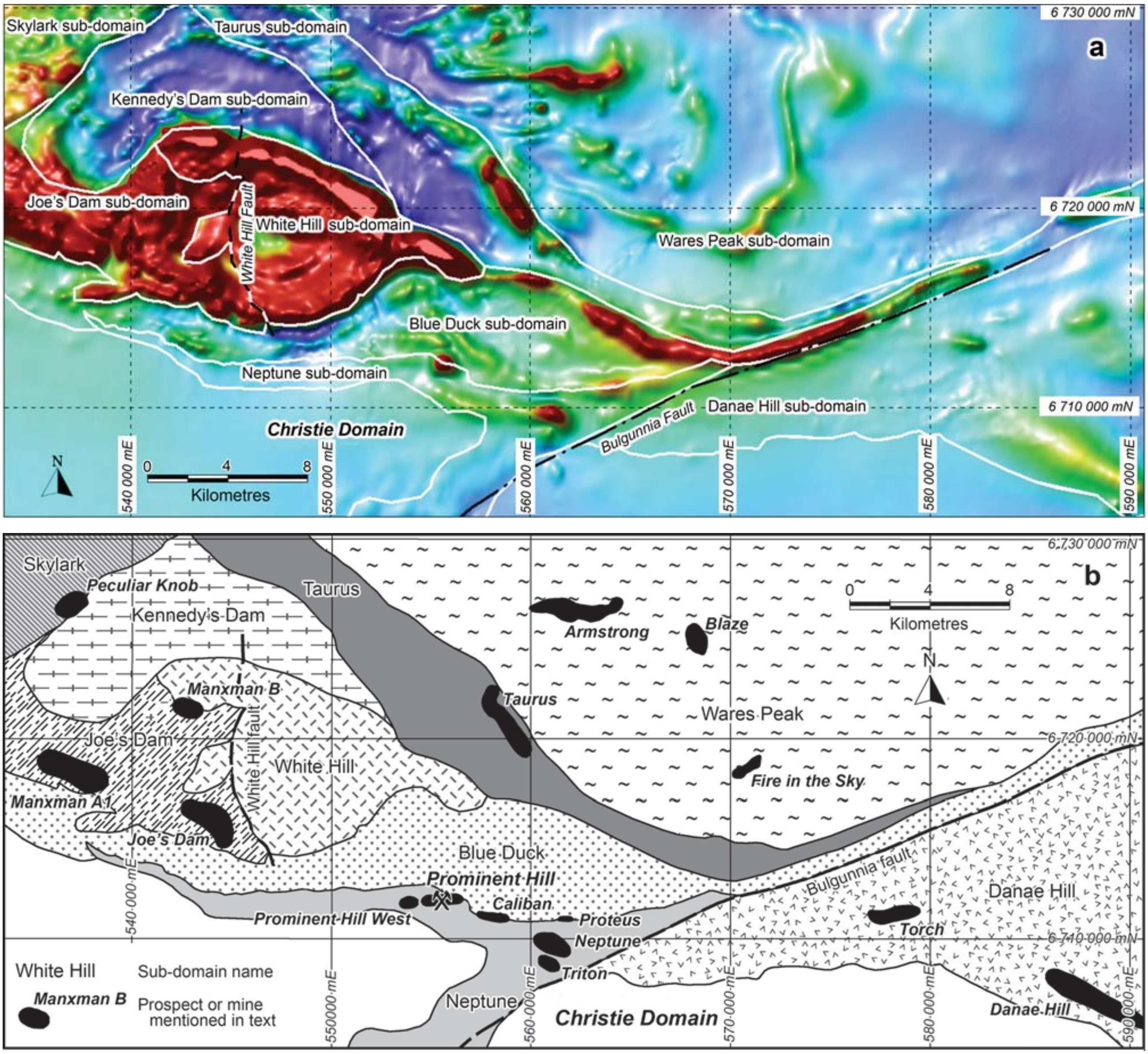


Figure 2: Tectonic and geophysical setting of iron oxide related mineralisation in the southern Mount Woods domain (MWD); **a)** RTP aeromagnetic image of the southern MWD showing the sub-domains discussed in this paper. The sub-domains are based on exploration drilling and geophysical data; **b)** The interpreted sub-domains of the southern MWD and location of prospects discussed in the text. The prospects correspond to magnetic and/or gravity anomalies.

some of the positive gravity anomalies are related directly to mafic intrusions within the basement.

In the study area, nine basement sub-domains have been defined, based on the criteria and limitations outlined above (Figs. 2a and 2b). These are discussed in detail below.

Neptune Sub-domain

This sub-domain is characterised by the Neptune Volcanics and the Prominent Hill Mine Sequence, and is situated along the southern boundary of the MWD. It is the most important with regard to IOCG exploration and economic potential within the MWD, containing the Prominent Hill copper-gold deposit and numerous other prospects with associated iron-oxide alteration (Fig. 2b). Reverse circulation drilling was first conducted here by Burmine in 1990, at the Neptune prospect, where strongly altered, porphyritic to aphyric lavas or sub-volcanic rocks were intersected with minor copper (Carter *et al.* 2003).

Compared to terrains further to the north, the Neptune sub-domain is characterised by relatively low amplitude linear aeromagnetic anomalies (Fig. 2a). Its southern boundary is very poorly defined and likely reflects deepening of the cover sequence rather than a fundamental feature of the basement geology. From drilling at Prominent Hill, Prominent Hill West, Neptune, Proteus, Caliban and Triton (Fig. 2), this domain is known to contain a sequence of lower greenschist facies, relatively undeformed, mafic to felsic volcanic rocks (basalt-andesite-dacite-rhyolite), hematite-cemented quartz conglomerate, sandstone, argillite and dolostone. This is the sequence that hosts the hematite copper-gold mineralisation at Prominent Hill (Belperio and Freeman 2004; Belperio *et al.* 2007). It coarsens southwards from argillaceous and calcareous rocks into coarse grained siliciclastic rocks (Figs. 3 and 4).

In the structural footwall to the Prominent Hill mineralisation, the volcanic rocks of the Neptune sub-domain are basaltic to andesitic in composition, commonly porphyritic and amygdaloidal. Felsic volcanic rocks become much more voluminous several kilometres west of Prominent Hill. Compositions range from dacite to rhyolite, with 'red-rock' hematite dusting of alkali feldspar making this unit distinctive compared to predominantly sericite-chlorite-earthy hematite-leucoxene-carbonate alteration within the basalts and andesites of the mine sequence (Fig. 5c).

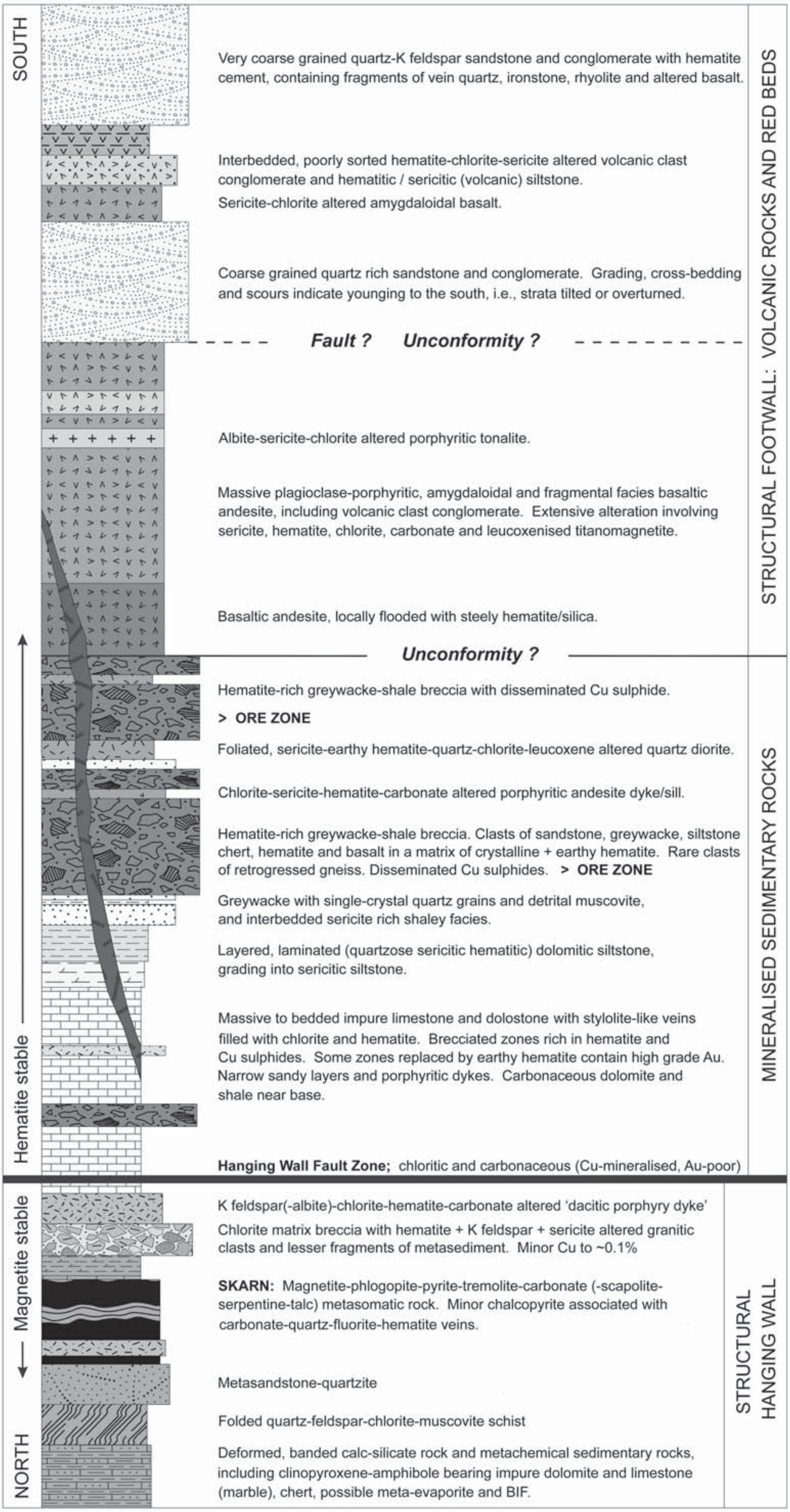


Figure 3: Simplified stratigraphic column showing the geology and mineralisation of the Prominent Hill mine sequence (Scale approximate).

The more felsic rocks exhibit weak to strong flow layering, the orientation of which is highly variable, suggesting possible lava domes. They are quartz-phyric and correlated with acid volcanic rocks intersected in drilling at the Triton prospect, to the southeast (Fig. 2).

To the east and west of Prominent Hill Mine, the Neptune sub-domain displays a more diffuse aeromagnetic signature, which could reflect either variations in the thickness of flat lying lithologies in cover sequences or areas where the volcano-sedimentary package in the basement is shallow dipping to flat lying. Mineral exploration drilling has demonstrated that the Neptune Volcanics extend for some 12 km west and 10 km east from the Prominent Hill orebody.

Fragmental lithologies are intercalated with the coherent footwall volcanic rocks at Prominent Hill, and include agglomerate, felsic tuff or ignimbrite (Belperio *et al.*, 2006; Fig. 5) and volcanic clast conglomerate. They are also intercalated with mafic to intermediate volcanic rocks and

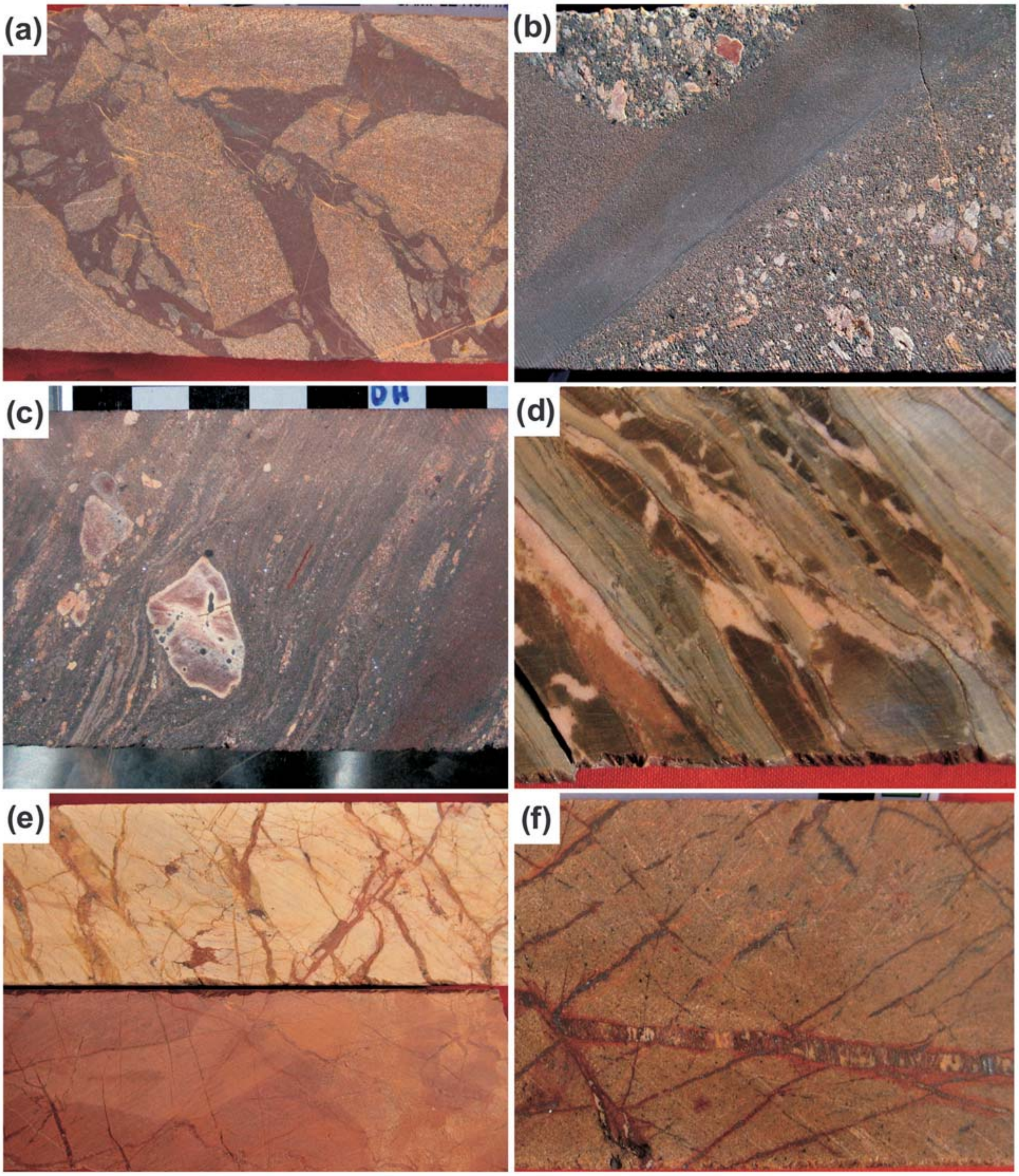


Figure 4: Core samples (NQ2 size, ~50 mm diameter) of Prominent Hill breccias and host sediments from the Neptune sub-domain. **(a)** Single-stage, monomict, mosaic hematite breccia comprising quartz-sericite sandstone clasts in fine-grained, granular hematite matrix. **(b)** Re-brecciated hematite-breccia from Prominent Hill "Western Copper Zone", showing late fine grained "milled" hematite cross cutting early coarse-grained breccia. While many of the PH breccias are considered single-stage, there are examples of multi-stage brecciation. **(c)** Hematite-matrix breccia containing zoned fragments of small flattened and coarse angular sedimentary rocks. Note the wrap-around texture of the matrix. **(d)** Interbedded sericitic argillite and dolostone. **(e)** Massive cream-yellow dolostone containing an irregular network of hematite + carbonate veins (top) and red-tan earthy hematite stained dolostone cut by hematite ±carbonate veins (bottom). Copper mineralisation in carbonates is generally confined to non-earthy hematite-stained varieties, whereas hematite-stained dolostones can contain high-grade, micro-vein hosted visible gold. **(f)** Medium to coarse-grained greywacke with single-crystal quartz grains and detrital, interstitial muscovite; commonly interbedded with sericite-rich shaly facies.

hematitic, quartz-feldspar conglomerate and interbedded coarse grained sandstone (Fig. 5a). The clastic sedimentary rocks exhibit steep, north- to south-dipping bedding, which parallels that of the mineralised host sediments. The mafic volcanic rocks with which they are intercalated are similar in appearance to ca. 1590 Ma lower Gawler Range Volcanics. At the Caliban prospect, ~1 km east of Prominent Hill (Fig. 2), the fragmental rocks range from poorly sorted, polymict, coarse grained, clast supported sedimentary breccias with elongate flat clasts (to 50 mm), through thin beds of medium grained, angular to sub-rounded, matrix supported conglomerate, grading into grit/sandstone beds with silty intercalations. 'Floating', 50 to 200 mm hematite, quartz and volcanic clasts are not uncommon. Many of the fine grained clastic sedimentary (and to a lesser extent, volcanic) rocks are intensely reddened and exhibit green/khaki reduction spots, typical of textures observed in "red bed" environments worldwide, indicating arid, saline oxidising weathering and more reduced diagenetic processes. The pebble sandstones and conglomerates also exhibit liesegang banding.

At Prominent Hill West, the mafic-felsic volcanic units are truncated by the domain-boundary fault. At Prominent

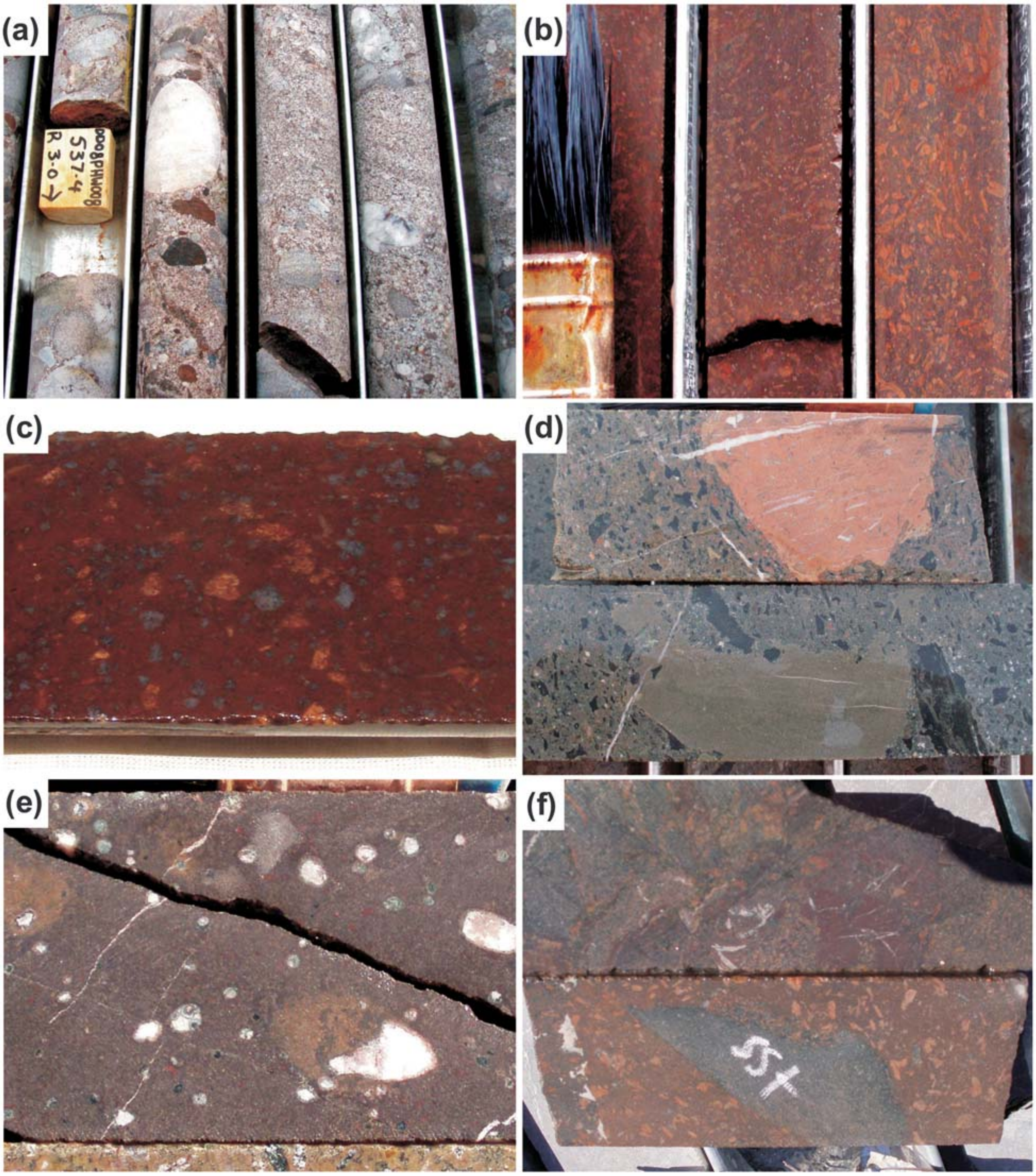


Figure 5: Drill core samples of Neptune Volcanics. All samples are NQ2 (~50 mm diameter) core. **(a)** Sub-vertically dipping, coarse-grained, lithic, quartz-hematite sandstone and conglomerate, containing fragments of vein quartz, massive and laminated ironstone, and altered, undeformed volcanic rocks. Cross-bedding indicates younging to the south. These sediments could be either part of the Gawler Range Volcanics or the later Pandurra Formation. **(b)** Hematite altered porphyritic andesite showing strongly flow-aligned to randomly oriented feldspar phenocrysts. **(c)** Quartz-feldspar-phyric rhyolite, from drilling ~1.5 km west of Prominent Hill. Feldspars are dusted with fine-grained hematite. **(d)** Sericite-chlorite-carbonate altered acid tuff or ignimbrite, from ~3.5 km west of Prominent Hill. **(e)** Amygdaloidal basalt, with carbonate replacement of amygdales. **(f)** Lithic fragments of quartz sandstone ("sst") in porphyritic, hematite altered andesite.

Hill itself, this east-west-trending structure (Hangingwall Fault Zone) dips 70 to 80º to the north, but further west it shallows slightly to 60 to 70º, and it is essentially vertical to the east of the mine. The Hangingwall Fault has been inferred to separate the hematite-stable sedimentary rocks of the copper-gold mineralised host sequence (and the Neptune sub-domain) from a magnetite-stable hanging wall sequence of chloritic pelite and pelitic carbonate rock of the Blue Duck Metasediments (see below). As observed in the northern part of the open pit at Prominent Hill, the hanging wall sequence is strongly metasomatised to a magnetite-phlogopite-tremolite-pyrite-chlorite "skarn". It is not presently clear if the boundary between hematite- and magnetite-dominant alteration assemblages has any displacement associated with it. An alternative explanation to significant dip-slip movement and subsequent juxtaposition of hematite and magnetite (as proposed in Belperio *et al.*, 2007) involves a low pressure metamorphic gradient increasing from south to north which is controlled by an inferred intrusive centre north of the mine. The most obvious candidate for this intrusion is the large White Hill Complex, discussed in a later section.

At least two types of mafic dykes are interpreted to intrude along pre-existing faults in the mine. The earlier generations are fine-grained, sericite-chlorite-hematite-silica altered mafic rocks, some containing Cr-spinel. The later dykes are generally unaltered. They clearly cross-cut mineralisation and contain primary igneous magnetite. They are the only magnetite-bearing rocks that occur south of the Hanging-wall Fault, and may be correlatives of the Neoproterozoic Gairdner Dyke Swarm (827±6 Ma; Wingate *et al.*, 1998).

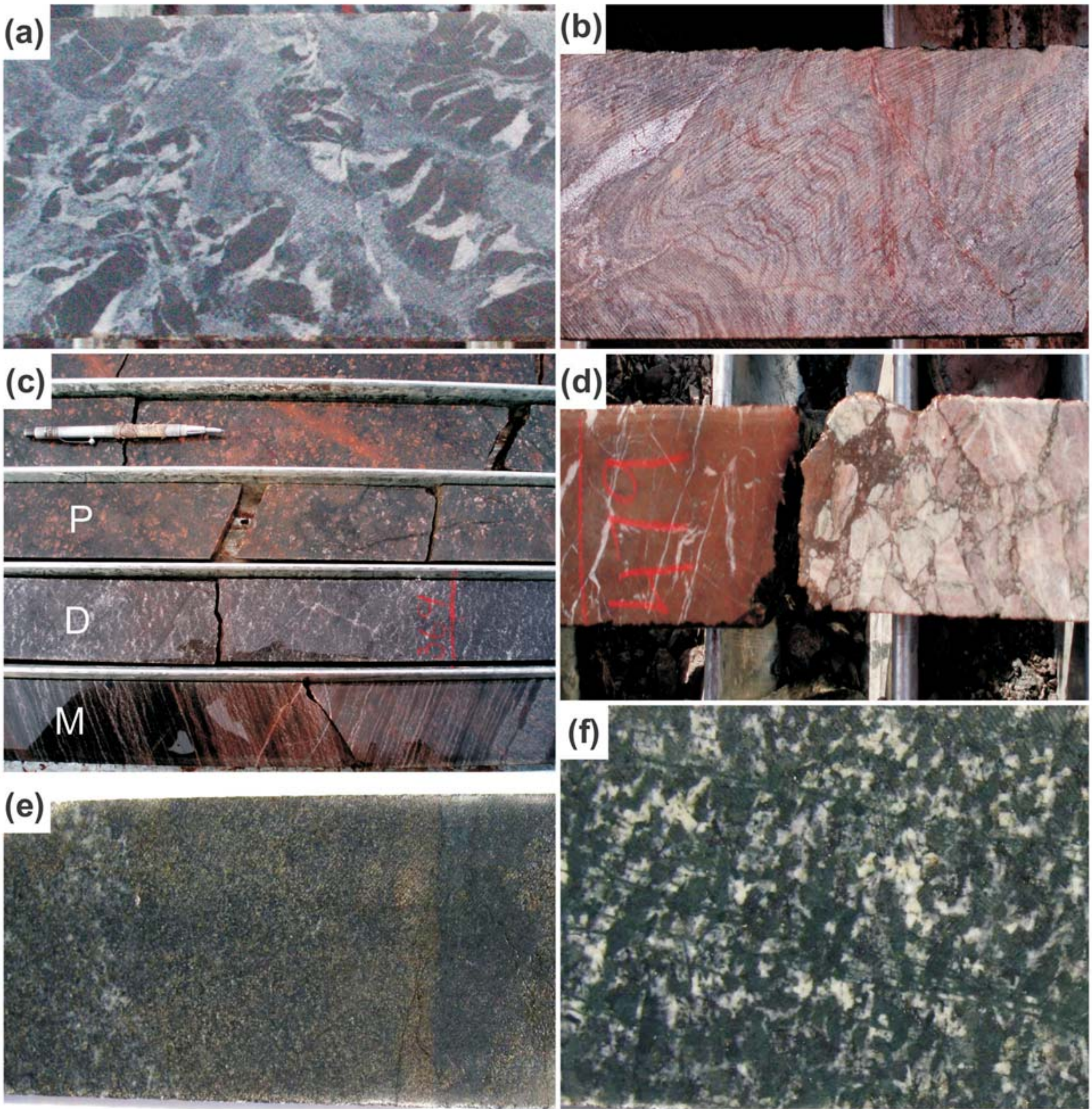


Figure 6: Drill core samples from the Blue Duck and White Hill sub-domains. All samples are NQ2 (~50 mm diameter). **(a)** Folded, argillaceous carbonate rock from northwest of Prominent Hill; overprinted by pale-grey second generation carbonate and exhibiting 'ghost' layering (relict of original folds). **(b)** Finely laminated, folded, arkosic metasediment of the Blue Duck sub-domain. **(c)** Undeformed feldspar porphyry [P], veined by hematite, with contact aureole comprising disaggregated white carbonate [D], grading into laminated, pelitic-calcareous metasediments [M]. **(d)** Sharp contact between monomict breccia containing clasts of Blue Duck metasediments (right) and strongly hematite altered, undeformed andesite (left). **(e)** Mafic cumulate rock from the northern margin of the White Hill Complex, comprising bands of orthopyroxene-magnetite (right), magnetite-hercynite-plagioclase-orthopyroxene (centre) and orthopyroxene-plagioclase (left). **(f)** Albite-sericite-epidote altered laminated gabbro with magnetite, ilmenite, apatite and pyrite cut by actinolite- and chlorite-filled fractures from the White Hill sub-domain.

Proterozoic basement is overlain by 90 to 150 m of flat-lying Permo-Carboniferous sandstone and diamictite (Boorthana Formation), and Cretaceous sandstone and black claystone (Cadna-Owie Formation and Bulldog Shale respectively). Post-mineral deformation is indicated by an east-west-trending set of reverse faults which have thrust Mesoproterozoic metasomatic rocks over Permo-Carboniferous sediments (Fig. 7). These faults do not extend into the Cretaceous rocks, thus placing timing of the deformation at between ~285 and ~135 Ma (? waning stages of Alice Springs Orogeny; e.g. Haines *et al.*, 2001).

Blue Duck Sub-domain

The Blue Duck sub-domain, which lies immediately to the north of the Neptune sub-domain (Figs. 2a and 2b), is lensoidal, narrowing to both the east and west, although it appears to have been folded around a north-south axis. It is characterised by narrow, medium amplitude magnetic linears which are continuous for several kilometres or more. The repetition of some of these linears is strongly suggestive of east-west- trending fold axes (locally refolded into more northwest- and northeast-trends in the central portion of the sub-domain). Exploration drilling immediately to the north of Prominent Hill has intersected a sequence of schistose, recrystallised K feldspar-biotite-chlorite-quartz-scapolite clastic metasediments, iron-rich, pelitic carbonate rock and possible meta-evaporites. Measurements on parasitic folds from orientated drill core north of Prominent Hill, suggest the sequence has been deformed by tight to isoclinal folds with a moderate westerly plunge.

The central and eastern portion of the linear magnetic anomaly forming the southern boundary of the Blue Duck sub-domain contains the skarn-like magnetite rich metasomatic rocks which were the targets of the first drilling at Prominent Hill. Drillholes on the western side of the sub-domain have intersected marble, calc-silicate, magnetite-pyroxene-quartz rock, carbonaceous rock and phlogopite-clinopyroxene-bearing schists. At least some of the linear magnetic anomalies are metamorphosed calc-silicate units with associated magnetite. Metamorphic grades vary significantly within the metasediments of the Blue Duck sub-domain, from greenschist facies along the southern margin (typically chlorite-serpentine-bearing) to mid-upper amphibolite in the north. This is tentatively attributed to proximity to the large mafic intrusive bodies of the White Hill Complex. The metasediments have been invaded by relatively coarse grained, undeformed intrusions, including massive, altered dolerite northwest of Prominent Hill, and hematite-alkali feldspar altered quartz diorite and intrusive 'dacite porphyry' from the Prominent Hill hanging wall sequence. Contact aureoles, consisting of strongly recrystallised dolostone with schist layers, are evident in drill core on the margins of narrow, late stage, porphyritic dykes (Fig. 6c).

To the northeast of Prominent Hill there is a lens-shaped zone bounded by strong magnetic linears. This zone is characterised by low magnetic intensity, with several weak magnetic lineaments near its centre that are only clearly delineated by filtered aeromagnetic data (Fig. 2a). There is no drilling to basement within this area, although the magnetic signature may be interpreted as representing either a northwest-southeast trending fold axis, or a late intrusion. A drillhole targeting the curvilinear magnetic anomaly on the northern margin of this zone intersected laminated, weakly carbonaceous biotite-quartz schist with metamorphic magnetite. This region is tentatively included within the Blue Duck sub-domain although there is little information available on which to base this correlation.

The metasediments of the Blue Duck sub-domain show lithological similarities to those of the Wallaroo Group in the southern portion of the Gawler Craton, in particular, lithologies of the Wandearah Formation of Yorke Peninsula which include calc-silicate, iron formation and feldspathic metasediments (Cowley *et al.*, 2003). If the inferred age correlation proves correct, the interpreted structure separating hematite- and magnetite-stable alteration at Prominent Hill and also the Neptune and Blue Duck sub-domains (the Hangingwall Fault Zone), marks a regional east-west unconformity between a 1760 to 1740 Ma sequence to the north and 1590 to 1580 Ma rocks to the south. Alternatively, it may simply represent a redox front and metamorphic boundary, with limited disclocation, in which case the host rocks to mineralisation at Prominent Hill are unmetamorphosed representatives of a pre-Gawler Range Volcanics sedimentary sequence.

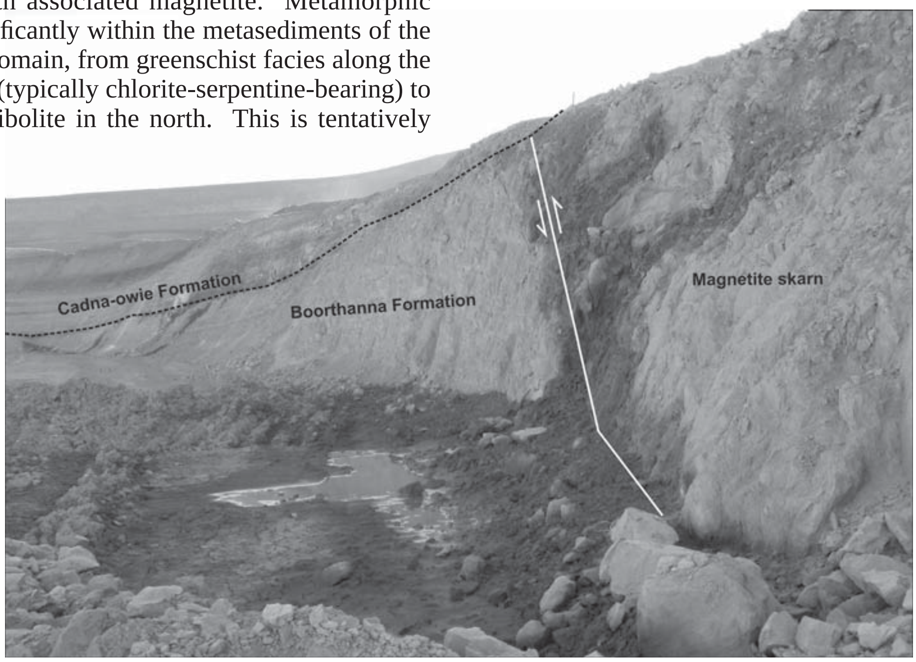


Figure 7: View west of a post-mineral, steep, north-dipping reverse fault exposed in the Prominent Hill open-pit, separating Proterozoic magnetite skarn and Permo-Carboniferous diamictite and sandstone. These faults do not extend into the overlying Cretaceous cover rocks.

White Hill Sub-domain

Many occurrences of definitively hydrothermal iron oxide mineralisation in the southern MWD occur close to the margins of the White Hill sub-domain. This sub-domain, which is the most magnetically distinct of those outlined in this study (Fig. 2a), coincides with rocks belonging to the White Hill Igneous Complex. It has an east-west elongated, broadly ellipsoidal shape, and is characterised by extremely high amplitude magnetic lineaments on its margins, more subtle concentric magnetic zoning in its centre, and a very

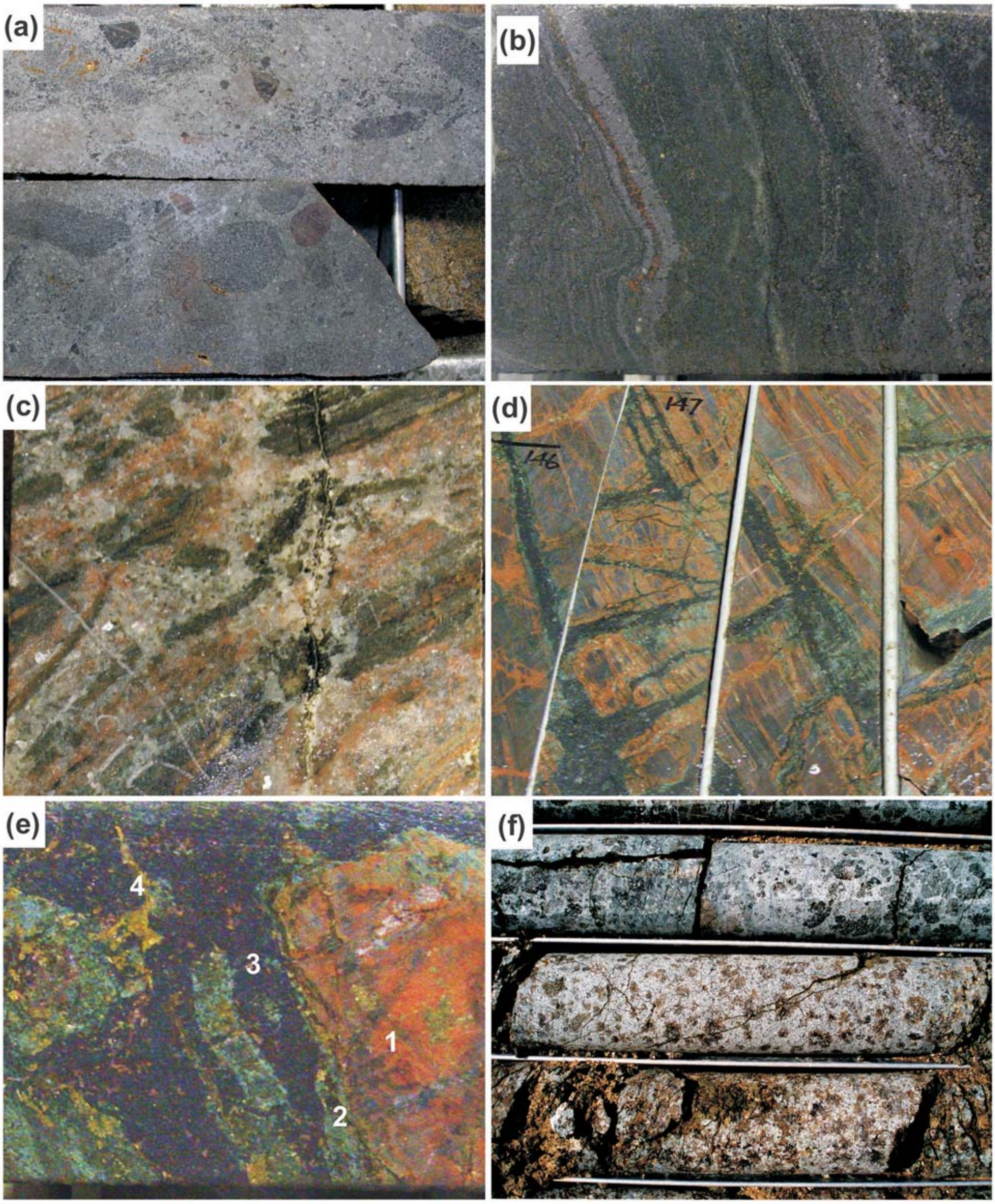


Figure 8: Drill core samples from the Joe's Dam, Skylark, Taurus and northern White Hill sub-domains. All samples are NQ2 (~50 mm diameter) core. **(a)** Hematite breccias from DDHMW6, Manxman B area. Iron oxide is locally recrystallised into coarse grained aggregates and veins. Clasts are pervasively replaced by hematite, indicating that the breccia was clearly polymictic prior to hematisation. **(b)** Laminated magnetite (grey) and quartz-pyroxene-feldspar rock ("BIF") from DDH MW1 on the northern margin of the White Hill sub-domain. **(c)** Albitised calc-silicate gneiss from the Kennedy's Dam sub-domain (hornblende + actinolite + epidote + plagioclase). **(d)** Albitised metasediments (grey-brown) with an early phase of hematite dusted albite veining (orange). These are in turn cut by veins of actinolite and diopside (green) with later massive to coarsely crystalline magnetite as dark grey/black vein fill (Joe's Dam prospect). **(e)** Detailed paragenesis at Joe's Dam: 1. Pervasive albitisation developed in metasediments preserving foliation; 2. Early formed actinolite ± diopside now lying on vein selvages and entirely replacing some clasts; 3. Coarse-grained magnetite infill in the centre of veins; 4. Brecciation of magnetite and very late stage infill by sulphides (pyrite ± chalcopyrite) and biotite/phlogopite? **(f)** Alkaline feldspathic phlogopite-hornblende pyroxenite, interpreted as a pyroxene-cumulate with post-cumulus plagioclase, hornblende and phlogopite, from the Peculiar Knob North prospect.

pronounced and complex gravity signature. Due to the extremely high magnetic susceptibility of some of the lithologies along the northern margin of the sub-domain, the banded nature of the rest of the eastern half of the region is largely obscured, except in filtered magnetic images. The thickness of cover is significantly greater in the central portion (>150 m) compared to the margins (<70 m) of the complex and this has a profound effect on geophysical (particularly gravity) responses.

A variety of iron oxide occurrences have been intersected by drilling into and on the margins of this sub-domain. These include: (1) deformed, laminated magnetite + silicate "BIF"; (2) hematite deposits in gneisses which have been strongly recrystallised during metamorphism; as well as (3) hydrothermal magnetite + silicate ± sulphide vein breccias. Historical drilling along the northern margin of the sub-domain also intersected finely laminated magnetite-quartz-pyroxene rock, characterised by fine-grained magnetite, deformation of laminations (e.g. Fig. 8b) and the presence of quartz and relatively high temperature metamorphic silicates, including pyroxene and amphibole. These rocks have been interpreted to be metamorphosed banded iron formations (Flint and Benbow 1977).

The White Hill Complex has been divided into two zones based on the geometry of aeromagnetic lineaments and irregularities around a north-south zone of disruption, herein referred to as the White Hill Fault (Figs. 2a and 2b). The zone to the east of the fault is characterised by a banded appearance caused by a series of narrow high amplitude magnetic lineaments separated by bands with much lower amplitudes. These bands are reasonably continuous and define a partially circular geometry. Within, and to the west of the White Hill Fault, the banding is still present but is much less continuous and overprinted by more irregular magnetic anomalies with varying trends.

Exploration drilling on the northern margin of the sub-domain intersected pyroxenite, norite and gabbro, with pronounced layering defined by plagioclase and pyroxene-rich layers, with interleaved disseminated to massive magnetite-ilmenite bands (Figs. 6e and 6f). This magnetite is interpreted as primary magmatic oxide, possibly from the preserved upper parts of a layered mafic intrusion. The gabbros and pyroxenites are hydrous, alkaline and enriched in volatile components, as shown by local enrichment in biotite/phlogopite and up to 8% modal apatite. These plutonic lithotypes are interpreted as forming part of a large lopolith like intrusion, the White Hill Igneous Complex. Measurements from oriented drill core confirm that overall, phase layering in the cumulate rocks is moderate to shallow dipping inwards towards the centre of the sub-domain, thus forming a large synformal or "basin" structure. The central, circular, non-magnetic (and gravity low) zone coincides with weakly altered, layered troctolite cumulates, with alternating olivine and plagioclase rich bands, and anorthosite. The rocks are largely undeformed and unmetamorphosed. Similar mafic rocks have also been intersected in drilling at the Joe's Dam and Manxman prospects in the southern portion of the Joe's Dam sub-domain (Figs. 2a and 2b).

Joe's Dam Sub-domain

Drillholes into the Joe's Dam sub-domain have encountered a suite of quartzo-feldspathic gneisses with intercalations of magnetite rich gneiss, and very few intersections of mafic material, supporting the contention that the well banded nature of the magnetic signature in the White Hill sub-domain is related to mafic intrusions which are not as abundant to the west.

The magnetite and hematite breccias and replacement bodies in the Joe's Dam sub-domain are developed in psammitic, pelitic and gneissic metasediments of higher metamorphic grade than those in the Neptune, Blue Duck and White Hill sub-domains. The voluminous Balta-aged magmatism (Hiltaba Suite) in the area cannot be dismissed as a potential cause of high temperature contact metamorphism of the pelites.

Skylark Sub-domain

The Skylark sub-domain lies to the northwest of the Joe's Dam and Kennedy's Dam sub-domains. In general, its magnetic signature, which is different to that of any of the other sub-domains, is typical of relatively high grade metasediments with elevated magnetite contents, although it does not appear to contain lithotypes that are dominantly composed of magnetite (i.e., banded iron formation). The aeromagnetic signature also suggests it contains numerous intrusions. Minor outcrop near Peculiar Knob consists of Balta Suite granite with actinolite ±magnetite veins. Drillholes in the Skylark sub-domain have intersected a variety of quartz+feldspar+biotite gneisses, all with accessory magnetite, and mafic to ultramafic igneous rocks. Metasediments include quartz-rich metasandstone with plagioclase, opaque oxide (magnetite and hematite), schistose biotite, fluorite and tourmaline.

The Skylark sub-domain is characterised by large intrusions with low to moderate magnetic responses, surrounded by narrow aureoles of higher magnetic intensity related to either hornfelsing or magnetite metasomatism. Drillholes several kilometres north of Peculiar Knob intersected pyroxenites, norites and diorites which are highly unusual in containing up to 40% phlogopite mica (Fig. 8f). These mafic and ultramafic rocks do not directly subcrop beneath the cover but are overlain by metasandstone. They are mostly undeformed, although some phlogopite bands do show local cleavage development. This suite of rocks has a U-Pb zircon age of 1587±4 Ma (Jagodzinski, 2005).

The sub-domain is also characterised throughout by large magnetic and gravity anomalism (Fig. 2a), possibly indicating that it is underlain by voluminous mafic and ultramafic igneous masses similar to the White Hill Igneous Complex. The relationship between the mafic/ultramafic rocks of the Skylark sub-domain and those in the White Hill Igneous Complex is not known, but they share a number of distinct similarities including their alkaline composition, hydrous and volatile-rich assemblages, their undeformed character, and the presence of pyroxene ± magnetite alteration veining without red alkali feldspar-hematite selvages.

Outside the limits of this study, aeromagnetic data shows that the northwest boundary of the Skylark sub-domain coincides with the Panorama Fault of Betts *et al.* (2003).

Kennedy's Dam Sub-domain

The area immediately to the north of the White Hill sub-domain appears to comprise a single sub-domain (Kennedy's Dam), cut by an approximately east-west trending structural break. This break divides zones characterised by relatively low magnetic susceptibility enclosing a few moderate to high amplitude, linear magnetic anomalies. These linear anomalies define a large scale doubly plunging fold with an original east-west trending axis that has now been dragged in a clockwise (dextral) sense into the Taurus sub-domain

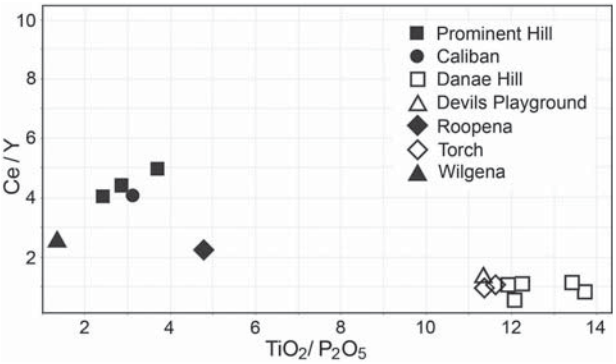


Figure 9: Immobile trace and REE ratio comparison between basalts of the Neptune Volcanics (Prominent Hill and Caliban), the Danae Hill Metavolcanics (Danae Hill and Torch), the late Archaean Devils Playground Volcanics and other Mesoproterozoic basalts of the Gawler Craton (Roopena and Wilgena). The data show that volcanics from the Danae Hill and Torch prospects exhibit greater similarities to the Devils Playground basalts than basalts of the Lower Gawler Range Volcanics. Data are from Table 1.

at its eastern end. The contact between the White Hill sub-domain to the south and the Kennedy's Dam sub-domain appears to have been partially folded.

A number of drillholes have penetrated basement in this sub-domain, intersecting a sequence of quartz-feldspar biotite-magnetite gneisses and "granulites" with very minor amphibolite and calc-silicate units, intruded locally by coarse grained granite and pegmatite. Minor magnetite veining or alteration is reported in a few of these holes.

Taurus Sub-domain

This narrow, northwest-southeast trending sub-domain is bounded to both the southwest and northeast by long strike length magnetic discontinuities, interpreted to represent major shear zones and faults. In the detailed filtered aeromagnetic image of the southern MWD, the Taurus sub-domain comprises a series of short strike length curvilinear magnetic anomalies which are terminated both to the east and west by major discontinuities. It appears to truncate the Blue Duck, Kennedy's Dam and Ware's

Table 1: Major and trace element data for samples of relatively unaltered basalts from the Neptune Volcanics (Caliban, Proteus, Triton, Prominent Hill) and Danae Hill Volcanics (Danae Hill and Torch prospects). Data from PIRSA geochemical database, Flint (1993) and this study.

Sample	346795	368299	369023	369028	345862	345887	345894	13770	9805	N/A	365101	310086	365147	365311	365397
Location	*Torch*	*Torch*	*Danae Hill*	*Danae Hill*	*Danae Hill*	*Danae Hill*	*Danae Hill*	*Devils Playground*	*Wilgena-1*	*Roopena*	*Caliban Prospect*	*Prom. Hill*	*Prom. Hill*	*Prom. Hill*	*Prom. Hill*
SiO_2	47.1	48.1	46.8	46.3	47.6	43.1	43.1	47.5	45.3	47.7	45.9	46.6	48.9	47.1	46.2
TiO_2	2.16	1.98	2.32	2.55	1.65	1.43	1.21	0.34	0.82	1.52	1.06	0.56	1.25	0.61	0.80
Al_2O_3	12.5	11.5	13.1	13.9	13.4	12.6	13	13.5	16.8	15.41	13.4	17.7	13.5	18.3	10.9
Fe_2O_3*	15.40	13.50	15.80	14.90	12.80	11.90	15.70	9.55	6.80	12.70	13.30	9.37	10.90	10.00	9.37
MnO	0.25	0.24	0.33	0.26	0.20	0.26	0.27	0.17	0.19	0.21	0.49	0.45	0.40	0.35	0.14
MgO	4.89	4.26	4.89	6.93	6.95	10.40	9.06	7.50	5.57	5.88	3.15	4.85	5.34	3.01	14.20
CaO	10.70	10.80	9.23	9.22	9.00	5.14	4.65	7.55	7.10	6.22	6.29	4.83	5.23	4.83	8.30
Na_2O	1.80	1.86	3.48	2.70	2.63	1.31	1.43	2.30	1.24	2.34	0.10	3.50	2.97	2.79	1.44
K_2O	0.66	0.73	0.82	0.62	0.18	0.62	1.40	0.71	4.72	2.61	3.83	1.65	1.23	2.80	2.56
P_2O_5	0.19	0.17	0.19	0.19	0.12	0.12	0.10	0.03	0.60	0.32	0.34	0.15	0.44	0.17	0.33
LOI	3.92	5.79	2.66	2.06	5.85	12.00	10.20	9.70	9.80	5.55	11.60	10.20	10.40	10.40	5.48
Rb	15	19.5	18.5	21	3.5	15.5	24	16	NA	69	170	52	30.5	94	120
Ba	190	145	250	200	100	120	195	210	1280	590	950	450	500	1550	1350
Th	36.5	32	38	29	27.5	22.5	24	2	24	9	33	18	32	18	80
U	8	20	42	42	2	2	2	2	4	2	2	2	5	6	2
Nb	6	4	7	6	3	2	1	7	21	8	9	2	12	3	62
Ta	1	1	1	1	1	1	1	NA	NA	NA	1	1	1	1	4
La	13	12	11	11	33	18	11	20	73	65	47	600	47	125	84
Ce	31	30	33	28	20	20	11	20	116	100	115	74	120	220	270
Pb	6	16	92	58	12	3	12	5	45	16	10	5	5	15	3
Sr	290	230	185	210	210	30	66	65	443	214	44	230	165	210	650
Nd	18.5	19.5	20.5	18	13.5	11.5	7.5	NA	NA	NA	38.5	24.5	43.5	43	140
Sm	5	5.5	5.5	4.5	4	3	2.5	NA	NA	NA	7	4	7.5	5	31
Zr	110	100	120	90	80	60	50	95	302	144	130	50	160	60	170
Hf	3	2	3	2	3	2	2	NA	NA	NA	3	3	4	2	5
Tb	0.5	0.5	0.5	0.5	0.5	0.25	0.25	NA	NA	NA	0.5	0.25	0.5	0.25	2.5
Y	31	27	32	24	23	19	20	15	45	44	28	15	27	15	66
Yb	3	3	3	2	2	2	2	NA	NA	NA	3	1	3	2	4
Pr	4	4	4	4	3	2	1	NA	NA	NA	10	7	11	15	30
Eu	2	2	2	2	1.5	1	1.5	NA	NA	NA	2	1.5	2	3	6
Gd	4	4	5	4	3	3	2	NA	NA	NA	5	3	5	4	20
Dy	5.5	5	6	4.5	4	3	3.5	NA	NA	NA	5	2.5	5	3	14
Ho	1	1	1	0.5	0.5	0.5	0.5	NA	NA	NA	0.5	0.25	0.5	0.25	1.5
Er	3	3	3	2	2	2	2	NA	NA	NA	2	1	3	1	5

* Total Fe expressed as Fe_2O_3

Peak sub-domains, and displays many features suggesting it is caught up between a major shear couple, components of which now form its western and eastern boundaries. Rotation of linear anomalies in adjacent domains indicates that a large component of strike slip movement has been accommodated across the Taurus sub-domain. There is a distinct possibility that it represents a sidewall ramp to a thrust or series of thrusts now delineating the northern boundaries of the other sub-domains.

Danae Hill Sub-domain

Mineral exploration in 2002 identified an area 20 to 30 km east of Prominent Hill characterised by discreet aeromagnetic anomalies and a large, positive gravity signature. The anomalies within this area were targeted on the basis of being a possible repeat of the Neptune Volcanic stratigraphy which hosts the Prominent Hill mine lying on the eastern side of the craton-scale, northeast trending Bulgunnia Fault (Figs. 2a and 2b). The region is characterised by a similar magnetic signature to the Neptune Volcanics, with low to moderate amplitude aeromagnetic linears. The aeromagnetic character of large parts of the sub-domain is complicated by the effects of cover. As with the Neptune sub-domain it does not appear to have been intruded by large granite or mafic bodies with distinct magnetic haloes. There are a number of narrow northwest-southeast trending aeromagnetic lineaments, interpreted as ca. 800 Ma Gairdner Dykes.

Drilling at the Danae Hill and Torch prospects (Fig. 2b) has identified a suite of altered, low-grade metamorphosed, sheared and brecciated basalts, with lesser metasediments and acid volcanic rocks, which collectively suggest a bimodal volcanic suite. While the age of the volcanic rocks remains uncertain, major and trace element geochemical comparisons with the Neptune Volcanics shows marked differences (Table 1). In particular, the Danae Hill metabasalts have more tholeiitic compositions, indicated by high iron and titanium concentrations, lower LREE and flatter REE patterns, relative to the Neptune Volcanics. This, combined with metamorphism to mid- to upper-greenschist facies, suggests that the Danae Hill Metavolcanics are likely older than the ca. 1590 to 1580 Ma Neptune Volcanics. If correct, this could make them either Archaean (i.e., Devil's Playground equivalent, 2558±6 Ma; Cowley and Fanning, 1991) or Palaeoproterozoic in age. A comparison of immobile REE and trace element data suggests some similarity to the former (Fig. 9), although previous workers have described the Devil's Playground Volcanics as a calc-alkaline suite.

Low temperature veins and alteration assemblages, comprising albite-carbonate-quartz-chlorite-leucoxene-sericite-epidote, cut the volcanic rocks at Danae Hill. Based on the mineralogy, temperatures of alteration are predicted to be in the range 250 to 350ºC. Copper-lead-zinc mineralisation also occurs in association with shear zones in acid volcanic rocks and slates at Danae Hill, where sphalerite, chalcopyrite, pyrite and galena are found in carbonate-quartz and adularia veins.

Ware's Peak Sub-domain

This large and relatively complicated sub-domain is located east of the Taurus sub-domain (Figs. 2a and 2b). It is characterised by a few high amplitude, strike continuous, but folded magnetic linears, and by large areas of diffuse magnetic signature suggesting moderately magnetic and eastward deepening younger cover. The Eagle and Brandish base metal prospects occur on the northern extension of this zone, beyond the detailed aeromagnetic coverage presented in this paper. Large scale fold closures are evident in the major magnetic linears within the Ware's Peak sub-domain. These show varying orientations, with the principal fold axes trending northwest-southeast through the centre of the domain. Close to the southern and western boundaries with the Taurus sub-domain, curvilinear, elongate, bifurcating aeromagnetic features suggest tight folds with axes sub-parallel to the bounding structure.

The only drilling within the Ware's Peak sub-domain has been concentrated around the Blaze, Armstrong and Fire in the Sky prospects (Fig. 2b). Holes at these prospects intersected a highly variable suite of magnetite, plagioclase and garnet bearing paragneisses (including graphite rich units), as well as feldspathic and quartz-poor to quartz-rich meta-igneous lithologies (including quartz diorite, monzodiorite, syenite, granite and pegmatite). Other samples seem to represent metasandstone, iron formation, calc-silicate, skarn, dolomite and marble units. Undeformed granite and gabbroic intrusions have also been identified in drilling. Metamorphic grades range from mid-amphibolite to granulite facies.

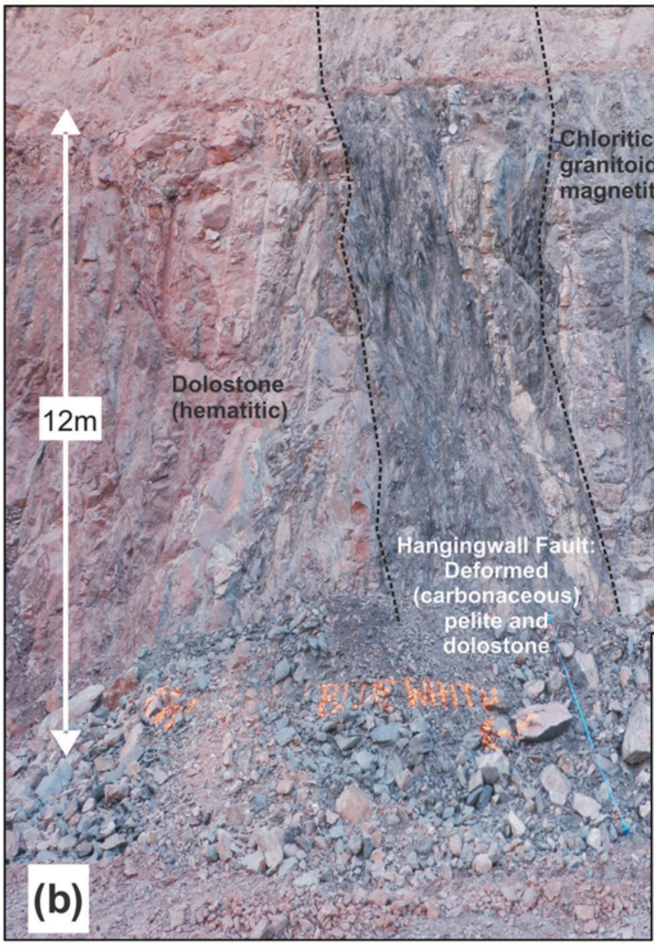
Prominent Hill

The Prominent Hill deposit is hosted within the Neptune sub-domain (Figs 2a and 2b), which incorporates a sequence of sedimentary and volcanic rocks displaying low- to mid-greenschist facies metamorphism. The geological characteristics of the deposit have been described in detail previously (Belperio and Freeman 2004; Belperio *et al.* 2007) and are only briefly reviewed here. The actual host rocks to the mineralisation comprise a series of interbedded sandstones, siltstones, coarse grained breccias and dolostone within the northern portion of the Neptune sub-domain (Figs. 3 and 11).

Global reserves and resources at the deposit as of May 2010 stood at: 278.8 Mt @ 0.98% Cu, 0.75 g/t Au and 2.5 g/t Ag.

The deposit comprises several phases of hematite alteration with associated sericite, clay minerals and chlorite, hosted by a sequence of northerly dipping breccias in the immediate footwall to the transition from the Neptune to Blue Duck sub-domains (marked by a relatively brittle, steep northward dipping fault, known as the Hangingwall Fault Zone in the mine - Figs. 3, 10a, 10b and 11). Magnetite is absent in the breccias which host the mineralisation but to the north of the deposit, and separated from it by components of the Hangingwall Fault, is a body of massive magnetite with associated, pyrite, actinolite, phlogopite, chlorite, serpentinite, carbonate and talc (magnetite "skarn" - Figs. 3 and 11). This body is very poorly mineralised in copper and gold and its relationship to the Prominent Hill orebody immediately to the south is not understood. Copper, gold, uranium and REE mineralisation is relatively late stage and overprints at least one phase of massive hematite replacement of the breccias.

The deposit and associated iron alteration defines a discrete gravity anomaly (which was the target of the discovery drillhole, (Carter *et al.* 2003). The gravity feature is associated with, but offset from, a magnetic anomaly related to the magnetite body in the hanging wall (Hart and Freeman 2003). The gravity anomaly is related to the hematite alteration associated with mineralisation and corresponding palaeotopographic highs.



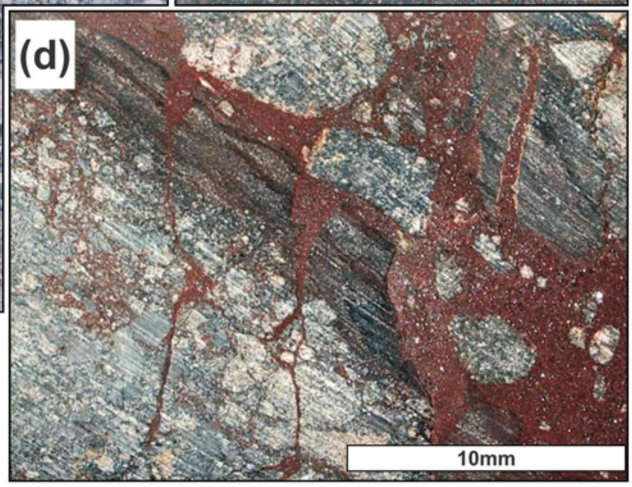


Figure 10: Prominent Hill pit geology and drill core samples **(a)** View from the south of the stage 1 pit, outlining cover units, basement domains and structures. **(b)** View looking west at Hangingwall Fault Zone. The fault separates earthy-hematite altered dolostone (left) from chloritic breccia (right). Kinematic indicators suggest reverse movement. **(c)** Graded bedding demonstrating fining upwards in hematitic breccia. Note small thrust-like pop-up in the top-centre. The apparent movement sense of the micro-structures indicate reverse movement and hence layer-parallel compression. **(d)** Original fragmental sediment and laminated shaly interbeds which have undergone progressive brecciation with hematitic infill.

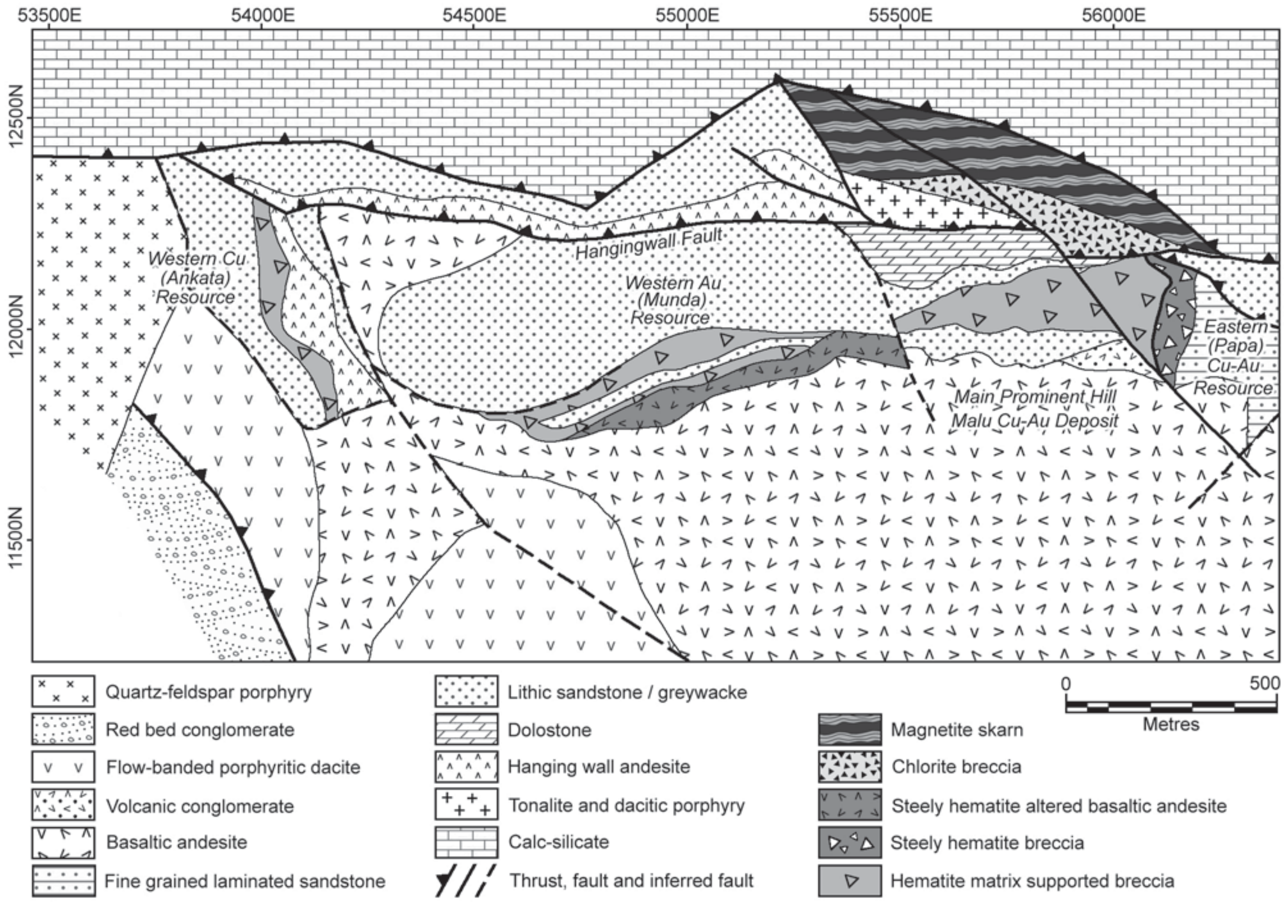


Figure 11: Simplified geological map of the Prominent Hill deposit area below the Phanerozoic cover, based on extensive drilling. The main copper-gold bearing clastic and shelf carbonate sequence is located between metamorphic calcsilicate and metasomatic skarn rocks to the north, and unmetamorphosed but strongly altered, volcanic rocks to the south. The main copper-gold ore is hosted by the hematite matrix supported breccias, while the steely hematite breccias contain variable gold (compare with Fig. 4). The location of the principal resource blocks (Main Prominent Hill Cu-Au, Eastern Cu-Au, Western Au and Western Cu) which lie within these breccias are indicated.

The intense hematite alteration within the coarse grained breccias is locally texturally destructive and this has inevitably led to varying interpretations as to their origin. A recent re-evaluation of the breccias has shown that they originated as a sequence of very coarse to fine-grained, laminated, clastic sedimentary rocks, that have been subject to later hydrothermal replacement with only minor additional brecciation during metasomatism. Distinctly bedded breccias, with bedding defined by the alignment of clasts and by grading, occurs over intervals to ~5 to 10 m within more massive, non-layered, poorly sorted hematite-matrix breccia.

In the open pit, individual bodies of breccia occur as a series of strata-bound, steeply dipping, tabular east-west trending sheets and westerly plunging shoots, collectively bound to the north by dolostone/Hangingwall Fault Zone and to the south by volcanic rocks. At the Western Copper deposit the stratigraphy, which includes mineralised hematite breccia and carbonaceous rocks, appears to be complexly folded.

The host sequence rocks are intensely altered by hematite + sericite + chlorite + carbonate (± quartz ± barite ± fluorite ± REE phosphates). Copper mineralisation occurs as fine grained disseminations of chalcocite, bornite and chalcopyrite in the breccia matrices and (to a lesser extent) in clasts. The copper sulphides display a variety of intergowth, replacement and infill textures including chalcocite-bornite symplectites and replacement of early formed pyrite.

The current weight of evidence indicates that the Prominent Hill mineralisation originated through relatively passive infiltration of hydrothermal fluids and metasomatism localised by porosity within a sequence of coarse grained sedimentary breccias. The amount of brecciation that can be attributed to hydrothermal processes is unclear. The copper and gold mineralisation can be shown to be paragenetically very late in the sequence and a direct genetic relationship between the copper and gold and the hematite is not proven. Geochemical trends suggest a strong relationship between gold mineralisation (in the copper-rich zones of the deposit) and REE phosphates.

Other Hematite Deposits & Prospects

Triton Prospect

The Triton prospect comprises a cluster of three gravity highs and one low amplitude magnetic anomaly, approximately 2 km south of Neptune (Fig. 2). The gravity anomalies were first identified by Minotaur Resources and drill testing of the main anomaly resulted in intersections of strong albite-hematite-chlorite-sericite-leucoxene alteration in undeformed porphyritic and vesicular andesite and basalt. Mineralisation in these holes includes up to 0.3% Cu and 26 m @ 0.18g/t Au.

To the southwest of the main gravity anomaly, a more subtle gravity feature coincides with a moderate amplitude magnetic high. Drill holes at this locality intersected strongly altered amygdaloidal basalt and hydrothermal magnetite-hematite breccias. The breccias are hosted

Table 2: Major iron oxide (copper-gold) deposits and prospects of the southern Mount Woods domain.

Prospect/ Deposit	South MWD sub-domain	Host Rocks	Metamorphism	Iron oxide(s)	Alteration	Mineralisation
Prominent Hill	Neptune	Conglomerate, hematite breccia, greywacke, shale, quartz diorite, basalt, andesite	Lower greenschist	Hematite (Magnetite in low grade hanging wall)	Sericite, chlorite, carbonate, quartz/silica, barite, fluorite, apatite, florencite, leucoxene Albite, K feldspar, phlogopite, tremolite, talc (HW)	Chalcocite, bornite, chalcopyrite, pyrite, uraninite, coffinite, native Au 278.8 Mt @ 0.98% Cu, 0.75 g/t Au (incl. Western Cu), ~80 ppm U, ~32% Fe
Neptune	Neptune	Basalt, andesite	Lower greenschist	Magnetite (>>hematite - late)	K feldspar (hematite dusted), quartz, albite, leucoxene, apatite, carbonate, minor late sericite + chlorite + fluorite	Pyrite > chalcopyrite e.g. 287 m @ 0.14% Cu, 0.02 g/t Au. 18% Fe
Triton	Neptune	Basalt, andesite, rhyolite, conglomerate	Lower greenschist	Hematite (north) Magnetite, martite (south)	Albite, chlorite, sericite, leucoxene-carbonate-fluorite (NW) K feldspar/sericite, quartz, chlorite, barite, fluorite, carbonate, apatite (SE)	Pyrite > chalcopyrite e.g. 24 m @ 0.35% Cu, 0.18 g/t Au, 6 m @ 0.9% Cu, 0.47 g/t Au, 5 g/t Au and 100 ppm U.
Caliban	Neptune	Fine grained sandstone, conglomerate, basalt, breccia	Lower greenschist	Hematite	Sericite, chlorite, carbonate, leucoxene	Chalcopyrite, pyrite e.g. 14 m @ 0.56% Cu, 0.24 g/t Au, 21% Fe
Proteus	Neptune	Phyllite, impure carbonate, sandstone, siltstone, conglomerate, andesite, basalt	Lower to upper greenschist	Hematite / Goethite	Quartz-sericite-chlorite-carbonate	Bornite, chalcopyrite e.g. 10 m @ 0.57% Cu, 0.23 g/t Au, ~10% Fe
Joe's Dam	Joe's Dam	Quartzo-feldspathic, pelitic metasediment, gabbro	Amphibolite	Magnetite (-hematite)	Albite, actinolite, scapolite, diopside, apatite, quartz, chlorite, epidote, biotite, K feldspar, fluorite ± sericite (Hampton, 1997)	Pyrite, chalcopyrite, pyrrhotite, arsenopyrite 186 m @ 0.13% Cu, 38% Fe
Manxman A1	Joe's Dam	Gneiss, "granulite", granite, pegmatite, pelite, dolostone	Amphibolite	Magnetite (-hematite)	Albite, ferro-actinolite, scapolite, diopside, biotite, chlorite, apatite, epidote, allanite, quartz, biotite, K feldspar, carbonate, fluorite (Hampton, 1997)	Pyrite, chalcopyrite, pyrrhotite, uraninite 287 m @ 0.23% Cu, 32% Fe[+]
Manxman B	Joe's Dam	Gneiss, granodiorite, pegmatite	Amphibolite	Massive, coarse grained hematite. Mushketovite	Quartz-tourmaline	Fe to 48%, trace pyrite
Peculiar Knob	Skylark	Magnetite bearing gneiss, meta-igneous rock	Amphibolite to granulite	Specularite	Hydrothermal enrichment of Fe in metamorphosed BIF.	19 Mt @ 63.7% Fe*
Taurus	Taurus	Graphic schist, dolomite, metasandstone, gabbro, granite	Amphibolite	Magnetite (hematite – early dusting)	Albite, K fedspar, scapolite, diopside, ferro-actinolite, calcite, epidote, quartz, apatite, serpentine, phlogopite, biotite	Broad intervals of 0.1 - 0.2% Cu, ~25% Fe and PGE (e.g. 146 m @ 0.5 g/t Pd+Pt, 28% Fe)
White Hill	White Hill	Gabbro, norite, anorthosite, pyroxenite	Upper greenschist to amphibolite	Titano-magnetite	Amphibole after pyroxene, albite, sericite, epidote	Fe up to 53%
Danae Hill	Danae Hill	Bimodal metavolcanics, tuff and slate	Upper greenschist	-	Actinolite-albite-chlorite-epidote-leucoxene ± quartz ± sericite	Anomalous Cu (to ~0.2%), Pb (to ~0.1%) and Zn (to ~0.5%)

***** Data from Western Plains Resources website (http://www.westernplainsresources.com.au/projects-peculiar-knob.html). [+] Drillhole 88EN43 (CRA Exploration) entirely within volcanic rocks and contain fragments composed variably of quartz, barite, fluorite, hematite± chlorite, and chalcopyrite in a matrix rich in magnetite± hematite±fluorite±chlorite±barite±chalcopyrite. The breccia fragments appear to be of lower temperature than the enclosing matrix.

Sulphide mineralisation at Triton occurs in four main styles: (1) Magnetite+hematite matrix breccia containing matrix sulphides (chalcopyrite±pyrite); (2) Volcanic rocks pervasively replaced by abundant disseminated magnetite ±pyrite±chalcopyrite; (3) Calcite+barite+fluorite+ hematite +chalcopyrite veins; and (4) Chalcopyrite pyrite+calcite +fluorite infill of amygdales.

Geochemical anomalism is typical of other iron oxide copper-gold systems on the Gawler Craton and includes Ba to 9.5%, U to 129 ppm and LREE to 3600 ppm (Ce+La).

Proteus and Caliban Prospects

Proteus (~2 km north of Neptune) and Caliban (1.5 km east of Prominent Hill; Fig. 2b) are both hematite dominant alteration systems, associated with moderate amplitude gravity anomalies, with no obvious association with metasomatic related magnetic anomalies. Both prospects occur along the east-west trending boundary between the Blue Duck (north) and Neptune (south) sub-domains, although mineralisation is mainly confined to sedimentary and volcanic sequences of the latter.

Strong hematite alteration at Proteus occurs in dolostone and andesite. Sedimentary rocks include sandy-siltstone and greywacke with a quartz-sericite-chlorite assemblage, resembling that of the host sediments at Prominent Hill. Mineralisation occurs in chlorite-hematite-matrix fault breccia (10 m @ 0.57% Cu and 0.23 g/t Au with anomalous Ag, U) in the carbonate rock, and hematite-bornite veins in greywacke (up to 0.6% Cu). Late dolerite dykes which crosscut the Proteus area are presumed to belong to the Neoproterozoic Gairdner suite.

Mineralisation at Caliban is similarly hosted by hematite veined and brecciated coarse grained greywacke, although fine grained, laminated, oxidised sandstone is also present and dips ~30ºS. Narrow hematite breccia zones are matrix rich and exhibit strong layering. Porphyritic and fragmental volcanic rocks from Caliban are petrographically similar to those found in the footwall at Prominent Hill.

Peculiar Knob Deposit & Manxman B Prospect

The coarse-grained Peculiar Knob specularite deposit (19 Mt @ 63.7% Fe; Western Plains Resources website, 2009) lies on the southeastern boundary of the Skylark sub-domain (Fig. 2b). The mineralisation takes the form of coarsely recrystallised hematite. Information from outcrop and exploration drilling suggests that the deposit lies close to the margins of felsic and mafic intrusions. It is hosted within magnetite gneisses and is a tabular, <50 m thick body, occurring in two separate, moderately northwest dipping lenses (Chalmers, 2007). Based on textural evidence of the hematite, it is interpreted to represent a metasomatic iron enrichment of early metamorphosed banded iron formation.

At Manxman B (diamond drillholes DDHMW6 and DD86EN38), hematite bearing gneisses have been intersected in which the hematite is present as bands parallel to gneissosity, and as larger accumulations of massive iron oxides. The gneisses have been intruded by a variety of quartz veins (some with coarse grained tourmaline), pegmatites (which, in places, display graphic intergrowths of quartz+feldspar+hematite), and fine grained aplitic dykes. These features collectively suggest that drillholes lie close to the margins of a felsic intrusion, an interpretation in keeping with the aeromagnetic signature. In both drillholes, the hematite bodies are magnetic to some degree suggesting that the hematite is intergrown with either magnetite or maghemite. In DD86EN38, some of the hematite displays mushketovite textures (magnetite pseudomorphing bladed hematite), which could reflect either hydrothermal alteration or contact metamorphism. In both drillholes, the hematite is coarse grained to steely, and displays total recrystallisation. Typically there is no evidence of a deformational fabric in this hematite which seems to have been recrystallised under conditions of low stress (i.e., contact metamorphism). In DDHMW6 the hematite has replaced a breccia with little or no evidence remaining of any form of open space fill (Fig. 8a). The hematite bodies intersected in both of these drillholes closely resemble the mineralisation at Peculiar Knob to the northwest, and contain little sulphide.

Magnetite Prospects

Neptune Prospect

The Neptune prospect lies approximately 6 km southwest of Prominent Hill and is defined by westnorthwest-trending gravity and magnetic highs (Fig. 2). Burmine Limited and Normandy collectively drilled four holes into the coincident magnetic and gravity anomalies in the period 1990 to 1993 (Carter *et al.*, 2003). Minotaur Resources drilled one vertical hole into the modelled peak of the gravity anomaly in 2001. All holes intersected alkali feldspar+magnetite (±apatite±fluorite±chlorite±carbonate±hematite) altered and brecciated basalt, andesite and minor felsic volcanic rocks. Potassic feldspar is commonly reddened by very fine grained hematite. Broad intervals of strong magnetite alteration contain anomalous to low grade copper mineralisation with minor zones of higher grade restricted to narrow, matrix-supported, magnetite rich hydrothermal breccias.

Four generations of secondary iron oxides have been identified at Neptune. These include: (1) Fine granular magnetite, enriched in basaltic protoliths; (2) Coarse granular magnetite, mostly in later hydrothermal 'mineralisation', some partly converted to hematite; (3) Magnetite, partly to completely replacing earlier, randomly clustered, bladed hematite (mushketovite); and (4) 'Fresh', randomly clustered, bladed hematite. These generations represent fluctuations in oxygen fugacity during hydrothermal alteration. Dominant sulphides are pyrite and chalcopyrite, with very minor, apparently 'supergene' chalcocite occurring immediately beneath the Phanerozoic-Proterozoic unconformity in one drill hole. The gold tenor is generally poor.

Joe's Dam and Manxman A1 Prospects

The magnetite replacement/breccia complexes at Joe's Dam and Manxman A1 are hosted within the Joe's Dam sub-domain (Fig. 2b). These breccias are largely developed in a sequence of pelite, banded quartzo-feldspathic gneiss, magnetite bearing gneiss and hematite altered gneisses that have been invaded by both undeformed, coarse grained granites and gabbroic intrusions.

The breccias display many characteristics common to the magnetite associated IOCG class of deposits. In particular, the alteration paragenesis shows strong similarities to that described from Mount Elliot in the Cloncurry district, Queensland (Wang and Williams, 2001). This includes (Fig 8d and 8e): (1) Early Na metasomatism, in the form of (grey-white) albite alteration as pinnate selvages extending from brittle fractures; (2) Hematite dusting of alkali feldspar; (3) Reopening of the same fractures and open space fill of diopside, actinolite-tremolite and minor magnetite; (4) Further reopening of existing fractures and development of new fractures infilled with massive magnetite (with local pinnate magnetite alteration selvages developed out from new fractures); and (5) Late stage re-brecciation of the magnetite fill and deposition of biotite and/or K feldspar with pyrite and chalcopyrite, and anomalous Au.

Both of these systems are dominated by vein and breccia-fill with localised magnetite replacement extending out from veins as pinnate selvages. They largely reflect hydrothermal infill of brittle, open space fractures. The components of this style of mineralisation are largely undeformed and unmetamorphosed. The structures controlling the vein breccias remain enigmatic although the Joe's Dam breccia complexes lie close to the White Hills Fault and Manxman A1 is thought to occur in the nose of an F_2 fold. Hampton (1997) discusses both of these prospects in detail.

Taurus Prospect

The Taurus prospect occurs on the eastern margin of the sub-domain of the same name and comprises coincident northwest-trending gravity and high amplitude magnetic anomalies northeast of the White Hill Igneous Complex. Interpreted as a fault/shear splay, Taurus is one of the most significant standalone magnetic features in the southern MWD. Its geological architecture consists of a steeply dipping, variably sheared, sequence of mafic and metasedimentary rocks. Host lithologies include granite, felsic gneiss, pelitic and graphitic schist, dolostone, metabasalt, mafic "pegmatite" and gabbro (Freeman, 2008).

Broad, low-grade copper-iron and palladium-platinum mineralisation is associated with zones of massive magnetite replacement, vein breccias and coarse grained mafic intrusive rock which share many similarities to the Joe's Dam and Manxman magnetite breccias of the Joe's Dam sub-domain, namely: (1) Na metasomatism, defined by scapolite and albite; (2) Ca metasomatism, reflected by diopside and actinolite; (3) Fe metasomatism and mineralisation defined by magnetite, pyrite, chalcopyrite, pyrrhotite, apatite and titanite; and (4) Post mineralisation alteration defined by pyrite, apatite, quartz, calcite, hematite and epidote. The iron-rich Stage 3 (the main mineralising event) occurs as relatively flat lying seams, and sub-horizontal vein arrays suggesting a component of vertical extension and possible north-south or east-west shortening (Freeman, 2008).

Summary and Conclusions

- Based on aeromagnetic signature, gravity data and results of widely spaced diamond and RC drilling over the last thirty years, it is possible to divide the southern portion of the Mount Woods Domain into a series of geological sub-domains. Each is characterised by unique lithological, structural, metamorphic and hydrothermal features, although some sub-domains share certain characteristics, such as later stage deformation histories, suggesting that they were juxtaposed during the later stages of the main deformation events that have affected the MWD.
- The relationships between the various sub-domains are as yet undetermined. Their boundaries are in all cases at least partly tectonic, and their original disposition prior to deformation and metamorphism is uncertain.
- The Prominent Hill iron oxide copper-gold deposit was developed in close proximity to the major fault separating the Neptune and Blue Duck sub-domains, occurring on the northern margin of the former. The deposit is hosted largely in sandstones and dolostones at the structural top of the volcano-sedimentary package dominating the Neptune sub-domain (Neptune Volcanics).
- Graded bedding, intercalated fine grained red shaly layers, coarse clastic debris flows, and clast supported conglomerate layers all suggest the Prominent Hill deposit is hosted within a sequence of oxidised clastic sediments. These have been overprinted by later hydrothermal features such as brecciation and intense hematite alteration. Volcanic rocks are a minor host to mineralisation.
- Previous interpretations suggesting that many of the breccias hosting the mineralisation at Prominent Hill are of hydrothermal "diatreme origin" may not be wholly correct. If the breccias are hydrothermal in origin, then the current vertical disposition of their "layering" and "grading" suggests that the deposit has been tilted into is current steep attitude subsequent to the hydrothermal activity, and that brecciation took place when the bedding was originally flat lying.
- Coarse grained hematite (±magnetite) bodies occur within the Joe's Dam and Skylark sub-domains (e.g., the Peculiar Knob deposit). These bodies show evidence of having formed by metamorphism of pre-existing hematite mineralisation, with partial conversion of hematite to magnetite and the formation of mushketovite. The largely undeformed nature of the recrystallised hematite suggests this process occurred through contact metamorphism around Balta (Hiltaba Suite) intrusions.
- The southern portion of the MWD is host to a number of large magnetite vein/breccia complexes hosted predominantly within the Joe's Dam sub-domain, with the exception of the Taurus prospect which lies within the Taurus sub-domain. In general, these magnetite complexes display alteration parageneses typical of other large magnetite dominated hydrothermal iron oxide deposits elsewhere (i.e., early albite with later magnetite+amphibole±pyroxene and even later minor sulphide, including pyrite, pyrrhotite and chalcopyrite associated with chlorite and lesser biotite). e.g., Cloncurry and the Chilean Iron Belt.
- Magnetite dominant systems of the Neptune sub-domain occur entirely within volcanic rocks and contain only relatively minor calc-silicate alteration, more abundant apatite and less abundant scapolite, compared to those of the Joes Dam and Taurus sub-domains.
- The magnetite breccias lie close to a large lopolith-like layered gabbroic intrusion (White Hill Complex). Hydrous (phlogopite/biotite bearing) mafic to ultramafic rocks occur in this complex and in the Skylark sub-domain to the west. A relationship between these mafic/ultramafic rocks and the iron oxide mineralisation is suspected.
- Fine to coarse grained, crystalline hematite alteration with copper sulphides is virtually non-existent in the magnetite replacement and breccia complexes, and

is limited to the structurally uppermost portion of the Neptune Volcanics in the vicinity of the structural break between the Neptune and Blue Duck sub-domains, close to the Prominent Hill Mine. The paragenesis of this style of mineralisation is distinct from that of the magnetite breccias in comprising hematite+clay minerals +muscovite (sericite)+chlorite+carbonate with very late stage bornite+chalcocite±chalcopyrite.

- The magnetite and hematite deposits are generally distinct in being hosted in different lithologies at differing metamorphic grades, with generally more reducing and higher temperature mineral phases characterising the magnetite systems. The exact relationship between the non-economic low grade copper-gold, magnetite dominant iron oxide alteration, and the economic, higher grade copper-gold, hematite dominant alteration is unclear.
- Sources of magnetic anomalism in the southern MWD vary widely. Long strike length, high amplitude anomalies such as that comprising portions of the northern White Hill, Blue Duck, and Wares Peak sub-domains, seem to originate from early accumulations of iron oxide within metasediments (typically quartzo-feldspathic gneisses but, in the Blue Duck sub-domain, calc-silicates and in the White Hill sub-domain possibly as original BIF) while in the main portions of the White Hill sub-domain, bands of primary magmatic magnetite-ilmenite occur within a layered gabbro-gabbronorite-anorthosite-troctolite intrusion. Widespread and diffuse, but relatively high amplitude, magnetic anomalism in the Skylark, White Hill, and far western Blue Duck sub-domains probably reflects hornfelsing around Hiltaba age granitic and mafic intrusions. Very high amplitude irregular and overprinting magnetic anomalism in the White Hill sub-domain (Joe's Dam and Manxman A1 prospects), the Taurus sub-domain (Taurus prospect) and the Neptune sub-domain (Prominent Hill hanging wall) are all related to magnetite replacement or vein breccias, and are of largely hydrothermal origin. Metamorphism of early formed hematite to magnetite in metasediments appears to have occurred at the Neptune and Manxman prospects. The wide variety of forms of magnetite occurrence in the MWD, only a few of which are directly associated with copper-gold mineralisation, means great care must be taken when interpreting magnetic anomalism for exploration targeting.
- Gravity anomalism within the MWD is equally variable in source, principally reflecting the depth to basement. The presence of dense mafic rocks, early massive hematite accumulations in metasediments, and later hydrothermal related accumulations of magnetite and hematite have also produced gravity anomalies. Once again, care has to be exercised in understanding the source of gravity anomalism during exploration and drilling.
- The widespread high grade metamorphism imposed on the rocks in all the sub-domains, with the exception of Neptune and Danae Hill, remains enigmatic. The possibility that much of the high-temperature/low-pressure granulite metamorphism recorded in the MWD is related to large scale thermal anomalism due to mafic underplating, with firstly deep and later high level crustal melting (with the Hiltaba Suite intrusions and the Gawler Range Volcanics possibly representing the highest and latest expression of this event) remains to be investigated.

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