WAGGA TANK / SOUTHERN NIGHTS AND MALLEE BULL, EVOLVING STORIES

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INTRODUCTION

Wagga Tank/Southern Nights and Mallee Bull are located approximately 160 kms and 110 kms respectively south of Cobar within the Cobar "Superbasin" (Figure 1). Recent exploration drilling has shed new light on the likely origin of the deposits, which share some similarities, but also some major differences.

At Wagga Tank/Southern Nights laminated to massive stratiform pyritic Zn/Pb sulphides overlie an intensely altered stringer veined zone, with many aspects suggesting a classical in situ VHMS/VAMS setting. It bears many similarities to the Rosebery VHMS/VAMS deposit (Cambrian) in western Tasmania.

Mineralisation at Mallee Bull occurs in a comparable stratigraphic package to Wagga Tank/Southern Nights, but differs in detail. Pyritic sphalerite/galena and chalcopyrite/pyrrhotite "lodes" are present and have historically been regarded as the products of a single mineralising event. However, chemically, mineralogically and texturally the Zn/Pb mineralisation differs markedly from the chalcopyrite/pyrrhotite, with the former showing many similarities to the stratiform Zn/Pb mineralisation at Wagga Tank/Southern Nights and is now considered likely to also be of VHMS/VAMS affinity. In contrast, chalcopyrite/pyrrhotite mineralisation is strongly fracture/breccia controlled, post-dating silica alteration and brittle fracturing. Whether it is best described as classical "Cobar style" or perhaps as a magmatic related "iron sulphide copper gold" deposit is debatable.

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WAGGA TANK/SOUTHERN NIGHTS

Located 160 kilometres SSW of Cobar, Wagga Tank mineralisation was discovered in 1968 by local pastoralist A.H. Lloyd while grading a fenceline and recognising that the iron rich rocks were of interest. The prospect has been subject to considerable exploration since then, and yielded several highly significant intersections before acquisition by Peel in 2016. Since then Peel has undertaken extensive exploration at Wagga Tank, resulting in discovery of the southward extension of the mineralised zone to what is now referred to as Southern Nights. A transformational event occurred in late 2018 with the drilling of hole WTRCDD150, which intersected 18.2 metres of laminated to massive sulphides grading 40.3% Zn, 15.7% Pb, 0.97% Cu, 356 g/t Ag and 2.77 g/t Au.

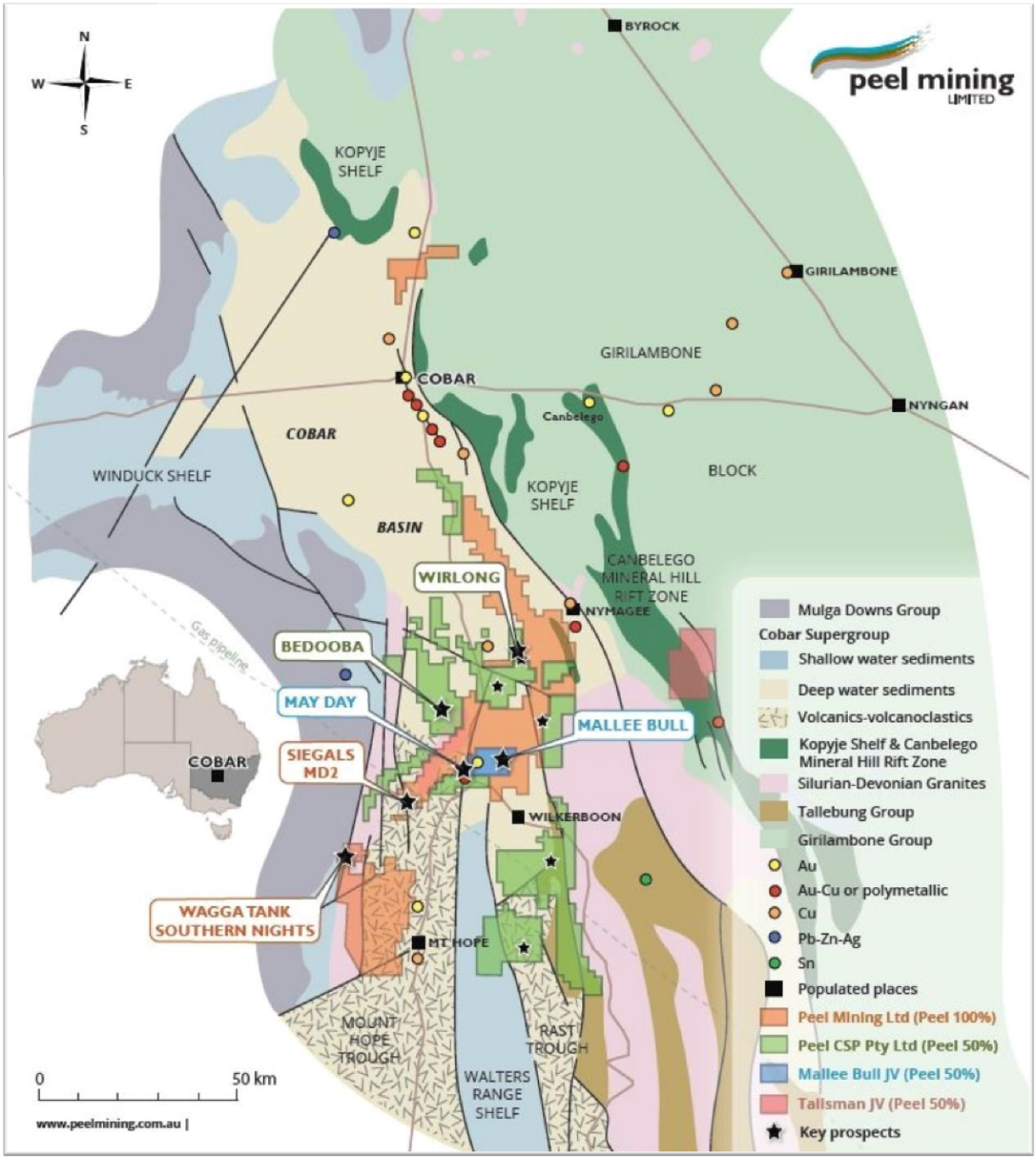

Figure 1: Location plan, May 2019.

Stratigraphy and Structure

Situated on the western edge of the central Cobar Superbasin, Wagga Tank/Southern Nights prospect lies on the western margin of the Mount Hope Trough. The mineralised zone occurs at the transition from Lower to Upper Amphitheatre Group in a steeply west to northwest dipping sequence (Figure 2). Metamorphic grade is lower greenschist facies and the area is a low strain environment when compared to that of classical “Cobar style” deposits.

Outcrop is common at Wagga Tank but southwards towards Southern Nights transported cover and in situ laterite profiles commonly extend to depths of around 50metres and 100 metres respectively.

Stratigraphically the sequence comprises a package of largely volcanic derived mass debris flow breccias and sandstones (collectively termed Vivigani Formation) contained within deep water turbidite facies shales and siltstones (Eastern Formation and Wagga Tank Formation). Some very large igneous bodies are present at Wagga Tank, but unequivocal evidence that they are in situ and not allochthonous blocks is yet to be demonstrated.

An informal local stratigraphy has been developed for the prospect (edited after Brown, 2018a):

Formal units	**Informal units**	**Lithology**
Upper Amphitheatre Group	Wagga Tank Formation	Turbidite facies shale and siltstone.
Mt Kennan Volcanics	Vivigani Formation	Coarse polymict volcaniclastic sandstone and breccia, mass debris flow breccias, minor shale/siltstone, fossils, possible peperites. Top contact often transitional.
Lower Amphitheatre Group	Eastern Formation	Turbidite facies shale, siltstone, debris flow breccias. Top contact sharp.

At the base of the sequence **Eastern Formation** comprises rather massive to thinly bedded turbiditic shale and minor siltstone, graded bedding is common. Coarse, poorly sorted breccias with angular clasts set in a fine muddy matrix are present locally and are interpreted as mass debris flow deposits (olistostromes). Collectively the unit has attributes typical of relatively deep marine settings, with the breccias suggesting the presence of proximal unstable shelf/slope areas where episodic collapse was occurring on an occasional basis.

Overlying **Vivigani Formation** marks a striking change with coarse to fine volcaniclastic breccias and sandstones dominating. The basal contact is sharp and most breccias contain dominantly angular clasts, though rounding is apparent in others. Clasts are polymict, with both sedimentary and volcanic origins (including vesicular rhyolite lavas) and some very large clasts (>1 metre) are present. Fabrics range from clast to matrix supported and it is inferred that they are coarse debris flow deposits shed from areas on and adjacent to unstable volcanic edifices. Deposition appears to have been episodic, with hiatuses marked by deposition of very fine grained sediments (silt and clay), commonly accompanied by fine grained massive to vaguely laminated pyrite. The local minor presence of allochthonous, commonly reddened/oxidised coral and crinoid fragments in breccias indicates shallow water depths around some of the volcanic centres. Breccias with extremely angular clasts are present locally and have textures suggestive of a peperite origin.

It is notable that no unequivocally in-situ subaerial volcanics have been identified at Wagga Tank/Southern Nights, and it is therefore considered likely that Vivigani Formation is also deep marine.

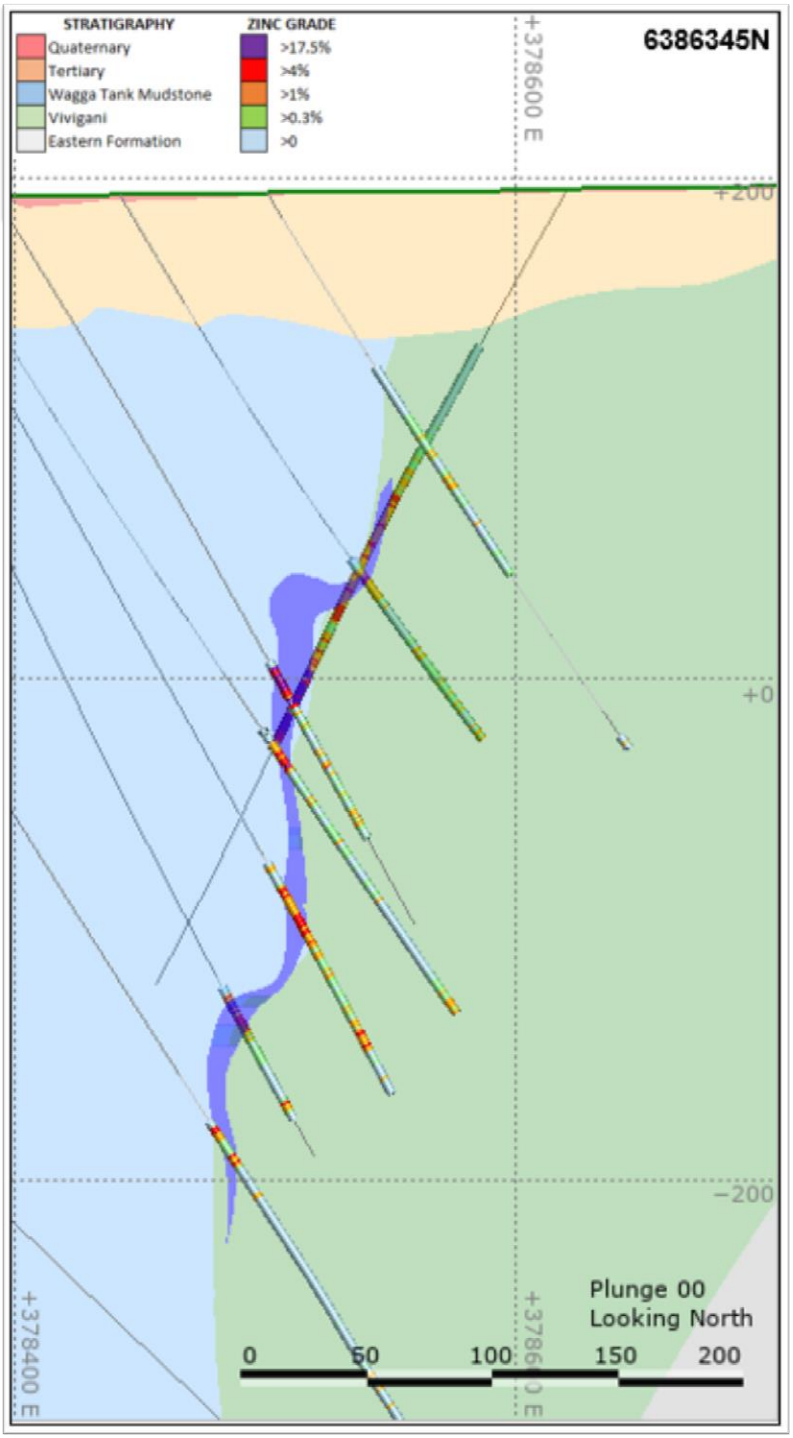

Figure 2: Southern Nights cross section 6386345N.

Cessation of Vivigani related volcanism and volcaniclastic sedimentation is marked by deposition of **Wagga Tank Formation**, comprising thin bedded shales and subordinate siltstones, with common graded bedding, sharp bases, scours and occasional fine cross bedding. They are typical turbidites, with the apparent absence of mass flow breccias perhaps suggesting a more distal setting than existed in Eastern Formation time. The Vivigani to Wagga Tank contact can be sharp, but is often transitional.

Alteration

One of the most striking features of Vivigani Formation rocks at Wagga Tank/Southern Nights is the intensity and extent of multi-phase hydrothermal alteration. Dominant styles are chlorite and silica/sericite +/- pyrite, with lesser siderite, calcite, rutile, adularia, fluorite, rhodocrosite and possibly scapolite (not yet confirmed).

Chlorite alteration is widespread and appears to be overprinted, at least in part, by silica/sericite/pyrite alteration. Collectively the alteration assemblage is strongly suggestive of emplacement of a high level hydrous rhyolitic to dacitic porphyry into or below the base of the sequence and consequent development of a major hydrothermal cell.

Development of such a porphyry driven hydrothermal cell would see fluid flow preferentially focused into more permeable zones. At Wagga Tank/Southern Nights volcaniclastics of the Vivigani Formation would be far more porous and permeable than enclosing shales and siltstones of Eastern Formation and Wagga Tank Formation. It is therefore not surprising that alteration is best developed in the volcaniclastics and that these also host almost all the stringer sulphide mineralisation (see below).

Near the base of the Wagga Tank Formation minor alteration comprises aggregates and stringer veins of pyrite with variable quartz, carbonate and sericite rims (locally termed “orbicular pyrite”). Intensity of this alteration diminishes rapidly upwards, rarely extending more than 10 to 20 metres above the contact with Vivigani Formation.

Sulphides and veining

Sulphides are widespread in the Vivigani Formation and at the base of the Wagga Tank Formation. Pyrite is generally the dominant phase with lesser sphalerite, chalcopyrite, galena, and rarer arsenopyrite. Sulphides occur in a range of styles and settings with resultant implications for their genesis, as well as for exploration and economics. The majority of the sulphides are interpreted as being the product of a major hydrothermal system that developed during Vivigani time, driven by emplacement of an intrusive of probable acid composition (rhyolite/dacite). Waning of the hydrothermal system and cessation of volcanism are reflected in the change from volcaniclastic (Vivigani) to fine sediment (Wagga Tank Formation) dominated regimes.

Disseminated sulphides

Pyrite occurs in all sulphide vein styles but is also widespread finely disseminated in the matrix of volcaniclastic breccias and sandstones. The disseminated pyrite is inferred to be an integral part of the silica/sericite alteration assemblage, with its distribution therefore reflecting permeability of the host and extent of alteration fluid flow.

Stringer veins

Discordant stringer veins are usually dominated by pyrite and silica, with lesser sphalerite, galena and chalcopyrite. They are only rarely fracture controlled and more usually have sinuous to anastomosing geometries (Figure 3), interpreted to be a consequence of hydrothermal fluid migration through permeable, semi-consolidated sediments (mainly Vivigani Formation volcaniclastics but also at minor levels in underlying Eastern Formation, and extending into basal Wagga Tank Formation). Sulphide components vary markedly from almost totally pyrite to pyrite/chalcopyrite, pyrite/sphalerite, pyrite/sphalerite/galena to nearly all sphalerite. Vein frequency can be very high, forming vein stockwork zones, but distribution can be highly variable.

A general vertical zonation of stringer vein sulphide composition is apparent in Vivigani Formation from pyrite and chalcopyrite at the base, through pyrite and sphalerite with minor

chalcopyrite, to sphalerite, pyrite and galena with minor chalcopyrite at the top and extending into the basal Wagga Tank Formation.

Figure 3: Sphalerite/pyrite stringer veining, hole WTRCDD105, 265-266m

Epithermal/colloform banded veins

Chalcedonic veining with classic epithermal colloform banding textures is locally present, with varying sulphide (mainly pyrite and sphalerite) and occasional jasperoidal silica. It is most common in the upper parts of Vivigani Formation where it generally corresponds with the change in stringer vein composition from pyrite/chalcopyrite to sphalerite/pyrite/galena.

Banded/laminated stratiform sulphides

The highest grade sulphides at Wagga Tank/Southern Nights occur as finely laminated to banded to massive sphalerite, pyrite, galena and chalcopyrite (Figure 4), almost always in basal Wagga Tank Formation or Vivigani Formation/Wagga Tank Formation transition, interbedded with very fine clastic sediments (shale and siltstone). Zn:Pb ratios are variable but average 3:1. Locally they are cut or disrupted by stringer pyrite, chalcopyrite and sphalerite veining. Textures in the laminated massive sulphides are strongly suggestive of a VHMS/VAMS exhalative origin.

It is inferred that with cessation of Vivigani related volcanism, venting sulphides were no longer being diluted by large volumes of volcaniclastic sediment, only minor inputs of clay and silt. As a consequence higher grade stratiform sulphides developed, in contrast to the discordant stringer vein zones seen in the Vivigani volcaniclastics. Ore textures are complex in places, particularly where there is overprinting stringer veining.

The overall pattern of sedimentation, alteration and mineralisation at Wagga Tank/Southern Nights is comparable to other well-documented volcanic hosted/associated massive sulphide deposits (“VHMS/VAMS”), notably Rosebery in Tasmania (Braithwaite, 1974, Denwer et al, 2017). The Rosebery deposit is hosted in Cambrian shales, tuffaceous siltstones and minor sandstones which overly intensely silica/sericite +/-chlorite +/- pyrite altered and stringer veined rhyolitic to dacitic pyroclastics. Sulphide lenses are up to 10 metres thick and range in composition from pyrite/chalcopyrite to sphalerite/pyrite/galena/chalcopyrite.

Figure 4: Laminated massive sphalerite, galena, pyrite, hole WTRCDD 192, 358m

Pyrite/silica/sericite aggregates

At the base of Wagga Tank Formation and commonly extending for 10-30 metres or more above both the laminated massive sulphides and stringer sulphide zones, aggregates of pyrite with associated quartz +/- carbonate +/- sericite are almost always present and probably reflect the last waning stages of the hydrothermal system.

Conclusions

At Wagga Tank/Southern Nights high grade laminated stratiform massive sulphides hosted in a low energy shale/siltstone sequence overlie a very large intensely silica/sericite/pyrite/chlorite altered and stringer sulphide veined zone which developed within permeable volcaniclastic breccias and sandstones. It is inferred that the hydrothermal alteration and mineralisation were driven by a high level intrusive of probable rhyolitic to dacitic composition, likely co-magmatic with the Mt Kennan Volcanics. Cessation of volcanism and volcaniclastic debris flow sedimentation but continued, albeit waning, hydrothermal venting resulted in the change in character of sulphide mineralisation from dominantly stringer veining within permeable volcaniclastics to exhalative stratiform sea floor massive sulphides.

This setting is analogous to other known in situ volcanic hosted ("VHMS") or volcanic associated ("VAMS") massive sulphide deposits, and therefore differs markedly from classical "Cobar type" structurally controlled discordant base and precious metal deposits.

MALLEE BULL

The Mallee Bull polymetallic sulphide deposit is located in the south central part of the Cobar Superbasin, approximately 110 kilometres south of Cobar (Figure 1). The deposit was discovered by Peel Mining in May 2011 drilling coincident magnetic and EM anomalies and comprises several stratabound to discordant zones contained within deep water sediments of the Amphitheatre Group. The host rock sequence is dominated by shale, siltstone and

sandstone but coarse volcaniclastic debris flow sediments are also present. The local sequence is comparable to that at Wagga Tank/Southern Nights and may be coeval, but there are differences in provenance, thickness, degree of alteration and styles of mineralisation.

Stratigraphy and Structure

Situated in the south central Cobar Superbasin, Mallee Bull prospect lies at the northern end of the Rast Trough. The main mineralised zone occurs at the transition from Lower to Upper Amphitheatre Group, on the northwest limb of a south-southwest plunging antiform (Figure 5). As at Wagga Tank/Southern Nights metamorphic grade of the host sequence is very low, at most lower greenschist facies.

Stratigraphically the sequence comprises a package of mixed volcanic and sedimentary derived mass debris flow breccias and sandstones contained within deep water turbidite facies shales, sandstones and siltstones. An informal local stratigraphy has been developed for the prospect (Brown et al., 2015, Brown, 2018b), slightly modified here:

Formal units	**Local informal units**	**Lithology**
Upper Amphitheatre Group	Mallee Bull Formation	Shale, siltstone, fine sandstone, turbidite facies
	Upper Volcaniclastics	Volcaniclastic breccia and sandstone, mass flow slump breccias (“olistostromes”), slump blocks (“olistoliths”)
	Keep It Dark Sandstone (“KID”)	Fine to medium grained quartzose sandstone, very minor volcaniclastic sandstone and shale
	Lower Volcaniclastics	Volcaniclastic breccia and sandstone, mass flow slump breccias (“olistostromes”), slump blocks (“olistoliths”)
Lower Amphitheatre Group	Shume Formation	Shale, siltstone, fine sandstone, turbidite facies

Shume Formation (formal name): The lowermost recognised unit at Mallee Bull, Shume Formation, is generally regarded as topmost Lower Amphitheatre Group, and comprises turbidite facies shale, siltstone and fine sandstone. Graded bedding and other facing structures are common and the sequence at Mallee Bull is upright. Shume Formation hosts much of the mineralisation at Mallee Bull and is commonly silica and chlorite altered proximal to mineralisation.

Shume Formation is a probable correlative of the the Eastern Formation (informal name) at Wagga Tank/Southern Nights. Both are turbidite facies, the major difference being that the overall grain size of sediments is somewhat coarser at Mallee Bull (fine sand/silt/clay) than at Wagga Tank/Southern Nights (clay/silt), suggesting Mallee Bull may have been more proximal to sediment source(s).

Lower Volcaniclastics (informal name): Overlying the Shume Formation, the Lower Volcaniclastics comprise coarse grained volcaniclastic and polymict slump breccias of mass debris flow origin. The unit is not laterally continuous. Felsic porphyry clasts are common, implying proximal active volcanism. Slump breccias frequently contain limestone clasts and shallow marine fossil material, notably corals and crinoids, likely to have originally occupied

shelf/reef settings fringing emergent volcanic edifices. Shale/siltstone is locally present at the top of the unit underlying, or perhaps transitional into the basal Keep It Dark Sandstone (see below).

Lower Volcaniclastics host significant mineralisation at Mallee Bull, notably zinc/lead (Chapman, 2012) and are commonly silica/sericite +/- chlorite altered (Chapman, 2012, Brown et al., 2015). They are tentatively correlated with the lower part of the Vivigani Formation at Wagga Tank/Southern Nights.

Keep It Dark Sandstone (informal name): A massive, fine grained quartzose sandstone overlies the Lower Volcaniclastics and is informally referred to as the Keep It Dark Sandstone (Brown et al., 2015). It is laterally discontinuous in the Mallee Bull area, generally overlies the Lower Volcaniclastics but where these are absent occurs immediately above the Shume Formation. The general lack of internal sedimentary structures and location within deep marine sediments suggests an origin by mass flow. Thinly bedded sediments are present locally and are inferred to reflect more quiescent sedimentation regimes. Minor volcaniclastic material is also present but its relative paucity and the dominance of quartzose sediments suggests a different primary provenance than existed for adjacent high energy volcaniclastic dominated debris flow units.

Keep it Dark Sandstone is weakly silica and chlorite altered and is almost always unmineralised.

A correlative of the Keep It Dark Sandstone has not yet been logged as such at Wagga Tank/Southern Nights, however quartz rich sandstones have been identified there within the Vivigani Formation in several holes and are likely lateral equivalents.

Upper Volcaniclastics (informal name): Upper Volcaniclastics comprise coarse volcaniclastic and sedimentary breccias, interpreted as mass debris flow deposits derived from an active felsic volcanic source area. The breccias are commonly silica/sericite altered and contain minor sulphides, but to date no potentially economic zones have been intersected. They are correlated with the upper part of the Vivigani Formation at Wagga Tank/Southern Nights.

Mallee Bull Formation (informal name): Previously referred to as “Mallee Bull Formation Undifferentiated” (Brown et al., 2015) this unit comprises turbidite facies shale, siltstone and sandstone of the Upper Amphitheatre Group. Sedimentary structures (grading, scours) confirm the sequence is upright at Mallee Bull. It is unaltered and unmineralised.

Mallee Bull Formation Formation is a probable correlative of the Wagga Tank Formation (informal name) at Wagga Tank/Southern Nights. Both are turbidite facies, the major difference being that the overall grain size is again somewhat coarser at Mallee Bull (fine sand/silt/clay) than at Wagga Tank/Southern Nights (dominantly clay/silt), suggesting Mallee Bull remained closer to the sediment source(s).

Alteration

Alteration is most pronounced in and adjacent to fractured and mineralised Shume Formation and in the more permeable volcaniclastic units. Pale green chlorite is common, particularly in the Shume Formation and Keep It Dark Sandstone, whereas patchy pale grey to greenish silica/sericite alteration is more common in the volcaniclastics and appears to overprint earlier chlorite. Chapman (2012) documents alteration in considerable detail, noting in particular a zonation upwards from Fe chlorite+silica+albite to silica+Mg chlorite+sericite.

Alteration is virtually non-existent in the Mallee Bull Formation.

Mineralisation

At Mallee Bull distinctive Pb/Zn and Cu "lodes" are present and have been historically regarded as having a common origin. However, there are major differences between the two. Geochemically the Zn/Pb lodes in Mallee Bull are quite distinctive when compared to the Cu sulphide zones. In Zn/Pb lodes Cu is low, as are Co and Bi (usually below detection). In Cu lodes Zn and Pb are low (though still significant), Bi and Co are higher. Given their sometimes close proximity, it is unlikely that these differences can be attributed solely to lateral variation from a single fluid source.

Average intersections for Silver Ray Main Zn/Pb Lode and all copper lodes:

Lode	Width m	Zn %	Pb %	Cu %	Ag ppm	Au ppm	As ppm	Bi ppm	Co ppm	Sb ppm
Silver Ray	7.4	19.4	11.9	0.3	281	1.44	8,711	0	44	819
All Cu/Po	4.6	0.2	0.4	4.3	55	0.54	2,380	188	198	696

Chapman (2012) documented temperatures of 340-400°C for alteration assemblages associated with chalcopyrite/pyrrhotite mineralisation, noting that these contrasted markedly with those for Zn/Pb lodes of <320°C. He also noted that sulphur activity for pyrrhotite systems are lower than for pyrite, but did not propose the possibility of differing ages or fluid sources. A comparison of the two sulphide assemblages (Zn/Pb vs Cu/Po) highlights some of the differences:

	Pyritic sphalerite/galena "lodes"	**Pyrrhotite/chalcopyrite "lodes"**
Cassiterite*	None recorded	Acicular void fill
Albite**	None recorded	Intergrown accessory
Fracture/breccia void filling	No	Yes
Laminated	Commonly	Rarely
Occur also as rafted clasts in volcaniclastic breccias	Yes (rare)	No
Sulphur activity**	High (pyrite)	Lower (pyrrhotite)
Fluid temperatures**	<320°C	340-400°C
Sulphide grain size	Fine-very fine	Fine-coarse

**Brown (2018b), **Chapman (2012)*

Copper bearing "lodes": At Mallee Bull these comprise varying proportions of pyrrhotite and chalcopyrite, and range in style from stockwork vein zones to semi-massive and massive sulphide (Brown et al., 2015, Davis & Cowan, 2016). Most are hosted in variably brecciated, silica altered Shume Formation but they locally extend upwards into the Lower Volcaniclastics (Figure 5).

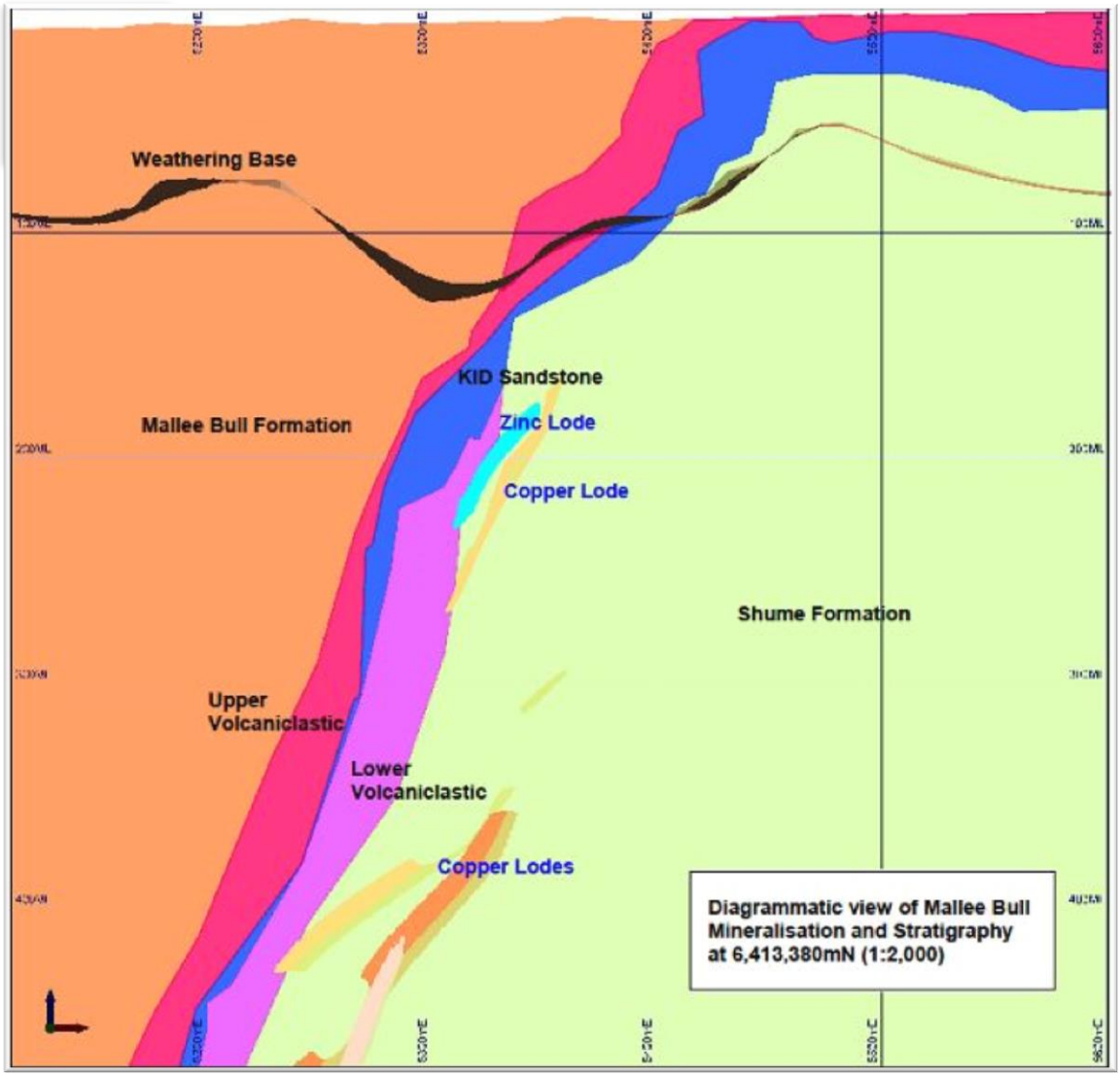

Figure 5: Mallee Bull diagrammatic cross section 6413380N

At the contacts between host rock and massive sulphide zones it is common to see a progression from crackle to mosaic to chaotic breccia (Figure 6) with increasing void fill sulphide, before eventual transition to massive sulphides with occasional angular, sulphide supported wall rock fragments. Silica alteration of the host rock therefore appears to have been an essential precursor to chalcopyrite/pyrrhotite mineralisation, rendering the host rocks brittle, allowing brecciation and creation of fracture permeability, in turn allowing fluid ingress and metal sulphide precipitation.

Figure 6: Brecciated silica altered shales with void fill chalcopyrite/pyrrhotite/silica, hole MBDD002, 421.5m.

This style of mineralisation clearly post-dates lithification and silica alteration. Albite alteration and the presence of acicular cassiterite intergrown with chalcopyrite and pyrrhotite, recorded by both Chapman (2012) and Brown (2018), are perhaps suggestive of a magmatic hydrothermal origin for the chalcopyrite/pyrrhotite mineralisation, though this is not yet supported by sulphur isotope studies (Downes et al., 2016).

Zinc/Lead lodes: Despite their proximity to Mallee Bull fracture/breccia controlled chalcopyrite/pyrrhotite mineralisation, the zinc/lead sulphides are of vastly different character. They are fine to very fine grained, pyrite is the dominant iron sulphide (pyrrhotite is rare/absent), and textures range from massive to laminated (Figure 7). There is no visual evidence of structure/fracture control. As noted in the tables above, there are also major chemical, mineralogical and fluid character differences between the two. Of particular significance is the occasional (albeit rare) presence of rafted clasts of laminated zinc/lead sulphides in overlying volcaniclastic breccias, a texture also seen locally in volcaniclastics of the Mount Read Volcanics.

The zinc/lead sulphides are texturally and mineralogically very similar to laminated sulphides at Wagga Tank/Southern Nights and also to the fine grained pyritic zinc/lead sulphides at Hellyer and Rosebery VHMS deposits in western Tasmania. It is therefore considered highly likely that they are of in situ VHMS/VAMS exhalative origin, pre-dating the alteration, fracturing and fluid ingress events that gave rise to the Mallee Bull chalcopyrite/pyrrhotite mineralisation. Stringer sphalerite/pyrite/galena veins are present locally in the Shume Formation, and are consistent with a proximal in situ feeder zone.

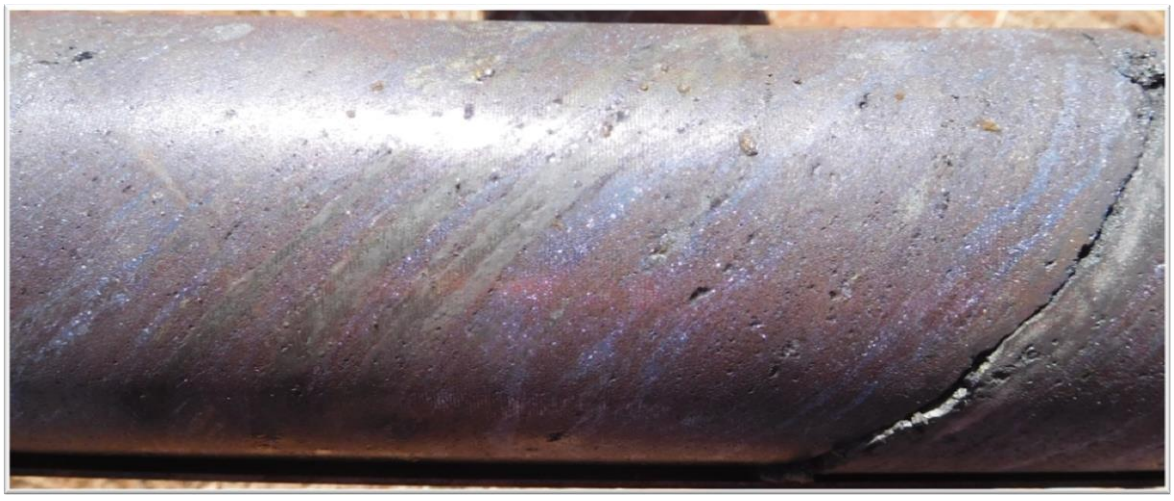

Figure 7: Laminated massive sphalerite, galena, pyrite, hole MBDD028, 85m.

Overprinting of laminated pyritic zinc/lead sulphides by discordant pyrrhotite/chalcopyrite veining is common, and renders textural relationships complex. Not surprisingly chemical analyses for these zones reflect the composite sulphide mineralogy.

Conclusions

Textural, mineralogical, geochemical, fluid chemistry and fluid temperature variations indicate that copper and zinc/lead mineralising events at Mallee Bull were probably unrelated. It is considered highly likely that the fine grained, laminated to massive, pyritic zinc/lead lodes are syngenetic, perhaps in part syndiagenetic and of exhalative VHMS/VAMS origin.

Pyrrhotite/chalcopyrite mineralisation is later, occurring where silica alteration has preceded brittle fracturing, fluid ingress and sulphide deposition as fracture/breccia void fill. Rather than being a classical “Cobar style” deposit it has some characteristics suggestive of a magmatic hydrothermal origin and may be better considered as an Iron Sulphide Copper Gold (“ISCG”) deposit.

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