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Rheological controls on the geometry of the Currawong VHMS Deposit, Lachlan Fold Belt, Victoria, SE Australia

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ABSTRACT

Base metal sulphides at the Currawong VHMS deposit in the Lachlan fold belt of Victoria, SE Australia, were formed in the late Silurian, but D2 deformation of the deposit in the Devonian Bindian orogeny was responsible for structural repetition that created the resource. The primary sulphide lenses were stacked by reverse-sense shear zones within a volcano-sedimentary sequence dominated by dacitic intrusions and turbidites. Shear zones were localized along lithological contacts, including the margins of the sulphide lenses. The competent dacitic intrusions did not fold during D2: folding was restricted to the packages of metasedimentary rocks. Overturning occurs within, but not between, the metasedimentary packages. The overall geometry of the deposit is that of a duplex, but the detailed shape does not conform to idealized duplex types, probably because of post-D2 deformation. A significant complicating factor for understanding the deposit, and for resource evaluation, is the dramatic variation in deposit geometry along strike, which may also be due to post-D2 deformation. The present day configuration of the deposit results from constructive thrust repetition of what may have been a single ore lens, and destructive along-strike disruption, controlled by rheology.

INTRODUCTION

Some economic mineral resources are created or enhanced by repetition of ore bodies by deformation after mineralization, but deformation and associated fluid flow can also be deleterious if it disrupts, dilutes, or terminates ore. All these processes can be anticipated in deposits with complex structural histories, depending on rheology. This paper presents an example of the rheological controls on the balance between ore enhancement and destruction, in the case of the Currawong VHMS deposit in the Tasmanides of SE Australia.

GEOLOGICAL BACKGROUND

The Tasmanides are a Pacific rim Palaeozoic orogenic belt that hosts a variety of mineral deposits (e.g. Vandenberg *et al* 2000; Glen, 2005). The Currawong deposit is hosted by a Silurian volcano-sedimentary succession in the Cowombat Rift, which is the southernmost, massive sulphide bearing Silurian basin in the Lachlan fold belt (Allen, 1992; Valenta and Bodon, 1995) of the Tasmanides. At least three major deformations may have affected the deposit. In the Lower Devonian, the Bindian Orogeny began with SE vergent contraction, and continued in a second phase to produce the most dominant and pervasive structural features. Post Bindian deformation consisted of open folding and sub-vertical block faulting, possibly as a result of Mid-Devonian Tabberabberan Orogeny (Allen, 1987).

THE CURRAWONG DEPOSIT

Mineralization at Currawong consists of five mainly pyrite and chalcopyrite massive sulphide lenses up to 30 m thick and separated by tens of m, within a package of andesites, dacites, rhyolites and turbidites, all at low greenschist facies metamorphic grade. The along-strike geometry of the lenses, and their relationship to each other, is variable over short distances, leading to a complex deposit geometry. The combined 2011 resource estimate was 9.4 Mt averaging 2% Cu, 4.2% Zn, 0.8% Pb, 42g/t Ag and 1.2 g/t Au (Independence

Group NL, 2011). Critical questions for resource delineation posed by this geometry are whether the repetition of the ore bodies is due to thrusting, folding, a combination of both, or primary replication.

METHODS

There is minimal surface exposure of the deposit, which has not been mined. Geological information is based entirely on drilling. Advances made in this study come from detailed analysis of 12 cores, in which observations of kinematic indicators such as SC fabrics were used to establish a structural history. The core logging was used to create a Leapfrog model of the major structures along an approximately 50 m wide cross-section of the deposit. The use of disks in the Leapfrog model to show the orientation of the shear zones and faults in particular was useful for establishing the shear and fault zone geometry.

STRUCTURAL GEOLOGY OF THE CURRAWONG DEPOSIT

Bedding, S0, consists of mm to cm layers defined by variations in grain size from sand to mud in the clastic rocks. Gradational grain size changes from sharp bases occur in graded beds, which provided a reliable younging indicator in many places. A **First Cleavage, S1** is parallel to bedding. The **Main Cleavage, S2**, is a spaced, moderate to strong cleavage, in many places also parallel to bedding. Tight to isoclinal F2 folds with rounded fold hinges on a cm scale are visible in the metasedimentary layers and in folded veins. These are commonly asymmetric, and plunge moderately NE or SW, with hinge surfaces dipping to the NW. Kink bands within the metasedimentary rocks have widths of several centimetres. Despite having generally similar orientations to F2 folds, they are distinguished by their localised occurrence and angular fold hinges. **Shear zones** are localised zones of strong foliation, commonly showing shear sense indicators such as SC fabrics and asymmetric porphyroclasts (Fig. 2), which can be used to deduce the orientation of the vorticity vector and thence the shear direction and sense (cf. Blenkinsop in press). Shear zones may also include quartz veins, gouges and breccias and occur in all types of rock, including the sulphide layers. **Faults** are discrete zones of cataclasis resulting in breccias, gouges and cataclasites, sometimes marked by surfaces with prominent quartz slickenfibres.

Textures in the sulphides are critical to the interpretation of the deposit. Pyrite may be heavily fragmented. The margins of the sulphide lenses are commonly sheared, especially where there is a significant chalcopyrite component, which may be strongly foliated. Durchbewegung texture occurs in the sulphides, and SC fabrics are observed in places (Fig. 2). The sulphide lenses have been folded by F2 folds. These observations indicate that the sulphide layers predate all deformation, compatible with VHMS origin of the deposit.

The interpretation of the deposit geometry shown in Fig. 3 exemplifies some of the features described above, and is a development of the geometry proposed by Bateman (2008, 2001). A network of shears dip to the NW. These shears separate the metasedimentary rocks from the felsic intrusives, and anastomose around the sulphide lenses. Many of these shears have reverse components of movement, but reactivation and contrary shear senses are also observed. Boundaries between the major rock types are not folded. Folding occurs only in shear-bound packages of the metasedimentary rocks, and gives rise to local stratigraphic inversion.

CONCLUSIONS

The structural geology of the Currawong deposit is dominated by a system of NW dipping shear zones, which are marked by intense fabrics and locally by gouges and breccias. These shear zones are responsible for large scale repetition of the stratigraphy, with the metasedimentary rocks and dacitic intrusive package doubled at Currawong. The sequence of five sulphide lenses is due to stacking of what may have been a single unit of sulphides beneath the rest of the metasedimentary rocks. The geometry is reminiscent of a duplex: this concept explains satisfactorily why the sulphide lenses are built up in the location of the ore body, and not dispersed more widely. However, the geometry of the deposit varies very significantly over short distances (tens of metres) along strike, and does not readily fit any idealised conventional thrust duplex model. This is probably due to late deformation events represented by the faults. Major packages of rocks are all separated by shear zones, and their boundaries are not folded. The folding that is observed on a cm –scale in the core, and inferred on a larger scale from changing younging directions, represents internal deformation within the metasedimentary rocks.

The key control on the large scale geometry of the deposit is rheology. The competent dacites did not fold. Instead, shearing was localised on lithological contacts, and folding occurred within the weaker and anisotropic layered metasedimentary rocks.

ACKNOWLEDGEMENTS

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FIGURE CAPTIONS

FIG 1 - Location of the Currawong deposit in the Lachlan Fold Belt, of the Tasman Fold Belt System (Tasmanides).

FIG 2 - SC fabrics in sulphides, Hole 08CWDD014, 294.2 m

FIG 3 – Cross-section looking NE showing sulphide lenses, shear zones and form lines in metasedimentary rocks. Blank areas are felsic intrusives.

TABLE CAPTIONS

TABLE 1 Deformation chronology at Currawong VHMS deposit. All events postdate formation of massive sulphides in the Silurian.

FIGURES

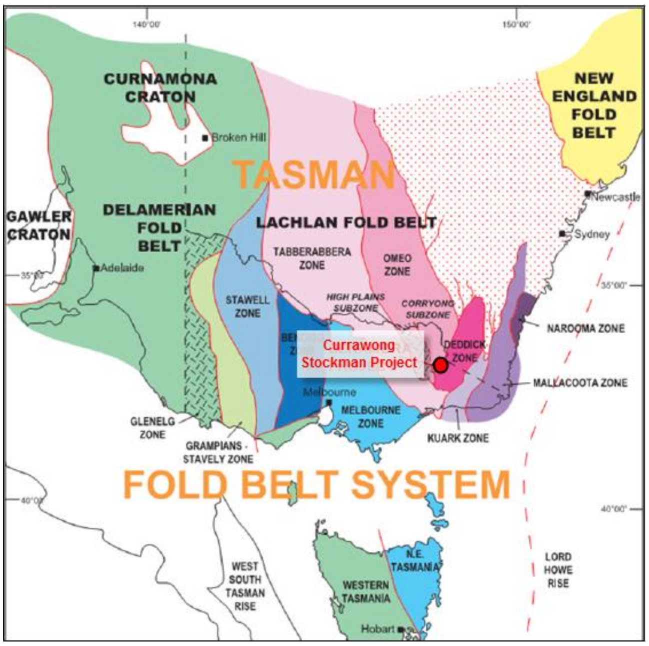

FIG 1 - Location of the Currawong deposit in the Lachlan Fold Belt, of the Tasman Fold Belt System (Tasmanides) (modified after Vandenberg *et al.,* 2000)

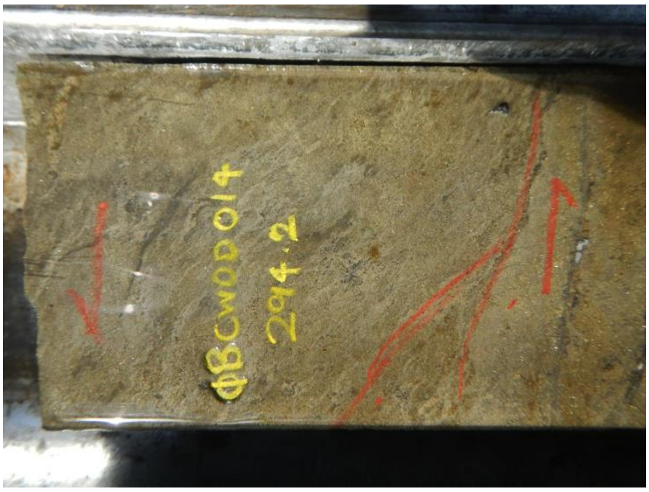

FIG 2 - SC fabrics in sulphides, 08CWDD014, 294.2 m

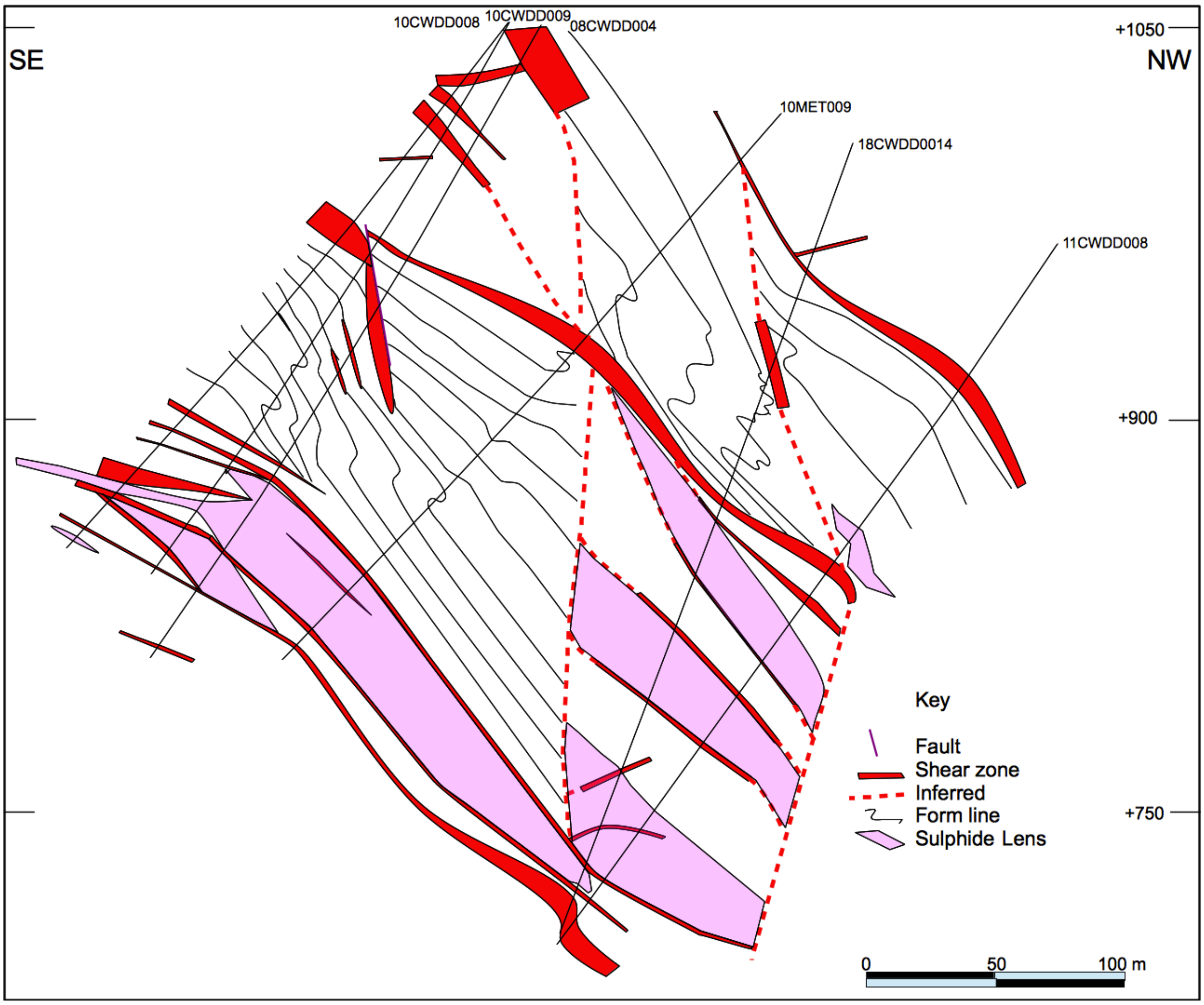

FIG 3 – Cross-section looking NE showing sulphide lenses, shear zones and form lines in metasedimentary rocks. Blank areas are dacitic intrusives.

TABLES

TABLE 1 Deformation chronology at Currawong VHMS deposit. All events postdate formation of massive sulphides in the Silurian.

Event	Description
D> 3	Faulting
D3	Kink bands
D2	Folding about NW-SE hinges with hinge surfaces currently dipping NW sub-parallel to bedding. Thrusting within shear zones around sulphide lenses, within metasedimentary rocks and at contacts between larger igneous bodies and metasedimentary rocks. Duplication of ore body, but no large scale inversion at Currawong. Widespread development of S2 cleavage parallel to NW dip of F2 fold hinge surfaces.
D1	Bedding parallel cleavage, S1