Structural Setting and Controls on Ni-Cu Sulphide Mineralisation at Nova-Bollinger, Fraser Zone, WA

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SUMMARY

Nova-Bollinger is a structurally modified magmatic Ni-Cu sulphide deposit in which sulphide melt was mechanically extracted from chonolithic intrusions and concentrated into structurally controlled positions within the footwall country rocks. The fertile intrusions were emplaced late during granulite facies high-temperature low-pressure (HT LP) metamorphism and deformation during Stage 1 of the Albany-Fraser Orogeny. Sulphide mineralisation, occurred initially as a magmatic melt and subsequently as a metamorphic modified melt that was mobilised along foliations and into F_2 fold hinges, post-foliation pegmatites and a shear zone in footwall granulite gneisses. Disseminated and net-textured sulphide was retained within the chonoliths. The Nova-Bollinger system therefore represents an important example of a structurally modified magmatic Ni-Cu deposit.

Key words: Nova Mine, Fraser Zone, Structural Geology, Ni-Cu sulphide.

INTRODUCTION

The Nova-Bollinger magmatic Ni-Cu deposit represents the first documented case of a structurally-modified, magmatic Ni-Cu sulphide deposit, within the 1.8-1.1Ga Albany-Fraser Orogen (AFO). Mining of the Nova-Bollinger orebody which contains 14.3Mt @ 2.3%Ni and 0.9%Cu, commenced in 2016.

This article builds on preliminary work presented in Parker et al., (2017) and reports upon key findings of a strategic relog of of 12 key drill cores, coupled with underground mapping of the Nova Decline, 2080, 2055, and 2030 levels in the 'pan-handle' of the Nova orebody. These observations significantly advance our understanding of the structural setting of the Nova Eye feature and the controls on sulphide mineralisation at Nova-Bollinger.

STRUCTURAL SETTING OF THE NOVA 'EYE'

The Nova-Bollinger Ni-Cu magmatic sulphide deposit was discovered in 2012 in the then under-explored AFO. The AFO is an approximately 1200 km long Paleoproterozoic to Mesoproterozoic intracratonic rift situated along the south and southeastern margins of the Archaean Yilgarn Craton (Figure 1). The orogen comprises two main tectonic units: the Northern Foreland and the Kepa Kurl Booya Province, which are distinct in both their structural position and degree of craton modification (Spaggiari et al., 2014a). The Northern Foreland comprises Archaean crust reworked by Paleoproterozoic to Mesoproterozoic events. The Kepa Kurl Booya Province is divided into a group of structural zones: the Paleoproterozoic Tropicana and Biranup Zones, and the Mesoproterozoic Fraser and Nornalup Zones. Nova-Bollinger is located in the centre of the Fraser Zone.

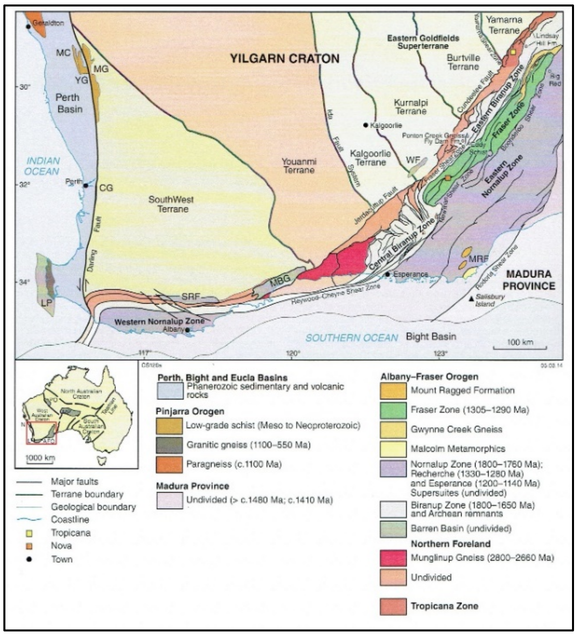

Figure 1. Simplified pre-Mesozoic interpreted bedrock geology of the Albany-Fraser Orogen and tectonic subdivisions of the Yilgarn Craton. The location of Nova-Bollinger Mine is highlighted by orange coloured square (From Spaggiari et al., 2014b).

Nickel-Cu magmatic sulphide mineralisation is associated with mafic-ultramafic intrusions emplaced into granulite facies country rocks comprising an interleaved sequence of mafic-ultramafic intrusions and volcanics, granite orthogneiss, and various siliclastic metasediments, marble and iron formations, equivalent to the c. 1.4-1.3 Ga Snowys Dam Formation (Spaggiari et al., 2014b). The host intrusions at Nova-Bollinger are arranged into two complexes: an upper mixed norite and peridotite complex, and a lower gabbronorite, olivine-norite and olivine pyroxenite complex. The Nova-Bollinger deposit is partly hosted by the lower intrusive complex and partly by granulite facies country rocks in the footwall. Nova-Bollinger has an elliptical, 'eye-shaped' expression in magnetic imagery, due to the upper mafic/ultramafic intrusive complex being hosted in the core of a doubly plunging synform created by magnetic units of the Snowys Dam Formation metasediments (Figure 2). The Nova Fault, a major NE-SW-striking fault zone defined by mylonitic granite, separates mafic granulite and charnockite of the 'Western Mafic Sequence' to the NW, from the Nova intrusive complex to the SE.

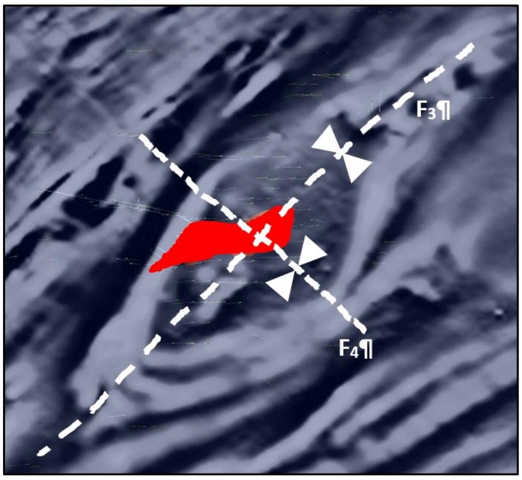

Figure 2. The magnetic image of the Nova Eye feature and showing the location of the Nova-Bollinger deposit. The elliptical eye-shape is aType-1 fold interference pattern between NE-trending F_3 folds and NW-trending F_4 folds. (Image courtesy of IGO).

Gneissic layering (S_1) in the mafic granulites and paragneisses, is the dominant fabric at Nova-Bollinger. A gentle to moderately NE-plunging sillimanite mineral lineation is pervasive within the pelitic gneisses. Banding in marble units is a composite S_0/S_1 foliation that is folded and transposed by F_2 and S_2, respectively. Skarn bands within the marbles are extensively boudinaged, with boudin necklines oriented parallel with the stretching lineation and gently NE-plunging F_2 fold axes. Intense hornfelsing and thermal recrystallisation of the main granulite gneissic layering occurs proximal to the mafic-ultramafic intrusions.

Folding is developed in all metamorphic rocks at Nova-Bollinger, with amplitudes ranging from the cm-scale to greater than 100m. Up to four phases of folding are recorded in the gneisses, although development of axial planar foliations is rare. F_2 folds affecting the S_1 gneissic foliation are dominated by NW-verging, S-folds that are developed, with no change in vergence, across both limbs and the hinge of the Nova Eye. F_2 folds plunge 25-40°→040-050°, subparallel to the sillimanite mineral lineation. The S_1 gneissic foliation and F_2 folds were subsequently reworked by NE-trending F_3 folds and NW-trending F_4 folds. This later two-stage Type-1 fold interference pattern was responsible for the 'eye' shape geometry evident in magnetic imagery. Fold orientation exerted a significant influence on the geometry of tube-like or chonolithic intrusions of olivine norite and olivine pyroxenite present in the lower intrusive complex. These chonoliths have the same plunge as the F_2 fold axes and the sillimanite mineral lineation, suggesting their intrusion was broadly contemporaneous with peak deformation and metamorphism at Nova-Bollinger. Norite dykes feeding the large norite sill in the upper intrusive complex cut across the S_1 gneissic foliation, however are folded by F_3 folds.

STRUCTURAL CONTROLS ON SULPHIDE MINERALISTION

Mafic granulite gneiss and paragneiss immediately beneath the ultramafic lower intrusive complex host the bulk of massive, breccia and 'stringer' sulphide mineralisation. Sulphide melt migrated along the gneissic foliation and accumulated in F_2 fold hinges, the necklines of foliation boudinage and in extension veins (Figure 3). Sulphide melt was also channelled into granite pegmatite dykes which cut the S_1 gneissic foliation. Sulphide melt remained mobile for a long period of time (up to 40 My), being constantly recycled during Stage 1 of the Albany-Fraser Orogeny.

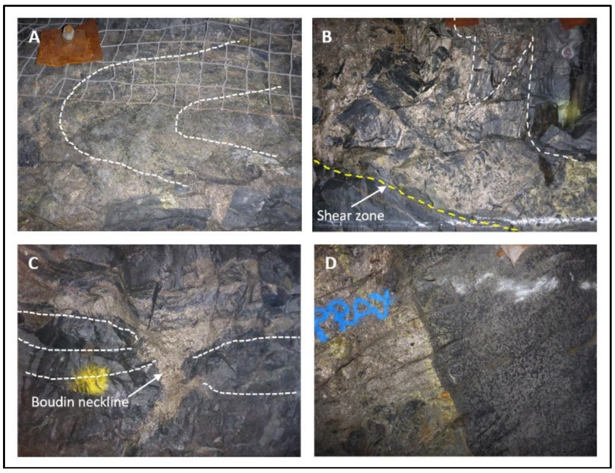

Figure 3. Structure types in sulphide at Nova-Bollinger. A: Passive invasion of recumbently folded mafic granulite gneiss (Nova 2030 OD, East Wall). B: Explosive invasion of a fold adjacent to shear zone (Nova 2055 OD, East Wall). C: Invasion of sulphide into boudinaged foliation Nova (2030 HW3 OD, East Wall). D: Mylonitic contact of olivine pyroxenite chonolith containin heavy next-textured sulphide, and breccia sulphide (Nova 2030 OD West Wall).

Massive sulphide was focussed into megascopic F_2 folds as two styles: 1) Fold-destructive injection resulting in brecciation and catastrophic destruction of fold geometry; 2) Fold preservative injection as passive melt injection along the gneissic layering, resulting in full preservation of fold geometry (Figures 3 and 4). Clasts of sulphide enriched folded gneiss are preserved within the fold-destructive zones, suggesting they are formed earlier in the evolution of the orebodies. Net-textured and disseminated sulphide mineralisation are limited to the tube-like olivine-norite and olivine-pyroxenite intrusions, which are interpreted as the magmatic plumbing and source of the sulphide. Rapid strain rates would be necessary to 'crack' these tubes and allow sulphide to escape and migrate into orogenic structures.

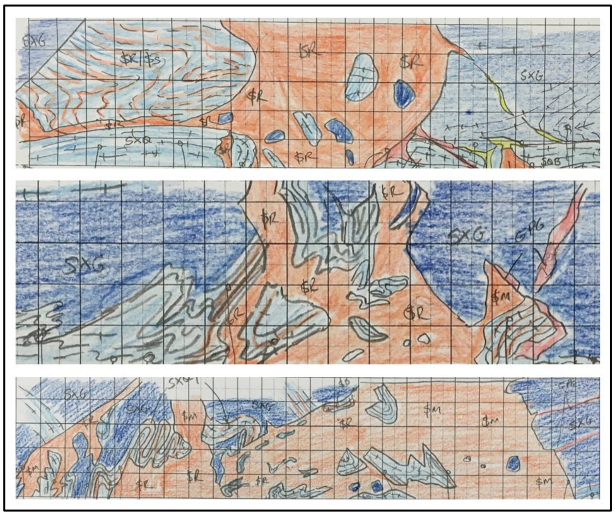

Figure 4. Wall mapping from the Nova 2030 OD, East Wall (top) and opposite walls (centre = East, lower = West) of the Nova 2080 OD. The 2030 level shows both examples of the sulphide concentration in F_2 fold hinges with passive and destructive influx. Abbreviations: SXG – mafic granulite, SXQ – mafic granulite gneiss, SM – massive sulphide, $R – sulphide breccia, $S – sulphidic gneiss. Cell size is 1m x 1m.

CONCLUSIONS

Formation of the Nova-Bollinger magmatic Ni-Cu sulphide deposit was contemporaneous to penecontemporaneous with granulite facies peak metamorphism and deformation associated with Stage 1 of the Albany-Fraser Orogeny (1.3-1.2Ga.). Tube-like ultramafic feeder dykes intruded into F_2 fold hinges, parallel with the principal stretching lineation. Ongoing deformation of these intrusions enabled the rapid extraction of sulphide melt and its emplacement into orogenic structures in the neighbouring gneissic wallrock. Ongoing recycling of sulphide melt during orogenesis resulted in the concentration of sulphide in fold hinges, shear zones and within granite pegmatite dykes. This study therefore highlights the fundamental role of structural architecture in focussing Ni-Cu sulphide mineralisation during orogenesis at granulite facies metamorphic conditions.

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