Characterisation of the Neoarchean Fortescue Group Stratigraphy – Integrated downhole geochemical mineralogical correlation from new diamond drilling

Jessica Stromberg*  
CSIRO Mineral Resources  
26 Dick Perry Ave, Perth, WA, 6152  
jessica.stromberg@csiro.au

Sam Spinks  
CSIRO Mineral Resources  
26 Dick Perry Ave, Perth, WA, 6152  
sam.spinks@csiro.au

Mark Pearce  
CSIRO Mineral Resources  
26 Dick Perry Ave, Perth, WA, 6152  
mark.pearce@csiro.au

SUMMARY

The flood basalts and gold-bearing basal sediments of the 2775-2629 Ma Fortescue Group unconformably overlie the Mesoarchean West Pilbara Superterrane to the south of Karratha, Western Australia. Fresh exposures of the sedimentary units are lacking and their geochemical, mineralogical composition and sequence stratigraphy under cover are largely unknown. This research outlines the results of integrated downhole geochemistry and hyperspectral mineralogy of two new diamond drill holes, 4 km apart, which intersect the Fortescue group stratigraphy into the Mesoarchean Pilbara basement. This has been combined with trace element geochemistry, and high-resolution XRF mapping of representative samples provide micro-structural insights and in-situ geochemistry with textural context.

The lithostratigraphy of the holes was defined using automated geochemical logging and tessellation methods, which provide objective classification of geologic units based on geochemistry and mineralogy. Individual basalt flows within the Kylena Formation can be correlated across holes based on chlorite content and geochemistry, and a chromium-rich geochemical marker horizon has been identified at the top of the siliciclastic Hardey Formation. The granitic basement rocks show evidence of significant fluid flow are interpreted to be a southern extension of the Maitland River Supersuite, consistent with regional geophysical anomalies that show a continuous gravity low.

This dataset provides an unprecedented view into the Fortescue Group stratigraphy and its geochemistry. Correlation of this dataset with previous drilling provides insights into the regional tectonic and depositional history of the basin. The depth to basement increases from 650 m to >2200 m over ~12km N-S and the thickness of the clastic sedimentary basal Hardey Formation increases from ~150 m to 1050 m respectively. This indicates significant variation in the geometry of the basement during the deposition of the basal Hardey Formation, which was likely influenced by synsedimentary rifting. This has implications on the distribution of potential gold-bearing conglomerate facies unconformably overlying the basement, and in the Hardey Formation.

Key words: Fortescue Group, Geochemistry, Stratigraphy, Hyperspectral

INTRODUCTION

The West Pilbara Superterrane is one of the major tectonic units of the northwest Pilbara craton and comprises the Karratha, Regal, and Sholl Terranes as well as the Nickol River Basin (Hickman, 2016). This region is intruded by a series unrelated granitic complexes including the 3006-2982 Ma Maitland River Supersuite which forms a >200km long, 50km wide belt of monzogranite, tonalite, and granodiorite intrusions (Figure 1) (Hickman, 2016).

Figure 1. Simplified regional geological map of the West Pilbara Superterrane, highlighting Sholl Terrane (ST), the Maitland River Supergroup, gold nugget showings, and the location of the three drill holes. Inset map of Western Australia with box showing area in geological map. Modified after (Van Kranendonk et al., 2002)

The Fortescue Group unconformably overlies the Pilbara craton and is the basal stratigraphic unit of the ~2.8-2.4 Ma Mount Bruce Supergroup. The Fortescue Group comprises ~6.5km of sedimentary and extrusive volcanic rocks which are divided into 7 formations: the basal Mount Roe Basalt, and the Bellary, Hardey, Kylena, Tumbiana, Maddina, and Jeerinah
formations. The base of the Fortescue Group is locally marked by a discontinuous polymictic conglomerate unit derived from the underlying granite-greenstones (Hickman and Kohan, 2003). The extent of this horizon at the Fortescue Group-basement unconformity is of primary importance to explorers in the region given the discovery of gold nugget-bearing conglomerate such as the Purdy’s Reward deposit on the northern margin (Figure 1).

To better constrain the extent of this horizon, two diamond drill holes (18ADAB01, 18ABAD02) were drilled into the Fortescue Group to intersect the basement contact to the south of the nugget bearing outcrops. These two drill holes intersected the Archean basement at 644 and 706 m respectively and were characterised in detail using a combination of geochemical and mineralogical methods from the drill hole to micron scale.

**METHODS**

Continuous downhole geochemical and hyperspectral measurements were collected for both drill holes using the Minalyze™ and HyLogger3™ instruments. The Minalyze™ system provides a continuous XRF line scan down the core aggregated into 10 cm and 1 m intervals. Lithogeochemical domains were determined from the Minalyze data using the wavelet tesselation method outlined by Hill et al., (2015) for automatic boundary detection.

The HyLogger3™ system (located at the GSWA core library) provides hyperspectral measurements in the SWIR (0.4-2.5μm) and TIR (6-14 μm) wavelength ranges as a 1cm line profile (Schodlock et al., 2016). The hyperspectral data were analysed, interpreted and integrated with the XRF data using TSG™ (The Spectral Geologist) software package.

Geochemical maps were collected using the Maia Mapper, a new laboratory XRF mapping system for efficient elemental imaging of drill core sections. Data were collected using a 20 μm source size, filtered using a 1.0 mm aluminium window, and (iii) an efficient XOS polycapillary lens with a flux gain 15,900 at 21 keV into a ~32 μm focus, all integrated with stage raster scanning (Ryan et al., 2018). Maps were processed using GeoPIXE, which uses the Dynamic Analysis method for image projection (Ryan et al., 2000).

**RESULTS**

The two drill holes intersect the Archean granitic basement at ~650-700 m after passing through what is interpreted as the Tumbiana, Kylena, and Hardey formations. The Hardey Formation lithologies are dominated by coarse siliciclastic sands and gravels with minor siltstone packages, consistent with deposition in a fluvial deltaic fan environment with intermittent overbank or lacustrine environments (Thorne and Trendall, 2001). The Kylena Formation is dominated by massive basaltic flows, pillow lavas, and hyloclastite breccias. The fluvial-lacustrine (Coffey et al., 2013) Tumbiana Formation lithologies are dominated by stromatolitic-carbonate siltstone-sandstone unit with abundant detrital pyrite sequences.

Geochemical domaining of the drill hole XRF data show variability in downhole geochemistry in the all units. Using Cr*Zr/Ti ratios in the wavelet tessellation method these stratigraphic units are well-defined when compared to lithological observations (Figure 2). Likewise, variation and periodicity in chlorite (Figure 3) and carbonate abundance observed in the Kylena Formation Hylogger datasets reflect individual basalt flows, and the large scale variability in chlorite chemistry (Figure 3) correlates with in the lithogeochemical domains (Figure 2). Maia Mapper μXRF geochemical maps show incredible detail that helps demonstrate the origin of geochemical anomalies, such as arsenic-rich pyrite associated with thick stromatolitic sections in the Tumbiana Formation (Figure 4A), and insights into alteration and fluid flow through the Archean basement (Figure 4B).
DISCUSSION

When the lithologies intersected in these drill holes are compared with older deep drill hole DD84MF1 which was collared ~20 km to the south (Figure 1), the thicknesses of the Kylena and Tumbiana formations are comparable across the basin (Figure 5). However, the Hardey Formation is considerably thicker in the DD84MF1 drill hole to the south. This suggests there was either possible synsedimentary faulting during the deposition of the Hardey Formation, or there was considerable variation in basement paleotopography. The comparable thicknesses of the younger units across the basin indicate that the majority of the basin accommodation space had been accommodated by the infill of the Hardey Formation and/or that any potential synsedimentary faulting had ceased prior to their deposition. The presence of NW-SE trending structures proximal to the deep DD84MF1 drill hole may explain relatively localised thick packages of Hardey Formation as they likely created deeper depocentres during regional rifting.

Figure 3. Downhole plots of chlorite abundance coloured by chlorite chemistry as defined by the depth (2250D) and wavelength (2250W) of the 2250 nm Mg-OH feature in the HyLogger SWIR spectrum.

Figure 4. Maia Mapper XRF maps of half core from the Tumbiana Formation (121.3-121.7m) (A) and Archean Basement (B) (708.1-708.4m) in hole 18ABAD01. A. Carbonate and pyrite rich stromatolite. B. Feldspar rich (K-feldspar (red) and plagioclase (green)) brecciated basement with iron rich breccia matrix.
CONCLUSIONS

- The distribution and thickness of the Hardey Formation was primarily controlled by synsedimentary rifting, leading to thick localised packages proximal to NW-SE trending structures.
- The deposition of the Hardey Formation sediment filled most of the accommodation space of the basin prior to the deposition of the Kylena and Tumbiana formations, suggesting that (in the study area), rifting had ceased.
- Structural control on the sedimentation of the Hardey Formation may influence the distribution of gold-bearing lithologies in the unit.

ACKNOWLEDGEMENTS

The diamond drill holes described in this work were drilled as a part of the GSWA Exploration Incentive Scheme (EIS) Co-funded Exploration Drilling Program. We acknowledge Artemis Resources and the GSWA for access to the drill holes, and GSWA and AuScope NVCL for the Hylogger data collection.

REFERENCES


