Mineral exploration under cover and the value of petrophysics – A case study from East Albany-Fraser Orogen, Western Australia.

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SUMMARY

Greenfield mineral exploration undercover presents a number of challenges. In the East Albany-Fraser Orogen, when faced with the possibility of 300-700m of cover and very little previous exploration, any available data is valuable. Collection of petrophysical data is a cost-effective method to optimise the information in the available drilling with three main benefits: Firstly, an understanding of the physical properties of the cover sequence of the Eucla Basin, the Madura and Loongana Formations and the underlying basement will aid in the geophysical modelling and development of the mapping and targeting program. Secondly, when the petrophysical data from a drill hole is effectively integrated with the mineralogy, geochemistry and observed lithology, a greater understanding of the geological controls of the petrophysical properties can be observed and the processes that are influencing them inferred. Finally, with comprehensive integration of these datasets, will significantly increase our confidence in the source, validity and interpretation of the geophysical responses.

A study was undertaken utilising Geological Survey of Western Australia (GSWA) Exploration Incentive Scheme (EIS) open file drillhole data from East_Fraser Orogen. Peterophysical data were collected on the available core and new acquired drillholes and this included magnetic susceptibility, dry bulk density, apparent porosity, grain density, p-wave velocity, acoustic impedance galvanic resistivity, chargeability and inducted conductivity. All drill holes reached basement, a few holes had cover that could be sampled, all holes had different levels of geochemical assaying, and petrography was available for some of the holes.

The results of the integration of the petrophysical data with the mineralogy, geochemistry and observed lithology were many. They included a strong correlation between the dense observations in the core and lithological and mineralogical changes in the basement and a better understanding of the cover and the source and nature of its conductivity response.

Key words: petrophysics, nickel, geochemistry, density, magnetic susceptibility

INTRODUCTION

The East Albany-Fraser Orogen is located in southern Western Australia on the eastern edge of the Yilgarn Craton (Figure1a). The basement is covered by the Madura shelf formation and the overlying Eucla Basin. This cover can have a thickness in part of more than 500m and has attributed to little exploration. This resulted in only a small number drill holes available to assess the geology. Two of the open file holes (Hannah1 and HDDH002 (Haig)) that were drilled 2006 and 2011 respectively, together with two drill holes recently drilled by BHP (Morphy and Roma) in 2021/2022 have been used in this study. Petrophysical data were collected on the four hole at 5metre interval and included magnetic susceptibility, dry bulk density, apparent porosity, grain density, p-wave velocity, acoustic impedance, galvanic resistivity, chargeability and inducted conductivity. These data were integrated with the geochemistry to gain a better understand of the geology and also to understand the physical properties of the units and investigate how they can be used in mapping and targeting.

BASEMENT COVER SEQUENCE

The cover sequence contains limestone and sandstone of the Eucla Basin which overlying shales, siltstones, mudstones, minor sandstones of the Madura Formation and running sands and conglomerate and Loongana Formation (Figure 1b). The open file drill holes did not contain the cover sequence other than approximately 80m near the unconformity of cover and basement in Hannah1 drill hole. The petrophysical data collected from the core recently drill by BHP (Morphy (SHDX001A) and Roma (SHDX004)) and newly release SHDX002, has shown that the cover has conductive response (Figure 2). This response coincides with the contact between the Eucla basin limestone and the Madura Formation around 150m -200m, and a further variation in the resistivity/conductive response in the Madura Formation closer to the unconformity with the basement. This observation would influence the design and consequent depth of penetration of any electromagnetic surveys. The petrophysical data complements the recently flown AusEM data and demonstrated that the airborne EM data is mapping the top of the Madura mudstone, but does not penetrate much further.

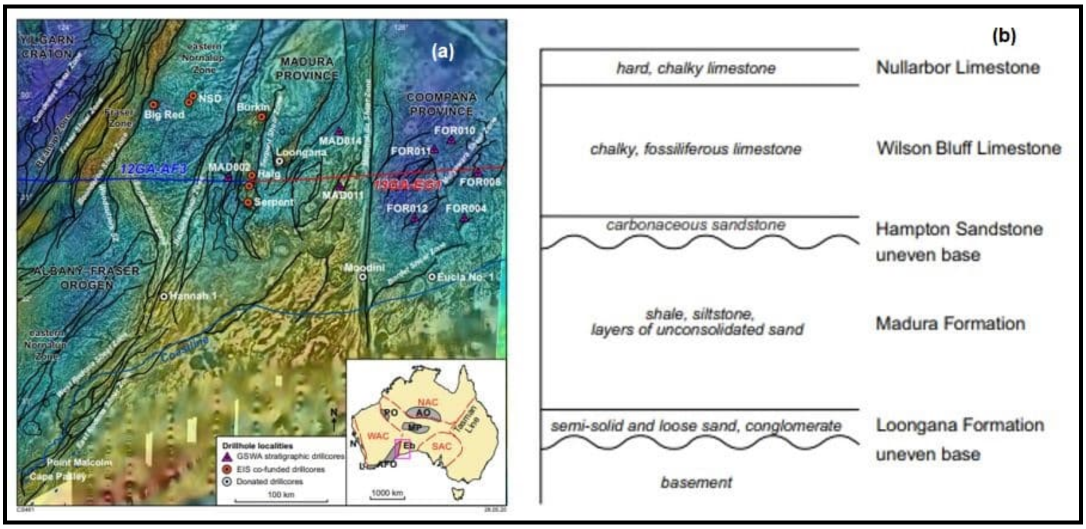

Figure 1 a) Simplified structures and drill sites on a draped image of GSWA gravity data (colour) and reduction to the pole first vertical derivative GSWA aeromagnetic data (greyscale). (Spaggiari, CV., et al. 2020). b) Schematic diagram showing the main lithologies of the cover sequence (Spaggiari, CV., et al. 2020).

This conductivity/resistivity contrast between the Eucla Basin and the Madura Formation adds value to water resources in the area. Based on the observed borehole information, the water table coincides with the unconformity at the contact of the Eucla Basin and the Madura Formation. Due to the nature of the Madura and Loongana Formations and the stability of the core, it was difficult to obtain good P-wave and acoustic impedance readings.

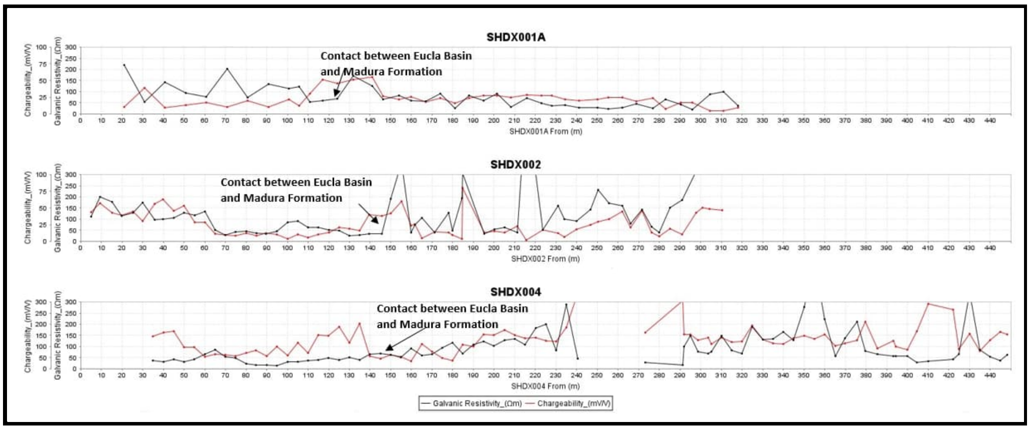

Figure 2 Drillhole petrophyical data of the cover - galvanic resistivity and chargeability.

MAPPING GEOLOGY OF THE BASEMENT

The basement of the East Albany Fraser Orogeny contains mafic lithologies of approximate ages of 1350Ma and 1140Ma. They are considered to represent events of the Stage I and II of the Albany-Fraser Orogeny. The two stages mark the collision, accretion and subduction (and further reactivation, during stage II) of the Loongana Arc to the eastern margin of the Yilgarn Carton. The petrophysical data has shown that the most significant physical property to map the contact between the cover sequence and these mafic lithologies of the basement is density (Figure 4). The basement lithology, intersected by the 4 drill holes, were geochemically different as well exhibiting different geophysical signatured observed in the GSWA airborne magnetics and ground gravity.

i. SHDX004 – Magnetic and Moderately Dense (Monzodiorite)
ii. HANNAH 1 – Strongly Magnetic and Moderately Dense (Granodiorite)
iii. HDDH002 – Magnetic and Dense (Gabbro)
iv. SHD001A – Weakly Magnetic and Dense (Gabbronorite)

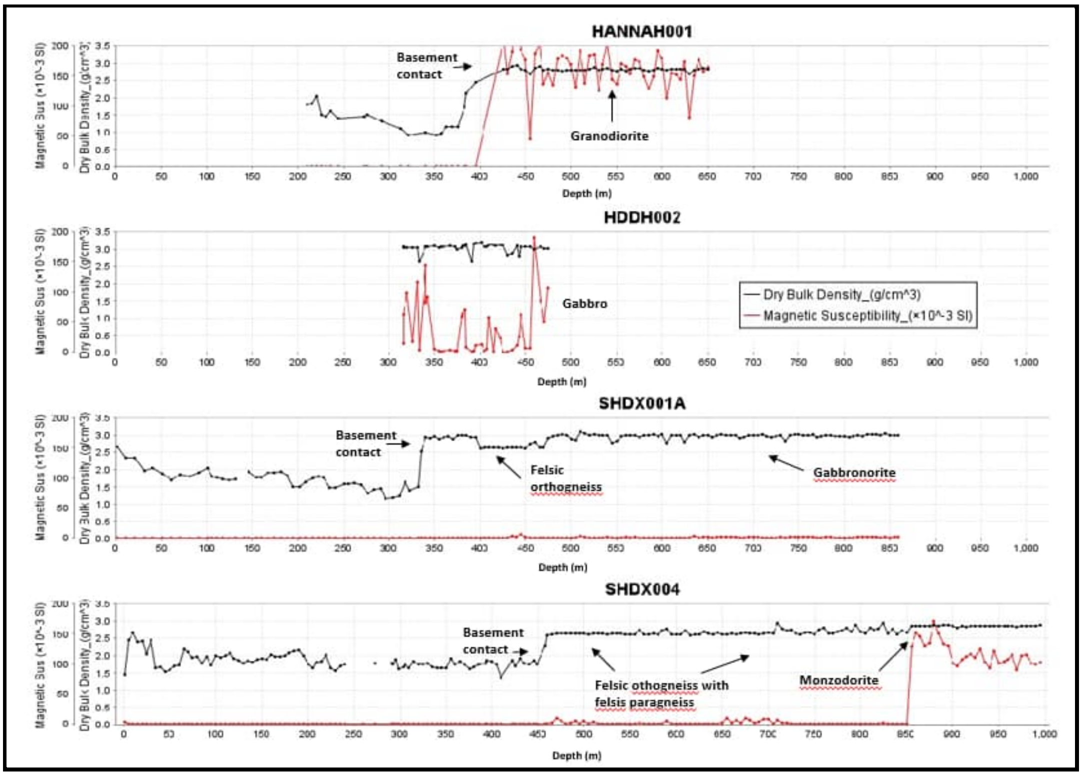

Figure 3 Dry bulk density and magnetic susceptibility data from drill holes Hannah001, HDD002, SHD001A, SHD004.

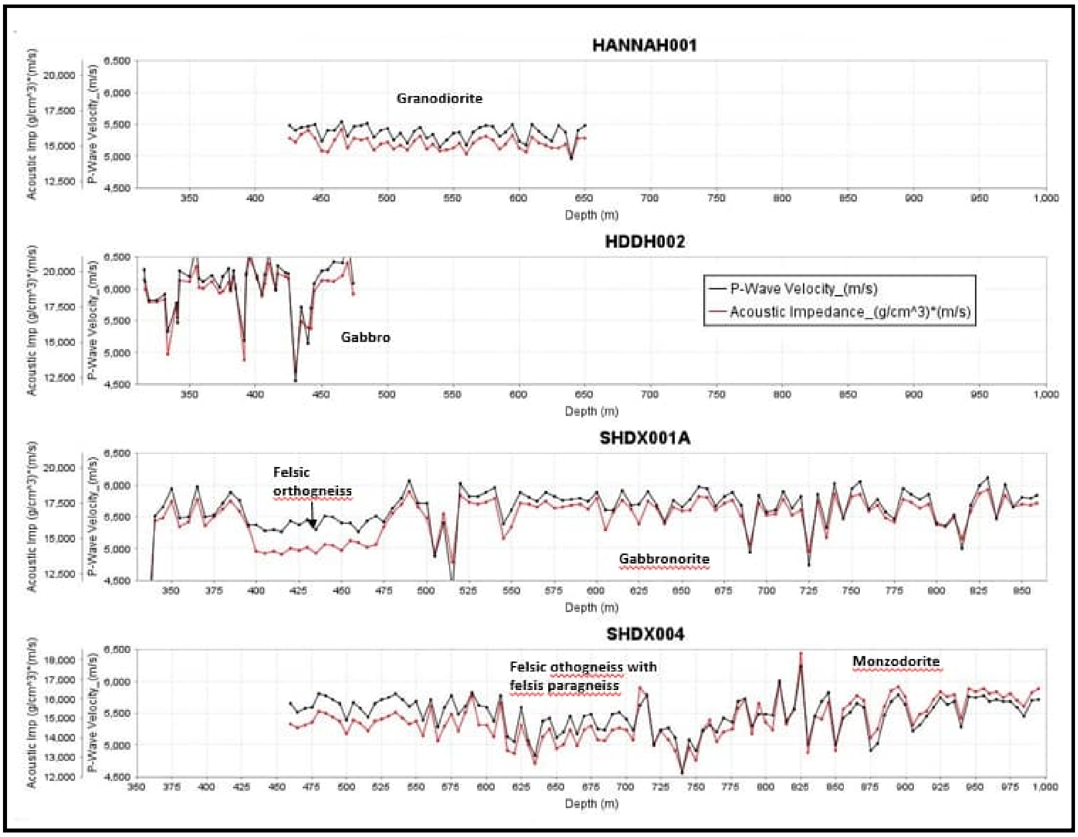

Figure 4 P-wave velocity & acoustic impedance for basement sequence of drill holes Hannah001, HDD002, SHD001A, SHD004.

The petrophysical data gave content to the observed airborne magnetic and ground gravity data but also added an understanding of the relationship of the physical properties and the mapped geology in the core. This is evident magnetic susceptibility and density reading as shown in Figures 3. The P-wave velocity & acoustic impedance data also showed variations that coincided with the basement geology Figure 4.

When the petrophysical data of the mafic rocks from the basement was integrated with the geochemical data the correlations became even more apparent, between the different drill holes. For example, Figure 5 shows the different mafic rocks encountered in the drill holes, while having differences in MgO and in part TiO_2 each, had a distinct degree of density. The increase in MgO coincides with the increase in density and the increase in TiO_2 sees a decrease in the density. Even the simple correlation between the magnetic susceptibility and the density (Figure 6) showed a unique physical properties associated with the different mafic rocks and their geochemistry encountered in the drill holes. The relationship between magnetic susceptibility and density is reflected in the different mineralogy and geochemical content, in this case MgO. Further detail work also identified subtle variations in the degree of variation of felsic orthogneiss to paragneiss in SHDX004 through density logs.

The data in Figure 5 and 6 had been filtered to just show the samples that had been logged as a mafic units. With this integration of the petrophysical and geochemical data, outliers can also be identified, as shown in the two circled in red in Figure 6. These outliers were logged as a Gabbro but based petrophysical data they may be slightly different than the Gabbro mapped in the rest of the drillhole.

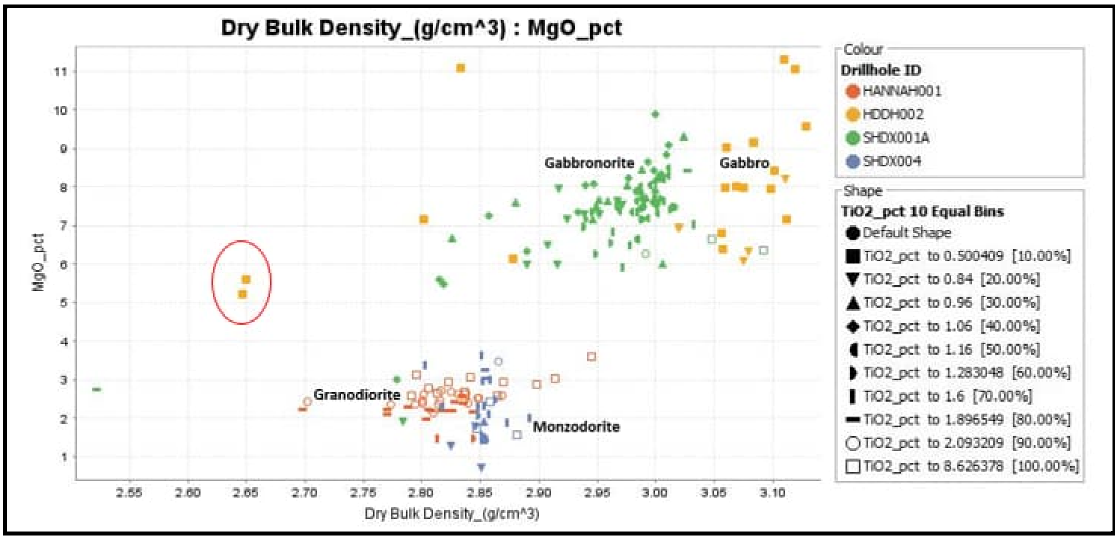

Figure 5 Plot of MgO v dry bulk density with symbol shapes reflecting TiO_2.

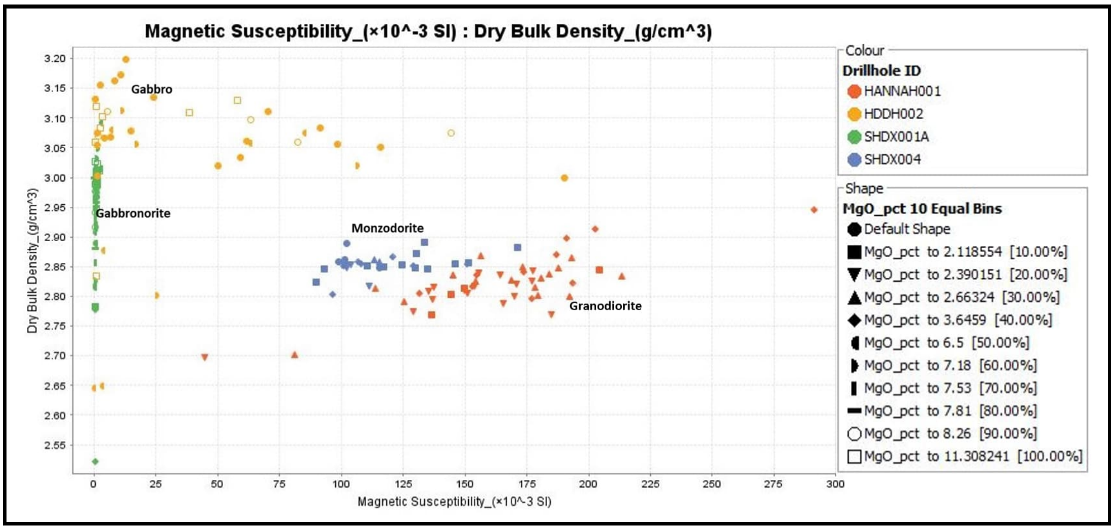

Figure 6 Plot of magnetic susceptibility v dry bulk density with symbols reflecting MgO.

CONCLUSIONS

The work completed has demonstrated the value of understanding the physical properties of the rock units that are being mapped when exploring undercover. In the case of the East Albany-Fraser Orogen, the cover sequence and basement are both of significance. The understanding from the results will aid exploration and future targeting and aid water resource that will benefit the landowner and aid future drilling.

This exercise of utilising the petrophysical data from GSWA EIS drillholes is a relatively cheap and easy process. The degree of interpretation is limited by the sample interval of the petrophysical data on core and the quality of the core that is returned from the drilling. As project develop, wireline petrophysical surveys would be undertaken to get the most value out of the drilling programs.

The petrophysical data combined with the core geology and geochemistry has played a vital part in understanding the relationship of the physical properties to the geology and enable the interpolation of this understanding to the greater region of the East Albany-Fraser Orogen.

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