Targeting Fractured Rock Aquifers using Magnetic Data

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SUMMARY

Fractured Rock Aquifers are an important source of water with approximately 40% of groundwater in Australia present in fractured rock. The water extracted from fractured rock aquifers is utilised in mining, irrigation, town water supply and stock watering. A third of water extraction bores in Australia are in fractured rock systems. Understanding the possible size, potential for fracturing and accurate locations for targeting bores is an important part of exploring for fractured rock aquifers. Magnetic data, both airborne and ground, can be used to assist in mapping fractures, dykes and identifying rock types with favourable rheology for hosting fractured rock aquifers.

Magnetic data have been collected by both government geological agencies and mining and exploration companies across large parts of Australia, ranging from 400m spaced data down to very detailed 25m spaced surveys. This is a low-cost solution for targeting bores as data can be acquired free of charge from government surveys or open file searches. The data can be filtered in several ways, such as second vertical derivative, to highlight the location of faults, fractures and potential water traps along dykes and other potential aquatards.

Two case studies are presented showing the use of magnetic data in identifying locations for potential fractured rock aquifers. The first example is a 25m spaced survey from the Pilbara where water was required for a processing plant for a mining company. The interpretation was completed in collaboration with the company and hydrologists to identify the best potential sites for drilling a water bore. Another example from the Great Southern, Western Australian used 80m line spaced magnetic data, which was interpreted to identify priority drilling targets close to existing infrastructure.

For fractured rock aquifer exploration, magnetic data filtering and interpretation is a cost-effective solution for identifying targets for exploration by drilling.

Key words: Water, Magnetics, Fractured Rock, Western Australia

INTRODUCTION

Two case studies are presented showing the use of magnetic data in exploration for fractured rock aquifers. Fractured rock aquifers equate to 40% of groundwater in Australia and are an important source of water for mining, irrigation and town water supplies. Magnetic data are an important and cost-effective resource in exploring for fractured rock aquifers, that in some circumstances can be underutilised by hydrogeologists.

The first case study, in the Great Southern Region of Western Australia, shows how magnetics was utilised to assist in water exploration for town water supply. The second case study, Warrawoona in the East Pilbara of Western Australia, shows how a dataset originally flown for gold exploration was utilised in exploring for water needed for a new processing plant. In both case studies a series of targets were supplied and assessed by the project hydrologists and integrated with other datasets.

METHOD

Standard airborne magnetics data were processed and filtered in both case study areas. Radiometrics data are usually collected concurrently with modern airborne magnetics surveys and were also processed and used as an additional complementary data set in both case studies. The radiometrics datasets are often referred to during the interpretation but due to cover, they often do not show as many clear fracture patterns as the magnetic data, however, the presence of outcrop or regolith cover can be important part of targeting. Magnetic data, due to its capability of seeing through non-magnetic cover, was the main tool used in both areas for identification of fractures.

The method for interpreting faults and fractures from magnetics is well described in Isles and Rankin, (2013) and a similar approach has been used in these case studies. Most faults and fractures observed are related to displacement or termination of magnetic units and demagnetisation. For both areas, the detail required for interpreting fractures was obtained by the use of magnetic filtering. A comparison between the reduction to pole image for the great southern case study areas in Figure 1 and the second vertical derivative image in Figure 2 show the level of detail that is obtained by careful cleaning and filtering of the original total magnetic intensity (TMI) data. Derivative images highlight important structural breaks that have been interpreted as faults and fractures.

In our experience, we sometimes find that hydrogeologists can have a limited understanding of the ways in which magnetic processing and enhancements can greatly assist in the interpretation of magnetics data. While exploration geologists are comfortable and familiar with the processing and products, such as derivatives, we often find hydrogeologists struggling to interpret regional TMI images in areas where detailed open file data can readily and cheaply be acquired, processed and filtered ready for interpretation.

For both case studies targeting for fractured rock aquifers was prioritized based upon the likelihood of the fracture containing significant extractable water in features such as major structures, rheology contrasts or intersecting fractures. The faults and fractures are not the only factor to be considered when targeting fractured rock aquifers, as the fractures can be very narrow, other factors such as recharge potential, and water quality was evaluated from drainage patterns, elevation, lithology and depth of regolith. These factors, as well as the proximity to infrastructure such as access tracks and existing pipelines, has been used for targeting.

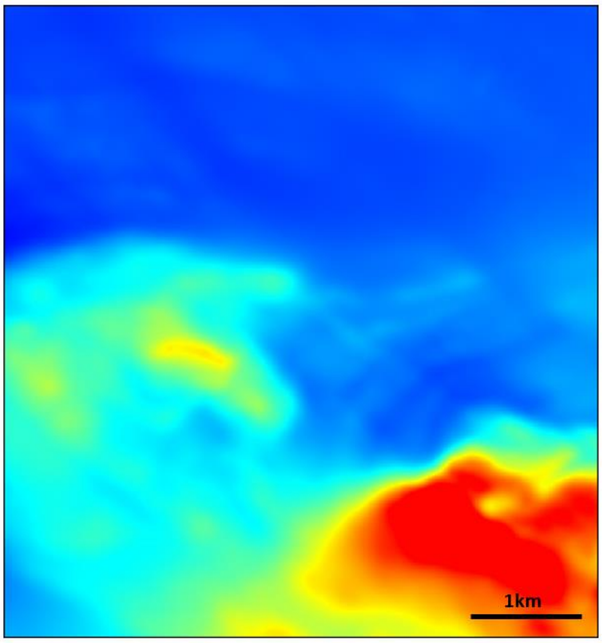

Figure 1. Total magnetic intensity image with linear colour stretch from the Great Southern case study area.

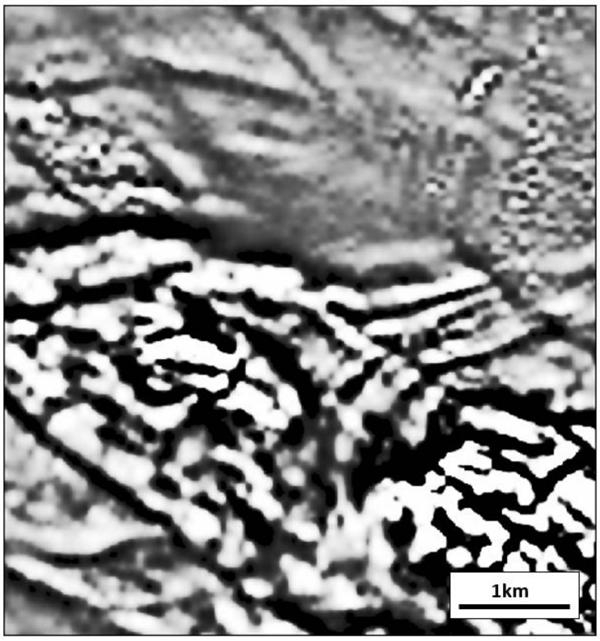

Figure 2. Second vertical derivative of total magnetic intensity image with linear colour stretch from the Great Southern case study area.

CASE STUDY 1 - GREAT SOUTHERN, WESTERN AUSTRALIA

Fractured rock aquifers have been investigated using magnetics in the Great Southern Region of Western Australia as a decrease in rainfall in the south west of Western Australia, coupled with increasing population has put pressure on multiple town water supply schemes in this region. The fractured rock investigation was aimed at locating new ground water supplies that were near existing infrastructure. An airborne magnetics survey was flown in 2016, but due to significant competition for groundwater resources in the area, the exact survey location is still confidential at this time.

Existing town water supplies predominantly rely on a combination of coastal sedimentary aquifers and surface water dams. The main aquifer system for town water supply bores in this area is the basal sand of the Werillup Formation, as well as quaternary coastal limestone aquifers, (Kern, A. M., 2007).

The 2016 airborne magnetic survey has 80m line spacing and north-south line direction. These data are a significant improvement over the existing 200m – 800m line spaced government magnetic data available in the area. A detailed structural interpretation was undertaken on the processed and filtered data.

Basement rocks comprise Proterozoic gneiss, high-grade metamorphic rocks and granitoids of the Albany-Fraser Province (Muhling, and Brakel, 1985). The main structural direction in the area is north west and numerous major faults/ shears have been interpreted from the magnetic data in this direction (Figure 3). The major faults extend throughout the survey area. Older structures trend easterly to north easterly. Faults/ fractures have also been interpreted in these directions. Numerous minor faults/ fractures occur in both dominant fault directions. Cainozoic sediments include the Plantagenet Group, which unconformably overlies the Precambrian bedrock. This group consists of the Pallinup Siltstone, which overlies the Werillup Formation. Quaternary coastal deposits, sand containing iron pisolites and laterite overlie the Tertiary Plantagenet Group.

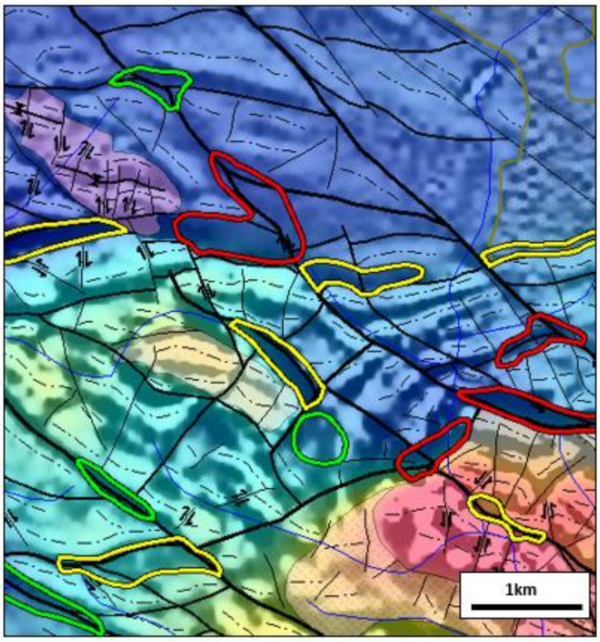

Figure 3. Reduction to pole of total magnetic intensity colour with second vertical derivative shade from the Great Southern case study area. Interpretation and targets overlayed on image, interpreted faults and fractures (black), targets (red, yellow and green), drainage (blue), shallow granitic bedrock (pink to yellow regions), and laterite (grey).

The basal sand of the Werillup Formation generally forms a water aquifer where it overlies basement structure or lithological trap structures, and groundwater may pool within these structures. Structural targets (Figure 3) comprised interpreted major or secondary faults or fractures in bedrock and the intersection between faults. Areas of shallow bedrock have been interpreted from radiometrics in Figure 4. Lithological trap structures comprised areas adjacent to raised basement blocks, where water may pond in the Tertiary sediments against the less permeable basement rocks.

The detailed magnetics survey combined with radiometrics has allowed for significant improved targeting of the fractured rock aquifer, and there has been some success with intercepting fracture zones, however, the salinity has been higher than is ideally wanted.

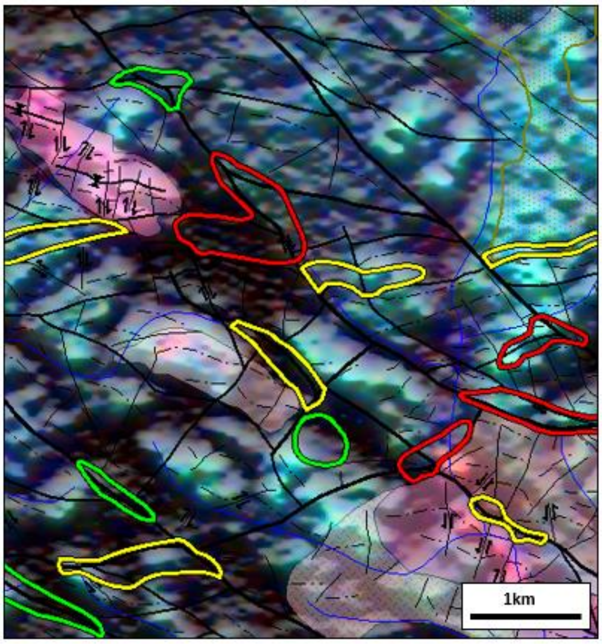

Figure 4. Radiometric ternary image, potassium (red), Thorium (green), uranium (blue) from the Great Southern case study area. Interpretation and targets overlayed on image, interpreted faults and fractures (black), targets (red, yellow and green), drainage (blue), shallow granitic bedrock (pink to yellow regions), and laterite (grey)

CASE STUDY 2 - WARRAWOONA

The Warrawoona Gold Project, owned by Calidus Resources Limited, is located in the East Pilbara Goldfield of Western Australia. The project focuses on the Klondyke Gold Deposit, which at the time of writing has a resource of 1.5 million ounces. Construction is in progress for the processing plant and mill, which will require a local water supply.

The mine and processing plant are located in the Warrawoona Greenstone Belt near Marble Bar in Western Australia (Figure 4). The Warrawoona Greenstone Belt is comprised of mafic to ultramafic volcanic lithologies with minor felsic volcanic and sedimentary rocks including bands of chert and silicified black shales (Van Kranendonk et al, 2006). The Warrawoona Belt is located between granitoids of the Mount Edgar Dome, north, and Corunna Downs Dome, south (Hickman and Van Kranendonk, 2008). The greenstones were strongly deformed and sheared during four major stages of mappable deformation (Miller et al, 2018).

The dominant deformation direction is in a north west to south east direction, which hosts the Klondyke Resource. The government mapping does indicate several late-stage cross cutting structures, including some dykes which cut across the main deformation direction. These cross-cutting features and dykes were targeted for fractured rock aquifers.

Available magnetic data over the project area originally consisted of government 400m line spaced data, with small blocks of open file magnetic data at 100m spacing (Figure 5). This dataset was being utilised by the project hydrologists for assisting in targeting fractured rock aquifers.

At the beginning of 2020 Calidus commissioned a detailed 25m spaced airborne magnetic and radiometric survey for mineral exploration purposes. At this time, it was identified that the data could also be utilised for the hydrology targeting. A series of filters were produced to identify which would assist in identifying fractured rock, with the second vertical derivative of reduced to pole being identified as the clearest filter for identification of faults, fractures and dykes (Figure 6).

The interpretation focused on the delineation of late-stage cross cutting structures and dykes. It was considered that dykes may have a rheology that fractures more than the surrounding sheared geology. Targets were selected based on fault/ fracture intersections, intersections of faults/ fractures and dykes and large scale through-going structures that have offset other lithologies and cut from higher to lower elevations (Figure 7). The targets were then ranked according to their proximity to access tracks.

The additional detail provided by the 25m spaced data has greatly improved the ability to identify faults, fractures and structures and assisted in fractured rock targeting.

CONCLUSIONS

The two different case study areas have vastly different geological settings and water requirements; however, the use of magnetic data has been able to greatly enhance the targeting of potential fractured rock aquifers in both areas. Magnetics data is often already available for many mining projects or can be acquired cheaply, compared to drilling costs. The use of magnetics data in minerals exploration is well known, however, hydrogeologists have often had limited exposure to the ways in which magnetics data can be processed and filtered to better define structure important in fractured rock aquifers and how it can complement other exploration methods at low cost.

ACKNOWLEDGMENTS

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REFERENCES

Hickman, A. and Van Kranendonk, M., 2008. Marble Bar WA Sheet 2855: Geological Survey of Western Australia, 1:100,000 Geological Series.

Isles, D.J and Rankin, L.R, 2013. Geological Interpretation of Aeromagnetic Data, CD Book Australian Society of Exploration Geophysicists.

Kern, A. M., 2007, Hydrogeological assessment of the western South Coast Region, Department of Water, Hydrogeological Report Series, No. HR260.

Miller, J., Lau, I., Birchall, R., and Shelton, T. C., 2018. Geology and mineralisation at the Warrawoona Project near Marble Bar, WA: CSIRO Kickstart Project Presentation.

Muhling, P. C., and Brakel, A. T., 1985, 1:250,000 Geological Series explanatory notes on the Mount Barker-Albany Sheet (sheets SI/50-11, SI/50-15). Geological Survey of Western Australia. ISSN 0729-3720. pp. 26.

Van Kranendonk, M. J., Hickman, A. H., and Huston, D. L., 2006, Geology and mineralization of the east Pilbara — a field guide: Western Australia Geological Survey, Record 2006/16, 90p

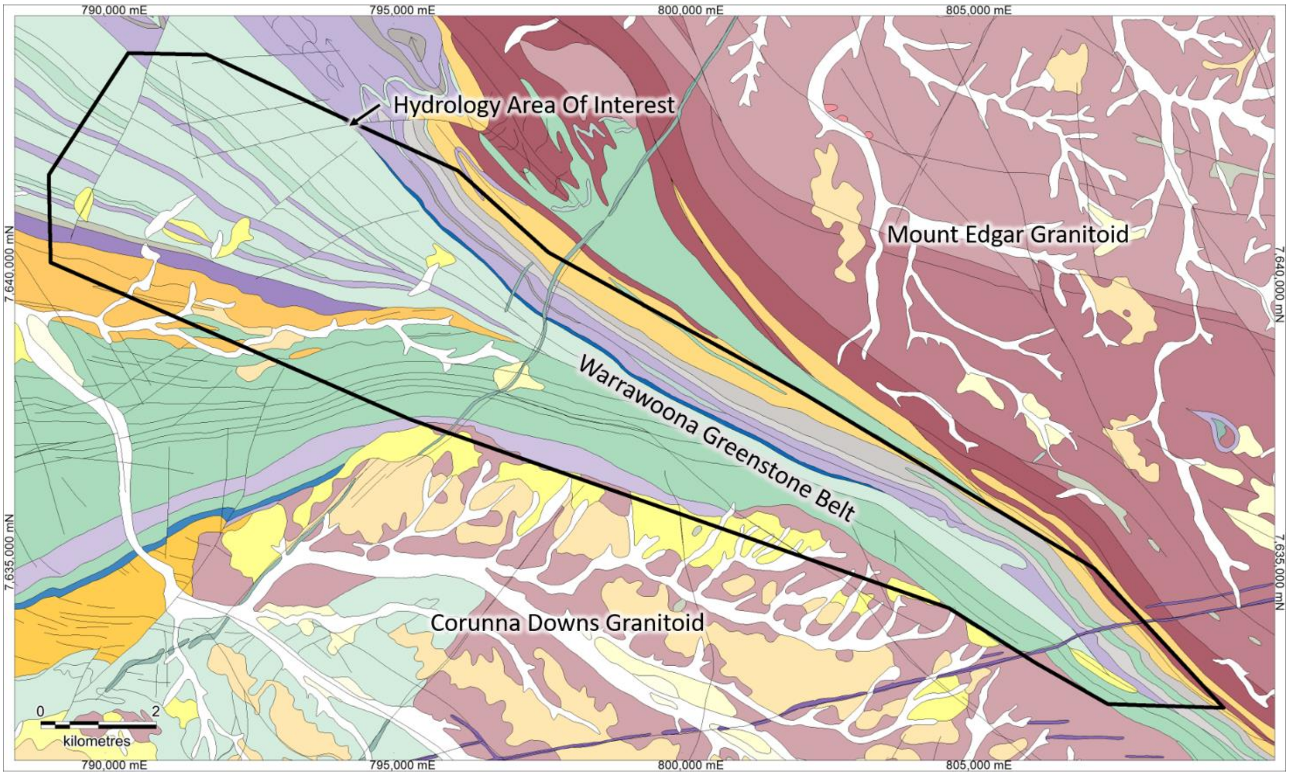

Figure 4. 100 000 scale government geology map (Hickman and Van Krenendonk 2008).

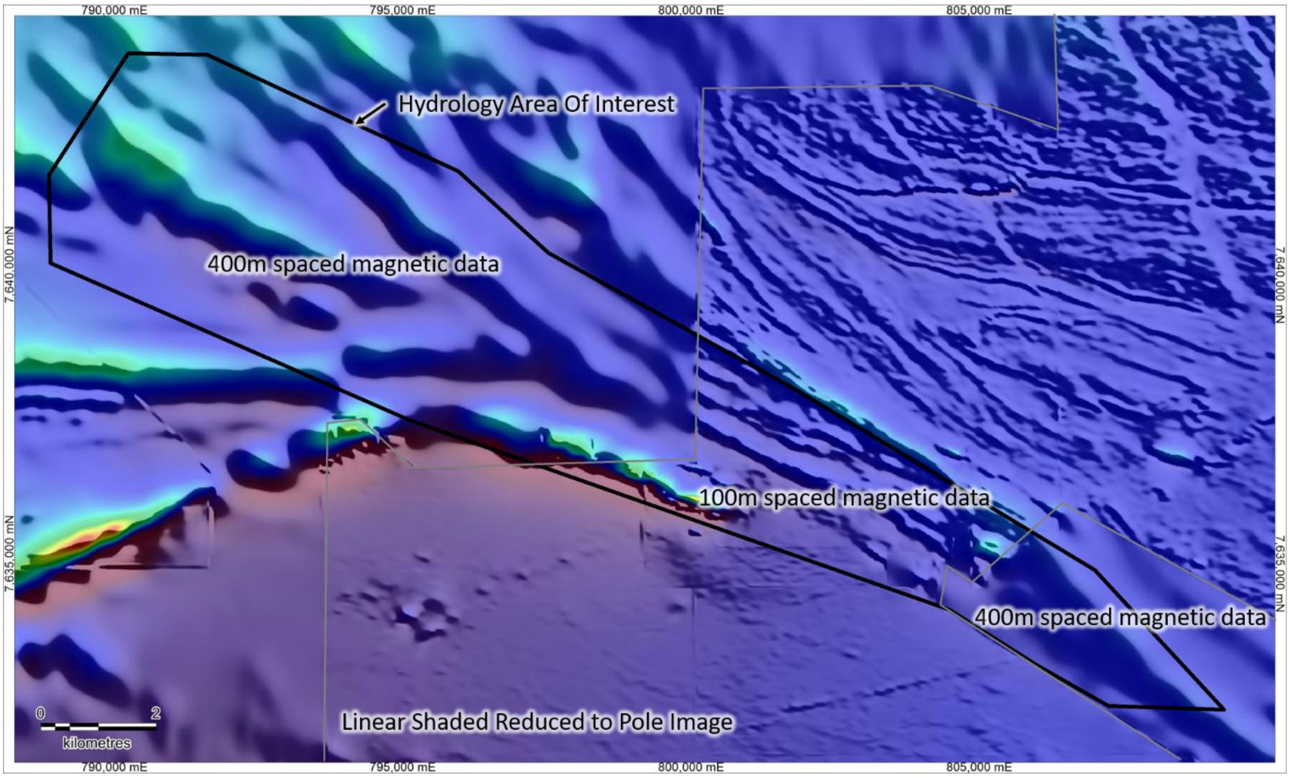

Figure 5. Government and open file linear shaded reduced to pole image.

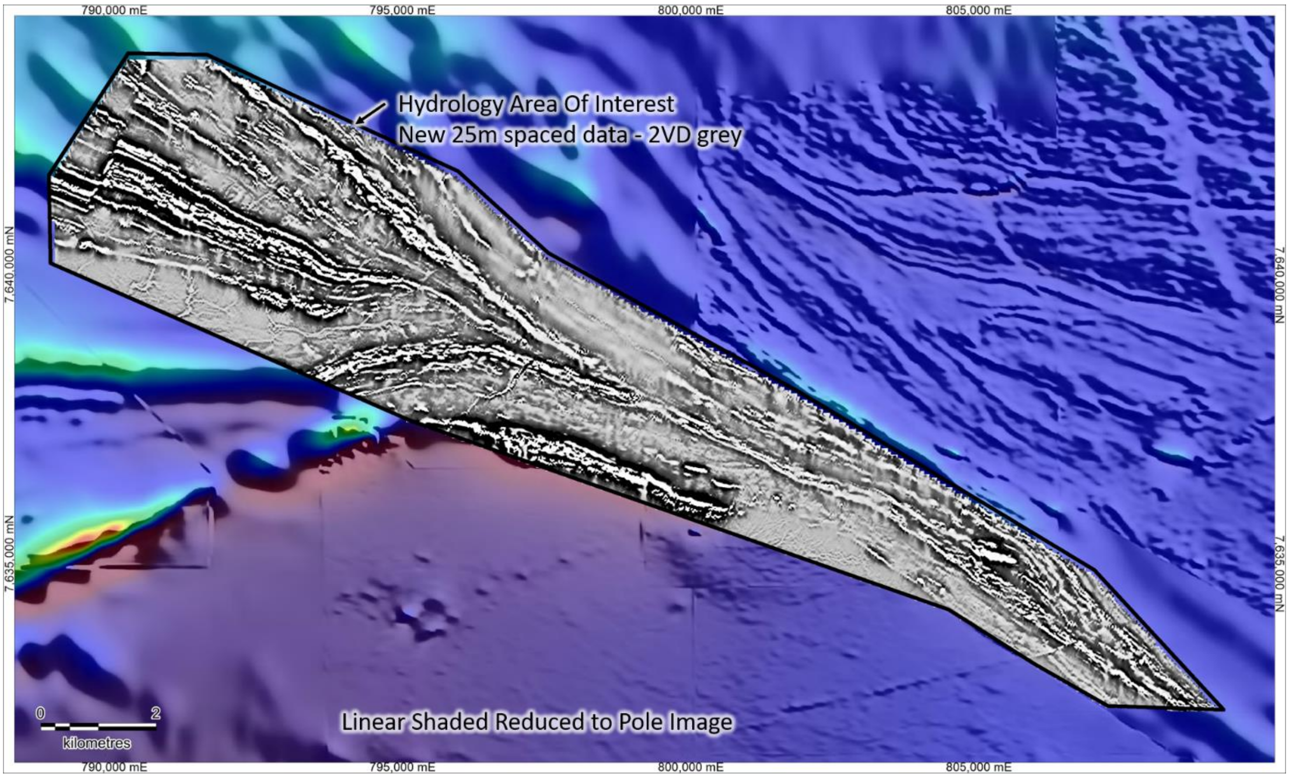

Figure 6. New 25m spaced second vertical derivative image on Government and open file linear shaded reduced to pole image.

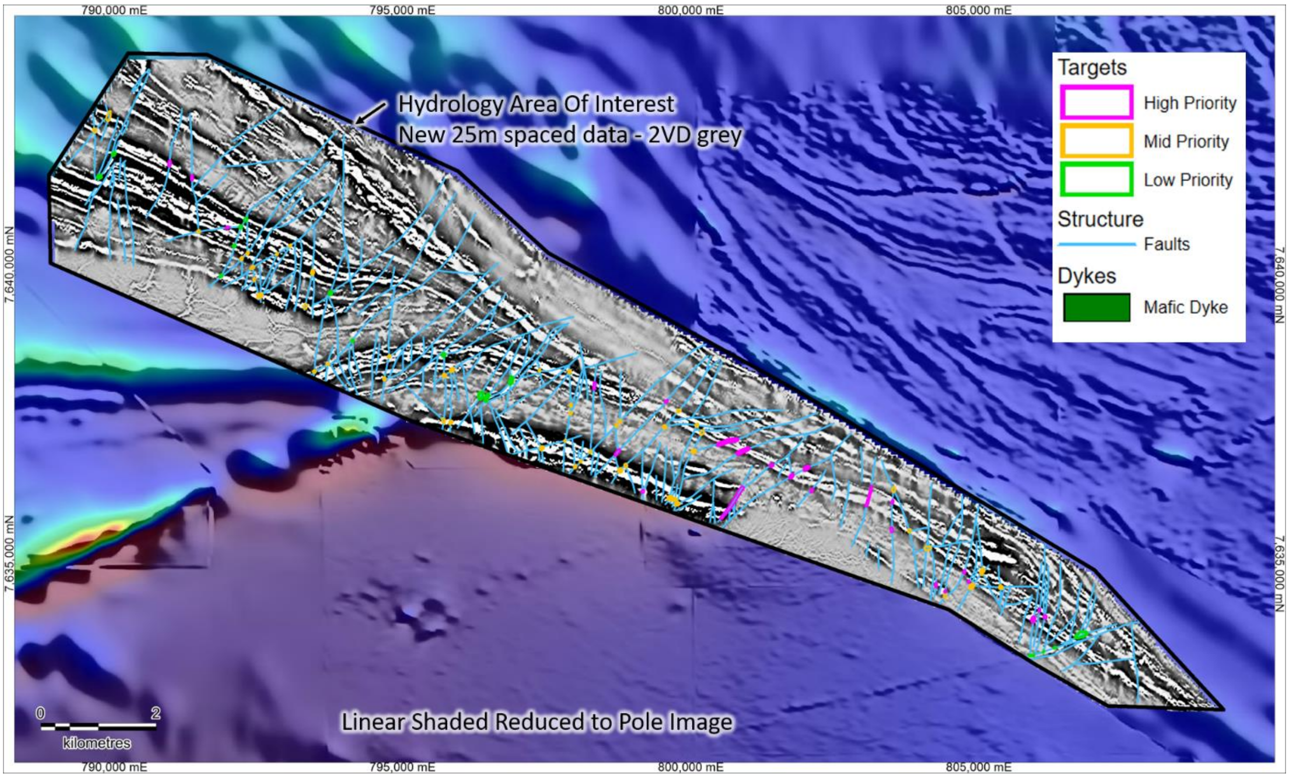

Figure 7. Interpretation and targets on new 25m spaced second vertical derivative image with government and open file linear shaded reduced to pole image in background.