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Mapping subsurface geological structure using TEMPEST data, McArthur Basin, Northern Territory

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SUMMARY

Airborne TEMPEST electromagnetic (EM) and magnetic data was acquired over the Bulman project area in the McArthur Basin to identify the geological environment of stratabound carbonate-hosted Pb-Zn mineralisation. The Late Palaeoproterozoic to Early Mesoproterozoic sedimentary fill of the McArthur Basin in the Bulman area is intruded by Early Mesoproterozoic dolerite dykes and sills. The location of the dykes and sills was mapped using magnetic data. The depth of the intrusives was estimated by mapping resistive basement on Conductivity Depth Transforms (CDTs) generated from the TEMPEST B-field Z-component data. Additionally, a 3D conductivity voxel model was constructed from the CDTs to show the conductivity distribution in rocks.

There is no marked conductivity contrast between intrusives and sediments making up the resistive basement. Instead, the resistive basement horizon is interpreted to represent the base of the Cenozoic unconsolidated deposits or part of the Proterozoic sedimentary rocks. In places, the base of a sub-surface conductive zone is interpreted to be the top of the intrusives. The thickness of sediments above the resistive basement is variable, reaching up to 170 metres in the central - eastern part of the study area.

3D geological model was constructed to assist in visualising the distribution of interpreted geological units and the tectonic pattern

Key words: Tempest, McArthur Basin, stratabound carbonate-hosted Pb-Zn mineralisation

INTRODUCTION

The airborne TEMPEST electromagnetic (EM) and magnetic survey is a proven tool for mapping geological structure for exploration. This technique has been utilised in the Bulman project area in the McArthur Basin with the aim of identifying the geological environment of stratabound carbonate-hosted Pb-Zn mineralisation hosted in a shallow carbonate platform sequence (Figure 2). The ore fluids are thought to be derived from evaporated seawater and driven within platform carbonates by large-scale tectonic events along major NW and WE trending structures.

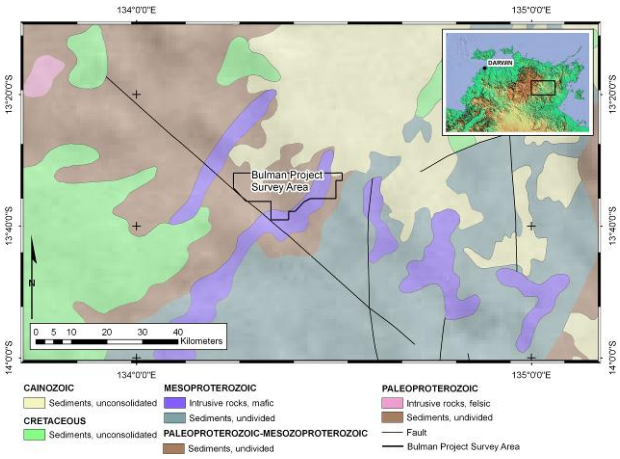


Figure 1 Location of the Bulman Project, McArthur Basin, Northern Territory,

GEOLOGICAL SUMMARY

The McArthur Basin is a Late Palaeoproterozoic to Early Mesoproterozoic fluvial-lacustrine to marginal marine carbonate-siliciclastic succession that is locally up to 12km thick (Jackson et al., 1987; Pietsch et al., 1994; Rawlings, 2001). The basin contains volcanic rocks and related intrusive igneous rocks. Faults systems and regional lineaments in the central part of the McArthur Basin show regular northwest, north, and northeast trends. The Bulman survey area is located in the central part of the McArthur Basin. In the survey area, the geological structure consists of the Late Palaeoproterozoic-to-Early Mesoproterozoic Dook Creek and Limmen formations (Figure 2). The Dook Creek Formation is composed of karstic dolomite, dolomitic sandstone and fine to coarse grained siliciclastic sediments (Plumb and Roberts, 1992). The formation is believed to be a major aquifer in the central part of the McArthur Basin. The Limmen Formation is composed of quartz-rich to sub-lithic, fine- to coarse-grained silicified sandstone, and lies disconformably over the Dook Creek Formation (Sweet and Brakel, 1999). Both formations are thought to be intruded by Early Mesoproterozoic fine- to coarse-grained dolerite and gabbro sills and dykes, referred to as the Derim Derim Dolerite. The strata are gently folded with shallow dips (Pietsch et al., 1994). The Proterozoic rocks are largely covered by unconsolidated deposits that range in age from the Cainozoic to the Quaternary. The principal tectonic

structure in the Bulman project area is the northwest-trending Bulman Fault.

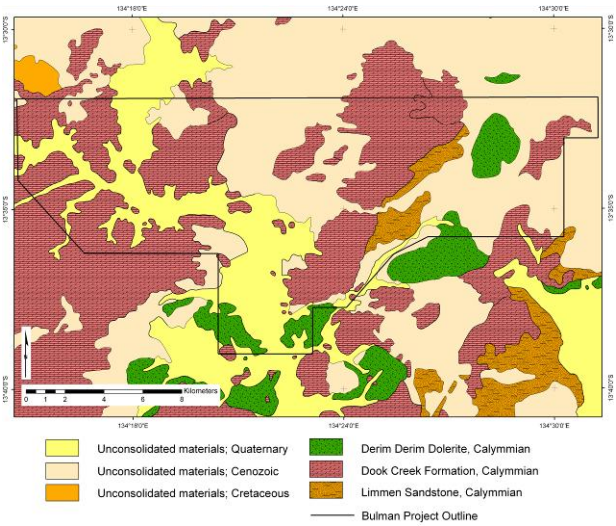


Figure 2 Geological map of the Bulman Project area,

TEMPEST DATA

The electromagnetic (EM) data interpretation was focused on the subsurface conductivity distribution, which may be related to changes in lithology and tectonic pattern. To accomplish this, a depth to resistive basement was mapped using Conductivity Depth Transforms (CDTs) generated from the TEMPEST B-field Z-component data (Figure 3).

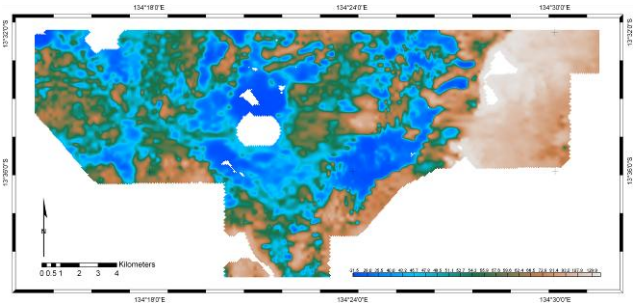


Figure 3 Depth to resistive basement map for the Bulman Project area.

Additionally, a voxel model was constructed from the CDTs to show the conductivity distribution beneath the survey area in three dimensions (Figure 4**Error! Reference source not found.**).

CDTs were used to map identifiable conductivity contrasts within the geological units. The CDTs were produced using EM Flow software (Macnae et al., 1991; Macnae et al., 1998), and are an effective transformation of airborne EM data provided the input dataset is well calibrated, broadband and has little noise. CDTs are relatively fast to compute, but have a tendency to overestimate shallow conductivities and are sensitive to noise (Hunter and Macnae, 2001). CDTs are particularly useful in areas such the McArthur Basin where an extensive conductive regolith and flat-lying or shallowly dipping sedimentary successions occur (Sattel, 2000; Smith and Klein, 1996). The Z-component of the electromagnetic field was utilised for the generation of the CDTs as this component is the most sensitive to sub-horizontal layered earth environments.

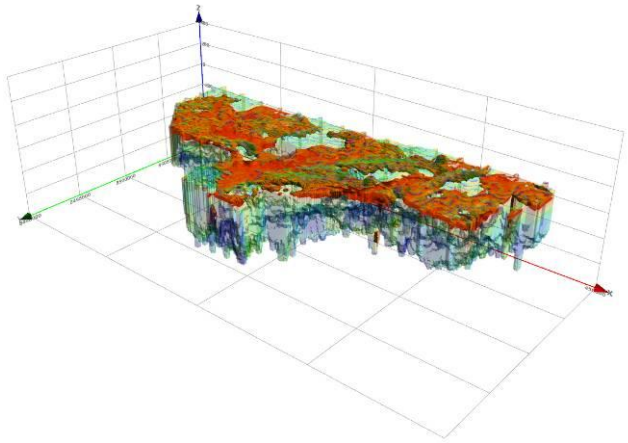


Figure 4: Semi-transparent 3-D EM voxel model for the Bulman Project area displayed with 15mS/m isosurface (in red). The isosurface corresponds to the bottom of a surface conductive unit that has been interpreted as both the base of the Cenozoic unconsolidated deposits and as part of the Proterozoic sedimentary rocks. View is from the southeast.

Magnetic data was acquired concurrently with the EM data, and was used to define the extent of the intra-sedimentary intrusives. Data enhancement and image processing of the newly acquired magnetic data focused on highlighting sills, dykes, lithological and structural features (Figure 5**Error! Reference source not found.**).

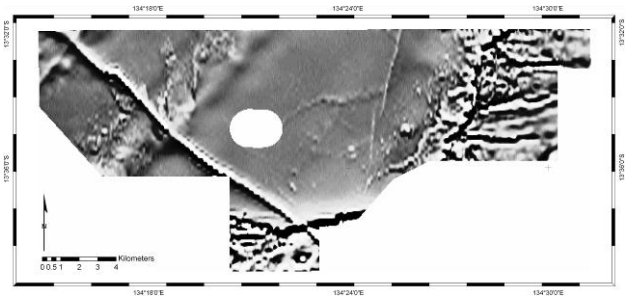


Figure 5: The First Vertical Derivative map of map of the Bulman project area

DEPTH TO RESISTIVE BASEMENT

The main objective of the depth to resistive basement interpretation was to map the interface between conductive cover and resistive 'basement'. Ideally, this should map the contact between conductive sediments and the underlying resistive basement. In the Bulman project area, the EM data shows no marked conductivity contrast between the Derim Derim intrusives and other rocks making up the resistive basement. As a result, the resistivity contrast boundary corresponds both to the bottom of a surface conductive unit interpreted to be the base of the Cenozoic unconsolidated deposits or a part of the Dook Creek Formation and, in places, the top of the Derim Derim intrusives.

The thickness of the conductive layer was calculated by subtracting the resisitive basement horizon from the digital elevation model (DEM). The thickness of sediments above the

resistive basement is variable, reaching up to 170 metres in its central - eastern part.

GEOLOGICAL INTERPRETATION

The geological interpretation is based on the integration of the EM and magnetic data with other available data, including previous mapping, tectonic sketches and various published papers.

The magnetic anomalies over the Bulman Project area occur in the eastern, southern and western sections of the Bulman prospect area. These have been assigned as intrusive rocks (Figure 6**Error! Reference source not found.**).

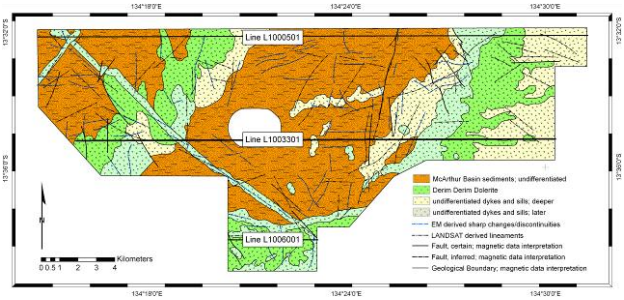
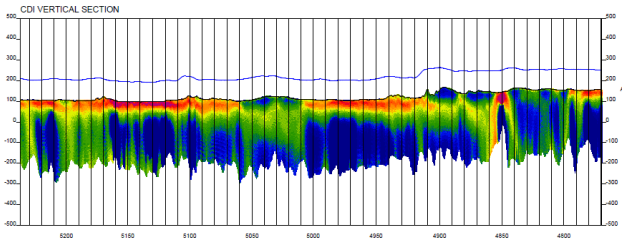


Figure 6 Interpretation of magnetic data showing subsurface location of the intrusive bodies and dykes. The location of the CDT section displayed on Error! Reference source not found. **is shown with solid black lines. The extent of the dykes and sills comprising the Derim Derim dolerites has been mapped from magnetic data**



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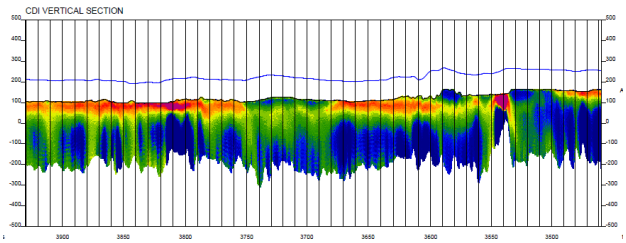

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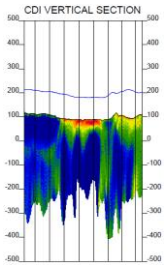

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Figure 7 CDT image for Lines displayed on Figure 6 showing the surficial conductive zone (red), which corresponds both to the Cenozoic unconsolidated deposits and part of the Proterozoic sediments.

The magnetic anomalies show variation in magnetic signal that is interpreted to be a function of the depth emplacement of the intrusive rocks and timing of magmatic events. The trend of the basalt dykes correlates closely with basement faults, suggesting that these structures were used as pathways by the magma to intrude the McArthur Basin sediments.

The conductivity pattern on the CDTs is related to the lithological distribution (Figure 7**Error! Reference source not found.**). The dolomites, dolomitic sandstones and siltstones comprising the Dook Creek Formation are more conductive than the overlying coarse sandstone of the Limmen Formation. The variablility in the conductivity signature of the Dook Creek Formation is influenced by the lithological variability, its karstic character, the content of the ground water, and the depth of the weathering profile. The disconformable boundary between the Dook Creek Formation and the overlying Limmen Formation is present in the EM data as a distinct conductivity interface. In contrast, the Limmen Formation displays a fairly uniform resistive EM response. It is indistinguishable from the Derim Derim Dolerite where the two share a common boundary. Intrusive bodies emplaced into the McArthur Basin sedimentary fill appear to be strong resistors. Lithological boundaries between the intrusives and sediments in the survey area have been defined indirectly, based on magnetic response and conductivity characteristics, where magnetic data was first used to define their location and the EM data subsequently used to determine a minimum top intrusive depth. Additionally, a 3D geological model was constructed to assist in visualising the distribution of interpreted geological units and the tectonic pattern (Figure 8**Error! Reference source not found.**).

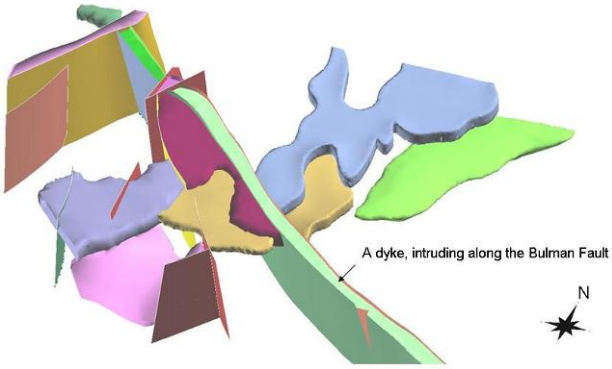

Figure 8 Perspective of 3D view model of western part of the Bulman project, showing several intrusive bodies emplaced at various depths. The intrusive rocks are cut by a younger dyke that has intruded along the Bulman Fault.

CONCLUSIONS

TEMPEST EM and magnetic data from Bulman project area in the McArthur Basin were utilised to define the geological environment and tectonic pattern related to the stratabound carbonate-hosted Pb-Zn mineralisation. The depth to resistive basement was mapped using Conductivity Depth Transforms (CDTs) generated from the TEMPEST B-field Z-component data. Additionally, a 3D conductivity distribution voxel model was constructed. The dolomites, dolomitic sandstones and siltstones comprising the Dook Creek Formation appear to be more conductive than overlying coarse sandstone of the

Limmen Formation, which is uniformly resistive. The Limmen Formation sanstones are indistinguishable from the Derim Derim intrusive rocks where the two share a common boundary. Intrusive bodies emplaced into the McArthur Basin sedimentary fill appear to be strong resistors and have been interpreted as the source of the magnetic anomalies.
Variability in the character of the magnetic anomalies is interpreted as a function of the depth of the intrusive emplacement and timing of magmatic events.

ACKNOWLEDGMENTS

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REFERENCES

Hunter, D. and Macnae, J. C., 2001, Subsurface conductivity structure as approximated by conductivity-depth transforms.

Jackson, M. J., Muir, M. D., and Plumb, K. A., 1987, Geology of the southern McArthur Basin, Northern Territory: Bureau of Mineral Resources, Geology and Geophysics, Bulletin, 1-220.

Macnae, J. C., King, A., Stolz, N., Osmakoff, A., and Blaha, A., 1998, Fast AEM data processing and inversion: Exploration Geophysics, 29, 163-169.

Macnae, J. C., Smith, R., Polzer, B. D., Lamontagne, Y., and Klinkert, P. S., 1991, Conductivity-Depth Imaging of Airborne Electromagnetic Step-Response Data: Geophysics, 56, 102-114.

Pietsch, B. A., Plumb, K. A., Page, R. W., Haines, P. W., Rawlings, D. J., and Sweet, I. P., 1994, A revised stratigraphic framework for the McArthur Basin,NT.: Australasian Institute of Mining and Metallurgy, Publication Series, 5, 135-138.

Plumb, K. A. and Roberts, H. G., 1992, The geology of Arnhem Land, Northern Territory. Mineral Provinces 15: Bureau of Mineral Resources, Record, 1992/55, 1-193.

Rawlings, D. J., 2001, McArthur Basin, Northern Territory (First Edition). 1:1 000 000 scale tectonostratigraphic map: Northern Territory Geological Survey.

Sattel, D., 2000, The effect of magnetic anomalies on transient electromagnetic data: Exploration Geophysics, 31, 140-149.

Smith, R. and Klein, J., 1996, A special circumstance of airborne induced-polarization methods: Geophysics, 61, 66-73.

Sweet, I. P. and Brakel, A. T., 1999, Mount Marumba, Northern Territory – 1:250 000 Geological Map Series. Explanatory Notes, SD 53-6 (second edition): Australian Geological Survey Organisation and Northern Territory Geological Survey (National Geoscience Mapping Accord).