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SUBJECT: Reconciliation of down hole density and magnetic data from hole WLMB1B with pre-drilling model

This memo reviews the drilling results from WLMB1B and reconciles them with the previous modelling from surface and airborne data.

Drill hole WLMB1B was drilled to test a coincident gravity and magnetic anomaly within the Waterloo project area and also to provide stratigraphic information for the general project. The hole, potential field anomalies and pre-drilling models are shown in plan view in Figure 1.

Possible explanations for the gravity and magnetic anomalies included a deep mafic intrusive plug which had penetrated the lower part of the Limbunya Formation and an Olypmic Dam style Iron Oxide Copper Gold (IOCG) deposit. If it were a deep mafic intrusion then there was a chance that it may represent a magma chamber feeding the Cambrian Antrim Plateau Volcanics, a target which had been searched for by others in the general area because of similarities between the volcanics and the flood basalts in Siberia hosting the giant Norilsk nickel deposit.

Magnetic modelling suggested a fairly simple stock like source at a depth of around 1800m. The gravity modelling was however less diagnostic and a range of body densities and depths could be used to explain the anomaly, as shown in Figure 2 and reported on in an earlier memo by the author. Although gravity models involving a dense disk of material sitting above the magnetic body, consistent with the IOCG model, provided a good fit to the data with the most simple model, a combination of deep and near surface density variations could also explain the observations and support a deep mafic plug.

The drill hole was therefore designed to test for an IOCG at economic depths and provide valuable stratigraphic information for use in the greater Waterloo project.
Figure 1: Image of reduced to the pole aeromagnetic data, overlain with contours of terrain corrected Bouguer gravity (2.5 T/m$^3$ - 5 µm/s$^2$ contour interval), wireframe outlines of pre-drilling models (green magnetics, blue gravity), access track (light blue) and collar and hole (light grey).
The hole was inclined slightly to the north east and in order to recover its true path it was surveyed using a multishot magnetic sensor tool (Reflex EZ-track). The tool uses a combination of orthogonal fluxgate magnetometers and accelerometers to provide dip and direction of the hole. However the same data can be processed in a different way to extract three component magnetic data and thus provide a down hole three component magnetic survey. The survey is normally undertaken by raising the drill string a couple of lengths from the bottom of the hole, running the tool down through the bit on a non-magnetic sub having previously set it to take readings at a predefined time interval and then synchronise rod breaks to that interval on tripping out of the hole. This generally provides a survey up the hole at 6m intervals. This was done in this case but in addition the hole was cased with PVC casing so that it could be later logged with down hole electromagnetics (DHEM). A magnetic survey was therefore taken, without any rods in the hole, running the tool inside the PVC, on the end of the rig’s winch. The log inside the PVC was significantly cleaner than that from below the drill string indicating that either the sub was not long enough, had caught up on the bit or was not non-magnetic. The magnetic data are plotted in profile form in Figure 3. In addition to the measured three components of the magnetic field (East, North and Vertical) the vector sum \( |B_t| \) and the magnetic intensity in the direction of the earth’s field (\( B_{t_{ITDOTEF}} = TMI \)) are plotted.

As part of the core logging process, specific gravity measurements were made using Archimedes Principle. Although it is unlikely that in summer, in Darwin, the water used in the measurement was at the standard 4°C required for a water density of 1 T/m³ the measured specific gravity will be close enough to the rock’s density for the purposes required here. The assumed density is plotted against lithology in Figure 4.
Figure 3: Stacked profiles of three component magnetic data for hole WLMB1B

The magnetic data are relatively noisy for a sedimentary environment with the bulk of the noise coming from the vertical component of the field. It is possible that the tool was yo-yoing on the end of the winch wire while the reading was being taken. Beneath the ~100 nT chatter the magnetic intensity steadily increases down the hole and no off hole responses are evident. This response is consistent with a deep magnetic source as predicted from the aeromagnetic modelling.
Figure 4: Log plot of SG and lithology against depth
The measured SGs lie in a quite believable range of 2.1 to 2.6 and form a cyclic pattern from low to high down the hole. These densities are also consistent with those measured in hole MSFDD001 drilled about 40km to the SE. That hole was interpreted by MMG to have passed through the Tijuna Group and Banyan Formation.

However the rocks encountered in hole WLMB1B have been tentatively assigned to the Limbunya Group although they are sufficiently different to type section that it has not been possible to ascribe unit names to the rocks. The densities measured in this study are less than or at the lower end of the range, of those reported for hole DD90VRB1, drilled about 8km SW of MSFDD001 by CRA and logged as upper Limbunya Group. If both stratigraphic interpretations are correct, then these rocks are generally significantly less dense than their equivalents, encountered by CRA, to the SE. This raises the possibility that the rocks in WLMB1B are younger which, if the mafic plug model is correct, would still allow the maximum documented thickness of 1300m between the base of the drill hole and anticipated basement depth of around 2km.

Using an average value of 2.5 T/m$^3$ for the rocks in WLMB1B and a mafic plug with a density of 3.15 T/m$^3$ intruding 600m into the Limbunya Group we get a reasonable fit with the observed gravity data as shown in Figure 5. The misfits on the north and south edges of the anomaly could be accounted for with a north dipping basement interface.

![Figure 5: NS trending section through the centre of the gravity anomaly showing the observed response (blue), calculated (red) and residual (green) in the upper frame and the ground surface (brown), dense body (blues) and wireframe of the magnetic body (grey)](image)

The background rocks here have been assumed to be 1D, i.e flat dipping and extending everywhere. In that way the increase in density with depth and unit based changes we see in Figure 4 will have the same effect everywhere and thus not contribute to the anomalous response. The same applies to basement which is assumed to have a density of around 3 T/m$^3$. If we tilt the host and basement slightly to the NNE as measured in drilling then we impose a gradient from high in the south to low in the north which would improve the fit of the gravity anomaly above.
In the model shown in Figure 5, the dark blue represents that part of the intrusive which has penetrated the lighter Limbunya Group rocks while the lighter blue reflects the part of the intrusion which lies within basement and therefore has a lower density contrast. Pushing the intrusion 600m into the Limbunya Group would imply that crystalline basement here would be around 2400m below surface which is consistent with values returned from the automatic depth to magnetic basement study performed on the aeromagnetic data.

Conclusions:

The drillhole data is consistent with a deep mafic intrusive and the hole itself discounts an IOCG deposit at current economic depths. There is no indication in the aeromagnetic or downhole magnetic data that the deep intrusion is connected to the surface in order to feed the Cambrian volcanics and a down hole EM survey, reported on separately by the author, does not point to off hole massive sulphides.

Although it is not the least complex model able to fit the observed data, it appears that the most likely source of the coincident gravity and magnetic anomaly is a deep (~1800m below surface) intrusion which has penetrated a few hundred metres into the lighter sediments above it. If so it is younger than the lower Limbunya Group and may be part of the Kalkarindji Volcanic Event, responsible for the Antrim Plateau Volcanics but in this case not obviously connected to them. It may have some potential to host mineralisation either within it or on its contacts but at 1800m it is very unlikely to be economic and is therefore considered tested and can be relinquished.