ASEG-PESA 2015
Geophysics and Geology together for Discovery
24th International Geophysical Conference and Exhibition
15–18 February 2015 Perth, Western Australia

Magnetic mapping of river channel and palaeochannel deposits – an example from Teetulpa, South Australia

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SUMMARY

High-resolution, low-level aeromagnetic surveys of the Teetulpa gold field in the Nackara Arc, South Australia, map the distribution of magnetic minerals in the alluvial cover, in the form of linear anomalies with a dendritic pattern typical of drainage systems. These anomalies are not evident in the regional aeromagnetic data flown at wider line spacing and higher elevation. Combination of the high resolution magnetic field data with mapping of present day drainage is an important input to gold exploration of the area. The magnetic anomalies can be modelled and inverted, and this might provide quantitative information to indirectly target and evaluate gold resources. Sampling and statistical analysis of relationships between the gold and magnetic minerals within the alluvium are required to form the basis for any such study.

Key words: magnetic anomaly, drainage, gold, alluvial.

INTRODUCTION

Over the last 20 years the most substantial advances in mapping bedrock geology across Australia have arisen from regional aeromagnetic surveys flown as part of State and Territory exploration initiatives. There is still more geological information carried in the earth's magnetic field, which can be recovered by surveys flown at closer line spacing and lower elevation. This geological signal relates particularly to near-surface units, which typically exist in smaller structures, and have weaker magnetizations and lower volumes than the bedrock units which provide most of the signal for the regional magnetic surveys. The value of detailed aeromagnetics in mapping palaeochannels has already been established (for example, Mackey et al., 2000). In this study we investigate aeromagnetic surveys flown to map near-surface deposits in the alluvial gold field of Teetulpa, in central South Australia. These surveys map considerable detail in the cover sequence, particularly river channel and paleochannel deposits, together with shallow basement structure, which is not resolved by the higher elevation regional survey. As well as the drainage-related anomalies focussed on in this paper, the new data has also revealed a semi-circular feature to the west and south of the Teetulpa area, interpreted as a basement high, possibly composed of a phyllitic unit containing a horizon rich in iron minerals, and also a compact anomaly due to a low positive-inclination, south-westerly directed remanent magnetization, which is possibly the expression of a kimberlite pipe. The higher resolution magnetic field data has also supported superior basement depth estimates, and improved inversions, run to elucidate the nature and structures of basement within the area.

GEOLOGY AND GOLD OCCURENCES

In the region of the Adelaide Geosyncline, modern drainage is predominantly, but not exclusively, superimposed on a Tertiary drainage scheme. Both drainage schemes in their upper reaches develop directly on Adelaidean metasediment basement rocks, which are part of a Neoproterozoic rift complex. The Nackara Arc is a sub-domain of the Adelaide Geosyncline, an arcuate fold and fault belt with fold axis trends varying from north-south to east-west in a regular manner, over a distance of ~250 km from the SW to the NE. The drainage, which passes to the east of the Adelaide Geosyncline, debauches onto broad flood plains consisting of Tertiary to Recent sediment. The particular area of interest, the Teetulpa Goldfield, is located near the eastern limit of the Nackara Arc.

Basement to the goldfield is a thick, monotonous sequence of metasiltstone of the Tapley Hill Formation of the Sturtian Umberatana Group, a sequence that includes much of the glacial deposits of the Adelaide Geosyncline. The geology of the Teetulpa area has been described by Morris and Horn (1990). Structurally the goldfield is located at the nose of a regional, E-plunging anticline. At Teetulpa exposed basement shows swarms of narrow NNW-trending, steeply dipping quartz-iron-oxide veins, many of which have been worked for gold. Recorded production of bullion gold for Teetulpa is in the order of 2.4 tonne, with the bulk of production being coarse to nugget alluvial gold won from both the modern stream beds, and from the preserved remnants of multiply incised, perched Tertiary palaeochannels. Production from reef gold deposits is estimated at 2.4 kg. Teetulpa is by far the most significant producer in the Nackara Arc. There are 8 goldfields with recorded gold production >100 kg, with the second most productive to Teetulpa being the Waukaringa Goldfield at

about 1.4 tonne (exclusively from reef gold deposits). Second to Teetulpa for alluvial gold is the Ulooloo Goldfield with production of ~160 kg. Workers generally agree that the bulk of alluvial gold is detrital, being sourced from mineralized quartz veins. Alluvial gold eventuates by the process of erosion, and deposition in local streams. There has been little scientific research on the geological history of these alluvial gold deposits. One study at the Ulooloo Goldfield indicates that a proportion of the gold is of secondary origin, being precipitated from solution in the palaeochannels. Further investigation of the palaeochannels may support studies such as that on the Gawler Craton by Hou et al. (2000) establishing links between palaeodrainage and mineral resources.

DRAINAGE-RELATED MAGNETIC ANOMALIES IN THE LOW-LEVEL, HIGH-RESOLUTION MAGNETIC DATA

Many regional aeromagnetic surveys across Australia flown at line spacings of 200 to 400 metres and at terrain clearances of 80 to 120 metres reveal magnetic signatures of magnetite and/or maghemite in drainage or palaeodrainage systems. The regional magnetic field coverage over Teetulpa does not show such anomalies, but nevertheless a company exploring for gold in the area selected to fly high resolution aeromagnetics at 20 metre spacing and 20 metre terrain clearance. Figure 2 shows a detail of some results from one of those surveys. The TMI image (Figure 2A) shows linear, dendritic anomalies, characteristic of drainage patterns, superimposed on more regional variations. A trend analysis has been applied to this data (using the CSIRO toolbox in the Pitney Bowes PA software), to highlight the axes of the anomalies. Figure 2B shows a vertical derivative enhancement of the magnetic data which delineates the drainage-related anomalies more prominently. Figure 2C shows the corresponding high resolution DEM generated from the same survey, with an identical trend analysis applied to pick the drainage pattern. Figure 2D shows the trend vectors from both the magnetics and drainage plotted together. There is a wealth of geological information in this image. Magnetic linears which are not associated with present day drainage may mark palaeochannels, and conversely, drainage patterns without associated magnetic linears suggest regions less prospective for heavy mineral accumulations. In some areas magnetic and drainage linears, or pairs of magnetic linears, are parallel but displaced, which may be due to migration of streams within a drainage system, or possibly that the magnetic minerals are contained in sheet wash on the margins of a river channel. There are also more diffuse zones of discontinuous drainage and magnetic linears, marked in part by truncation of perpendicular magnetic linears. Some short disrupted zones might mark areas of previous alluvial mining, but many of these zones are quite extensive, and may possibly trace regions where drainage has exploited irregular fault zones, and/or has been disrupted by recent tectonics. Interpreted in conjunction with sedimentological studies, combined mapping of present day drainage and magnetic linears is invaluable to deduce the alluvial history of the region. In particular, it may be possible to use the magnetics to trace the provenance of the magnetic minerals upstream.

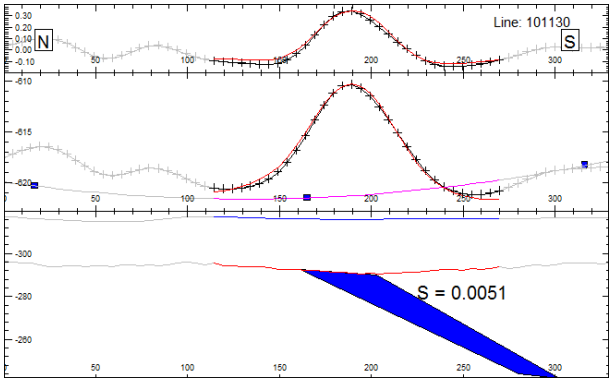

Figure 3. Example model section of a profile across one of the prominent drainage-related anomalies. The lower data track is TMI, the upper track is the vertical derivative of TMI.

The magnetic data also supports quantitative studies through modelling and inversion. Figure 3 shows an example of modelling a flight line across one of the prominent shallow linear anomalies. Anomaly separation from the background regional field is problematic, and to assist the modelling, the vertical derivative of the model computed field has also be matched to the (1D) vertical derivative of TMI, as shown. For this model the source body appears to be a plunging sheet, more readily interpreted as sheet-wash than a river channel deposit. The apparent susceptibility of 0.005 SI is high for a sediment, and suggests a considerable concentration of magnetic minerals. Furthermore, although the anomaly is remarkably consistent along strike, the geological unit is unlikely to be homogeneous, and some internal layers or zones may well have substantially higher magnetizations. It is feasible from such magnetic modelling, to estimate the total magnetization within an area. With a modest sampling exercise it should then be possible to transform that magnetization estimate to an estimate of the bulk tonnage of magnetic minerals (assuming there is a single dominant mineral contributing to the magnetization). If it is then also possible to establish a quantitative spatial relationship between the magnetic mineralogy and the gold, then magnetic modelling and inversion can be used as an exploration targeting tool, and possibly also to indirectly evaluate gold resource tonnages. The feasibility of applying magnetic interpretation in this way requires more detailed modelling studies, and ground-truthing of the results with quantitative mineral and gold studies (note the magnetization studies should also investigate possible viscous magnetization components in addition to the induced magnetizations arising from magnetic susceptibilities). The gold is in part nuggety, requiring large sample volumes, and possibly reducing the correlation of its distribution with finer magnetic mineral phases, which may behave quite differently in alluvial transport. A report on magnetic field interpretation prior to availability of this high resolution data (Miller, 1998) maps major structures through the area, but lacked this new information on the geophysical expression of the alluvial deposits.

CONCLUSIONS

Linear magnetic anomalies revealed in a high resolution aeromagnetic survey of the Teetulpa gold field are demonstrably due to present and palaeo-drainage features in the alluvial cover. These anomalies provide a great deal of information about the distribution and history of the drainage system, which is critical to understanding the distribution of gold within it. The anomalies are not evident in the regional data, demonstrating the ongoing contribution of magnetic field studies to reveal new geological information, particularly about shallow cover units.

ACKNOWLEDGMENTS

We would like to acknowledge the contributions of Laz Katona, who worked on the DEM and drainage data, John Irvine who managed the GIS, Steve Hill who has worked on the regolith, and Brian Morris, who was the original map sheet geologist for the Teetulpa area.

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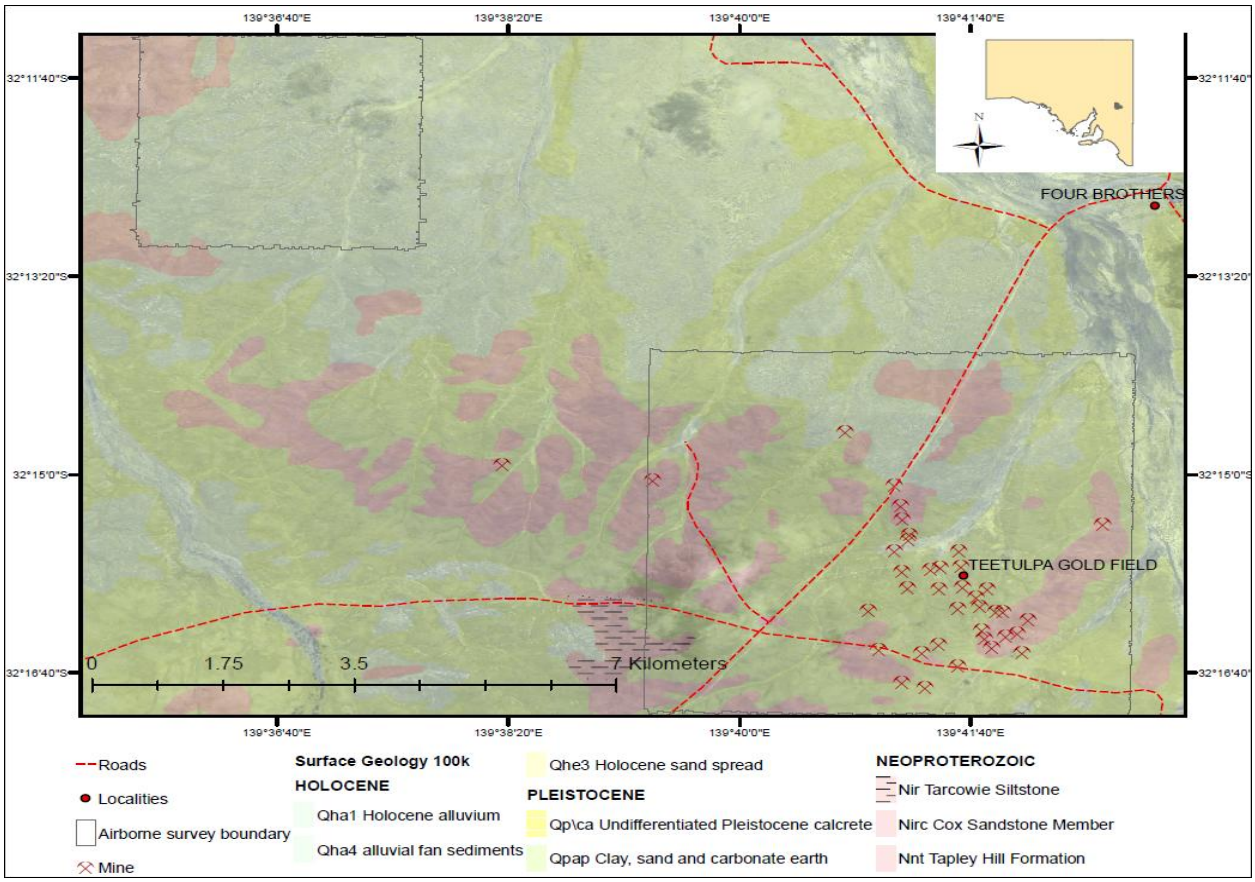

Figure 1. Geology and location of the study area, showing the outline of two low-level, high-resolution aeromagnetic surveys.

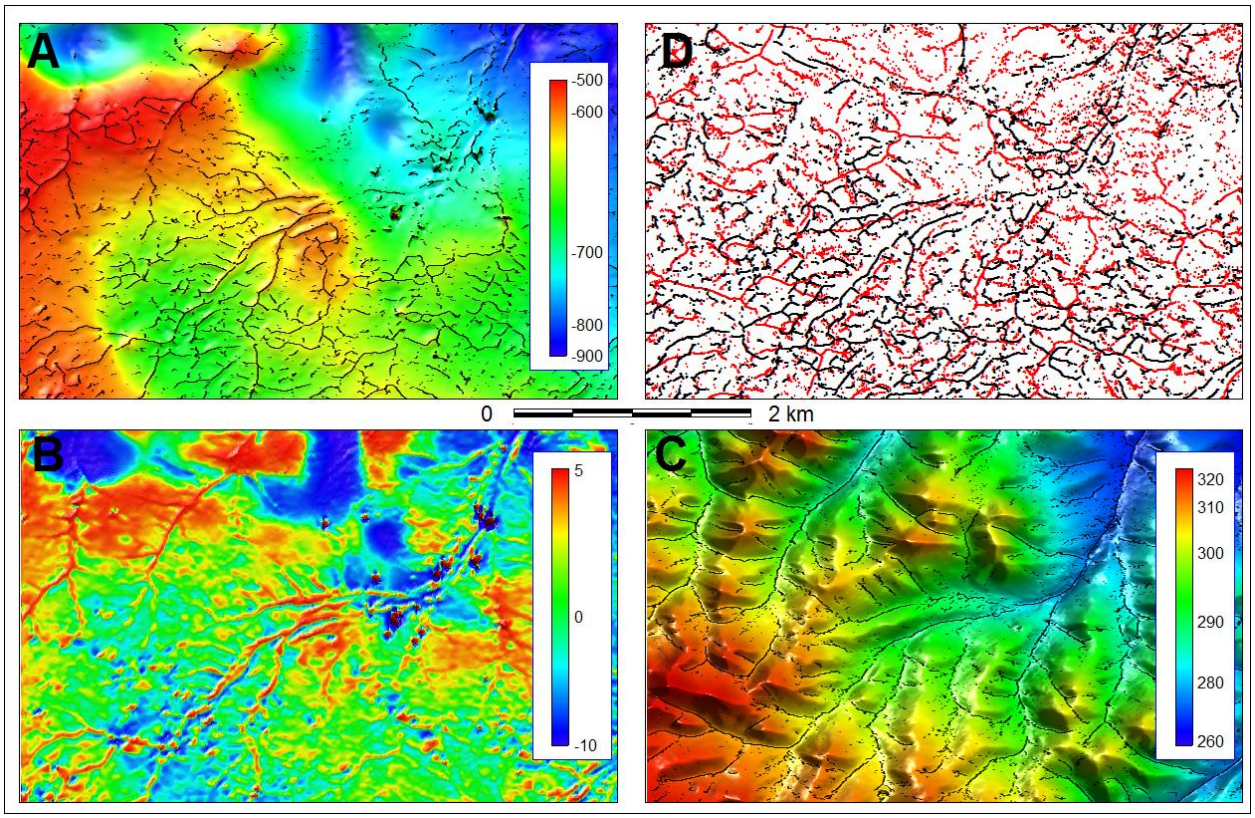

Figure 2. Section of one of the high resolution surveys. A) TMI with trend vectors, B) vertical derivative of TMI, C) elevation with drainage trend vectors, D) drainage (red) and magnetic (black) trend vectors