GEOPHYSICAL INVESTIGATIONS OF CRUSTAL ARCHITECTURE AROUND THE CHALLENGER AU MINE, NW GAWLER CRATON, SOUTH AUSTRALIA: A BASIC STEP TOWARDS UNDERSTANDING AU DISPERSION PATHWAYS

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The northwest Gawler Craton, South Australia, is comprised of late Archaean to earliest Proterozoic basement that has undergone extensive deformation through at least two events: the late Archaean to earliest Proterozoic Sleafordian Orogeny, and the Palaeoproterozoic Kimban Orogeny, with a cryptic third event or events, grouped as the Mesoproterozoic Kararan Orogeny (Daly *et al.* 1998). Extensive regolith development has meant that studies of the basement rocks of the area have been limited, and the tectonic evolution of the area remains complex and cryptic.

In 1995 the Challenger gold deposit was discovered in an area of complete cover (Tomkins & Mavrogenes 2002). With other discoveries of gold in the covered areas of the Gawler Craton, e.g., Barns (Drown 2002) and Nuckulla Hill (Parker 2003), the importance of developing techniques to understand Au dispersion pathways within and beneath the regolith has increased dramatically, in order to avoid wasteful drilling of spurious Au anomalies unrelated to basement mineralisation.

The Challenger Gold deposit, now being mined by Dominion Resources, is situated in the northern Gawler Craton, 750 km northwest of Adelaide, and 140 km northwest of Tarcoola (Figure 1). The mineralisation is hosted by Mulgathing Complex paragneiss of the Christie Domain, which comprises both the original Archaean protolith, on which younger units have been deposited or incorporated (Daly & Fanning 1993, Teasdale 1997). Nd model ages suggest a protolith age of ~2900 Ma (Tomkins & Mavrogenes 2002). Peak metamorphism occurred at ~2440 Ma without introduction of foreign fluid or melt. Spherical gold sulphide inclusions in peak metamorphic garnet, and invisible gold in loellingite, but not in adjacent arsenopyrite, indicates that Au was present before the peak metamorphic event (Tomkins & Mavrogenes 2002). Metamorphism caused the partial melting of the host rock and the formation of an immiscible gold-rich melt, allowing gold to be physically transported rather than chemically dissolved. This enabled extensive mobilization of Au, producing gold-enriched leucosomes within the host gneisses (Tomkins & Mavrogenes 2002).

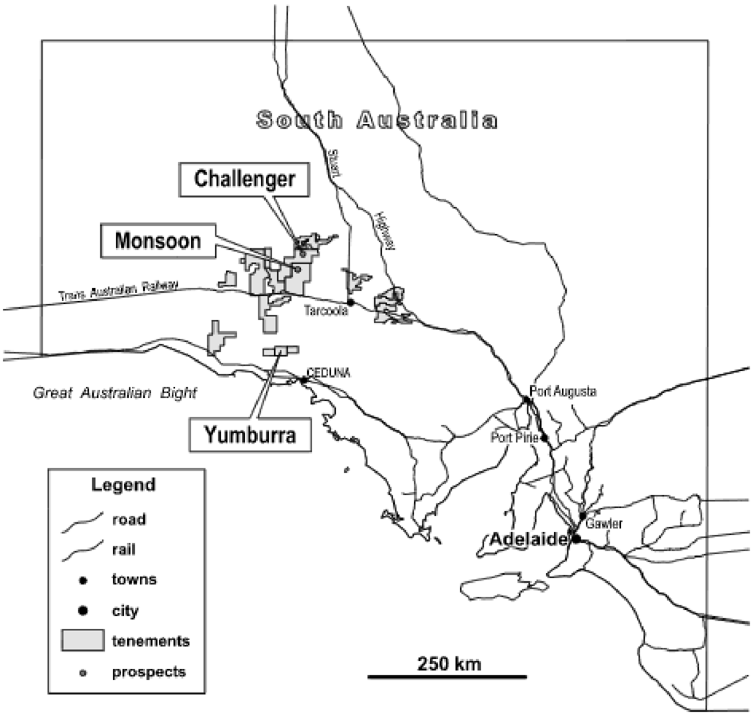

Figure 1: Location of Challenger Gold Mine and other Au exploration tenements in the study area (highlighted box), northwest Gawler Craton, South Australia. Modified after Dominion Mining Ltd.

Mafic dykes and sills (lamprophyres and dolerites) intruded the deposit post-peak metamorphism (~1710 Ma, T. Poustie *Pers. Comm.* 2003) but did not remobilise the Au. Competency differences between the dykes/sills and the Au-bearing gneiss provided fluid pathways, allowing some remobilisation of the Au (Tomkins & Mavrogenes 2002). There are also many late shear zones in the northern Gawler Craton that may have acted as fluid pathways (Lane & Worrall 2002), suggesting that an understanding of the structural controls of fluid flow in the area, syn- and post- peak metamorphism, will allow for more efficient and less costly regolith and calcrete sampling programs, and may lead to the discovery of new gold deposits.

Geophysics, in particular potential field geophysics, plays a major role in establishing a framework for understanding Au dispersion pathways in these covered areas. Recently acquired regional aeromagnetic data (Primary Industries and Resources of South Australia, PIRSA), and ground regional gravity (Geoscience Australia—GA) have been used to create a revised basement geology map of the Challenger region. This map can be used to understand the likely fluid pathways present at different times during the crustal evolution of this area. As has been shown by Kerrich & Wyman (1990) and Groves *et al.* (2000), primary Au mineralisation is often associated with "second order" shear zones and fault structures formed during or immediately after orogenic activity. Identification of such features beneath younger cover is thus likely to offer some insights into the primary/secondary distribution of Au in this terrane, and thus give a context in which much younger Au dispersion anomalies in the regolith can be interpreted.

In conjunction with the new regional data, two detailed gravity traverses were conducted orthogonally to strike of the major linear features in the region (Figure 2). 368 new gravity stations were acquired at 500 m intervals, to study the geometry of the major scale faults and shear zones that occur in the area. A fault will generally cause offset between different rock types, which will more often than not have a different density that can be detected by the gravity technique (Paul *et al.* 1966). In a similar way, the offset caused by faulting may produce a magnetic signature when two blocks of differing magnetic susceptibility are juxtaposed (Grauch *et al.* 2001). The size and symmetry or asymmetry of the gravity or magnetic response curves give clues to the dip direction and size of the fault. With the increase in computer modelling programs and power, it can now be a quick process to create a variety of models all with differing features to find the model that gives the greatest correlation between computed response and observed data. This can be used to find the most likely dip and orientation of the fault, and for listric structures, model the depth to detachment (Direen 1998).

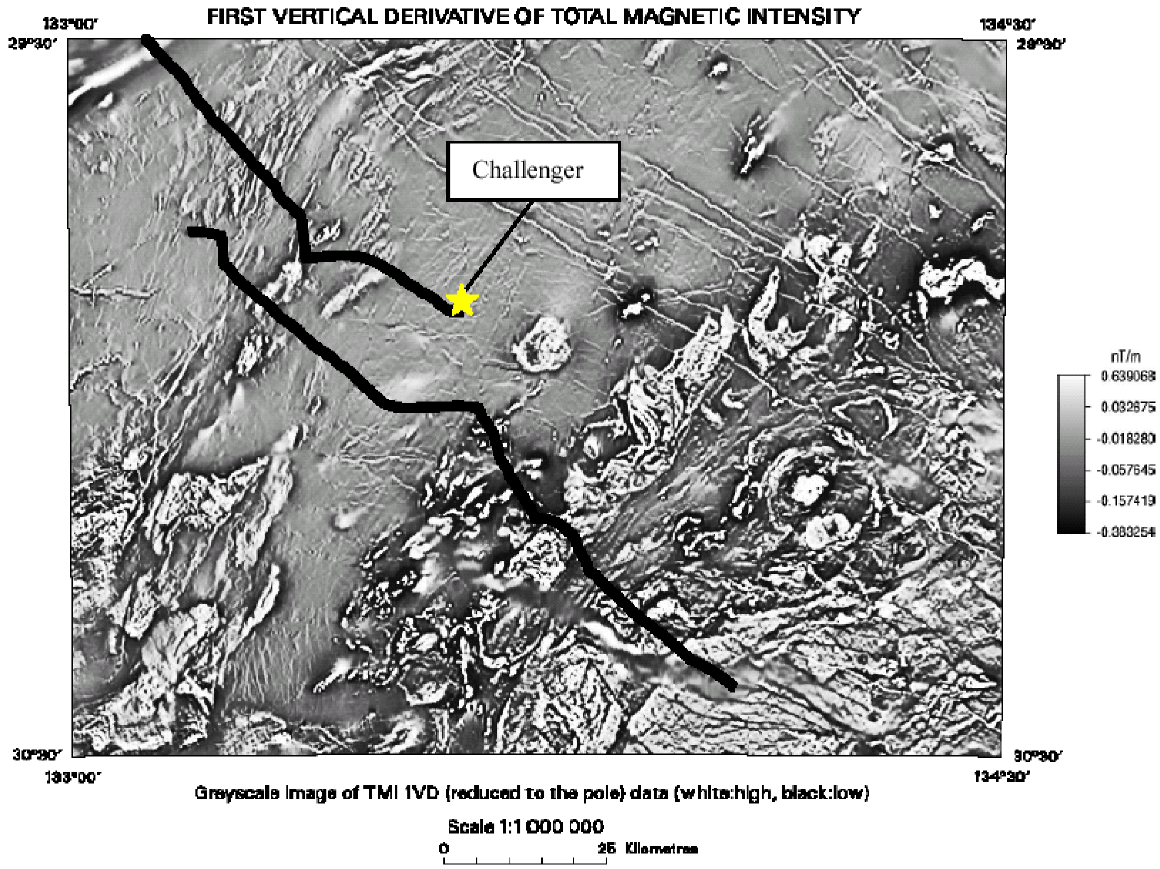

Figure 2: Greyscale TMI 1VD image of study area showing the two gravity transects orthogonal to the strike of the major magnetic features.

2.5D models of the crustal architecture have been created using the constraints from field observations, and petrophysical data from the Challenger mine, GA and other published sources. The models can be used to propose a history of the shear zones that may have influenced redistribution of gold mineralisation through time. The modelled geometries may also provide a contribution to the understanding of how the Gawler Craton was assembled and fits into the broader Australian Proterozoic. Preliminary modelling suggests the following:

- Regolith cover in the area, although extensive, is generally only ~30m deep, and is probably not the source of the regional gravity highs and lows;
- The Mulgathing Complex may be subdivided into at least three units with contrasting potential field geophysical signatures and distinguishable petrophysical properties: BIF rich; more pelite-rich; and more orthogneiss-rich;
- Major shear zones probably extend to at least 15 km below the present surface;
- Major shear zones and boundaries between units (faults?) dip steeply NW, possibly suggesting an overall top-to-SE compressional regime;
- Post shear-zone faulting has steeper dips to the NW;
- Much of the magnetic signature of the study area is due to thin layers of BIF within the Mulgathing Complex gneisses, and larger magnetic intrusions (Ifould/Tunkillia suite: 1680 Ma; Ferris *et al.* 2002).

Airborne Electromagnetic data (AEM) was acquired over the Challenger deposit and surrounds, in 2000. These data were subsequently interpreted by GA in collaboration with PIRSA, Dominion Mining and CRC LEME, as described in Lane & Worrall (2002). Images from the survey show some linear conductive features of in-situ conductive material, which are believed to be associated with zones of deeper weathering, and have been interpreted as faults or shear zones. The Challenger mine is located on a linear conductive feature. The deep weathering associated with this feature may be due to the presence of sulphides. There are some small-scale (500 x 1000m) resistive structures northeast of the mine. These anomalies may be felsic masses derived from the silicate melt formed by the granulite facies metamorphism during the Sleafordian Orogeny. This being the case, the masses may be mineralised although no drill core is available to prove this. Alternatively, the equant ovoid shape of these features means they might be much younger post-tectonic intrusions such as the Ifould/Tunkillia Suite (1680 Ma), or possibly even Hiltaba Suite (~1590 Ma) granitoids.

In the past many of the Gawler Craton gold deposits have been found using random regolith sampling techniques looking for anomalous amounts of trace gold. By using geophysical methods to model basement under cover, a greater understanding of the geometries and types of structures (e.g. faults and shear zones) that have occurred in the Challenger region in the past can be achieved. This will provide a better framework within which exploration companies can conduct geochemical sampling studies. The evidence so far from the Challenger Gold mine suggests strongly that there is more Au to be found: it is just a matter of knowing where to look.

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