Taking geology beneath cover at Broken Hill

Implications of structurally controlled magnetic anomalies for interpretation and mineral exploration

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As part of the Broken Hill Exploration Initiative, AGSO has been field-checking high-resolution aeromagnetic data acquired in 1996. This work has revealed that magnetic anomalies have multiple sources, and that many are structurally controlled and do not reflect stratigraphy.

Interpretations of aeromagnetic data in the Broken Hill region have previously assumed that magnetic anomalies were caused by magnetic stratigraphic units and hence stratigraphy could be mapped beneath cover (e.g., Tucker 1983: AusIMM Conference, Broken Hill, 81–114). Some anomalies are, no doubt, stratiform (e.g., banded iron formation and specific units in the Paragon Group). Other anomalies are caused by intrusive rocks, in particular post-peak metamorphic mafic and ultramafic rocks. However, many of the narrow linear anomalies visible on aeromagnetic images reflect magnetite development in metamorphic fabrics and structurally controlled corridors.

Structurally controlled magnetite

Early magnetite (?D_2)

The earliest magnetite formed during high-temperature metamorphism, as evidenced by sillimanite intergrowths with magnetite. In the core of the Broken Hill Synform, east of Broken Hill, magnetite–sillimanite rock causes an intense, folded magnetic anomaly (BHS, Fig. 4). The rock has a well-developed, steeply plunging sillimanite lineation of D_2 age interpreted as a stretching lineation. A smaller magnetic anomaly, most likely caused by quartz–magnetite rock, appears to be truncated against the magnetite–sillimanite rock, which is interpreted as a shear zone.

Magnetite in S_3 fabrics

Many narrow linear anomalies parallel the trend of the S_3 regional foliation, which formed during greenschist- to amphibolite-facies metamorphism. This fabric strikes northeast in the central part of the Broken Hill Block and north-northeast in the northern part (Figs. 4 and 5).

In the Sculptures–Archery Range area, northwest of Broken Hill (SA, Fig. 4), a linear magnetic anomaly is sourced by pelitic and psammopelitic metasediments of the Sundown Group, in which S_3 trends northeast and is superimposed on a more gently dipping S_2 fabric. Considerable strain-partitioning accompanied the D_3 deformation; packets of more gently dipping bedding are separated by high-strain zones in which bedding, S_2, and S_3 are steeply dipping and trend northeasterly. The magnetic anomaly in this area shares the same northeast trend and requires a steeply dipping source, suggesting S_3 controlled the distribution of magnetite. One possibility is that D_3 led to a dynamically induced increase in permeability, promoting fluid flow and the formation of magnetite. S_3 also has a strong control on magnetite distribution in the Waukeroo Bore area in the north of the block (WB, Fig. 4; see Giddings et al. this issue, pp. 7–10).

Magnetite at lithological contacts

Superposition of aeromagnetic data and geological maps reveals a close spatial association between some Potosi gneiss units and magnetic anomalies (Potosi gneiss is a local term for garnet-rich quartzofeldspathic gneiss spatially associated with Broken Hill-type mineralisation). About 1.2 km southeast of the Centennial mine, a unit of Potosi gneiss is surrounded by pelitic schist (CM, Fig. 4). The highest magnetic susceptibilities occur in metasediments adjacent to the Potosi gneiss. Both the Potosi gneiss and the metasediments away from the contact have low susceptibilities. It appears that strain has been partitioned into the contact between the moderately competent Potosi gneiss and less competent metasediments. The magnetite in this zone is interpreted to have formed during fluid flow that was focused along this contact. Similar relationships between Potosi gneiss units and magnetic anomalies also occur west of the Parnell mine and in the Southern Cross mine area. Granite gneiss and Potosi gneiss have similar competency contrasts with surrounding metasediments, and, in some locations (e.g., Mount Darling Range), granite gneiss units also have magnetic anomalies along their margins, interpreted to be a result of the same process.

Later-stage magnetite

Although most magnetite formed at high temperatures, some also formed later at lower temperatures. An isolated magnetic anomaly near Gairdners Tank in the Euriowie Block coincides with a mapped retrograde shear zone (GT, Fig. 4). It is caused by coarse-grained euhedral magnetite in schistose metasediments, and surrounded by low-susceptibility lithologies that strike obliquely to the trend of the anomaly. The magnetite formed penecontemporaneously with a steeply dipping chlorite-rich schistosity (greenschist facies) which overprints a peak-metamorphic sillimanite-bearing assemblage.

Amphibolite

Amphibolite is widely distributed in all stratigraphic units below the Sundown Group, and occurs as sills and dykes. Most amphibolite has a low magnetic susceptibility which is insufficient to produce an aeromagnetic anomaly. Some amphibolite bodies, however, have extremely high susceptibilities, and produce some of the most intense anomalies in the region (e.g., the western limb of the Stirling Vale Synform; SVS, Fig. 4). Many of these amphibolites appear to be situated close to shear zones — possibly former channels of oxidising fluids that contributed to the formation of magnetite.

Implications for interpretation and exploration

The abundance of structurally controlled magnetic anomalies in the Willyama Supergroup has important implications for aeromagnetic interpretation, irrespective of the mechanism of magnetite formation. Although some magnetic anomalies are stratigraphically controlled, many are evidently structurally controlled, and these cannot be used to interpret stratigraphy beneath cover. Bedding and magnetic trends are not necessarily parallel, and in some locations are nearly perpendicular. Some areas are more structurally complex than aeromagnetic images suggest because the rocks were deformed before magnetite formed.

Some elements of the geology have a high susceptibility and are readily mappable from the aeromagnetic data. These include banded iron formation, some amphibolites, quartz–magnetite rocks, garnet-poor composite gneiss, and altered mafic and ultramafic intrusives. However, true stratigraphic anomalies are too sparse to readily erect a 'magnetic stratigraphy' for the Willyama Supergroup; most unaltered metasediments have a uniformly low susceptibility.

Structurally controlled magnetic anomalies may prove useful for delineating fluid pathways in mineral systems. Fluids that controlled the formation of magnetite may have transported base and/or precious metals. Although metal deposition may not have occurred at the time of magnetite formation, the ability to map fluid migration paths is potentially valuable for reconstructing the mineral system as a whole.

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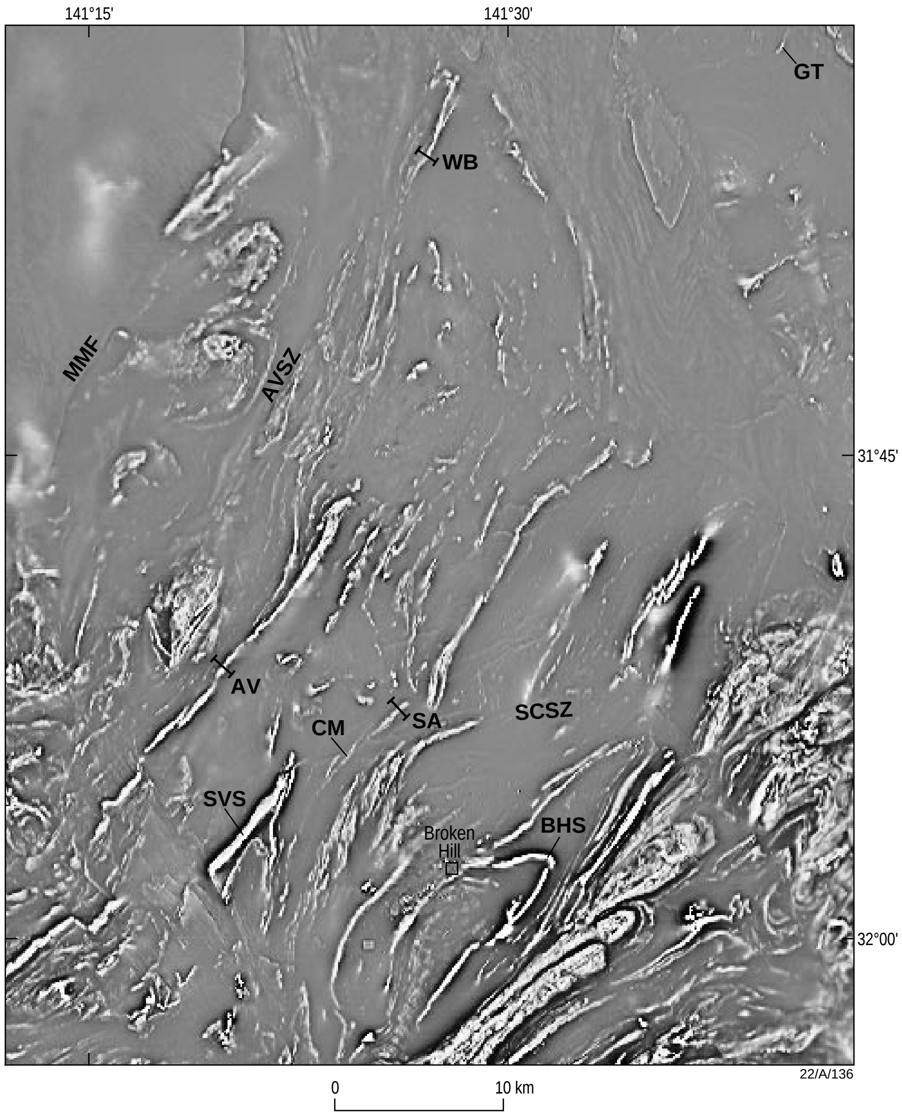

Fig. 4. First vertical derivative of total magnetic intensity for the central and northern parts of the Broken Hill Block. BHS: Broken Hill Synform; SA: Sculptures/Archery Range; WB: Waukeroo Bore; CM: Centennial Mine; GT: Gairdners Tank; SVS: Stirling Vale Synform; AV: Acacia Vale; SCSZ: Stephens Creek shear zone; MMF: Mundi Mundi Fault; AVSZ: Apollyon Valley shear zone.

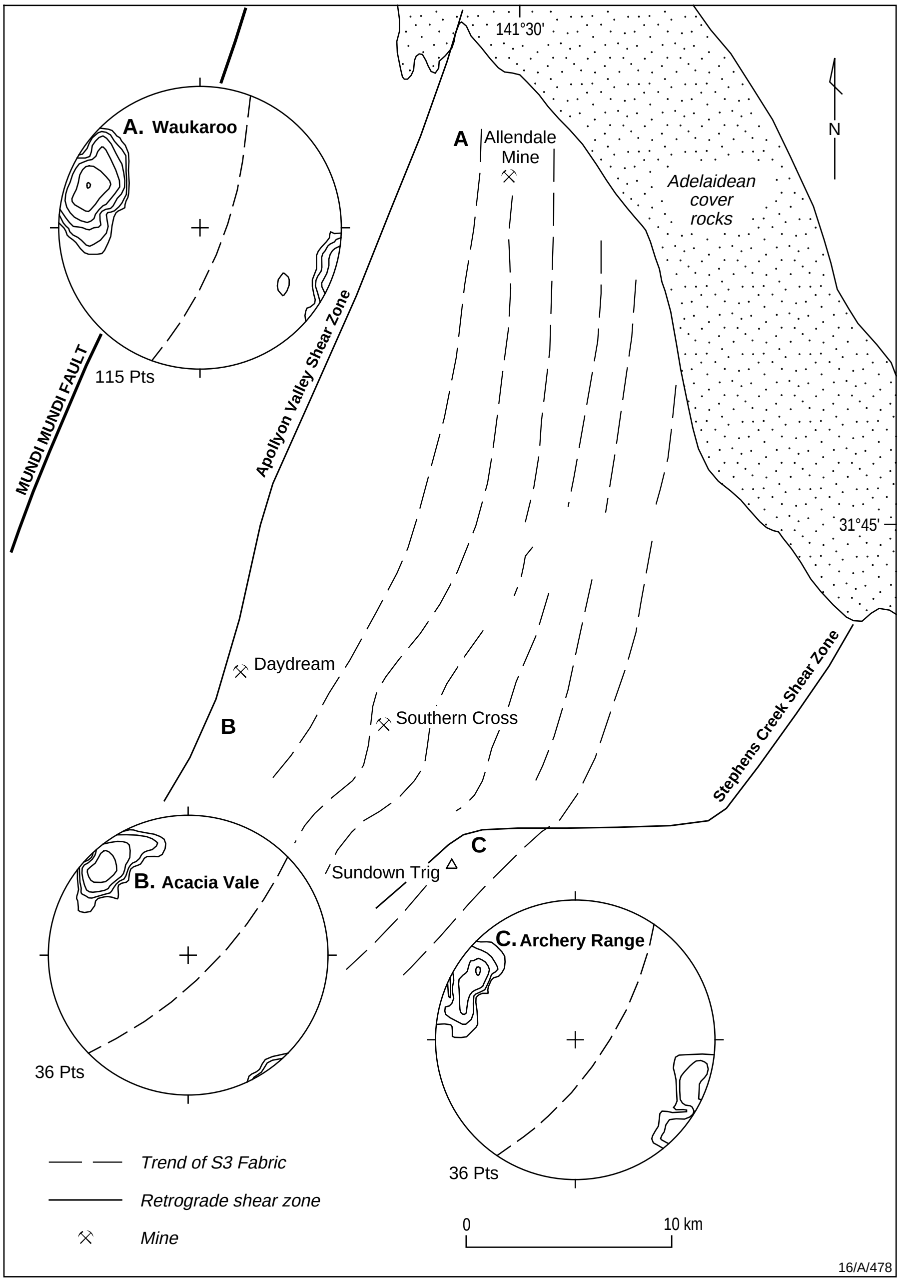

Fig. 5. Trend of S_3 across the central and northern parts of the Broken Hill Block (much the same area as Fig. 4). The S_3 fabric parallels many linear magnetic anomalies and suggests that S_3 had a significant regional control on magnetite formation.