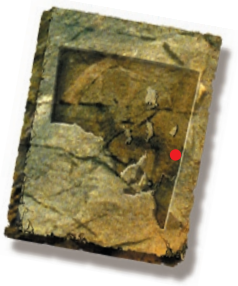


Mesoproterozoic granitoids of the Billeroo area, southwest Curnamona Province

Mathias L. Knaak, A. John Parker and Richard B. Flint (Geosurveys Australia Pty Ltd)

Introduction

The Curnamona Province, a near-circular craton consisting of Palaeoproterozoic metasedimentary and metavolcanic rocks (Willyama Supergroup), and Palaeoproterozoic to Mesoproterozoic plutonic rocks, is well delineated by airborne magnetic and gravity data. The southwest portion of the province coincides with a significant regional north–south-trending gravity anomaly of low amplitude with dimensions of ~100 x 30 km (Fig. 1).

Semi-detailed geological mapping and geophysical interpretation at 1:50 000 scale was undertaken in the Billeroo Hill area by personnel from Geosurveys Australia Pty Ltd as part of PIRSA's contribution to the Broken Hill Exploration Initiative (Knaak et al., 2001). The mapped area includes Jagged Rocks, 'Glenorchy' Homestead, Mt Victoria Hut and Billeroo Huts, encompasses the northwestern exposure limits of the Olary Domain, and coincides with the southern limit of the regional gravity anomaly (Fig. 1). Special attention was directed at granites and related intrusives, dominated by monzogranite, that form ~30% of basement exposures in the region, as these coincide with the southern limit of the gravity anomaly. Deformational trends of the Olarian Orogeny are predominantly east-northeast and are clearly not consistent with the regional north–south-trending gravity anomaly.

Regional geological setting

Major stratigraphic units of the Willyama Supergroup — the volcano-sedimentary Wiperaminga and Ethiudna Subgroups (Curnamona Group) — along with the pelite-dominated Saltbush Subgroup (Strathearn Group), were deformed during the Olarian Orogeny at ~1600–1580 Ma (Ludwig and Cooper, 1984; Cook et al., 1994; Page et al., 2000; Conor, 2000). Three main phases are recognised — development of a layer-parallel schistosity and gneissosity associated with amphibolite-facies metamorphism during OD_1, development of tight to isoclinal folds and at times a new axial planar schistosity during OD_2, and development of open to closed folding and retrograde shear zones during OD_3 (Berry et al., 1978; Grady et al., 1989; Flint and Parker, 1993).

Granitoids emplaced during the Olarian Orogeny are poorly classified and their timing with respect to the main deformational phases is poorly known throughout the entire Olary Domain — most granitoids have been simply

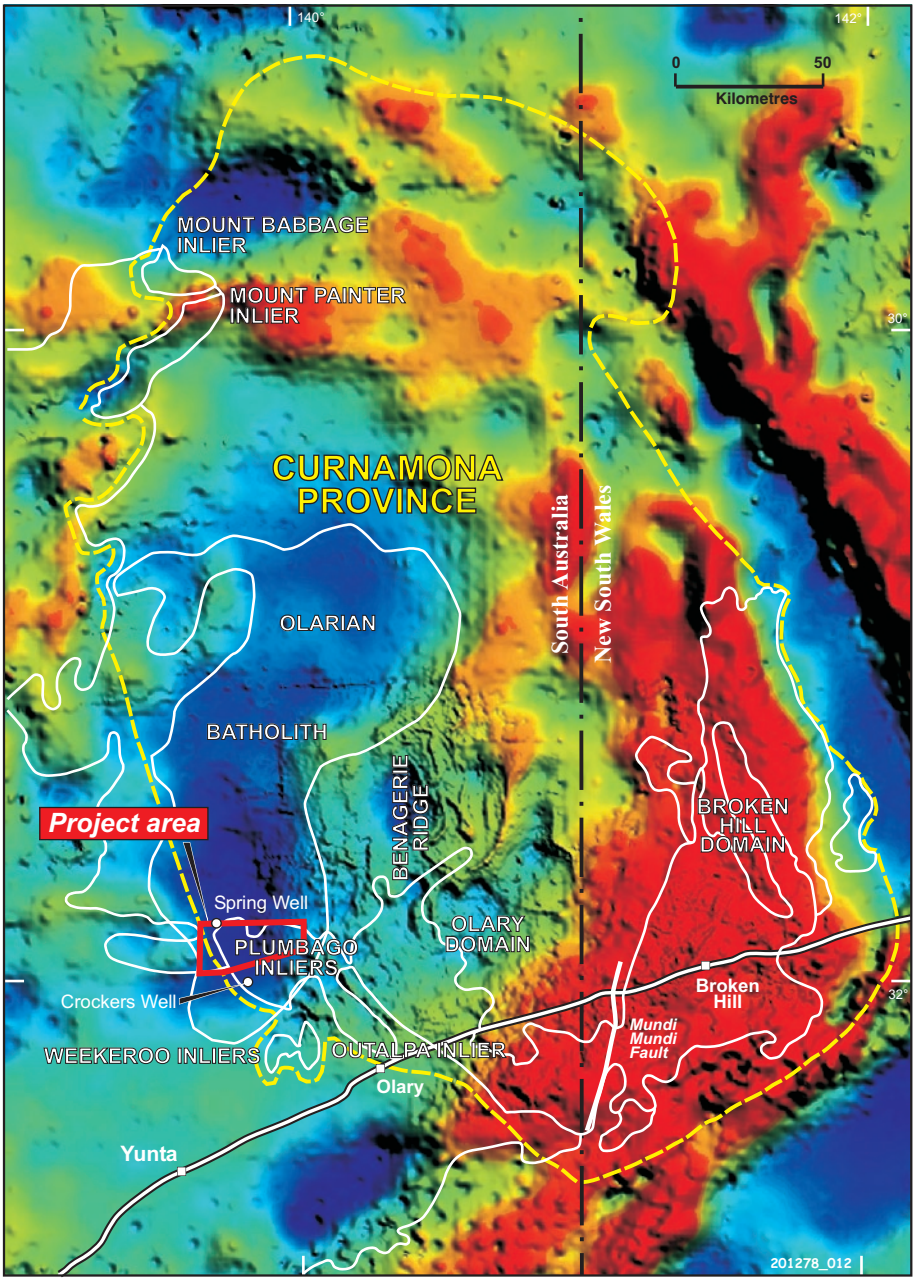


Fig. 1 *Location plan superimposed on the gravity image of the Curnamona Province.*

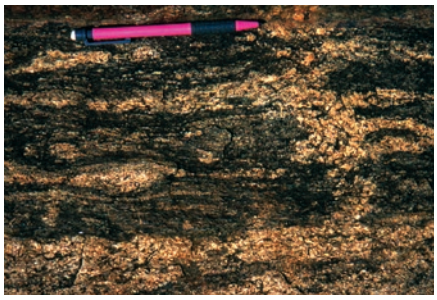
referenced as 'regional S-type granites' or as 'Bimbowrie Suite'. Gneissic granites, migmatitic gneisses, granodioritic to tonalitic gneisses, and some foliated granites and pegmatites formed during OD_1 and OD_2 deformational phases. However, some granitoids (e.g. Triangle Hill, Tietz Dam, Antro Woolshed) are either massive or contain only a weak foliation, are dominantly potassic, often porphyritic, and were most probably emplaced during OD_3 (Flint and Parker, 1993; Ashley et al., 1998). OD_3 granitoids are often megacrystic, peraluminous, fractionated, and commonly muscovite and magnetite-bearing (Wyborn et al., 1998).

At Crockers Well, ~8 km south of the Billeroo area, a sodic granitoid yielded U–Pb zircon ages of 1579±2 Ma (Ludwig and Cooper, 1984) while a nearby 'regional' granitoid yielded an age of ~1580 Ma (Cook et al., 1994). Sodic granitoids comprising leucocratic trondhjemite and granodiorite contain significant uranium and thorium mineralisation as thorian brannerite within phlogopite-rich granitoid breccia (Campana and King, 1958; Ashley, 1984; Painter, 1992). Associated granitoids are relatively mafic, and include hornblende-bearing quartz monzodiorite and biotite granodiorite. Emplacement of Crockers Well granitoids relative to major deformational episodes of the Olarian Orogeny has not been clearly established.

Granitoid geology

Exposed granitoids in the Billeroo area (Plumbago Inlier) are surrounded by highly migmatised, psammopelitic metasedimentary rocks (Fig. 2). The degree of migmatisation and proportion of melt component increases towards the granitoid plutons, though their relative ages are not known. The migmatisation fronts are irregularly shaped and broadly trend northwards, apparently discordant to regional OD_1 fabrics.

Irregularly shaped and zoned composite plutons of the Billeroo area comprise coeval mafic and felsic phases displaying magma mixing and mingling features. Monzogranite is the dominant composition. Small volumes of more mafic phases range in composition from granodiorite to quartz diorite to diorite, and commonly occur as dykes and small intrusive bodies at the margin of the larger monzogranite bodies. Individual mafic bodies are up to 50 m wide



Migmatitic metapsammopelitic gneiss with biotite-rich melanosome, northeast of Mount Victoria Hut. (Photo 48603)

Migmatitic gneiss with greater leucocratic neosome, northeast of Jagged Rocks. (Photo 48604)

and, at their contacts, complex zones of magma mixing comprise hybrid granitoids of various composition containing abundant oval to round enclaves (20–100 mm across) of fine-grained microdiorite. Monzogranite and

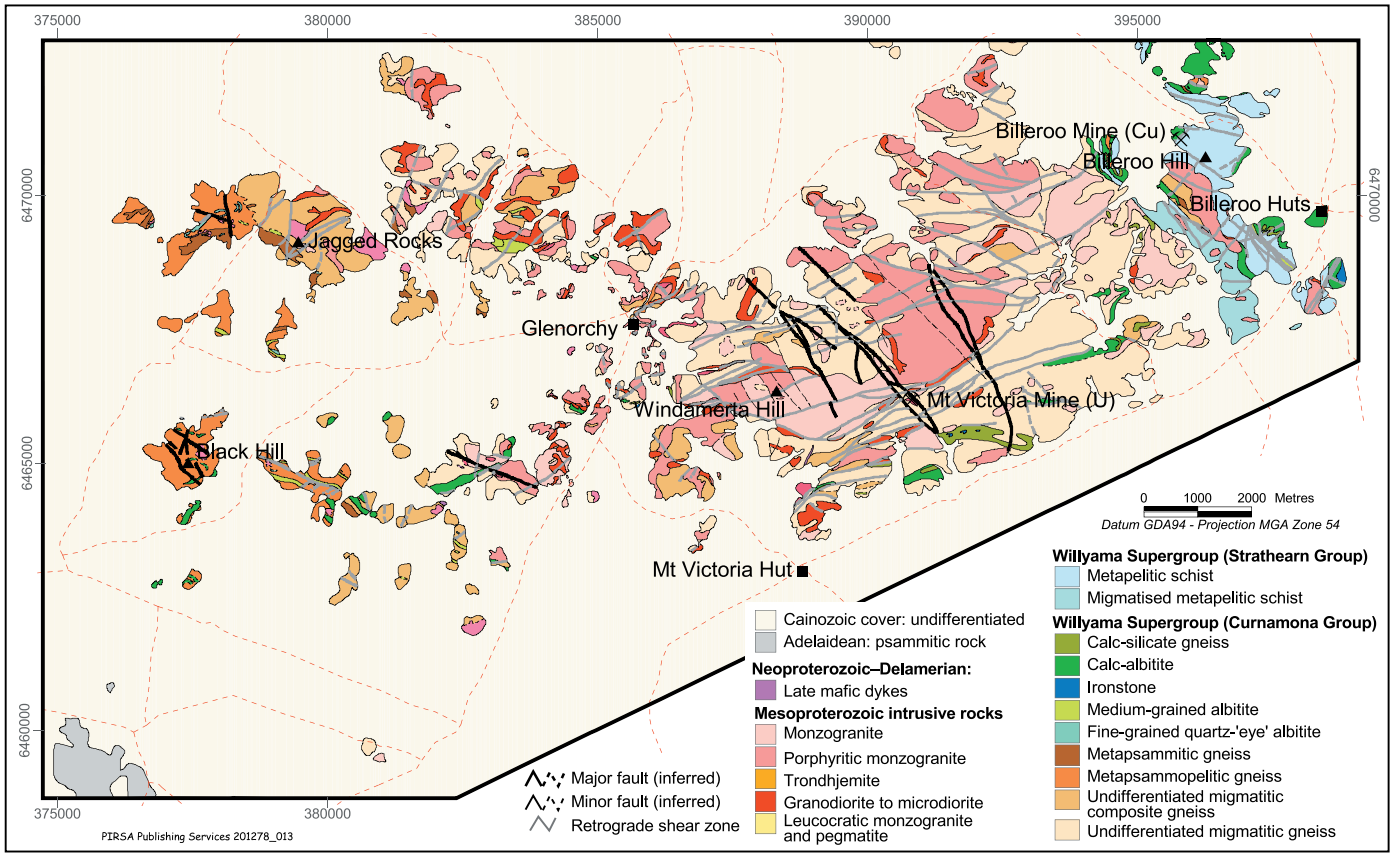


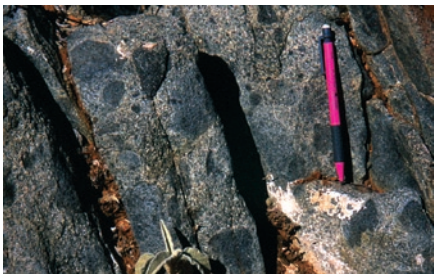
Fig. 2 *Geological map of the Billeroo area.*

porphyritic monzogranite often contain rafts up to several hundred metres long of gneisses and migmatites which contain high-grade metamorphic fabrics interpreted as predating plutonism. Trondhjemite, though present, forms only a small constituent of the plutons. Magnetite is a common accessory within most phases though ilmenite is usually present within trondhjemite. Muscovite is totally absent from all phases.

The granitoids are predominantly equigranular and medium to coarse grained, though both aphyric and weakly porphyritic varieties are also present. Monzogranite is often porphyritic; K-feldspar phenocrysts up to 50 mm long are commonly aligned, in part defining an igneous fabric trending to the north to north-northeast and in part re-orientated subparallel to an OD_3 fabric.

Porphyritic monzogranite with aligned feldspar phenocrysts, northeast of 'Glenorchy'. (Photo 48605)

Sills of microdiorite and monzogranite, northeast of Jagged Rocks. (Photo 48606)



Microdiorite enclaves within granodiorite near the contact with monzogranite, northeast of Mount Victoria Hut. (Photo 48607)

Granitoid textures and fabrics range from massive to strongly foliated, especially within localised zones of ductile–brittle deformation. High-grade metamorphic fabrics typical for OD_1 and OD_2 are absent, suggesting that plutonism was post–OD_2 and either pre- or syn-OD_3.

Geophysical data

Magnetic susceptibility values vary considerably throughout the granitoids — 0–80x10^{-5} SI for trondhjemite, 0–1500x10^{-5} SI for monzogranite, 500–4500x10^{-5} SI for granodiorite, and 2000–5500x10^{-5} SI for diorite. Higher magnetic susceptibility values correlate with both biotite and mafic-rich phases.

Despite the moderate to at times high-field susceptibility values for the granitoids, airborne magnetic imagery defines either mottled, very weakly magnetic domains or linear to semicircular anomalies of moderate amplitude that correspond in the field to exposures of composite monzogranite and granodiorite (Fig. 3). Curvilinear magnetic anomalies indicate small plutons ranging in diameter from ~1 to 5 km.

Monzogranite of the Billeroo area generally displays higher magnetic susceptibility values than equivalent granitoids of the southern portion of the Plumbago Inlier (e.g. Crockers

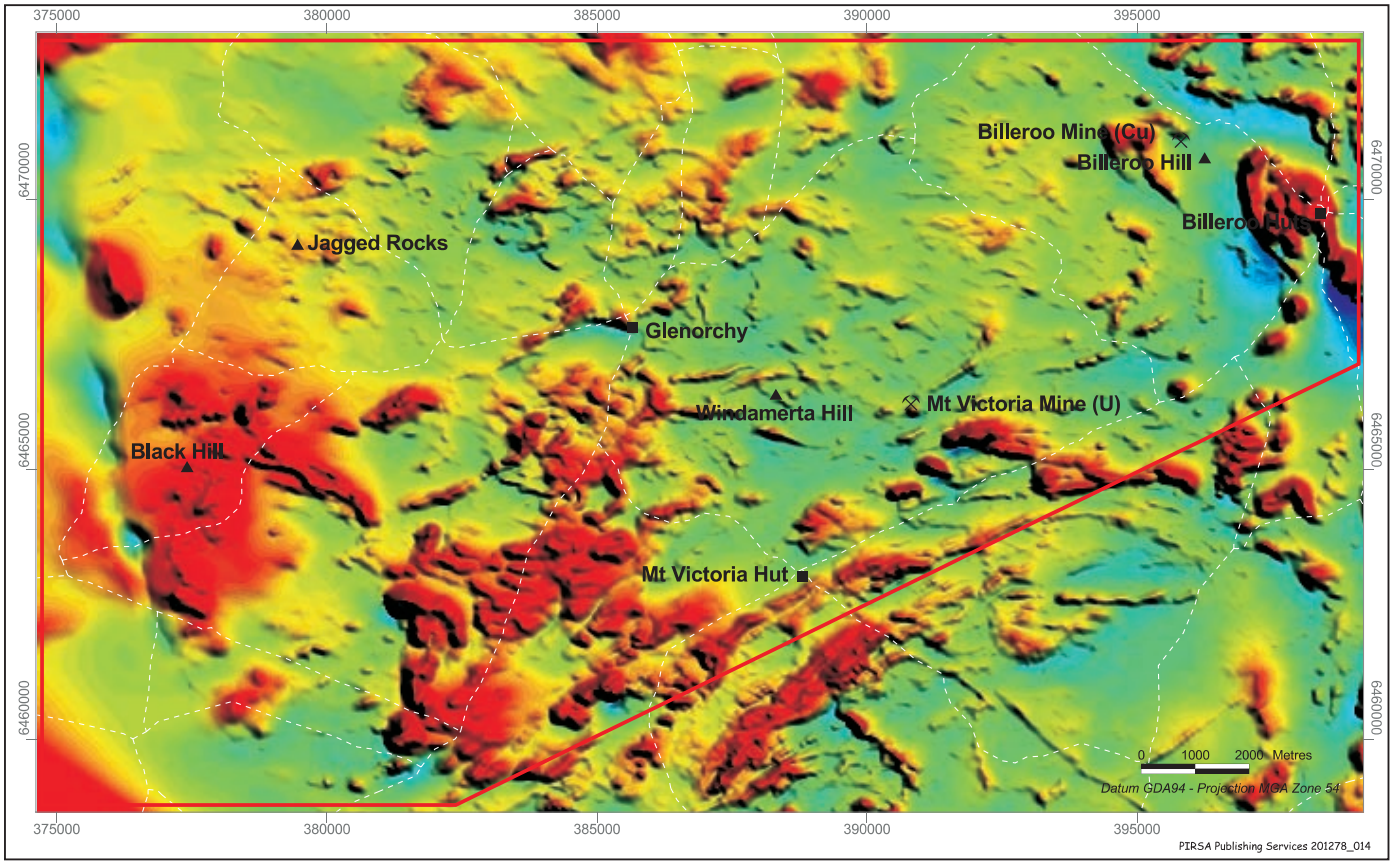


Fig. 3 *Total magnetic intensity image of the Billeroo South area.*

Well region), but this is not reflected in airborne magnetic images.

K–U–Th ternary gamma-ray spectral imagery reveals broad north–south bands, ranging from pinkish red hues in the west for schists and gneisses, through greenish blue hues for migmatised metasediments (and granitoids), to white hues in the east for granitoids (Fig. 4). This zonation is discordant to regional OS_1 and OS_2 fabrics observed in exposures, and there appears to be a strong correlation between the degree of melt development within the migmatised metasediments and distance to granitoid-dominated areas to the east. However, it is not known if the greenish blue hues are directly linked to melt component or indirectly through perhaps these lithologies having been metasomatised (albitised) to greater degrees than metasediments further west.

Discussion

For much of the Jagged Rocks, 'Glenorchy' and Mt Victoria Hut area (excluding the Billeroo Huts area), trends for OS_1, OS_2 and OS_3 fabrics within metasedimentary units are all similar and broadly to the east-northeast (Knaak et al., 2001). Only OD_3 structural elements are present within the granitoids, and these are superimposed on an earlier igneous alignment of K-feldspar phenocrysts that trends broadly north to north-northeast. Structural relationships and the presence of migmatitic gneiss inclusions clearly demonstrate that emplacement of the composite zoned plutons is pre- to syn-OD_3 of the Olarian Orogeny. However, the trend for igneous fabrics and migmatisation fronts are at a high angle to the pervasive OD_3 axial surface (Fig. 5).

Basement exposures in the Billeroo and Crockers Well areas coincide with the southern limit of a significant north–south-trending regional gravity low which was tentatively proposed by Robertson et al. (1998) to reflect the presence of a much larger granite body than suggested from the exposures. The north–south trend is supported by new observations on the trend of migmatisation fronts defined both in the field and in K–U–Th ternary gamma-ray spectral imagery, and by igneous alignment of K-feldspar phenocrysts. Individual plutons are interpreted as being relatively small at ~1–5 km, but are thought to be an integral part of a regional batholith that extends northwards for ~100 km, perhaps aligned along a major crustal lineament.

Common to most Proterozoic terrains is the close association of mineralisation with the latest tectono-thermal or igneous event (Wyborn et al., 1998). Extensive, low-grade uranium mineralisation, principally as thorian brannerite, occurs disseminated and concentrated within fractures, breccias and quartz veins within sodic granitoids at Crockers Well, and a resource of at least 10 Mt containing 500 ppm U_3O_8 to a depth of 100 m has been delineated (Ashley, 1984). At Mt Victoria uranium mine, a resource of 2965 t of U_3O_8 consists of davidite associated with quartz, haematite and minor copper sulphides in shear zones; uranium mineralisation occurrences are also known at Jagged Rocks and Spring Hill (Campana and King, 1958; Robertson et al., 1998).

The relative age(s) for uranium mineralisation with respect to granitoid emplacement is enigmatic. Mineralisation may be related to trondhjemite phases (and brecciated trondhjemite) that may represent final differentiates within the

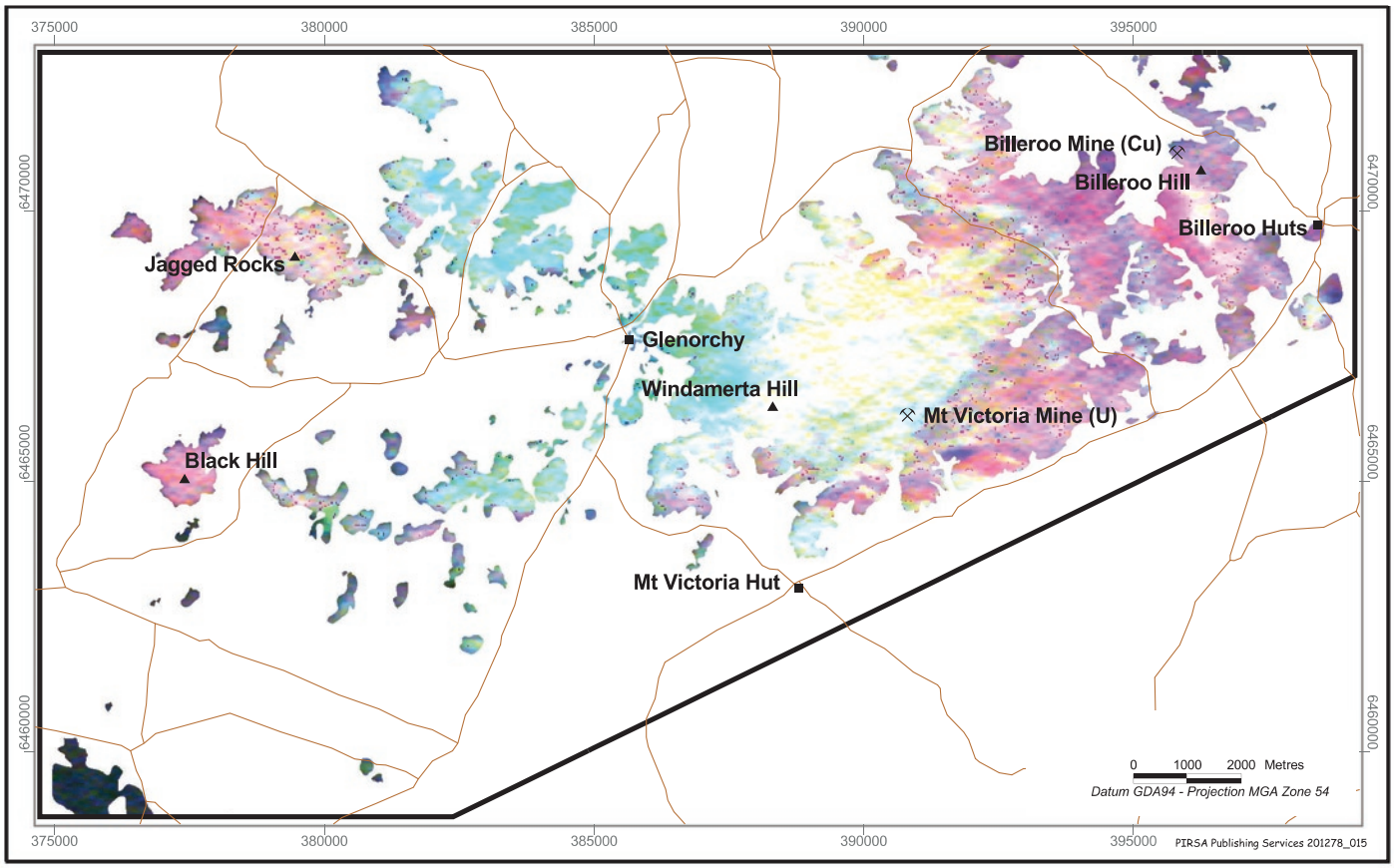


Fig. 4 *Gamma ray spectral image of the Billeroo South area.*

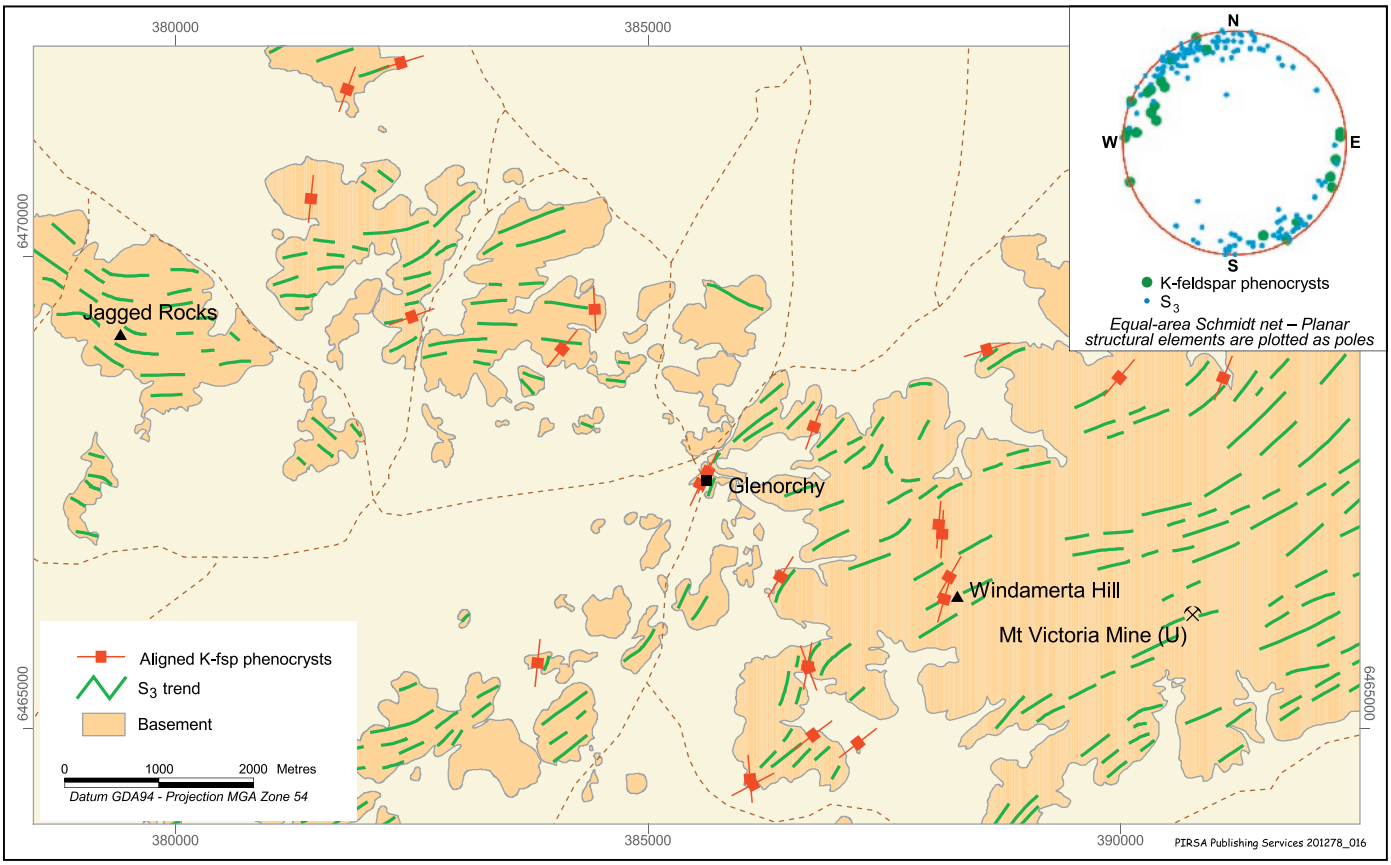


Fig. 5 *Alignment of K-feldspar phenocrysts and S_3 trend near 'Glenorchy'.*

mafic–intermediate complexly zoned plutons, as at Crockers Well (Ashley, 1984). Some mineralisation also occurs along brittle north-northwest-trending fractures that are probably very late-OD3 or Delamerian features. However, this may represent concentration and remobilisation of earlier mineralisation. Little time difference may exist between these two events, and the granitoid batholith remains as a very prospective target for uranium mineralisation.

References

Ashley, P.M., 1984. Sodic granitoids and felsic gneisses associated with uranium–thorium mineralisation, Crockers Well, South Australia. *Mineralium Deposita,* 19:7-18.

Ashley, P.M., Conor, C.H.H. and Skirrow, R.G., 1998. Geology of the Olary Domain, Curnamona Province, South Australia: field guide to the Broken Hill Exploration Initiative excursion 13–15 October 1998. *South Australia. Department of Primary Industries and Resources. Report Book,* 99/12.

Berry, R.F., Flint, R.B. and Grady, A.E., 1978. Deformational history of the Outalpa area and its application to the Olary Province. *Royal Society of South Australia. Transactions,* 102:43-54.

Campana, B. and King, D., 1958. Regional geology and mineral resources of the Olary Province. *South Australia. Geological Survey. Bulletin,* 34.

Conor, C.H.H., 2000. Definition of major sedimentary and igneous units of the Olary Domain, Curnamona Province. *MESA Journal,* 19:51-56.

Cook, N.D.J., Fanning, C.M. and Ashley, P.M., 1994. New geochronological results from the Willyama Supergroup, Olary Block, South Australia. *In: Australian Research on Ore Genesis Symposium, Adelaide, 1994. Proceedings,* 19.1-19.5.

Flint, D.J. and Parker, A.J., 1993. Willyama Inliers. *In:* Drexel, J.F., Preiss, W.V. and Parker, A.J. (Eds), The geology of South Australia. Vol. 1. The Precambrian. *South Australia. Geological Survey. Bulletin,* 54:82-93.

Grady, A.E., Flint, D.J. and Wiltshire, R.J., 1989. Excursion guide for Willyama Supergroup and related rocks, Olary district, SA. *South Australia. Department of Mines and Energy. Report Book,* 89/23.

Knaak, M.L., Flint, R.B. and Parker, A.J., 2001. Geological and geophysical mapping of Billeroo South, Curnamona Province, South Australia. Geosurveys Australia Pty Ltd. Report, GS2001/14 (unpublished).

Ludwig, K.R. and Cooper, J.A., 1984. Geochronology of Precambrian granites and associated U–Ti–Th mineralisation, northern Olary Province, South Australia. *Contributions to Mineralogy and Petrology,* 86:298-308.

Page, R.W., Stevens, B.P.J., Gibson, G.M. and Conor, C.H.H., 2000. Geochronology of Willyama Supergroup rocks between Olary and Broken Hill, and comparison to northern Australia. Broken Hill Exploration Initiative. Abstracts of papers presented at the May 2000 conference in Broken Hill. *Australian Geological Survey Organisation. Record,* 2000/10:72-75.

Painter, M.G.M., 1992. Syntectonic U–Th mineralization and its relationship to the granitoids and metasediments of the Willyama Supergroup at Crockers Well, South Australia. *University of Melbourne. B.Sc. (Hons) thesis* (unpublished).

Robertson, R.S., Preiss, W.V., Crooks, A.F., Hill, P.W. and Sheard, M.J., 1998. Review of the Proterozoic geology and mineral potential of the Curnamona Province in South Australia. *AGSO Journal of Australian Geology and Geophysics,* 17(3): 169-182.

Wyborne, L.A.I., Budd, A.R., Stevens, B.P.J., Ashley, P.M., Conor, C.H.H. and Bastrakova, I.V., 1998. Major felsic igneous units of the Broken Hill–Olary region and their metallogenic potential. *In:* Gibson, G.M. (Compiler), Broken Hill Exploration Initiative. Abstracts of papers presented at Fourth annual meeting in Broken Hill, October 19–21, 1998. *AGSO Record,* 1998/25:123-126.