AGSO Journal of Australian Geology & Geophysics, 17(3), 145–168

Tectonic evolution and exploration potential of the Gawler Craton, South Australia

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Interpretation of newly acquired high-resolution aeromagnetic data, accompanied by reassessment of corresponding integrated geological data, establishes a complex Archaean to Mesoproterozoic tectonic history for the Gawler Craton in South Australia.

A key outcome is the recognition of major tectonic events between 1540 and 1565 Ma and at ~1650 Ma that postdate the Kimban Orogeny. The northwest part of the craton was subjected to high-grade metamorphism at these times, whereas in the central part of the craton coeval deformation is focused within major shear zones. The proposed new name for this orogenic advent is the Kararan Orogeny, derived from the major crustal feature the Karari Fault. Deformation during the Kararan Orogeny was essentially contemporaneous with Hiltaba Suite and Gawler Range Volcanics magmatism and is a critical factor in the emplacement of copper-gold mineralisation.

We propose that deformation associated with the Kararan Orogeny is related to continental collision between the eastern proto-Yilgarn Craton, in the northwest, and the central Gawler Craton–East Antarctic Craton (the Mawson Continent) in the south. The Fowler Orogenic Belt is one of the most intensely deformed regions within what is a broad collisional zone, and together with adjacent less-deformed crust may host mantle-sourced Proterozoic nickel deposits.

Although recognition of the Kararan Orogeny is significant to our new understanding of the craton, there is a long and complex record of events that commenced in the late Archaean. Each stratigraphic unit within the craton and the subsequent tectonothermal history are briefly summarised. Newly available data have been included as far as possible following on from Drexel et al. (1993).

It is well known that the Gawler Craton is host to the world-class Mesoproterozoic Olympic Dam Cu–U–Au deposit. The craton also has significant potential for the discovery of additional Cu–Au deposits related to acid volcanism and/or late-stage high crustal level granitic intrusives associated with altered and deformed Archaean and Palaeoproterozoic hosts. This potential is now being realised with application of the cost-effective calcrete sampling technique to detect anomalous gold. The discovery, in 1996, of shear-hosted gold in the central Gawler Craton within the Yarlbrinda Shear Zone has intensified exploration in those regions where Hiltaba Suite and Gawler Range Volcanics intrude shattered basement.

Exploration expenditure for Archaean gold has increased significantly following discovery of the Challenger gold prospect in June 1995. Gold mineralisation occurs in complexly deformed Archaean quartz–feldspar–garnet–cordierite gneiss. Many other calcrete-hosted gold anomalies remain to be tested within poorly exposed Archaean Mulgathing Complex, which also includes layered ultramafic sills and exposed komatiites.

Introduction

The Gawler Craton (Fig. 1) underlies the greater part of central South Australia. It is defined as that region of Archaean to Mesoproterozoic crystalline basement that has undergone no substantial deformation, except for minor brittle faulting, since 1450 Ma (Thomson 1975, Parker 1993a). The margins of the predominantly polygonal craton are well delineated by aeromagnetic and gravity images. The craton records crust formation and tectonothermal events (Fig. 2) in the late Archaean to earliest Proterozoic (Sleafordian Orogeny), Palaeoproterozoic (Kimban Orogeny), and Mesoproterozoic (Kararan Orogeny).

The northwest, northeast and western boundaries correspond to faulted margins of thick Neoproterozoic and Phanerozoic sedimentary basins. Part of the reworked basement beneath these sediments, to the northwest, is considered to have been affected by the Musgravian Orogeny at ~1100 Ma (Parker 1993a). The eastern and southeastern boundaries are defined by the Torrens Hinge Zone, the western limit of the Adelaide Fold Belt. Imaged gravity and aeromagnetic data clearly show that reworked Gawler Craton crystalline basement underlies the western margin of the Adelaide Geosyncline. Basement outcrop within the Adelaide Fold Belt recording Delamerian (Cambro-Ordovician) deformation includes the Barossa Complex immediately east of Adelaide (Preiss 1993) and the Peake and Denison Inliers east of Coober Pedy (Ambrose et al. 1981). The southern boundary is shown as the edge of the continental shelf.

High-resolution aeromagnetic data flown by World Geoscience Corporation, Geoterrex and Kevron for Mines and Energy South Australia (MESA) during 1992–95 have for the first time allowed integration of geology and geophysics for the greater part of the Gawler Craton. Geological mapping compiled at 1:100 000 scale or better is available (in digital or hard copy format from MESA) for most of the region as well as summary stratigraphy for all open file exploration drillholes. Digital integration of these data sets with aeromagnetic and gravity data and newly available SHRIMP U–Pb geochronology has enabled us to present this revised interpretation of the tectonic history of the craton. Recent work has focused on the northern Gawler Craton, where, prior to the release of aeromagnetic data, extensive thin surficial sand and soil cover hindered understanding of the extent to which the tectonic history differs from that of the more extensively exposed and better understood southern Gawler Craton.

Archaean to earliest Proterozoic

Sleaford Complex

The Carnot Gneisses of the Sleaford Complex (Figs 2, 4) have excellent exposure along the southern coast of Eyre Peninsula. They comprise garnet quartz–feldspar paragneiss, augen gneiss, hypersthene garnet gneiss and basic granulite (Fanning et al. 1981, Daly & Fanning 1993).

The paragneisses include layered garnet gneiss (quartz–feldspar–biotite–garnet–sillimanite) intercalated with biotite–garnet gneiss (quartz–feldspar–garnet–biotite–cordierite–sillimanite), cordierite–garnet gneiss (quartz–feldspar–garnet–cordierite) and migmatitic feldspar–quartz–biotite–garnet leucogneiss. These metasediments contain boudins of basic granulite, interpreted as tholeiitic basalt flows or gabbro sills emplaced prior to metamorphism. The paragneisses are now structurally concordant with plagioclase–quartz–biotite–garnet gneiss containing abundant K-feldspar augen. The augen gneiss that forms the greater proportion of the spectacular coastal outcrop at Cape Carnot is interpreted to be an in-situ partial melt of the supracrustal sequence.

Large, concordant, hypersthene gneiss bodies containing metamorphosed remnants of tholeiitic basalt and/or gabbro also occur along the coast. In part, the hypersthene gneisses have been interpreted as synorogenic intrusions into the paragneiss sequence (Fanning et al. 1986, Daly & Fanning 1993). Conventional multi-grain U–Pb zircon geochronology of a hypersthene gneiss from Cape Carnot gave an interpreted age of 2637±21 Ma, originally considered to record emplacement age and, therefore, a minimum age for sedimentation (Fanning et

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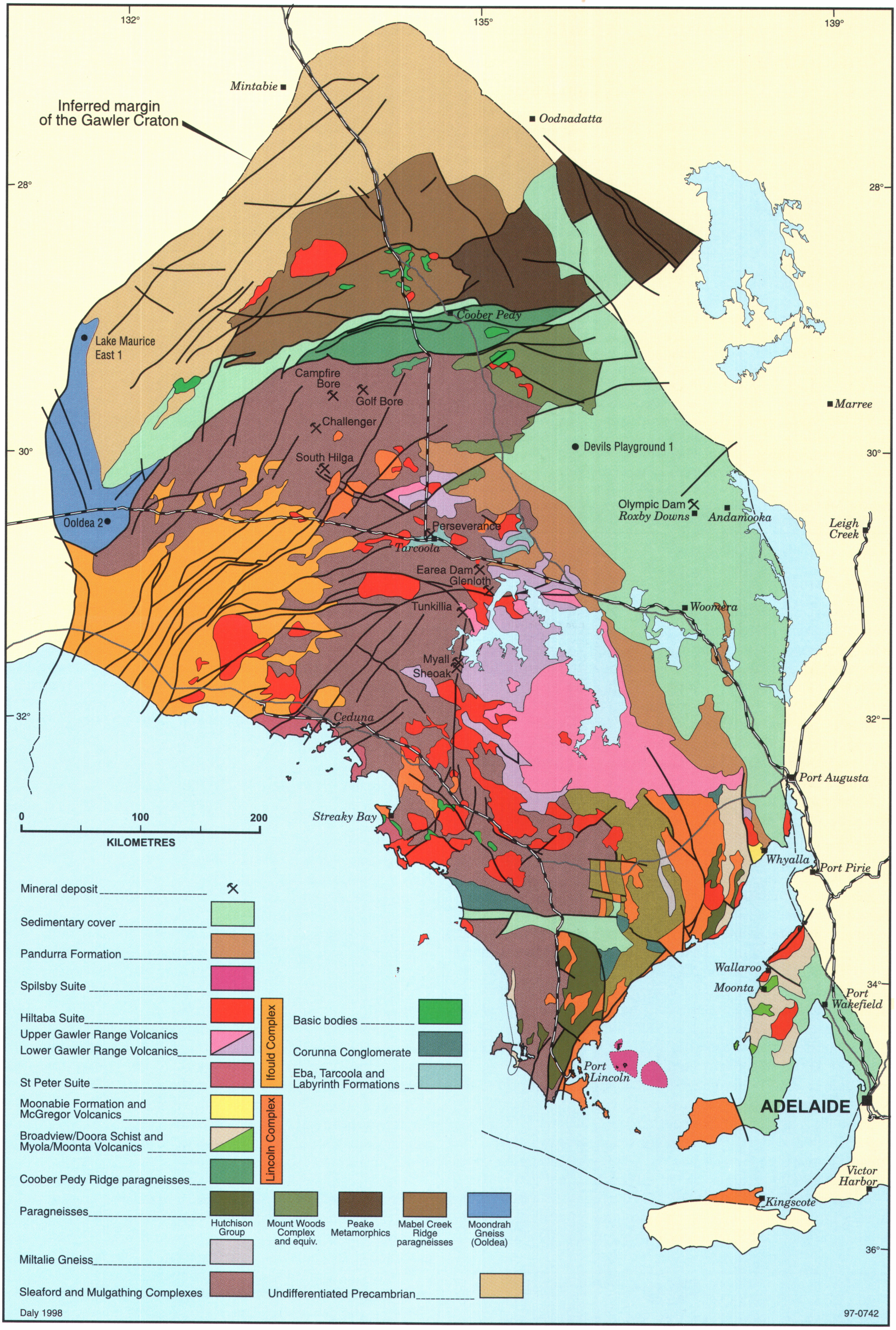


Figure 1. Interpreted subsurface geology of the Gawler Craton, South Australia.

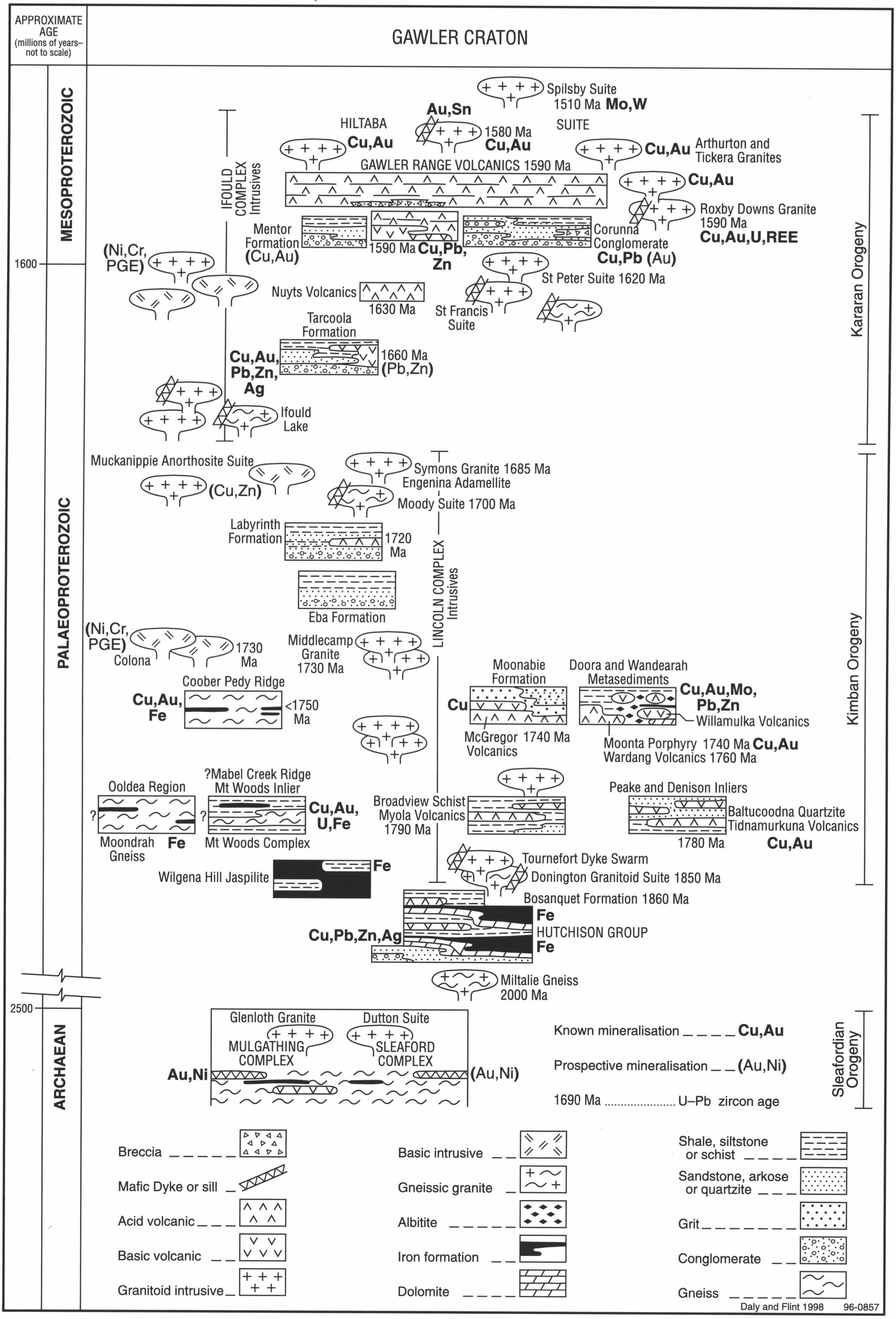


Figure 2. Nomenclature and suggested correlation of Precambrian rock units in the Gawler Craton.

al. 1986). SHRIMP U–Pb analyses, however, now show a complex age history with zircon components as old as 2950–3150 Ma, reflecting inheritance from older crust. The more dominant U–Pb analyses for zircon from the hypersthene gneiss range between 2400 and 2440 Ma, reflecting a period of peak metamorphism during the Sleafordian Orogeny (Fanning 1997).

Prograde mineral assemblages for the Carnot Gneisses indicate granulite-facies metamorphism during the Sleafordian Orogeny. Geothermometry from coexisting pyroxenes indicate equilibration temperatures of 800–860° C (Fanning et al. 1986) and hypersthene–garnet assemblages indicate pressures of ~9 kb. Rb–Sr and U–Pb geochronology of the paragneisses indicates peak metamorphism at 2420–2440 Ma (Fanning 1997).

Further north at Warramboo, in central Eyre Peninsula (Fig. 3), linear aeromagnetic trends, reflecting Archaean banded iron formation, strike east–west, discordant to nearby younger Palaeoproterozoic Hutchison Group sediments. The quartz–feldspar–magnetite–garnet–cordierite–sillimanite banded iron formation is interlayered with migmatitic garnet-rich pelitic gneiss and thin marble layers; these rocks are broadly similar to Archaean metasedimentary Carnot Gneisses to the south, and the Christie Gneiss described from the northern Gawler Craton (Daly & Fanning 1993). East of Warramboo at Cootra (Fig. 3), mafic rocks interpreted to have been tholeiitic metabasalt or gabbro (now mafic granulite) are concordant with quartz–feldspar garnet paragneiss. From limited drilling data and the comparatively complex aeromagnetic signatures, it is probable that a far greater variety of metabasic rock types may occur within the Sleaford Complex in the Warramboo region. These rock types are prospective for Archaean gold and nickel deposits (see later discussion of the Mulgathing Complex).

On southern Eyre Peninsula, aeromagnetic data delineate the north-trending boundary between 'magnetically-busy' granulite-facies Carnot Gneisses to the east, and the comparatively low-amplitude signature of high crustal level syn-Sleafordian Orogeny granites (Dutton Suite) to the west. This boundary (Figs 3, 4) is parallel to and ~25 km east of the Coulta–Cleve Subdomain boundary of Parker (1993a). It is now interpreted as a major fault or terrane boundary along which granulite facies Sleaford Complex is juxtaposed against lower grade high crustal level granites, i.e. a faulted boundary between the Archaean lower and upper crust (Fanning et al. 1995, Fanning 1997.).

The high crustal level granitoids of the Dutton Suite (Fig. 2) include the Coulta Granodiorite, Kiana Granite, and Whidbey Granite. The grey, foliated plagioclase–quartz–K-feldspar–biotite Coulta Granodiorite contains abundant hornblende–plagioclase–biotite xenoliths and is intruded by variably deformed, pinkish, strikingly porphyritic K-feldspar–quartz–plagioclase–muscovite–biotite Kiana Granite. The relationship between the Kiana Granite and the mildly deformed, massive, pinkish Whidbey Granite (which only occurs on the present-day continental shelf) is unknown. Rb–Sr geochronology for the Dutton Suite gave isochron ages of 2337±71–2316±71 Ma (Webb et al. 1986), in part reflecting partial resetting during the Kimban Orogeny. More reliable U–Pb zircon geochronology records magmatic crystallisation ages at 2459±15, 2558±27 and 2517±14 Ma (Fanning 1997).

Limited outcrop of Archaean metasediment (as well as Dutton Suite) occurs on Coffin Bay Peninsula, near Lake Hamilton and along the coast west of Mount Greenly and The Frenchman. The quartz–feldspar–biotite–muscovite Wangary Gneiss has been interpreted as a lower grade equivalent of the Carnot Gneisses and has a U–Pb zircon metamorphic age of 2479±8 Ma (Fanning 1997). The Wangary Gneiss is clearly a basement into which the Dutton Suite was intruded.

At Cape Carnot, metamorphic layering forms isoclinal SF_2 folds, i.e. folds developed during the second phase of the Sleafordian Orogeny (nomenclature as per Drexel et al. 1993 p.7). Later folds are more open and orientated parallel to northerly trending Palaeoproterozic syn-Kimban Orogeny fold axes (Parker et al. 1988). Aeromagnetic data show that the Archaean paragneisses have been rotated into parallelism with regional fold trends (KF_3) within the Palaeoproterozoic metasedimentary Hutchison Group, indicating that folds developed during the third phase of the Palaeoproterozoic Kimban Orogeny. U–Pb zircon analyses of hypersthene gneiss layers at Redbanks, 1 km north of Cape Carnot (Fig. 3), record the presence of younger intrusive events at approximately 2000 Ma and 1700 Ma. A crosscutting aplite dyke at Cape Carnot also has a U–Pb zircon age of ~1700 Ma.

Mulgathing Complex

Whilst the northern Gawler Craton (Figs 5, 6) has been affected by extensive and prolonged Proterozoic tectonism, a significant proportion of the region retains Archaean to earliest Proterozoic radiometric ages. Archaean metasediments of the Mulgathing Complex (Daly 1985) were derived, at least in part, from an existing continental basement, and include banded iron formation, chert, carbonate, calc-silicate, quartzite and aluminous sediments. Komatiite and tholeiitic basalt flows, and pyroxenite and peridotite sills are inferred to be contemporaneous with sedimentation. Together with abundant other mafic rocks intersected in the subsurface (Robertson et al. 1992, Daly & van der Stelt 1992, Morris et al. 1994), these metabasic and ultramafic rocks are inferred to represent regional attenuation of the Archaean crust and may indicate the presence of oceanic crust during sedimentation. Peak regional granulite-facies metamorphism during the Sleafordian Orogeny (9 kb at 860°C) and associated extensive syntectonic granites, tonalites and norite have been dated at ~2450 Ma from both Rb–Sr whole rock and U–Pb zircon geochronology (Fanning 1997).

Aeromagnetic data (Fig. 5) and field/drilling observations show that the dominant regional structures for the Mulgathing Complex, developed during the Sleafordian, are tight to isoclinal folds (SF_3) up to 40 km long, refolding earlier macro- and micro-isoclinal folds SF_2. In some areas limbs of SF_3 folds become increasingly attenuated and grade into mylonite. These shear zones are interpreted to be Archaean in age (developed during peak metamorphism) and were reworked during Proterozoic tectonism. Progressive rotation of Archaean SF_3 axial surfaces and parallel shear zones, from predominantly north-trending, immediately south of the Karari Fault Zone (Fig. 5) and near Mount Christie, to easterly near Lake Harris, may be explained by strike-slip fault drag along portions of Proterozoic ductile shear zones.

A range of prograde Sleafordian metamorphic conditions is recorded within the Mulgathing Complex. Granulite-facies hypersthene–garnet, magnetite–spinel and cordierite–garnet mineral assemblages at Mount Christie and to the northwest are in distinct contrast to the much lower metamorphic grade komatiite flows which contain relic cumulus olivine near Lake Harris and the mildly deformed acid volcanic rocks north of Kingoonya in Devil's Playground DP1 (Fig. 5). The original crustal architecture of the Mulgathing Complex during the late Archaean through Palaeoproterozoic is not as well defined as in southern Eyre Peninsula (see above). Major structures controlling the juxtaposition of differing crustal levels are suspected to be high strain zones parallel to SF_3 axial planes, subsequently rotated in part by the ductile Proterozoic shear zones.

Economic geology of the Mulgathing Complex

Challenger deposit. In June 1995, Dominion Mining Ltd and Resolute–Samantha (Gawler Joint Venture) announced significant gold results from the Challenger prospect 50 km west of Commonwealth Hill Homestead (Fig. 5). Regional calcrete sampling of 10 000 km^2, at 1.6 x 1.6 km spacing, of the Joint Venture leases in the western Gawler Craton delineated about 70 calcrete gold anomalies (Kennedy 1996). The most promising anomaly had a 400 m northeast strike extent with a peak value of 296 ppb Au (Edgecombe 1997). Discovery holes 95CHAR 6 intersected 22 m at 2.8 g/t Au from 18 m, and 95CHAR 7, 28 m at 5.9 g/t Au from 12 m (Dredge 1995a). Further results were released in July 1995 (Dredge 1995b), including 29 m at 6.4 g/t from 12 m (95CHAR 83). Preliminary drilling indicated the deposit reached near surface and dipped northwards.

Subsequent drilling of the deposit has delineated a pipe-like main gold shoot with a north-northeasterly strike and northerly plunge. The gold shoot has a 450 m plunge length and a 230 m vertical depth. The main shoot remains open down plunge and deep drilling is continuing (Resolute 1997). Cross-section dimensions of the main shoot are approximately 30 m by 30 m (Reg Beaton, Resolute Ltd, pers comm, AIMM meeting July 1997). Gold values include 33 m at 9.3 g/t Au and 19 m at 22.5 g/t Au. Drilling has also intersected two other blind high-grade shoots, one 50 m east and the other 200 m east of the main shoot. Both are parallel to the main shoot. The most easterly begins at 80 m depth and remains open down plunge. Best results include 3 m at 68.1 g/t Au. Significant potential exists for discovery of other high-grade gold shoots (Resolute 1997) within the regional structure of the Challenger Prospect.

The ore shoots may be interpreted, from data released by the joint venture partners, to be contained within a broader regional north-northwesterly trending, steeply dipping, axial planar surface. The Challenger main gold shoot and parallel shoots, appear to be located on the north-plunging nose of a subsidiary fold. The character of the folds is similar to Sleafordian Orogeny SF_3 folds seen near Mount Christie (Daly & Fanning 1993). Gold occurs in foliated quartz–feldspar–garnet–gneiss associated with pyrite, arsenopyrite and rare bismuthinite. The host unit has been interpreted as the metasedimentary Christie Gneiss (Edgecombe 1997).

Significant other prospects located within the Mulgathing Complex include:

- ***Golf Bore prospect*** (Gawler Joint Venture), located approximately 50 km northeast of Challenger, a 4 km calcrete gold anomaly defines a 3 km long bedrock anomaly of >100 ppb Au. The mineralisation occurs within a regionally extensive shear zone. RC drilling has currently defined an 800 m (open along strike) northeast-striking, steeply dipping mineralised zone in biotite–garnet gneiss. Gold values include 15 m at 2.8 g/t Au, 4 m at 11.7 g/t Au, and 7 m at 10.92 g/t Au (Resolute 1997).
- ***Campfire Bore prospect*** (Gawler Joint Venture), 30 km northeast of Challenger, a north-easterly trending, bedrock anomaly, approximately 1.5 km long and up to 200 m wide, of >100 ppb Au. RC drilling has intersected steeply dipping narrow zones of gold mineralisation hosted by Archaean gneiss. Gold values include 4 m at 3.06 g/t Au and 3 m at 3.41 g/t Au (Dominion 1997).
- ***Hilga South prospect*** (Gawler Joint Venture), 35 km south of Challenger, anomalous gold occurs within a folded sequence of banded iron formation, pyroxenites and quartz–feldspar–garnet gneiss. Drilling indicates low grade gold only within a 700 m by 100 m westerly to northwesterly trending zone. Best results include 2 m at 3.64 g/t Au and 5 m at 2.02 g/t Au (Dominion 1996).
- ***Golf North prospect*** (Equinox Resources N.L.), 55 km north of the Challenger prospect, air core drilling has delineated a mineralised zone over a strike length of 500 m and up to 100 m wide. Gold values include 12 m at 0.4 g/t Au from 28 m (WAC-42), 8 m at 0.5 g/t Au from 20 m (WAC-8), and 6 m at 0.42 g/t Au from 36 m (WAC-41) (Williams 1996).
- ***Birthday prospect*** (Minotaur Gold N.L.), 30 km east of the Challenger deposit, this anomaly covers an area of 4 km^2. Bedrock intersected includes Archaean quartz–feldspar–garnet gneiss, mafic gneiss and ultramafic with significant levels of sulphide. RAB drilling of the southern portion of the anomaly over a 68 ppb gold-in-calcrete peak has yielded bottom hole intercepts of up to 1.5 g/t Au. RC drilling into fresh bedrock has similarly included intercepts of up to 1.6 /t Au (Minotaur 1997).

Komatiitic and peridotitic nickel. The Archaean Lake Harris Komatiite, 22 km southwest of Kingoonya (Fig. 5), has a probable strike length of 25 km and composite thickness of 2000 m. Geochemistry indicates MgO values 27–41% and up to 2500 ppm Ni. There has been no exploration of this isoclinally folded shallow ultramafic body since its discovery (Daly & van der Stelt 1992).

Similarly, there has been no exploration of the differentiated ultramafic sill at Aristarchus, 16 km southwest of Mount Christie (Fig. 5) (Daly & van der Stelt 1992), where visible nickel sulphides occur in peridotite. Interpretation of imaged ground magnetic data, two diamond drillholes and three RC holes suggests thickness >75 m and strike length of 500 m.

Palaeoproterozoic

Miltalie Gneiss

At Plug Range (Figs 2, 4) the basal Warrow Quartzite of the Hutchison Group is structurally unconformable on a quartz–feldspar gneiss, the Miltalie Gneiss. This meta-igneous gneiss has a U–Pb zircon age of 2003±13 Ma (Fanning 1997). Similar gneisses crop out west of Tumby Bay and hypersthene bearing varieties of similar age occur to the north of Cape Carnot at Redbanks. All have U–Pb zircon magmatic ages of ~2000 Ma (Fanning et al. 1988, L. Rankin, MESA, pers comm. 1992, Fanning 1997).

We suggest that this magmatic event occurred in response to localised tectonism of the Sleaford Complex, juxtaposing the lower crustal granulite-facies Carnot Gneisses and the high crustal level Dutton Suite and Wangary Gneiss. This tectonism reflects a period of extension that gave rise to a shallow continental shelf along the east margin of the Archaean nucleus. Further, it is probable that in response to similar extension, a number of broadly contiguous depocentres developed around a central Archaean nucleus, with subsequent sedimentation between 2000 and 1700 Ma.

Hutchison Group

The Hutchison Group was deposited on a shallow continental shelf, deepening to the east, as manifest by the preservation of the thick sediments parallel to the current eastern craton margin, with thinner cover on Archaean gneiss in the central part of the craton. Other Palaeoproterozoic sediments, not recognised as Hutchison Group, were deposited in a similar continental shelf tectonic setting within the Peake and Denison Inliers and to the north and northwest in the Mount Woods Inlier, along the Coober Pedy and Mabel Creek ridges, and in the Ooldea area (Figs 1, 6).

The well-exposed Hutchison Group (Figs 2, 4) in eastern Eyre Peninsula (Parker 1993b) has an estimated total thickness of at least 3500 m. The sequence includes basal Warrow Quartzite, Middleback Subgroup (containing thick micaceous Cook Gap Schist separating Lower Middleback Jaspilite and Katunga Dolomite from Upper Middleback Jaspilite), overlain by either Yadnarie Schist or the laterally equivalent Bosanquet Formation.

The Warrow Quartzite was deposited in a fluvial to marine shelf environment. Its basal section consists of quartz-pebble conglomerate with a predominantly quartz matrix, which is variably feldspathic and micaceous. At Plug Range and in the Cowell Jade Province, thin calc-silicate and marble interbeds also occur near the base. Relict cross-bedding is locally preserved, but the quartzite is predominantly massive. It becomes flaggy near the top, reflecting an increasing abundance of pelitic schists towards the contact with overlying carbonate and iron-rich Middleback Subgroup. Total thickness is at least 1000 m, but estimates are made difficult by structural thinning, and intrusion and partial assimilation by syntectonic granites.

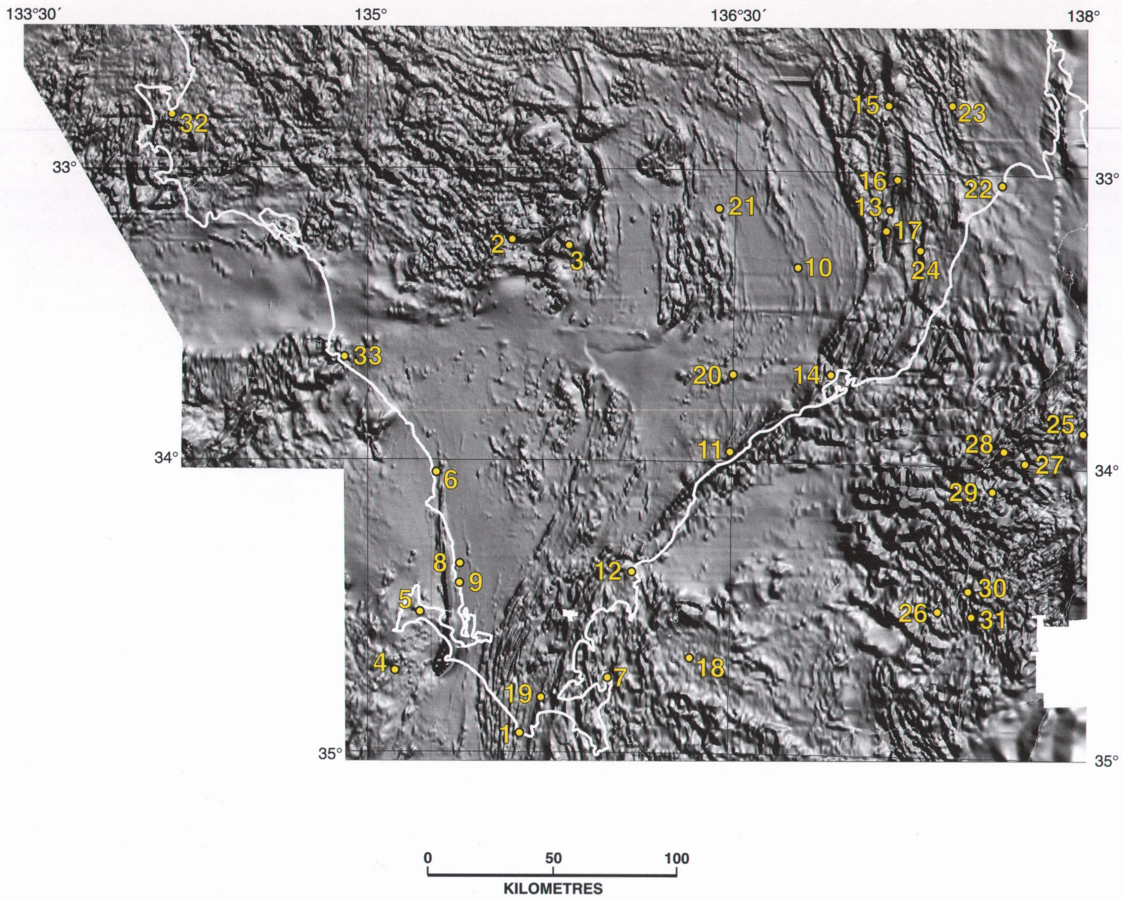


Figure 3. Grey-scale TMI image of the southern Gawler Craton.

The base of the Middleback Subgroup is the Katunga Dolomite, a dolomitic marble containing bands of serpentine (after forsterite) and calcite±diopside±tremolite interlayered with dolomite. The dolomite becomes increasingly iron-rich and grades into overlying Lower Middleback Jaspilite. The iron formation (Parker & Lemon 1982) contains finely banded chert±iron oxides±iron silicates±carbonate and locally abundant graphite and iron sulphides. Silicate and carbonate facies are laterally equivalent, interfinger along strike, and grade upwards into oxide facies.

The Cook Gap Schist comprises quartz, mica, garnet± feldspar±sillimanite with thin calc-silicate units, pegmatitic segregations and concordant amphibolites. The abundant amphibolites are considered most likely meta-igneous quartz-tholeiite flows or sills. The overlying Upper Middleback Jaspilite is very similar in lithology to the Lower Middleback Jaspilite, resulting in uncertainties in correlation, particularly in regions of poor outcrop.

The Middleback Subgroup is overlain by quartz+mica-rich Yadnarie Schist and the laterally equivalent Bosanquet Formation, which consists of foliated grey rhyodacite (with coarse phenocrysts of microcline), and is interlayered with calc-silicate and marble. U–Pb zircon dating gives an age of 1859±11 Ma (Rankin et al. 1988, Fanning 1997) for the rhyodacite and, therefore, a minimum age limit for sedimentation of the Hutchison Group. The Miltalie Gneiss at ~2000 Ma constrains the maximum age.

Economic geology of the Hutchison Group

Iron ore. High-grade haematite (~68% total iron) orebodies occur in north–south-trending synclinal keels (KD_2 and/or KD_3) cross-folded or faulted about northwest–southeast and east–west axes (Owen 1964, Miles 1954, Furber & Cook 1975). Remobilisation and recrystallisation of precursor magnetite occurred during deformation and metamorphism followed by supergene oxidation and enrichment with the removal of silica and loss of carbonate. Ore varies from hard fine-grained haematite with microscopic cores of magnetite to powdery and soft banded haematite. Manganese minerals are generally less than 0.5%, but are locally enriched to 30%.

Annual iron ore production from the Middleback Range in 1970 was 7.36 Mt, decreasing to 2.5 Mt in 1993. Total production figures to the end of 1990 were: Iron Knob 130 Mt, Iron Baron 56 Mt, and <1 Mt for Iron Duke (for locations see Fig. 3).

Copper–lead–zinc–silver mineralisation. The Middleback Subgroup is prospective for stratiform copper, lead and zinc

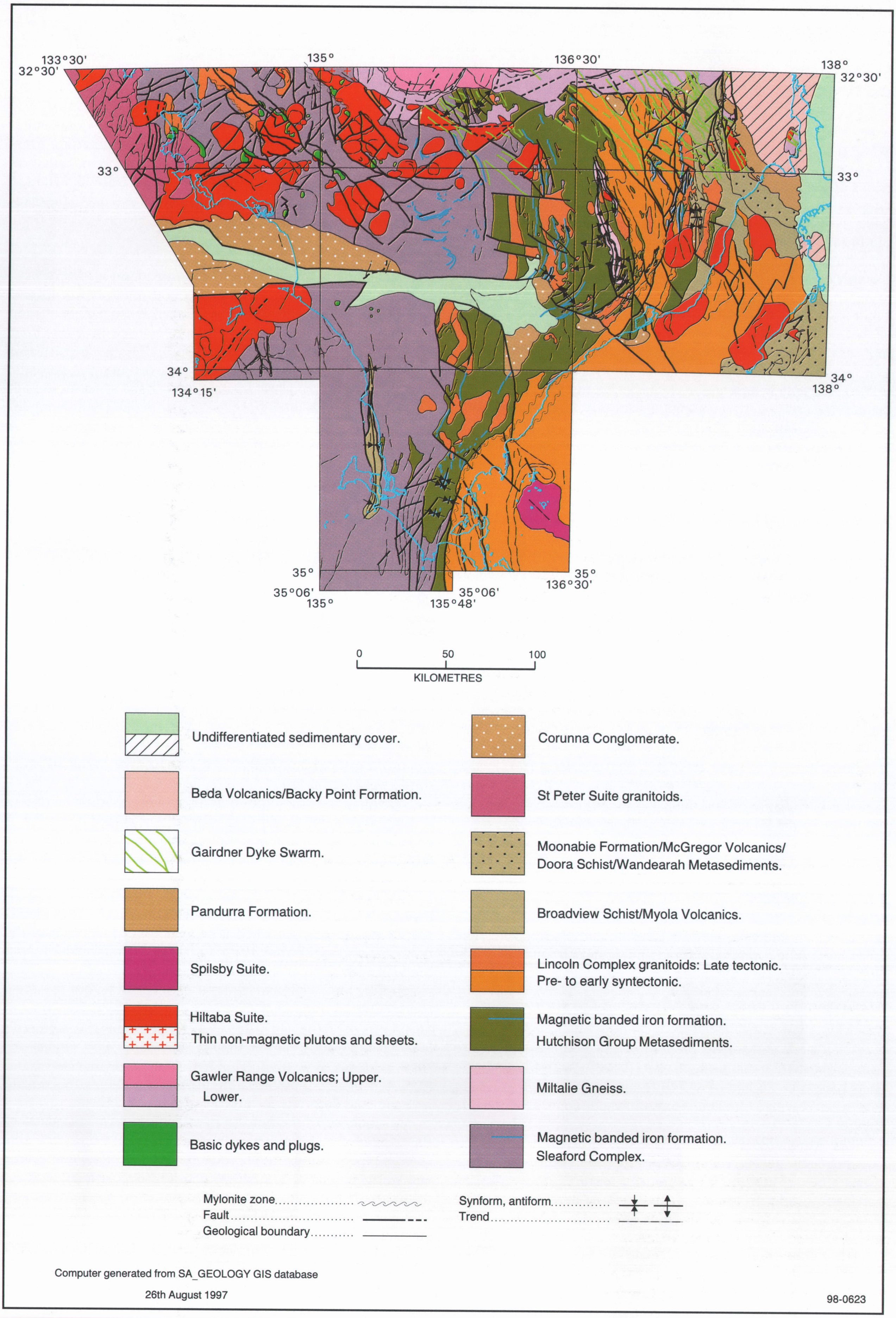


Figure 4. Interpreted subsurface geology of the southern Gawler Craton (after Schwarz 1996).

sulphides, which are disseminated within serpentine-rich marbles, diopside-rich ferroan calc-silicates and graphitic schist throughout east-central Eyre Peninsula (Cowley & Parker 1992). Several small high-grade deposits, produced by recrystallisation and remobilisation during regional metamorphism and plutonism, were mined between 1870 and 1920. For example, Atkinson's silver mine, near Cowell, contained a small high-grade pod of 6–21% Ag, 58% Pb, and 3.4% Cu (Johns 1961).

Cowell Jade deposit. At the base of the Warrow Quartzite near Cleve (Fig. 3), high-quality commercial nephritic jade occurs in ellipsoidal pods and lenses, up to 40 m long and 3 m wide, within metasomatically altered serpentinised dolomitic marble and calcsilicate (Parker & Fanning 1997). Together, these have been intruded by early tectonic granitoids of the Lincoln Complex and overprinted by several phases of retrograde alteration. Over 120 pods have been identified within two main limbs of an isoclinally folded marble unit, giving a total strike length of ~8 km. The nephrite varies from black to pale green in colour and was produced by late-stage addition of silica and loss of $CaCO_3$ (Parker 1981, Flint & Dubowski 1990). Approximately 40% of the jade is dark green to black; the most valued colour for carving and jewellery making. Estimated reserves to a depth of 10 m are ~80 000 t (Barnes et al. 1988). Over 2000 t have been produced since mining began in 1967.

Uley Graphite. Coarse flake graphite occurs adjacent to pegmatitic intrusives in the Middleback Subgroup in southern Eyre Peninsula (Parker 1993b). At Uley, graphite-rich schist hosts an indicated resource of 400 000 t of ore containing 11% fixed carbon. The regional inferred resource is 350–400 Mt containing 6–7% fixed carbon. Graphite in low-grade subeconomic deposits also occurs in the Cowell and Kimba regions (Valentine 1994, Keeling 1996).

Myola Volcanics and Broadview Schist

Scattered outcrops of foliated porphyritic rhyolite and rhyodacite, the Myola Volcanics (Figs 2, 4), occur interbanded with felsic and hornblende-rich gneisses east of the Middleback Range (Parker 1993b). U–Pb zircon geochronology gives an age of 1791±4 Ma (Fanning et al. 1988), significantly younger than the Hutchison Group, but similar to the age for the Tidnamurkuna Volcanics (1780±12 Ma; Fanning 1997) from the Peake and Denison Inliers east of Coober Pedy. Geochemistry for both stratigraphic units shows similar highly evolved chondritic trace element patterns, with an abundance of LREE, which have been interpreted to indicate a relatively shallow crustal source (Parker 1993b).

The Broadview Schist is exposed between the Middleback Range and the Myola Volcanics (Figs 2, 4), but stratigraphic relationships are not observed. Rock types include quartz–muscovite schist, and thin-bedded quartzite and amphibolite. The latter have relict ophitic textures, indicating an igneous origin (Parker 1993b).

McGregor Volcanics and Moonabie Formation

The McGregor Volcanics (Figs 2, 4) crop out on northeastern Eyre Peninsula and consist predominantly of subaerial rhyolite to dacite with minor andesite–basalt (Parker 1993b). Ignimbritic units have a U–Pb age of ~1740 (Fanning et al. 1988) and are interlayered with Moonabie Formation sediments at Moonabie Range.

The Moonabie Formation (Figs 2, 4) contains abundant volcaniclastic debris, ranging from grit to cobble size. Some clasts show evidence of hyalopilitic textures, indicating an epiclastic origin proximal to a volcanic source. The relative abundance of volcanic debris decreases northwards away from the Moonabie Range.

Near Mount Laura, volcaniclastic conglomerate is overlain by lithic sandstone, siltstone, and feldspathic sandstone (Weste 1996). Folding of the Moonabie Formation has been interpreted by Parker (1993) to have occurred during KD_3. The Moonabie Formation near Roopena Homestead is unconformably overlain by laminated dolomitic to micaceous siltstone tentatively assigned to the Wandearah Metasiltstone. The sequence is fault bounded and intruded by rhyolitic 'Angle Dam porphyry', which is commonly fragmental, brecciated, haematised and sericitised. Copper mineralisation in the Moonabie Formation and ?Wandearah Metasiltstone is associated with north–south bounding faults, rhyolitic porphyry and haematitic alteration. Massive sulphides also occur in dolomite (Weste 1996). Siliceous and haematitic alteration in MESA Roopena DDH 6 occurs in brecciated inferred Wandearah Metasiltstone and not in the overlying Corunna Conglomerate.

Wallaroo Group

The Palaeoproterozoic Wallaroo Group (Conor 1995) from northern Yorke Peninsula comprises both metasediments and metavolcanics (Figs. 2, 4). Deposition of these sediments and contemporaneous bimodal volcanism occurred between 1765 and 1735 Ma (Fanning in Conor 1995). The geology of this group has been collated from scattered drilling and sporadic coastal and mine exposure. Metamorphic grade varies from mid-greenschist to mid-amphibolite facies, with variations being locally rapid.

The upper age limit of the Wallaroo Group is provided by the Hiltaba Suite equivalents, i.e. the Tickera Granite and Arthurton Granite, which were intruded during the period ~1600–1575 Ma.

Stratigraphic subdivision of the Wallaroo Group is currently being assessed; therefore, the terms Wandearah Metasiltstone and Doora Schist (Parker 1993), and Wandearah Metasediments and Doora Metasediments (Conor 1995) are expected to be revised (Conor pers. comm.). However, the names of volcanic units (i.e. Moonta Porphyry, Wardang Volcanics, Willamulka Volcanics) are unlikely to change.

Metasediments. The metasediments are uniformly fine grained with only rare instances of units with particle size approaching and including fine sand. Argillites, siltstones, calc-silicates, and rarer carbonates, graphitic sediments and BIFs are known. A common but unusual lithotype is laminated albitite, the origin of which remains the subject of debate. Bedforms are generally planar laminated with only rare signs of traction-induced structures.

Owing to the sparsity of outcrop and the sporadic nature of drilling, field relationships are generally unknown. However, it is plain from the available sampling that, at least in places, certain lithological groups are prevalent: some of these are described below.

The northern part of the area, which was sampled by drilling near Wokurna and Port Pirie, is characterised by finely laminated metasiltsone, described as being dolomitic and haematitic. It was these rocks that Parker (1993b) named Wandearah Metasiltstone (one of the names undergoing revision).

Similar metasediments are present near Bute, but contain a coarser detrital component. They are planar-bedded, fine-grained muscovite-bearing argillites or siltstones, interlayered with locally, thin, fine-grained, quartz sandstone. The sandstones show evidence of younging, but have undergone diagenetic disruption. Locally, there are thin albitite and magnetite-bearing laminae, and dolomite is variably present as cement.

A sequence of medium to fine medium-grained, planar to flaser-bedded metasandstones and interbedded albitic calc-silicates is exposed along the shoreline at Port Victoria, Point Pearce and Wardang Island. The sediments show depositional features in common with the intimately associated felsic Wardang Volcanics (Bone 1984, Huffadine 1993), including locally peperitic textures.

Near Alford, Paskeville, and immediately east of Kadina are sediments that are dominantly chemical in nature (referred to as LX1 in the mapping of Conor 1995). This composite suite, which may be present as one stratum or more, comprises laminated alkali-feldsparites, calc-silicates, albite–graphite–sphalerite rocks and banded albite–magnetite iron formations (taconites); the iron content of the latter varies up to 36.6% Fe_2O_3. These lithologies are associated both with the extensive (several kilometres strike length) copper anomaly at the East Alford Prospect and the zinc (Pb–Cu–Au) mineralisation of the Smithams and Pridhams prospects east of Kadina.

Parker (1993b) named a suite of schistose metasediments in the Kadina township and Wallaroo mines area as the Doora Schist, but, because the metasediments contain similar varieties to those described immediately above, Conor (1995) modified the name to Doora Metasediments; both these names are under review. The lithologies are planar laminated, fine to medium grained with variable composition; however, in general they can be considered as iron-rich calc-silicates (i.e. plagioclase–quartz–amphiboles–biotite–magnetite±pyrite), but include laminated albitites, marbles, pelites, and iron formations. The rocks are commonly sulphide-rich (pyrite, pyrrhotite, chalcopyrite), but because of the prevalence of high strain schist zones it is not known whether the sulphides are syngenetic or epigenetic. These metasediments are interdigitated with felsic volcanics (Moonta Porphyry equivalent) and basic lithologies (possibly Willamulka Volcanics equivalent).

The relationship between the amphibolite-facies (i.e. 'Doora Schist') and the associated greenschist-facies metasediments (e.g. 'Wandearah Metasiltstone') is not seen in outcrop. Owing to the contrasting metamorphic states, Parker (1993b) interpreted the former as predating and constituting the basement to the latter. In contrast, Lynch (1982) and Conor (1995) considered the amphibolite-facies and greenschist-facies rocks to be broadly contemporaneous. In support of the latter interpretation, felsic volcanic units within the 'Doora Schist' have U–Pb zircon ages of 1741±9 and 1737±5 Ma (Parker 1993b); similar volcanic rocks associated with the 'Wandearah Metasiltstone' at Bute have ages of 1750±7 and 1756±14 Ma (Fanning in Conor 1995). Conor (1995) concluded that the abrupt variations between lithological domains were due to faulting, a high degree of strain partitioning, and metasomatism.

Metavolcanics. The rhyolitic to dacitic Moonta Porphyry is host to the copper–gold Moonta mines lodes. It extends from Moonta to Kadina and at both localities is interdigitated with metasediments. The Moonta Porphyry is interpreted to have been deposited either as a series of ignimbrites or subaerial flows with adjacent epiclastic sediments and/or waterlain tuffs (Lemar 1975, Parker 1993b), or in a submarine setting (Conor 1995). Huffadine (1993) suggested a cryptodome origin for the equivalent felsic rocks near Port Victoria, inferring water depths of >3500 m. The Wardang Volcanics from Wardang Island (Bone 1984), Port Victoria, and Point Pearce are also rhyolitic to rhyodacitic with a U–Pb zircon age (~1755 Ma; Fanning in Conor 1995) similar to that of felsic volcanic rocks at Bute, though slightly older than that of the Moonta Porphyry.

Interlayered with metasediments (in Bute DDH 5) are the fine-grained amygdaloidal Willamulka Volcanics, interpreted as either lava flows (Thomson 1973 Parker 1993b) or shallow intrusives. It is possible that these basic rocks are contemporaneous with acid volcanics in the Bute area, where intercalated acid and basic rocks can be seen in drillcore (Conor 1995), and with the Moonta Porphyry. The Bute Metadolerite (formerly Bute Amphibolite—Cowley pers. comm., Conor 1995) possibly represents the subvolcanic component of the Willamulka Volcanics (Parker 1993b). Amphibolites are commonly associated with the felsic volcanics of the Port Victoria district. The presence of bimodal, presumably contemporaneous volcanism, some of which is subaqueous, indicates that the Wallaroo–Moonta Subdomain is prospective for volcanogenic massive sulphide (VMS) deposits. Disseminated chalcopyrite mineralisation in volcanogenic breccias and sediments related to the Moonta Porphyry (e.g. drillhole DDH 151) supports a syngenetic component to the mineralisation.

Tectonic Setting. The prevalence of fine-grained, finely layered to laminated metasediments suggests deposition in either a large rift lake or a restricted marine basin below wave base. The quartz-rich sediments of Kadina and the Port Victoria District are spatially related to felsic volcanics and, thus, may represent locally derived, reworked tuffaceous detritus. Incursion of fine to medium-grained, quartz-sand detritus as discrete layers in parts of the sequence (e.g. at Bute) indicates turbidity current sedimentation from a relatively proximal land mass. There is little evidence of desiccation or evaporite deposition. However, Whitehead (1980) interpreted an evaporitic environment for the banded iron formations. The presence of finely laminated albitites indicates sodium enrichment and so may also support an evaporitic setting. A deeper water hypothesis is supported by the cryptodome interpretation of Huffadine (1993). In contrast Wurst (1994) suggested a Lake Magadi-type environment, where seasonal changes affected sediment input into a highly alkaline rift environment.

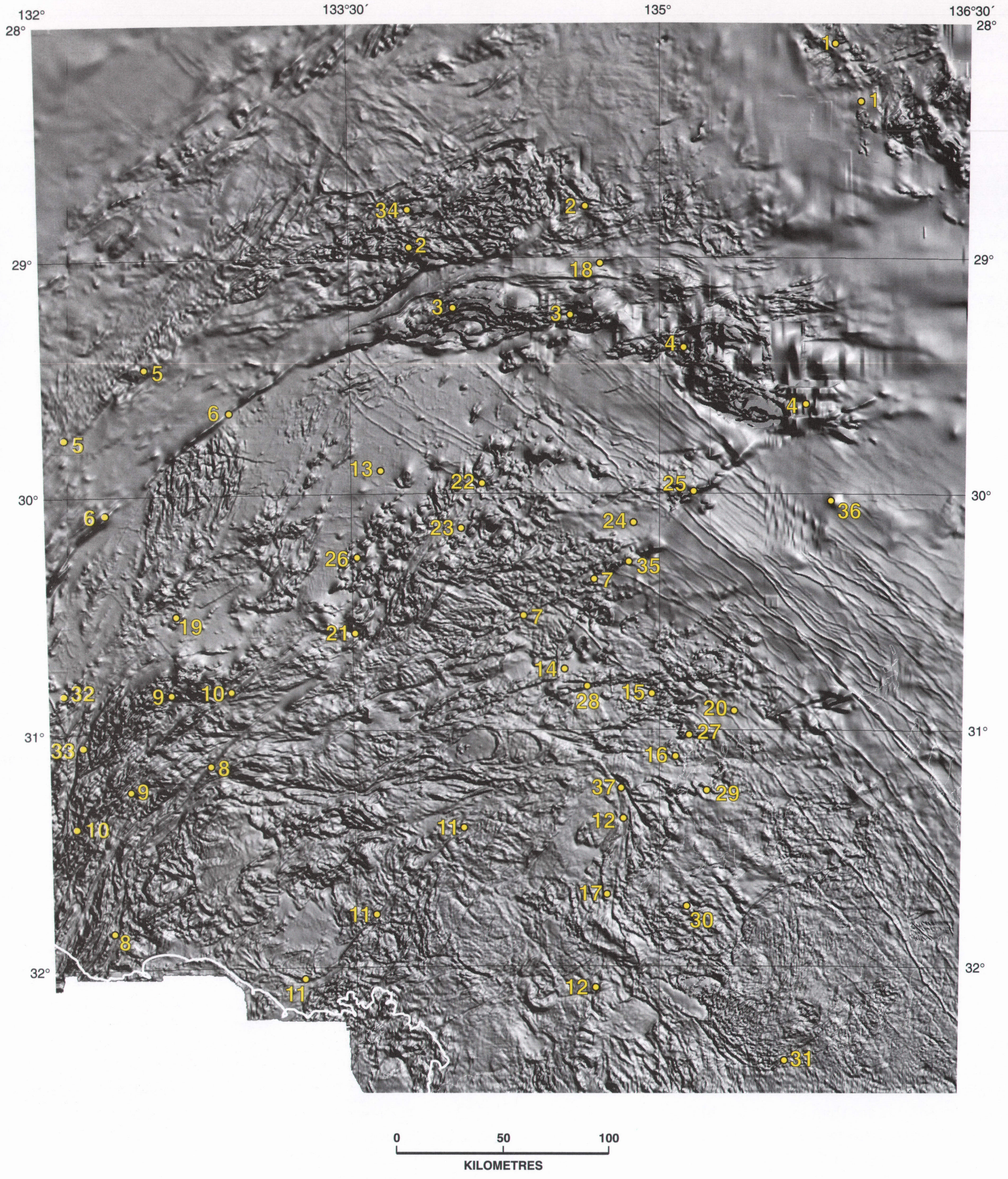
Lithological, intrusive and metasomatic similarities between the Moonta Subdomain and Curnamona Province regions has led Conor (1996) to suggest that the two blocks were once contiguous. Conor (1995) proposed that the Wallaroo–Moonta region records the effects of an easterly migrating thermal event, where felsic igneous rocks young from Eyre Peninsula to Broken Hill. The McGregor Volcanics and Moonabie Formation (1740 Ma), the Moonta Subdomain volcanics and sediments (1765–1735 Ma), and felsic igneous rocks from Olary (~1710 Ma; Conor pers. comm., ~1700 Ma; Cook et al. 1994) and in the Broken Hill district (~1690 Ma; Page & Laing 1992) may represent an eastward migration of underplating, possibly due to a slow-moving mantle plume with associated uplift, extension, accretion of basins, sedimentation, and volcanism. Moreover, Conor (1996) pointed to the important similarity of some depositional ages, intrusive events and alteration style between the Gawler Craton, the Moonta Subdomain, the Curnamona Province and the Cloncurry region of central Queensland.

Wilgena Hill Jaspilite

In the Tarcoola–Kingoonya region, Archaean paragneiss and orthogneiss are overlain by distinctively banded, jaspilitic banded iron formation, known as the Wilgena Hill Jaspilite (Fig. 2, 5). Micro-laminations within each red and black mesoband indicate deposition under very stable conditions (Daly 1980). The iron formation, which is >700 m thick, is interlayered with subordinate carbonate, calc-silicate and quartzite, and is preserved as isolated fault-bound remnants. Wilgena Hill Jaspilite also occurs as fragments in an overlying clastic sequence (Labyrinth Formation) that contains interbedded rhyolite. U–Pb geochronology for the rhyolite indicates a sedimentation age for the Wilgena Hill Jaspilite of greater than 1723±10 Ma (Fanning 1997). The iron formation is mildly to strongly deformed and recrystallised. At Hawks Nest (Fig. 5), high-grade iron ore (Morris et al. 1996) occurs within sheared isoclinal fold hinges adjacent to the Bulgunnia Shear Zone (Fig. 5), with the metamorphic grade varying from greenschist to amphibolite facies.

Peake Metamorphics

Thicker, more persistent, and predominantly higher grade Palaeoproterozoic paragneisses form the Peake and Denison Inliers (Peake Metamorphics), the Mount Woods Inlier, and the Coober Pedy and Mabel Creek gravity and magnetic ridges. They also occur to the west at Ooldea (Figs 1, 5 and 6). The Peake Metamorphics (Ambrose et al. 1981) are a mildly deformed, predominantly quartzite sequence (Baltucoodna Quartzite) with interbedded amygdaloidal basalts and rhyolite (Tidnamurkuna Volcanics), and quartz–chlorite–muscovite schists. A rhyolite within the Tidnamurkuna Volcanics has a SHRIMP U–Pb zircon age of 1780±12 Ma, whereas the



1 Peake and Denison Ranges
2 Mabel Creek Ridge
3 Coober Pedy Ridge
4 Mount Woods Inlier
5 Nawa Ridge
6 Karari Fault Zone
7 Bulgunnia Fault Zone
8 Coorabie Fault Zone
9 Fowler Suture Zone
10 Colona Fault Zone
11 Koonibba Fault Zone
12 Yarlbrinda Shear Zone
13 Challenger prospect
14 Tarcoola Goldfield
15 Earea Dam Goldfield
16 Glenloth Goldfield (Monarch and Mount Mitchell Mines)
17 Myall and Sheoak prospects (Nuckulla Hill Project)
18 Coober Pedy
19 Barton
20 Kingoonya
21 Wynbring
22 Commonwealth Hill HS
23 Mulgathing HS
24 Bulgunnia HS
25 Hawks Nest
26 Mount Christie
27 Lake Harris
28 Talia
29 Kokatha
30 Lake Everard HS
31 Yardea HS
32 Lake Ifould
33 Lake Tallacootra
34 Paragon Bore PB2
35 Bulgunnia 1
36 Devils Playground DP1
37 Tunkillia prospect

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Figure 5. Grey-scale TMI image of the northwestern Gawler Craton.

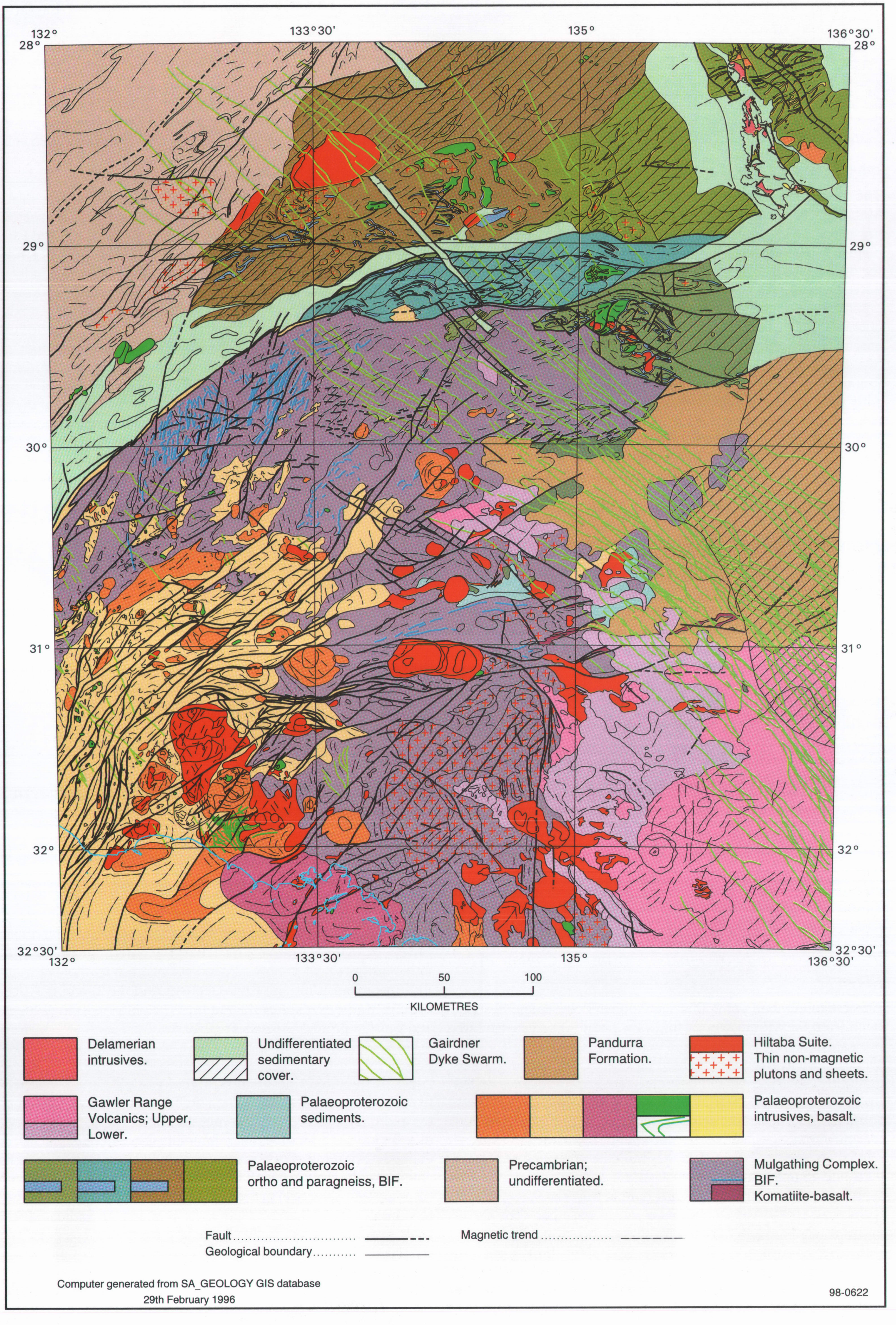

Figure 6. Interpreted subsurface geology of the northwestern Gawler Craton (after Fairclough & Daly 1995 a, b).

syntectonic Wirriecurrie Granite gives 1793±8 Ma (Fanning 1997). These ages are within analytical uncertainty and so place general constraints on the timing of sedimentation and magmatism in the Peake and Denison Inlier. Interpretation of aeromagnetic data (Fig. 5) indicates that the Peake Metamorphics and the Mabel Creek Ridge to the west are less deformed than the Coober Pedy Ridge and Mount Woods Inlier to the south.

Paragneisses from the Mabel Creek Ridge

The Peake Metamorphics and iron-rich paragneisses on the Mabel Creek Ridge appear to onlap from the east onto a rigid, presumed Archaean basement (Fairclough & Daly 1995a). Aeromagnetic data are interpreted to show a characteristic thin-skin tectonic pattern for the central and eastern Mabel Creek Ridge. Metasediments in AMOCO/BHP Paragon Bore PB2 include amphibolite to granulite-facies banded iron formation, pyritic cherts with garnet±pyroxene±graphite, olivine-bearing carbonates and quartz–feldspar–garnet–sillimanite gneiss (Purvis 1982, Mason 1990). From Nd isotopic compositions (Fanning 1997) it is inferred that the sediments have an Archaean source, possibly foliated granite and tonalites from the southern Nawa Ridge (Figs 5, 6) further to the west. A quartz–plagioclase–garnet–biotite–sillimanite paragneiss from Paragon Bore PB2 has a U–Pb SHRIMP age of ~1550 Ma, interpreted as recording the timing of high-grade metamorphism (Fanning 1997). The Mabel Creek Ridge is separated from the Coober Pedy Ridge and Mount Woods Inlier by the Karari Fault Zone.

Mount Woods Inlier

From limited outcrop and diamond-drill core, the Mount Woods Inlier can be seen to comprise fine-grained finely layered quartz–magnetite–feldspar–clinopyroxene–orthopyroxene–apatite banded iron formation, quartz–feldspar–garnet–cordierite–sillimanite gneiss, and clinopyroxene and hornblende-bearing calc-silicates, indicating brief burial at granulite-facies conditions (Flint & Benbow 1977). Aeromagnetic data for the Mount Woods Inlier (and the Coober Pedy Ridge) show ductile metamorphic layering (Fig. 5), and it is inferred that the underlying Archaean crust has been reworked during this Proterozoic event. Conventional multi-grain U–Pb analyses of metamorphic zircons give an age for this high-grade event of 1742±27 Ma (Fanning et al. 1988), more recently refined by SHRIMP at 1736±14 Ma (Fanning 1997). The intrusive weakly deformed Engenina Granite has a SHRIMP U–Pb zircon age of 1691±25 Ma (Fanning 1997). The Balta Granite, an undeformed Hiltaba Suite equivalent has an age of 1584±18 Ma and is associated with anomalous copper–gold mineralisation and haematitic alteration in the fractured granulite-facies metasediments.

Paragneisses and orthogneisses from the Coober Pedy Ridge

Aeromagnetic data show that the Coober Pedy Ridge is separated from the Mount Woods Inlier by a major northeast-trending fault, which is associated with the Karari Fault Zone. Metasediments from the Coober Pedy Ridge are coarse-grained granulites. Quartz–magnetite–spinel–feldspar–pyroxene banded iron formations are interlayered with quartz–feldspar–garnet–cordierite gneiss, quartz–feldspar–orthopyroxene–garnet granulite and pyroxene–plagioclase–hornblende calc-silicates (Mason 1995). These mineral assemblages indicate pressures of at least 9 kb and temperatures of 900°C. Rare sapphirine–quartz assemblages (Mason 1995) indicate temperatures of 950–1000°C (Ellis et al. 1980). The Coober Pedy Ridge was, therefore, metamorphosed at a deeper crustal level than the Mount Woods Inlier and Mabel Creek Ridge. SHRIMP U–Pb zircon geochronology has been undertaken for BHP drillholes CR 9119 and CR 9125 in the centre of the Coober Pedy Ridge (Fanning 1997). CR 9119 intersected meta-granodiorite or tonalite and CR 9125 intersected cordierite–garnet–biotite–sillimanite paragneiss containing zircons with relict cores of ~1750 Ma, whilst the metamorphic rims have an age of 1565±8 Ma. It may be inferred from these data that the paragneisses forming the Coober Pedy Ridge were derived from the neighbouring Mount Woods Inlier and deformed under high-grade granulite-facies conditions at 1565±8 Ma. This ~1565 Ma high-grade event is not recorded at Mount Woods (see later discussion on the Fowler Orogenic Belt).

Moondrah Gneiss (Ooldea region)

Magnetite-rich aluminous metasediments have been intersected in MESA DDH Ooldea 2, Amoco ORP 1 (Miller 1981) and Elf-Aquitaine–MESA Lake Maurice East 1 SMD 5002 (Fig. 1). For these metamorphic rocks, we propose the name Moondrah Gneiss. Mineral assemblages that include hypersthene–sillimanite and sapphirine–quartz (Daly 1987) indicate very high-grade metamorphic conditions of 8–10 kb and 950–1000°C. Exsolution of haematite–magnetite symplectites in garnet is interpreted to indicate initial reduction in peak P/T conditions and may indicate by their preservation that initial exhumation was rapid, possibly at greater than 700°C. Further study of these complex aluminous, magnesium-rich metapelites has been undertaken by Teasdale (1997). SHRIMP U–Pb analyses of zircon record an age of 1653±8 Ma for the high-grade metamorphic event (Fanning 1997), with inherited components at ~1700 Ma. Aeromagnetic data show that the iron-rich metasediments trend east–west and are truncated to the south-east by the Karari Fault Zone.

In summary, it can be seen that the metasediments in the Ooldea region and those forming the Coober Pedy Ridge have undergone high-grade metamorphism at ~1650 and ~1565 Ma, respectively. Those within the Mount Woods Inlier underwent high-grade metamorphism at ~1740 Ma. The high-grade events at Ooldea and Mount Woods produced ductile metamorphic layering that is oblique to the Karari Fault. However, the ductile layering within the Coober Pedy Ridge is essentially concordant with the fabric of the Karari Fault Zone and, thus, the ~1565 Ma age for metamorphic zircon constrains the latest high-grade event (Kararan Orogeny) associated with movement along this major structure.

Economic geology of the Palaeoproterozoic, northern Gawler Craton

Iron ore. Regional aeromagnetic data for the Coober Pedy and Mabel Creek Ridges, the Mount Woods Inlier, and Hawks Nest area near Bulgunnia Homestead show persistent iron-rich sedimentary facies within Palaeoproterozoic metasediments. Potential iron ore resources are enhanced with increasing metamorphic grade, recrystallisation adjacent to major shear zones, and proximity to Mesoproterozoic Hiltaba Suite granite and Palaeoproterozoic gabbro. Prospects nearest to the Permian Phillipson and Wintinna Coal Deposits and the Tarcoola Alice Springs Railway were evaluated for the South Australian Steel and Energy Project (Morris et al. 1996).

The Hawks Nest prospect (Fig. 5), southeast of Coober Pedy, occurs within finely laminated Wilgena Hill Jaspilite. Narrow zones of fractured fine-grained, higher grade Fe are developed in subvertical shear zones, which are inferred to be axial planar to isoclinal folds. Preliminary investigations of the central zone of a 20 km long aeromagnetic anomaly have delineated more than 600 Mt of low-grade magnetite-banded iron formation ore, which may be readily beneficiated to a high-grade product (Morris et al. 1996). Kestrel is the largest prospect with an indicated resource of 260 Mt at 36.4% Fe. At Buzzard, an indicated resource of 5 Mt at 60.2% Fe of massive haematite has been established. In addition, high-grade magnetite zones of unknown extent have been intersected at the Kestrel and Kite deposits. These contain up to 69% Fe and are suitable as direct-feed magnetite ore. Further, a low-grade magnetite-banded iron formation with an inferred resource of 240 Mt at 36.5% Fe has been outlined at Giffen Well, southwest of Hawks Nest (Morris et al. 1996).

The Mount Woods Inlier, 50 km north of the Hawks Nest prospect, hosts a large number of untested iron-rich bodies. The Peculiar Knob prospect is an elongate subvertical zone of medium to coarse-grained, consistently high-grade haematite (averaging 63.2% Fe), which represents Palaeoproterozoic banded iron formation recrystallised and remobilised by adjacent Balta Granite. The prospect has a Mesozoic sedimentary cover of 20–40 m and an inferred resource of 14 Mt to 100 m depth (Morris et al. 1996).

Eba Formation

Excellent outcrop of Eba Formation (formerly assigned to the Tarcoola Formation) occurs at Wallabyng Range and Mount Eba near Kingoonya (Cowley & Martin 1991). The basal 500 m at Wallabyng Range is a distinctive, clean, thick-bedded, white quartzite with abundant granules and pebbles of white quartz and reddish Wilgena Hill Jaspilite. The overlying 500 m of quartzite is less well sorted, with bed thickness of 0.2–1 m, relict trough cross-bedding, and thin, local, pebble conglomerate beds. Detrital fuchsite is moderately abundant, probably derived from nearby Archaean greenstones. Bedding is frequently obscured by silicification. The upper part of the sequence at Mount Eba comprises 220 m of micaceous siltstone, shale, variably haematitic cross-bedded sandstone, and overlying quartzite, equated with that at Wallabyng Range. Amygdaloidal basalt is inferred to be interbedded with these sediments.

Deposition occurred in a high to moderate-energy fluvial or shallow marine environment with an abundant influx of quartz. Outcrop appears to be restricted to the Kingoonya region (Fig. 5, 6), although some isolated outcrops in the Tarcoola area may be correlatives. The sequence at Mount Eba has been partly repeated by low-angle reverse faulting and is unconformably overlain by the Labyrinth Formation (Fig. 2).

Labyrinth Formation

The Labyrinth Formation (Cowley & Martin 1991) comprises basal finely laminated chert (after carbonate) with well-preserved, gently domed and laterally linked stromatolites, overlain by cross-bedded pebbly sandstone to boulder conglomerate. Clasts include jaspilite, Eba Formation and cherty carbonate in a quartz, sericite, chlorite, clay and rock fragment matrix. Poor strike continuity and poor sorting indicate rapid deposition from local sources. The basin was probably fault controlled, shallow and limited in size.

Sericitic sandstones show well-developed planar or crenulated cleavages. A thin interbedded rhyolite has a SHRIMP U–Pb zircon age of 1723±10 Ma (Fanning 1997), considerably older than the earlier reported conventional multi-grain U–Pb zircon age of 1640–1600 (Fanning 1987). These alluvial lithic sandstones can no longer be regarded as contemporaneous with the Gawler Range Volcanics, despite lithological similarity to sandstones interlayered with Ealbara Rhyolite near Bulgunnia Homestead (Daly & Cowley 1993). The regional distribution of these older volcanics and interbedded sediments is at present unknown.

Kimban Orogeny, syn-Kimban intrusives (Lincoln Complex) and development of major shear zones

The Kimban Orogeny is defined from the Cowell–Cleve area in eastern Eyre Peninsula (Parker 1993b) and consists of three tectonic events. The earliest (KD_1 1845–1795 Ma) produced layer-parallel schistosity, now only preserved in hinge zones of KD_2 folds. The second (KD_2 1795–1745 Ma) produced tight to isoclinal folds with axial planar schistosity where P–T conditions varied from 5–7 kb and 600–675°C in central Eyre Peninsula and 7–9 kb and 800–850°C in southern Eyre Peninsula (Bradley 1980, Parker, et al. 1988). The third phase (KD_3, 1745–~1700 Ma) produced upright, open to tight regional folds with variable plunges and major mylonite zones. Peak P–T conditions in central Eyre Peninsula were 1.5–2 kb and 150°C less than for KD_2 indicating uplift before and during KD_3 (Parker 1993b).

A range of syntectonic intrusives accompanies each event and so enables age constraints to be determined. The oldest intrusives affected by KD_1 are the Donington Granitoid Suite on southern Eyre Peninsula (Parker 1993b). Mortimer et al. (1988) proposed that the parent magma was mantle derived and emplaced at 845°C and >8 kb. The quartz gabbro–norite at Cape Donington was interpreted as a cumulate, while alkali-feldspar granites (Cape Tournefort to Pt Neill) probably represent a residual fraction, following separation of the Memory Cove Charnockite (Cape Catastrophe to Cape Donington). An emplacement age of 1849.8±1.1 Ma has been obtained for the gabbro–norite (Fanning & Mortimer in press). The Donington Granitoid Suite contains abundant dolerite and amphibolite dykes of the Tournefort Dyke Swarm (Parker et al. 1987). These are interpreted as having been derived from a depleted mantle source with evidence of crustal contamination (Mortimer et al. 1988). Near the Kalinjala Mylonite Zone the Donington Granitoid Suite becomes increasingly deformed, with the development of retrograde amphibole and garnet in mafic rocks and coarse augen K-feldspar in granites.

On the Cape Donington Peninsula at Cape Colbert, a grey hornblende granite (Colbert Suite) contains xenoliths of foliated granite, inferred to be Donington Granitoid Suite. The Colbert Suite is considered to be post KD_1 and was probably deformed by KD_2 (Mortimer 1984, Parker 1993b). Rb–Sr total rock analyses for the Colbert Suite give an isochron age of 1757±14 Ma (Mortimer et al. 1986), which has been used to help constrain the KD_2–KD_3 interval (Parker 1993b). However, more recent SHRIMP U–Pb zircon analyses of the Colbert Suite record a magmatic age of 1846±14 Ma (Fanning & Mortimer in press), essentially within uncertainty of that for the gabbro–norite. The Colbert and Donington Granitoid Suites were emplaced in a short time interval and, therefore, the early deformations of the Kimban Orogeny in southern Eyre Peninsula are equally closely spaced in time.

The older phases of the Minbrie Gneiss in northern Eyre Peninsula (from Elbow Hill to Lake Gilles) are considered to be time equivalents of the Donington Granitoid Suite (Parker 1993b). The garnetiferous banded meta-tonalite to adamellite contains rafts of Hutchison Group metasediments showing KD_1 deformation. Younger gneissic granite phases of the Minbrie Gneiss contain rafts showing KD_2 and KD_3 deformation. The Middle Camp Granite in the vicinity of Cowell and Cleve (Parker 1978) also contains rafts of Hutchison Group metasediments. It is a foliated adamellite to granodiorite with the foliation deformed by KD_3 indicating emplacement during KD_2.

Granites contemporaneous with KD_3 are broadly grouped under the Moody Suite (Parker et al. 1988). Components of this suite have in general only been mildly deformed. Plutons are discrete with distinctive mineralogy and textures, and range from felsic to hornblende-rich, granite to granodiorite. The Moody Suite granitoids have U–Pb zircon ages of ~1700 Ma (Fanning 1997).

The Kimban Orogeny has also affected Archaean and Palaeoproterozoic rocks in the central and northern parts of the Gawler Craton. There is no clearly defined 'Kimban Orogen' as proposed by Myers et al. (1996). Palaeoproterozoic sediments in the Mount Woods Inlier have undergone granulite-facies metamorphism at 1736±14 Ma (Fanning 1997), whereas Archaean prograde granulite facies mineral assemblages west of Mulgathing Homestead and near Earea Dam Goldfield were recrystallised under amphibolite-facies conditions (Whitehead 1980, Daly & Fanning 1993). Rb–Sr geochronology of phlogopite from MESA DDH Skuse 2 (3 km southeast of Mount Christie) indicates a minimum age for inferred Kimban recrystallisation in this area of 1650±10 Ma (Fanning 1997). U–Pb geochronology gives ages of 1690±10 Ma for the Symons Granite near Mulgathing Homestead and 1691±25 Ma for the Engenina Adamellite near Mount Woods. Both intrusions are interpreted to be contemporaneous with the Kimban Orogeny (Fanning 1997).

Major shear zones have developed throughout the craton during the Proterozoic (Fig. 1). These include the Kalinjala Mylonite Zone, the Karari, Coorabie, Colona, Bulgunnia and Koonibba Fault Zones, and the Yarlbrinda Shear Zone. The age of the Kalinjala Mylonite Zone is considered by Parker (1993b) as syn KD_3 and is best constrained by a discordant, undeformed pegmatite at Port Neill, which has a Rb–Sr total-rock–mica age of 1710 Ma (Fanning 1984). Radiometric ages and deformational histories of other shear zones are currently poorly known, though geochronological studies are underway.

Recent studies of drillcore together with U–Pb geochronology for the northwestern Gawler Craton (as summarised herein) have established that this region underwent high-grade granulite-facies deformation after the Kimban Orogeny (as defined in Eyre Peninsula). Terranes affected include Ooldea (1653±8 Ma), Coober Pedy Ridge (1565±8 Ma), Mabel Creek Ridge (~1550 Ma), and meta-gabbro to diorite in the Fowler Orogenic Belt northwest of Ceduna (1543±9 Ma, see *Development of the Fowler Orogenic Belt*). These U–Pb zircon ages record the time of new growth during high-grade metamorphism and postdate KD_3 defined by Parker for the eastern Gawler Craton (1745–~1700 Ma). Whether these terranes were affected by the Kimban Orogeny, then overprinted by the Kararan and intervening high-grade events is uncertain. Considerably more geochronology (in association with detailed structural studies) is necessary in order to define the extent of the Kimban Orogeny in the north and western Gawler Craton.

Tarcoola Formation

This fluvial to marine sequence was deposited on deformed Archaean and Palaeoproterozoic basement within an elongate east–west-trending graben or half graben (Figs 2, 5, 6). The southern margin of the basin is a fault parallel to regional isoclinal axial plane orientations (SF_3) within adjacent Archaean Mulgathing Complex.

The basal Peela Conglomerate Member is a pebbly to conglomeratic arkosic quartzite interbedded with and overlain by chloritic, lithic sandstone and conglomerate. Clasts include Wilgena Hill Jaspilite, Archaean orthogneiss, Eba Formation quartzite, and rhyolite to basalt. The conglomerate contains feldspathic crystal fragments and basalt bombs (Daly 1993a) and is overlain by stromatolitic dolomite, micaceous sandstone and clean white quartzites of the Fabian Quartzite Member. Finely laminated carbonaceous Sullivan Shale Member, with distinctive graded bedding and altered dacitic to andesitic water-laid tuffs, overlies and intertongues with the Fabian Quartzite Member. Altered basaltic sills (possibly sub-sea floor) occur within the quartzites (Daly 1984).

The Tarcoola Formation is >2000 m thick and was deposited in alluvial fans adjacent to active faults, which were likely conduits for contemporaneous volcanism. Water depth and basin size increased up sequence with deposition of fluvial to shallow marine well-sorted quartzose sands succeeded by anoxic carbonaceous shales deposited below wave base. Slumping within these shales may indicate periodic seismic activity during volcanism. U–Pb zircon geochronology for altered water-laid tuffs gives an age of 1656±7 Ma (Fanning 1990).

Although the Tarcoola Formation sequence is lithologically and structurally similar to the Macarthur Basin and is prospective for base metals, very little exploration has been undertaken. Anomalous copper, lead and zinc occur within carbonate-cemented, carbonaceous shale and altered tuffs (Daly 1984).

The Tarcoola Formation was folded (post Kimban Orogeny) about predominantly east–west-trending upright axes (parallel to faulted southern margin), with axial plane cleavage well developed locally. Cross-cutting northerly trending gold-bearing quartz veins were emplaced in conjugate fractures related to displacement along a northeast-trending Palaeoproterozoic fault in underlying Archaean basement (shown well in detailed aeromagnetic data). Contacts between sediments and intrusive mineralising Hiltaba Suite granite are poorly exposed and locally sheared. Small-scale decollemont structures are associated with reverse faults (approximately parallel to bedding) that postdate mineralisation. Undated porphyritic volcanic dykes correlated with the Gawler Range Volcanics intrude sediments and granite. The dykes contain up to 4 ppm Au and rare fragments of gold-bearing vein quartz.

Mesoproterozoic

Gawler Range Volcanics

The Gawler Range Volcanics (GRV) and comagmatic Hiltaba Suite (Blissett et al. 1993) crop out extensively in the central Gawler Craton (Figs 1, 6). This huge volcanic province has a scattered regional extent within longitude 134–138° and latitude 30–34°. More than 25 000 km^2 of GRV outcrop is preserved despite extensive erosion contemporaneous with deposition (predominantly to the northeast) of fluvial Pandurra Formation (1400 Ma), Neoproterozoic glaciation, Permian glaciation, and widespread Mesozoic fluvial and marine sedimentation. GRV also underlie Neoproterozoic sediments of the Stuart Shelf and are correlated with volcanics of similar age and composition in the Mount Painter Inlier and Curnamona Craton. Outcrops are aligned in a broad northwest–southeast zone (Blissett 1987), reflecting orientation of syn-Kimban basement faults. These faults are the dominant structural controls of extrusion, and may be highly prospective for Olympic Dam-style mineralisation (e.g. the Bulgunnia Fault Zone).

The volcanics (Fig. 2) have been subdivided into two broad groups. Detailed stratigraphy is described by Blissett et al. (1993). The lower GRV are more varied in composition and more widespread, reflecting restricted eruptions from many vents. All sequences are composite, predominantly ignimbritic dacite–rhyodacite–rhyolite with minor breccias and lava flows. At Talia, Kokatha, Childera (Fig. 5), near Olympic Dam (Haynes et al. 1995) and Roopena (Fig. 3), thick sequences of basaltic lavas are interlayered with felsic ignimbrites. The lower GRV have moderate to vertical dips (Turner 1975, Daly 1981,1985), reflecting basement tilting, presumably in response to extrusion of large volumes of magma. Thin contemporaneous sediments occur near Bulgunnia (Fig. 5) and Roopena Homestead (Daly & Cowley 1993).

The overlying upper GRV are thick, composite, porphyritic, ignimbritic, rhyodacite and dacite sheets, which are flat lying to gently dipping. The most voluminous, the Yardea Dacite, has an estimated exposure of 12 000 km^2 and total erupted volume of 3000 km^3, one of the largest felsic eruptive units known. The dacite unit was erupted at 950–1000°C (Creaser & White 1991) and is now densely welded, with characteristic cooling columns.

Geochemistry of felsic GRV shows very similar chondritic trace-element patterns for both the upper and lower stratigraphic units (Flint in Blissett et al. 1993). Similarly, U–Pb zircon geochronology gave respective ages of 1591±3 and 1592±3 Ma (Fanning et al. 1988), indicating that the structural break between lower and upper GRV was short and geochemically unimportant.

Vent characteristics for these magmas are poorly known. Branch (1978) proposed a caldera for the Kokatha area, but field evidence for a resurgent margin or ring fracture is not convincing. Giles (1980 1988) suggested a linear fissure for the Arburee Rhyolite and Wheepool Rhyolite near Lake Everard. Recently, A.F. Crooks (MESA, pers comm. 1995) has found evidence for a probable vent in the Yardea Dacite near Yardea

Homestead (Figs 3, 4). Blocks (<10 m) of fine-grained volcanics with larger quartz xenocrysts, coarse-grained hybrid granite showing partial remelting and resorption textures, and one of quartz–feldspar gneiss (with new K-feldspar growing across fabric) are supported by a matrix of fine-grained dacite (Crooks 1996). These textures indicate residence in a magma chamber for some time. This zone of fragmental rocks occurs in the centre and near the southern margin of a saucer-shaped structure at least 50 km across and is delineated by recent SAEI aeromagnetic data (Fig. 5). Limited outcrop of fragmental dacite is surrounded by alluvial plains, which may mask possible altered vent breccia.

The huge volume of Mesoproterozoic (~1600 Ma) melt is considered to have been produced by extensive underplating of continental Archaean and Palaeoproterozoic crust (Giles 1980 1988). Mantle-derived mafic material was intruded into the crust, causing further partial melting and weakening. Increasing volumes of mafic material produced more melt, followed by amalgamations of magma chambers, culminating in individual eruptions of up to 300 km^3 for the Yardea Dacite alone. Total extrusion volume (assuming an average thickness of 200 m and 80% welding) may have exceeded 6000 km^3.

Mantle diapirism may have been caused by an extensive stationary continental plate preventing conductive cooling of the mantle (Flint 1993a). It is probable that this plate included the Mawson Continent (consisting of the Gawler Craton and the East Antarctic Shield, Fanning et al. 1996) and the proto-Yilgarn Craton before extrusion of the GRV (see later discussion on the collision zone in the northern Gawler Craton).

Hiltaba Suite

Hiltaba Suite outcrops are most abundant on the western and southwestern margins of the GRV (Figs 1, 4, 6, Flint 1993a). Limited drilling data suggest that Hiltaba Suite plutons are also abundant on the northeastern margins of the GRV, and overlain by ~1400 Ma Pandurra Formation and Adelaidean sediments. Field relations show that Hiltaba Suite granite intrudes the 1592±3 Ma Yardea Dacite, the youngest and most widespread GRV stratigraphic unit (Blissett 1977).

The Hiltaba Suite varies widely in texture and aeromagnetic signature, depending on the level of crustal emplacement, degree of fractionation, and oxidation state. The suite is typically K-feldspar dominant with a distinctive pink-reddish colour, owing to disseminated iron oxides in K-feldspar and plagioclase. At Olympic Dam the Hiltaba Suite is a quartz syenite to quartz-poor granite (Reeve et al. 1990). Hornblende-bearing monzodiorite and quartz monzonite have also been described by Creaser (1989) from drillholes in the vicinity of Olympic Dam and Andamooka.

Felsic plutons contain 70–75% SiO_2, whereas the more mafic phases have ~60%. Although each Hiltaba Suite pluton has discrete geochemical characteristics (Flint 1993b), chondritic trace-element patterns show that they are broadly similar to the GRV. Creaser (1989) suggested that mafic and felsic plutons in the Olympic Dam area represent the cumulate and fractionated portions of a magma of intermediate composition (~66% SiO_2). It is possible that the Hiltaba Suite crystallised from the huge volumes of magma emplaced at high crustal levels during and immediately after extrusion of the Yardea Dacite (68% SiO_2).

Most Hiltaba Suite granites have U–Pb zircon ages of 1600–1585 Ma (Flint 1993a). At Olympic Dam, the Roxby Downs Granite, a pluton within the Burgoyne Batholith (Reeve et al. 1990) and host to the Olympic Dam copper–uranium–gold orebody, has an age of 1588±4 Ma (Creaser & Cooper 1993). Ore was precipitated in an active hydrothermal system penecontemporaneously with emplacement of high-level extrusives and intrusives. U–Pb ages of these rocks are indistinguishable from GRV elsewhere and from the host Roxby Downs Granite (Johnson & Cross 1991).

In the Moonta region the Arthurton and Tickera granites are broadly similar in age to other Hiltaba Suite plutons. However, in detail they record a range of U–Pb zircon ages (Fanning 1997) The Arthurton Granite is an A-type pluton, ranging in composition from granite through adamellite to quartz-monzonite (Wurst 1994); this granite has returned a U–Pb zircon age of 1583±7 Ma (Creaser & Cooper 1993). It is generally non foliated.

The nearby Tickera Granite is a composite body, including granite, I-type leuco-monzonite and S-type 'leuco-tonalite' (Wurst 1994). A 'leuco-tonalite' from the Tickera Granite has a U–Pb zircon age of 1598±7 Ma, whereas a foliated quartz-monzonite gave 1575±7 Ma (Fanning in Conor 1995). The Tickera Granite is generally deformed, locally with partitioning of strain being extreme; foliated or lineated fabrics vary from incipient to mylonitic to rodded gneissic. Both the Arthurton and Tickera granites show local endoskarn-like alteration to calc-silicate, alkali-feldspar and magnetite metasomatites.

Mineral deposits associated with Hiltaba Suite and Gawler Range Volcanics

Olympic Dam deposit. The Olympic Dam deposit, wholly owned and operated by Western Mining Corporation, has total proved and probable ore reserves of 569 Mt of 2.0% Cu, 0.6 kg/t U_3O_8, 4.9 g/t Ag and 0.7 g/t Au within total inferred and indicated resources of 1620 Mt of 1.1% Cu, 0.4 kg/t U_3O_8, 2.4 g/t Ag and 0.4 g/t Au (Danti 1996). Approximately 83 000 t Cu, 1650 t U_3O_8, 11 865 kg Ag and 1030 kg Au were produced in 1995–96 from ~3 Mt of ore. Environmental assessments and approval processes are in place for a possible increase up to 150 000 tpa Cu (and associated products) in accordance with the existing EIS. Detailed descriptions of the deposit may be found in Roberts & Hudson (1983), Reeve et al. (1990), Oreskes & Einaudi (1990, 1992), Cross et al. (1993), and Haynes et al. (1995).

The orebody is wholly contained within the Olympic Dam Breccia Complex, a zoned breccia derived from, and hosted by, Roxby Downs Granite (Reeve et al. 1990). The breccia body is broadly funnel shaped and elongated in a northwesterly direction. The central core of barren haematite–quartz breccia is intruded by diatremes and dykes and surrounded by mineralised haematite-rich breccias. The outer zone consists of variably brecciated, variably altered Roxby Downs Granite. The central core and mineralised breccias are ~3 km by 3.5 km (in plan) with a northwesterly arm 3 km long and 300–500 m wide. Individual breccia bodies in the northern and northwestern parts of the breccia complex (where more information is available) also trend northwest and dip steeply, reflecting larger scale contemporaneous strike-slip faulting (Sugden & Cross 1991).

Breccia types range from wholly granite-rich to haematite-rich and are very complex due to polycylic brecciation and alteration by hot, iron-bearing fluid. Ore is richest in heterolithic haematite breccias, which contain a wide variety of haematitic clasts with different textures and grain sizes, indicative of many phases of brecciation and alteration. Copper grades are typically 1–5% and gold 0.3–1 g/t, although zones of gold enrichment occur locally. Uranium (pitchblende) is usually associated with copper mineralisation. Throughout the deposit, ore is broadly zoned in an irregular funnel-shaped distribution, which dips more steeply towards the central barren core. A relatively sharp interface exists between bornite±chalcocite and chalcopyrite±pyrite mineralisation. This interface is believed to reflect contact between upwelling hot, reduced iron-rich fluid and colder oxygenated water (Reeve et al. 1990, Haynes et al. 1995). Flame-like irregularities in this surface extend vertically up to 100 m above the underlying chalcopyrite±pyrite mineralisation.

The Olympic Dam deposit formed in an active hydrothermal system with contemporaneous magmatism and seismic activity. Persistent phreatomagmatic venting accompanied by brecciation produced a composite nested crater in which phreatic and volcanic debris was deposited. The floor periodically collapsed, presumably during phreatic and/or phreatomagmatic activity, so that discrete blocks of finely laminated crater sediments and ash were incorporated in breccias (Reeve et al. 1990). Ore-fluid modelling suggests that economic ore is unlikely to have formed without an abundant source of cooler oxygenated surface water (Haynes et al. 1995). The deposit was later eroded and covered by more than 300 m of flat-lying Neoproterozoic and Cambrian sediments.

Acropolis and Wirrda Well prospects. The Acropolis and Wirrda Well prospects (Paterson 1986b, Cross 1993) are 20 km southwest of the Olympic Dam deposit in altered brecciated basement, respectively, under 480 and 330 m of flat-lying barren sedimentary rocks. Mineralisation (Fe–Cu–U–Au) at Acropolis occurs in magnetite±haematite-rich vein networks and alteration zones in GRV dacite. The volcanics overlie laminated siltstone, foliated syn-Kimban granite and diorite. These rocks are also variably to intensively altered to haematite± magnetite±sericite±chlorite associations. At Wirrda Well, haematitic breccias occur within Hiltaba Suite granite (Burgoyne Batholith). In contrast with Olympic Dam breccias, Wirrda breccias also contain fragments of deformed granite and metasediments. Mineral assemblages from Acropolis were deposited under higher temperatures and more reduced conditions than at Wirrda Well. Similarly, mineral assemblages at Wirrda Well record higher temperatures and more reduced conditions than those at Olympic Dam (Oreskes & Einaudi 1992, Haynes et al. 1995).

Tarcoola goldfield. Over 2000 kg of gold (at an average grade of 37.5 g/t) has been produced from the Tarcoola goldfield since 1893 (Fig. 5; Daly et al. 1990). Most was won from crosscutting subvertical quartz veins and preferentially altered adjacent carbonaceous siltstone, but some also occurred in adjacent altered granite. BHP drilling of the Perseverance prospect, near the Tarcoola Blocks mine, intersected altered gold-bearing granite and sediment (silica, sericite, haematite and chlorite alteration). U–Pb zircon geochronology of nearby unaltered fresh granite gives an age of 1575±7 Ma (Fanning 1997) slightly younger than other Hiltaba Suite granites. Lead isotope signatures for pyrite, galena and gold from vein quartz are indistinguishable from feldspars in the granite (Fanning 1988), indicating that the granite is the most likely source of the gold or, alternatively, that the Au-bearing fluids equilibrated with the granite. Hein et al. (1994), however, inferred that the Tarcoola Formation may have been the source of gold and base metals.

Exploration by BHP and, later, by Grenfell Resources has established a measured resource of 620 000 t containing 3 g/t Au for the Perseverance prospect, and an indicated and inferred resource of 220 000 t of 1.6 g/t for the Last Resource and 25 000 t of 3.5 g/t for the Wondergraph prospect.

Diamond drilling in 1996 to test deeper portions of the Perseverance shear zone intersected high-grade gold (predominantly in granite), including 7 m at 31.7 g/t from 196 m (GP002D) and 6 m at 16.2 g/t Au from 154 m (GP005D) (Isles 1996, Isles et al. 1996). Further drilling in the northern end of the Perseverance prospect intersected shallow mineralisation within granite, including 2 m of 40.8 g/t Au from 92 m and 18 m of 3.7 g/t Au from 106 m (GP068R), 12 m of 6.0 g/t Au from 72 m (GP060R) and 2 m of 45.2 g/t from 58 m (GP059R) (Limb 1997). Base-metal mineralisation is also associated with gold mineralisation. The highest values were intersected in drillhole GP002D. Metal values from 200–202 m include 76.1 g/t Au, 112 g/t Ag, 0.19% Cu, 6.9% Pb and 8.8% Zn. Gold mineralisation has been established for the Perseverance shear over a strike length of at least 400 m with depths in excess of 200 m (Isles et al. 1996).

Earea Dam goldfield. Gold-bearing vein quartz occurs on a small scale within sheared Archaean Kenella Gneiss at Earea Dam (Fig. 5) (Daly 1993b). Vein quartz also crosscuts inferred syn-Kimban (~1700 Ma) northeast-trending dolerite and gabbro dykes. Gold ore contains silver and locally abundant cassiterite. Total gold production, predominantly from the Wilgena Enterprise and Perseverance mines during 1899–1903 and 1933–1941, was 59.2 kg from 1869.6 t of ore (35.3 g/t Au) (Fradd 1988). Recent exploration has located an additional mineralised zone (Circosta & Gum 1988). Hiltaba Suite granite is an inferred source of the gold and tin, and a granite batholith immediately south of the goldfield can be interpreted from aeromagnetic data.

Glenloth goldfield. Sheared and fractured Archaean to Palaeoproterozoic Glenloth Granite (Figs 5, 6) hosts composite auriferous quartz veins up to 1 m wide. Gold also occurs at the Monarch mine, in a microfractured Palaeoproterozoic syn-Kimban dolerite dyke, inferred to be a barrier to gold-bearing solutions. Cassiterite has been mined at nearby Mount Mitchell. The gold and tin-bearing quartz veins are believed to be derived from a shallow Hiltaba Suite batholith (Blissett 1985). Total recorded production is 315.4 kg Au from 14 620 t of ore at an average of 21.6 g/t Au.

Meninnie Dam, Telephone Dam and nearby prospects. These base-metal prospects occur within Middleback Subgroup carbonates, 50 km north of Kimba, immediately south of extensive Mesoproterozoic GRV outcrop (Figs 3, 4). Mineralisation was first discovered in 1981 and the prospects are currently being explored by a joint venture project of Billiton Australia Ltd and Aberfoyle Resources Ltd.

At Meninnie Dam, steeply dipping metasediments have been affected by the Kimban Orogeny (KD_2 and KD_3 folding) and are intruded and altered by porphyritic rhyolite dykes. Roache & Fanning (1994) have interpreted these dykes to be feeders to very thin, lithic-rich volcaniclastic breccia, extrusive rhyolite, and rhyolitic ignimbrite, all of which unconformably overlie the metasediments.

Lead–zinc–silver mineralisation is hosted by interlayered diopside–calcite–talc–epidote–garnet calc-silicate, serpentinitic marble, graphitic and ankeritic dolomitic marble, and carbonate-facies banded iron formation. The steeply dipping mineralisation is broadly concordant with enclosing metasediments, although it is discordant on a smaller scale. Sulphides have replaced carbonates and calc-silicates, producing irregular and diffuse boundaries between mineralised and non-mineralised zones. The movement of fluid fronts through host carbonates has formed delicately banded sulphides. Massive sulphide horizons include pyrite, sphalerite, and galena with subordinate chalcopyrite and pyrrhotite. Typical grades over 0.5 m intervals from DDH MD 6 range from 5.8% Pb, 14% Zn, 60 g/t Ag and 0.45 g/t Au to 25.4% Pb, 7% Zn and 178 g/t Ag (Higgins et al. 1990).

Early company reports considered the ore to have formed by recrystallisation and fluid mobilisation of primary sulphides during Kimban deformation and metamorphism (Beeson 1990). However, the recognition of post-Kimban metamorphic ore textures, ore fragments in overlying volcaniclastic breccia, and alteration of carbonate clasts by sulphide mineralisation, both in the volcaniclastic breccia and in breccias surrounding intrusive rhyolite dykes, all indicate contemporaneity with rhyolite emplacement. SHRIMP U–Pb zircon dating of an intrusive rhyolite gave an age of 1591±15 Ma, which is indistinguishable from the age of the GRV (Roache & Fanning 1994).

Wallaroo–Moonta copper–gold field. The Wallaroo–Moonta region produced more than 355 000 t of copper metal and 2 t of gold between 1860–1923 and 1986–1994 and remains highly prospective for copper and gold.

Several authors, from Lockhart Jack (1917) to the present (e.g. Both et al. 1993), have suggested that the Tickera and Arthurton Granites were to a greater or lesser degree related to the development of the Moonta district copper–gold lodes. Field evidence suggests that these Hiltaba Suite-equivalent granites were responsible for widespread 'skarn-like' metasomatic alteration, characterised by assemblages variously dominated by alkali feldspar, magnetite (haematite), carbonate, and calc-silicate; rocks derived by this process are assigned to the Oorlano Metasomatites (Conor, 1995). The mineralisation associated with this skarn-like alteration includes copper, gold, zinc, molybdenum with lesser lead and uranium. Granite emplacement and alteration were at least partly syntectonic, with the latter preferentially developed along metamorphic foliae, shear zones, fractures and within implosion breccia bodies. This type of alteration is identical to that of the Cloncurry District, Queensland.

During 'Hiltaba times' the Wallaroo Group was considered by Conor (1995) to have undergone northwest–southeast shortening with development of northeast-trending folds with long limbs and steep axial planes. Strain was heterogeneous, locally polyphase, and partitioning caused the development of shear zones. There is evidence in places (e.g. Wallaroo mines) to show that deformation focused fluid flow, which in turn exacerbated strain and localised both alteration and mineralisation. The Wallaroo mines copper–gold lodes (chalcopyrite, pyrite, pyrrhotite) were developed in Wallaroo Group metasediments in shear-induced schist zones, which show evidence of high temperature syntectonic potassium–iron (biotite, amphibole, magnetite) metasomatism. The host of the Moonta mines copper–gold lodes (chalcopyrite, bornite, pyrite) is the earlier Palaeo-proterozoic Moonta Porphyry. The lodes are fracture controlled, but the fractures show distinct parallelism with the fabric of the highly foliated containing zones. The Moonta mines' lode structures strike northerly and northeasterly and dip westerly; updip thrust displacement is from the northwest.

Whilst the spatial and temporal association of mineralisation and the Hiltaba Suite in the Moonta district is real, the metal source is as yet unknown. The sourcing of metals from either the Wallaroo Group or the Hiltaba Suite or a combination of both is possible. On the one hand, Hiltaba Suite mineralisation is best developed where no Palaeoproterozoic sediments are known (e.g. Olympic Dam). On the other hand, disseminated chalcopyrite mineralisation in volcanogenic breccias and sediments related to the Moonta Porphyry (e.g. drillhole DDH 151) supports a syngenetic component to the mineralisation. Moreover, the presence of Palaeoproterozoic bimodal, presumably contemporaneous, volcanism, some of which is subaqueous, indicates that the Wallaroo–Moonta Subdomain is prospective for volcanogenic massive sulphide (VMS) deposits.

As previously mentioned, extensive copper (+gold) and zinc (+lead) anomalies are related to chemical metasediments (i.e. LX1—alkali feldsparites, calc-silicates, albite–graphite metasiltstone, banded albite–magnetite iron formations) at prospects such as East Alford, Pridhams, and Smithams. Copper and zinc mineralised intersections, whilst low grade (e.g. ~0.25%), are extensive in places.

A wide zone characterised by late-stage, low-temperature, siderite-bearing, kaolinite-dominated alteration parallels the southern margin of the Tickera Granite. Locally, the zone is mineralised by large masses of disseminated chalcocite-coated pyrite, giving intersections of 100 m or more at ~0.25–1.0% Cu.

The most significant prospects are as follows:

- Alford (Cu, Au, Mo): a small shallow supergene copper deposit estimated at 60 000 t grading 2% Cu. Deeper drilling has returned promising intersections, e.g. 5 m at 2.78% Cu and 3.17 g/t Au in calc-silicate metasomatite.
- A broad zone of later stage argillic (kaolinite) alteration is superimposed upon the calc-silicate skarns. Locally chalcocite-coated, disseminated pyrite forms extensive low-grade (~0.25% Cu) copper-mineralised zones.
- Pridhams (Cu, Au) ('East Kadina'): extensive low-grade copper mineralisation has been intersected in 'skarn' metasomatised Wandearah Metasediments associated with felsic volcanics, e.g. 73.1 m at 0.24% Cu and 213 m at 0.36% Cu plus anomalous gold.
- Smithams (Cu, Pb, Zn)('East Kadina'): sphalerite occurs as disseminations and veinlets in graphitic meta-albitites and siltstone. Many intersections exceed 30 m at 0.25% Zn, e.g. 101 m at 0.46% Zn.
- West Doora (Cu, Au): five drillholes have intersections exceeding 150 m at >0.3% Cu in the vicinity of the old Wallaroo mines in shear zones within the Doora Metasediments. An inferred resource of 2.7 Mt at 2.1% Cu has been defined to a depth of 300 m.
- East Alford (Cu, Au). Auger drilling of weathered bedrock has outlined a 10 km by 1 km north–south zone characterised by >200 ppm Cu. Deeper diamond and percussion/RC drilling has shown the underlying lithologies to be laminated albitites, calc-silicates, graphitic metasediments, and an amphibolite sill, lithologies which are not dissimilar to the more highly deformed sequence at the Wallaroo mines.

Yarlbrinda Shear Zone hosted prospects

Tunkillia prospect. In February 1996, calcrete sampling was begun by Helix Resources NL on the northern end of the Yarlbrinda Shear Zone (Figs 5, 6). Systematic sampling highlighted fourteen gold anomalies, ranging from 5 ppb up to 230 ppb against a background of 1–3 ppb. The largest gold anomaly in calcreted sandy soils was an elongate zone of 25 km^2 that corresponded with the distinctive northwest-trending bend on the northern end of the Yarlbrinda Shear Zone. At this locality, the north–south-trending shear zone is gradually reorientated into another major east–west-trending shear zone (as yet unnamed). Martin (1996) has interpreted the northwest-trending portion of the fault zone as a thrust (northeast over southwest).

The most significant mineralisation intersected to date occurs along the margins of the Yarlbrinda Shear Zone. Highly silicified mylonitic rocks that occur on the southwestern and northeastern margins of the shear zone appear to have acted as boundaries along which gold-bearing hydrothermal fluids passed. These pathways are seen on aeromagnetic images as elongate demagnetised zones. Detailed aeromagnetic data for the exploration licence shows that the internal fabric of the shear zone has been overprinted, indicating that the alteration system is probably late syn-tectonic to post tectonic (Martin 1996).

Drilling throughout 1996 and early 1997 delineated gold anomalism (greater than 0.2 g/t, up to 3.2 g/t) for the 6.5 km strike of the demagnetised zone drilled to date. Gold occurs in a series of narrow (presumed steeply dipping) high-grade zones with assays of 5.4–25.5 g/t Au over intervals of 1–14 m (Helix 1996, Mosig 1997). Area 223 (with a strike length of 500 m) is the richest intersected to date, with a gold mineralised zone 10–120 m wide with broad intervals averaging 0.6–4.8 g/t Au. The mineralisation includes a high-grade zone 10–25 m wide with individual 4 m drill intercepts of up to 32.4 g/t Au. The high-grade zone occurs on the western side of a steeply dipping mafic dyke, which may have acted as an impermeable barrier. The strike length and depth of the high-grade zone is still to be fully tested.

Basement beneath 40–60 m of thin younger sediments and saprolite is undeformed to highly sheared and variably altered granite. Alteration and veining include haematite±silica±sericite ±chlorite±pyrite. Base metals (copper, lead and zinc) generally total <0.1%. Silver accompanies gold with a silver:gold ratio of approximately 4:1 (Mosig 1997).

Nuckulla Hill project—Myall, Sheoak, and Bimba prospects. In January 1996, Equinox Resources N.L., in joint venture with Phelps Dodge Australasia Inc., announced the discovery of anomalous gold in altered and sheared felsic gneiss near Nuckulla Hill, on the western margin of the Gawler Ranges (Williams 1995). The Mines and Energy South Australia Exploration Initiative 1993 aeromagnetic data for the western Gawler Ranges had delineated a major north–south shear zone over 130 km long in inferred Archaean basement, intruded by multiphase Hiltaba Suite granites (Figs 5, 6). Field mapping of the shear zone near Nuckulla Hill located outcrop of highly deformed and foliated granite and volcanic dykes. Further south there is evidence of undeformed Hiltaba Suite (Koondulka batholith) crosscutting mylonitic fabrics, indicating that granite emplacement and deformation were broadly concurrent (Parker 1996). At Yarlbrinda Hill, haematitic, brecciated, mylonitic K-feldspar-dominant granite may also be interpreted as deformed Hiltaba Suite granite.

Calcrete soil geochemistry over the Yarlbrinda Shear Zone detected anomalous gold. RAB, RC and diamond drilling results from the Myall prospect include 11 m of 0.5 g/t Au from 49 m (NHAC 8) (Willliams 1995). Host rocks are fractured and brecciated granite to syenogranite with epidote±quartz ±prehnite± chlorite, sericite and chlorite±leucoxene alteration. The brecciated granitoids are interleaved with feldspathic metamorphosed rocks with 5 mm thick sericitic lenses after sillimanite, interpreted as deformed granite and volcanics (Parker 1996).

Initial air-core drilling results for the Sheoak prospect, 3 km to the south, show 7 m at 3.1 g/t from 52 m, including 3 m at 6.2 g/t from 56 m (NHAC 26), and 16 m at 1.3 g/t from surface (NHAC 27). Later drilling intersections include 22 m from 113 m of 1.1 g/t (NHRC-1) and 8 m of 0.4 g/t Au from 125 m and 1 m of 78.1 g/t Ag from 147 m (NHDDH-1). Diamond drilling (NHDDH-1) intersected altered and brecciated quartz diorite to adamellite and mylonitic gneiss and schist, including a 5.2 m zone with 2–5% sulphide (pyrite with minor galena±sphalerite± chalcopyrite). The presence of fibrolitic sillimanite suggests amphibolite facies metamorphism before alteration. Post peak metamorphic sericitisation and quartz veining were followed by calc-silicate±epidote veining±chlorite±adularia±quartz±fluorite or calcite (Parker 1996).

Air-core drilling of the Bimba prospect, 10 km north of the Sheoak prospect, intersected 3 m of 1.67 g/t from 36 m (NHAC 150) and 5 m of 1.71 g/t Au from 44 m (NHAC 152). The holes were drilled to base of weathering (Williams 1996). Other prospects (to be tested further in 1997) in the Yarlbrinda Shear Zone include Parakylia, 5 km south of the Sheoak prospect, and nearby Printie and Gecko prospects.

Sediments associated with Gawler Range Volcanics

Corunna Conglomerate. The Corunna Conglomerate (Fig. 2) is best exposed in the Corunna Range, north of Iron Knob (Fig. 4). The gently folded sequence (Lemon 1972, Lemon & Gostin 1983) consists of fluvial conglomerate, containing clasts of local basement and undeformed volcanics, and quartz sandstone overlain by possible marine sandstone and finely bedded carbonaceous shale. Rarely, thin acid volcanic interbeds are also present. Rhyodacite intrudes conglomerate in MESA Corunna DDH CC1 and is interpreted by Blissett (DME, pers. comm. 1978) as a feeder to the Nonning Rhyodacite (upper GRV).

Near Roopena Homestead, diamond drillholes intersected volcaniclastic sandstone, carbonaceous and glauconitic siltstone, and thin conglomerate, interlayered with vesicular basalt (Roopena Volcanics) and rhyolitic subaerial tuff with well-preserved glass shards (Daly & Cowley 1993). U–Pb zircon geochronology of acid tuff in MESA Roopena DDH 6 gave an age of 1587±15 Ma (Johnson 1991), indicating contemporaneity with the GRV. The sedimentary sequence at Roopena has been tentatively correlated with the Corunna Conglomerate in the Corunna Range.

The Roopena Volcanics, interbedded sediments, and the underlying Moonabie Formation and ?Wandearah Metasediments are variably mineralised, particularly near to the Roopena Fault and parallel north–south-trending faults (David 1985, PNC Exploration (Aust.) Pty Ltd 1988, Weste 1996). Anomalous copper and lead occur in acid volcanics, sediments, and basalt. Felsic volcanics contain detectable gold (David 1985). The extensive and long-lived fracture systems have considerable mineral potential.

Mentor Formation. The Mentor Formation (new name; these rock units were formerly assigned to the Labyrinth Formation (Cowley & Martin 1991), which is now seen to be an older sequence) sediments are by definition contemporaneous with GRV. Drillholes near Bulgunnia Homestead (Fig. 5) intersected chloritic and sericitic mudstone containing small angular lithic fragments of K-feldspar, acid volcanics, chert, and BIF, and larger fragments of vesicular basalt and tuffaceous and porphyritic rhyolite–rhyodacite. Many of the larger volcanic fragments have altered rims, suggesting either they were still hot when deposited in shallow water or possibly affected by later low-temperature alteration. Other sediments are unaltered (cold) volcanic debris, possibly derived from nearby unwelded tuff. In MESA Bulgunnia 1 (Daly 1988), chloritic mudstone, tuffaceous sediment, and granitic breccia are interlayered with and altered by tuffaceous rhyolite. The granitic breccia layers are veined by iron oxide and contain anomalous barium. Bulgunnia 1 is adjacent to the Bulgunnia Shear Zone (Fig. 5), which was the most likely focus for volcanism, and has considerable potential for Olympic Dam-style mineralisation. The presence of near-surface cold water to act as an oxygenated precipitating fluid may be crucial.

Development of the Fowler Orogenic Belt

Southeast of the Karari Fault Zone, aeromagnetic data show clearly that vertical north-trending (SF_3) axial planes within Archaean Mulgathing Complex gneisses have been rotated dextrally into partial parallelism with the fault zone (Fig. 5). In central Barton 1:250 000 map area, Archaean gneiss has been intruded by irregularly shaped zones of Proterozoic granite to diorite (Morris et al. 1994), which, from aeromagnetic data, also have foliations parallel to the northeast-trending Karari Fault Zone.

Within southern Barton (Rankin et al. 1996) and Fowler 1:250 000 map areas, the Mulgathing Complex has been extensively affected by voluminous dense and magnetic Palaeoproterozoic intrusives. The intense, magnetically high domains are separated by complex anastomosing shear zones, which comprise the Fowler Orogenic Belt (formerly the Fowler Suture Zone of Daly & Rankin 1993, Daly et al. 1995). This orogenic belt is also broadly parallel to the Karari Shear Zone to the north and is considered genetically related (Fig. 1).

Prominent east–west-trending shear zones within Archaean Mulgathing Complex to the east are rotated into the Fowler Orogenic Belt, indicating progressive sinistral strike-slip movement. The shear zones are most likely Archaean to Palaeoproterozoic magnetic domain boundaries reactivated during development of the Fowler Orogenic Belt.

The magnetic domains within the Fowler Orogenic Belt consist of meta-igneous calc-alkaline cumulus gabbro–diorite and tonalite (Daly et al. 1994). Much less evolved, primitive gabbro (Poseidon 1992) and altered chromite-bearing olivine-rich ultramafic rocks (Morris et al. 1994) have also been intersected in drill core. Interpretation of aeromagnetic data would indicate that the polyphase, variably deformed intrusives were likely to have been syndeformational with the Fowler Orogenic Belt. Sillimanite–garnet–feldspar–quartz gneiss and banded iron formation intersected in diamond-drill core (Afmeco 1982) near Lake Tallacootra, in the southeastern part of the shear zone, have concordant regional aeromagnetic fabrics. The extent of these Proterozoic sediments and their relationship with the mafic and ultramafic rocks is uncertain. The mafic bodies may have been seafloor sills intruded into the original Proterozoic basin.

SHRIMP U–Pb zircon geochronology of mildly deformed coarse-grained cumulus gabbro in MESA DDH Colona 43 gives an emplacement age of 1730±10 Ma (Fanning 1997), whereas small zircons grown during high-grade metamorphism of a gabbro or basalt in MESA DDH Nundroo 2 have a U–Pb age of 1543±9 Ma (Fanning 1997). This is in contrast to the interpretation in Daly & Fanning (1993). From these data it can be concluded that the Fowler Orogenic Belt developed between 1730 and 1540 Ma, though it is possible that some shearing may be even younger.

Southeast of the Fowler Orogenic Belt are voluminous, undeformed to mildly deformed acid and basic multiphase plutons intruding much less deformed crust, as delineated from aeromagnetic data. Some of these plutons may be correlatives of the mildly deformed granite–diorite St Peter Suite, which has a U–Pb zircon age of ~1630 Ma (Flint et al. 1990). Others are totally structureless, indicating no deformation, and may possibly correlate with the ~1585 Ma Hiltaba Suite and/or the 1510±12 Ma Spilsby Suite (Fanning 1997). These bodies have stoped into the crust, exploiting pre-existing major fractures (Fairclough & Daly 1995b), and represent prime copper–gold exploration targets.

Evidence for a possible collision zone in the northern Gawler Craton

Although aeromagnetic images of the Fowler Orogenic Belt and Karari Fault Zone show indications of predominantly strike-slip movements, this is not consistent with outcrop-scale observations. Stretching lineations at Ifould Lake, Lake Tallacootra and in the Coorabie Fault Zone southeast of Wynbring generally pitch more than 60–70° to the north within subvertical foliation planes. Similarly, lineations measured in MESA DDH Ooldea 3, intersecting the Karari Fault Zone south of Ooldea, plunge steeply (Rankin et al. 1989). Rare S–C fabrics (cf. Lister & Snoke 1984) in outcrop are consistent with an east-block-upward dip-slip movement component. Such observations indicate that sinistral strike-slip movement is locally and spatially only a minor component of the deformation, and that to achieve the 50–100 km lateral displacement apparent in aeromagnetic images, an extreme degree of associated oblique-slip movement is required within the Fowler Orogenic Belt.

A similar contradiction between geophysical and geological evidence has been described by Bleeker (1990a, b) for the Thompson Nickel Belt, Manitoba. Detailed structural analysis in that region has revealed that transpressional deformation, with strain partitioning partly or wholly into broad dip-slip and intense narrow strike-slip domains (Jones & Tanner 1995), can account for the apparent discrepancy. Imaged aeromagnetic data for the Fowler Orogenic Belt show many geometric similarities to the Thompson region. It is suggested that transpressional deformation can also account for regional structural features apparent in the Fowler Orogenic Belt, with broad basement zones deformed by dip-slip strain accounting for most of the rare outcrop, separated by volumetrically minor (non-outcropping) zones of concentrated strike-slip deformation. Given the longevity and size of the zone, partitioning may have occurred temporally (Kirkwood 1995) as well as spatially. Individual strike-slip zones exhibit extensional duplexing, owing to the gross regional 'releasing bend' geometry (Woodcock & Fischer 1986).

We propose that the Fowler Orogenic Belt reflects the effects of an oblique Palaeoproterozoic collision zone between two Archaean–Palaeoproterozoic microplates, one being the Mawson Continent, comprising the Gawler Craton and parts of the East Antarctic Shield, the other the proto-Yilgarn Craton. Associated with this collision were the development of a duplex-style shear system, syn-orogenic intrusions, and intrusion of late-stage zoned plutons during a period of subsequent relaxation (Daly et al. 1995).

The Karari Fault Zone is one surface that may have been the leading edge of the overriding plate, forming the very high-grade rocks at Ooldea and along the Coober Pedy Ridge during collision. Immediately following the peak high-grade ~1650 Ma event (at Ooldea), crustal relaxation was initiated and this is reflected by extensive igneous intrusions at ~1630 Ma, recorded well by the intense gravity low southeast of the Fowler Orogenic Belt. Another possible leading edge in this continental collision lies at the northwestern margin of the Gawler Craton.

Thompson Nickel Belt analogues. Recognition of these younger tectonic events and the associated acid and basic intrusions in the western Gawler Craton is crucial for exploration. The mafic and ultramafic intrusions which exploited the weakened crust during the continental plate collision and development of the Fowler Orogenic Belt have potential for Proterozoic nickel deposits. The region has many structural similarities to the Thompson Nickel Belt, Manitoba, where pelitic schists and pyritic banded iron formation host primitive mafic and ultramafic seafloor shallow intrusives, locally containing rich poddy nickel sulphide deposits, in a complex collisional zone between two continental plates (Bleeker 1990 a, b, Cranstone 1996).

Shear-hosted copper–gold. Hiltaba Suite granites and comagmatic GRV in the central Gawler Craton locally contain anomalous gold, uranium, and copper. Adjacent to younger mobile belts in the western and northern Gawler Craton, for example near the Fowler Orogenic Belt and within the Mount Woods Inlier, these granitic rocks have intruded very fractured Archaean or Palaeoproterozoic gneissic basement, which had significant permeability. Prospectivity around these variably magnetic plutons within fractured and altered crust is high. In the mobile belts, Hiltaba Suite plutons also have the potential to host structurally controlled gold and copper–gold mineralisation. Any associated mineralisation may also be deformed. For example, in the Coober Pedy Ridge and the Fowler Orogenic Belt, if deformation is consistent across each domain, magnetic alteration haloes and associated mineralisation will appear as ductile layering.

The Kimban and Kararan Orogenies in summary

Prograde Proterozoic deformation ages for the Peake and Denison Inliers are 1793±8 Ma (excluded from the Gawler Craton sensu stricto because of overprinting by the Delamerian Orogeny ~580 Ma), the Mount Woods Inlier 1736±14 Ma, the Coober Pedy Ridge 1565±8 Ma, the Mabel Creek Ridge ~1550 Ma, Ooldea 1653±8 Ma, and the Fowler Orogenic Belt 1730±10–1543±9 Ma. Each subdomain has had a different tectonic history to that of its neighbour and, with the exception of Mount Woods and the Peake and Denison Inliers, has a metamorphic age significantly younger than for deformed rocks in the central and eastern Gawler Craton.

The Kimban Orogeny described by Parker (1993a) in the eastern Gawler Craton comprises KD_1 1845–1795 Ma, KD_2 1795–1745 Ma, and KD_3 1745–~1700 Ma. In the northwestern Gawler Craton there are several younger high-grade granulite facies events, one at ~1650 Ma (Ooldea) and another at ~1565–1540 Ma (Mabel Creek, Coober Pedy, Nundroo). Neither of these can be directly related to the Kimban Orogeny. Similarly, use of the term Lincoln Complex (by definition associated with the Kimban Orogeny) may not apply to many foliated granitoids in the western Gawler Craton. It is proposed here to introduce the term Kararan Orogeny to include the 1650 Ma and 1565–1540 Ma events and the proposed continental collision, and the term Ifould Complex for deformed multiphase plutons intruded during this orogeny (~1650–1540 Ma).

Summary

The Gawler Craton has considerable economic mineral potential. Systematic exploration is only now being undertaken in the Archaean Mulgathing Complex, even though Archaean supracrustal rocks were recognised in that region over 20 years ago. The large number of calcrete-hosted gold anomalies overlying weathered Archaean basement indicates the potential for many other significant prospects. The discovery of the Challenger gold prospect has also encouraged exploration of traditional structural traps within little explored Archaean BIF, greenstones, and possible acid volcanics.

Recent U–Pb geochronology indicates deformation and metamorphism (1650–1540 Ma) contemporaneous with the emplacement of voluminous hot metal-bearing GRV and Hiltaba Suite. This new understanding has significant implications for exploration. The economic potential of these younger tectonically active subdomains is largely untested. Emplacement of metal-bearing fluids at ~1590 Ma within deforming crust rich in iron and carbonate has produced extensive copper–gold mineral-isation in the Moonta–Wallaroo area. Similarly, copper–gold mineralisation has been found in altered Palaeoproterozoic BIF and calc-silicates in the deformed northern margin of the Mount Woods Inlier and within the Coober Pedy and Mabel Creek Ridges.

Mafic and ultramafic bodies also occur within these mobile belts. The most primitive are in the Fowler Orogenic Belt, where the crust was thinnest, and along the southeastern margin of the same zone in fractured Archaean and Palaeoproterozoic meta-igneous basement. These bodies have significant potential for nickel and chromium deposits.

Acknowledgments

This paper attempts to summarise the geology of the Gawler Craton as currently known. Much will be superseded in the next few years as the results of high levels of exploration activity become available. The authors gratefully acknowledge the many geologists who have painstakingly acquired the vast body of geological knowledge for the Gawler Craton. Special thanks go to our colleagues (or ex colleagues) in Mines and Energy, South Australia for this reason and to referees Ken Cross (Western Mining Corporation) and John Parker (Geosurveys Australia) both of whom made considerable contributions to this paper.

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