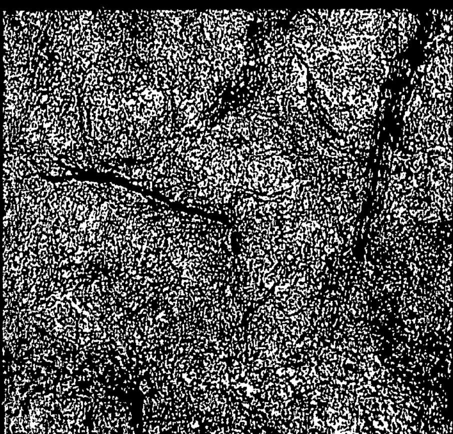
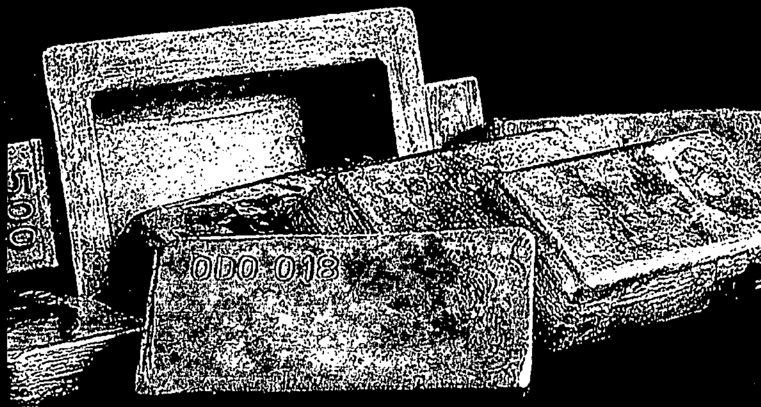
COPPER and GOLD in SOUTH AUSTRALIA





MINES and ENERGY
SOUTH AUSTRALIA

Report Book 95/41

DEPARTMENT OF MINES AND ENERGY

GEOLOGICAL SURVEY

SOUTH AUSTRALIA

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COMMODITY REVIEW
COPPER AND GOLD IN SOUTH AUSTRALIA

by

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DEPARTMENT OF MINES AND ENERGY
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Commodity Review Copper and Gold in South Australia

R S ROBERTSON

The giant Olympic Dam deposit has a total resource of about 2 200 million tonnes grading 1.4% Cu, 0.5 kg/t U_3O_8, 0.5 g/t Au and 3.1 g/t Ag. Development of Olympic Dam, with current annual production of 67 000 t of copper and further expansion planned, again makes South Australia a major copper producer as in the late nineteenth century. Other important producing mines have included Kapunda, Burra, Wallaroo, Moonta, Kanmantoo and Mt Gunson. Olympic Dam is associated with Proterozoic Hiltaba Suite granite and Gawler Range Volcanics. These units are widespread on the Gawler Craton and potential for further discoveries is high. Proterozoic rocks of the Gawler Craton and Curnamona Province are also prospective for Cu-Au type mineralisation as found in the eastern Mt Isa Block, Qld, and in Tennant Creek, N.T. Adelaidean and Cambrian rocks of the Adelaide Geosyncline and Stuart Shelf host numerous, widespread copper occurrences and there is good potential for discovery of further stratiform or structurally controlled deposits. There is also potential for development of low cost, heap leaching operations. The state has many gold workings, particularly in the Adelaide Geosyncline and Tarcoola regions, but total production has been small. However Olympic Dam is a major gold resource and the potential for discovery of further Proterozoic gold-copper and gold-only deposits is considerable. Archaean terranes of the northwest Gawler Craton have recently been shown to include mafic-ultramafic suites enhancing similarities to gold bearing Archaean greenstone belts elsewhere. Across much of South Australia extensive soil and sediment cover blanketing basement rocks has hampered exploration. Airborne geophysics and drilling undertaken as part of the South Australian Exploration Initiative and Broken Hill Exploration Initiative have highlighted the prospectivity of many areas and will be a key factor in future exploration.

INTRODUCTION

Copper mining has played a key role in the development of South Australia since European settlement in 1836. The discovery of rich copper deposits at Kapunda (1842), Burra (1845), Wallaroo (1859) and Moonta (1861) led to the development of vital wealth sources in the early history of the State. The Moonta and Wallaroo mines, which operated until 1923, were major operations even by today's standards. In this era, hundreds of small, often rich, near surface secondary accumulations were discovered in areas of the state with outcropping basement rocks. Burra, Kanmantoo, Mt Gunson and Moonta were also mined by open cut methods in the 1970's and 1980's.

The discovery in 1975 of the huge Olympic Dam Cu, U, Au, Ag deposit 300 m beneath the Stuart Shelf marked the return of South Australia as a major copper producer. The discovery also highlighted the potential of the large areas of mainly concealed Palaeo and Mesoproterozoic rocks in South Australia to host major copper (gold, uranium) orebodies.

The numerous copper mines and occurrences particularly in the Adelaide Geosyncline, eastern Gawler Craton and Curnamona Province confirm the potential of these regions for copper mineralisation. They may provide guides to adjacent, previously unrecognised ore and in some cases provide opportunities for low cost leaching operations.

The total gold resources and reserves (1025 tonnes) at Olympic Dam dwarf all previous gold finds in South Australia and are the largest in Australia. Numerous other deposits of alluvial and reef gold are scattered across the south of the State, particularly in the Adelaide Geosyncline, but total production is small. Significant byproduct gold has come from copper mines at Moonta, Wallaroo and Kitticoola.

In the following discussion significant copper and gold deposits and prospective geological provinces are described briefly.

A detailed description of the geology of these provinces is contained in Bulletin 54 'The geology of South Australia' (Drexel et. al. 1993).

Gold production figures ar assumed to be for pure gold metal unless labelled as bullion.

GAWLER CRATON

The Gawler Craton comprises a diverse association of rock units of late Archaean to Mesoproterozoic age occupying an area of about 450 000 km^2 in the centre of South Australia much of which has a relatively thin cover of Neoproterozoic to Cainozoic sediments. The late Archean to early Palaeoproterozoic Sleaford and Mulgathing Complexes occur in the west and northwest of the Craton and comprise paragneiss and orthogneiss, mafic to ultramafic intrusives and extrusives and banded iron formation. Palaeoproterozoic metasedimentary and metavolcanic rocks occur mainly on the eastern Gawler Craton. These include the Hutchison Group with quartzite, carbonate, banded iron formation and schist (~1900-1845 Ma), Moonta Porphyry (~1737 Ma), Doora Schist, Wandearah Metasiltstone and McGregor Volcanics (~1740 Ma) and Moonabie Formation clastics and Tarcoola Formation clastics and volcanics (~1656 Ma). Granitoids and intermediate to basic rocks of the Lincoln Complex (~1850-1700 Ma) intrude these units throughout the Craton.

A large area in the centre of the craton is covered by the felsic Gawler Range Volcanics (~1592 Ma) and associated clastic sediments. Hiltaba suite granitoid intrusives, similar in age and composition to the Gawler Range Volcanics are widespread on the Craton, occurring particularly around the margins of the volcanics.

Significant copper and gold occurrences of the Craton are described below. A major theme to emerge from these descriptions is the importance of the Gawler Range Volcanic - Hiltaba Suite extrusive/intrusive event as a source of mineralisation. The substantial crustal heating associated with this major magmatic episode is likely to be the common driving force for the diverse styles of mineralisation associated with the event. Prospective rocks include Hiltaba Suite granitoids, Gawler Range Volcanics and related sediments and older units (e.g. Hutchison Group, Wandearah Metasiltstone, Doora Schist) affected by major magmatic - hydrothermal systems. Known copper and gold mineralisation is associated particularly with the eastern and northeastern margins of the Gawler Craton at localities such as Moonta - Wallaroo, Roopena, Olympic Dam and Mt Woods.

Olympic Dam

The Olympic Dam copper, uranium, gold, silver deposit is one of the largest known accumulations of metals in the world. Resources and reserves as at June 1994 are summarised in Table 1.

Olympic Dam geology and mineralisation is described in detail by Cross *et al.* (1993), on which the following description is based, and Reeve *et al.* (1990).

The deposit is situated in Mesoproterozoic rocks of the northeastern Gawler Craton beneath about 300 m of undeformed Adelaidean and Cambrian platform sediments of the Stuart Shelf. The deposit lies within an undeformed alkali feldspar-rich granite, the Roxby Downs Granite, part of an extensive batholith ranging in composition from syenogranite to quartz monzodiorite. The batholith is part of the Hiltaba Suite with U-Pb zircon ages ranging from 1598$\pm$2 to 1588 $\pm$ 4 Ma (Mortimer et al., 1988; Creaser and Cooper, 1993).

Within the granitoid a large hydrothermal haematite granite breccia complex is host to the mineralisation. The breccia complex is broadly zoned with a core of barren haematite-quartz-breccia flanked by 1-2 km wide zones containing haematite-rich breccias intermingled with altered granitic breccias. All the known significant copper - uranium mineralisation occurs within these zones (Fig 2). A halo of variably altered and brecciated granite extends up to 3 km beyond the outer limits of the haematite-rich breccias. Alteration minerals include haematite, sericite, chlorite and silica.

Also within the breccia complex are high level intrusives, extrusives and sediments derived from them. The intrusives range in composition from ultramafic to felsic and form either well defined dykes or fragmental pipe-like bodies. The fragmental bodies may broaden upwards into zones of surficial volcaniclastic rocks including laminated ash, lapilli tuff and conglomerate. These rocks are interpreted to have formed in maar craters produced by volcanic eruptions. Fragments and blocks of layered sediments derived from volcanics are found in some breccia bodies. These are believed to have been derived from the collapse of the maar craters.

The deposit is cut by a complex array of faults and veins of variable orientation. Most post-date the major breccia - forming event, but some are inferred to be syn-hydrothermal. The complex structural pattern shows evidence of a long history of episodic fault activity.

Ore mineralisation mainly comprises disseminated and fragmental chalcocite, bornite, chalcopyrite, pitchblende and very finely disseminated free gold. Sulphide veinlets are developed locally. The sulphides show a complex, broadly vertical, zonation from pyrite at depth, upwards through chalcopyrite, to bornite then chalcocite. Copper, uranium and silver grades are richest in the bornite-chalcocite ore zones and these zones are the focus of current production.

Gold and uranium mineralisation is generally closely associated with the copper sulphides although some comparatively small, discrete, higher grade gold zones with low copper and uranium are found. Silver occurs mainly within copper sulphide.

Most of the breccia complex is patchily enriched in light rare earth elements (LREE). Haematite-rich copper-mineralised breccias are generally more LREE enriched (about 0.5% La plus Ce) than other breccias. Very fine grained bastnaesite and florencite are the most abundant REE minerals. REE are not extracted in the mineral processing at Olympic Dam.

Olympic Dam mineralisation appears to have formed in a large, high-level hydrothermal, intrusive and volcanic system. Faulting, brecciation, alteration, magmatic intrusion and extrusion and metal precipitation were interdependent and multistage. Metal precipitation may have been the result of the mixing of ascending hot, reduced, Fe-rich waters with cooler near surface waters. The structural pattern of the breccia complex suggests that the evolution of the deposit was influenced by strike-slip movement on a regional west-northwest trending fault zone.

U-Pb zircon ages of intrusive and extrusive rocks within the breccia complex are indistinguishable from the age of the Roxby Downs Granite and the Gawler Range Volcanics. This dating and all other evidence suggest the deposition of ore minerals was penecontemporaneous with the breccia-forming events. Formation of the Olympic Dam deposit is therefore believed to be related to GRV - Hiltaba Suite volcano - plutonic activity.

Discovery and Development

The first exploratory hole (RD 1) drilled in the Olympic Dam area by Western Mining Corporation in July 1975 discovered copper - uranium mineralisation. The hole was sited to test a combination of geophysical and tectonic components of a genetic model involving sediment - hosted copper deposits. The Olympic Dam site has near coincident positive gravity and magnetic anomalies (Fig. 2). Some subsequent drillholes provided further encouraging assays but others were virtually barren and it was not until drillhole RD 10 intersected 170 m of 2.1% Cu and 0.59 kg/t U_3O_8 that the potential of the deposit was realised. Even then the main areas of thick, high grade ore still lay 1 000 m to the northeast of RD 10 (Woodall, 1994).

First ore treatment in the processing plant and official opening of the mine was in 1988. Mining of the Olympic Dam deposit is by underground methods. The Whenan Shaft and a decline provide access and ore and mullock haulage. The on site metallurgical plant and refinery produce refined copper cathode, gold, silver and 98.5% pure uranium oxide (yellowcake). Production in 1993-94 is summarised in Table 2.

The mine has recently undergone an expansion, including the construction of a second haulage shaft (Robinson Shaft), and additions to the metallurgical plant and refinery lifting annual mining capacity to 2.9 Mt of ore production capacity to 85 000 t/year copper and 1 500 t/year uranium oxide.

Basement to Stuart Shelf - Other Prospects

At Acropolis prospect, 22 km southwest of Olympic Dam, copper sulphides (66 m containing 0.7% Cu in drill hole ACD-1), uranium and rare earth elements are associated with large bodies of haematite-magnetite alteration within felsic to intermediate volcanic rocks. The volcanics are faulted against diorite and gneissic granite and intruded by alkali quartz syenite. The prospect has affinities with Olympic Dam although in detail the style of mineralisation is different (Parker, 1990; Paterson, 1986).

At Wirrda Well, 30 km south of Olympic Dam, copper, uranium and gold are associated with pervasive haematite and magnetite in a granite breccia body within a gneissic, megacrystic granite. Altered intermediate to mafic volcanics occur on the northern edge of the breccia. (Parker, 1990)

Paterson and Muir (1986) also report significant copper (gold) intersections in granite, felsic volcanics, haematite breccia and iron formation beneath Stuart Shelf sediments at Dromedary Dam, Horse Well, Cocky Swamp and Winjabbie. Davidson and Paterson (1993) describe a large Cu-U-Au bearing iron-oxide body at Oak Dam East.

Gow *et al.* (1994) describe copper-uranium-gold mineralisation within a large iron-oxide body of hydrothermal origin at Emmie Bluff hosted by felsic volcanics and Wandearah Metasiltstone.

In the Mount Gunson region anomalous copper occurs in both intermediate to basic volcanics and in underlying haematitic, locally folded and brecciated Wandearah Metasiltstone. The latter contains individual assays up to 15.2% Cu, 6.9% Zn, 1.8% Pb and 75 g/t Ag. in drillhole SAR 8 (Parker, 1990; Knutson *et. al.*, 1983).

Moonta and Wallaroo

The Moonta and Wallaroo copper deposits on Yorke Peninsula near the eastern margin of the Gawler Craton have produced a combined total of 9.6 Mt of ore from which 350 000 tonnes of copper and about 3.6 tonnes of gold were recovered (3.7% Cu and about 0.4 g/t Au recovered) (Robertson, 1991). Most production came from underground mining between 1860 and 1923. The Poona and Wheal Hughes lodes, part of the Moonta system, were mined by open cut and underground decline mining from 1988 to 1993 to produce 476 000 t of ore from which concentrate containing 17 500 tonnes of copper and 423 kg of gold was recovered (3.4% Cu and 0.6 g/t Au recovered).

The Moonta lode system comprises a series of steeply dipping, generally northeast-southwest trending pegmatitic veins occurring over an area of about 6 x 2 km east of the town of Moonta. Host rock for the lodes is the Palaeoproterozoic Moonta Porphyry (U-Pb zircon age 1737 $\pm$ 5 Ma, Fanning *et. al.* 1988), a foliated, rhyolitic, meta - feldspar porphyry of probable volcanic origin. Mineralisation, where unweathered, comprises chalcopyrite, pyrite and bornite in a quartz, feldspar, tourmaline, chlorite and haematite gangue. In the weathered profile a pronounced zone of secondary sulphide (chalcocite, covellite) enrichment capped the lodes overlain by a near-surface, barren zone.

The Wallaroo deposit, near the town of Kadina, is hosted by Doora Schist comprising metamorphosed and deformed mica schist, amphibolitic schist, quartzite, gneiss and iron formation. Doora Schist is interbedded with bands of porphyry and is probably the lateral equivalent of the Moonta Porphyry.

The lodes at Wallaroo are near vertical shear zones containing stringer, vein and laminated mineralisation. Major sulphide minerals are chalcopyrite, pyrite and pyrrhotite in a gangue of quartz, biotite, feldspar and tourmaline.

Both the Moonta and Wallaroo lodes had virtually no surface expression.

Although the lode patterns at Moonta and Wallaroo are somewhat different, Dickinson (1942) considered them to be the result of the same deformation process. Hiltaba Suite granitoids in the region (Arthurton Granite, Tickera Granite) are a likely source of the hydrothermal fluids that formed the Moonta and Wallaroo lodes. However, Parker (1993) suggests that the mineralisation may have been remobilised from submarine exhalative mineralisation in the Doora Schist.

Recent review of drill core from the region has highlighted widespread metasomatic alteration assemblages involving biotite-magnetite-actinolite-sulphides, scapolite-albite-actinolite-magnetite-pyrite and K-feldspar-sericite-chlorite-haematite ('red-rock'). Potential exists for intrusive related, hydrothermal ('Ernest Henry type'), volcanogenic massive sulphide and chemical sediment hosted SEDEX mineralisation (Conor, 1993).

Resources of 2.7 Mt grading 2.1% Cu have been reported in the West Doora area of Wallaroo by Western Mining Corporation (1987).

Morris (1988) reported a resource of 969 000 tonnes of tailings grading 0.51% Cu and 0.20 g/t Au at the old Devon concentration plant site at Kadina.

Eastern Eyre Peninsula

Numerous small copper (as well as lead and silver) mines and occurrences are located on eastern Eyre Peninsula within Palaeoproterozoic Hutchison Group rocks. Many are hosted in carbonate and calcsilicate units near the base of the Middleback Subgroup or in calcsilicate gneiss within the Warrow Quartzite at the base of the Hutchison Group. Economic mineralisation was typically confined to near surface, supergene enriched ore and production was minor. More significant deposits included the Pt Lincoln (Cu) Tumby Bay (Cu) and Miltalie (Pb, Ag, Cu) mines (Johns, 1961; Parker, 1990).

Mt Woods Inlier

The Mount Woods Inlier southeast of Coober Pedy comprises Palaeoproterozoic iron formation, felsic granulite, schist, gneiss and calcsilicate intruded by Mesproterozic Hiltaba Suite (?) granitoids and mostly covered by younger sediment (Flint, 1993). CRA Exploration (1990, 1993 a,b) carried out exploration in the area between 1981 and 1993 concentrating on prominent regional aeromagnetic anomalies. Drilling located highly altered, siliceous host rocks with extensive magnetite bodies containing large amounts of sulphides and significant Cu, Au and U.

At the Manxman A Prospect, massive and brecciated, sulphide rich magnetite, haematite-chlorite breccia, laminated siliceous rock, gneiss and acid volcanics were intersected. Hole EN 24 encountered 0.35% Cu over 34 m and 2.5 ppm Au over 2.5 ppm Au over 2 m. Hole EN 25 had maximum values of 0.6% Cu over 6 m, 1.45 ppm Au over 1.5 m and 231 ppm U over 7.5 m.

Cu and Au mineralisation was also intersected at several other prospects including Joes Dam in magnetite rich gabbro, Joes Dam West in massive magnetite bands within gneiss (including 8 m containing 1.52% Cu and 0.34 ppm Au) and at Cairn Hill in massive magnetite zones associated with gneiss and granite.

At Mount Brady Cu mineralisation, together with phosphorous and rare earth elements, is hosted by lithologies and sulphide rich magnetite associated with a gabbro body. Carbonatite material was also identified.

Roopena Area

At Roopena, southwest of Port Augusta, drilling by MESA and Samedan Oil Corporation located extensive copper, lead, zinc and silver mineralisation in Palaeo and Mesoproterozoic rocks adjacent to the Roopena fault. (Thompson, 1980; David, 1985)

Narrow copper and silver-rich zones comprising chalcopyrite, disseminated and in veins, are found in Wandearah Metasiltstone. This mineralisation is associated with extensive 'Olympic Dam style' haematite - sericite-chlorite-carbonate alteration of the Wandearah Metasiltstone and underlying Moonabie Formation. Overlying these units, Roopena Volcanics basalt (Gawler Range Volcanic equivalent) and Corunna Conglomerate shale, siltstone and sandstone are unaffected by this alteration but contain chalcopyrite, galena and sphalerite both stratiform and in veins. Few samples were analysed for Au but some sporadic gold was detected. Although no economic mineralisation has been located in this area the extent and multiphase nature of mineralisation and alteration suggest potential for major mineralising systems in this type of environment.

Tarcoola - Kingoonya Region

Regional MESA bedrock drilling programs in the Tarcoola (Robertson *et al.*, 1993) and Kingoonya (Morris, 1992) areas located significant Cu, Zn, Pb, As and Au anomalies in Gawler Range Volcanics and associated sediments. Most of the basement rocks in this region are obscured by shallow soil and sediment cover.

The Tarcoola program also revealed a large intermediate to basic intrusive complex ('the Malbooma anorthosite complex'). Rock types include anorthosite, gabbro, diorite, pyroxenite, mafic rich syenite, quartz monzonite and granodiorite. The complex, tentatively assigned to the Palaeoproterozoic Lincoln Complex, contains widespread highly anomalous Cu (maximum 2935 ppm) and Zn (maximum 1660 ppm).

In the Mulgathing area, northwest of Tarcoola, the drilling program located highly anomalous gold values in Archaean Mulgathing Complex paragneiss and band iron formation. At Woomera Tank 700 ppb Au was detected over 10 m in gneiss adjacent to a basic intrusive with lamprophyrric affinities. In the South Hilga - West Well area several holes located Au values in the 50-300 ppb range in banded iron formation rocks and adjacent paragneiss and schist.

Subsequent exploration by Dominion Mining Ltd and the Resolute - Samantha Group has confirmed the presence of significant gold mineralisation in the region.

Dominion Mining Ltd's Quarterly Report of December 1993 reported percussion drilling of a surface geochemical anomaly in the South Hilga area. Hole MHP 84 intersected 4 m containing 1.2 g/t Au from 44 m. Hole MHP 85 intersected 14 m containing 1.6 g/t Au from 34 m including 2 m with 5.5 g/t Au.

In an announcement to the Australian Stock Exchange of 28 June 1995 Dominion Mining Ltd reported encouraging gold results from rotary-air and reverse circulation drilling of the 'Challenger' surface geochemical anomaly. Results included 28 m containing 6.7 g/t Au from 11 m in CHRC 80 and 29 m with 6.4 g/t Au from 12 m in CHAR 83.

MESA also carried out a program of diamond drilling in the northwest Gawler Craton which confirmed the presence of mafic and ultramafic rocks within the Mulgathing Complex including a komatiite body at Lake Harris (Daly and van der Stelt, 1992). As well as potential hosts to nickel, copper and platinoid mineralisation these bodies enhance similarities with major Archaean greenstone belts elsewhere and hence potential for major gold mineralisation.

Tarcoola Goldfield

At the Tarcoola Goldfield subvertical gold bearing quartz veins crosscut Palaeoproterozic Tarcoola Formation (1660 Ma) carbonaceous siltstone and interbedded quartzites. Gold was also mined from the adjacent Hiltaba Suite granite (~ 1580 Ma). 2.4 tonnes of gold bullion have been produced from the field from 64 000 tonnes of ore. Most mining was in the early 1900's. Recent drilling at the Perseverance Prospect by BHP Gold and Grenfell Resources has established a resource of 975 000 tonnes containing 2 g/t Au including 500 000 tonnes at 3.2 g/t. (Daly et al., 1988; BHP Gold, 1989)

Glenloth Goldfield

At the Glenloth Goldfield, southeast of Tarcoola, gold-bearing quartz veins occur within fractured and foliated Glenloth Granite (~ 2400 Ma) and Kenella Gneiss of the Mulgathing Complex. Gold also occurs in mafic dykes (~ 1700 Ma) and in crosscutting dykes of the Gawler Range Volcanics. Mines are located along northwesterly trending shears cutting the Glenloth Granite. A concealed Hiltaba Suite granite batholith is suggested as the source of the gold-bearing quartz veins.

Total recorded production is 315 kg of gold bullion from 14 620 t of ore, mainly between 1893 and 1901. (Horn *et al*, 1985; Daly, 1993)

Earea Dam Goldfield

Situated northwest of Glenloth, Earea Dam has a total recorded production of 59.2 kg of gold bullion. Gold and tin occur in quartz veins within Kenella Gneiss. Again Hiltaba Suite granite is the suggested source of the gold. Recent drilling has located a new gold bearing zone (Circosta and Gum, 1988; Crettenden 1989)

CURNAMONA PROVINCE AND OTHER BASEMENT INLIERS

The Curnamona Province is a large area of Palaeoproterozoic to Mesoproterozoic rocks in the northeast of the state. Most of these rocks are obscured by younger sediment but they are exposed in the Willyama Inliers of the Olary-Broken Hill region and in the Mt Painter and Mt Babbage Inliers to the north. The centre of the Province, where rocks are undeformed by the Cambro-Ordovician Delamerian Orogeny, is referred to as the Curnamona Craton. The late Palaeoproterozoic Willyama Supergroup occupies the Willyama Inliers which in South Australia comprise the Olary Block and the southwestern portion of the Broken Hill Block.

The Olary Block sequence comprises gneisses at the base overlain by quartzo-feldspathic rocks including albitites, calcsilicates, amphibolite, a distinctive sulphide rich unit, the Bimba Formation, and carbonaceous and pelitic schist. The metasediments are intruded by late Palaeoproterozoic to early Mesoproterozoic granitoids including Hiltaba Suite equivalents.

The metasedimentary rocks of the Olary Block are correlated with those hosting the Broken Hill lead-zinc silver deposit in New South Wales and have undergone a similar complex deformational and metamorphic history. However they appear to have been deposited in a different sedimentary environment and intrusive granites are much more common in the Olary Block. (Ashley *et al.* 1994; Flint and Parker, 1993).

The Willyama Supergroup in South Australia hosts numerous and widespread occurrences of copper, lead, zinc, uranium and gold but production has been very small. Largest copper producer and known resource is the Mutooroo Copper Mine in the Broken Hill Block with a resource of 8.7 million tonnes of 1.8 % Cu. Sulphides including chalcopyrite occur in steeply dipping quartz lodes cross cutting amphibolite within gneissic rocks. Elsewhere in the Mutooroo region large low grade stratiform bodies of disseminated copper and/or zinc sulphides have been found at localities such as King Dam (Cu) (Yates, 1992).

In the Olary Block, the Bimba Formation, calcsilicate and albitic units are host to numerous copper, lead and zinc occurrences and prospects with gold also present in some localities. Gossans after iron and basemetal sulphides are widespread, particularly in the Bimba. Prospects and mines include Dome Rock (Cu, Au), Telechie (Cu, Zn), Mt Howden (Cu) and Waukaloo (Cu, Au) (Yates and Randell, 1994). Typically at these prospects, copper and gold are enriched in the supergene zone with subeconomic values at depth.

Copper and gold also occur in stratabound quartz-magnetite bodies lower in the sequence in the quartzo-feldspathic suite at localities such as the Perryhumuck, Olary Silver and Green & Gold Mines. Copper and gold are also associated with quartz-vein systems of probable Cambro-Ordovician age. The best example of this style of mineralisation is the Luxemburg-Queen Bee Mine area near the McDonald Shear Zone, a major regional fault zone bounding one of the Inliers.

Extending north of the Olary Block, the Benagerie Ridge area contains metasediments mostly overlain by relatively thin younger sediments. The metasediments, which include graphitic schist and albite, magnetite and scapolite bearing pelites and carbonates, are probably part of the Willyama Supergroup although less deformed and of lower metamorphic grade. Significant intersections of Cu, Zn and Au mineralisation have been found in these rocks (Teale, 1985).

Both the nature of some of the mineralisation and the lithostratigraphy of the Willyama Supergroup suggest comparisons with the approximately coeval rocks of the Mt Isa Block in Queensland. In particular the region is prospective for copper-gold mineralisation of the styles found in the Cloncurry Belt, perhaps related to younger granitoid intrusives.

The Mount Painter and Mount Babbage Inliers (Coats and Blissett, 1971; Teale, 1993) comprise Palaeo-and Mesoproterozoic metasediments, metavolcanics (dominatly felsic and silicic) and granitoid intrusives. The Palaeoproterozoic rocks were deterred and metamorphosed in the Olarian Orogeny and stratigraphic and lithological similarities have lead to correlation with the Willyama Supergroup. All Proterozic units have also been affected by the Delamerian Orogeny and intruded by Delamerian granitoids.

In the Mount ~ inter Inlier the Parabarana Copper Prospect is hosted by Palaeoproterozoic calcareous metasediments. An inferred resource of 6Mt of 0.9% Cu has been defined. Copper and molybdenum mineralisation occurs in veins and fractures cutting quartz-albite rocks. The host rocks have skarn-type alteration assemblages. Mineralisation may be related to the nearby Mesoproterozoic Mt Neill Granite which intrudes the sequence (Coats and Blissett, 1971; Brewer, 1978; Dubowski, 1989).

Copper and, to a lesser extent, gold are found mostly as minor occurrences elsewhere in these Inliers in both Palaeo and Mesoproterozic host rocks. Copper is associated with uranium and rare earth elements at some localitities.

The Peake and Denison Inliers, southeast of Oodnadatta, have quartzite, schist and metavolcanics of the Peake Metamorphics (~ 1800 Ma) within rocks of the Adelaide Geosyncline. These Inliers are a probable extension of the Gawler Craton. The Inliers host several small copper occurrences associated with quartz - haematite veins (Ambrose *et al.*, 1981).

Five inliers in the Mt Lofty Ranges in the south of the Adelaide Geosyncline comprise the largely metasedimentary Barossa Complex (metamorphic age ~ 1580 Ma),. The Barossa Complex hosts scattered, mostly minor copper and gold workings. The most significant known mineralisation is the Barossa Goldfield discussed in the Adelaide Geosyncline section.

MUSGRAVE BLOCK

The Musgrave Block is a large area of Mesoproterozic rocks flanked by Adelaidean and Palaeozoic sedimentary basins in the northwest of the state. Within the Block the Birksgate Complex consists of metasediments and meta volcanics and older metamorphic rocks (some > 1700 Ma), all metamorphosed in the Musgravian Orogeny (~ 1200 Ma). The Birksgate Complex was intruded by grainitoids of the Kulgera Suite (1225-1190 Ma) and the mafic to ultramatic Giles Complex a well as several generations of basic dykes. At the end of the Adelaidean, uplift of the block occurred along east-west-trending mylonitic thrusts. (Major and Conor, 1993).

Exploration and mineral potential of the Musgrave Block have been summarised by Tonkin (1991). Copper sulphides are found in several small stratabound deposits in the eastern Musgrave Ranges in the Birksgate Complex. At the Kenmore 2 prospect metasediments enclosing an ultramafic body contain disseminated pyrite and chalcopyrite in a zone 5 m thick and 430 m long. Best intersection was 9.8 m containing 0.41% Cu. Other prospects in the area contained Cu in the same stratigraphic horizon. Copper has also been found associated with basic dykes and faults.

Tonkin (1991) suggests that the Musgrave Block and surround Adelaidean and Cambrian sediments are prospective for:

- Stratabound copper mineralisation in the Birksgate complex.
- Volcanogenic massive sulphide (VMS) deposits in the Birksgate Complex.
- Stratiform copper in Adelaidean sediments.
- Gold associated with Kulgeran granitoids, mafic igneous rocks, felsic volcanics and gold in Adelaidean Moorilyanna Conglomerate.

ADELAIDE GEOSYNCLINE, STUART SHELF

The Adelaide Geosyncline and Stuart Shelf are described in detail by Preiss (1987) and Drexel *et al.* (1993).

The Adelaide Geosyncline is a major, deeply subsident Neoproterozoic to Cambrian sedimentary rift basin deposited on Palaeoproterozoic to Mesoproterozoic basement. The Geosyncline sediments were deformed by the Cambro-Ordovician Delamerian Orogeny.

Largely undeformed, platformal extensions to the sediments occur in the Stuart Shelf overlying rocks of the Gawler Craton, the Officer Basin and on part of the Curnamona Craton.

At the base of the Neoproterozoic (Adelaidean) succession, the Callanna Group includes evaporitic sediments and basic volcanics deposited in rift basins controlled by major crustal lineaments. The Burra Group, also deposited in rift basins, comprises clastics, dolomite, sedimentary magnesite and siltstone. After a basin-wide hiatus, sedimentation resumed with the Umberatana Group comprising Sturtian age glacial and post-glacial sediments, marine siltstone, clastics and carbonates and finally Marinoan age glacials. The overlying Wilpena Group comprises two upward-coarsening clastic sequences. After a break at the end of the Proterozoic, sedimentation resumed in the Early to Middle Cambrian prior to deformation by the Cambro-Ordovician Delamerian Orogeny. Equivalent, flat-lying Adelaidean and Cambrian sediments to the west of the Geosyncline, that were unaffected by the Delamerian Orogeny, form the Stuart Shelf.

Early Cambrian Hawker and Normanville Groups were deposited in a widespread marine transgression and are dominated by carbonate rocks with lesser clastics and the mafic to intermediate Truro Volcanics.

Kanmantoo Group clastics with lesser carbonate and some sulphide-rich rocks were deposited in a trough formed by renewed rifting late in the Early Cambrian. These rocks are exposed in the southeast Mt Lofty Ranges and on Kangaroo Island. Kanmantoo Group and adjacent Adelaidean rocks have been variably metamorphosed up to amphibolite facies and affected by multiple phases of deformation during the Delamerian Orogeny. Granitic and, less frequently, mafic intrusive rocks of Cambrian to Ordovician age associated with the Delamerian Orogeny are concentrated along the eastern margin of the Kanmantoo Trough and Nackara Arc but are also found in the Mt Painter and Peake and Denison Inliers. Delamerian intrusives and Cambrian and Adelaidean (?) sediments and volcanic rocks are now known to occur extensively beneath the Murray Basin (Rankin *et al*, 1991; Hill, 1995). There is also evidence at Mount Painter and Burra of intrusive and hydrothermal activity in the Adelaide Geosyncline region much younger than the Cambro-Ordovician events (Drexel and Major (1987); Drexel and McCallum (1986)).

Copper mineralisation is widespread in Adelaidean and Cambrian rocks in and around the Adelaide Geosyncline. Mineralisation occurs in a wide variety of environments but a combination of structural and stratigraphic controls is evident.

Copper occurrences are found through much of the stratigraphic succession but certain units are favoured. These include Callanna Group rocks particularly as diapiric breccia, Skillogalee Dolomite and Saddleworth Formation of the Burra Group, Appila Tillite and Tapley Hill Formation (Umberatana Group), Bunyeroo Formation (Wilpena Group) and Early Cambrian rocks. Reid *et al.* (1994) point out the association of mineralisation with pyritic shales immediately above major unconformities.

Structural setting however is usually a key factor in localising mineralisation. Many deposits are associated with faults on both local and regional scales. Diapiric breccias, diapir margins and anticlinal cores are clearly favoured areas. These structural breaks, both syn- and post-depositional, have acted as pathways for mineralising fluids and assisted in preparing dilational sites for mineralisation. Nature of the mineralising fluids is poorly known but they may include basinal brines, diagenetic fluids, metamorphic fluids in higher grade areas and fluids influenced by Delamerian intrusives and other sources of high heat flow such as basement inliers.

Supergene processes have also played an important role. The majority of mined copper deposits are near surface secondary enrichments of primary sulphide mineralisation.

Gold mineralisation is concentrated in the south of the Geosyncline, particularly the Mt Lofty Ranges, and in the Nackara Arc. Both vein mineralisation and alluvial deposits in Tertiary to Recent sediments derived from nearby gold-bearing veins have been mined. Favoured units for gold mineralisation include the Saddleworth Formation (Burra Group), Cox Sandstone Member, Appila Tillite, Wilyerpa Formation (all

Umberatama Group) and sandstones of the Marinoan glacials.

Morris and Horn (1988) suggest an association of gold deposits in the Adelaide Geosyncline with deep seated fractures visible as lineaments on remote sensing imagery. Movements on these features may control the fold closures and flexures on which many gold deposits are located. Fractured quartzite and sandstone provide a permeable host rock for gold bearing solutions. Brecciation due to flexural slip on fold limbs between units of different competency may also provide permeable zones. The Adelaide Geosyncline, particularly the Nackara Arc, has features which suggest considerable potential for Telfer (Western Australia) style mineralisation.

Delamerian granitoid intrusives east of the Nackara Arc are associated with extensive hydrothermal systems and gold-copper mineralisation. Morris (1977) and McCallum *et al.* (1993) report on hydrothermal alteration and mineralisation associated with the Anabama and Bendigo granitoid bodies respectively. All the regions affected by Delamerian intrusives have potential for vein gold and skarn and porphyry style gold-copper mineralisation.

Some of the more significant copper and gold deposits and prospects of the Adelaide Geosyncline and Stuart Shelf are discussed below.

Copper

Mount Gunson

The following description of the Mt Gunson copper deposits on the Stuart Shelf is mainly derived from Tonkin and Creelman (1990).

Outcropping oxidised copper was first discovered at Mt Gunson in 1875, with sulphide mineralisation discovered soon after. Mining has taken place mainly in the periods:-

- 1898-1919: 3250 tonnes of ore containing between 8-16% Cu were mined.
- 1941-1943: the Zinc Corporation Ltd. mined 32 380 t of ore containing 3.5% Cu to produce 1 100 t Cu metal and 452 kg Ag.
- 1970-1971: Pacminex Pty Ltd and United Uranium NL. mined 234 000 t of ore, recovered grade 0.79% Cu, to produce 1850 t Cu and an estimated 2 800 kg Ag.
- 1974-1984: CSR Ltd and 1984-1986: EMAC Partnership mined 7.5 Mt of ore containing 1.9% Cu to produce 127 000 t Cu and 62 000 kg Ag
- 1987-June 1994: Adelaide Chemical Co. mined 660 000t of ore from which concentrate containing 11 700 t Cu metal was recovered.

Total production is about 142 000 t of copper metal from about 8.4 Mt of ore (average grade 1.7%). Open cut operations have been carried out on four orebodies, Main Open Cut, West Lagoon, East Lagoon and Cattle Grid. Cattle Grid was by far the largest orebody providing the bulk of the 1974-86 production.

Since 1987 Adelaide Chemical Company have been using heap leaching to produce a high-grade copper cement for transport to their Burra plant. Oxidised ore mainly from the Main Open Cut, House and Gunyot deposits has been used in the heap leaching. In 1990 the company announced its intention to mine the MG14 orebody which has an indicated resource of 1.5 Mt containing 1.5% Cu as sulphide.

The Mount Gunson deposits occur within Mesoproterozoic Pandurra Formation red sandstone and in unconformably overlying Adelaidean Whyalla Sandstone and Tapley Hill Formation. A complex horst structure in the Pandurra Formation known as the Pernatty Culmination was a major influence on Adelaidean sedimentation and on mineralisation.

Most of the economic sulphide mineralisation comprises chalcopyrite, bornite and chalcocite with lesser sphalerite and galena. The sulphides occur in a network of fracture filling veins in sandstone breccia and sandstone of the Pandurra Formation and overlying Whyalla Sandstone. Brecciation and frost wedging of the top of the Pandurra Formation by permafrost during the Marinoan glacial period played an important role in providing permeable zones for mineralising fluids (Williams and Tonkin, 1985). The Cattle Grid orebody is of this type. Mineralisation also occurs within Tapley Hill Formation dolomitic shale (e.g. MG 14 orebody). The Main Open Cut, House and Gunyot orebodies lie partly above the present day water table and hence are partly or completely oxidised.

Burra

Rich copper carbonates were discovered by a shepherd at Burra in 1845. Surface and underground mining between 1845 and 1877 produced approximately 700 000 tonnes of ore containing 50 000 tonnes Cu. From 1969 to 1981 firstly Samin Ltd and then Adelaide and Wallaroo Fertilisers Ltd produced 2 Mt of ore containing 40 000 tonnes copper from an open cut at the same locality as the older workings. Total production was 2.7 million tonnes of ore containing 90000 tonnes copper for an average grade of about 3.3% Cu.

The Burra metallurgical plant, originally built to treat ore from the 1969 - 1981 mining, is now operated by Adelaide Chemical Company. The Mt Gunson operations have been the principal source of feedstock for the plant but concentrates from other sources are now treated including copper-gold concentrate from the Telfer Mine. Value-added specialty copper chemicals such as cupric oxide are produced from the plant as well as gold bullion with the recent addition of a carbon-in-leach circuit.

Major copper minerals mined at Burra were malachite, azurite and chrysocolla with minor chalcocite, cuprite and native copper. Copper mineralisation is found as matrix to brecciated country-rock and as veins, blebs and nodules in country-rock. Host rock is intensely altered Adelaidean Skillogalee Dolomite comprising dolomite, siltstone and minor sandstone and limestone in faulted contact with unmineralised diapiric breccia. Hydrothermal alteration occurs in a pipelike zone and is marked by kaolinisation, potash metasomatism, chloritisation and silicification. Syenite porphyry dykes and subaerial volcanic rocks have been found within the orebody. Drexel & McCallum (1986) interpret the emplacement of the porphyry and volcanics, mineralisation and hydrothermal alteration to have taken place in a near surface environment after stripping of overlying Adelaidean and younger rocks. It was therefore much later than the Delamerian Orogeny; a Late Silurian - Early Carboniferous age is suggested.

Kanmantoo

Copper was discovered at Kanmantoo in 1845 and the area was worked by several companies by both underground and open cut methods. By the time mining ceased in 1874, 3 200 tonnes of copper had been produced. Following major drilling and geophysical programs in the 1960's open cut mining of a new orebody was carried out from 1970 to 1976 to produce 4.05 million tonnes ore containing 36 000 tonnes of Cu (average grade 0.89% Cu).

The Kanmantoo mineralisation is hosted by garnet-andalusite-schist within the Tapanappa Formation of the Cambrian Kanmantoo Group. Verwoerd and Cleghorn (1975) describe the orebody as consisting of a number of lenses of sulphide mineralisation flattened parallel to the major, axial-plane schistosity. Together the lenses had the overall shape of an elongated pipe plunging steeply to the northeast. Maximum horizontal dimensions of the orebody are 120 m x 180 m.

Primary ore comprised chalcopyrite, pyrrhotite and magnetite with minor gold and silver. Within the ore lenses mineralisation occurs as veins parallel to and cross-cutting the schistosity, massive bands and pockets and fine-grained disseminations along bedding.

Verwoerd & Cleghorn describe alteration accompanying mineralisation including chloritisation and other changes of mineralogy in the ore zone.

The Kanmantoo orebody at discovery was covered by laterite and had no surface expression. Below the laterite cover was a zone of malachite, azurite and iron oxides overlying a zone containing chalcocite, covellite and minor bornite, cuprite and native copper. 507 000 tonnes of oxidised copper ore from the near surface zone was mined during the open pit operation. 121 000 tonnes of this was processed and 386 000 tonnes containing ~1% Cu remains in a stockpile at the site.

Kapunda

The major period of mining at Kapunda was between discovery in 1842 and 1879 with peak production around 1857. Further intermittent small-scale mining took place until 1912. Total recorded production according to Dickinson (1944) was about 69 000 tonnes of ore containing 13 700 tonnes of copper metal. Exploration programs on the Kapunda deposit were undertaken by several companies in the 1960's and 1970's. These involved extensive drilling programs, some induced polarisation geophysical surveying and metallurgical test work. From these programs a variety of estimates of resources of shallow supergene sulphide and oxide ore have been made (Horn et. al., 1989). These estimates range up to 15 million tonnes containing 1.2% Cu by Northland Minerals in 1983.

In 1993 Adelaide Chemical Company estimated a resource of 3.7 million tonnes at 1.2% Cu (Bampton, 1993). In addition Utah-Northland suggested that a large, low-grade resource of primary chalcopyrite-pyrite mineralisation is present at depth.

Host rock at Kapunda is feldspathic dolomitic quartz-siltstone of the Adelaidean Tapley Hill Formation extensively bleached and kaolinised in the ore zone. Most production was of secondary copper carbonates, oxides and supergene sulphides associated with quartz veins. The quartz veins occupy a set of fractures on the west limb of an anticline. At depth primary sulphides occur as fine-grained disseminations and along bedding planes. The Kapunda mineralisation has been interpreted both as essentially stratiform in nature with some copper remobilised later into cross cutting veins (Hillwood, 1963 and Drummond *et al.*, 1978) and as structurally-controlled, epigenetic mineralisation (Dickinson, 1944).

Other Copper Deposits

Some of the numerous copper deposits and prospects of the Adelaide Geosyncline and Kanmantoo Trough are summarised below. The northern Flinders Ranges area particularly has a large number of copper occurrences.

The Blinman Mine produced an estimated 207 000 tonnes of ore and 9 935 tonnes of copper metal between 1862 and 1918. Mineralisation was located within the Blinman Diapir in a rafted block of dolomite and siltstone probably derived from Callanna Group sediments. The orebody was conformable within the sediments with copper sulphides both as disseminations and cross cutting veins (Dickinson, 1944; Newton & Crettenden, 1982).

Adelaide & Wallaroo Fertilisers Ltd (1988) and Adelaide Chemical Co Ltd (1990) investigated several areas of copper mineralisation in the Copley region. At the Mountain of Light workings a resource of 0.55 million tonnes of oxidised ore containing 1% Cu (mostly as malachite and azurite) was established in two orebodies in Tapley Hill Formation siltstone bordering the Copley diapir.

The Lynda (resource 1.1 Mt with 0.72% Cu) and nearby Lorna Doone (0.86 Mt with 0.81% Cu) Mines have malachite and copper oxides to about 36 m depth in the Tindelpina Shale Member of the Tapley Hill Formation and diamictite of the Yudanamutana Subgroup. Numerous small copper workings are located along the southern margin of the Mt Coffin diapir near the contact of the Tindelpina Shale Member and Yudanamutana Subgroup. Malachite, chalcocite and cuprite mineralisation is associated with cross cutting veins. Resources were established at Elsie Adair (2.0 Mt with 0.9% Cu) and West Jubilee (0.12 Mt with 0.97% Cu) but the mineralised zones are steeply dipping and patchy.

The Yudnamutana Mining Field on the western margin of the Mt Painter Inlier comprises numerous old working which exploited small deposits of high grade secondary copper mineralisation mostly in faulted, carbonate-rich Wywyana Formation of the Callanna Group. Exploration by the Department of Mines and Energy and Utah Development Company indicated widespread low-grade copper mineralisation as vein or skarn deposits accompanied by strong hydrothermal alteration (Fairburn, 1982).

The Paull Consolidated Mine northeast of Leigh Creek produced an estimated 35 000 tonnes of ore containing 1 000 tonnes of Cu from the mid 1890's to 1920 (Nixon, 1965). Copper carbonates, oxides and secondary sulphides occur in Tindelpina Shale and sandstone of the Yudnamutana Subgroup near the southern margin of the Burr Diapir. Little exploration has been carried out at this locality apart from the early underground mining but the deposit appears to have had rich patches of secondary copper carbonates, oxides and sulphides to about 100 m depth.

At Copper Claim Prospect near Eurelia, exploration by Utah Development Co located copper mineralisation extending over an area of 2.5 x 1.0 km in lower Adelaidean sediments in an anticlinal core. Utah Development Co. interpreted the host sediments as Callanna Group but they are best regarded as Saddleworth Formation and Skillogalee Dolomite of the Burra Group. Sulphide mineralisation is both stratiform and associated with cross cutting quartz and calcite veins (Robertson, 1981; Rowlands *et al.* 1978). Limited reanalysis (20 samples) of drill core from this prospect has shown anomalous gold (maximum 0.38 ppm Au) associated with the copper mineralisation. Recent reconnaissance bedrock drilling has located anomalous copper, zinc and gold in similar anticlinal cores in the region (Janz, 1993).

The Prince Alfred Mine produced an estimated 40 000 tonnes of ore containing about 5% Cu between 1866 and 1908. Chalcopyrite occurred in siderite, calcite and quartz infilling a fault zone within Tapley Hill Formation shale and grit.

The Myall Creek copper prospect north of Whyalla on the Stuart Shelf has copper and lesser zinc and lead mineralisation over an area of 15 x 3 km occurring at the base of the Tapley Hill Formation, unconformably overlying the Mesoproterozoic Backy Point Formation. Although the mineralisation shows similarities to the Zambian Copperbelt and Kupferschiefer stratiform (syngenetic?) styles of mineralisation, Mason (1982) considered the basemetal sulphides to be of epigenetic origin.

The Bremer Mine is located 3.5 km southeast of the Kanmantoo Mine in biotite schist within Tapanappa Formation of the Kanmantoo Group. Between 1850 and 1875, 35 000 tonnes of copper ore with an estimated grade of about 9% Cu was produced from the mine. Copper carbonates, oxides and sulphides occurred in quartz and calcite veins and disseminated in tabular lodes discordant to bedding. Drilling by Northern Mining Corp N.L. indicated a sulphide resource at depth of 610 000 tonnes containing 1.1% Cu (Northern Mining Corp N.L., 1976).

The Kitticoola Mine is situated in the Cambro-Ordovician Palmer Granite intruded into Kanmantoo Group metasediments at the eastern edge of the Mt Lofty Ranges. Gold and copper bearing lodes occur as fault infillings within brecciated and altered granite. The lodes occupy two fracture sets related to the Palmer Fault. Recorded production is 37 000 tonnes of ore containing 162 600 gms of gold (4.4 g/t) and an unknown amount of copper. (Drexel, 1979)

Placer Exploration Ltd (1993) investigated a large area of copper and gold mineralisation near the Anabama Copper Mine. The prospect lies a few kilometres south of the large Cambro-Ordovician Anabama Granite body. Consistent low grade copper and patchy gold mineralisation occur in a zone about 200 m wide and 3000 m long associated with a shear zone in Adelaidean metasediments and basic volcanics (Boucaut Volcanics). A resource of 4Mt containing 0.6% Cu (0.1% Cu cut off) was estimated for the higher grade portion of the zone. In a report to the Australian Stock exchange on 28 June 1995, Copperfield Gold N.L. announced encouraging results from follow up drilling of the mineralised zone found by Placer. Results included 48 m from 2 m with 0.68% Cu including 12 m from 18 m with 1.51% Cu from hole AB13. All copper is in the form of copper oxide minerals.

Elsewhere in the area similar copper (gold) mineralisation has also been located at White Rock (Placer, 1993) and Cronje Dam (Morris, 1977)

Widely spaced reconnaissance drilling by MESA in the Coomandook area in 1994 beneath relatively thin Murray Basin sediments intersected graphitic shale, siltstone, carbonate, metabasic volcanics (Normanville Group ?) and mafic intrusives. Values of up to 0.93% Cu, 0.94% Zn and 900 ppm Pb were obtained in these rocks emphasising the prospectivity of this poorly known region for base metal mineralisation (Hill, 1995).

Gold - Mt Lofty Ranges

Echunga

The Echunga Goldfield is situated southeast of Adelaide in the Mt Lofty Ranges. The biggest producers within the field were the Old Echunga and Jupiter Creek diggings with estimated production of 3 100 kg and 930 kg of gold respectively (Drew, 1992). Old Echunga was the subject of a major alluvial mining rush between discovery in 1852 and 1855. Several other periods of mining took place up to the 1930's. Most gold was found at shallow depth in Tertiary and Quaternary fluvial sediments. Some gold was also produced from quartz veins in the underlying Adelaidean Aldgate Sandstone and Woolshed Flat Shale. The diggings are also notable for the finding of over 50 alluvial diamonds in the course of gold mining.

The main period of alluvial mining at Jupiter Creek was from discovery in 1868 to 1871. Several periods of reef mining took place up to the 1930's. Alluvial gold was produced from shallow Tertiary and Quaternary sediments mostly along modern drainage channels. There was also considerable production from quartz veins in Adelaidean Aldgate Sandstone (Robertson, 1991).

Barossa

The Barossa Goldfield, in the Mt Lofty Ranges northeast of Adelaide, was discovered in 1868. Most production was alluvial gold particularly from gravels at the base of the Tertiary fluvial sediments and in modern drainage channels. Gold was also found in small quantities in quartz and haematite veins within underlying schist and gneiss of the Palaeoproterozoic Barossa Complex, which forms five basement inliers within younger Adelaidean rocks in the Mt Lofty Ranges (Robertson, 1991). Total production from the Barossa Goldfield is estimated at about 3 100 kg (Drew, 1992).

Deloraine

At the Deloraine Mine in the Mt Lofty Ranges gold was mined underground from 1909 to 1939. Gold was found in quartz veins in fissures and crush zones in Burra Group clastic and carbonate metasediments. Total production was 948 kg of bullion from 48 300 tonnes of ore (19.6 g/t recovered grade). Host structures to gold mineralisation may be controlled by a major north-south strike fault (Robertson, 1976; Robertson, 1991).

Woodside

The Woodside Goldfield in the eastern Mt Lofty Ranges has bullion production of 735 kg recorded between 1879 and 1938. Gold occurs in quartz-sulphide veins in Umberatana Group metasediments over a distance of about 3 km. Some alluvial gold was also found in nearby water courses.

Birdwood

Workings of the Birdwood Goldfield extend over an area of about 7 x 5 km around the town of Birdwood in the eastern Mt Lofty Ranges. Gold was first discovered in the area in 1869. Total recorded production is 622 kg of bullion. Production was both from extensive alluvial workings and from quartz reefs. Workings extend across both Adelaidean metasediments of the upper Burra Group and Cambrian Kanmantoo Group metasediments.

Gold - Nackara Arc

Teetulpa

An estimated 2 400 kg of gold has been produced from the Teetulpa Goldfield, the bulk of production coming from alluvial mining in the year following discovery of the field in 1886. Alluvial gold was found mainly near the base of poorly sorted fluvial sediments within palaeochannels cut by modern drainage channels. The sediments unconformably overlie shale and siltstone of the Adelaidean Tapley Hill Formation which host gold-bearing quartz-carbonate-sulphide veins. These veins are the source of the alluvial gold and were also mined in numerous small underground workings although total production from this source is thought to be small (Horn & Fradd, 1986; Robertson, 1991).

Waukaringa

Discovered in 1873, the Waukaringa Goldfield has produced 1 440 kg of gold bullion from 58 000 tonnes of ore from underground workings. Gold occurs in quartz-ironstone-pyrite veins with mined ore having an average grade of 24.5 g/t Au. Veins are broadly concordant with bedding in the Adelaidean Umberatana Group sedimentary host rocks. Main host is the Cox Sandstone Member of the Tarcowie Siltstone with the underlying Tapley Hill Formation also hosting some veins. The deposit lies on the northern flank of the Waukaringa Syncline, one of several northeast trending synclines and elongate anticlinal domes in the northeastern Nackara Arc (Townsend & Horn, 1988).

Other Deposits

Other significant gold deposits in quartz vein systems in the Nackara Arc are discussed below.

The Wadnaminga and Taltabooka Goldfields are situated on the northern limb of an anticlinorium in dolomite, siltone and phyllite of the Belair Sub-Group and underlying Saddleworth Formation (both Burra Group). Gold bearing quartz veins occur over a large area in a variety of stratigraphic positions and lithologies although dark grey, pyritic silttone is the most common host rock. The large Anabama Granite body is located to the south of the anticlinorium and a genetic link to the quartz vein systems is possible. Total production from Wadnaminga is in excess of 525 kg of gold bullion from about 20 000 tonnes of ore. (Horn et al., 1985; Morris and Horn, 1988).

Mongolata Goldfield has gold in quartz and ironstone veins and stockworks in Umberatana Group glacial sediments. Main host rock is brittle, fractured Cox Sandstone Member quartzite with some gold also in underlying slate. Discovered in 1930, Mongolata has produced about 350 kg of gold from underground workings. Minerslisation has been found over a distance of about 12 km north-south along strike (Morris, 1978; Horn *et al.*, 1985).

At Mannahill Goldfield stratifom gold mineralisation occurs in a series of conformable, quartz-sulphide veins in Enorama Shale (Umberatana Group) on the the northern flank of a major syncline. Ore comprises finely interbanded quartz, siderite and minor barite. Only the near-surface, oxidised portion of the vein system has been mined. Mannahill has produced about 115 kg of gold bullion from 5 850 tonnes of ore since discovery in 1885. (Horn *et al.*, 1985; Morris and Horn, 1988).

Nillinghoo Goldfield is situateed on the northern limb of an east-west trending anticlinal domal structure. Mineralisation occurs within quartz - limonite - pyrite - haematite veins hosted by feldspathic quartzite of the Wilyerpa Formation (Umberatana Group). Most ore has been extracted from open cuts. Since discovery in 1894, recorded production is about 122 kg of gold bullion. (Horn *et al.*, 1985; Morris and Horn, 1988).

At Mount Grainger Goldfield stratabound gold mineralisation is found in quartz-vein sets and stockworks within Umberatana Group rocks. Main host is the basal sandstone unit of the Appila Tillite and to a lesser extent Tarcowie Siltstone and Gumbowie Arkose higher in the sequence. Workings are scattered around the nose of a broad, north-trending anticlinal dome. The dome has a core of diapiric breccia containing Callanna Group rocks. Discovered in 1894, Mt Grainger has produced a total of 66 kg of gold. (Horn *et al.*, 1985; Morris and Horn, 1988).

Kings Bluff Goldfield is located on the nose and southern limb of an easterly trending anticline in quartzite of the Wilyerpa Formation (Umberatana Group), Gold was found in quartz and clay veins occuping fracture sets mainly near the contact of the quartzite with underlying shale and siltstone. Recorded production is about 32 kg of gold bullion from 967 tonnes of ore. (Horn *et al.*, 1985).

At Eukaby Hill gold occurs with lead and silver mineralisation in quartz vein sets within Tapley Hill Hormation (Newton *et al.* 1982).

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Table 1

OLYMPIC DAM - RESERVES AND RESOURCES

Commodity Unit	Tonnage	Average Grade				Contained Metal			
	Mt	Cu	U_3O_8 kg/t	Au g/t	Ag g/t	Cu Mt	U_3O_8 Mt	Au t	Ag t
Copper - Uranium Total Reserves -Proved and Probable	582	2.1	0.6	0.6	4.9	12	0.36	340	2900
Copper-Uranium Total Resources - Indicated and Inferred	1603	1.1	0.4	0.4	2.4	18	0.64	680	3900
Copper-Gold Reserve	2.3	2.0	0.4	2.2	3.3	.046	.00092	5	7.6
Total Reserves and Resources	2187	1.4	0.5	0.5	3.1	30	1.0	1025	6800

Based on Western Mining Corporation, 1994. Annual Report to Shareholders.

Table 2

OLYMPIC DAM - PRODUCTION 1993-94

Ore Treated Mt	Grade Cu %	Copper Tonnes	Grade U_3O_8 Kg/tonne	U_3O_8 Tonnes	Grade Au g/tonne	Recovered Grams	Au Troy Oz	Grade Ag g/tonne	Recovered Kg	Recovered Ag Troy Oz
2.390	2.95	66684	0.79	1289	0.45	807683	25968	5.5	13168	423374

Based on Western Mining Corporation, 1994. Annual Report to Shareholders.

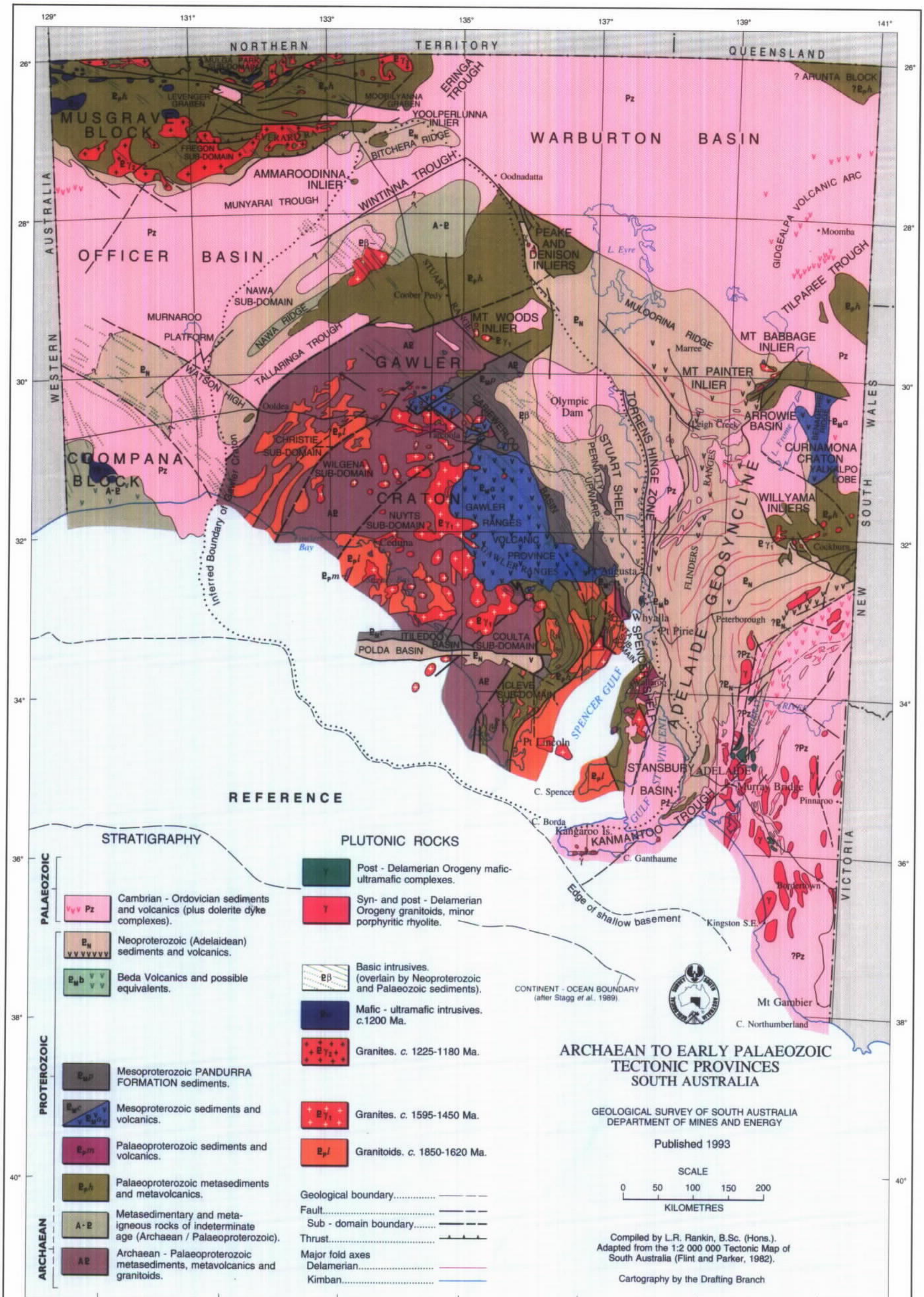
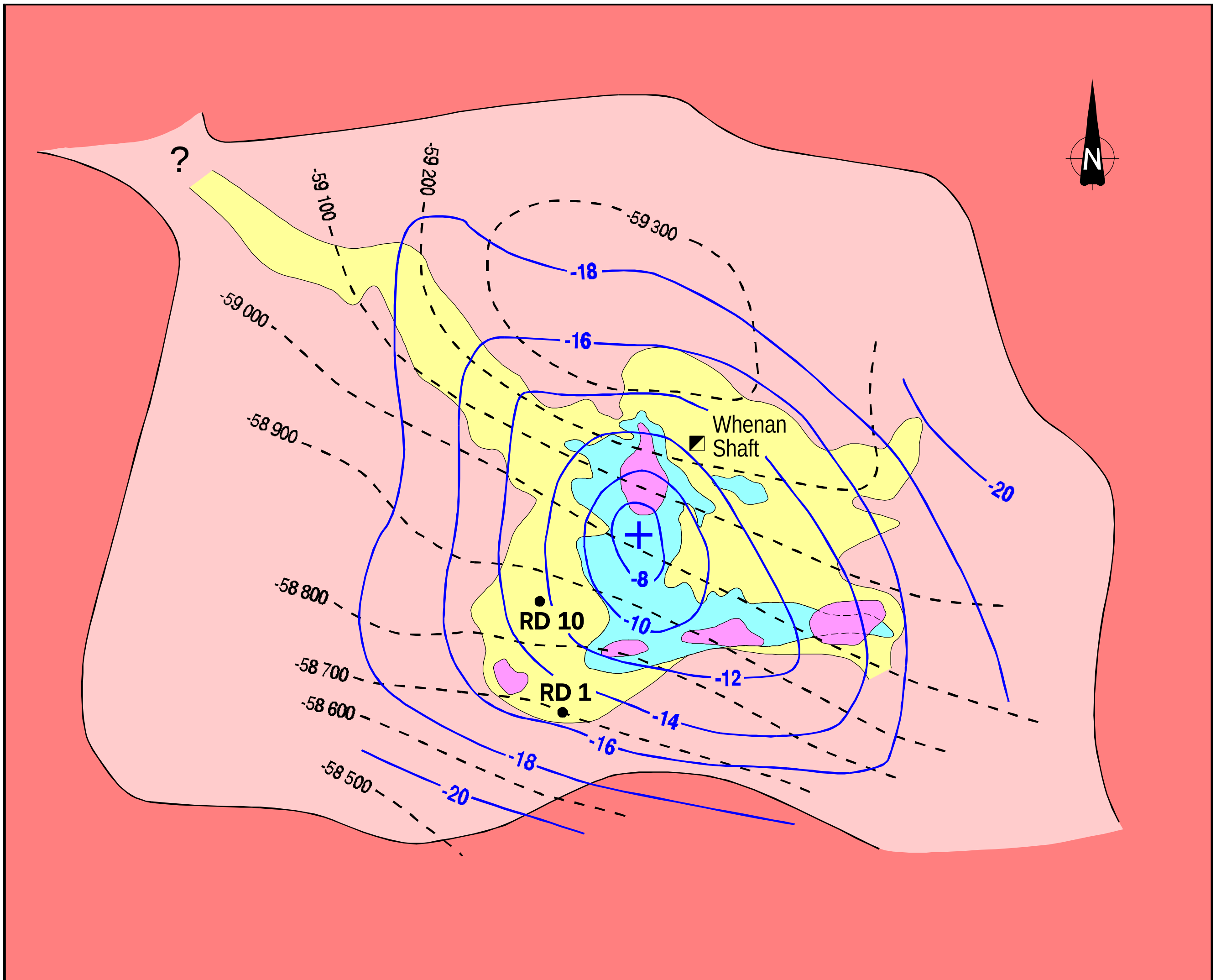


Figure 1
95-854 MESA



Roxby Downs Granite	Gravity contour (mgal) -20
Granite and granite breccias	Magnetic contour (nT) -58 500
Haematite-rich and granite-rich breccias	
Haematite-quartz breccias *(distribution at main level of mine development)*	
Volcaniclastic rocks in diatreme structures	

0 2
KILOMETRES

Figure 2
OLYMPIC DAM DEPOSIT
95-694

MINES AND ENERGY
SOUTH AUSTRALIA

6320SR

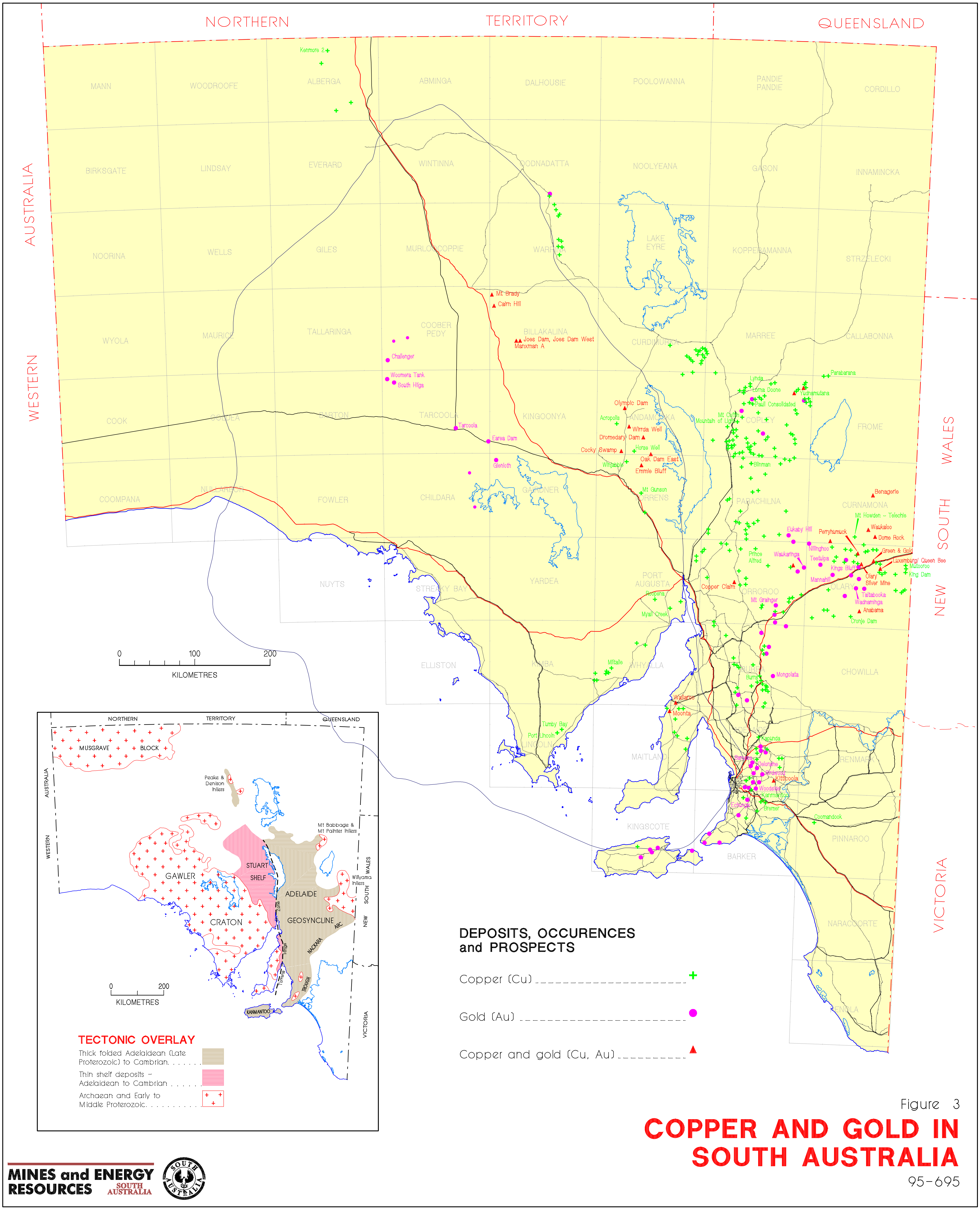


Figure 3

COPPER AND GOLD IN SOUTH AUSTRALIA

95-695