REVIEW OF THE BURRA MINE PROJECT, 1980–2008— A PROGRESS REPORT

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Front cover: Northerly aerial view of the Burra Mine, processing plant and tailings dams in January 1981. *(407315)*

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J.F. Drexel

ABSTRACT

The Burra (Burra) Mine, situated 150 km north of Adelaide within the Adelaide Geosyncline, produced 2.7 million tonnes of copper ore in two major mining phases — 1845–1877 and 1970–81. The first phase was initially by underground high-grade tributing, with later open cutting in the 1870s to reduce costs. This realised around 700 000 t averaging 7% Cu. The second phase, carried out by Samin Ltd, was entirely by open cutting a resource estimated at the time as ~3.5 million tonnes grading 1.52% Cu. The final amount of ore mined during 1970–81 was 1.89 million tonnes grading 1.71% Cu. The pre-mining grade was close to 3% Cu.

Field mapping in 1980–81 by Mines and Energy Geologists J.F. Drexel and W.S. McCallum, followed by petrology of approximately 150 rock samples during 1983–84, and reinterpretation of the thin- and polished sections during the current appraisal of the Burra Mine, has concluded that the orebody was developed by secondary remobilisation of presumably primary chalcopyrite mineralisation associated with syn-depositional and post-depositional magmatic and hydrothermal activity during sedimentation of the host Skillogalee Dolomite of Neoproterozoic age. Secondary copper sulphides, mostly chalcocite, developed from the primary sulphides in an epigenetic environment. Primary and secondary sulphides are now scarce in the open cut, but chalcocite, bornite, covellite and chalcopyrite were present at the bottom of the pit. Supergene enrichment developed the main copper minerals that have been mined — malachite, azurite, chrysocolla and cuprite, with lesser native copper and libethenite. These developed as fracture fills and veins in a relatively open-space environment. Gem-quality botryoidal malachite made the mine world renowned during the 1845–77 mining period. Jigsaw and crackle breccias, often copper mineralised, occur in country rock up to 200 m from the magmatic foci, and related mineralisation extends slightly beyond the open cut limits.

The Skillogalee Dolomite in the Burra area consists of a lower portion comprising dominantly pale-coloured dolomite and an upper portion of dark blue-grey dolomite. Within the lower unit, a distinctive assemblage of siltstone, limestone and dolomite that is atypical of the remainder of the Skillogalee Dolomite has been traced southward from Burra towards Robertstown during regional mapping by W.V. Preiss and is labelled 'Nms9' on the Burra 1:50 000 geological map. The name 'Kooringa Member' has been reserved for this unit, and will be formalised in a future publication.

The geology of the Burra open cut is divided in two by the Kingston Shear. On the west side, a diapiric body intruding the Skillogalee Dolomite occupies the entire length of the pit and may extend up to 500 m to the west. On the east side, the greater part of the pit is occupied by an overall east-dipping succession of the Kooringa Member, with pale-coloured dolomites of the Skillogalee Dolomite above and below. Petrographic examination by A. Kemp and M. Farrand indicates that the Kooringa Member contains probable volcaniclastic or air-fall tuff components developed during a period of syn-depositional magmatic activity which culminated in intrusion of a felsic porphyry, which has been dated during this current project at 797±5 Ma by PIRSA Geochronologist A. Reid. This date has led to significant reinterpretation of the timing of primary mineralisation.

Recognition that the porphyry and associated mineralisation are of similar age to the host Skillogalee Dolomite promotes large tracts of the Adelaide Geosyncline as prospective for similar mineralisation. The Burra orebody was previously thought to be much younger than the

dolomite, and probably post-Delamerian, which influenced previous exploration programs. Rather than being confined to a fault-emplacement model for copper mineralisation, the Kooringa Member, which at Burra is ~150 m thick, should now be the focus as it represents a period of possibly widespread volcanism in an otherwise carbonate-dominated sedimentary environment.

Coarsely crystalline dolomitic marble and brecciated dolomitic marble carrying variable amounts of copper sulphides and pyrite were exposed at the very bottom of the open cut and in small pods along Kingston Shear. Of several possible origins considered, recrystallisation and mineralisation by hydrothermal fluids of the lower portion of the Skillogalee Dolomite is considered the most likely.

Diapiric material, which is generally unmineralised, is juxtaposed adjacent to the mineralisation at Burra by the Kingston Shear, and it too may have been tapped from lower in the Adelaidean sequence, using the Kingston Shear as its conduit to higher levels in the sedimentary pile.

RATIONALE FOR THE 1980–81 FIELD MAPPING PROJECT

Adelaide & Wallaroo Fertilizers Ltd, mine operators during the 1970–81 mining phase, made a decision in 1980 to rapidly mine and stockpile ore for processing through the adjacent plant owned by the company. This decision was based on the need to reduce the cost of dewatering the open cut at a rate of approximately 10 ML/d. Twelve dewatering bores were in operation as at December 1979, removing 12 kL/min, which approximated to 27 tonnes of water for each tonne of ore mined (McLean, 1979; pers comm., 2008). Instability of the southeastern pit slope (and its subsequent failure in January 1981) was also taken into account by the company and influenced the decision to rapidly mine the remaining ore over the final six months of operation.

The former Department of Mines and Energy was involved in discussions with the company, particularly on safety issues, and it was at that time that the mapping project was initiated to collect unique geological data before the ore and hosts rocks were either mined out or flooded.

FIELD PROCEDURES

A stadia survey was carried out from late November 1980 until February 1981 by Mines and Energy staff Bob Harris, Mark Flintoft and John Harrison. The author and Wayne McCallum geologically mapped the open cut, commencing early December 1980 and completing the initial work in early February 1981. Field observations were plotted directly onto copies of the surveyed base. A tape measure extended along each mine face was used to determine the location of each sample or annotation site. Each sample location was designated a sequential ‘B/80’ field number, with the last in-pit sample taken for the mapping project being designated B291/80 (Table 1). All samples were given a weak hydrochloric acid test in the field on both solid surfaces and powdered samples to provide a rudimentary breakdown into limestone, dolomite and non-carbonate materials. A Munsell colour was assigned to all samples, recognising that some units showed a range of colours and that each sample may not be representative of the entire unit.

Detailed mapping was carried out as soon as practical on faces revealed by mining, as subsequent mining was likely to remove the exposure within a day or so. Completed pit faces higher in the open cut that would not be subsequently mined were mapped during periods when it was impractical or unsafe to venture to the lower benches due to mining activity. This method of mapping provided the opportunity to identify rock and ore units in successive vertical ‘slices’ as mining progressed, although not all parts of the pit could be revisited in this manner due to the rapidity and ever-decreasing radius of operations as the final pit depth was reached.

The worked out faces on the southeastern side of the pit were geologically mapped before the massive slope failure in January 1981. The operating company was well aware of the pit instability through constant monitoring, and modified their mining method to allow as much ore as practical to be recovered without causing further instability or safety concerns prior to the failure. The slope failure, when it happened, effectively sterilized some ore below its toe (reportedly 40–50 000 t, from conversation with mine personnel at the time), and mining proceeded with caution in this area. The numerous shallow benches and faces that pinch out at their southern extremities near the eastern pit base are the result of both pre- and post-slope failure modifications to the mining method.

A short visit was made by Drexel, McCallum and surveying assistant Ashley Smith to the now closed mine on 15/2/84 to survey and sample an aggregate quarry being developed in the eastern pit faces. This has removed most of the former exposures, and scree now blankets lower benches down to the pit pool, which represents the local groundwater level. Samples B292 to B297/80 were taken during this visit.

The only fieldwork undertaken in the Burra area by the Geological Survey since that time has been regional mapping by W.V. Preiss for the second edition of the BURRA 1:250 000 map, and two single-day visits by J.F. Drexel, W.V. Preiss, A. Reid and W.M. Cowley to collect additional samples and information to enable definition of the Kooringa Member (Preiss et al., in prep.).

The accompanying geological map (Fig. 18) represents the mine exposure at its maximum extent on 14 February 1981, the day the mine ceased operating.

LABORATORY PROCEDURES

PETROGRAPHY

A suite of 98 rock samples from the 1980–81 mapping project were submitted to Amdel on 20/7/82, mostly for thin section petrography. Polished section petrography was requested on 12 ore samples, and XRD determination of optically indeterminate phases was requested on a further six. Samples were etched with hydrofluoric acid and stained with sodium cobaltinitrite to help distinguish quartz and felspar. The resulting petrological report (Amdel GS1/1/271 progress report 2; Kemp, 1982) was received on 31 March 1982.

This report highlighted the possibility of a significant number of the samples having a volcanic origin — 37 of the 98 samples were listed as tuffaceous or volcaniclastic. Isolated igneous rocks had been recognised previously in the Burra Mine vicinity by Dickinson (1942 — a feldspar porphyry mapped 600 m southwest of the open cut, but not mentioned subsequently), Nixon et al. (1965 — porphyry within the original open cut), and Scriven (1977 — an interpreted welded tuff). But such a large number of possible new occurrences in what until then had been thought of as a predominantly carbonate sequence had implications for not only the interpretation of the origin of the orebody, but the wider interpretation of the Skillogalee Dolomite.

The thin sections were recovered from Amdel and SA Department of Mines and Energy petrologist Dr M. Farrand was asked to complete his own petrography and comment on the original interpretation by Dr Kemp. His summary was released as Report Book 83/28 (Farrand 1983).

The initial batch of 98 rock samples was predominantly from the ore zone and near environs, and included the feldspar porphyry. To help identify or eliminate this as a possible source of volcanic material in non-ore-bearing units of the Skillogalee Dolomite within the pit, a further 42 samples were forwarded to Amdel on 5/3/84 for thin section preparation, staining with alizarin red, and etching and staining of offcuts with hydrofluoric acid and sodium cobaltinitrite. The sections and offcuts were returned to Dr Farrand for full petrographic analysis within the Department of Mines and Energy. His summary, Report Book 84/62 (Farrand 1984), was completed in July 1984. Specific requirements he reported on included depositional environment, non-carbonate sedimentation, evidence of a pyroclastic contribution within the Skillogalee Dolomite, carbonate sedimentation and diagenesis, and metasomatic changes.

Other samples have been forwarded to Amdel for thin section description or identification of minerals, resulting in the following unpublished laboratory reports:

- Amdel Report GS2099/81 (Dr S. Whitehead) — petrographic description of samples 6630RS96 (diapiric float) and 6630RS97 (diapiric breccia) taken two months prior to commencement of the Burra mapping project.
- Amdel Report GS3481/80 (Dr R. Brown) — XRD identification of libethenite in a rock sample from an unrecorded location in the ore zone of the Burra open cut.
- Amdel Report GS4433/80 (Dr R. Brown) — XRD identification of malachite in a rock sample from an unrecorded location in the ore zone of the Burra open cut.
- Amdel Report GS4536/83 (Dr R. Brown) — XRD identification of microcline feldspar in sample B51/80.

GEOCHEMICAL ANALYSIS

A batch of 157 rocks representative of much of the Burra open cut was forwarded to Amdel on 30/11/81 for ‘Metalscan’ emission spectroscopy analysis. Although less precise than other analytical methods, ‘Metalscan’ was a cheap, quick and effective way to determine anomalous elemental presence in a large number of samples. The resulting geochemical report (Amdel AC1/1/271) by Dr K. Rowley was received on 2/2/82.

A further batch of 116 rocks comprising most of the remaining Burra project samples was forwarded to Amdel on 8/3/83 for ‘Metalscan’ analysis. The resulting geochemical report (Amdel AC4694/83) by Dr K. Rowley was received on 28/3/1983.

EARLY REPORTING ON THE BURRA PROJECT

Drexel and McCallum, due to other commitments within the Department of Mines and Energy immediately after the field mapping project, undertook a rapid assessment of all data relevant to the Burra Mine in late 1985. The initial objective was to prepare a comprehensive Report Book on the project. This had to be downsized, and resulted in publication of *Quarterly Geological Note* 98 titled ‘Origin and age of the Burra copper orebody’ (Drexel and McCallum, 1986), which until now has been the only ‘modern’ geological summary available. Ancillary unpublished material compiled mostly by W.S. McCallum at that time, including mine survey data, underground levels, drilling summaries and a list of historical maps, are appended to the current report (Appendices A–F).

QGN 98, and its revelation of a much more extensive volcanogenic component in the Burra Mine, caused healthy debate amongst geologists. This resulted in two papers in QGN 126 — Bampton (1993) proposed a diapiric origin for much of the rock mass in the Burra pit, arguing that other diapirs within the Adelaide Geosyncline are known to contain volcanic clasts, and a response by Preiss and Drexel (1993) who provided evidence to the contrary.

Mention of the Burra Mine is made in Preiss (1987, p.105), where evidence for penecontemporaneous volcanism was interpreted cautiously. At that time field evidence still appeared to favour the porphyry as a younger intrusive post-dating the Delamerian Orogeny, and the extent of tuffaceous siltstones within the temporally related Kooringa Member had not been recognised.

MINING AND PROCESSING OPERATIONS

1845–1877

The mineralised outcrop at Burra, discovered in 1845, is described in Auhl (1986) as ‘a bubble of copper…cropping through the surface to the extent of from three to six feet above the ground’ and ‘some fourteen feet in length’. It was unusual in that, rather than being mostly malachite and azurite, typical of other copper deposits in South Australia, it comprised mainly cuprite, the richest of all copper minerals.

Underground mining commenced in September 1845, with ore being sorted on site for transport by bullock wagon to Port Adelaide and shipment to Swansea, Wales, for treatment. Large smelters (The Smelts) built on the opposite side of Burra Creek to the mine were opened in 1849 to save transport costs. Dewatering the mine was a huge problem, and several Cornish beam engines were employed throughout much of the 1845–77 mining period.

The mine was converted to open cut operations in 1870, and The Smelts were disassembled and shipped to Newcastle. From 1870, most of the Burra concentrates were smelted at Port Adelaide. Open cutting continued till 1875, when the mine operator realised that concurrent underground mining of remaining rich pods was the only way to keep the operation viable. High dewatering costs and depressed copper prices forced the mine to close in 1877.

The1845–77 period realised around 700 000 t of ore containing ~50 000 t of copper (Drexel, 1982).

1970–1981

The second phase of mining at Burra, carried out by Adelaide & Wallaroo Fertilizers Ltd, was entirely by open cutting a resource estimated at the time as ~3.5 million tonnes grading 1.52% Cu. The company made a decision to rapidly mine and stockpile ore over the final six months of operations for processing through the adjacent plant owned by the company. This decision was based on the need to reduce the cost of dewatering the open cut at the rate of ~10 ML/d. Dewatering commenced in 1975, and 12 dewatering bores were in operation as at December 1979, removing 12 kL/minute, which approximated to 27 tonnes of water for each tonne of ore mined (McLean, 1979; pers comm., 2008). At that time the hydrostatic water level in the pit had been lowered by 69 m, to 3 m below the pit floor. Instability of the southeastern pit slope was also taken into account by the company and influenced the decision to rapidly mine the remaining ore.

Much of the bulk mining, in particular removal of mullock but also mining of friable ore towards the pit bottom, was done by a Marion electric shovel. A Kato excavator was used for selective and below-grade mining. Drilling and blasting were required in the northern part of the pit in the relatively unaltered Skillogalee Dolomite overburden. No blasting was employed during mining of the ore in the southern part of the pit, where it was generally soft, friable and easy to dig.

Two small karst features filled with copper-mineralised clasts were excavated from below the northern haul road for processing, and the karsts backfilled (D. McLean, former Burra Mine Geologist, pers. comm., 2008).

Hard, recrystallised dolomitic ore at the western bottom of the pit adjacent to Kingston Shear, and as a bar across the centre bottom of the pit, was scraped clean of softer ore, and left in place. Much of this was covered with mullock during construction of the haul road to access ore on the eastern side of the pit during the final phase of mining (Fig. 1). This dolomitic ore, although high grade, could not be treated successfully by the ammonia leach process employed at the Burra plant. Similarly, the porphyry, which contained a high percentage of copper sulphide, mostly as chalcocite, was mined and stockpiled to the south of the treatment plant. The stockpile was frequently turned by bulldozer to encourage oxidation, and all porphyry ore was eventually processed through the plant (D. McLean, pers. comm., 2008).

Pods and lenses of high-grade ore were recovered from small areas such as that centred on mine grid 4330mN, 3150mE (AMG 307685mE, 6271645mN) close to the porphyry. This pit, and other similar pits developed during the mining of small ore pods, were subsequently backfilled with mullock to allow construction of the haul road to the bottom of the open cut and mining of the eastern face. It was during this latter stage of operations that the unstable eastern pit wall was induced to fail on 14 January 1981 by the operating company pumping water down the slide surface (Fig. 2). This controlled failure caused ~150 000 t of material to slump to the pit floor, and sterilised some ore (reportedly 40–50 000 t, from conversation with mine personnel at the time).

Operations ceased on 7 February 1981, with a final maximum pit depth of 106 m below surface (Fig. 3). At that time, 4.8 million tonnes of dolomite–siltstone overburden and 1.89 million tonnes of ore grading 1.71% Cu had been mined since 1970 (Armstrong, 2002). The ore stockpile of ~380 000 t continued to be processed by Samin Ltd (which had purchased the mining rights from Adelaide & Wallaroo Fertilizers Ltd) at its adjacent plant for several years, after which various types of copper feed, including copper cement from the Mt Gunson Mine, were used. The product at that time was a range of specialty copper-based chemicals, including cupric oxide and copper sulphate. An overview of the ammonia process employed is described by Armstrong (2002).

The Burra Copper Sulphate Plant was officially opened by the Hon. R.J. Gregory, SA Minister for Labour, on 13 December 1989. The plant continues operating to the present day, using secondary ores and copper concentrates from other mines around South Australia, including Mountain of Light, Kanmantoo and Mt Gunson, and scrap copper. Its main products are now copper oxide and synthetic malachite. Around 10 000 t of combined products are produced annually.

Figure 1. Preparing the haul road on the western side of the Burra open cut prior to mining the lower southeastern side. Fill is being placed over the worked out area in which mostly recrystallised dolomite marble was exposed. The truck is dumping over the former location of the porphyry shown in Figure 6. Diapir is to the right of view. December 1980. *(407316)*

Figure 2. Failure of the southeastern pit wall induced on 14 January 1981 by pumping water down the slide at the top of the open cut. *(045790)*

Figure 3. Burra open cut the day before mining operations ceased on 7 February 1981. The view is northerly along the open cut from the vicinity of Morphett's Engine House. *(T026047)*

GEOLOGICAL MAPPING AND INTERPRETATION

OVERVIEW

Lithological subdivisions of the Skillogalee Dolomite in the northern two-thirds of the open cut could be traced with confidence during the 1980–81 mapping project, although mullock from active mining operations disguised some benches and faces. The southern third of the open cut contains lithologies that have been altered to varying degrees by a combination of processes including potash metasomatism, silicification, introduction of magmatic phases, brecciation, and acid leaching presumably from the breakdown of metallic sulphides within the original orebody. Partial silicification of predominantly clastic quartz in the siltstone units in the southern third of the open cut has in places increased grain size such that 'sandstone' recorded in this area during mapping does not have a lateral equivalent in the unaltered northern two-thirds of the pit. These factors have made correlation difficult, and that part of the project has yet to be completed — information relevant to any correlation still resides on the original hand-sketched field plans prepared by Drexel and McCallum during 1980–81, and in further examination of the 'B/80 series' of samples taken at that time and stored at the Glenside Core Library.

Acid testing of samples taken during 1980–81 provided a rudimentary breakdown of lithologies into dolomite, limestone and non-carbonate, enabling 14 units to be distinguished within Skillogalee Dolomite exposed in the open cut. Subsequent thin-section petrography identified a 'significant' silt component of quartz and feldspar in samples logged as dolomitic in the field (note that a low threshold of only 15% clastics was sometimes sufficient for the petrologist to denote a rock as 'siltstone'). Dolomite in the field was often identified in thin section as a silty dolomite or dolomitised siltstone. Facies changes, and dolomitisation along bedded units closer to the centre of the open cut, are also present, such that a limestone may, within a few hundred metres, be mapped as a dolomite.

A distinctive package of predominantly siltstone–dolomite–limestone was recognised extending southward from Burra toward Robertstown by W.V. Preiss during regional mapping and labelled 'Nms9' on the Burra 1:50 000 geological map (Preiss, 2002). The term 'Kooringa Member' was reserved with the Stratigraphic Nomenclature Committee for future formal definition (Preiss et al., in prep.). The Kooringa Member is well exposed in the northern haul road of the open cut (Units 2–14 on Fig. 18), which will be used as its type section. It was initially thought that the Kingston Shear may have truncated the lower part of the member, but it is now apparent that the complete unit is preserved and both overlies and underlies pale coloured dolomite of the lower portion of the Skillogalee Dolomite.
The dolomitic siltstones identified in thin section sometimes have a K-feldspar component of 50% and more in some laminae and beds. Splintered quartz grains in some add weight to the two petrographers' (Kemp, 1982; Farrand, 1983, 1984) interpretation of a volcaniclastic ash-fall component in several units of the Kooringa Member exposed in the pit. These lithologies provide potential for age dating of any associated zircons.

Stromatolites and cryptalgal laminations are present in some units, particularly in the limestones and pure dolomites. Some limestone beds display extremely regular and rhythmic fine laminations best interpreted as chemical precipitates in a lacustrine environment.

A suite of igneous units identified towards the base and southwestern side of the open cut includes the porphyry and agglomerate. These intrude earlier deposited tuffaceous siltstones and dolomite of the Kooringa Member. Jigsaw brecciation, mostly copper mineralised, occurs within Skillogalee Dolomite units up to 100 m from the northern limit of leaching and alteration. Crackle (granular) breccia within mostly dolomitic units may be related to this — both are presumed to have formed by hydraulic brecciation due to pressurised volcanic fluids, a concept first discussed by Nixon et al. (1965). Near-vertical ferruginous pipes and larger areas of ferruginisation, sometimes with very coarse limonite pseudomorphs after pyrite, occur within and adjacent to the copper mineralisation. These were formerly iron- and perhaps copper-sulphide-rich bodies.

The ‘cross-fault’ shown by previous authors (e.g. Wright, 1975) and orientated east–west across the centre of the pit was not readily apparent during mapping. The ‘fault’ was perhaps inferred to account for the rapid change of lithology at the northern edge of the main orebody. It is proposed here that the ‘cross-fault’ is instead the northerly extent of leaching by acidic waters resulting from oxidation of the primary sulphide orebody to produce the present copper carbonate ore.

The western edge of the open cut is bounded by the Kingston Shear, to the west of which is a small diapiric breccia body exposed over the full length of the pit.

DESCRIPTION OF LITHOLOGIES IN THE OPEN CUT

Bedded Skillogalee Dolomite units

As described in several petrological reports prepared by Amdel and departmental geologists, in particular Kemp (1982) and Farrand (1983, 1984), a large part of the Kooringa Member was deposited in a quiescent, almost stagnant environment that sponsored the deposition of dolomite as a primary chemical precipitate. Minor limestone, sometimes accompanied by algal growth and stromatolites, was also present. The Coorong is a modern analogy.

Into this environment were deposited significant amounts of microcline feldspar and quartz as euhedral to subhedral, sometimes shattered fragments. The freshness of the feldspar, angularity of clasts and high potassium content of the matrix are compatible with, but not definitive of, a volcanic origin, but petrology indicates the most likely genesis as air-fall tuffaceous siltstone horizons. The siltstones, along with interbedded limestones, dololimestones and dolomites, are unusual in a regional context within the dominantly dolomitic Skillogalee Dolomite (W.V. Preiss, PIRSA, pers. comm., 2008). They have been assigned to Units 2–14 described below, and collectively comprise the Kooringa Member to be formally defined by Preiss et al. (in prep.). Unit 1 is a relatively clean dolomite with no indication of silt-sized components, and is assigned to the lower portion of the Skillogalee Dolomite immediately underlying the Kooringa Member. Unit 14, at the extreme eastern edge of the open cut, contains a small amount of limestone, and is therefore also included in the member. To the east of the open cut, the more typical dolomite (with little if any siltstone and limestone) of the Skillogalee Dolomite is exposed.

Unit 1

Dolomite: cream to light grey, massive, extremely fine-grained sedimentary dolomite. Fractured to granular appearance on freshly broken surfaces.

Unit 2

Siltstone, dolomite: light to dark grey, banded to laminated ex-pyritic siltstone beds to 100 mm wide interbedded light brown, finely laminated and more massive, light grey-brown dolomite interbeds to 400 mm width. Minor sandy interbeds. More finely bedded in upper 3–4 m.

Unit 3

Dolomite, siltstone: 1.5 m thick medium grey, extremely fine grained, partly cryptalgal-laminated sedimentary dolomite, overlain by a 150 mm thick pale brown laminated siltstone, and an upper 800 mm thick dolomite similar to the lower dolomite.

Unit 4

Siltstone, dolomite: fine grained, light orange to buff, finely laminated siltstone interbedded with more weathered and eroded light grey dolomite. Individual interbeds are 50–100 mm wide.

Unit 5

Siltstone, dolomite: narrow interbeds of brown, laminated siltstone and medium grey dolomite in lower 3 m; tectonically folded and partly brecciated with minor silicification along northern haul road. Upper 7 m is a soft, altered, copper-mineralised, layered, sandstone-like remnant of the northern orebody; some probable shearing subparallel to bedding.

Unit 6

Dolomite: massive, cream-grey sedimentary dolomite (60–300 mm beds) interbedded with finely laminated (0.5–3 mm) slightly darker grey dolomite and minor siltstone. Stromatolitic in part.

Unit 7

Limestone, dolomite: light grey finely laminated limestone 800 mm thick at base, overlain by ~1 m wide massive medium grey dolomite, then 1 m wide dark grey (almost black), dense, faintly laminated dolomite and tan, very finely laminated dololimestone to limestone. This is overlain by 2–3 m of cryptalgal laminated, stromatolitic and stylolitic limestone. Weathering of the limestone units produces a strong fissile parting.

Unit 8

Limestone, dolomite: white to cream, laminated to massive folded and brecciated limestone-dololimestone lens; trace white mica flakes.

Unit 9

Dolomite, limestone: medium-grey dolomite and limestone interbeds with cream, millimetre-scale laminae. Upper half of the unit is massive grey-buff dolomite with white-cream dolomite interbeds; the top 1 m is laminated grey-buff and white dolomite.

Unit 10

Limestone, dolomite: white to cream laminated limestone with 0.6 m wide grey dolomite band 1 m above base. Overlain by 3 m of white-cream to mid-grey laminated to massive limestone. Upsequence becomes a finely laminated dolomitic limestone, overlain by a very dark grey, black and buff limestone with extremely regular and rhythmic laminations. The top of the unit is buff limestone with fewer and less distinct cryptalgal laminae.

Unit 11

Dolomite, limestone: light grey, hard, dense, massive sedimentary dolomite with minor bedding-confined ‘shothole’ texture comprising 3–10 mm cavities sometimes filled with red clay. Sandy dolomite and dolomitic limestone in places; minor cryptalgal laminae. Some limestone interbeds to 200 mm.

Unit 12

Dolomite: Massive, light grey dolomite with some thinly laminated beds. Shows strong ‘shothole’ texture towards base, and cryptalgal laminations towards the top. ‘Shothole’ cavities of 2–10 mm sometimes filled with a white to yellow powder.

Unit 13

Dolomite: white-grey-cream laminated dolomite with 100–400 mm beds of light grey non-laminated dolomite. Minor limestone interbeds.

Unit 14

Dolomite: 1–5 m wide dark grey dolomite with lighter grey and brown dololimestone or limestone interbeds. Overlain by a fine-grained, grey dolomite with 2–10 mm sandy interbeds outlined by finely crenulated bands of probable stromatolitic origin.

Skillogalee Dolomite units in the southern part of the open cut have been affected by alteration not seen in the northern part of the pit. Silicification, potash metasomatism, hydraulic brecciation, volcanism, and probable leaching and bleaching by acidic fluids released by breakdown of sulphides have transformed the former carbonates and siltstones into clay and sand at the extreme. This made correlation of units difficult along the full length of the open cut, indicated by the undifferentiated southern portion of Figure 1 which, when interpretation is completed, will show mostly Units 1–10 plus the volcaniclastics and ore horizons.

Siltstones of Units 2 and 4 will probably eventually be traced with reasonable certainty as their clastic quartz and feldspar content proved more resistant to alteration. Characteristic millimetre-scale quartz ‘discs’ containing very small ex-pyrite pseudomorphs just inside their periphery were found in samples B10, B46, B75, B97, B116, B227 and B243; these are thought to belong to Units 2 and 4.

Euhedral white mica books 2–5 mm across were noted in predominantly limestone or dololimestone units during field mapping, and were described in several thin sections (B103, B126, B265 and B266). Petrology initially identified these as muscovite, but in B126/80 Farrand (1984) identified phlogopite, a magnesium-rich mica that usually occurs in crystalline limestones as a result of de-dolomitisation. These mica occurrences are scattered across Units 5, 6, 7 and 10, but may assist in correlation through the southern part of the open cut.

Recrystallised, mineralised dolomitic marble

One of the few indurated lithologies exposed in the bottom of the open cut is a dense, white dolomitic marble with euhedral dolomite rhombs up to 20 mm across. The rock is laced with secondary copper sulphide, oxide and carbonate veining; mineralisation in a polished section of sample B54/80 comprises chalcocite (98%), covellite (1%) and cuprite (1%), with azurite veining and patchy replacement. Despite its copper content, much of the marble was left in place during mining as it was generally too hard to dig by excavator without blasting, and the ammonia process employed at the plant could not effectively recover the high copper content in the sulphide ore (Fig. 4).

Figure 4. Southerly view of selective mining at the very bottom of the Burra open cut on 8/12/80. Less-indurated ore has been mined by excavator, leaving behind the wooden supports and fill from the 1800s underground mining, and hard recrystallised dolomitic marble that could not be free dug. *(407317)*

All occurrences of the dolomitic marble are in contact or near contact with the Kingston Shear and diapiric breccia. Early reports of copper ore being won from marble breccia are most probably referring to this marble rather than the diapir itself, as no mineralisation of any note was found in the latter during mapping, despite it being in direct contact with high-grade copper ore.

The marble was exposed by mining over a maximum width of approximately 45 m and length of 130 m, with its southernmost limit being at the very southern end of the open cut in the vicinity of Peacock's Shaft. Similar but smaller bodies of the marble up to 30 m in length occur immediately adjacent to the porphyry below Graves Enginehouse, and as 'windows' within faulted Units 1 and 2 further north adjacent to Kingston Shear. The marble in some places has been brecciated (e.g. B282/80).

Three possible scenarios for development of the recrystallised (±copper mineralised) dolomite marble (±brecciation) have been considered:

- The marble may have crystallised from hydrothermal fluids driven from the parent body of the porphyry. The lack of carbonate veining further away from the marble body renders this concept problematical.
- W.V. Preiss (PIRSA, pers. comm., 2008) has suggested that the marble may be a more recrystallised version of the lower Skillogalee Dolomite that occurs immediately below the mine sequence, and also west of the Kingston Shear. It is possible that the folding exhibited in the northern and eastern pit walls is sufficient to allow the lower member to appear in the western and southern part of the open cut. Smaller exposures of marble along Kingston Shear in the northern part of the pit appear to cut across bedding in Unit 1, but the contacts are sheared and the relationships could result from tectonic imbrication in the shear zone.
- The marble may be a carbonatite body, perhaps sourcing material from similar depths to the immediately adjacent diapir. This idea should be tested by geochemistry.

An unusual variant of the marble that can still be accessed in the open cut is at sample site B264/80. The outcrop here is a layered, copper-mineralised recrystallised dolomitic breccia containing clasts and layers of potash feldspar. The feldspar was probably derived from, or associated with, the quartz-feldspar metasomatites common in and around the main orebody. To its immediate east is a dolomite breccia (grey, angular dolomite clasts in a yellow-brown dolomite matrix) containing a possible dolomitic sandstone dyke (sample site B288/80); this breccia is unmineralised, despite being in contact with the heavily copper stained recrystallised dolomitic breccia. A detailed study of this outcrop may provide information relevant to the understanding of potash metasomatism and mineralisation in the Burra orebody.

A small area of the recrystallised, mineralised dolomitic marble at sample site B280/80 differs from the remainder of the marble occurrence in that it shows little recrystallisation by comparison. Instead, the rock appears as a light grey dolomite with extensive malachite–azurite veining, and traces of chalcocite in stringers. A sawn surface of the rock shows numerous arcuate structures that appear to truncate earlier arcuate structures, much like mineralised, interlocking liesegang rings. Petrology by Kemp (1982) indicates that the rock may be dolomitised (a process which would have obliterated former coarsely crystalline components). It could equally be a Unit 1 (or lower) dolomite precursor that escaped the more robust recrystallisation process that may have been associated with the nearby intrusion of porphyry or agglomerate.

Magmatism recorded in the Burra Mine

OVERVIEW

Dickinson (1942) mapped a small body of feldspar porphyry 600 m southwest of the mine but made no further mention of it. Nixon et al. (1965) first identified a feldspar porphyry outcrop in the Burra open cut that had been deliberately avoided by the miners of the 1800s, who were unable to treat the contained copper sulphides (chalcocite, bornite). It was shown on their map (L65-82) as five sub-parallel dyke-like bodies to the immediate west of the old mine pool (the hydrostatic groundwater level). Nixon and Townend (1966) also reported on the occurrence. The porphyry was completely mined out by the end of the 1970–81 mining phase. Scriven (1977) re-examined the porphyry and interpreted eutaxitic textures characteristic of a welded tuff, and identified it as of rhyolitic composition.

Drexel and McCallum (1986), reporting on outcomes of the 1980–81 mapping program, identified a much larger area of volcanics in the bottom of the open cut, up to 160 by 75 m adjacent to the porphyry. Thin-section evidence cited for recognition of the volcanics included: flow banding, trails of gas bubbles parallel to flow banding, partially digested sedimentary xenoliths, aligned compacted devitrified glass shards, and a very fine matrix of angular quartz and feldspar. It was at this time that an agglomerate was identified (sample B53/80) during routine petrology by Kemp (1982) and Farrand (1983, 1984). Kemp and Farrand also identified numerous samples of Skillogalee Dolomite from the Burra open cut that contain angular subhedral to euhedral feldspar shards and shattered quartz indicating little if any abrasion that would normally be associated with a waterborne origin. Their most probable origin is from volcanic ash clouds.

Several occurrences of probable magmatic rocks within the Kooringa Member have been recorded up to 5 km from the open cut.

TUFFACEOUS SILTSTONES OF THE KOORINGA MEMBER

Within the Burra open cut

Bedded siltstones in Units 2, 4 and 5 along the northern haul road of the open cut contain laminae with a high feldspar content, e.g. B7/80 (50% K-feldspar, 5% plagioclase) and B10/80 (up to 80% feldspar and kaolinite). Towards the centre of the open cut, B274/80 in Unit 4 was identified as containing 40% K-feldspar and 5% plagioclase, with 20% sericitic mica. These locations were re-sampled in December 2008 for geochronology.

Samples B10, 46, 75, 97, 116, 227 and 243, all laminated siltstones, contain millimetre-scale flattened quartz discs with minute ex-pyrite pseudomorphs just inside their periphery. B116 also contains 70% microcline feldspar and 30% quartz. All are probable volcaniclastics from along the length of the open cut; further work is needed before some are assigned to individual Units 2, 4 or 5. The origin of the flattened discs is unknown at present, but may have been derived from a proximal volcanic source.

Sample B122/80, collected during the 1980–81 mapping project from the eastern lip of the open cut, was identified by Farrand (1984) as containing '…the most significant bed of all. This consists of relatively coarse grained, angular fragments of plagioclase in a matrix of coarse and fine grained dolomite…The plagioclase appears to be rather pure albite…It is hard to avoid the implication…that a shower of fragments was contributed to stagnant water by an agency which did not involve increased current action.' This site was also re-sampled in December 2008 for geochronology.

B199/80 is described by Kemp (1982) as a 'very fine-grained, faintly laminated, silicified, dolomitised acid ?volcanic', while Farrand (1983) recognises it as a 'dolomitised shale'. It is much finer grained than other lithologies in the open cut, and differs in that it contains fresh sulphides (~5% total volume) identified in polished section (Kemp, 1982) as pyrite (+99%) and chalcocite (trace).

B101/80, described in field notes as 'highly altered fine-grained siltstone-like rock with contorted dark red-purple and white banding', has not been described in thin section. It is highly reminiscent of a flow banded tuff. B252/80 and B286/80, both from ferruginised pods near the bottom of the open cut, are also potential candidates as volcaniclastics.

B261/80, from very low in the stratigraphic succession on the western side of the open cut, contains 65% feldspar, dominantly microcline, as euhedral laths up to 1.75 mm in thin section. Quartz comprises 20% of the section. Kemp (1982) described the rock as a partially silicified feldspathic tuff. The number and euhedral shape of the laths sets this sample apart from all others at Burra, and its location in the Kooringa Member is still uncertain. It is in an area originally mapped in the field as Unit 1 because of nearby dolomite exposures, but its feldspar–quartz content renders this correlation problematic. It may be Unit 2, or could be another tuffaceous siltstone below or within Unit 1. The sample is from an area of probable imbrication close to the Kingston Shear, and more detailed mapping is required for a resolution. The tuff should also be sampled for geochronology.

Outside the Burra open cut

Whittle (1966) reported a tuffaceous shale from an old quarry immediately north of the Adelaide–Burra road, approximately 1.5 km south-southeast of the open cut. The important feature in his thin section description is the recognition of a 'smaller proportion of … zircon…' This shale is within the Kooringa Member as mapped by Preiss (2002), and may prove dateable. Whittle (1973) described a 'fenitised?–carbonatised? chert' from ~200 m south of the open cut (mine grid 3779 N, 3170 E), possibly from a similar horizon.

Redfire Resources (Elliott et al., 2003) reported a possible sheared syenitic rock with residuals of primary quartz–microcline in the small 'Grove quarry' adjacent to the Barrier Highway 5 km north-northwest of Burra. In November 2008, samples were taken for petrography from this quarry by Preiss, Drexel and Cowley who also identified bleached fragmental layers in the nearby exposure as possible volcaniclastics. This occurrence may therefore be a possible northern extension of the Kooringa Member.

Although the Redfire sample may be too altered to provide useful feldspar or zircon, the other samples should be re-examined, or specimens collected from the field or Glenside Core Library, to determine any mineral components, particularly zircon, that may provide an age date for that unit within the Skillogalee Dolomite.

AGGLOMERATE

Sample B53/80, from the bottom of the open cut at least 50 m from the last recorded occurrence of the feldspar porphry, was described by Kemp (1982) as a probable welded tuff, and by Farrand (1983) as an altered ?lava. Both petrographers were quite definite that the rock is of volcanic origin. Farrand stated that '…the flow banding is regular enough to suggest a lava rather than and ash-flow tuff of agglomerate'. He also found xenoliths (undefined lithology) that may have been subject to autobrecciation. The occurrence was noted in the field as an unremarkable 1 m wide pod of dark red ?ferruginised, altered ?feldspathised rock within an altered silicified halo. It is therefore most likely to have formed within a side vent or fissure to a larger volcanic vent from which erupted the ash clouds that contributed feldspar and quartz shards to the siltstones of the Kooringa Member. The agglomerate should therefore be considered within the stratigraphic sequence of the member.

Sample B141/80 was identified in thin section by Farrand (1983) as an agglomerate, and by Kemp (1982) as a breccia composed dominantly of volcanic fragments and fragments of ?siltstone possibly formed by explosive volcanic activity (Fig. 5). This copper-mineralised sample differs from B53/80 in that the clasts are readily visible and clearly are not entirely of local origin. Kemp noted that small, irregular fragments of volcanic glass are common, frequently displaying spherulitic and flame structures. Farrand also noted the jumble of fragments of diverse lithologies, both sedimentary and volcanic, but did not indicate the existence of volcanic glass. The possibility remains that this is an agglomerate, or perhaps an autoclastic volcanic breccia.

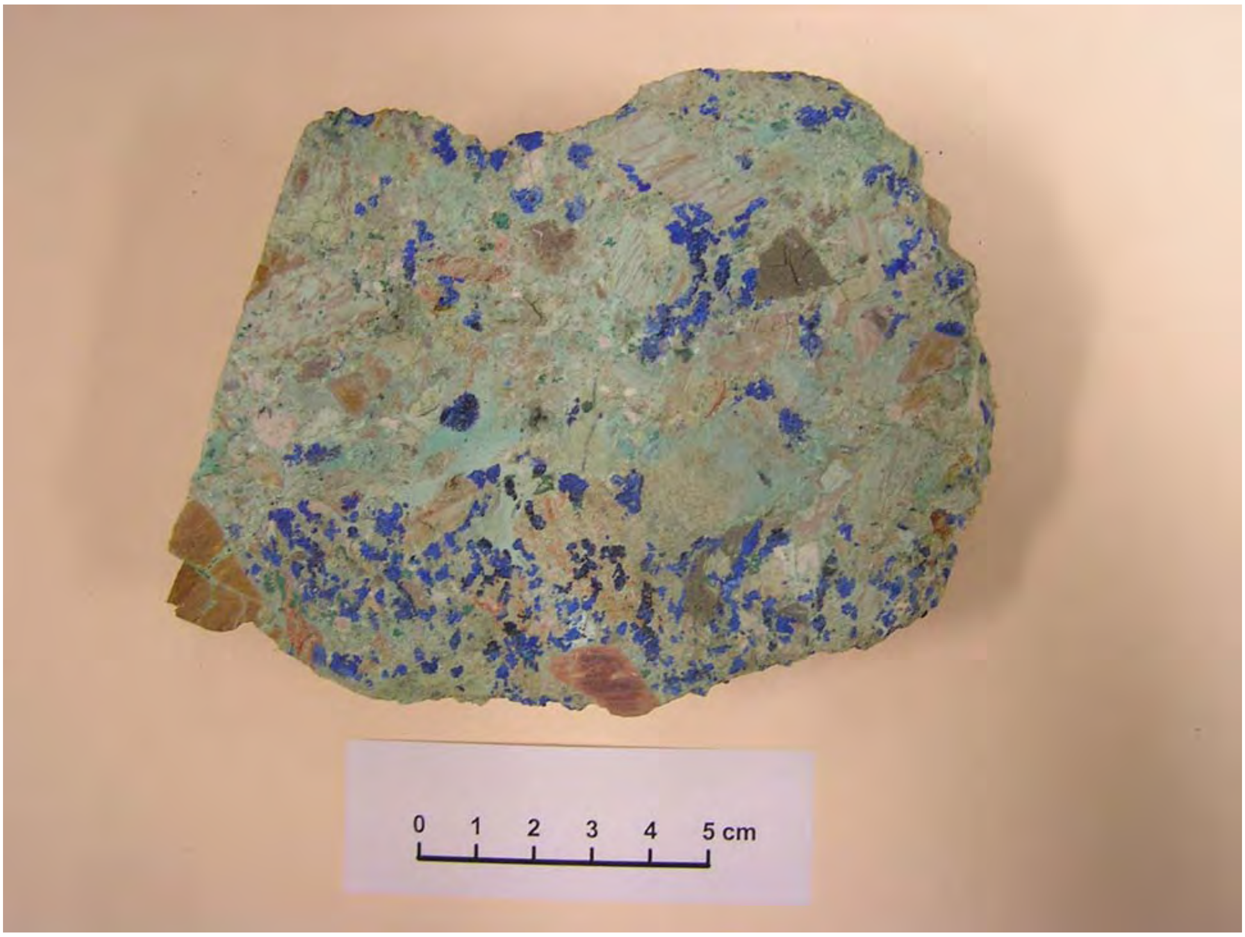

Figure 5. Copper-mineralised agglomerate intruding Unit 5 siltstone, sample site B141/80. *(407318)*

PORPHYRY

Black and white photographs taken of the mine post-1877 but pre-1970 show the porphyry as a white outcrop perhaps 3 m high at the level of the mine pool. This is one of the five curved but sub-parallel pods that were exposed over a distance of ~30 m (Nixon et al., 1965). Each pod was less than 2 m wide. Only one pod could be accessed during 1980-81 mapping project, and this showed a distinct dyke-like attitude, cutting the near-vertical Skillogalee Dolomite units at a relatively low angle (Fig. 6). Plotting the location of 'porphyry' occurrences at successive levels during mining indicated that the pods plunge ~20° to the southeast at the higher elevations seen by Nixon and Townend (1966), and 50° towards the southeast at the pit bottom.

Sample B285/80 of the porphyry is surprisingly indurated considering the degree of alteration and weathering of immediately adjacent Skillogalee Dolomite country rock. Thin section C35027 indicates a relatively fresh rock with a strong igneous texture of predominantly feldspar and quartz. Coarsely crystalline feldspar patches have been interpreted as phenocrysts of microcline and untwinned K-feldspar in a groundmass of microcrystalline quartz and feldspar, including microcline. Veins and patches of secondary feldspar appear to be mostly albitic. The polished section description (PS30625) identified the sulphide phases as chalcocite (50%) and pyrite (50%), with traces of bornite, chalcopyrite and possibly cubanite.

Figure 6. Porphyry exposed on 7 October 1980 on the western side of the open cut. The porphyry is the narrow ~3 m wide grey zone at extreme right, with wooden supports from previous underground mining operations on either side just below the top of the face. Montmorillonite and kaolin alteration comprises most of the white material to the left of the porphyry. Stope fill and wooden supports are exposed over the remainder of the face. Diapir is in the background. *(407319)*

Age of the porphyry — 797± 5 Ma

Approximately 10 kg of the porphyry (sample B285/80) were collected by Drexel and McCallum in 1981 and stored at the PIRSA Glenside Core Library until commencement of the current project, when the decision was made to age date any zircons recovered from crushing a 1 kg sample. Anthony Reid, PIRSA Geological Survey Branch geochronologist, arranged zircon separation and dated the zircons at Adelaide University using the Laser Ablation – Inductively Coupled Plasma Mass Spectrometry technique (Appendix G).

The age of 797±5 Ma determined from the zircons was most surprising, as field evidence had consistently been interpreted as indicating emplacement of the 'porphyry' and associated mineralisation into a probable post-Delamerian Orogeny near-surface environment. The porphyry was exposed by mining in near-vertical dyke-like bodies cross-cutting at relatively shallow angles steeply easterly dipping Skillogalee Dolomite. It was therefore assumed that the Skillogalee and other Adelaidean units had been folded during the Delamerian into their present attitudes prior to the 'porphyry' and agglomerate bodies being emplaced.

It now appears that the volcanism was penecontemporaneous with Skillogalee-age deposition, and that the porphyry intruded soon after deposition in only slightly discordant sill-like attitudes. It is postulated that the thin bodies of porphyry and agglomerate were likely formed within side vents and sills from a proximal larger parent vent that has not yet been discovered. The porphyry in particular probably intruded late during deposition of the Kooringa Member, as copper-mineralised hydraulic breccias thought to be developed by pressurised magmatic fluids are present throughout the member. The angular clasts derived from the Kooringa Member indicate that induration was well advanced prior to their incorporation into the breccias, presumably aided by rapid carbonate-cementing processes.

Implications for future exploration

It is highly probable that much of the non-carbonate part of the Kooringa Member is of volcaniclastic origin. Only a few representative siltstone samples were taken during the 1980–81 field mapping from its 13 units and these showed no unusual characteristics in hand specimen, but most contained high percentages of feldspar fragments. Geochronology has demonstrated a probable close temporal association between the Kooringa Member and the porphyry, which has great implications for future exploration for similar copper orebodies in the Adelaide Geosyncline. Rather than concentrating on mineralisation related to post-Delamerian igneous intrusion via a pre-existing conduit (the Kingston Shear) as previously thought, the entire outcrop length of the ~150 m thick Kooringa Member holds potential for mineralisation. The prime aim would be to find indications of other volcanic vents throughout this widespread horizon.

POTASH METASOMATISED LITHOLOGIES

Potash metasomatism associated with silicification was recorded in outcrop and in numerous thin sections. First indication of potash feldspar seen during the 1980–01 mapping project was as a widespread pink colouration on many rock surfaces approximately 5–10 m above the final pit bottom. This was not seen at higher levels, perhaps due to weathering effects, or it not having been present at those levels. Sample B191/80, described by Kemp (1982) as containing 77% K-feldspar and 20% quartz, was taken approximately 20 m east of agglomerate sample B53/80 described above. This is a typical sample of a highly feldspathised lithology, identified by Kemp as a ?tuffaceous precursor, and probably belonging to the Kooringa Member.

Numerous other examples of in situ potash and silica metasomatism have been recorded on the accompanying geological map and description of rock samples from the Burra open cut (Fig. 18; Table 1). Many breccia samples also include potash metasomatised lithologies as clasts, indicating that metasomatism occurred early in the mineralising event, possibly around the time of the porphyry intrusion. B198/80 is a spectacular example of potash metasomatised clasts in a ‘vein’ of malachite at least 70 mm thick (Fig. 7). This sample demonstrates that the ground was thoroughly prepared for copper mineral infusion, probably by hydraulic ramming associated with volcanic fluids. Well-developed botryoidal malachite on the outer edge of the sample demonstrates that the supergene mineralisation was deposited in an open-space environment.

Potash feldspar also occurs in sample B264/80 described above in the section titled ‘Recrystallised, mineralised dolomitic marble’. Here, Kemp (1982) records it as occurring as ‘replacement of a grey material’, as grains of dolomite, quartz and feldspar, and as a part matrix to all the above. Its occurrence at this location is problematic. Figure 8 shows a funnel-shaped mass of potash metasomatised and silicified rock near the southeastern base of the open cut.

TOURMALINISED LITHOLOGIES

Tourmaline was identified by thin-section petrology in several samples, generally from alteration zones around or near the porphyry and volcanic lithologies towards the bottom of the open cut. B212/80 from within 25 m of the agglomerate, described by Kemp (1982) as a ‘structureless, friable, dark grey, partially oxidised rock with patches of kaolin’, is comprised of 60–70% clay minerals with 15–20% quartz and 10–25% tourmaline. The tourmaline extensively replaces quartz, feldspar and ?kaolinite.

Adjacent sample B201/80, a soft, friable faintly laminated kaolinitic rock is ‘dusted’ with tourmaline, and has an overall 10% tourmaline content. Sample B250/80 from immediately below the porphyry contains 1% tourmaline, and sample B285/80 of the porphyry itself contains a trace of tourmaline.

No further work has been done on these samples to understand the process of tourmalinisation. From the descriptions above, it probably developed during a metasomatic process after potash metasomatism and silicification, and is probably related to intrusion of the porphyry.

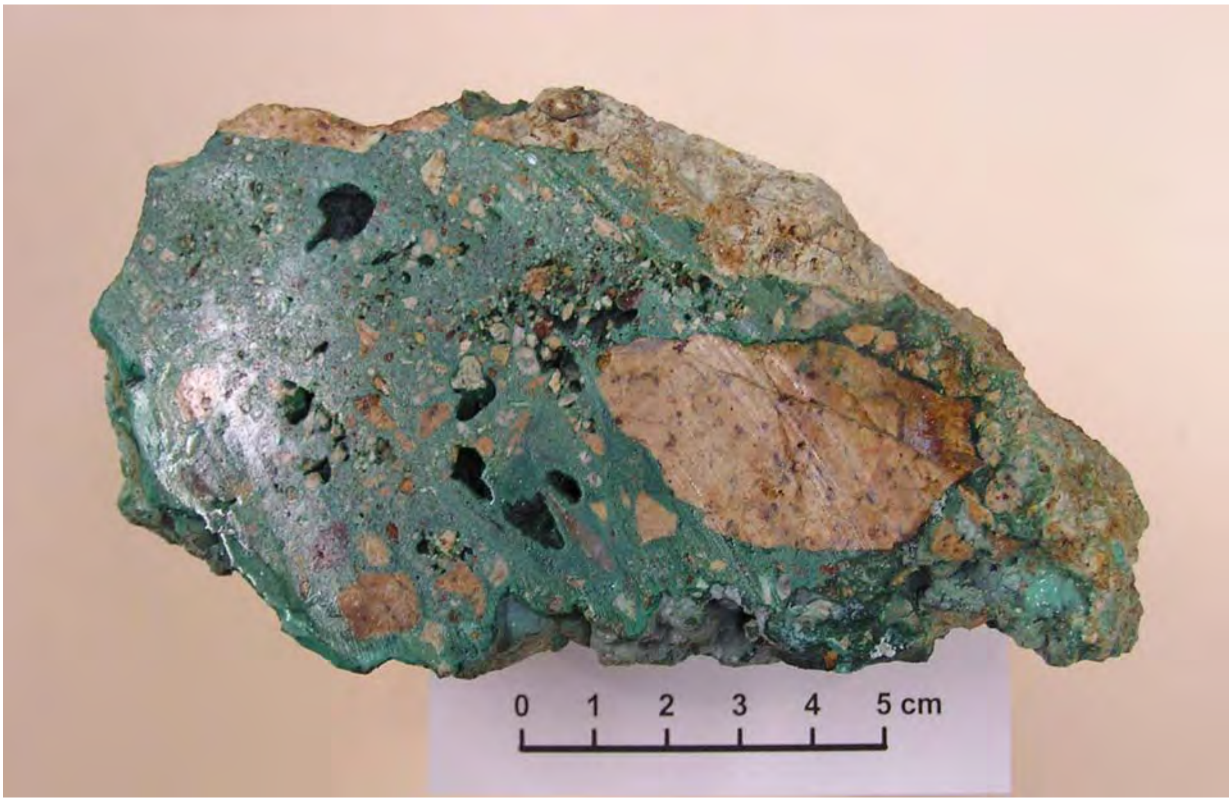

Figure 7. Potash metasomatised clasts in a matrix of malachite in one of the breccia lithologies in the Burra open cut. Sample B198/80. *(407320)*

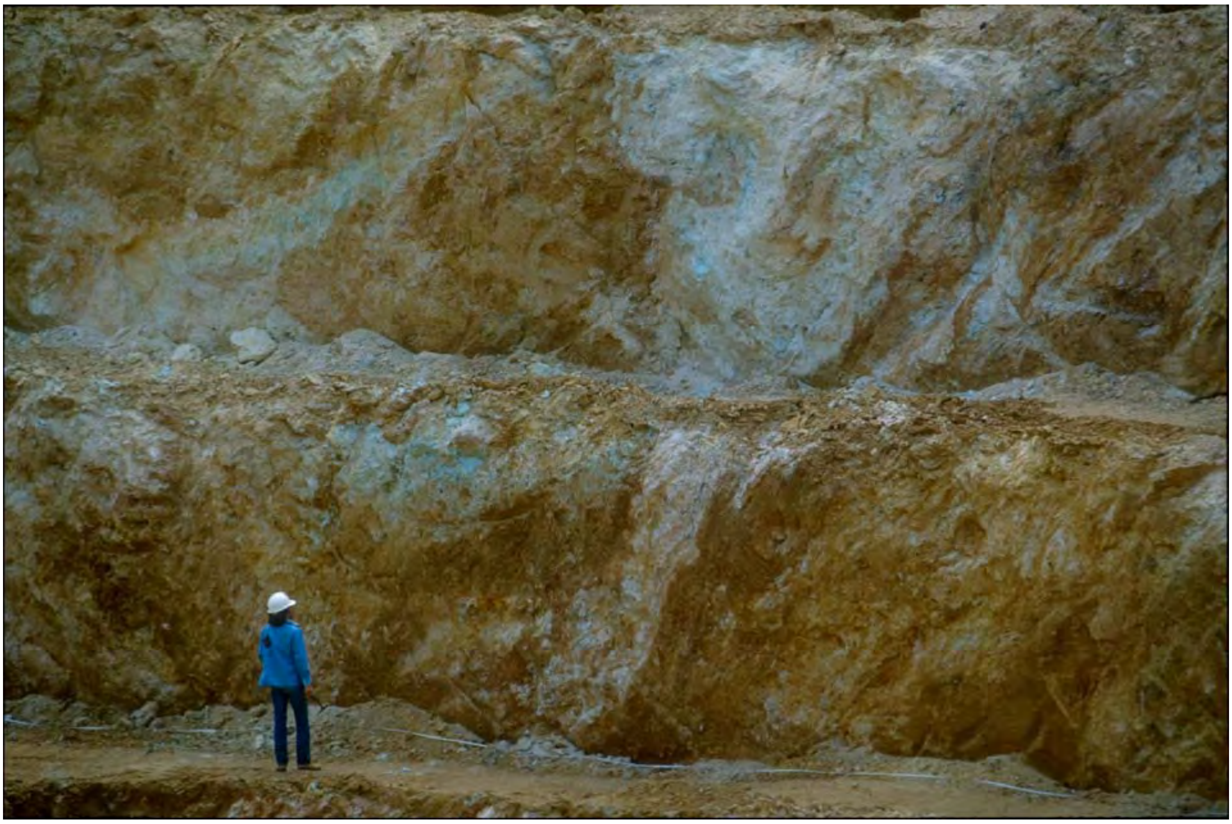

Figure 8. Funnel-shaped mass of silicification and potash metasomatism surrounding sample site B195/80 on the southeastern side of the open cut. Kemp (1982) described the lithology as highly altered silicified volcanic rock, probably a tuff. *(407321)*

Breccia lithologies

Ten types of breccia, some copper mineralised, were mapped in the Burra open cut during 1980–81. Two varieties of agglomerate have already been described above. The recrystallised (± copper-mineralised) dolomitic marble is in places also brecciated, either by proximity to the Kingston Shear, or by hydraulic fluids associated with the volcanic processes. The other varieties of breccia are described below.

COPPER-MINERALISED JIGSAW BRECCIA

A breccia comprising light brown non-laminated, ?silicified and ?ferruginised clasts of an unidentified Kooringa Member ?siltstone host was picked up as float from the vicinity of sample site B256/80 during late-1980 mining operations. A sawn surface reveals near in situ clasts enveloped in a matrix of cuprite (+99% identified in a polished section PS30621 of B256/80) and flecks of native copper (Fig. 9). Parts of the cuprite have been pseudomorphed by malachite.

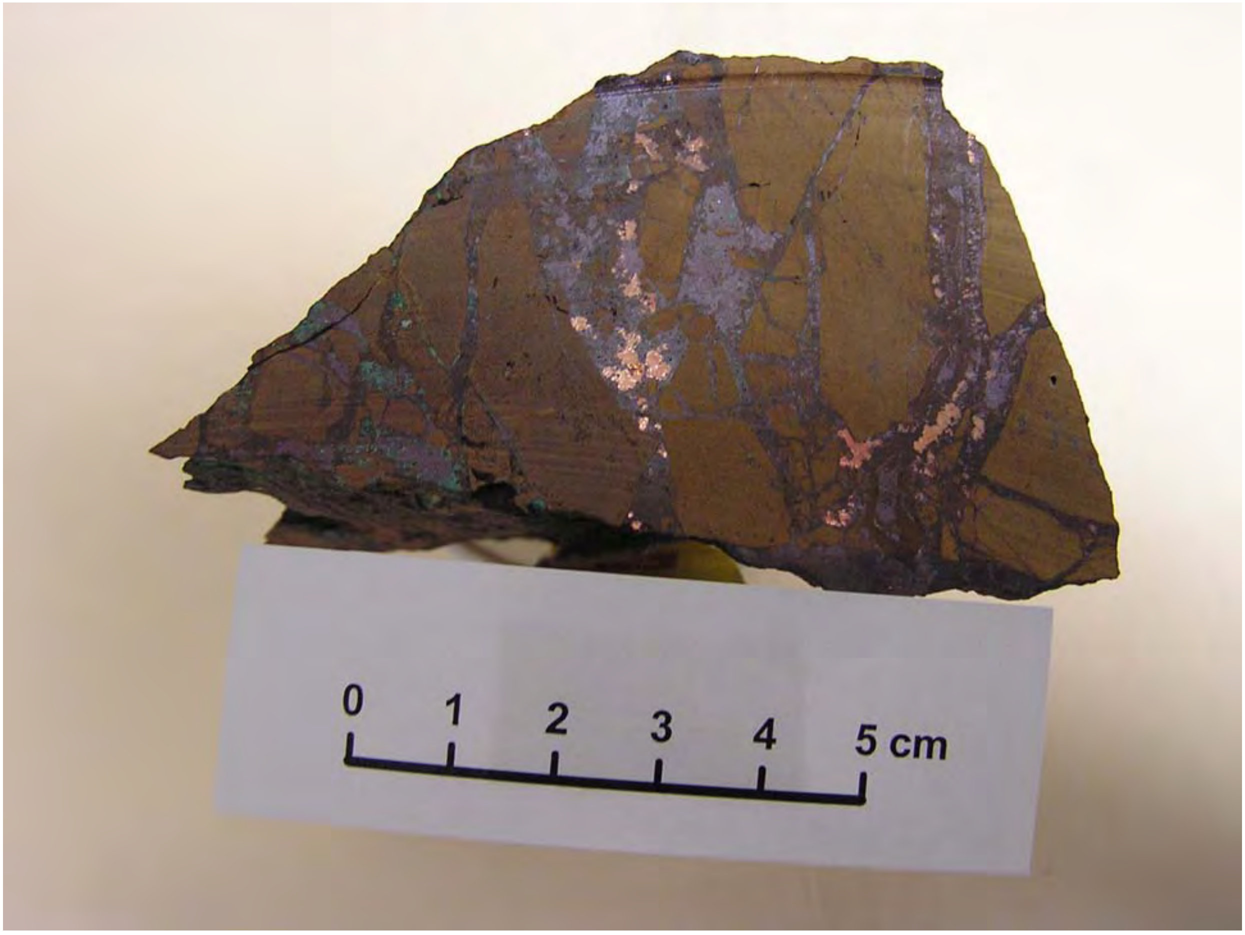

Figure 9. Jigsaw breccia of Kooringa Member siltstone clasts cemented by cuprite and native copper from near sample site B256/80. *(407334)*.

Another jigsaw breccia of faintly laminated Kooringa Member clasts in a matrix of malachite and gemmy azurite crystals was recovered from an approximate mine grid location of 4225mN 3180mE (AMG 307770mN, 6271570mE). This has a most unusual texture in places where clasts have been completely infused with malachite, then the clast rims ?bleached to leave a 'core' of malachite. This alteration has only affected part of the sample, and immediately adjacent clasts appear to be unaffected. (Fig. 10)

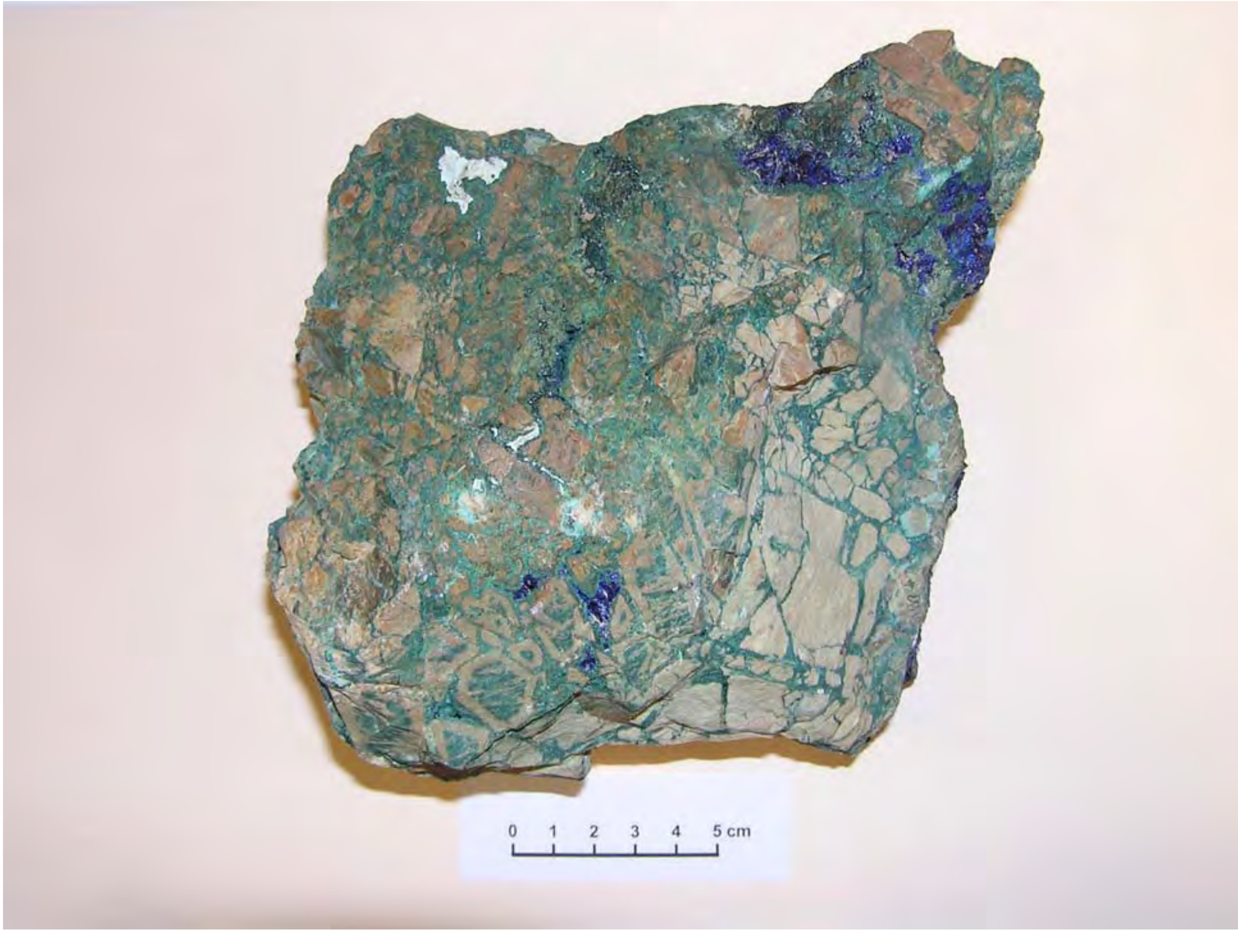

Figure 10. Stockwork veins of malachite and chrysocolla in a jigsaw brecciated siltstone host. The parallel banded and botryoidal malachite has precipitated in angular voids, indicating development by hydraulic fracturing rather than dissolution of sedimentary carbonate material. *(407323)*

COPPER-MINERALISED CROSS-CUTTING FLUIDISED BRECCIA

Several good exposures of layered cross-cutting breccias are still visible in the open cut, the best example being at the base of a mine face at approximate mine grid 4395mN 3240mE (AMG 307720mN, 6271745mE; Fig. 11). Here the breccia is of sand to granule-sized clasts of probable Kooringa Member lithologies and quartz in a finer grained malachite stained matrix. Some larger (~40 mm) angular clasts of pink-coloured ?quartz-?K-spar-altered rock are semi-aligned with the layering, which shows vague signs of grading. Small azurite nodules, probably developed from chalcocite (as discussed under 'Mineralisation'), are arranged in stringers sub-parallel to the boundary of the ~0.7 m wide breccia vein, which extends to the full height of the 5 m bench, although it thins upwards. The vein cuts across the near-vertical bedding in the dolomite host at an angle of ~10°. It is interpreted to have formed as a hydraulically driven fluidised breccia, derived perhaps during emplacement of the porphyry.

COPPER-MINERALISED REBRECCIATED BRECCIA

Sample B37/80 is one of the more important examples of breccia, as it is the only sample recovered during the 1980–81 mapping program that exhibits a re-brecciated breccia texture (Fig. 12). The original breccia of Kooringa Member siltstone clasts was cemented by veins of azurite and chrysocolla, with lesser malachite. This breccia has been clearly disrupted through part of the sample by a secondary brecciation process. The copper-mineralised veins have been truncated, and clasts in the secondary breccia are more finely comminuted. Malachite is the main copper mineral in the matrix of the secondary breccia.

Figure 11. Copper-mineralised, layered, cross-cutting fluidised breccia vein in Unit 10 dolomite ~3 m west of sample site B135/80. Note the stringers of azurite nodules, which are probably pseudomorphs after chalcocite. *(407324)*

Recognition of a re-brecciated breccia is strong supporting evidence for the presence of hydraulic fluids prior to or during the epigenetic sulphide-mineralising phase associated with intrusion of the porphyry. Subsequent oxidation in a supergene environment altered these sulphides to the present copper carbonates. It is less likely that the hydraulic brecciation occurred during supergene enrichment.

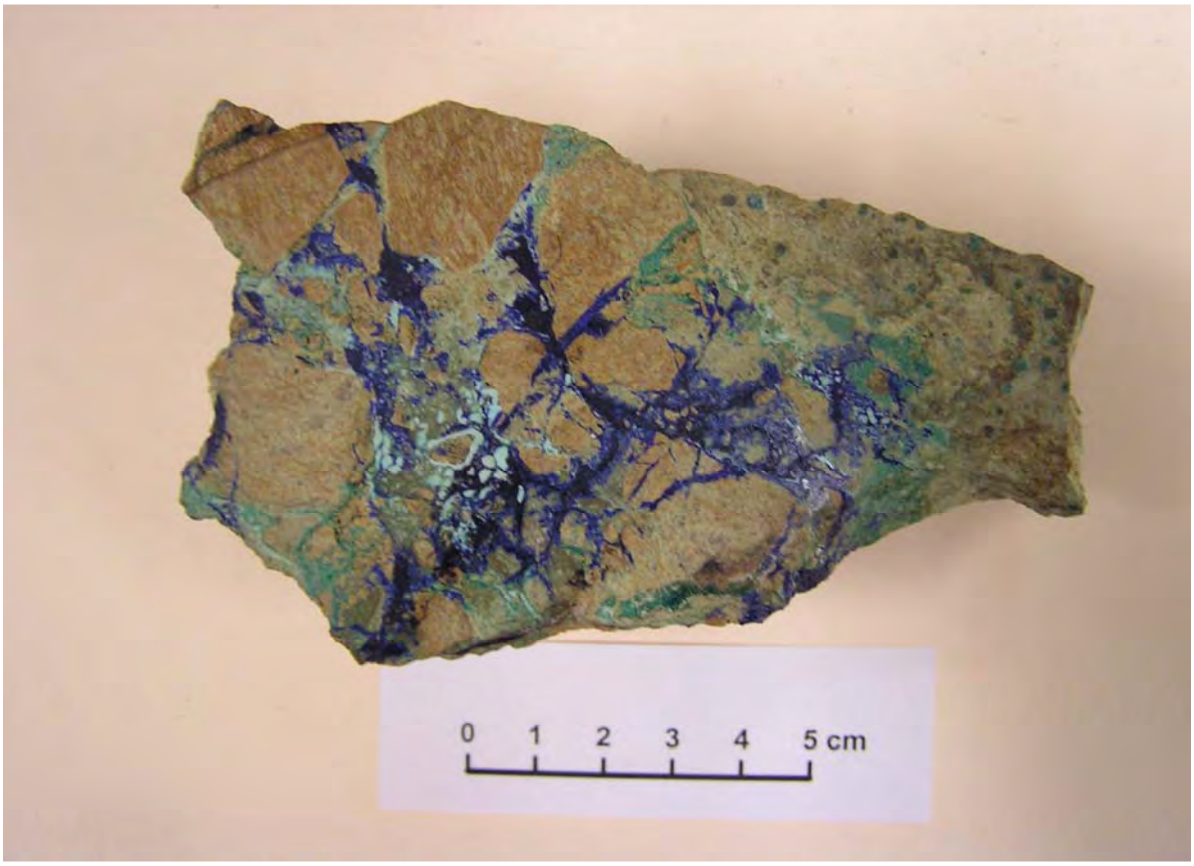

Figure 12. Re-brecciated breccia of altered angular siltstone clasts veined by azurite, malachite and chrysocolla from ~20 m east of the agglomerate near the base of the Burra open cut. The re-brecciated portion is the right quarter of the sample. (sample B37/80) *(407325)*

KARST BRECCIA

Although not available to inspect at the time of the 1980–81 mapping program, two small karst features filled with copper-mineralised clasts were excavated from below the northern haul road for processing, and the karsts backfilled (D. McLean, former Burra Mine Geologist, pers. comm., 2008). Copper ore in sink hole and solution cavities at Burra had been previously recorded by Johnson (1962) in the general area described by McLean.

COLLAPSE BRECCIA

A breccia mass extending for over 100 m, centred on sample site B30/80, is exposed over two mining bench heights on the central northern lip of the open cut. It is outlined by a ferruginous rim up to 300 mm thick, and capped and underlain by Unit 13 dolomite. Silicified (chert) horizons towards the top of the mass have similar bedding orientations to the immediately adjacent dolomite, but become more disjointed, to the point of appearing brecciated, towards the base of the mass. The breccia was initially thought to be a karst fill, but the description above, in particular its passage upward into undisturbed dolomite, does not support this origin.

The mass was possibly developed by lateral movement of acidic water released by oxidation of the original sulphide orebody when exposed to meteoric water at some stage in the relatively recent past. Leaching and bleaching created space for collapse of the corroded dolomite, with more space being available at the base of the mass where a collapse breccia developed. The siliceous (chert) layers may have formed during the early stages of corrosion, or they may be diagenetic within the dolomite as is common in the Skillogalee Dolomite elswhere. Similar acidic water was probably the agent of leaching of the bulk of the carbonate from the southern part of the open cut.

Dolomite breccia and sandstone dykes

A dolomite breccia is exposed in several places near the Kingston Shear on the western edge of the open cut, with the best exposure being centred on sample site B288/80 (Fig. 13). Here the breccia comprises angular dolomite clasts up to several tens of centimetres across in a sand-sized dolomite-quartz matrix. Some dolomite clasts are laminated, and may have been locally derived. Despite being in direct contact with a copper-mineralised unit, there has been no remobilisation of copper carbonates into the breccia.

The breccia is unusual in that it contains at least one dolomitic sandstone dyke up to 500 mm wide, with a near-vertical attitude, extending almost the full bench height. The base of the dyke merges into the dolomite breccia described above, but is almost clast free higher up on the mine face. Another similar sandstone unit is centred on B270/80.

Origin of the dolomite breccia is uncertain and several possibilities have been considered:

- being immediately adjacent to the Kingston Shear, it could have formed as a talus deposited against a rising fault block during Skillogalee-age sedimentation, but after earlier deposited carbonates had sufficiently lithified to endure brittle fracturing (cf Napoleon Megabreccia Member; Preiss, 1985).
- it could be a post-depositional tectonic breccia squeezed into its present location by movement along the shear.
- it could be a fluidised breccia injected along the shear by hydrothermal activity.

Figure 13. Sandstone dyke within angular dolomite breccia at sample site B288/80. (*407326*)

DIAPIRIC BRECCIA

The large body of diapiric breccia on the western side of the open cut, separated from the orebody and Skillogalee Dolomite units by the Kingston Shear, was first recognised as a diapir by Coats (in Thomson, 1963), and supported by Wright (1975). It crops out over the full length of the open cut, but regional mapping by W.V. Preiss (PIRSA, pers. comm., 2008) shows that does not extend more than a few hundred metres north and south beyond the open cut. The adjacent processing plant, stockpiles and tailings dumps have effectively disguised its western limit, but again it is thought to be no more than 500 m wide. Only macro features and structures were mapped in the diapir during 1980–81, as the Skillogalee Dolomite and mineralisation were the main focus of attention before mining removed the evidence.

Matrix to the diapir is dominantly calcite, with subhedral to euhedral dolomite crystals up to several millimetres across. Talc, chlorite and mica are trace to minor constituents. Clasts are mainly angular dolomite and siltstone, with minor biotite schist. These are mostly of granule to pebble size, but several megaclasts are exposed in the open cut. Of note is an overturned heavy mineral laminated sandstone clast almost 50 m across near survey station B10, which was exposed by the former northwestly mine access road. W.V. Preiss (SADME, pers. comm., 1985) identified this as Rhynie Sandstone, which significantly underlies the Skillogalee Dolomite. A 25 m wide crocidolitic siltstone clast, which is now rapidly weathering, is exposed immediately below Graves Engine House. Equally large sandstone and recrystallised dolomite clasts are revealed in the pit faces further south.

Despite its proximal position to high-grade copper mineralisation along most of its length, little evidence was found of mineralisation in the diapir. Minor malachite staining occurs along some shear planes, and a 20 m wide pod of malachite–chrysocolla staining occurs across the diapir, Kingston Shear, Unit 1 and Unit 2 boundaries ~100 m south of the northern haul road. This is reasonable evidence to assume that the diapir was juxtaposed by faulting after the main phase of supergene copper enrichment. The Figure 3 cross-section in Drexel and McCallum (1986), derived mainly from the log of diamond-drillhole BD1B, indicates that the Kingston Shear is listric, and may truncate the orebody and possible volcanic neck at depth. This provides a challenge to find the ‘other half’ of the Burra orebody, if indeed it exists.

Bampton (1993) believed the diapir to occur on both sides of the Kingston Shear, citing occurrences of volcanic units in other Adelaide Geosyncline diapirs as an explanation for the volcanics present in the Burra open cut. Preiss and Drexel (1993) in their response cited that Skillogalee Dolomite stratigraphy can be traced in places around the agglomerate and porphyry exposures in the pit bottom. There is no evidence of the volcanics occurring as clasts, and alteration haloes including montmorillonite and silicification from around the volcanics extend into the Skillogalee units. Secondly, the Kingston Shear is the regional structure passing through the open cut, not the Tinline Fault as cited by Bampton. His assumption would require two diapirs to be precisely juxtaposed, an unlikely scenario in an already highly fortuitous situation with a diapir being precisely juxtaposed adjacent to a copper orebody. Regionally, the Kingston Shear forms the boundary between highly recrystallised dolomite, locally intruded by diapiric breccia, to the west and fine-grained, well-preserved dolomites to the east. It is one component of a regional series of dislocations extending north-northwesterly for over 200 km from the northern end of the Kanmantoo Trough to Carrieton in the Flinders Ranges. Thirdly, convincing evidence was noted during 1980–81 mapping that the porphyry intrudes in situ Skillogalee Dolomite at a relatively acute angle to bedding, and is definitely not an inclusion within a clast of dolomitic siltstone in a diapir.

MINERALISATION

Burra Mine became world renowned in the mid- to late 1800s because of the large masses of beautifully formed botryoidal malachite and gemmy azurite crystals. The richness of its ore was also well known, with the original surface assay being reported as 70% Cu from cuprite mineralisation (Auhl, 1986). Tributors from that period undoubtedly high-graded their finds of malachite and azurite, with overall recovery estimated at 700 000 t averaging 7% Cu. Ore totalling 1.89 Mt at a grade of 1.71% Cu was recovered during 1970–81. The pre-mining ore grade is estimated at close to 3% Cu.

Burra Mine was also noted for crystalline native copper, flecks up to 10 mm across of which were found during routine diamond sawing of rock samples collected during 1980–81. Libethenite was recorded by Robert Noble (SADME Technical Officer; Noble, 1980) during crystallography and photomicroscopy of mineral samples from across the state when compiling the *Catalogue of South Australian Minerals — 1983* (Noble et al., 1983). This publication also provides excellent colour images of many of the minerals found at Burra.

Three copper mineralising events have been recognised in the open cut. The first was primary sulphide, presumably mainly chalcopyrite, but only a few remnants of this mineral were recorded during mapping. The porphyry is of such small volume that it is hard to envisage this carrying the volume of copper now extracted from the orebody. Nixon and Townend (1966) noted euhedral chalcopyrite crystals with included bornite blebs that altered to chalcocite on exposure in the porphyry. However, exposures of the porphyry at depth examined during the 1980–81 mapping program revealed mostly pyritohedra up to 50 mm completely pseudomorphed by chalcocite. It is therefore possible that the porphyry was originally pyrite rich but copper poor. It is likely, however, that copper-bearing hydrothermal fluids were derived at depth during the 797 Ma magmatism, and precipitated chalcopyrite in the present location of the Burra orebody (Fig. 14). To infer a younger mineralising event would require too many coincidences to occur in the same location over a long period of time, i.e. magmatism with development of tuffaceous siltstones and intrusion of the porphyry, mineralisation at a later time, then faulting by the Kingston Shear and emplacement of a diapir juxtaposed to the orebody.

Epigenetic alteration and concentration of primary mineralisation resulted in the secondary copper sulphide chalcocite, with some covellite. Later supergene enrichment resulted in formation of the copper carbonates malachite and azurite, and appreciable quantities of chrysocolla (Figs 15–17).

Figure 14. 1.5 m wide ferruginised mass at sample site B286/80 adjacent to a mined out pod of copper mineralisation and ?montmorillonite–?kaolin alteration in the centre of the former haul road on the western side of the open cut. This is possible evidence of former massive sulphide mineralisation at Burra. The photo was taken on 26/5/81, four months after mining ceased, and the natural groundwater table has appeared at lower left. *(407327)*

Azurite nodules up to 100 mm across were recorded in several locations in the open cut as individuals and as stringers of nodules. Their occurrence was problematic at the time of the mapping project, but subsequent diamond-saw sectioning of several revealed cores of chalcocite. Polished section 30624 of one nodule was described by Kemp (1982) as '…an approximately concentrically zoned specimen of chalcocite, malachite and azurite replacing a coarsely crystalline quartzo-feldspathic rock. Chalcocite occurs as a dense network of fine veins and patches, giving the impression of a breccia.' Azurite (and malachite) in this specimen occurs as an alteration of chalcocite. It is therefore reasonable to assume that the stringers of azurite nodules recorded in the copper-mineralised cross-cutting fluidised breccias described above were originally blebs of sulphide (chalcocite), now pseudomorphed.

Pyrite, generally pseudomorphed by limonite, commonly occurs as very small crystals and blebs disseminated throughout much of the Kooringa Member. Several zones of ferruginisation that are not confined to particular lithologies also contain pyrite pseudomorphs, the largest being on the eastern side of the pit but now removed by recent aggregate quarrying operations. Here, a 40 by 10 m zone of ferruginisation had an outer rim up to 60 mm wide of pyrite pseudomorphs, some nearly as wide as the rim itself.

Of importance in the understanding of mineralisation in the Burra Mine are two samples containing pyrite — B199/80 and B118/80. B199/80, described by Kemp (1982) as a very fine-grained, faintly laminated, silicified, dolomitised acid ?volcanic, and by Farrand (1983) as a dolomitised shale comprised of an ultra-fine-grained mass of clay minerals, contains numerous extremely small sulphide blebs identified in polished section (PS30616) as pyrite (99%) and chalcocite (trace). This sample comes from an area of extreme alteration and weathering near the bottom of the open cut, an environment unlikely to have preserved fresh sulphides. It may, however, be from the very top of an underlying sulphide body.

Sample B118/80, although weathered, contains patches of extremely small fresh sulphide grains, presumably pyrite. It is from much higher in the pit than B199/80, almost at the present watertable. The pyrite appears to be bedded, in continuity with limonite pseudomorphs outside the preserved sulphide patches. The Nairne Pyrite Member within the Kanmantoo Trough may be an analogy. But small cavities within the patches indicate probable dissolution of a soluble mineral. If this is the case, then the sulphide is probably secondary as it would be unlikely to remain unaltered in the presence of a solvent. Silicification may have preserved the sulphide, but thin- and polished section petrology is required to help define an answer.

Listed below are the metallic minerals presently recorded from the Burra Mine, and their abundances based on visual estimates during mapping, and subsequent laboratory analysis. This list is not necessarily comprehensive. Compilation of information contained in the 1980–81 field notes, Kemp (1982), Farrand (1983, 1984), Noble (1983) and other petrological descriptions, should enable a paragenetic sequence, including non-metallic alteration phases, to be constructed.

Name	Composition	Overall relative abundance
Azurite	$Cu_3(CO_3)_2(OH)_2$	Sub-dominant
Bornite	Cu_5FeS_4	Accessory
Chalcocite	Cu_2S	Accessory
Chalcopyrite	$CuFeS_2$	Trace
Chrysocolla	$CuSiO_3.2H_2O$	Sub-dominant
Covellite	CuS	Trace
Cubanite	$CuFe_2S_3$	Trace
Cuprite	Cu_2O	Accessory
Gold	Au	Trace
Libethenite	$Cu_3P_2O_8.Cu(OH)_2$	Accessory
Malachite	$Cu_2CO_3(OH)_2$	Dominant
Native copper	Cu	Trace
Neodigenite	Cu_9S_5	Trace
Pseudomalachite	$Cu_5(PO_4)_2(OH)_4.H_2O$	Trace
Pyrite	FeS_2	Accessory
Sphalerite	ZnS	Trace

Figure 15. Mining operations in early 1981 at the southern end of the Burra open cut, just prior to the induced failure of the face at extreme right on 14 January. The worked out area at left has been backfilled to form the haul road to current operations. A very rich zone of predominantly malachite and chrysocolla passes diagonally up the face to the right of the mining equipment. *(045361)*

Figure 16. Wayne McCallum examining the malachite–chrysocolla ore zone shown in the image above. *(407328)*

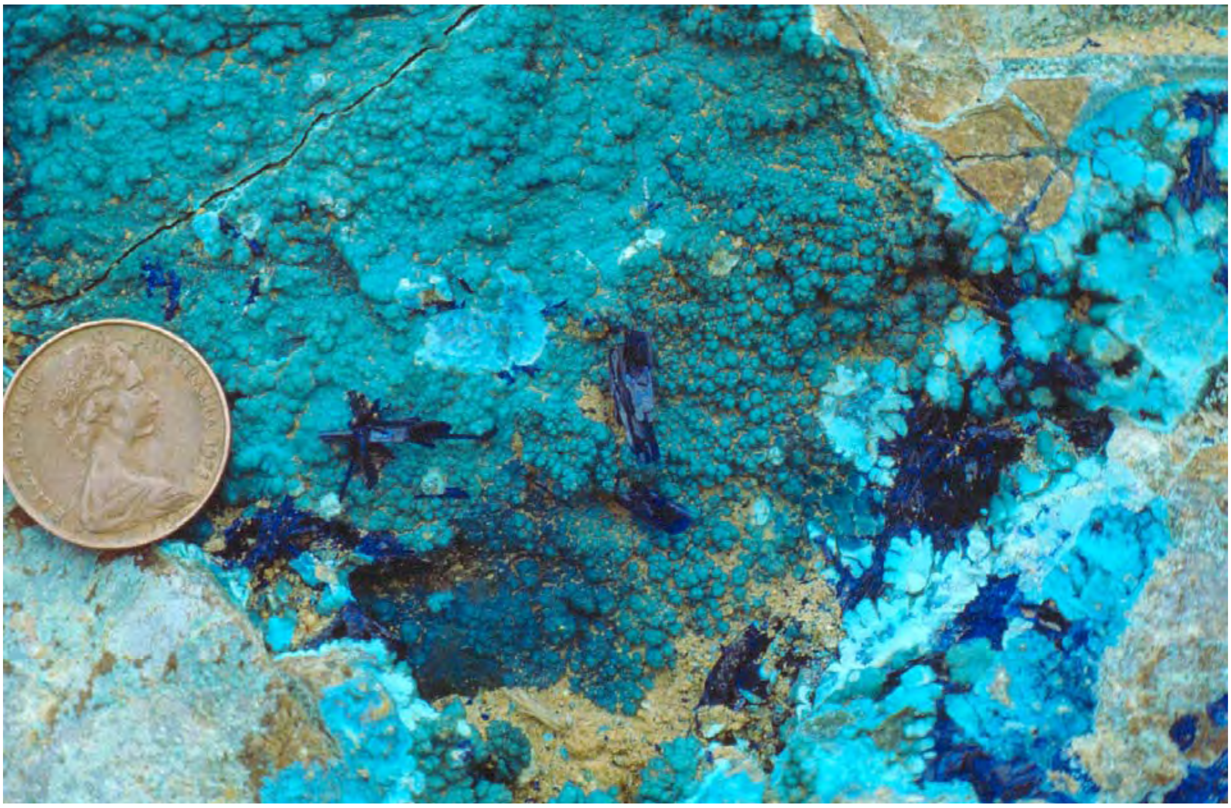

Figure 17. Typical copper ore from near the southeastern base of the Burra open cut. Gemmy azurite crystals rest on malachite and chrysocolla. *(048865)*

DRILLHOLE INFORMATION

Appendix C summarises SA Department of Mines drilling for the period 1963–64, and Mines Exploration Ltd drilling for 1966–67 is summarised in Appendix D. The latter was mostly for grade control, but eight steeply inclined diamond drillholes (BS1–8) were completed with varying success. Drilling conditions were difficult, particularly through the diapir where talc-enclosed clasts merely rotated on the bit tip, and penetration rates were sometimes extremely slow.

Core for holes BS5–8 is stored in the Glenside Core Library, although some sections are missing. Core for BS1–4 has not been recorded as stored by PIRSA, but there is the possibility of it being in the old 6 foot wooden trays not yet catalogued at the Moonta Core Library. BS4 is of particular importance as it may hold the key to interpreting the orientation of the Kingston Shear at the contact between the diapir and Skillogalee Dolomite.

Drillhole BS1B (Appendix E), drilled from the eastern lip of the pit by Adelaide and Wallaroo Fertilizers in 1981, suggests that the shear is listric, and possibly cuts off the copper mineralisation 200–300 m below the surface.

BS4, spudded in diapir and drilled to the east, was logged in 1966 as passing from marble breccia into the Skillogalee Dolomite. The present author believes there is uncertainty in the drill-log recognition of a distinction between diapir and recrystallised dolomitic marble (which is sometimes brecciated). Much of the hole (including the diapir) was logged as marble breccia. Within the open cut and in nearby outcrops, diapir always occurs on the western side of Kingston Shear. The marble and marble breccia as currently mapped is part of the Skillogalee Dolomite or mineralised sequence, and is always to the east of the shear. Relogging of the core, with the advantage of having had the orebody exposed by mining after BS4 was drilled, may better define the downhole location of Kingston Shear.

The determination of the possibility of the orebody being present at depth below the open cut has great bearing on any future exploration model around Burra. If the orebody is potentially present at depth, then regional exploration could concentrate on similar occurrences along Kingston Shear. If the orebody has been truncated by the shear, then exploration could also be directed towards looking for ‘the other half’.

POTENTIAL FURTHER ANALYSIS OF BURRA SAMPLES

THIN- AND POLISHED SECTION PETROGRAPHY

A suite of samples collected during 1980–81 field mapping re-examined during the current exercise show probable volcanogenic features, including flow structures, volcaniclastic contribution, and unusual textures not typical of sediments. Specific samples are tabulated in the ‘Recommendations’ below.

FLUID INCLUSION STUDIES

Quartz sample B204/80 was taken from an area of intense quartz veining adjacent to a large area of potash metasomatism and silicification near the base of the Burra open cut. Quartz sample B281/80 was taken from the porphyry near the central western part of the open cut near the contact with the diapir. Both should be examined for suitability for fluid inclusion studies to help determine the environment under which the quartz formed.

SULPHUR ISOTOPE STUDIES

Numerous samples in the Burra open cut contain pyrite, as both primary and secondary mineralisation. Authigenic disseminated pyrite pseudomorphs ranging from microscopic to millimetre scale are present in siltstone, limestone and dolomite units along the northern pit faces. These areas are still accessible for further sampling if necessary.

Sample B118/80 contains apparently bedded, unaltered pyrite within small patches in an otherwise weathered siltstone. Fresh pyrite also occurs in sample B199/80, described as a dolomitic shale, or a very fine-grained dolomitised acid ?volcanic. Both samples are described above in the section on mineralisation.

Secondary pyrite in vein material, generally quartz, occurs within the main ore zone towards the bottom of the pit. Chalcocite and covellite are common minerals in the porphyry and recrystallised dolomitic marble along the western edge of the orebody.

Sulphur isotope studies may add to the determination of the environment under which the pyrite and other sulphides formed. Sampling of pyrite from the Kooringa Member at a distance from the open cut should provide a benchmark for comparison.

RECOMMENDATIONS

Materials and information gathered during the 1980–81 field mapping program provide a unique record of one of the State’s oldest mines. The ore has been all but completely mined out and the open cut flooded. Along with the site now declared as being reserved from the Mining Act, there are only small exposures of remaining mineralisation and limited field evidence to help determine the origin of the orebody. Consolidation of all mapping, rock samples, thin and polished sections, and 35 mm colour transparencies into a linked digital format available on line should be a priority, as this will provide both a scientific and historical database for future work by PIRSA and industry. Listed below are recommendations to consolidate this information:

1. The timeframe for preparation of the current report precluded incorporating all available information from the 1980–81 mapping program and other sources on the accompanying geological map (Fig. 18). In particular, inclusion of additional comments captured on the original hand-sketched field maps should enable a realistic configuration of Units 1–14 to be made along the full length of the open cut. As discussed above, intense leaching and alteration (including silicification, potash metasomatism, probable volcanic effects, brecciation and shearing) in the southern part of the open cut has made correlation of units difficult, but further examination of

data will almost certainly result in a more complete geological map. **Note:** Not all information collected during the 1980–81 mapping can be represented on the final pit outline, as some observations were taken in areas subsequently mined out.

2. All information relating to the ~300 rock samples collected from the Burra Mine should be placed in SA_Geodata. Summary data to each of these currently reside in Table 1 to this report in a format that is readily acceptable into the departmental database. **Note:** Not all samples collected during the 1980–81 mapping can be represented on the final pit outline, as some were taken from areas subsequently mined out.

3. Structural data (predominantly bedding and shear foliation) should be captured from the scanned image and recorded in SA_Geodata.

4. Re-examination of the ~300 rock samples has identified a suite of breccias, possible volcanics and potash metasomatised lithologies that should be examined petrologically to help refine the extent of magmatism and metasomatism in the open cut. Of particular importance are:

Field No. (/80)	**R No.**	**Description, and identification required**
B101	77488	Highly altered fine-grained siltstone-like rock with contorted dark red-purple and white banding. **Is this flow-banded tuff, or an altered, slumped sediment?**
B118	77546	Partly weathered pale brown siltstone with fresh pyrite as an apparently bedded constituent of the sediment. Holes within the ‘bedded’ pyrite layers indicate that a mineral has been leached, yet the pyrite is unaltered. **Is the pyrite syngenetic or secondary? A polished section may be required.**
B119	77549	Copper mineralised, white-grey weathered ?silty ?ex-dolomite, some laminae; pink and yellow bands may be either laminae or chemical fronts; minor brecciation in places. **General description, but with particular reference to alteration.**
B135	77611	Pod of copper mineralised breccia which cuts across bedding; angular clasts of pink-coloured ?quartz-?K-spar are semi-aligned; sand-sized quartz in matrix; possible graded layers which in the field show dips of +45°. **Is there any evidence of a volcanic contribution in this rock?**
B142	77637	Cream, hard, slightly vuggy rock with a mottled, granular appearance; sawn surface shows patchy light pink colouration. **Is this a partly silicified and potash metasomatised rock?**
B177	77748	Brown, altered breccia; some clasts to 20 mm are laminated ex-dolomite; layering possibly due to ‘flow’; slickenslides; copper mineralisation only in matrix. **Is there any volcanic contribution that may indicate this rock to be a tuff or agglomerate?**
B180	77760	Brown, sandy matrix breccia with angular clasts <5 mm; coarsely layered; possible clasts of malachite-mineralised rock and ?dolomite. **Is there any evidence of a volcanic contribution in this rock?**
B190	77796	Grey-brown, altered, ?silicified ?siltstone; some beds highly friable (break down into ‘silt’); sawn face shows numerous ex-py blebs as stringers that define layering. **Is there any evidence of a volcanic contribution in this rock?**
B219B	77904	Cream-grey, semi-translucent, ?sericitic,?feldspathised, network-veined rock. **Is this a metasomatite?**
B227	77932	Brown, laminated, silicified siltstone interbedded with paler yellow-brown ochreous rock; characteristic quartz ‘discs’ to 1.5 mm. **Is there any evidence of a volcanic contribution in this rock?**
B248	78002	Two samples: (a) Copper mineralised, cream-grey, partly silicified, bedded but fractured to brecciated dolomitic ore-zone rock with fresh sulphides; (b) well-laminated, altered, dolomitised ?siltstone-?dolomite with dolomite rhombs to 3 mm, dark grey with white laminations. **General description of both, but with particular reference to alteration.**
B252	78018	Dark red-brown pod of highly altered medium soft rock; light apple-green waxy mineral in places; sawn face shows grey-black, hard ?clasts of unknown com-position in a brick-red matrix; becomes extremely friable when wet. **General des-cription, but with particular reference to any volcanic contribution in the rock.**
B286	78146	Dark red-brown rock from a ferruginous pipe; breaks down to clay-sized particles when wet; possible rounded quartz-overgrowth grains; may be a highly ferruginised dolomite. **Is there any evidence of a volcanic contribution in this rock?**

5. Three samples of siltstone with probable high feldspar content have been collected from the vicinity of the northern haul road for separation of zircon concentrates. If present, the zircons should provide a direct age of deposition of the Kooringa Member. The age of the porphyry obtained during this study provides a minimum age for the Kooringa Member.

6. All volcaniclastic, breccia and metasomatic samples should be categorised, including through whole-rock geochemistry, to help determine or confirm their petrogenesis and relationships. This process can be subdivided into the microcline-rich and albite-rich ?tuffaceous horizons in the Skillogalee Dolomite, and the porphyry, agglomerates and other volcaniclastics associated with the copper mineralisation. Isotopic studies of components of these rocks may assist in distinguishing between magmatic and meteoric water contributions, particularly in relation to copper mineralisation.

7. Sample site B122/80 was re-sampled in December 2008 to determine the presence of any zircon crystals that may have accompanied the albite feldspar in an ash cloud as proposed by Farrand (1984) as the most probable source of these clastics in an otherwise quiescent, dolomite-precipitating environment. Likewise, sample sites B7/80 and B10/80, and another site in Unit 2 on the southern side of the haul road just inside the Burra open cut, were re-sampled to determine the zircon content of the K-feldspar-rich laminae which petrology has also indicated developed from probable ash falls. It is recommended that these samples have zircon concentrates prepared and, if suitable, age dated.

8. Samples taken by Preiss, Drexel and Cowley in November 2008 from the ‘Grove quarry’ ~5 km north of Burra require thin section petrography. Lithologies described by Redfire Resources in the quarry include sheared syenite rock and probable potash meta-somatism. This occurrence is a possible northern extension of the Kooringa Member, as mapped on the Burra 1:50 000 geological sheet (Preiss, 2002), and the association with metasomatism provides a possible link to mineralisation in the Burra open cut.

9. A dolomite breccia (grey, angular dolomite clasts in a yellow-brown dolomitic sand matrix) at sample site B288/80 includes a possible dolomitic sandstone dyke, and is flanked to the immediate west by a layered, copper-mineralised recrystallised dolomitic breccia containing clasts and layers of potash feldspar (B264/80). This exposure needs detailed examination to determine the origin and sequence of formation, and any data that may shed additional light on metasomatism and development of the main orebody.

10. Southeastwards along the same bench described in (6) above, and on the bench below, is a complex area of shearing, alteration, brecciation, and probable imbrication of several rock units. Altered, micaceous siltstone containing 5 mm laminae of almost 100% microcline (B259/80) is one of the lithologies present; this may be Unit 2 or, less likely, another tuffaceous siltstone below Unit 1. A large body of breccia between sample sites B262/80 and B289/80 on this bench was mapped in the field as having bedding of Unit 2 apparently wrapped or draped over the present upper contact. This area needs further detailed mapping before final annotation is made on the geological map.

11. A large amount of information is available in the field notes, Table 1, and Kemp (1982) and Farrand (1983, 1984), from which to derive a paragenetic sequence for the Burra Mine copper mineralisation. Some additional thin- or polished section descriptions from the ~300 samples from the project stored at Glenside Core Library may assist.

12. Core from diamond drillholes BS5–8 is stored in the Glenside Core Library, but core from several important Burra Mine holes is missing, particularly BS1–4. Phoenix Copper is conducting its own search of the old Broken Hill South coreyard at Broken Hill. Locating the Kingston Shear (if present) in any drillhole should be a priority to assist in determining the orientation of the shear with respect to the possibility of the orebody continuing at depth. Drillhole BD1B indicates that the fault is listric, and may truncate the orebody and possible volcanic feeders at a depth of only a

few hundred metres. Further evidence to confirm or refute this is required to firm up an exploration model for finding replicates of the Burra orebody, or trying to find ‘the other half’.

13. All geo-referenced mine plans, including the successive field bench maps produced during 1980–81 and the 1965 surface geology (Nixon et al., 1965), should be ‘wire-framed’ to produce a pseudo-3D image of the mine geology. To this can be added the 3D orebody outlines prepared by Phoenix Resources from production drilling. As an extension of this, mine-level plans prepared from the late 1800s onwards could be added to indicate the extent of underground mining from 1845 to 1870, after which the mine was operated mostly by open cutting until cessation of the original mining campaign in 1877 (the Nixon et al. (1965) map captures the geology as exposed in 1877). Although the 3D model will have gaps in the data, it should reveal most macro geological features.

14. The department has over 400 maps of the Burra area recorded in SARIG (and Appendix F to this report). These should be examined for historically relevant information and added to the 3D image if the data are suitable, and to add to the knowledge base of adjacent areas. As an indication, the SA Department of Mines Annual Report 1961–62 states that ‘The old mine area and accessible openings have been mapped in detail at a scale of 1in.=20ft., and a strip of country extending north for several miles and south to the vicinity of the Princess Royal mines has been mapped at a smaller scale’.

15. All rock samples collected from the Burra open cut during the 1980–81 mapping project (the ‘B/80 series’) should be digitally imaged in high resolution using a neutral background (to provide consistent colour tones) to allow on-line perusal of images via SAMREF.

16. All thin sections prepared for the Burra Mine Project (~132) should be digitally imaged in plane and polarised light (using identical image areas) to allow on-line perusal via SAMREF. Multiple images may need to be taken of individual thin sections because of the variety of features present, particularly within the breccia and volcanic lithologies.

17. Several hundred colour transparencies taken by the author during the 1980–81 field mapping project should be digitally scanned and added to the PIRSA Photo Database. Many of these can be linked to specific locations and subjects in the open cut. Some relate to specific rock samples. Most will require captioning and geo-locating.

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The author is indebted to colleague Wayne McCallum for the meticulous approach he brought to the 1980–81 mapping project. His ‘on-the-rocks’ discussions were invaluable when recording the field data. Wayne also compiled Appendices A–F in preparation for a draft report circa 1986 on the Burra Mine that did not eventuate due to circumstances beyond both his and the current author’s control. Dr Wolfgang Preiss spent countless hours enthusiastically discussing the project in the office and field, allowing the author to firm up interpretations and ideas on the project. His knowledge of the Adelaidean in general, and Skillogalee Dolomite in particular, helped to distil the acceptance of probable ash-fall events recorded in the Burra open cut but not yet recognised elsewhere in that formation. He is also thanked for his meticulous review of the draft to this report. Dr Anthony Reid dated the porphyry and immediately saw the value of attempting to date the ash-fall events recorded in the Kooringa Member. He and Wayne Cowley also assisted Wolfgang Preiss and the author in measuring the type section for the Kooringa Member, and became involved in very useful geological discussions. Ursula Michael and Gareth Davies are thanked for scanning the field maps and associated information, which were then geo-referenced and rectified by Laszlo Katona, George Gouthas and Elaine Appelbee. Wolfgang Preiss used these to prepare a fully symbolised GIS dataset and map representing the present state of knowledge. Glenside Core Library staff Michael Willison, David Groom, Irish Flaherty and Brian Logan are thanked for tracking down Burra rock samples and core collected almost 30 years ago, and making inspection facilities available.

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Table 1. Summary of petrological interpretation of rock samples from the Burra Mine open cut.

Field No. (/80) (yellow=checked at Glenside Core Library; red=checked; sample in office)	Mine grid No.	R No.	RS No. (6630)	Thin section No.	Polished section No.	Geochem analysis No. (Field No unless shown otherwise)	Munsell colour	Reaction to 10% HCl (on powdered sample unless shown otherwise)	Field identification by JF Drexel and WS McCallum	Mineralisation (field ID unless shown as TS – thin section) Ma=malachite; Chr=chrysocolla; Az=azurite; At=atacamite; Bo=bornite Li=libethenite; Cu=cuprite; Cpy=chalcopyrite; Cc=chalcocite; Co=covellite; Li=libethenite, Py=pyrite; Sph=sphalerite	Alteration (field ID unless shown otherwise)	Petrological identification by Dr A Kemp (Amdel Report 1/1/271)	Petrological identification by Dr M Farrand (RB83/28; *RB84/62)	Most likely rock type and origin (based on field evidence only [thin section modifier in brackets]); pale green=final interpretation; yellow=uncertain or further work required before interpretation) (pyritic refers to fresh sulphide in sample; ex-pyritic refers to limonitic pseudomorphs after pyrite) Pink = Kemp and/or Farrand ID; recheck if necessary on thin sections	Most likely unit	Key field, thin and polished section features	Further work
B1	F3	77478	101				2.5Y(8/4)	Nil	Pale yellow, weathered/altered, laminated silty ?dolomite; weathers to mostly clay and a coarse sand probably produced by secondary quartz overgrowths prior to weathering	Many **Ma** blebs to 0.5 mm	Probable partial quartz overgrowths on clastic grains	—	—	Silty dolomite	undifferentiated Skillogalee Dolomite		
B2	F3	77829	102	C41982			2.5Y(8/2); 10YR(8/1)	Slight	White **dolomite** with a granular fabric; light grey partings; probably an unaltered version of B1	Numerous small **ex-Py pseudos**; radiating **Ma** xtl aggregates to 2 mm on fractures	mm-scale dendritic blebs on some surfaces	—	*Silty sedimentary dolomite; minor potash metasomatism	Silty dolomite (sedimentary)	undifferentiated Skillogalee Dolomite	Minor potash metasomatism	
B3	F3	78165	103				10YR(4/6); 10YR(8/1)	Nil	Yellow-brown, highly friable, weathered/altered, laminated silty ?dolomite; brown areas mostly clay; lighter coloured areas are coarse sand probably produced by secondary quartz overgrowths prior to weathering	Sparse **Ma** blebs and stains	Some Mn dendrites	—	—	Silty dolomite	undifferentiated Skillogalee Dolomite		
B4	F3	78200	104				10YR(6/8)	Nil	Brown-yellow, weathered/altered friable fine sand-sized material; sand probably produced by secondary quartz overgrowths prior to weathering; some vague white laminae	Minor very small **Ma** grains		—	—	Silty dolomite	undifferentiated Skillogalee Dolomite		
B5	F3	78240	105	C34940			10R(6/6); SG7/2; SGY7/1	Nil	Light red and pale green, hard, partly **silicified K-metasomatised rock**	Numerous small **ex-Py pseudos**, some to 7 mm; **Ma** blebs and stains to 3 mm	Partly **silicified** and **potash metasomatised** qtz veining; some pale green soapy material	Silicified (20% qtz) and feldspathised (80% felds) ?welded tuff	Partly kaolinised potash metasomatised possible volcanic rock, probably exhalative	Silicified, potash metasomatised rock	metasomatite	Possible volcanic; potash metasomatism; similar to B50 and B285	Petrology to re-examine for volcanic contribution
B6	A3	78282	106	C41983			10YR(7/1)	Slight	White-cream uniformly coloured, dense, massive to granular dolomite			—	*Partly silicified sedimentary dolomite	Dolomite (partly silicified, sedimentary)	1	Potash metasomatism	
B7	A3	78324	107	C41984			10YR(7/2)	Nil	Light brown, laminated siltstone interbedded with more massive grey dolomite; bedded to flaggy; more laminated in upper 3-4 m	Numerous very small **ex-Py pseudos**	Trace Mn blebs	—	*Siltstone or pyroclastic (50% potash feldspar)	Siltstone	2	Possible volcanic	Petrology to re-examine for volcanic contribution
B8	A3	78360	108	C41985			10YR(6/1)	Slight	Medium grey, massive, hard dolomite interbedded with B9; some probable cryptalgal laminae		Minor qtz veining; ferruginisation along numerous fractures	—	*Magnesium-rich sedimentary carbonate (95% carbonate)	Dolomite (sedimentary)	3		
B9	A3	78397	109				10YR(7/4)	Nil	Pale brown, weathered and/or altered, bedded to coarsely laminated non-carbonate rock interbedded with B8; slickenslides on some surfaces	Some **ex-Py holes**	White soapy mineral on bedding planes and in fractures; veins of similar material 2-3 mm wide	—	—	Altered siltstone or dolomitic siltstone	3		
B10	A3	77482	110	C34941			7.5YR(4/4)	Nil	Light orange-buff, weathered, laminated, fissile siltstone interbedded with more weathered grey ?ex-dolomite; individual beds 50-100 mm wide; characteristic quartz-ex-pyrite blebs	Larger euhedral **ex-sulphide pseudos** in quartz veins, and much finer grains scattered through thin section (Kemp)	Quartz-ex-pyrite blebs	Finely laminated siltstone (up to 80% felds)	—	Laminated feldspathic siltstone	4	undifferentiated Skillogalee Dolomite	
B11	A3	77517	111	C41986			2.5YR(6/6)	Nil	Light red, weathered, laminated, copper-mineralised sandstone-like rock; irregular bedding 5-100 mm thick; distrupted layering; sand-sized quartz shows 'rounding' typical of quartz overgrowths	Much **Chr** parallel to laminae; **Ma** nodules and stains; probable **ex-Py pseudos** in TS (Farrand)	Heavy ferruginisation in places; euhedral qtz in scattered veins; small silicification pods; probable quartz overgrowths	—	*Highly altered, partly recrystallised siltstone	Altered, partly recrystallised siltstone	5		
B12	A3	77552	112	C41987			10YR(8/1)	Slight	Massive, white, dense, hard dolomite (60-300 mm beds) interbedded with finely laminated (0.5-3 mm) slightly darker dolomite	Traces of **Ma** and **Chr**	Very minor Mn aggregates	—	*Sedimentary dolomite	Dolomite (sedimentary)	6		
B13	B3	77593	113				2.5Y(N7/0)	Slight	Buff-grey, dense, bedded dolomite, laminated towards top; minor 'shotholes' filled with white-yellow sugary material	Minor **Ma** staining	Trace Mn blebs on some surfaces; some kaolin pods and lenses	—	—	Bedded to laminated dolomite	6		
B14	B2	77627	114				10YR(8/1)	Slight	White-buff, massive to finely laminated, copper mineralised dolomite, similar to B13, but brecciated and contorted	**Ma** mineralisation fills voids between breccia fragments	Much kaolin	—	—	Partly brecciated, bedded to laminated dolomite	6		
B15	B2	80455	115	C41988			2.5Y(N7/0)	Slight	Light grey, dense, hard, laminated dolomite with minor cream dolomite interbeds to 100 mm; laminations are evenly spaced at ~1 mm	Minor **Ma-Chr** blebs on some surfaces; **ex-Py pseudos** in outcrop and TS (Farrand)	Many Mn aggregates and dendrites	—	*Silty dolomite; much of the dolomite is secondary and the original rock was probably a quartz siltstone	Laminated dolomite (silty)	6		
B16	B2	77687	116	C34942			2.5Y(N3/0); 10YR(7/1)	Slight to strong	Dark grey (almost black), dense, faintly laminated **dolomite** and tan, finely laminated **dololimestone to limestone**; shaly interbeds to 0.4 m; tectonic breccia along some bedding planes	Faint trace of **Ma**	Mn blebbing on fracture surfaces	Thinly laminated dolomite (97% dolomite)	—	Interbedded dolomite (sedimentary) and limestone	7	Large lath-shaped voids; strong similarity to B103, although the latter has lath-shaped muscovite	
B17	B2	77722	117	C41989			10YR(6/1)	Slight	Medium grey, dense, hard **dolomite** with cream mm-scale laminae; minor warping or rippling of bedding planes; white mm-scale blebs (?precursors to 'shotholes')		Trace Mn aggregates	—	*Sandy dolomite similar to B15 but coarser grained; much secondary dolomite (90%)	Laminated dolomite (sandy dolomite)	9		

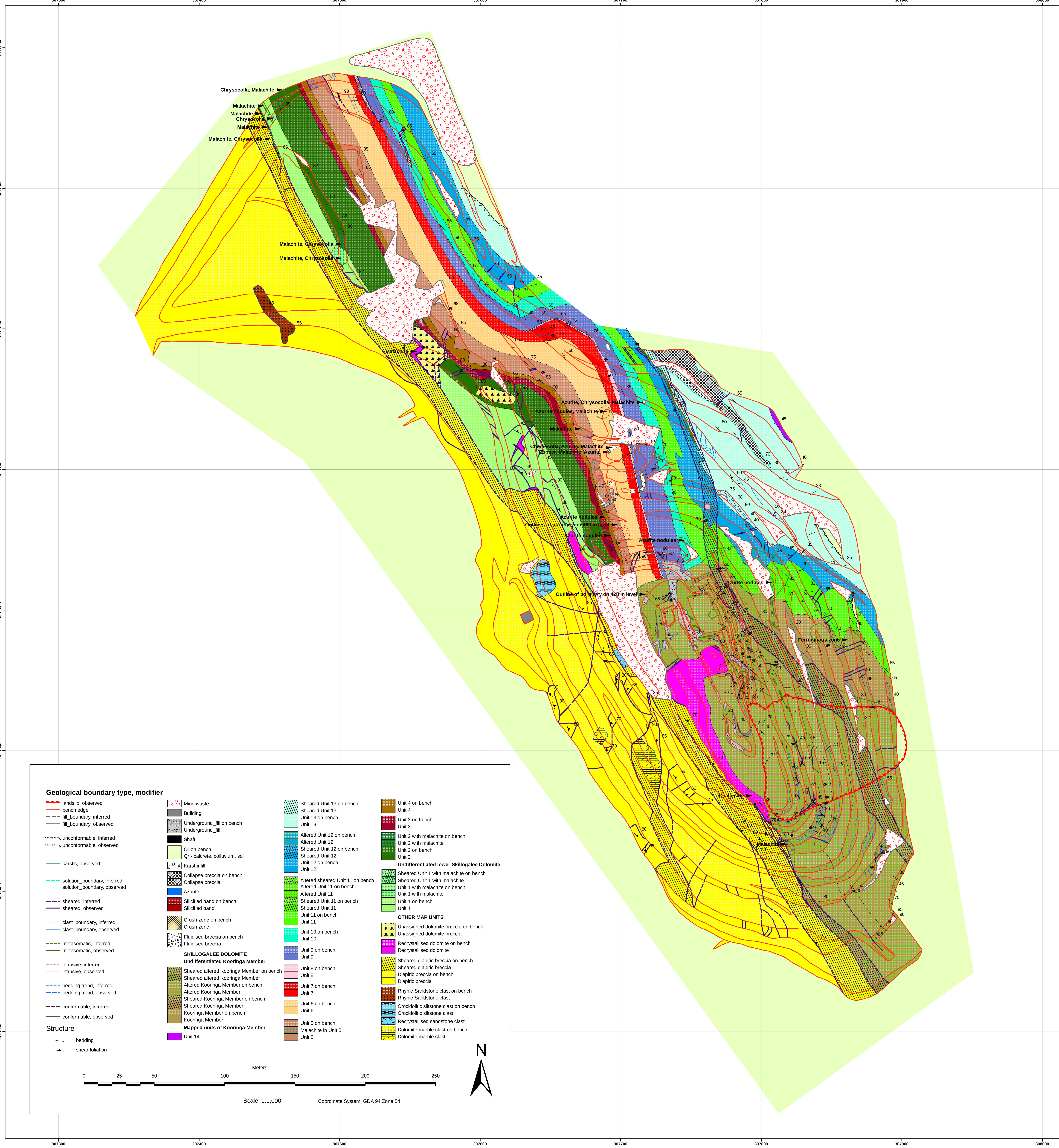

Figure 18: GEOLOGY OF THE BURRA MINE OPEN CUT

Geological mapping by J.F. Drexel and W.S. McCallum, 1981

Produced By: PIRSA Geological Survey Branch

Date: 19th January 2009

Government of South Australia
Primary Industries and Resources SA

To accompany report book 2008/16

APPENDIX A: BURRA COPPER MINE SURVEYING; MINE GRID AND HEIGHT DATUM

Mine Grid

Local Mine Grid: 1960s (SADM)

The local mine grid was established by the SA Department of Mines during 1962–63.

M. Mason (geologist) and R. Adams (survey assistant) mapped the open cut at 1:240 scale. Surveying, as shown on SADME plan L62-78, included 36 survey stations (i.e. Stations c to g, Station 1, Stations B and B', Stations D to Y, Stations N-2, N-4 and N-5, and Stations C-D and D-A. Survey stations were within, or immediately adjacent to, the 1962 pit limits.

The local mine grid was established with Grid North 43° west of Magnetic North such that Grid North approximated the strike of the orebody. All measurements were imperial. The 10 000 ft E line was arbitrarily positioned adjacent to the west of the pit, and the 15 000 ft N line to the north of the pit, with the 14 500 ft N line through Tinlines Shaft. Height datum was zero at 100 ft below LWOST.

Subsequent SADM geological mapping and drilling (Nixon et al., 1965) was related to this grid.

The grid was extended beyond pit limits in 1964 with pegs at 100 ft coordinate intersections (plan L64-145; M.G. Mason and R. Adams, Stadia Field Books 288, 303 and 304).

Local Mine Grid: 1970–71 (SAMIN)

In 1970–71, SAMIN Ltd established Survey Stations BM01 to BM16 adjacent to the proposed pit limits or within or adjacent to the processing plant and offices (Table A-1).

Stations were plotted on SAMIN Ltd, Burra Project, Mine Layout, plan No. 70-519 at 1:2400 scale, as surveyed by Kinnaird Hill de Rohan and Young, Consulting Engineers. Additional topographic and survey data for the plant and offices were shown on plan 70-520 — Primary Earthworks, Sheet 1; plan 70-572 — Setting Out Details; and plan 70-573 — Setting Out Details.

Coordinates relative to the imperial mine grid were shown for 10 of these stations: BM02, BM03, BM04, BM05, BM07, BM10, BM12, BM13, BM14 and BM15. No elevations were shown for these.

Elevations relative to mine datum (100 ft below LWOST) were quoted for five stations: BM01, BM06, BM08, BM09 and BM16, all of which are along the fence boundary north of the pit and plant. No coordinates were shown for these stations.

Neither coordinates nor elevation were shown for BM11.

Therefore no survey station included both coordinates and elevations.

All subsequent company mapping (i.e. SAMIN Ltd, Adelaide & Wallaroo Fertilizers Ltd) has been based on the local mine grid and local datum, with measurements being metricated in 1973.

SADME Surveying, 1980 onwards

1.

As part of the South Australia Department of Mines and Energy (SADME) stadia survey of the Burra open pit during 1980–81 by R.J. Harris (Technical Officer), 12 Survey Stations (B01 to B12) were established (SADME Stadia Field Books 646, 647, 651 and 652). Station B07 was destroyed by subsequent mining, and stations B05, B08, B09 and B12 were destroyed by the 1981 flooding of the pit after the mine dewatering pumps were turned off (Table A-2).

Five stations (NP, NP-A2 and TP 1 to 3) were established by J.D.A. Harrison (Supervising Technical Officer, Surveying). Stations TP1 to 3 were in the District Council rubble pit to the immediate northeast of the Burra Mine (Table A-2).

Nine geographical points near the Burra Mine were surveyed by J.D.A. Harrison, comprising suitable fixed permanent marks for any future survey (Table A-3).

Between 1975 and 1980, Adelaide & Wallaroo Fertilizers completed 16 dewatering boreholes (Boreholes 1–14, PB88 and Bottom Bore). All except Boreholes 1, 9 and 14 were surveyed by J.D.A. Harrison (Table A-4).

Adelaide & Wallaroo Fertilizers established a permanent base station (Station BS, Table A-2) in August 1980 as part of a slope stability control program (Sweetman, 1983, pp.83–85).

Survey station B13 was established in 1984 by A.J. Smith (SADME Field Assistant) in the Roche Bros, road metal pit on the eastern side of the main pit (Table A-2).

2.

Two SA Department of Lands survey stations (6630/1144 and 6630/1157) were located by J.D.A. Harrison in l981, enabling Australian Map Grid (AMG) metric coordinates to be calculated for all post-1980 SADME survey stations, fixed geographic points and boreholes.

Similarly, Department of Lands Bench Mark 6630/4006 was located, enabling Australian Height Datum (AHD) elevations to be calculated for all post-1980 SADME survey stations etc.

3.

In order to relate the 1980–81 mapping project by J.F. Drexel and W.S. McCallum to prior work, the original mine grid was re-established by J.D.A. Harrison in 1981.

SAMIN Survey Stations BM02, BM03, BM13 and BM15 were relocated and surveyed, and related to AMG. Their original imperial mine grid coordinates were metricated. From these four points (with coordinates known in both AMG and local mine grid) the local mine grid coordinates for all post-1980 survey stations and fixed points were derived via a Lauf transformation (R.B. Frost, Computer Systems Officer, SADME).

Both Mine Grid and AMG coordinates are shown in accompanying Tables A-l to A-4.

From the relative coordinate systems was derived an accurate measurement of grid north:

> Mine Grid North = 323°47’47’ True North <u>or</u> Mine Grid North is 36°12’13’ west of True North, equating well to the 43° West of Magnetic North quoted by Mason and Johnson (1962, SADME plan L62-78).

4.

SAMIN Survey stations (1970–71; Table A-l) were updated as follows:

- BM02, 03, 12 and 15 were related to AMG, AHD and Mine Grid (outlined above).
- BM01, which had not been coordinated by SAMIN, was relocated and coordinated.

- Thus BM01, 02, 03, 03, 13 and 15 are the only SAMIN stations for which both elevation and coordinates are available.
- BM06, 08, 09, 11 and 16 were not originally coordinated and could not be relocated, hence their coordinates are unknown.
- Coordinates or elevations for remaining stations were converted numerically from imperial to metric datums.

Data availability is as follows:

Survey Station No. (BM)

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16
Coordinates	*	*	*	*	*		*			*		*	*	*	*	
Elevation	*	*	*			*		*	*				*		*	*

where * = data available

Surface Height Datums

Imperial mine height datum for surface data prior to the mid-1970s was zero at 100 ft below Low Water Ordinary Spring Tide (LWOST) at Port Adelaide. The earliest located reference to this datum was Segnit (1939, fig. 45). Prior datums were arbitrary local datums.

LWOST is 1.73 m (5.68 ft) lower than Mean Sea Level (MSL), Port Adelaide. MSL is 0.216 m above Australian Height Datum (AHD) at bench mark 6630/4006 at Burra.

Therefore, 100 ft below LWOST = 100 ft (30.48 m) + 1.73 m - 0.216 m AHD, and 100 ft below LWOST = 31.99 m AHD at Burra.

SAMIN Survey Station BM01 had an elevation of 1712.02 ft, equivalent to 489.83 m AHD using the above conversion, and an elevation of 490.00 m AHD as surveyed from Bench Mark 6630/4006. BM01 was the only levelled imperial survey station to be relocated and re-surveyed in 1981. To correct the slight discrepancy, elevations in feet were converted to AHD by conversion to metres and subtraction of 31.82 m.

Metric elevations used by Adelaide & Wallaroo Fertilizers in the 1970s and 1980s are a direct metrification of the 100 ft below LWOST datum. These elevations have been converted to AHD by subtracting 31.82 m.

Table A-l Survey stations established by SAMIN Ltd, 1970.

	Mine Grid		AMG		AHD
	Easting	**Northing**	**Easting**	**Northing**	
BM01	3200.238	4737.318	307362.186	6271820.013	490.00
BM02	3200.400	3931.920	307837.963	6271170.301	498.84
BM03	2895.600	4267.200	307394.130	6271260.646	518.82
BM04	3322.320	4267.200	307738.233	6271512.668	na
BM05	2895.600	4724.400	307123.758	6271629.434	na
BM06	(3252)	(4724.4)	na	na	(487.76)
BM07	2529.840	4724.400	306828.796	6271412.605	na
BM08	(2895.6)	(4839)	na	na	(482.51)

BM09	(2763)	(4887)	na	na	(475.04)
BM10	2676.530	4843.810	306876.155	6271595.936	na
BM11	(2515)	(4742)	na	na	na
BM12	2750.630	4711.090	307014.653	6271532.820	na
BM13	3017.520	4267.200	307492.430	6271332.670	511.88
BM14	2895.600	4480.560	307268.026	6271432.689	na
BM15	3048.000	4724.400	307246.830	6271719.610	491.8
BM16	(2628)	(4927)	na	na	(471.85)

NB: 1. na = data not available.
2. coordinates in brackets have been scaled from imperial plans.
3. relative levels in brackets have been converted from imperial datum, 100 ft below LWOST; other levels have been related to AHD via bench mark 6630/4006.

Table A-2 Survey stations established by SADME, 1980–84.

	Mine Grid		AMG		Elevation AHD	Comments
	Easting	Northing	Easting	Northing		
B01	2956.442	4265.448	307444.223	6271295.179	520.53	
B02	3187.570	4725.056	307359.194	6271802.626	490.85	
B03	3225.250	4491.335	307527.634	6271636.177	496.15	
B04	3139.936	4446.700	307485.153	6271549.778	486.85	
B05	3198.835	4293.747	307622.998	6271461.178	438.80	Now under water
B06	3071.162	4228.142	307558.775	6271332.861	487.38	
B07	3263.370	4166.760	307750.033	6271396.877	486.52	Destroyed by mining; now under water
B08	3159.981	4165.600	307667.342	6271334.882	420.42	Now under water
B09	3144.510	4170.500	307651.955	6271329.692	418.8	Now under water
B10	3070.467	4618.226	307327.741	6271647.153	502.0	
B11	3053.963	3987.086	307687.259	6271128.288	516.7	
B12	3167.560	4360.740	307558.193	6271496.732	444.6	
B13	3262.342	4145.195	307761.940	6271378.880	486.86	
NP	3189.894	4418.978	307541.832	6271556.917	458.17	
NPAZ	3200.233	4703.475	307382.169	6271792.671	486.50	
TP1	3323.729	4615.461	307533.854	6271794.496	493.43	Council rubble pit
TP2	3343.656	4542.243	307593.142	6271747.151	504.02	Council rubble pit
TP3	3286.776	4487.571	307579.504	6271669.462	502.56	Council rubble pit
BS	Adelaide & Wallaroo Fertilizers Pty Ltd, base station, slope stability control					Mounting plate set onsteel post set in concrete
	3458.24	4145.74			487.00	

Table A-3 Survey coordinates, geographic fixed points, SADME, 1981.

Station	Mine Grid		AMG		Elevation AHD
	Easting	Northing			
Department of Lands: Coordinated points (AMG)					
6630/1144	1278.729	5283.261	305491.860	6271112.218	475.90
6630/1157	-2253.447	-5073.437	307382.859	6260934.604	670.60
Department of Lands:Bench Mark (AHD)					
6630/4006	3440.316	4446.326	307727.718	6271726.784	512.09
Geographical Points, surveyed by J.D.A. Harrison					
Lookout Hill	3425.687	3745.855	308129.637	6271153.398	532.29
TV Pole	3421.955	4585.138	307631.034	6271827.959	514.08
Ladder Pole	2970.803	4334.517	307414.997	6271359.362	524.79
Johnny Green Chimney	3655.575	4106.535	308101.710	6271579.928	493.86
North Chimney	3379.403	3924.344	307986.791	6271269.957	530.84
South Chimney	3253.521	3843.588	307932.998	6271130.440	531.80
East Silo Vent	3182.670	5036.963	307170.968	6272051.957	511.29
West Silo Vent	3155.205	5032.614	307151.303	6272032.204	511.26
Plant Chimney	2678.396	4720.250	306950.953	6271497.460	505.68

Table A-4 Adelaide & Wallaroo Fertilizers Ltd dewatering boreholes survey coordinates and underground levels, 1975–80.

Borehole No.	**Coordinates** mN	mE	**Collar elevation AHD**	**Depth** (m)	**Date drilled**		**Drilled by**	**Water level**	**SADME Bore Serial No. 6630-**	**Old workings encountered** (metres depth); **from SADME Bore File**	**Interpreted mine level intersected** (fathoms) **(from Sweetman, 1983)**
1	–	–	–	72.8	drilled	13/06/75	Preiss		1298	72.8	40?
					developed	22/09/75	SADME				
2	3092.037	4315.839	487.57	85.9	completed	03/10/75	Walsh				50?*
(AMG)	307523.81	6271415.92									
3	3091.704	4313.776	487.73	84.9	completed	28/11/75	Walsh				50?*
(AMG)	307524.76	6271414.06									
4	3148.000	3912.755	503.20	122.7	completed	15/12/75	Nitschke				50 and 60?*
(AMG)	307807.02	6271123.89									
5	3146.632	3913.832	503.28	102.5	completed	30/08/76	Walsh	-56.3 m on 27/9/77	1300	43 to 46	20F?
(AMG)	367805.28	6271123.95		123.0	deepened	July 1979	SADME	i.e. 447 m AHD	1301	74.5 to 78.5	40F?
									1294	100 to 102.5	50F?
										123	60F?
6	3145.305	3914.543	503.12	102.5	completed	15/09/76	Walsh		1299,	43?	20F?
(AMG)	307803.79	6271123.74		123.0	deepened	July 1979	SADME		1301,	122	60F?
									1348		
7	3143.664	3915.163	502.53	90.0	abandoned	25/08/77;	Sides				
(AMG)	307802.10	6271123.27)			not developed						
8	3141.389	3915.447	503.51	141.2	drilled	?	Sides	-76 m on 19/3/78	1295		50F?*
(AMG)	307800.08	6271122.18			developed	14/03/78	SADME	i.e. 437 m AHD	1301	123	60F?
9	Central between boreholes		–	55.5		22/10/78	Walsh	-30 m on 22/10/78	1296	0-13 fill and	
	10, 11, 12, and 13									timbers	
10	3243.841	4344.822	459.3	93.0		27/10/78	Walsh	-18 m on 27/10/78	1292		
								i.e. 441 m AHD			

11	3172.497	4357.032	445.14	53.0		07/02/79	Walsh				
(AMG)	307564.38	6271496.67									
12	3202.587	4383.809	449.60	62.0		03/02/79	Walsh				
(AMG)	307572.84	6271536.04									
13	3195.539	4301.705	438.77	94.0		02/03/80	Walsh?				
(AMG)	307615.64	6271465.65									
14			?	56.0		26/02/80	SADME	-19 m on 28/02/80	1347	2.5 to 4.5 m	
										8 to 9 m	
										14 to 16.8 m	
										24.5 to 28 m	
										49 to 53 m	
Bottom Bore	3163.062	4166.764	420.57	–		–	–				
(AMG)	307669.14	6271337.64									
PB80	3193.791	4357.993	448.48	–		–	–				
(AMG)	307580.99	6271510.02									

APPENDIX B: UNDERGROUND LEVELS, CONVERSION TO AHD

Underground levels were developed at the following fathom levels:

6, 8, 12, 17, 20, 25, 30, 35, 40, 45, 50, 55, 60, 70.

The upper four levels to 17 fathoms were not continuous, and no comprehensive maps are available. Below this, the 20, 30, 40, 50 and 60 fathom levels are more extensive than intervening levels. The 70 fathom level is restricted.

Relating the levels to AHD or local mine datum is difficult. Levels were probably measured down from the surface at one of the older shafts, possibly Roach's, Kingston's or Graham's Main Shaft. Surface elevation of these shafts in unknown; no surveyed surface plans are available and the shafts have been destroyed by open cut mining.

Relationship of levels to AHD can only be inferred.

(1) SADME plan 1657

'Traced from very old undated plan loaned by A.F. and P.A. McBride, AMD Buildings, 27/11/40.'

Plans shows main underground levels, and a schematic north–south section, with horizontal and vertical scales 1 inch:40 feet. The following data are derived by scaling from plan 1657.

The difference in elevations between levels, although nominally a multiple of 10 fathoms, is not consistent.

A horizontal, undefined line extends the length of the section, near the top, and may be the datum. This line is above ground through the open cut (pre-1971 extent of open cut) and is below ground in the south of the section, i.e. at Waterhouse, Morphett and Hector Shafts.

Scaled distances between levels are:

- surface to datum? (at Morphett's Engine Shaft = 9.5 m (5 fathoms)
- datum? to 20 fathoms = 37 m (20 fathoms)
- 20 to 30 fathoms = 20 m (11 fathoms)
- 30 to 40 fathoms = 16.5 m (9 fathoms)
- 40 to 50 fathoms = 23.5 m (13 fathoms)
- 50 to 60 fathoms = 16.5 m (9 fathoms)
- 60 to 70 fathoms = 19.5 m (10.5 fathoms)

Morphett's Engine Shaft: Elevation as surveyed in 1981 is 502 m AHD.

Therefore datum? line on section is 492.5 m AHD
20 fathoms is 455.5 m AHD
30 fathoms is 435.5 m AHD
40 fathoms is 419.0 m AHD
50 fathoms is 395.5 m AHD
60 fathoms is 379.0 m AHD
70 fathoms is 359.5 m AHD

(2) Dickinson, 1942 (page 75)

‘At the 30-fathom or 180 ft level, about 40ft, below the present water level, ...'

Static Water Level:

- Mason and Johnson (1962; SADME plan L62-78).
  Water level = 1604.5 ft (mine elevation) in January 1962
  = 489.05 m (mine elevation)
  = 457.23 m AHD.
- Nixon, Fairburn and Warne (1965; SADME plan L65-82).
  Water level = 1606.1 ft (mine elevation) on 5 February 1965
  = 489.54 m (mine elevation)
  = 457.72 m AHD.
- Sweetman (1983, Fig. 8).
  Water level before dewatering:
  = 491 m (mine elevation)
  = 459 m AHD
- Static water level in 1984, two years after pumps were switched off
  = 456 m AHD (approx.).

The mine was not being worked or pumped in 1942. Water level before dewatering is calculated at between 456 and 459 m AHD. Therefore, the 30 fathom level is between 444 and 447 m AHD.

(3) Dewatering boreholes

Dewatering boreholes 1 to 14, as developed for SAMIN or Adelaide & Wallaroo Fertilizers between 13/6/75 and 26/2/80 are detailed in Table A-4 in Appendix A.

Underground workings were intersected in boreholes 5, 6, 8, 9 and 14 as reported in SADME borefiles. Reliable collar elevations and depths of workings are available only for boreholes 5, 6 and 8.

Table B-l shows interpreted mine levels for Borehole 5 (20F, 40F and 50F), Borehole 6 (20F and 60F), and Borehole 7 (60F).

(4) Armstrong (?1981)

Unpublished plan. Section shows open cut, underground levels, shafts and pumps.

20 F = 85 m	(mine elev.)	=	453 m AHD
40 F = 453 m	(mine elev.)	=	421 m AHD
50 F = 429 m	(mine elev.)	=	397 m AHD
60 F = 409 m	(mine elev.)	=	377 m AHD
70 F = 395 m	(mine elev.)	=	363 m AHD

(5) Sweetman (1983; page 33)

- 40 Fathom level is 454 m mine elevation (422 m AHD) and 40 F = 73 m.
  Therefore zero fathoms is 495 m AHD.
- 60 Fathom level is 413 m mine elevation (381 m AHD) and 60 F = 110 m.
  Therefore zero fathoms is 491 m AHD.

Summary

Results from the above sources are summarised in Table B-1. Results from Dickinson (1942) vary by 10 m from other data, and an average or interpreted best fit of remaining data is presented in Table B-l.

The underground levels were probably not horizontal, varying in elevation by at least several metres across the mine. The levels may have been developed with a slope down to the nearest main shaft to assist ore haulage.

Table B-1 Burra Mine underground levels summary (relative elevations, metres AHD).

	Scaled from SADME Plan 1657	**Dickinson (1942)**	**Adelaide & Wallaroo Fertilizers dewatering boreholes**			**Armstrong (1981)**	**Sweetman (1983)**	**Interpreted best fit**
			No.5	**No.6**	**No.8**			
Datum?	492.5							493
20 fathom	455.5		456 to 459	459		453		455
30 fathom	435.5	444 to 447						436
40	419		423 to 427			421	422	419
50	395.5		399 to 402			397		397
60	379			380	379	377	381	379
70	359.5					363		360

APPENDIX C: SUMMARY OF SADM DRILLING, 1963–64

Data from Nixon et al. (1965) — includes all drill logs and analyses.

(1) Steep diamond drillholes (Table C-l)

- DDH 1, to 233.7 m, 17/1/63–2/8/63.
- DDH 2, to 258.8 m, 9/8/63–6/3/64.

(2) Sub-horizontal rotary drillholes (Table C-2)

- RDH 3–12, drilled 29/7/64–6/11/64.

(3) Vertical percussion holes (Table C-3)

- PB 1 drilled 2/10/64–23/10/64;

GB 8, 10, 12, drilled 26/10/64–14/11/64;
PB 2–13, drilled 16/11/64–21/4/65.

- Target was 100 ft (30 m) below watertable, BUT GB 8, 10, 12 only to watertable,

PB7 was stopped in unmineralised dolomite at 11.4 m.
PB 12 blocked at 3.8 m, and replaced by PB 13.

- Coordinates are from MEPL survey data, as shown on Envelope plan No. 680-16.

Table C-1 Burra copper mine, steeply inclined diamond-drillholes (wet), drilled by SADM 1963–64.

Hole No.	Depth (m)	Mine coordinates		Collar RL (m AHD)	Azimuth	Inclination
		mE	mN			
DDH1	233.7	3359.5	4159.6	482.7	270° mag.	0 m – 53°
						30.5 m – 52°
						61 m – 51°
						91.5 m – 50°
						167.6 m – 47°
						198.1 m – 42°
						204.2 m – 42°
						222.5 m – 61°
DDH2	258.8	3316.2	3829.5	524.2	242° mag.	0 m – 65°
						30.5 m – 66°
						59.4 m – 67°
						121.9 m – 70°
						152.4 m – 68°
						201.2 m – 71° towards 248° mag.
						231.7 m – 72° towards 252° mag.

Table C-2 Burra Copper Mine, sub-horizontal rotary and diamond-drillholes, drilled by SADM 1964.

Hole No	Depth (m)	Mine coordinates		Collar RL (m AHD)	Azimuth (magnetic)	Inclination	Date
		mE	mN				
RDH3	25.9	3156.2	4276.0	464.4	249°	-1°	29/7/64–3/8/64
RDH4	36.6	3135.3	4281.8	472.3	241°30’	0°	4/8/64–8/8/64
RDH5	16.8	3182.1	4325.9	458.3	246°30’	0°	11/8/64–13/8/64
RDH6	36.6	3150.3	4331.1	463.8	247°30’; from 16.8 m 253°	0°	14/8/64
RDH7	85.3	3208.0	4414.1	463.5	225°; from 15.2 m 232°; from 45.8 m	+2°	21/8/64–1/9/64
RDH8	38.1	3208.3	4193.4	471.4	242°30’; from 15.2 m 252°	+2°	4/9/64–8/9/64
RDH9	3.4	3135.8	4197.1	476.9	241°30’	0°	9/9/64–10/9/64
RDH10	36.0	3135.2	4183.8	480.3	235°; from 16.8 m [illegible]	+2°	11/9/64
DDH11	18.3	3135.2	4272.8	468.1	247°	+2°	16/9/64–18/9/64
DDH12	65.1	3201.00	4552.2	491.9	205°	-28°	6/10/64–6/11/64

Table C-3 Burra copper mine, vertical percussion drillholes, SADM, 1964–65.

Hole No	Depth (m)	Mine coordinates		Collar RL (m AHD)	Date
		mE	mN		
PB 1	62.5	3159.7	4292.5	460.6	2/10/64–23/10/64
PB 2	54.9	3152.4	4224.4	476.6	16/11/64–23/11/64
PB 3	62.5	3158.2	4143.3	486.8	25/11/64–2/12/64
PB 4	27.4	3174.1	4347.3	459.3	3/12/64–3/2/65
PB 5	29.9	3185.8	4282.0	459.5	4/2/65–10/2/65
PB 6	33.5	3194.5	4260.7	?459.5 (SADM) ?480.6 (MEPL)	12/2/65–22/2/65
PB 7	11.4	3208.0	4323.9	459.2	23/2/65–25/2/65
PB 8	33.5	3211.7	4306.8	458.3	25/2/65–11/3/65
PB 9	64.0	3180.4	4173.8	485.6	19/3/65–3/4/65
PB 10	134.1	3169.0	4223.6	480.3	–
PB 11	54.9	3138.3	4223.2	480.9	5/4/65–12/4/65
PB 12	3.8	Location uncertain, replaced by PB 13; no drill log			
PB 13	57.9	3144.3	4172.0	483.9	15/4/65–21/4/65
GB 8	25.9	3136.1	4207.4	479.8	9/11/64–12/11/64
GB 10	25.0	3121.5	4221.7	482.4	12/11/64–14/11/64
GB 12	24.4	3167.1	4223.1	479.4	26/10/64–6/11/64

APPENDIX D: SUMMARY OF MEPL DRILLING, 1966–67

(1) Steep diamond drillholes (Table D-1)

- Drillholes BS1 to 5, drilled 3/2/66 to 4/1/67.
- Drillhole BS6 drilled 19/1/67 to 28/2/67, still in progress on 28/2/67 but no later information available.
- Drillholes BS7 and 8, no information available.
- All data adapted from Rogers et al. (1967); includes drill logs for BS 1–5.

(2) Vertical percussion and rotary drillholes (Table D-2)

- Rotary drilling from 14/2/66 to 6/9/66.
- Percussion drilling from 22/2/66 to 28/2/67 (end of report period).
- 57 holes completed, comprising PB 20 to PB 72, and PB 29*, PB 34(2), PB 44(2), PB 56(2) and PB 62(2), but not PB 37.
- Depth and assay data from Rogers et al. (1967).
- Coordinate and elevation data from Envelope plan no 680-16. Elevations of collars were determined barometrically (Keith Rodgers, ex-MEPL staff, pers. comm., c.1985).

4. No geological drill logs are available.
5. Rogers et al. (1967 (Env. 736)) indicated that drillholes PB 26, 50, 52, 54 and 55 were to be deepened after 28/2/67 but there is no subsequent record.

Table D-1 Burra copper mine, Mines Exploration Pty Ltd, steep diamond-drillholes.

Hole No.	Depth (m)	Mine coordinates mE	Mine coordinates mN	Collar RL (m AHD)	Azimuth (magnetic)	Inclin.	Date	Reference
BS 1	132.6	3293.4	3748.7	523.7	226°30’	-55°	3/2/66–11/5/66	Env. 736, geological log and Cu, Pb, Zn analyses from 91.4 to 132.6 m
BS 2	240.2	3340.0	4847.5	478.8	226°30’	-65°	3/3/66–14/6/66	Env. 736, geological log and Cu, Pb, Zn analyses from 140.2 to 167.6 m
BS 3	274.0	3048.6	3749.0	523.2	046°30’	-55°	25/5/66–19/7/66	Env. 736, geological log
BS 4	272.2	3048.0	4114.8	501.6	046°30’	-55°	23/6/66–9/9/66	Env. 736, geological log, bedding angle log, Cu analyses from 143.2 to 182.9 m
BS 5	148.4	31294.3	2438.4	–	226°30’	-52°	30/9/66–4/1/67	Env. 736, geological log and bedding angle log
BS 6	164 m on 28/2/67	2991.6	4221.5	No data available			19/1/67	
BS 7	?	?	?	No data available			?	
BS 8	?	2991.62	4221.5?	No data available			?	

Table D-2 Burra copper mine, MEPL vertical percussion and rotary drillholes.

Hole No.	Type	Depth (m)	Mine coordinates		Collar RL (m AHD)	Analysis	
			mE	**mN**		**Interval** (m)	**Cu** (%)
PB20	C	68.6	3133.3	3992.9	501.7		
PB21	C	68.6	3148.6	3992.9	499.0		
PB22	R	27.4	3163.8	3992.9	497.9		
PB23	C	91.4	3134.9	4023.4	501.0	82.3–91.4	0.71
PB24	C	91.4	3150.1	4023.4	498.1		
PB25	C	87.8	3165.4	4023.4	496.9		
PB26	R	91.4	3136.1	4053.5	499.7		
PB27	C	70.1	3151.3	4053.5	497.5		
PB28	C	91.4	3166.6	4053.5	496.2		
PB29	C	80.8	3181.8	4053.5	494.9		
PB29*	R	13.7	3174.2	4053.5	495.5		
PB30	C	91.4	3141.0	4084.3	497.0	45.7–91.4	2.37
PB31	C	91.4	3156.2	4084.3	496.0		
PB32	R	31.1	3171.4	4084.3	495.4		
PB33	C	80.5	3147.1	4114.8	494.9	39.6–80.5	2.85
PB34	R	24.4	3161.7	4114.8	494.4		
PB34(2)	C	86.9	3163.8	4114.8	494.4	51.8–85.3	1.03
PB35	C	91.4	3177.5	4114.8	492.2		
PB36	R	35.1	3192.8	4114.8	492.2		
PB37	Not drilled						
PB38	P	85.3	3206.5	4198.6	471.1		
PB39	P	86.9	3197.4	4221.5	469.0	61.0–82.3	1.66
PB40	P	86.3	3212.6	4221.5	469.3	60.5–85.3	0.96
PB41	?	18.3	3123.0	4252.9	482.4		
PB42	P	79.3	3161.3	4252.2	467.7	0–79.2	1.93
PB43	P	78.9	3170.2	4252.0	467.5	9.1–77.7	2.49
PB44	P	35.1	3185.2	4245.7	467.5	9.1–35.1	2.04
PB44(2)	P	89.3	3182.1	4248.9	467.5	0–89.3	1.71
PB45	P	91.4	3200.4	4247.4	467.8	12.2–91.4	1.10
PB46	P	80.8	3215.9	4247.9	468.7	0–9.1 64.0–73.2	2.02 1.56
PB47	P	54.6	3226.5	4297.7	467.8	0–48.8	1.47
PB48	P	12.5	3207.0	4325.9	459.4		
PB49	R	36.6	3125.7	4572.0	497.1	0–15.2	1.65
PB50	R	15.2	3134.9	4572.0	496.3		
PB51	R	43.3	3144.0	4572.0	495.3	0–18.3	1.60
PB52	R	39.6	3159.3	4572.0	492.4	18.3–24.4	1.95
PB53	R	39.6	3176.0	4693.9	493.4	0–27.7	1.62
PB54	R	44.8	3185.2	4693.9	492.8	6.1–23.5	2.66
PB55	R	64.6	3194.3	4693.9	492.1		
PB56	R	9.1	3209.5	4693.9	499.0?		
PB56(2)	R	41.5	3210.5	4693.9	490.8?		
PB57	R	49.7	3166.9	4693.9	493.8		
PB58	R	97.6	3118.3	3993.1	504.5	88.4–91.4	0.88
PB59	R	80.8	3119.6	4023.4	501.9		
PB60	R	97.5	3120.5	4054.1	499.4	0–15.2	2.07
PB61	R	79.3	3122.7	4084.3	497.7	0–6.1	0.90
PB62	R	13.1	3130.6	4114.2	496.3	0–13.1	2.01
PB62(2)	C	88.4	3132.7	4115.4	496.4	0–15.2	1.69
PB63	R	73.2	3191.9	4736.6	490.7		
PB64	R	91.4	3200.4	4733.5	490.2	12.2–18.3	1.27
PB65	R	36.6	3209.0	4730.0	489.9		
PB66	Not drilled						
PB67	R	67.1	3143.0	4623.0	495.4		
PB68	R	42.7	3216.3	4624.0	494.3	6.1–21.3	3.64
PB69	R	79.9	3167.0	4624.7	504.8	12.2–18.0	2.15
PB70	R	37.5	3180.6	4626.9	491.0	6.1–18.3	2.78
PB71	R	38.1	3192.8	4626.9	490.6	2.4–27.4	0.83
PB72	R	44.5	3203.5	4626.9	490.1		

Note: P = Percussion; R = Rotary; C = combination

APPENDIX E: GEOLOGICAL LOG OF ADELAIDE AND WALLAROO FERTILIZERS LTD DIAMOND DRILLHOLE BDIB, AND SUMMARY LOG

Table E-1 Burra copper mine, Adelaide & Wallaroo Fertilizers Ltd, diamond-drillholes 1980-81.

Hole no.	**Mine coordinates**		**Collar RL** (m AHD)	**Azimuth** (mag.)	**Inclin. of collar**	**Depth** (m)	**Date drilled**	**Comments**
	mE	mN						
BD1	3310	4200	483	217°	-50°	54	26/7/80–29/7/80	Rotary precollar, abandoned
BD1A	3310	4205	483	217°	-60°	135	28/6/81–26/8/81	Rotary precollar to 101 m, abandoned at 135 m
BD1B	3310	4210	483	217°	-70°	323	1/10/81–27/10/81	Rotary precollar to 200 m
BD2	3245	4000	498	217°	-75°	288	2/7/81–28/9/81	Rotary precollar to 101 m
BD3	3300	3800	520	217°	-50°	32	30/7/80–3/8/80	Rotary precollar, abandoned
BD3A	3250	3800	515	217°	-75°	278.7	31/8/81–18/9/81	Rotary precollar to 101 m

Table E-2 Geological log of diamond drillhole BD1B drilled by Adelaide & Wallaroo Fertilizers Ltd.

Collar RL 515 m AHD
Coordinates 4210 mN, 2315 mE; inclination 70° towards 217° magnetic at collar
Rotary precollar 0–200 m, 17/9/81–30/9/81
Diamond drilling 200–323 m, 1/10/81–27/10/81
Logged by J.F. Drexel and W.S. McCallum, 14–15/6/84

Depth (m)		**Lithology**	**Bedding angle to core**	**Secondary veins and structures**
From	**To**			
201.1	207.2	Dolomite, light grey; faint to strong white laminae, 1-4 mm. Minor etched out voids concentrated in bedding planes.	90°	**201.7 m** White dolomite veins, 1-2 mm, perpendicular to bedding.
207.2	208.1	Dolomite, grey, as above.	80-90°	
208.1	212.8	Dolomite, as above, light brownish grey, red iron staining on joints. **211.7-212.0 m** Breccia zone; angular (1-15 m) grey dolomite in paler matrix; sharp top and bottom contacts.	90°	**209.5-209.7 m** Numerous steep fractures. **212.1 m** Dolomite and siderite vein, 5 mm, 10° to bedding. **212.3 m** Dolomite and siderite vein, 50 mm. **212.6 m** Dolomite and siderite vein, 30 mm, 10° to bedding, including dolomite rhombs.
212.8	216.6	Dolomite, fractured, fawn-brown, few laminae, rare voids, some 10-30 cm thick darker grey dolomite.		**212.8 m** Minor fracture zone. **214.6 m** Iron-stained fracture zone, 100 mm. **216.24 m** White dolomite vein, 30 mm, fractured, with 1 mm pyritohedra.
216.6	229.6	Dolomite, alternating fawn and light grey, 20–60 cm thick; laminae in greyer sections.	70-90°	**216.6m** White dolomite vein, 30 mm, with red ferroan dolomite, 45° to bedding. **217.5 and 217.6 m** Thin veins, 10-20 mm, white dolomite core rimmed with pyritohedra, up to 20° to bedding. **221.2 m** White dolomite vein, 30 mm, 80° to core, pyrite in footwall dolomite for 5 mm and in brecciated hanging wall dolomite for 15 mm. **221.4 m** 70 mm breccia, numerous 1-5 mm dolomite veins, vuggy. **223.9-224.2 m** Numerous 2-3 mm fractures, infilled with ferroan calcite.
		226.1-226.4 m Pyrite disseminated in dolomite.		
				226.5 m 70 mm white dolomite vein, 20° to bedding, pyrite in vugs. **227.5-227.7 m** White dolomite vein, 0° to bedding, then dolomite vein 90° to bedding; veins include minor pyrite. **229.0 m** White dolomite mass, 50 mm, diffuse irregular boundaries, includes pyrite; may replace darker dolomite.
229.6	231.0	Dolomitic siltstone, grey, fine laminae, fissile parting parallel to laminae, lighter below 230.3 m.	70°	**230.5 m** White dolomite vein, 10 mm, 10° to bedding, pyrite near upper contact.

231.0	235.0	Dolomitic siltstone, light brown, laminated. Light red-purple staining cross-cutting bedding from 231.0 to 232.6 m. Below 231.0 m, hydrothermal alteration(?) has etched selected beds up to 50 mm thick; restricted to light brown dolomite. **231.0-237.9 m** Numerous small holes	75°	
		232.8-233.1 m Extensively etched. **233.9-234.3 m** Extensively etched, disintegrated.	45°	
235.0	237.9	Dolomite, laminated, light grey to light orange-brown (hydrothermal?) stained; contorted, soft sediment slumping? Abundant white secondary dolomite.	45°	
237.9	240.0	Dolomite, light grey, few laminae. Abundant fine disseminated sulphide below 237.9 m.	70°	**239.0 m** White dolomite vein, 20 mm; dolomite is crystalline in centre, rare pyrite. **239.9 m** White dolomite vein, 20 mm, fractured for 50 mm above.
240.0	243.2	Dolomite, grey, laminated.	90°	
243.2	250.1	Dolomite, grey, rare pale laminae; irregular bedding; some parting parallel to laminae. **244-244.4, 245.0-245.1, 245.7-247.0 m** Fractured and disintegrated.	50°	Numerous patches and veinlets of secondary white dolomite, crystalline, or vuggy in centre. **247.0 m** 120 mm white dolomite mass cross-cutting bedding.
250.1	258.0	Dolomite, grey, poorly defined laminae 1-2 mm; abundant fine (<1 mm) angular etched voids on core surface. **246.4-256.9 m** Extensively fractured.	70°	**253.0 m** 100 mm, fractured and recrystallised irregular grey dolomite with diffuse margins in white dolomite matrix.
258.0	259.4	Dolomite, light brown, fissile discontinuous 1-2 mm laminae, fine pyrite stringers along laminae; plus mid-grey dolomite interbeds. Soft sediment deformation at 259.2		
259.4	267.2	Clay, soft, expansive, off whjte, friable, montmorillonite? 50-100 mm bands of hard grey dolomite, massive, non-laminated at 259.5, 260.5, 261.0, 261.3, 261.5, 261.7, 263.3, 263.8, 265.3, 265.5, 265.9, 266.6, 266.9 m, i.e. approx. 80% clay, 20% dolomite.		
267.2	270.2	Limestone, pale brown, poorly defined 1-5 mm bedding; with 1 mm by 3 mm banding parallel to bedding. Extensively replaced by grey		**267.6 m** Calcite vein, 10 mm, 45° to core.
270.2	274.2	Dolomite, fissile, brown, parting 1-3 mm, finely laminated, 100 mm thick beds at 270.2 and 271.8 m, with interbedded grey dolomite. Finely laminated dolomite may be algal. Includes bedded or massive pyrite.	80°	
274.2	295.9	Clay, soft, expansive, friable, comprising 80% of rock, with core as follows:		

277.0		Limestone–dolomite, dark grey, laminated.		**277.0 m** Pyrite veins parallel and perpendicular to laminae; white dolomite vein with pyrite in centre.
279.6		Dolomite, dark grey, with interbedded brown laminated dolomite.		
280.1		Dolomite, grey. Intrusion of secondary hydrothermal dolomite in 80 mm high domal structure with pyrite stringers. Passive replacement of dolomite in adjacent host.		
283.0		Dolomite, pale brown-pink colour, iron stained or K-feldspar alteration? Pyrite disseminated in dolomite and in thin quartz vein.		
				285.9 m White dolomite and quartz vein 20-30 mm, fractured, rare pyrite in adjacent dolomite.
289.0		Dolomite, dark grey, faint laminae with fine brown laths.		**289.0 m** Quartz(?) vein 3 mm, replacing dolomite, subparallel to bedding, plus disseminated cubic pyrite in host. **289.8 m** White dolomite, 30 mm, coarsely crystalline cleavage fragments, probably vein.
291.0		Dolomite, dark grey, possible algal laminae, with bedded and disseminated pyrite.		
292.4		Dolomite breccia, angular dark grey laminated dolomite fragments in lighter grey dolomite matrix, all finely recrys-tallised; bedded pyrite in clasts.		
295.0		Dolomite, grey, with dolomite laths, with etched iron-stained margins.		**295.0 m** White quartz masses, replacing dolomite, with pyrite on margins.
295.9	298.5	Solid core. Dolomite, finely recrystallised, brecciated?; dark grey clasts and matrix; clasts may be recrystallised dolomite rhombs or rhombs with overgrowths; plus fragments of pink		**296.7 m** Shear zone, 100 mm, infilled with calcite and fibrous white amphibole. **298.0 m** Dolomite vein, 5 mm.
298.5	323.0	Diapiric breccia. Abundant dolomite clasts in dolomite matrix$_r$ light brown to grey. Rarer clasts of chloritic siltstone, with bedded pyrite; dolomite rhombs; and pink dolomite with clear dolomite rhombs. Rare pyrite in matrix.		**298.5 m** Chlorite shear, 100 mm. Fracture or shear zones: **301.1 m** 20 mm thick. **302.7 m** 200 mm thick. **303.3 m** 200 mm thick. **304.5 m** 100 mm thick. **315.0 m** 100 mm thick. **315.7 m** 100 mm thick. **316.4 m** 100 mm thick. **316.8 m** 200 mm thick. **319.0 m** 200 mm thick.
323.0		End of hole		

Table E-3 Summary geological log, drillhole BD1B.

Sedimentary lithology	Alteration	Veining	Sulphide mineralisation in host rock
201.7-229.6 m Laminated very finely recrystallised grey dolomite. Minor etched voids (feldspar?) on weathered surfaces to 298.5 m.		**201.7-253.0 m** Abundant white dolomite veins. Pyrite in veins, near contacts, common from 216.2 to 239.0 m.	**201.7-237.94 m** Very minor pyrite, less than 1 mm,disseminated in darker dolomite.
229.6-235.0 m Fissile dolomitic siltstone and grey dolomite. **235.0-237.94 m** Grey dolomite with soft sediment slumping.	**231.0-232.6 m** Red iron staining. **231.0-237.9 m** Selected dolomite beds are stained light brown, and etched and fretted, resulting in total disintegration in extreme cases.		
237.9-258.0 m Laminated grey dolomite; abundant voids (feldspar?) on weathered surface below 250.1		**253.0-283.0 m** Occasional dolomite veins with minor pyrite.	**237.9-258.6 m** Abundant very fine disseminated pyrite.
258.0-259.4 m Dolomitic siltstone, soft sediment deformation at 259.2 m.			**258.6-298.5 m** Pyrite increases and is generally bedded, lesser amounts disseminated.
259.4-267.2 m Grey laminated dolomite.	**259.4-267.2 m** Alteration to friable clay (80% of rock) with remnants of solid core.	**267.6 m** Calcite vein.	
267.2-270.2 m Pale brown limestone. **270.2-274.2 m** Fissile brown dolomite, algal in part? **274.2-278.5 m** Grey limestone. **278.5-292.4 m** Grey laminated dolomite, possible algal laminae at 291 m.	**274.2-295.9 m** Alteration to friable clay (80% of rock) with remnants of solid core. **280.1 m** Intrusion of hydrothermal dolomite with pyrite stringers in 80 mm dome. Passive replacement, dolomite replacing dolomite, in adjacent host. **283.0-298.5 m** Occasional zones of pink K-feldspar(?)	**283.0-295.0 m** Occasional dolomite and quartz veins.	
292.4-298.5 m Grey dolomite breccia, re-crystallised, soft sediment deformation? **298.5-323.0 m** Diapiric breccia, clasts in dolomite matrix.	**295.9 m** Solid core.		**298.5-323.0 m** Trace of pyrite in breccia matrix.
323.0 m	End of hole		

APPENDIX F: INVENTORY OF SADME PLANS

Table F-1 Burra copper mine, plans from underground mining era, 1850-1901, chronological index.

Plan No.	Title	Date	Comments
1988	Surface plan.	1850?	Shows offices, winding houses, etc.
1989	Burra, plan of 30 fathom level.	1850?	Survey of portion from Kingston's No.1 to Ayer's No.1 Shaft.
1981	Traverse of the 30 fathom level.	1850?	Drives and pitches between Kingston's No.1 and Ayer's Shaft.
63-643	Roach's Engine Shaft, Burra Burra Mine.	1850	Timbering and pump mechanism.
1982	Traverse of the 30 fathom level at the Burra Burra Mines.	10/1/1851	Drives between Stock's Shaft and Peacock's Air Shaft.
1985	Traverse of the 40 fathom level at the Burra Burra Mines.	10/1/1851	Drives and pitches on small portion of 40 fathom level.
1987	Traverse of the 50 fathom level.	Aug. 1852	Survey of main drives.
GRG30 series 74	Burra Burra Mines, plan of surface works and underground levels; also cross sections and water lines.	1852-1853?	Underground levels to 50 fathoms; offices, workshops and shafts on surface; surveyed topographic sections to east of mine. Original coloured plan in State Records.
63-199	Burra Mines. Composite plan showing surface and underground workings.	1852-1853?	Traced from GRG30, series 74.
1986	Burra, plan of 50 fathom level.	12/7/1855	Sketch of main drives from Peacock's Shaft to Ayer's No.1 Shaft.
1993	Plan of the levels in the Burra Mine.	Late 1850s	Detailed survey of 6, 12, 20, 25, 30, 35, 40, 45, 50 fathom levels.
1994	Composite plan, shows levels to 50 fathoms.		Plan missing; probably similar to 1993.
1984	Burra, plan of 60 fathom level.		Main drives from Roach's Shaft to Morphett's Shaft
1980	Plan of the levels in the Burra copper mines.		Shows 50, 55, 60 fathom levels, main drives from Peacock's Shaft to Morphett's Shaft.
1647	Plan of the levels in the Burra Mine.	Mid-1860s	Detailed survey of 8, 12, 20, 25, 30, 35, 40, 45, 50, 55, 60 fathom levels. Copied from plan lent by A.F. and P.A. McBride in 1940.
1657	Plan and sections of the Burra Mine.	Mid-1860s	Detailed survey of above 12, 17, 20, 25, 30, 35, 40, 45, 50, 55, 60, 70 fathom levels. Copied from plan lent by A.F. and P.A. McBride in 1940.
1983	Burra copper mine. Plan of Allen's and Tinline's Lodes. Also Bon Accord property.	1873	Surface plan showing lode trace.
1990	Burra, bore site.	13/8/1898	
1554	Burra copper mines, longitudinal section.	15/10/1900	Drawn by H.R. Hancock.
1558	Burra copper mines, plan of lodes, open cut and shafts.	15/10/1900	Drawn by H.R. Hancock.
1992	Longitudinal and cross sections, Burra Mine.	10/12/1901	Topographic sections through dumps, ore floors, etc.

Table F-2 Burra copper mine, geological plans prepared in 1941–42 (S.B. Dickinson).

Plan No.	Title	Comments
2144	Burra copper mine, levels and shafts.	Plan missing, probably copied from plan 1657.
2144/a	Burra copper mine, longitudinal projection of workings.	Plan missing, probably copied from plan 1657.
2226	Geological map of Burra Burra Mine area, cross sections, and longitudinal projection of workings.	Reproduced in Bulletin No. 20, Figs 22, 22a.
2230	Burra district, regional geological map and geological sections.	Reproduced in Bulletin No. 20, Figs 21,21a.
4416	Level at 12 fathoms, RL 1660.	Plan missing, probably copied from plan 1657.
4417	Level at 20 fathoms, RL 1660.	Plan missing, probably copied from plan 1657.
4418	Level at 30 fathoms, RL 1535.	Plan missing, probably copied from plan 1657.
4419	Level at 40 fathoms, RL 1490.	Plan missing, probably copied from plan 1657.
4420	Level at 50 fathoms, RL 1415.	Plan missing, probably copied from plan 1657.
4421	Level at 60 fathoms, RL 1365.	Plan missing, probably copied from plan 1657.
4422	Level at 70 fathoms, RL 1300.	Plan missing, probably copied from plan 1657.
4423	Level at 85 fathoms, RL 1210.	Plan missing, probably copied from plan 1657.
4424	Transverse section 0.	Plan missing.
4425	Transverse section 1.	Plan missing.
4426	Transverse section 2.	Plan missing.
4427	Transverse section 3.	Plan missing.
4428	Transverse section 5.	Plan missing.
4429	Transverse section 6.	Plan missing.
4430	Transverse section 7.	Plan missing.
4431	Vicinity of Sheet A-B.	Plan missing.
4432	Vicinity of Sheet C?	Plan missing.
4433	Vicinity of Sheet F.	Plan missing.
4434	Vicinity of Sheet E.	Plan missing.
4435	Vicinity of Sheet D.	Plan missing.
4436	Regional geology, maps and sections, Burra district.	Preliminary version of plan 2230.
4437	Regional geological cross section.	Plan missing, preliminary version of cross sections in plan 2230.
4438	Topographic map.	Plan missing.
4439	Geology of Burra copper mine, first interpretation.	Plan missing, preliminary version of plan 2226.
4440	Portion of plan.	Plan missing.
4441	Portion of plan.	Plan missing.
4442	Northern extension.	Plan missing.
4443	Portion of plan.	Plan missing.
4526	Geophysical layout, Plan No.1.	Plan missing.

Table F-3 Burra copper mine, geological plans, SADM, 1937–65.

Plan No.	Title	Date	Compiler
1004	Geological plan of Burra Mines.	2/3/1937	R.W. Segnit
1562	Diagrammatic section of copper veins showing secondary enrichment.	1940	L.K. Ward, in Bulletin 20, Fig. 24
1531	Geological map of Burra Mines and district.	24/4/1948	R.W. Segnit, plan missing
S560	Burra district factual geological plan.	28/2/1952	C. Wegener
S562	Burra district geological plan.	11/3/1952	C. Wegener
52-125	Geological plan and section of the dolomite quarry, Burra Showgrounds.	28/3/1952	C. Wegener
61-722	Plan of part of Hd. Kooringa Co. Burra, showing proposed prospecting area.	11/10/1961	B.P. Thomson
61-729	Geological map, Burra Burra Mine.	18/10/1961	B.P. Thomson, after S.B. Dickinson
61-730	Regional map of sections of Burra district.	16/10/1961	B.P. Thomson, after S.B. Dickinson
S2899	Burra Mine main open cut, ore zone details of east wall.	11/10/1961	B.P. Thomson
S2900	Burra Mine main open cut, details of portion of ore zone at northern end of open cut.	12/10/1961	B.P. Thomson
S2901	Burra Mine main open cut, shale flowage in north face.	12/10/1961	B.P. Thomson
S2902	Burra Mine main open cut, slump breccia localising Burra ore bodies.	12/10/1961	B.P. Thomson
L72-78	Geological investigation Burra Burra copper mine. Detailed geology of main open cut.	6/6/1962	W. Johnson and M.G. Mason
63-95	Burra Mine traverse section 5.	26/2/1963	W. Johnson, after S.B. Dickinson
L63-169	Burra district regional geological map.	29/5/1963	W. Johnson
63-525A	Burra district regional geological map (legend).	3/6/1963	W. Johnson
63-550	Interpretation of the geology of the Burra Burra Mine.	12/6/1963	W. Johnson
63-552	Geological plan of the Burra Burra Mine.	13/6/1963	W. Johnson and M.G. Mason
63-592	Regional geology, Burra district	1963	Plan missing
L64-65	Geological map of the Burra Mine area.	1964	K.R. Warne
64-59	Geological map of the Burra area.	24/7/1964	K.R. Warne
L64-145	Burra copper mine area. Survey plan.	14/8/1964	M.G. Mason, R. Adams?
L64-164	Burra copper mine area. Geophysical survey location plan.	1964	Nixon et al., 1965 (RB61/47)
64-591	Geological map of the Burra area, showing location of West Burra copper mine.	24/2/1964	K.R. Warne
S3952	West Burra Copper Mine.	18/11/1964	K.R. Warne
65-82	Geological plan, Burra open cut and environs.	1965	Nixon et al., 1965 (RB61/47)
L65-86	Burra open cut and environs, Sample locality plan, showing diamond drill and percussion bore sites.	1965	Nixon et al., 1965 (RB61/47)
65-671	Burra Mine area, cross sections through proposed Diamond Drill Hole No. 13.	18/6/1965	K.R. Warne

Table F-4 Burra copper mine, geophysical plans, 1952–65.

Plan No.	Title	Compiler
52-39	Burra geophysical survey.	McPharlin, D. and Kerr Grant, C., 1952, in Kerr Grant et al., 1952
52-278	Burra North, resistivity plan.	McPharlin, D., 1952, in Kerr Grant et al., 1952
52-279	Burra North, lines of equal vertical magnetic intensity.	McPharlin, D., 1952, in Kerr Grant et al., 1952
52-280	Burra North, Bouguer gravity anomalies.	McPharlin, D., 1952, in Kerr Grant et al., 1952
S672	Burra North, depth resistivity.	McPharlin, D., 1952, in Kerr Grant et al., 1952
S675	Burra North, self potential survey.	McPharlin, D., 1952, in Kerr Grant et al., 1952
S676	Burra North, self potential profiles.	McPharlin, D., 1952, in Kerr Grant et al., 1952
57-221	Burra standard sheet, gravity plan.	Seedsman, K., 1957
61-674	Burra Mine area, potential gradient cross sections of geophysical test traverses.	Bureau of Mineral Resources
62-226	Geophysical survey at Burra SA, Morphett's Shaft and northern layout geophysical profiles.	Bureau of Mineral Resources
62-227	Burra Mine area SA, potential gradient cross sections, geophysical test traverses.	Bureau of Mineral Resources
L62-4	Burra Mine SA, plan and sections of potential gradient contours, northern layout.	Bureau of Mineral Resources
62-532	Burra standard sheet, mosaic of aeromagnetic flight lines.	–
L63-257	Burra area, induced polarization survey, contours of resistivity and induced polarization, Lines 6N, 1N, 6S.	?
63-657	Burra standard sheet, aeromagnetic map of total intensity.	Plan missing
63-678	Burra standard sheet, aeromagnetic map of total intensity.	Plan missing
63-515	Burra Burra Mine area, IP traverses at 200' electrode spread.	Benlow, J.C., 1963, in Report Book 56/136
63-524	Burra area, IP traverse at 400' electrode spread.	Benlow, J.C., 1963, in Report Book 56/136
63-525	Burra area, IP and resistivity sections, 200' electrode spread.	Benlow, J.C., 1963, in Report Book 56/136
63-526	Burra area, IP and resistivity sections, 400' electrode spread.	Benlow, J.C., 1963, in Report Book 56/136
S3406	Burra area, regional sketch map.	Benlow, J.C., 1963, in Report Book 56/136
S3407	Burra area, gravity and magnetic profiles, Line 1N.	Benlow, J.C., 1963, in Report Book 56/136
S3551	Burra area, IP survey. Geological locality plan showing eastern IP anomalies.	Taylor, B.J., 1963
63-997	Burra Burra Mine area, IP traverses at 400' electrode spread showing induced polarization anomalies.	Taylor, B.J., 1963
63-998	Burra area, induced polarization survey, contours of resistivity and induced polarization shot lines.	Taylor, B.J., 1963
L63-257	Burra area, induced polarization survey, contours of resistivity and induced polarization, Lines 6N, 1N, 6S.	Taylor, B.J., 1963
63-999	Burra area, induced polarization survey, metal factor contours showing eastern anomaly.	Taylor, B.J., 1963

64-249	Burra, resistivity and metal factor contour Lines 6.5N-4N.	Taylor, B.J., 1964
L64-74	Burra Mines, geological regional map. Plan showing induced polarization traverses and anomalous zones.	Taylor, B.J., 1964
L64-75	Burra Mines, induced polarization survey, Zone C, resistivity and metal factors. Plan showing contours.	Taylor, B.J., 1964
L64-80	Burra geological plan showing IP traverses and anomalous zones.	Taylor, B.J., 1964
64-380	Burra area, EM survey northwestern area. Geological plan showing IP and EM grid and associated anomalies.	Taylor, B.J., 1964
64-381	Burra area, EM survey northwestern area. Profiles on Lines 5.5N, 6N and 6.5N.	Taylor, B.J., 1964
64-820	Burra IP survey, first IP report, FE values. Lines 1N, 00, 1S, 2S and 4S.	Fairburn, W.A., 1964
64-821	Burra IP survey, first IP report, contoured FE values. Lines 5N, 2N, 1N and 00.	Fairburn, W.A., 1964
64-822	Burra IP survey, second IP report, contoured FE values. Lines 5N, 4N, 2N, 00, 1S, 2S, 4S and 5S.	Fairburn, W.A., 1964
64-823	Burra IP survey, second IP report, contoured FE values. Lines 6N, 1N and 6S.	Fairburn, W.A., 1964
64-824	Burra IP survey, third IP report, contoured FE values. Lines 4.0, 4.5, 5.0, 5.5, 6.0 and 6.5N.	Fairburn, W.A., 1964
S3887	Burra IP survey, third IP report, FE vectorial analysis. Line 6N.	Fairburn, W.A., 1964
L64-164	Burra copper mine area, geophysical survey location plan.	Fairburn, W.A., 1964
65-209	Burra area, location of traverses, IP and EM anomalies.	Taylor, B.J., 1965
65-210	Burra area, Line 5N. Contours of resistivity and frequency effects with 400’ dipole configuration.	Taylor, B.J., 1965
65-211	Burra area, Line C. Contours of resistivity and frequency effects with 200’ and 100’ dipole-dipole configuration.	Taylor, B.J., 1965
65-212	Burra area, Lines 5.5N and D. Contours of resistivity and frequency effects with 400’, 200’ and 100’ dipole-dipole configuration.	Taylor, B.J., 1965
65-213	Burra area, Line E. Contours of resistivity and frequency effects with 200’ and 100’ dipole-dipole configuration.	Taylor, B.J., 1965
65-214	Burra area, Lines 6N and F. Contours of resistivity and frequency effects with 400’, 200’ and 100’ dipole-dipole configuration.	Taylor, B.J., 1965
65-215	Burra area, Line G. Contours of resistivity and frequency effects with 200’ and 100’ dipole-dipole configuration.	Taylor, B.J., 1965
L66-40	Burra area, Line 1N. Contours of resistivity, frequency effect and metal factors; geological cross section.	Taylor, B.J., 1966
L66-41	Burra area, Line 6N. Contours of resistivity, frequency effect and metal factors; geological cross section.	Taylor, B.J., 1966
L66-42	Burra area, Line 6S. Contours of resistivity, frequency effect and metal factors; geological cross sections.	Taylor, B.J., 1966
L66-66	Burra area. Plan showing location of geological boundaries, geophysical traverses, anomalous zones, and power and water facilities.	Taylor, B.J., 1966
66-307	Burra area, Line 6.5N. Contours of resistivity, frequency effect and metal factors.	Taylor, B.J., 1966
S4734	Burra area. Profiles and interpretation of electrical sounding.	Taylor, B.J., 1966
S5375	Burra area. Gravity and elevation profiles of Lines 1N and 6N.	Taylor, B.J., 1966

Table F-5 Burra copper mine, miscellaneous plans, SADM.

Plan No.	Title	Date	Comments
1624	Burra copper dumps.	28/4/1940	Survey of tonnage of copper dumps near Morphett's Shaft, C.E. Gregory
2084	North Works Smelting LLTO.	1941	Title search
2224	Burra copper mines, plan and sheet of calculations.	18/8/1941	Survey of slag dump and tonnage estimate
2258	Burra area.	?	Levelled traverses north and south of mine, prior to geophysics
S744	Burra district copper workings. Locality plan.	17/3/1953	Locations only; R.K. Pitman and M.L. Raynor
54-216	Burra district locality plan.	23/9/1954	Mine locations
L63-144	Portion of a plan of Burra Corporation.	1963	Cadastral boundaries
63-390	Plan of Burra Corporation.	1963	Plan missing
SK-786	Samin Ltd. Burra operations, dewatering bore at Burra.	18/9/1975	J.H. Perry

APPENDIX G: U-PB ZIRCON DATING OF THE PORPHYRY, BURRA MINE

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December 2008

Methods

Zircons from two samples of the porphyry, R1662960A and R1662960B (Fig. A), were dated using the laser ablation-inductively coupled plasma mass spectrometry (LA-ICPMS) method. Details of the instrumentation and methodologies can be found in Reid et al (2006) and are identical to those followed by Payne et al. (2006) and Wade et al. (2007). Briefly, zircons were separated by standard crushing, magnetic and density processes at a commercial mineral separating laboratory, MinSep Laboratories, Denmark, WA. These zircons were mounted in epoxy resin and polished so as to expose the grains. The zircons were imaged under transmitted light and using cathodoluminescence (CL) function of a Phillips XL-20 scanning electron microscope housed at Adelaide Microscopy, the University of Adelaide. The isotopic analyses were also conducted at Adelaide Microscopy, using a New Wave Research Nd–YAG laser operating at an output wavelength of 213 nm. Ablated material is transported into an Agilent 7500 quadrupole ICPMS within the clear plastic tubing via the action of an Ar–He carrier gas medium. Time-resolved signals of $^{204, 206, 206, 208}$Pb, ^{232}Th and ^{238}U acquired with a 30µm spot size and a 5 Hz repetition rate were processed using the GLITTER software of van Achterbergh *et al.* (1999). ^{235}U was calculated assuming $^{235}U=^{238}U/137.88$.

The GJ standard zircon of Jackson *et al.* (2004) was used to calibrate Pb/U fractionation, and data quality was monitored by analysing both the 91500 standard zircon and a Sri Lankan gem quality zircon standard, 'BJWP'. Thirteen analyses of 91500 produced a weighted mean ^{207}Pb/^{206}Pb age of 1070 ± 41 Ma (MSWD = 0.51) and a ^{206}Pb/^{238}U age of 1065 ± 10 Ma (MSWD = 0.19), within error of the thermal ionization mass spectrometry (TIMS) age for this zircon (^{207}Pb/^{206}Pb age = 1065.4±0.6; Wiedenbeck et al., 1995). Likewise, ten analyses of the BJWP standard yielded a ^{206}Pb/^{238}U age of 729.6 ± 8.5 Ma (MSWD = 0.61), within error of the c. 727 Ma age quoted for this zircon (Payne et al., 2006; Wade et al., 2007). In general, the low ^{207}Pb signals obtained during the course of the present study mean that the ^{207}Pb/^{206}Pb and ^{207}Pb/^{235}U ages are less precise than the corresponding ^{206}Pb/^{238}U ages, hence the latter ratio is used exclusively in the calculation of weighted mean ages.

Data for ^{204}Pb is compromised by interference from ^{204}Hg, a trace contaminant in the Ar-He carrier gas. Nevertheless, this isotope is monitored for the presence of elevated common Pb. All analyses except one made in the course of this work showed negligible net ^{204}Pb and no common Pb correction has been applied to the data. The analyses with high net ^{204}Pb is flagged in the discussion of the results below and is omitted from the weighted mean age calculations. Weighted mean age calculations and inverse Concordia diagrams have been constructed using Isoplot v3 (Ludwig, 2003), while probability density distributions have been constructed using AgeDisplay (Sircombe, 2004). Inverse Concordia (Tera-Wasserburg) diagrams are very useful since they are able to indicate the presence of common Pb in addition to Pb loss.

Results

Zircon characteristics

Zircon populations from the two samples are exclusively euhedral to sub-euhedral transparent grains (Figs B, C). Grains range in morphology from tabular to needle-shaped, with many grains showing small inclusions of presumably apatite and more rarely, opaque species, possibly sulphide. Under CL the grains show oscillatory zonation typical of igneous zircons, which is consistent with the strongly euhedral, unmodified crystal habit of many of the grains.

Thus the zircons in both samples are interpreted to represent a single population of igneous crystals formed during the crystallisation of the porphyry.

LA-ICPMS results
Forty analyses were made on zircons from sample R1662960A. These analyses range from concordant to strongly discordant, with fourteen analyses being >10% discordant (Table A). Such discordance is not unexpected given the variably altered nature of the porphyry sample. When plotted on an inverse Concordia (Terra Wasserburg) plot, the analyses are seen to cluster around Concordia, with a two analyses lying above Concordia (60A-15, -17), indicating the likely presence of common Pb in these grains. A Concordia age calculated from all the data yields a Model 2 (data points equally weighted, ignoring individual errors) lower intercept age of 787 ± 8 Ma (MSWD = 2.1; Fig. D). Analysis 60A-32 is 25% discordant and has a comparatively young $^{206}Pb/^{235}U$ age of 714±13 Ma and, since it lies to the right of the Concordia cluster, is likely to have suffered Pb loss. Omitting this data point from the Concordia age calculation yields a more acceptable MSDW of 1.3 for a lower intercept age of 790 ± 7 Ma. A probability density distribution of the $^{206}Pb/^{235}U$ ages reveals a unimodal age population (Fig. D). Omitting the analyses with discordance >10%, a weighted mean $^{206}Pb/^{238}U$ age of 795 ± 5 Ma can be calculated (n = 26; MSWD = 1.09; probability = 0.35). This weighted mean age is inferred to be the best estimate for the timing of magmatic zircon crystallisation in this sample.

Twenty-three analyses were made on zircons from sample R1662960B. Similar to the previous sample the data show a range of discordance with seven analyses being >10% discordant (Table B). The inverse Concordia plot shows a number of analyses lying above Concordia indicating the presence of common Pb (Fig. E). In addition, two analyses, 60B-2 and-21, lie to the right of the main population, indicating they have undergone Pb loss. The probability density distribution for this sample shows the majority of the $^{206}Pb/^{238}U$ ages cluster at ~800 Ma, similar to the previous sample (Fig. E). Note that the probability density distribution reveals a slight shoulder to the younger side of the main peak at ~800 Ma. This shoulder appears due to a number of analyses having ages between ~780 and ~760 Ma. It is clear that some of the analyses have undergone Pb loss, and it is possible that a slight lowering of some of the $^{206}Pb/^{238}U$ ages has occurred. The suggestion that Pb loss being more prevalent in this sample, R1662960B, compared to the previous sample reflects the more strongly altered nature of this rock. Nevertheless, the data from sample R1662960B remain statistically indistinguishable and a weighted mean $^{206}Pb/^{238}U$ age of 800 ± 9 Ma (MSWD = 1.60; probability = 0.05; n = 19) can be calculated from all the data that lies within ±10% discordance.

Since both samples are from the same porphyry intrusion the data may be pooled. A weighted mean $^{206}Pb/^{238}U$ age of 797 ± 5 Ma can be calculated from the forty-five analyses that lie within ±10% discordance (MSWD of 1.3; probability = 0.08). This age is considered to be the best estimate from the LA-ICPMS data for the timing of magmatic crystallisation of the porphyry.

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Figures

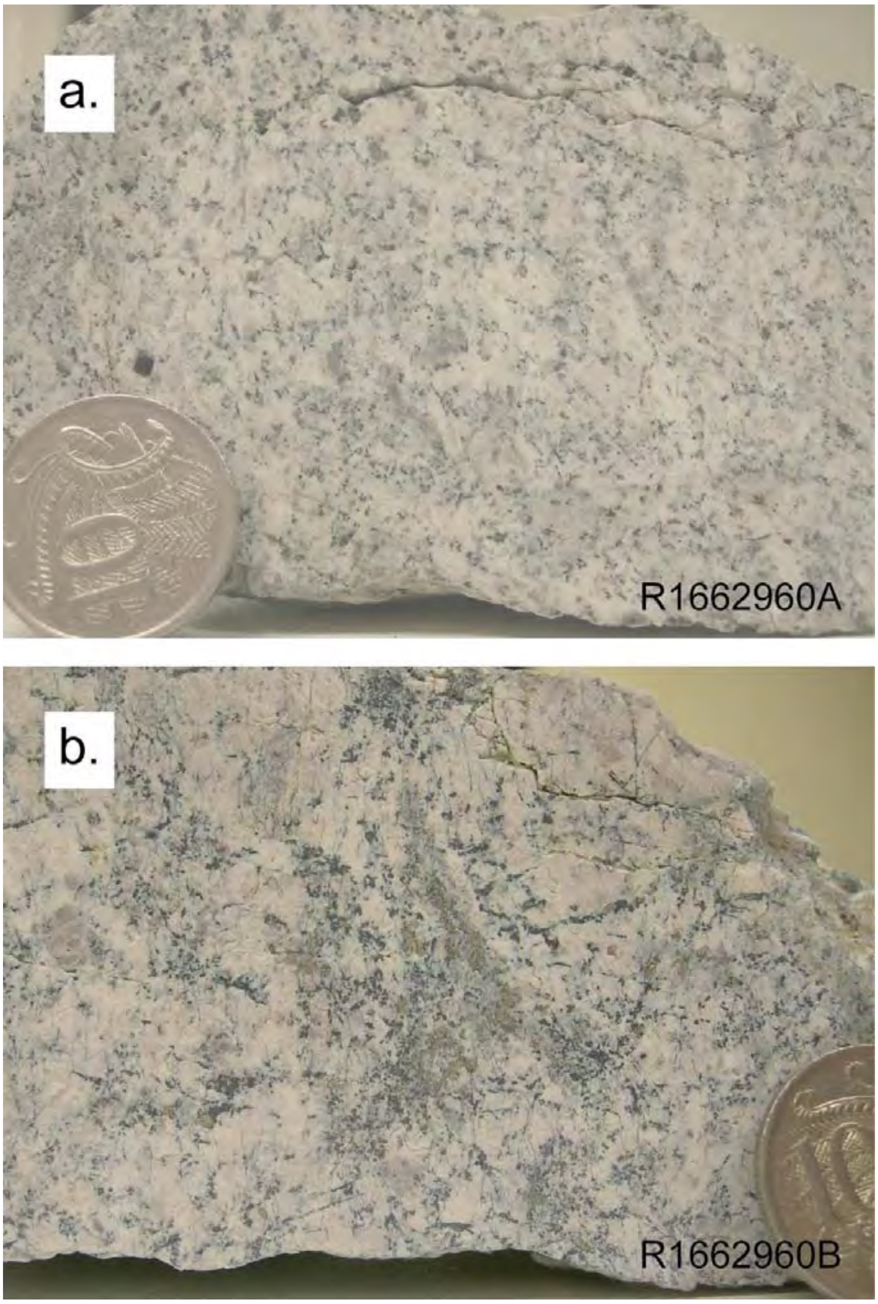

Figure A. Photograph of rock samples from which zircons were extracted. Ten cent coin (22mm diameter) for scale. a. Sample R1662960A. b. Sample R1662960B. Note the presence of sulphides in both samples, an in particular in sample B, where coarse chalcocite and pyrite are observed in the central portion of the sample. *(407329)*

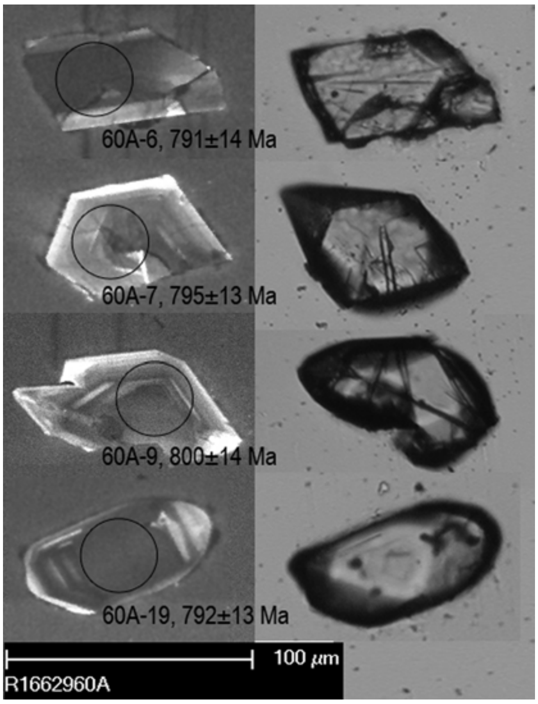

Figure B. Selected zircons from sample R1662960A. Left panel shows CL images and right panel the transmitted light photomicrographs of the corresponding zircons. Also indicated are the site of laser ablations spot analyses with the corresponding $^{206}Pb/^{238}U$ age. *(407330)*

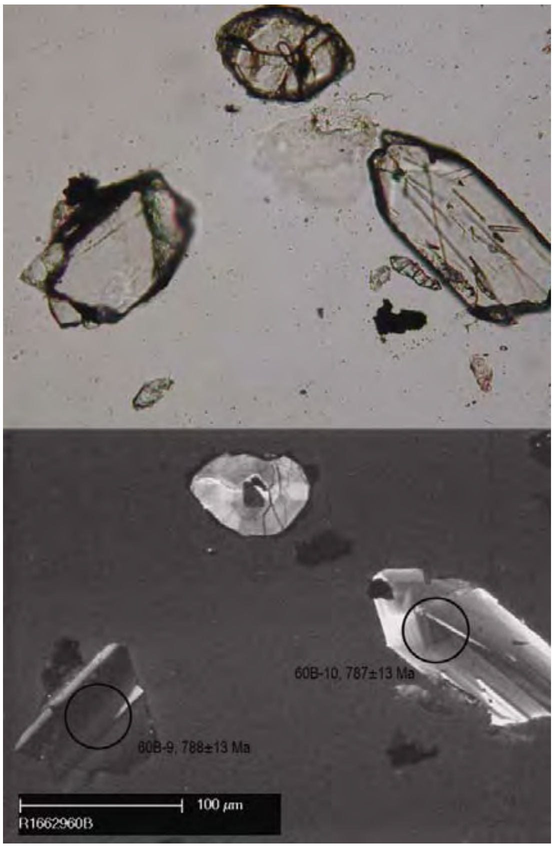

Figure C. Selected zircons from sample R1662960B. Top panel shows transmitted light photomicrographs and the bottom panel the CL images of the corresponding zircons. Also indicated are the site of laser ablations spot analyses with the corresponding $^{206}Pb/^{238}U$ age. *(407331)*

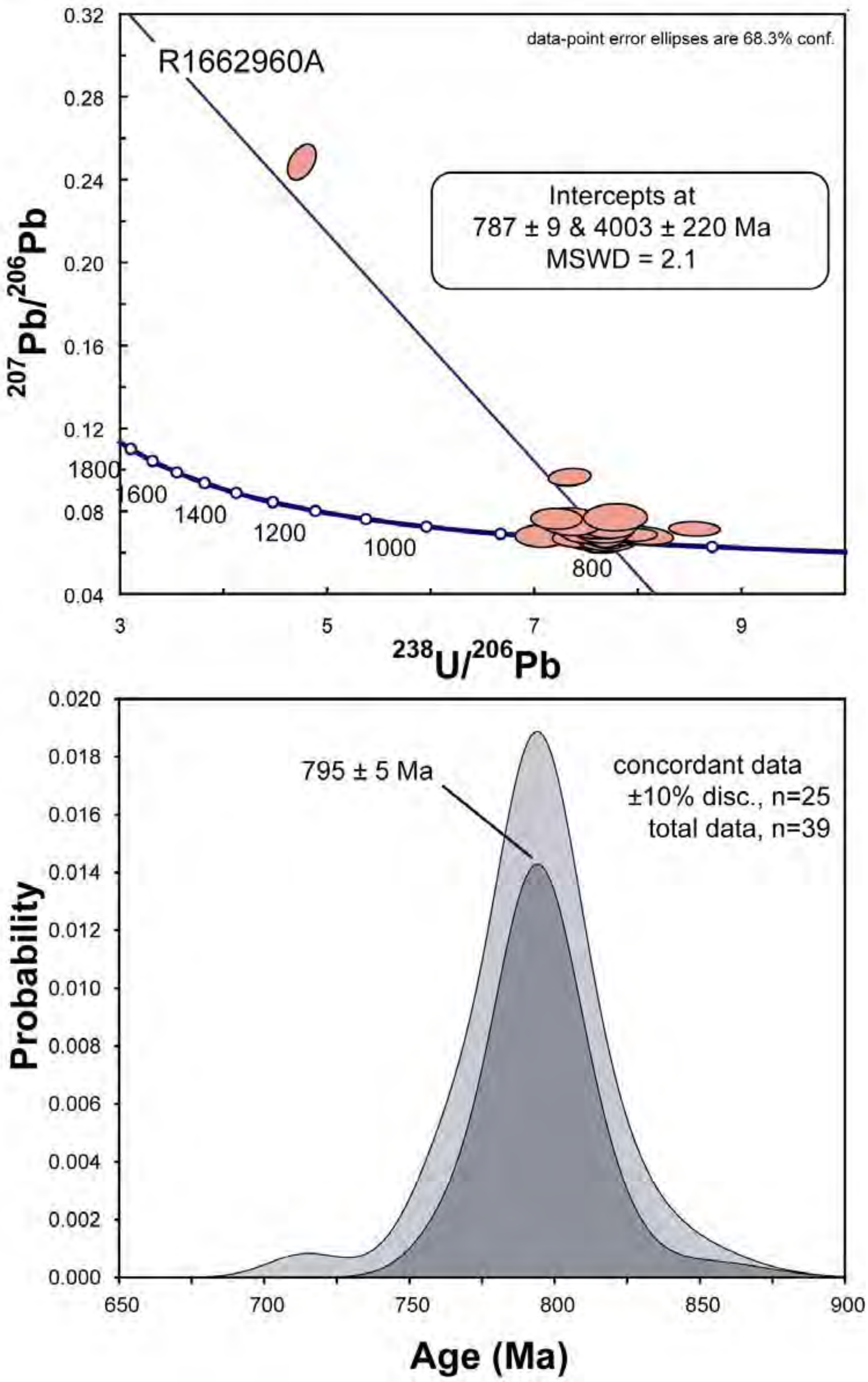

Figure D. Concordia (top) and probability density distribution (bottom) showing concordant (Dark grey) and discordant (light grey) data for sample R1662960A. Age indicated on the probability density distribution is the weighted mean age calculated from the data ±10% discordance.

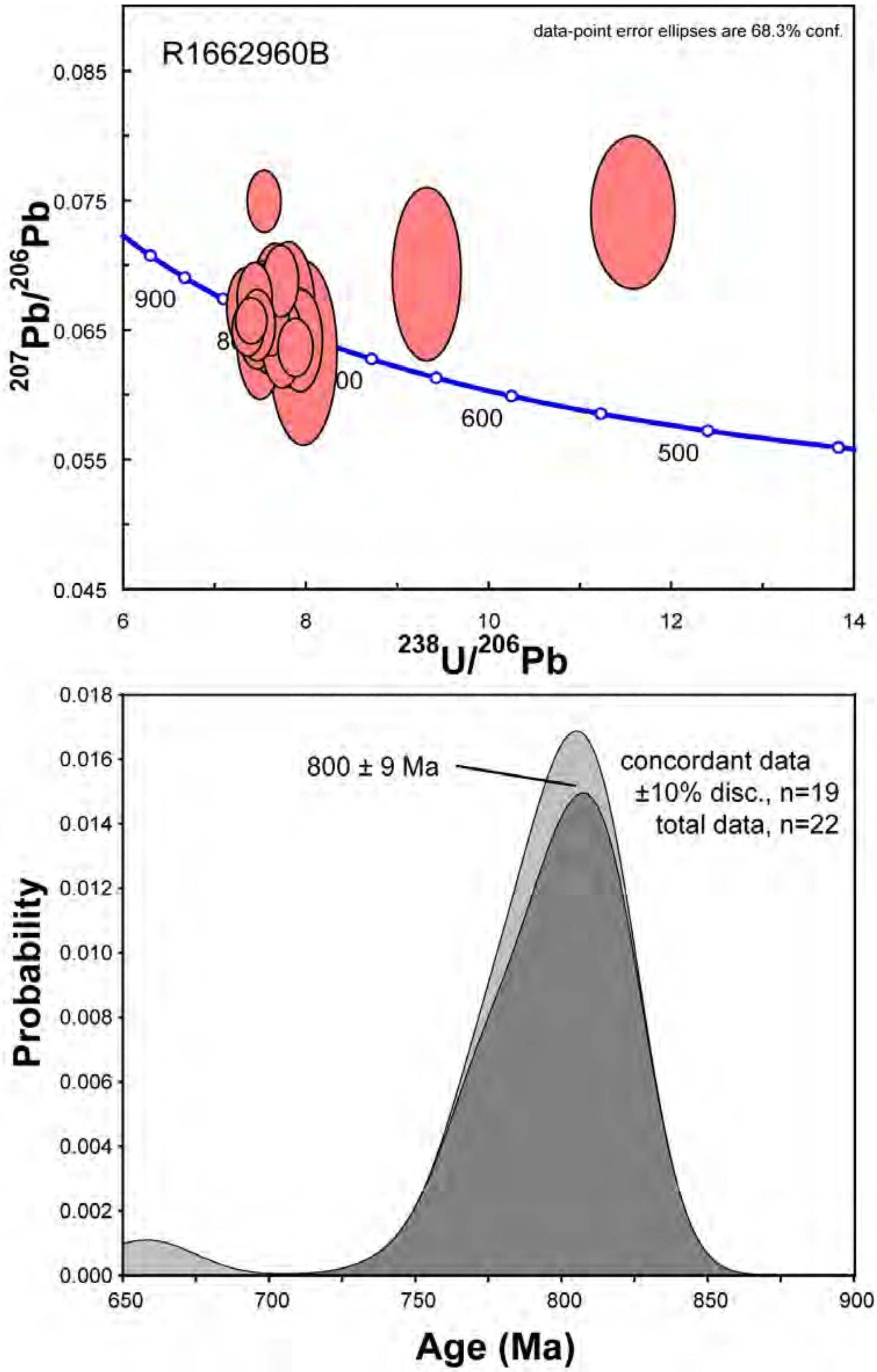

Figure E. Concordia (top) and probability density distribution (bottom) showing concordant (Dark grey) and discordant (light grey) data for sample R1662960B. Age indicated on the probability density distribution is the weighted mean age calculated from the data ±10% discordance.

Table A. Summary of LA-ICPMS analysis of zircons from sample 1662960a.

Analysis	Isotopic ratios						Ages (Ma)						
	Pb207/ Pb206	1σ	Pb206/ U238	1σ	Pb207/ U235	1σ	Pb207/ Pb206	1σ	Pb206/ U238	1σ	Pb207/ U235	1σ	disc %
60A-1	0.065	0.003	0.1313	0.0027	1.1725	0.0528	769	95	795	15	788	25	-3
60A-2	0.065	0.002	0.1317	0.0022	1.1751	0.0379	767	68	797	13	789	18	-4
60A-3	0.064	0.002	0.1303	0.0022	1.1557	0.0384	754	70	790	13	780	18	-5
60A-4	0.069	0.002	0.1350	0.0022	1.2790	0.0358	891	58	816	12	836	16	8
60A-5	0.066	0.003	0.1321	0.0025	1.2050	0.0478	812	83	800	14	803	22	2
60A-6	0.067	0.005	0.1305	0.0025	1.2055	0.0823	838	137	791	14	803	38	6
60A-7	0.064	0.003	0.1312	0.0022	1.1558	0.0623	739	111	795	13	780	29	-8
60A-8	0.066	0.004	0.1330	0.0024	1.2042	0.0725	797	122	805	14	803	33	-1
60A-9	0.064	0.004	0.1321	0.0024	1.1723	0.0723	754	126	800	14	788	34	-6
60A-10	0.067	0.004	0.1306	0.0024	1.2115	0.0713	847	119	791	13	806	33	7
60A-11	0.065	0.004	0.1303	0.0033	1.1752	0.0758	789	135	790	19	789	35	0
60A-12	0.066	0.003	0.1349	0.0029	1.2297	0.0598	811	102	816	17	814	27	-1
60A-13	0.076	0.004	0.1388	0.0032	1.4459	0.0739	1084	103	838	18	908	31	23
60A-14	0.067	0.002	0.1309	0.0023	1.2007	0.0420	824	73	793	13	801	19	4
60A-15	0.096	0.003	0.1365	0.0025	1.8005	0.0582	1542	62	825	14	1046	21	47
60A-16	0.071	0.003	0.1314	0.0024	1.2796	0.0458	947	74	796	14	837	20	16
60A-17	0.249	0.006	0.2112	0.0041	7.2385	0.1669	3176	39	1235	22	2141	21	61
60A-18	0.068	0.002	0.1254	0.0022	1.1703	0.0382	859	68	762	12	787	18	11
60A-19	0.065	0.002	0.1307	0.0022	1.1758	0.0393	783	70	792	13	789	18	-1
60A-20	0.063	0.003	0.1308	0.0028	1.1453	0.0595	725	110	793	16	775	28	-9
60A-21	0.067	0.004	0.1416	0.0035	1.3123	0.0769	844	122	854	19	851	34	-1
60A-22	0.065	0.002	0.1317	0.0022	1.1828	0.0371	779	66	798	12	793	17	-2
60A-23	0.067	0.004	0.1244	0.0030	1.1547	0.0652	848	118	756	17	780	31	11
60A-24	0.063	0.002	0.1294	0.0020	1.1321	0.0298	724	55	784	11	769	14	-8
60A-25	0.067	0.003	0.1280	0.0026	1.1764	0.0537	828	95	776	15	790	25	6
60A-26	0.069	0.004	0.1319	0.0030	1.2468	0.0672	887	112	799	17	822	30	10
60A-27	0.067	0.003	0.1260	0.0025	1.1684	0.0500	847	89	765	14	786	23	10
60A-28	0.067	0.002	0.1308	0.0020	1.2159	0.0286	851	47	793	11	808	13	7
60A-29	0.068	0.003	0.1264	0.0025	1.1787	0.0497	859	88	767	14	791	23	11
60A-30	0.070	0.003	0.1294	0.0027	1.2564	0.0574	942	94	784	15	826	26	17
60A-31	0.074	0.005	0.1363	0.0038	1.3915	0.0954	1044	138	824	21	885	41	21
60A-32	0.071	0.003	0.1171	0.0022	1.1393	0.0457	948	82	714	13	772	22	25
60A-33	0.069	0.002	0.1308	0.0023	1.2490	0.0428	910	71	793	13	823	19	13
60A-34	0.069	0.004	0.1306	0.0031	1.2395	0.0692	898	115	791	17	819	31	12
60A-35	0.070	0.003	0.1324	0.0027	1.2764	0.0553	931	89	801	15	835	25	14
60A-36	0.066	0.003	0.1265	0.0023	1.1503	0.0434	809	79	768	13	777	20	5
60A-37	0.066	0.002	0.1312	0.0021	1.1954	0.0356	813	62	795	12	799	16	2
60A-38	0.064	0.004	0.1329	0.0029	1.1787	0.0621	756	111	805	17	791	29	-6
60A-39	0.069	0.004	0.1334	0.0030	1.2660	0.0691	899	113	807	17	831	31	10
60A-40	0.076	0.005	0.1287	0.0034	1.3518	0.0842	1105	125	780	19	868	36	29

Note: disc % denotes percentage discordance, where 0 indicates a concordant analysis

Table B. Summary of LA-ICPMS analysis of zircons from sample 1662960b.

Analysis	Isotopic ratios						Ages (Ma)						
	Pb207/ Pb206	1σ	Pb206/ U238	1σ	Pb207/ U235	1σ	Pb207/ Pb206	1σ	Pb206/ U238	1σ	Pb207/ U235	1σ	disc %
60B-1	0.0667	0.0026	0.1325	0.0025	1.2185	0.0456	830	78	802	14	809	21	3
60B-2	0.0693	0.0050	0.1075	0.0029	1.0264	0.0709	908	141	658	17	717	36	27
60B-3	0.0640	0.0027	0.1295	0.0025	1.1424	0.0470	742	87	785	14	774	22	-6
60B-4	0.0654	0.0038	0.1325	0.0031	1.1944	0.0661	788	116	802	18	798	31	-2
60B-5	0.0688	0.0022	0.1298	0.0022	1.2299	0.0387	891	64	787	13	814	18	12
60B-6	0.0658	0.0030	0.1342	0.0027	1.2176	0.0533	799	92	812	16	809	24	-2
60B-7	0.0662	0.0042	0.1284	0.0032	1.1710	0.0717	811	127	779	18	787	34	4
60B-8	0.0642	0.0030	0.1263	0.0026	1.1169	0.0511	748	97	767	15	762	25	-2
60B-9	0.0653	0.0022	0.1343	0.0023	1.2092	0.0394	785	68	812	13	805	18	-4
60B-10	0.0659	0.0023	0.1317	0.0023	1.1972	0.0418	804	73	798	13	799	19	1
60B-11	0.0674	0.0022	0.1348	0.0023	1.2524	0.0402	850	66	815	13	825	18	4
60B-12	0.0645	0.0036	0.1337	0.0030	1.1880	0.0646	757	114	809	17	795	30	-7
60B-13	0.0650	0.0017	0.1360	0.0021	1.2194	0.0320	775	54	822	12	810	15	-6
60B-14	0.0666	0.0025	0.1366	0.0025	1.2548	0.0452	826	75	825	14	826	20	0
60B-15	0.0661	0.0032	0.1329	0.0028	1.2101	0.0573	808	99	804	16	805	26	0
60B-16	0.0632	0.0053	0.1256	0.0038	1.0943	0.0878	715	169	763	22	751	43	-7
60B-17	0.0668	0.0037	0.1308	0.0030	1.2056	0.0638	832	110	793	17	803	29	5
60B-18	0.0749	0.0020	0.1329	0.0021	1.3723	0.0364	1067	52	805	12	877	16	25
60B-19	0.0665	0.0028	0.1319	0.0026	1.2094	0.0501	823	87	799	15	805	23	3
60B-20	0.0657	0.0032	0.1317	0.0029	1.1930	0.0557	798	98	798	16	797	26	0
60B-21	0.0741	0.0046	0.0865	0.0023	0.8822	0.0519	1045	120	535	13	642	28	49
60B-22	0.0657	0.0015	0.1354	0.0021	1.2261	0.0289	797	48	819	12	813	13	-3
60B-23	0.0636	0.0018	0.1271	0.0020	1.1145	0.0315	729	59	771	12	760	15	-6

Note: disc % denotes percentage discordance, where 0 indicates a concordant analysis

APPENDIX H: SUPPORTING GIS DATA FOR REPORT BOOK 2008/16

Compiled by L. Katona, G. Gouthas and E. Appelbee (2008)

GIS methodology for the Burra Mine geology, boundary and 3D datasets.

The sources of the spatial datasets were the 1981 hardcopy base plan map (including the mine grid), mine geology map, base plan elevation map and elevation survey data captured when excavation of the pit was completed.

The 1:500 scale base plan displaying the mine benches was scanned and georeferenced against current ortho-imagery using control points recorded on the mine plans located in and around the mine.

The base plan was vectorised using ArcGIS™ software and edited to remove unwanted lines. The scanned geology map was then georeferenced against the mine grid on the base plan. The geological boundaries were digitised and added to the base plan lines. Conversion of the lines to polygons resulted in boundary (polyline) and geology (polygon) datasets. The geology polygons and boundaries were tagged with their geological attributes and checked for topological correctness.

A version of the base map with elevation survey points was georeferenced to the base plan and the elevation points were digitised from the georeferenced map (into a point dataset). The elevations were then added to the elevation point dataset, referenced from stadia books recorded at the time of the mine survey. In addition to the elevation points, borehole and survey station points were captured and saved in separate point datasets.

The point dataset elevation values were transferred to the base plan lines (where spatially coincident), and these lines were used to generate a 3D triangular irregular network (TIN). Elevation points not spatially coincident with base plan lines were added to the TIN separately. The TIN was resampled to a grid and exported to a variety of GIS and 3D software formats. The Geology dataset was draped over the TIN in a 3D visualisation environment and output to Adobe 3D pdf for display in Acrobat Reader™.

All datasets were converted to MapInfo format and are displayed in layouts supported by Mapinfo and ArcGIS. The file “Directory&File metadata.txt” on the data disk contains a complete explanation of the files contained on the disk.