South Australia

EXPLORATION TOWARDS 2000

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ADELAIDE 13 December 1990

EXTENDED ABSTRACTS

DEPARTMENT OF
MINES AND ENERGY

SOUTH AUSTRALIA

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Compiled by

A.J. PARKER

Geological Survey

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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Opening Speech

John Klunder
Minister of Mines and Energy

Mr. Chairman; Ladies and Gentlemen: Welcome to Adelaide and the Exploration Towards 2000 Seminar.

This Seminar is about changing perceptions - your perceptions of South Australia as a desirable target for mineral and petroleum exploration.

It is part of an ongoing effort by the Government and the Department of Mines and Energy to lift exploration levels in this State.

Jointly, we recognise that this can only be achieved effectively by stimulating private sector investment in mineral exploration and development.

While we are pursuing these objectives from a base of significant current mineral production, and an important role historically in Australian mining, the Government and the Department recognise that exploration is the key to the future.

The value of South Australia's mineral production reached a new record of $1.18-billion in 1989. However, by far the largest part of that production came from the energy minerals of the Cooper and Eromanga Basins and the Olympic Dam mine.

While petroleum exploration levels remain relatively high, exploration for metallic and non-metallic minerals has been in long term decline.

This concerns the Government and has led it to initiate and fund programmes through the Department designed to reduce the perceived risk of exploration in this State.

A report, commissioned by the Department, has concluded that the major disincentive to exploration is the widespread presence of sands and clays which mask the prospective underlying rocks. Overcoming this requires special treatment - including remote sensing, geophysical techniques and drilling.

Experience has shown that where our geoscientific mapping is upgraded, using the best of modern techniques, the industry's perception of risk is reduced and exploration interest and expenditure rises.

The best example of this relates to the Eyre Peninsula aeromagnetic survey acquired in 1988 as a joint venture between the Department, the Bureau of Mineral Resources and two mining companies.

Prior to the survey, 15 exploration licences were current in the area with expenditure commitments totalling $1.3-million per annum.

After release of the survey data, annual expenditure increased by $2.4-million and the number of licences more than doubled to 34. Expressed another way, exploration expenditure rose from $24 per square km before the survey to $66 per square km after the release of the data. This increase is still well over 100% even after deducting the $14 per square km cost of the survey.

We were encouraged by these results and followed-up with a lead/zinc initiative designed to encourage the search for these minerals, which are required to meet the long term needs of the Port Pirie Smelter. Areas with lead/zinc potential have been drilled and significant results will be presented today.

Our strategy was taken a step further in September when I announced a long term programme to stimulate exploration. The centrepiece of this thrust will be the National Geoscience Mapping Accord.

As many of this audience will know, the principal goal of the Accord is to produce a national geoscience digital data base and a new generation of geoscientific maps for Australia.

It will be a collaborative effort between the B.M.R., State Geological Surveys, the minerals industry and universities. The latest technology will be used and your industry will ultimately be one of the main beneficiaries of a vital new tool in the quest for minerals.

Under the Accord in South Australia, the Commonwealth has committed about $6.4-million to deep crustal seismic profiling, acquisition of new airborne geophysical data and assistance with mapping during the first five year period. Some additional State funds have also been provided in the current Budget.

Projects identified under the Accord after a comprehensive industry-oriented survey include:

* increased emphasis on the geological mapping of the Northern Gawler Craton and the Musgrave blocks

* a system known as SA GEOLOGY which produces computer-generated geological maps. A demonstration of this system in on view in the foyer

* the PEPS system, which is a complete data base of all you ever wanted to know about petroleum. This is also on display today

* airborne geophysical processing in a continuation of the Eyre Peninsula programme; and

* drilling programmes with special emphasis on lead/zinc.

The Government and the Department are confident that the evolution of these projects will enable your industry to examine South Australia's mineral prospectivity in a positive new light. I can assure you that the Department is committed to ensuring that the data produced is brought to the attention of the industry as quickly as possible.

I'd like now to turn to some of the other matters on today's agenda.

Along with others, I've recently expressed the view that the 1990s will be an exciting decade for petroleum exploration and development.

Australia's declining self sufficiency in oil should be the catalyst for expanded and more sophisticated exploration concepts and practices.

For many years, the Cooper and Eromanga Basins have been the primary targets for exploration and development in South Australia. This area remains the nation's largest onshore petroleum province and activity continues at a high and generally satisfactory level.

However, these proceedings will focus attention on the Otway and Officer Basins.

The Otway is entering a phase of increased exploration activity following the discovery of commercial quantities of gas at Katnook, sufficient to supply the local market.

Today, we are releasing data packages for four blocks in the Officer Basin. Later in the morning, a paper discussing the prospectivity of the area will be given and a display in the foyer offers further information.

In addition, I expect soon to be in a position to offer offshore permits to the successful applicants for Bight and Duntroon Basins acreage which was advertised earlier in the year.

Provision of high quality geological and geophysical data is, of course, only one of the elements essential to an active and committed exploration industry.

Access to land for exploration is another and, in South Australia the Government believes it has, and is making, significant progress.

Effective multiple land use concepts have been put in place since 1986, when the Government adopted a policy that no decision should be made to deny or limit access for exploration over any areas without careful review and consideration of the area's mineral potential.

This process has been formalised by introducing the concept of regional reserve park categories into the National Parks and Wildlife Act. These reserves enable the conservation of an area's wildlife or natural or historic features while at the same time permitting the utilisation of the natural resources of the land. The most successful example of this approach is the Innamincka Regional Reserve which allows exploration, but with special conditions applying to the environmentally sensitive Coongie Lakes area.

In the case of Aboriginal Land, considerable progress has been made in recent times.

Discussions have been held between the Department and both the Maralinga and Pitjantjatjara peoples on the geological mapping of the Lands and company exploration within them.

BHP Exploration has been granted several licence areas near OOLDEA for mineral sands after negotiating successfully with the Maralinga people.

And both the Maralinga and Pitjantjatjara people have expressed interest in the Department of Mines and Energy providing educational assistance to help them develop a better understanding of the processes of mineral exploration and development.

A Departmental report has been prepared assessing the mineral potential of the Maralinga Lands and one is in preparation for the Pitjantjatjara Lands.

The proposed Pitjantjatjara Lands Geological Survey over the Musgrave Block is a joint venture between my Department, the B.M.R., and the Northern Territory and West Australian Geological Surveys under the auspices of the National Geoscience Mapping Accord. As many of you will be aware, the Musgrave Block is believed to have considerable potential for base and precious metals and many other minerals.

The Government hopes the promising signs which have emerged recently will lead in time to a greater degree of exploration within the Aboriginal Lands. However, this will require lengthy and patient consultation on the part of both the Government and the industry and I urge you to adopt that course.

Mineral exploration is all about confidence and, with this in mind, I'd like to conclude my contribution to this seminar on a positive note.

The Centre for South Australian Economic Studies has noted in a recent report that the mining sector has been, without doubt, the fastest growing contributor to the State economy.

However, we need to make it faster and this seminar is only the first in a series of stages designed to achieve that objective.

I trust you will all find something sufficiently interesting in today's programme to whet your appetite for exploration in South Australia. Departmental officers will bend over backwards to provide any further assistance or advice you may require.

It now gives me great pleasure to declare the Exploration Towards 2000 Seminar officially open.

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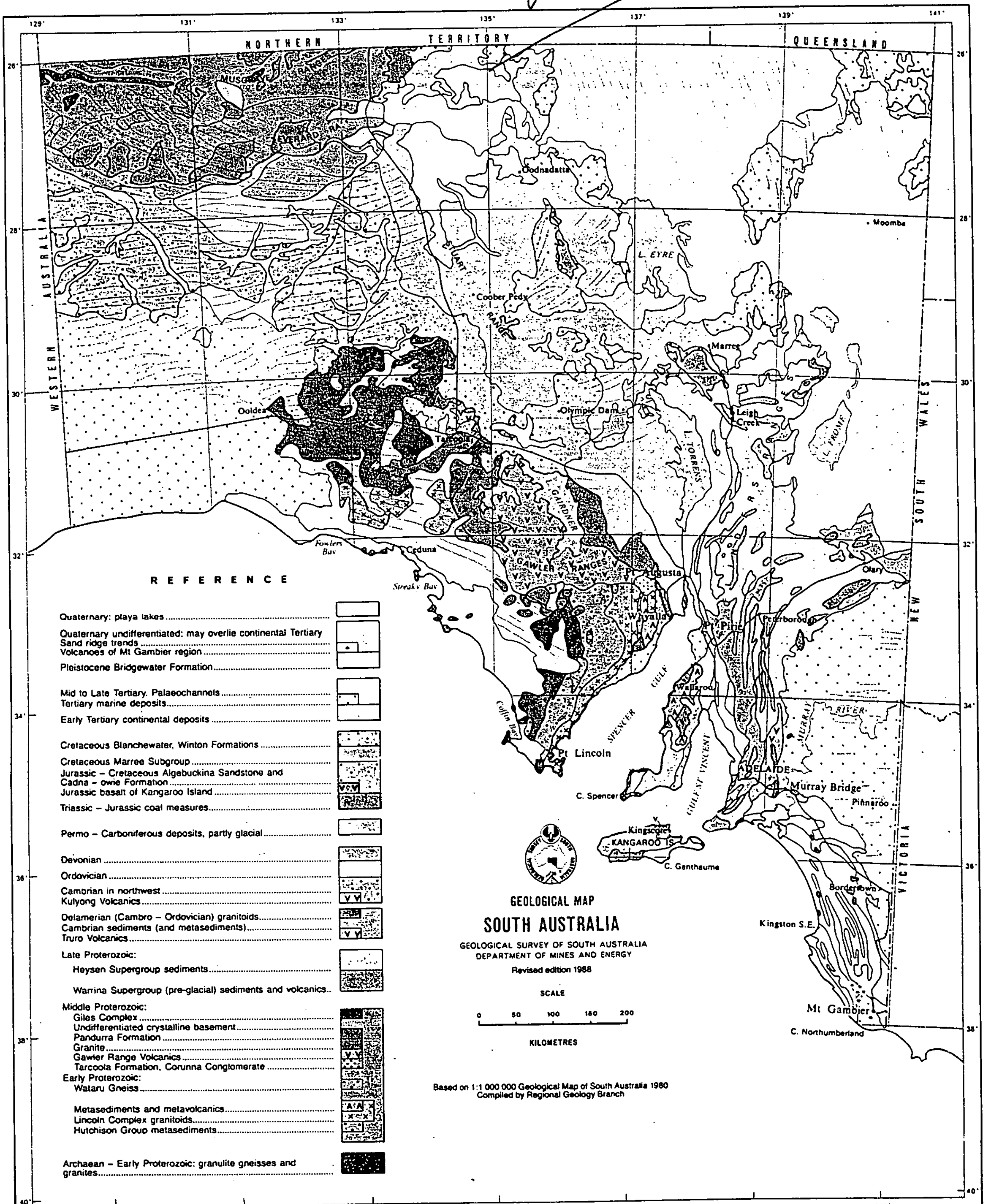
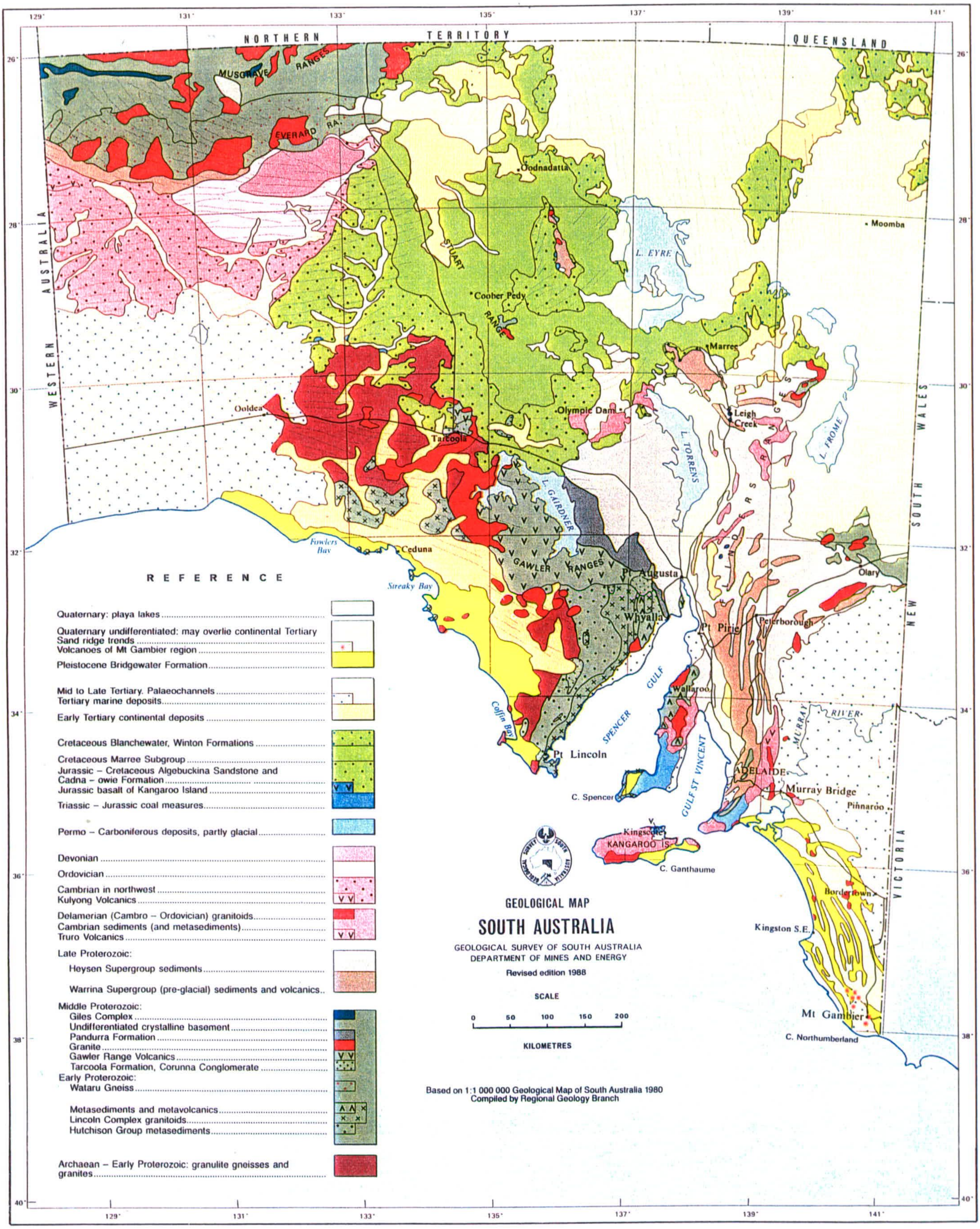



GEOLOGICAL MAP
SOUTH AUSTRALIA
GEOLOGICAL SURVEY OF SOUTH AUSTRALIA
DEPARTMENT OF MINES AND ENERGY
Revised edition 1988
SCALE
0 50 100 150 200
KILOMETRES
Based on 1:1 000 000 Geological Map of South Australia 1980
Compiled by Regional Geology Branch
REFERENCE
Quaternary: playa lakes
Quaternary undifferentiated: may overlie continental Tertiary
Sand ridge trends
Volcanoes of Mt Gambier region
Pleistocene Bridgewater Formation
Mid to Late Tertiary. Palaeochannels
Tertiary marine deposits
Early Tertiary continental deposits
Cretaceous Blanchewater, Winton Formations
Cretaceous Marree Subgroup
Jurassic – Cretaceous Algebuckina Sandstone and Cadna – owie Formation
Jurassic basalt of Kangaroo Island
Triassic – Jurassic coal measures
Permo – Carboniferous deposits, partly glacial
Devonian
Ordovician
Cambrian in northwest
Kulyong Volcanics
Delamerian (Cambro – Ordovician) granitoids
Cambrian sediments (and metasediments)
Truro Volcanics
Late Proterozoic:
Heysen Supergroup sediments
Warrina Supergroup (pre-glacial) sediments and volcanics
Middle Proterozoic:
Giles Complex
Undifferentiated crystalline basement
Pandurra Formation
Granite
Gawler Range Volcanics
Tarcoola Formation, Corunna Conglomerate
Early Proterozoic:
Wataru Gneiss
Metasediments and metavolcanics
Lincoln Complex granitoids
Hutchison Group metasediments
Archaean – Early Proterozoic: granulite gneisses and granites
NORTHERN TERRITORY
QUEENSLAND
WESTERN AUSTRALIA
NEW SOUTH WALES
VICTORIA
MUSGRAVE RANGES
EVERARD RA.
Oodnadatta
L. EYRE
Moomba
STUART RANGE
Coober Pedy
Marree
Olympic Dam
Leigh Creek
L. TORRENS
L. FROME
FLINDERS RANGES
Ooldea
Tarcoola
L. GAIRDNER
GAWLER RANGES
Fowlers Bay
Ceduna
Streaky Bay
Pt Augusta
Whyalla
Pt Pirie
Peterborough
Olary
Wallaroo
SPENCER GULF
Coffin Bay
Pt Lincoln
GULF ST VINCENT
MURRAY RIVER
ADELAIDE
Murray Bridge
Pinnaroo
C. Spencer
Kingscote
KANGAROO IS.
C. Gantheaume
Bordertown
Kingston S.E.
Mt Gambier
C. Northumberland
129° 131° 133° 135° 137° 139° 141°
26° 28° 30° 32° 34° 36° 38° 40°

National Geoscience Mapping Accord: Mapping towards 2000

A J Parker
Geological Survey

The National Geoscience Mapping Accord is a collaborative plan by State and Federal geoscientific bodies to re-map Australia over the next 20 years and promote responsible exploration and development of the nation's mineral, energy and water resources. For the South Australian Department of Mines and Energy (SADME), a key component of this mission is to produce geological, geophysical and related maps (new and/or revised editions) of all of the State with an emphasis on areas either not currently being actively explored by the private sector, poorly- or un-mapped, or of environmental concern.

Recent reviews commissioned by the Department have concluded that the primary deterrents to company exploration investment in South Australia are:

- the large amount of surficial cover which masks prospective bedrock (about 75% of the State),
- the lack of subsurface information on which to base exploration strategies, and
- restricted access to large areas of the State.

In order to address these deterrents, the Premier of South Australia in presenting the State's Mineral and Energy Policy Statement strongly endorsed South Australia's involvement with the National Geoscience Mapping Accord.

Specific objectives are:

- completion of 1st-edition 1:250 000 geological maps for the entire State
- revision or updating of old or obsolete 1:250 000 geological maps in areas of high priority,
- provision of detailed 1:100 000 or 1:50 000 geological maps, digital geological map data and associated datasets,
- integration of detailed low-level airborne geophysical data with regional survey data to enable generation of high quality image-processed maps of the entire State,
- accelerated production of mineral occurrence, petroleum exploration and geochemical maps and datasets,
- intensified drilling programmes to support field mapping but with emphasis on metallic, non-metallic, energy and water resources,
- acquisition of new geophysical data (including regional magnetic and/or deep seismic reflection surveys) in areas of poor data quality, and

- production of groundwater maps or datasets in remote areas.

These objectives are being pursued in conjunction with the Bureau of Mineral Resources, Geology and Geophysics (BMR) and, where appropriate, interstate geological surveys.

The South Australian Government has pledged substantial funding to support the Mapping Accord over the next five years, and for 1990-91 this will be invested in the following programmes:

- integration and relevelling of regional aeromagnetic data to image-processing quality (whole State),
- geological mapping and associated geochemical sampling in Pitjantjatjara Lands within the Musgrave Block,
- geological mapping and drilling in the northwestern Gawler Craton and adjacent areas of the Officer Basin, Eucla Basin and Coompana Block,
- digitizing of detailed geological map data and integration of related datasets (whole State),
- provision of petroleum exploration and production information, and,
- planning and field testing in readiness for a major N-S deep seismic reflection traverse across the Officer Basin (to be carried out by the BMR).

These projects are in addition to continuation of the existing geological mapping program (Fig. 1). Further details are outlined below.

Aeromagnetic Maps

The ultimate aim of this program is to reprocess and integrate all data from all airborne geophysical surveys ever flown in South Australia.

In the short term (1990-91), emphasis will be on integration and superlevelling of SADME and BMR regional aeromagnetic surveys to produce a range of image-processed maps at 1:1 million scale for subsequent analysis and interpretation. This has already been achieved for Eyre Peninsula where the recent 1988 joint SADME-BMR survey has been merged with pre-existing regional surveys in adjoining areas, partially superlevelled and processed.

Integration of Musgrave Block data will follow, then data from sheets surrounding the core Eyre Peninsula survey will be progressively merged to form a continuous digital dataset of high quality for the entire State.

Pitjantjatjara Lands Geological Survey

This joint SADME-BMR-NTGS-WAGS program is aimed at helping Aboriginal Communities, Governments and Mineral Exploration Companies find and develop mineral resources within the Musgrave Block. It will initially involve detailed geological mapping and geochemical soil, stream and rock sampling to enable identification and selection of exploration targets or small areas with the greatest potential for discovery. The program is being developed in conjunction with Aboriginal Communities to maintain their interests in and association with the land and to promote the Commonwealth and State Government policies of sustainable development in harmony with environmental considerations and traditional land users. There has been little or no geological mapping or mineral exploration in the region for over 20 years yet there is considerable potential for base metals, platinoids, gold, nickel, chromium and many other metallic and non-metallic minerals. Production of detailed geological and geochemical maps and acquisition of low-level magnetic data will be the main products.

Northwestern Gawler Craton

Geological mapping in the northern and western areas of the State will concentrate mainly on the WINTINNA, GILES, BARTON, OOLDEA, NULLARBOR and COOMPANA map sheets (Fig. 1) with drilling programs initially on NULLARBOR, COOMPANA, TALLARINGA and TARCOOLA. Emphasis will be placed not only on production of traditional 1:250 000 geological maps but also on obtaining as much subsurface information as possible. Critical components will be compilation of depth to basement data, and acquisition of new geophysical data in selected areas. Drilling on NULLARBOR will commence early in 1991. The Officer Basin Seismic Transect (see below) will form part of this project.

SA_GEOLOGY

A major part of South Australia's Mapping Accord is the generation of detailed, large-scale maps particularly at 1:100 000 and 1:50 000. Resources to publish, by traditional means, maps of this detail for all areas of economic priority would be quite considerable. Therefore, a programme to digitize geological maps has been developed in order to produce a comprehensive computerized geological map database from which special-purpose detailed geological maps at various scales from say 1:10 000 to 1:100 000 can be produced at greatly reduced costs. Structure/tectonic and province maps would also be produced using computer-assisted techniques and would be complemented by geochemical and drillhole location maps. These would provide a basis for further computer analysis, interpretation and integration with image-processed data.

In the long term, it is proposed to complement traditional 1:250 000 geological maps and explanatory notes with comprehensive CD-ROM datasets. These would comprise all available data for a particular map area including drillhole locations and logs, geochemistry, geological field notes, aeromagnetic and bouguer gravity images, detailed geological map data (in image form), mineral occurrences, and software to access and display the data.

Petroleum Exploration and Production System (PEPS-SA)

This system has been developed to assist petroleum exploration in South Australia. It provides a subset of Departmental drillhole data including general well information, log data, formation tops and production data for drillholes that are most useful to current or potential petroleum explorers. New modules under development include well completion reports, digital log data, seismic data, palynology, hydrocarbon geochemistry and well tests.

Officer Basin Seismic Transect

The Officer Basin remains probably the least known geological province on continental Australia. Although considered mainly as a high risk petroleum province, the basin is prospective for oil, gas, evaporite minerals, lead-zinc and a host of other strata-bound or structurally-controlled deposits.

Currently there is little or no exploration or geological research in this huge area. Water is scarce, much of the basin is concealed beneath the relatively young dunefields of the Great Victoria Desert, and the region is extremely difficult to work in, there being few tracks and only far-distant supply centres.

The primary aims of this project are:

- to establish a detailed basin stratigraphy and basin architecture for the Officer Basin,
- to establish the relationship between the Officer Basin and Musgrave Block
- to establish the deep crustal structure of the Musgrave Block
- to provide Government, Aboriginal Communities and exploration companies with an improved understanding of the groundwater, mineral and energy resources of this desert region, and
- to enable basin models and ore genesis concepts to be developed to encourage exploration.

Preliminary experimental work is proposed for 1991 to establish water resources, develop seismic techniques through the dense but cavernous limestone of the Eucla Basin region, and to determine/resolve other logistical problems with acquisition of the data. Subject to the success of this work, the full 600 km long transect would be undertaken in 1992. Stratigraphic drilling would be undertaken based on seismic results.

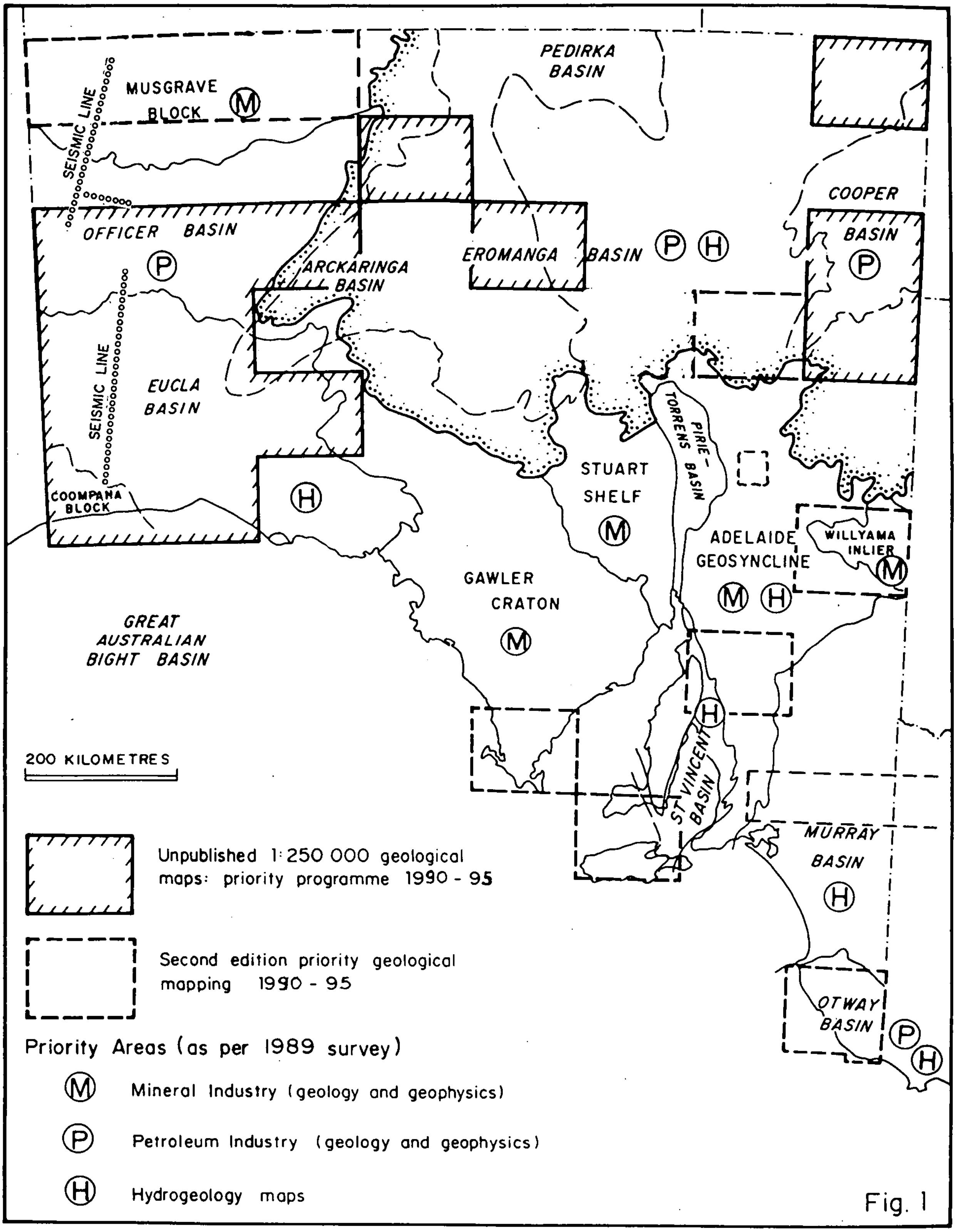


Fig. 1. Current and proposed geological mapping by the South Australian Geological Survey, 1990-95.

Geology and geophysics of South Australia

W V Preiss
Geological Survey

South Australia's rich and varied rock record ranges in age from late Archaean to Holocene. All geological periods except the Silurian are represented, and their deposits host a wide variety of mineral and fossil fuel resources. Recent advances in geological mapping, mineral exploration and geochronology, combined with improved resolution of geophysical data, have provided a better framework for interpreting this record. The State is divided into a number of geological provinces, including both Precambrian crustal blocks and younger sedimentary basins. Geophysical data, especially aeromagnetic patterns and seismic surveys, are used to define province boundaries where surficial cover is extensive. Regional gravity data are more difficult to relate in detail to known geology, since they reflect density variations through the whole crust.

The oldest rocks are found in the **Gawler Craton**, where chemical and clastic sediments, mafic lavas and granitic rocks, together comprising the *Mulgathing* and *Sleaford Complexes*, were metamorphosed, mainly to granulite facies, at 2.5 to 2.6 Ga during the *Sleafordian Orogeny*. By analogy with the Yilgarn Block of Western Australia, the Archaean rocks have potential for gold, nickel, chromium, tin, iron, and base metal exploration, although their general high-grade metamorphism and poor outcrop make interpretation difficult. Locally, however, Archaean bimodal volcanics show evidence of only low metamorphic grade.

The Archaean basement was overlain by Palaeoproterozoic marine shelf sediments (now quartzite, dolomite, banded iron formation, schist) of the *Hutchison Group* (1.8-2.0 Ga), which were strongly deformed by three fold phases, and metamorphosed to amphibolite facies, during the *Kimban Orogeny* (1.65-1.8 Ga). Synorogenic granitoids comprise the *Lincoln Complex*. Mineral deposits in the Hutchison Group include the large iron ore reserves of the Middleback Ranges, graphite in schist, and copper-lead-zinc-silver mineralisation and nephrite deposits in carbonate rocks. Younger Palaeoproterozoic rocks include both strongly and weakly metamorphosed sedimentary and felsic volcanic sequences, such as the *Moonta Porphyry* (1.74 Ga), host to the Poona copper mine, the gold-mineralised *Tarcoola Formation* (1.65 Ga), and low-grade silty metasediments possibly coeval with the mineralised rocks of Mount Isa (*Wandearah Metasiltstone* and equivalents).

During the Mesoproterozoic, thick sheets of felsic ignimbrite and lesser mafic lava were extruded on a vast scale over much of the Gawler Craton (*Gawler Range Volcanics*: 1.59 Ga). The anorogenic *Hiltaba* and related granite suites, intruded at high crustal levels, are broadly coeval; several have considerable building stone potential. The giant copper-gold-uranium-silver-rare earth deposit at Olympic Dam is associated with these igneous events, the orebody being localised at the intersection of two important lineaments. The fluvial *Corunna Conglomerate* (ca 1.59 Ga) and *Pandurra Formation* (ca 1.4 Ga) were deposited near the eastern margin of the Gawler Craton. The northwest-trending mafic *Gairdner Dyke Swarm*, believed to be feeder dykes to the *Beda Volcanics*, intruded the Pandurra Formation at about 1.1 Ga.

In the northwest of the State, rocks of sedimentary and possibly volcanic origin in the **Musgrave Block** underwent granulite and amphibolite facies metamorphism between 1.6 and 1.2 Ga, and were intruded by mafic and ultramafic magmas of the Giles Complex at 1.2-1.1 Ga, with considerable potential for nickel, gold and platinoid element exploration. The Kulgeran granitic suite was intruded during a similar time span.

The **Curnamona Cratonic Nucleus** is a smaller block in the east of the State. The basement, exposed mainly in the **Willyama Inliers** to the south, is the *Willyama Supergroup*, possibly coeval with the Hutchison Group. During the Olarian Orogeny, these rocks were deformed three times, intruded by granite, and metamorphosed to amphibolite facies. Calc-silicate rocks have potential for lead-zinc mineralisation analogous to Broken Hill. Low-grade, possible Mount Isa Group equivalent metasiltstone and Mesoproterozoic acid volcanics, minor basalt and sediments are inferred to overlie the basement to the north.

The **Mount Painter** and **Mount Babbage Inliers** contain Willyama Supergroup equivalents as well as Mesoproterozoic metasedimentary, metavolcanic and granitic rocks. The basement of the **Peake and Denison Inliers** comprises Palaeoproterozoic clastic metasediments with mafic and acid volcanic intercalations (1.8 Ga). In the Mount Lofty Ranges, basement inliers comprise highly retrogressed schist, gneiss and minor granitic rocks, whose age and tectonic history are poorly understood.

In the eastern portion of the State, the Neoproterozoic to Cambrian **Adelaide Geosyncline** is the dominant tectonic feature. Initial rifting occurred circa 0.85 Ga along northwest-trending, partly offset troughs. Mafic volcanism was widespread and was followed by evaporitic, mixed clastic-carbonate sedimentation and widespread associated copper mineralisation (*Callanna Group*). Much of this sequence is disrupted in intrusive breccia bodies (diapirs) of the Flinders Ranges. A more meridional trough then formed east of the **Torrens Hinge Zone** (eastern margin of the Gawler Craton) and west-derived clastics and carbonates of the *Burra Group* accumulated over a wider belt within the geosyncline. Sedimentary magnesite is the major economic resource, although the basal fluvial sandstone and younger black shale units of the Burra Group have potential for gold exploration. Sedimentation was interrupted by a basin-wide unconformity and resumed under glacial conditions. The *Umberatana Group* comprises tillites at the base and top; known gold deposits tend to be concentrated in associated fluvioglacial sandstone units. The interglacial sequence comprises mainly siltstone and carbonate; various carbonate units are host to micaceous hematite, talc and secondary magnesite deposits. The *Wilpena Group* is post-glacial and records two major transgressive-regressive cycles. The latter two groups are not confined to the Adelaide Geosyncline, but onlapped adjacent cratonic regions (**Stuart Shelf, Curnamona Cratonic Nucleus** and **Officer Basin**). Later, the deep **Munyarai Trough** developed near the northern margin of the Officer Basin. The youngest sandstone units of the Wilpena Group contain the famous Ediacara metazoan assemblage in the Flinders Ranges, and are also responsible for most of the spectacular scenery, and hence tourist potential, of that region.

After a major hiatus, sedimentation resumed in the Adelaide Geosyncline during the Cambrian; deposits are preserved in the **Arrowie Basin, Stansbury Basin,** and **Kanmantoo Trough**. Carbonate sediments are dominant in the Early Cambrian *Hawker* and *Normanville Groups*, which contain Mississippi Valley type lead-zinc mineralisation. Redbeds of the *Lake Frome Group* and deeper basinal clastics of the *Kanmantoo Group* extend into the Middle Cambrian. Sedimentation in the Adelaide Geosyncline was brought to a close by the Delamerian Orogeny (ca 0.5 Ga), during which Neoproterozoic and Cambrian sediments were folded, faulted and overthrust, with maximum compression in the southern part of the fold belt. Syn-tectonic to post-tectonic granitoids range in age from 0.52 to 0.48 Ga, and extend eastwards below the Cainozoic Murray Basin. The igneous and metasedimentary rocks of this poorly known region are currently being investigated for their lead-zinc potential.

In the **Officer Basin**, marine carbonate and non-marine evaporites and coarse clastic sediments accumulated in the Early to Middle Cambrian (*Marla Group*). Both Cambrian and Neoproterozoic beds have demonstrated petroleum source-rock potential. Equivalents of the Officer Basin sequence extend beneath the late Palaeozoic **Boorthanna Trough**, where seismically defined diapiric structures enhance the potential for mineral exploration and petroleum traps. The Officer Basin also includes the Ordovician, largely arenaceous *Munda Sequence*.

The deeply buried **Warburton Basin** in the northeast of the State has a record of Cambrian carbonate sedimentation and volcanism (*Kalladeina Formation* with source-rock potential, and acid to intermediate *Mooracoochie Volcanics*) as well as Ordovician siltstone and quartzite (*Dullingari Group*).

Devonian strata are confined to the central part of the **Officer Basin** and to extensions of the **Darling** and **Amadeus Basins** into South Australia. Overthrusting of the Musgrave Block and thrusting within the Officer Basin succession took place in the mid-Palaeozoic *Alice Springs Orogeny*, providing potential for structural petroleum traps. Carboniferous granite was intruded into the Warburton Basin in the Moomba area.

During the Late Carboniferous to Early Permian, ice sheets spread over Gondwana, of which South Australia was a part. Ice movement toward the northwest is recorded by glaciated pavements on Fleurieu Peninsula. Largely terrestrial Permian depocentres include the **Nadda, Troubridge, Polda, Denman, Arckaringa, Pedirka** and **Cooper Basins**. The latter basin, defined entirely by seismic and drilling data, supplies natural gas to Adelaide and Sydney markets and oil, condensates and LPG for domestic and overseas sale. Large coal reserves exist in the Arckaringa Basin. In the Flinders Ranges, Permian glacials are known at Blinman, while a Late Permian diamondiferous conglomerate in the intermontane Springfield Basin contrasts with the commonly accepted Jurassic age of South Australian kimberlite and lamprophyre intrusives.

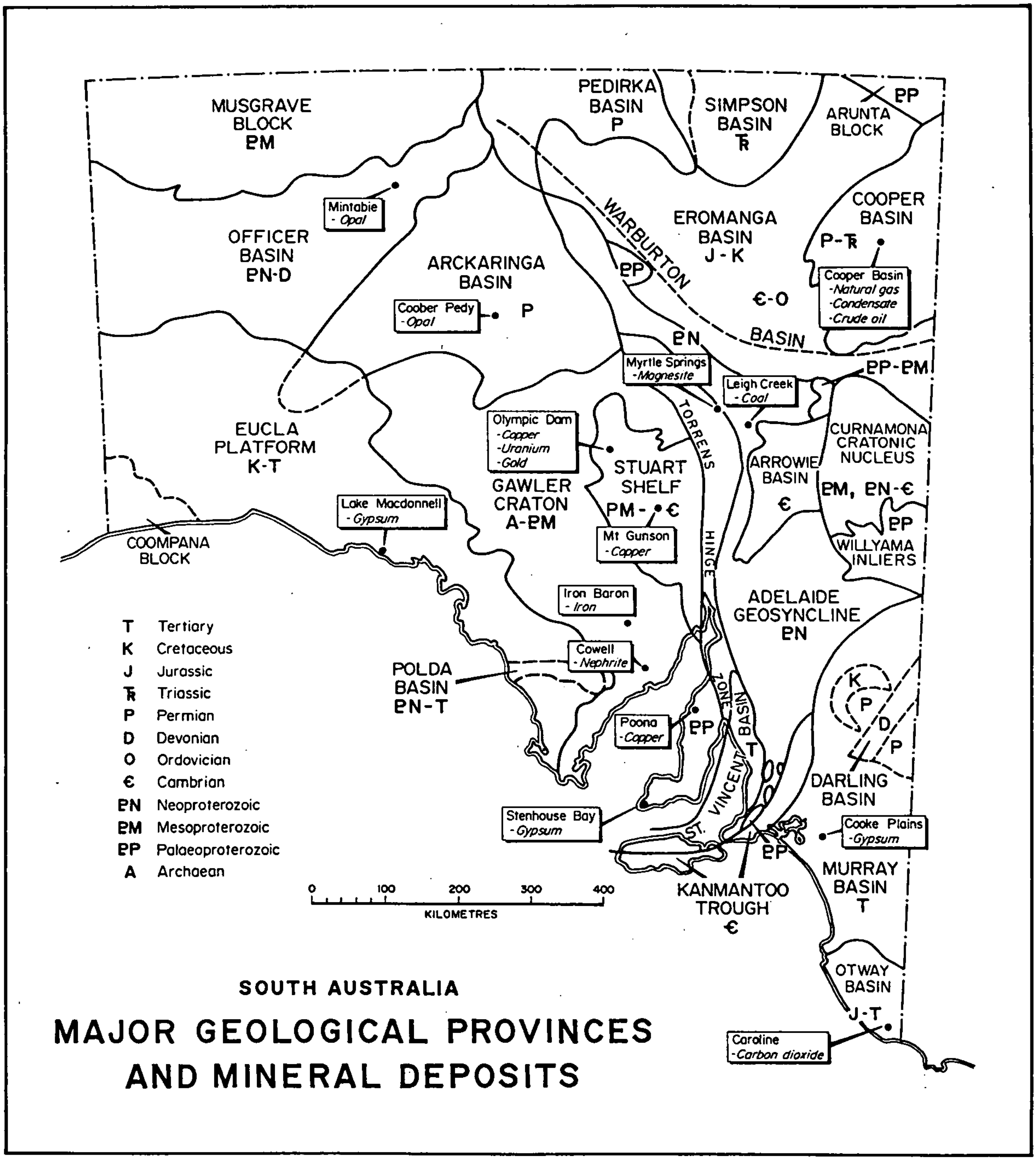
Mesozoic cratonic basins cover large areas of northern South Australia, while positive regions were subject to deep weathering. Sedimentation continued from the Permian into the Triassic in the **Cooper Basin**, and the Triassic **Simpson Basin** subsided mainly east of the Permian Pedirka Basin. The intermontane **Telford Basin** of the northern Flinders Ranges supplies sub-bituminous coal to the Port Augusta power station. The **Eromanga Basin** developed in the Jurassic with fluvial deposition of the *Poolowanna Formation*, *Hutton Sandstone* and *Namur Sandstone*, which contain substantial oil reserves. Lacustrine deposits are intercalated in basinal areas while, near the margin, the *Algebuckina Sandstone* oversteps the older infrabasins and provides an important artesian aquifer. With marine transgression in the Early Cretaceous, the *Neales River Group* was deposited throughout the basin, with thin onlapping marginal deposits; equivalents occur in the **Berri Embayment** and **Eucla Platform**.

During the Jurassic, major east-west rifts (**Bight**, **Duntroon** and **Otway Basins** and, to a lesser extent, **Polda Basin**) developed in the southern part of the State, prior to the eventual break-up of Australia and Antarctica in the Late Cretaceous. The Katnook natural gas discovery is in the Cretaceous *Otway Group* of the **Otway Basin**, while the overlying *Sherbrook Group* produces carbon dioxide at Caroline.

Thin Cainozoic sediments are extremely widespread in South Australia, but thick sequences are confined to the newly formed continental margin basins (e.g. **Otway Basin, Bight Basin**). Widespread early Tertiary terrestrial sedimentation in the **Eucla, Lake Eyre, St Vincent, Murray, Pirie, Torrens** and **Willochra Basins** produced numerous lignites and local uranium deposits (e.g. **Frome Embayment**). Epicontinental marine sedimentation commenced in the Eocene and dominated in the mid-Tertiary in the **Eucla, St Vincent** and

Murray Basins; shoreline deposits have potential for heavy mineral sands. Inland, the **Lake Eyre** and **Billakalina Basins** were lacustrine depocentres in the mid-Tertiary. Land areas were affected by extensive Tertiary weathering, lateritisation and silcrete formation; silicification was associated with the formation of precious opal. The highland regions of the State (e.g. Flinders and Mount Lofty Ranges) were continuously uplifted during the Cainozoic. Moderate seismic activity continues to the present day in these ranges, on Eyre Peninsula and in the Simpson Desert.

Quaternary coastal-plain deposits in the southeast of South Australia record numerous glacio-eustatic sea-level fluctuations, preserved through gradual uplift. Elsewhere, the record is discontinuous. Inland, widespread alluvial, aeolian and playa-lake deposits range from Early Pleistocene to Holocene; gypsum and celestite are important resources. Late Quaternary volcanism is confined to the southeast corner of the State.



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The Cambrian setting for petroleum and minerals

DI Gravestock
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Present day boundaries of Cambrian sedimentary basins in South Australia (Arrowie, Stansbury, Warburton, Officer) obscure both their original depositional geometry and the fac that they shared a common, though varying, coastline through much of the Cambrian (Fig. 1). Transgressive-regressive sequences deposited in each basin reflect changes in relative sea-level, which, if significant enough to modify local variations in subsidence rate and sediment supply, permit correlation between neighbouring basins. At present, this is the best means of correlation where biostratigraphic control is poor in one region relative to another. Cambrian strata form four sequence sets (supersequences), the oldest two of which can be subdivided into five sequences (Fig. 2). At this level of detail the depositional components of each sequence (lowstand, transgressive and highstand systems tracts) clarify basin geometry and regional palaeogeography in 'time slices' of relatively short duration. Eustatic variations have been overprinted by syntectonic and volcanic episodes of varying intensity in each basin. They also form a useful basis for 'event correlation', and serve in part to subdivide the Cambrian depositional setting outlined below.

Sequence C1.1 to C1.3: Early Cambrian, pre-Kangarooian Movements

- Arrowie Basin palaeobathymetry deepened north (to Warburton Basin) and south (to Stansbury Basin) from a central, shallow marine shelf between exposed Stuart Shelf and Willyama Block. Adjoining Stansbury Basin deepened east from a shallow marine shelf that fringed the Gawler Craton. Officer Basin strata were confined to the Wintinna and Tallaringa Troughs with marine access only to the northeast. The surrounding hinterland was a source of abundant terrigenous clastics. Apart from volcanics, these sequences have not yet been drilled in the deeply buried Warburton Basin.

- Carbonate-dominated C1.1 shelf deposits in the Arrowie and Stansbury Basins were exposed over a wide area during the C1.2 lowstand. Extensive tracts, mainly in the Torrens Hinge Zone, remained exposed to meteoric weathering, dolomitisation and karst development. Petroleum and mineral occurrences in C1.1 carbonate reservoirs (lower Wilkawillina Limestone, Woodendinna Dolomite, Fig. 2) include Wilkatana drillholes (oil) and Ediacara mineral field (Pb-Ag); MVT prospects include those on the western flank of Heysen Range.

- Halite/clastic/carbonate, aeolian, salina and shallow epeiric sea sediments were deposited during sequence C1.1 in the Officer Basin. Carbonates were exposed during the C1.2 and C1.3 lowstands when terrigenous input increased. The first thick, arkosic sandstone in the Stansbury Basin (Stokes Bay Sst.) may also be C1.2 lowstand deposits. First significant sand in the Arrowie Basin (Bunkers Sst.) was deposited later during the C1.3 lowstand. Effects of low relative sea-level diminish in deeper water slope and basin settings, chiefly muddy limestone and shale, hence the lower boundary of sequence C1.3 is difficult to locate in the Stansbury Basin.

- Maximum marine transgression (Fig. 1) occurred in C1.2 when Stuart Shelf was inundated (Andamooka Lst.) and an epeiric seaway may have reached Hughes wells near Coompana Block in the Officer Basin (mid Ouldburra Fmn).

- Volcanism commenced in C1.2, peaked in C1.3 and waned in C2.1, as shown in Stansbury Basin by Truro Volcanics and associated tuff beds (in Parara Lst., Heatherdale Shale), and in Arrowie Basin by tuffs (in Parara Lst., Oraparinna Sh., Wilkawillina Lst., Billy Creek Fmn). Mooracoochie Volcanics (eastern Warburton Basin) and Mt Wright Volcanics/Cymbric Vale Formation (western NSW) are correlatives. No evidence of volcanism exists in eastern Officer Basin. Bungadillina Monzonite (Peake and Denison Ranges) was possibly emplaced during C1.3 time.

Kangarooian Movements

First record of major tectonic activity expressed as follows:

- In upper C1.3 by shallow submarine erosional channels in northern Arrowie Basin from Mt Scott Range east to Yalkalpo Syncline, rapid deposition of Narina Greywacke, sand influxes in southwestern Arrowie Basin (Chace Range) and western Stansbury Basin (Horse Gully). Mineralisation in this sequence (associated with diapirs ?and/or channel fill) at Puttapa, Aroona, Sliding Rock and Wirrealpa Mines.

- Uplift in upper C1.3 of Proterozoic Benagerie Ridge, separating Yalkalpo and Moorowie Synclines. Speculatively, uplift of Mt Painter/Mt Babbage Inliers and along Muloorina Ridge, separating Warburton from Arrowie Basin.

- In upper C1.3 and C2.1, fault uplift led to erosion in Torrens Hinge Zone (upper Ajax Lst, Mt Scott Range) and southern extensions - Pine Point Fault (Minlaton Fmn), Investigator Strait High (White Point Conglom).

- Alluvial fan deposition in northeastern Officer Basin (Wallatinna Fmn), continuing into C2.2 (Mt Johns Conglom; ?Moorilyanna Conglom.).

- Initial subsidence of Kanmantoo Trough in C2.1 related to renewed rapid crustal extension in Stansbury Basin.

Top sequence C1.3 to C2.2: Early Cambrian palaeogeographic consequences

- Shoals/islands barred open marine circulation in Arrowie Basin from Benagerie Ridge to Stuart Shelf. Regional shallowing to peritidal carbonate-evaporite deposits in C1.3, then red beds in C2.1 (Billy Creek Fmn), which developed as a result of sea-level fall in restricted epicontinental sea. Moderately organic-rich source rocks occur in sequence C1.3. Northerly palaeoslope was lost, but access south to Stansbury Basin was maintained.

- Generally marine conditions returned in sequence C2.2. Shelf carbonates prevailed in eastern Warburton Basin (basal Kalladeina Fmn) and Arrowie Basin (Wirrealpa Lst.). Clastics and carbonate accumulated in eastern Officer (Mt Johns Conglom., Apamurra Mem.) and western Stansbury Basin (Ramsay Lst. - Coobowie Lst.). Deeper marine lowstand fan and fine-grained transgressive clastics were deposited in Kanmantoo Trough.

- Widespread non-marine sedimentation occurred in eastern Officer Basin, consisting chiefly of alkaline playa lake, saline mudflat and fluvial deposits. Moderately organic-rich oil-prone source rocks occur in playa lake facies which intertongue locally with alluvial fan deposits.

- Generally marine conditions returned in sequence C2.2 in all basins, including eastern Warburton (basal Kalladeina Fmn shelf carbonates). Anoxic, deep marine sediments were deposited in Kanmantoo Trough (Talisker calc-siltstone, Karinya Shale). Gold mineralisation confined to lower Kanmantoo Group.

Sequence set C3: Middle Cambrian, Mootwingee Movement

- Thick but incompletely preserved (upper levels eroded) red beds in eastern Officer, Arrowie and western Stansbury Basins. Environments range from deltaic to shallow marine; fluvial in upper Lake Frome Group (Grindstone Range Sst.). Shallow to deep marine siliciclastics transported from Gawler Craton into Kanmantoo Trough. Part of Lake Frome Group could be derived from deformation and uplift of Wonominta Block (western NSW) during Mootwingee Movement.

- Basal Kalladeina carbonate in eastern Warburton Basin was exposed and dolomitised during basal C3 lowstand, and has yielded heavily gas-cut salt water on test (Gidgealpa 1).

- Transgressive - highstand tracts in middle Kalladeina Formation represent shallow marine carbonate shelf, deeper slope and shale basin environments in Gidgealpa-Kalladeina area.

- Major hiatus further north through C2 and C3 (Coongie-Cuttapirrie area). This correlates with depositional break on Wonominta Block associated with Mootwingee Movement.

Sequence set C4/01: Late Cambrian - Early Ordovician: Delamerian Orogeny

- Upward shallowing in eastern Warburton Basin to fine-grained siliciclastics of upper Kalladeina Fmn (?and Innamincka 'Red Beds') by Early Ordovician time.

- Volcanism renewed in Late Cambrian in eastern Warburton Basin.

- Mafic volcanism in eastern Stansbury Basin (e.g. Nanyah, Coonalpyn drillholes) possibly occurred in Late Cambrian but stratigraphic data are lacking.

- Speculatively, Kulyong Volcanics in eastern Officer Basin are correlatives, implying that underlying rocks were folded during the Middle Cambrian.

- Intrusion of synorogenic granites at depth in Kanmantoo Trough. Shear zones in granites host copper-gold mineralisation.

- Delamerian Orogeny brought deposition to an end in Stansbury and Arrowie Basins. Sedimentation continued without break into Early Ordovician in eastern Warburton Basin, and resumed in eastern Officer Basin after hiatus (Munda Sequence).

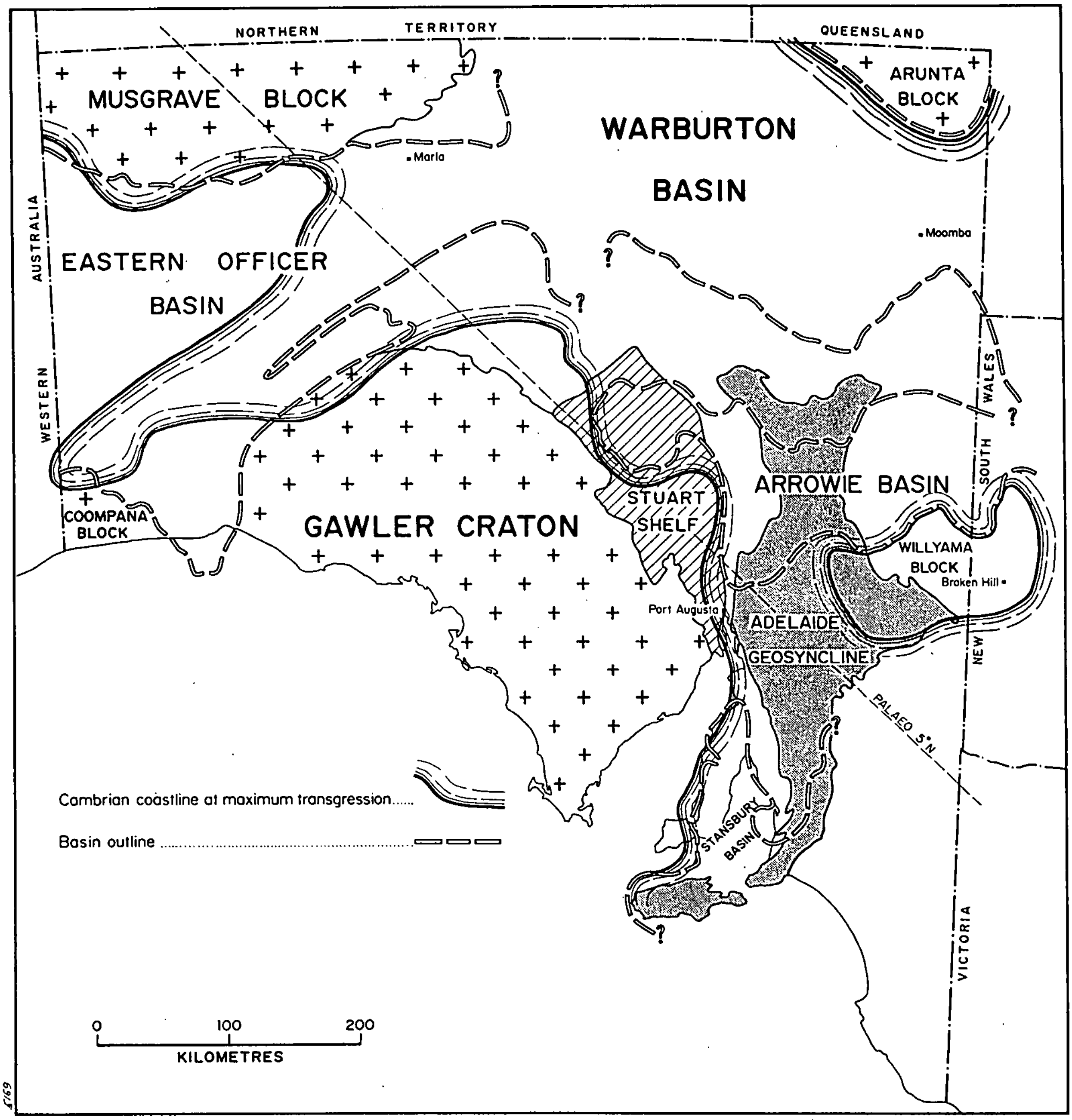

Figure 1. Cambrian sedimentary basins, present limits and coastline at maximum marine transgression

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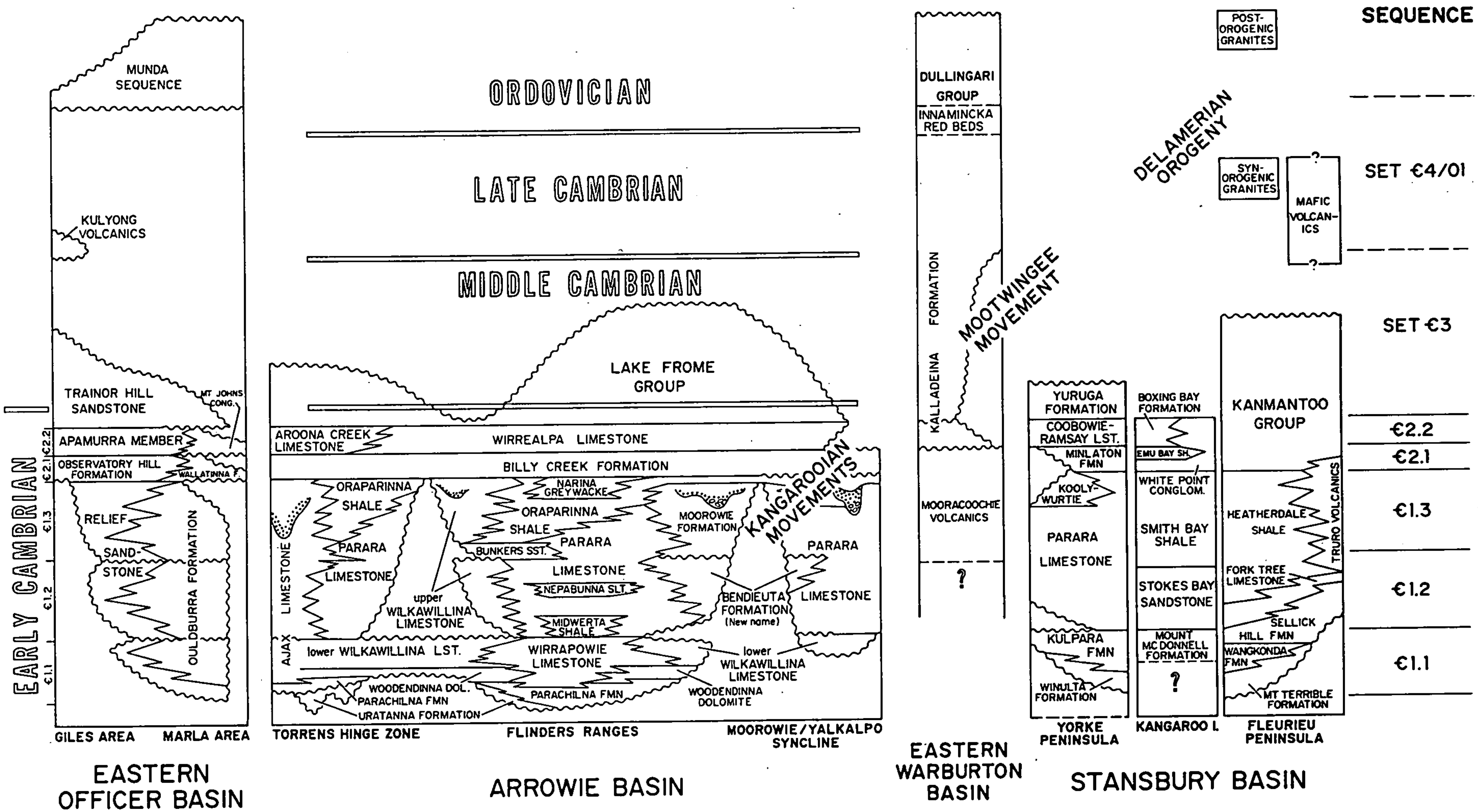

Figure 2. Cambrian sequences in South Australia

SADME S21810

Petroleum overview

RA Laws
Oil, Gas and Coal Division

Petroleum exploration and development within South Australia in the next decade will see a renewed interest in areas outside the Cooper and Eromanga Basins, traditionally the focus of exploration and development activity, with new exploration strategies being applied to these areas.

As at 20 November 1990 there were 12 Petroleum Exploration Licences (PELs) covering 148,000 km^2 (15% of total state area) and 2 offshore Exploration Petroleum Permits (EPPs) current in South Australia (Fig. 1).

An additional 4 onshore PELs totalling 35 000 km^2 have been accepted but not yet granted and 1 exploration permit, totalling 27 graticular blocks in the offshore Otway Basin within the State 3 mile limit, has been offered.

Applications for a further 5 PELs and 2 EPPs are currently being processed. This brings the total number of offshore and onshore exploration licences to 26 with a further 4 PELs and 2 EPPs on offer. This represents a record number of petroleum tenements for the State.

The increased level of activity reflects the varied play types in the prospective basins. The trend towards reduced size of exploration tenements allows industry to concentrate more on detailed geological and geophysical studies which will lead to better prospect definition, and hopefully to an increased success rate.

As at 1/1/90, 1020 petroleum wells have been drilled and 187 319 km of seismic recorded in the State (Fig. 2). Significant exploration potential exists in eight key South Australian basins - the Cooper, Eromanga, Otway, Bight, Duntroon, Simpson, Officer and Warburton.

Cooper and Eromanga Basins.

Since the discovery of gas in 1963 in Gidgealpa 2, the Cooper Basin Producers have consistently maintained a gas wildcat discovery rate of approximately 1:2 although in 1989 this figure dropped to 1:3.

Success ratios for the 57 Cooper/Eromanga wells drilled in 1989 were 1:3 for gas wildcats, 1:1.4 for gas appraisal and 1:1.2 for gas development wells. In contrast, oil wildcats had a success ratio of 1:15 although historically this figure has been approximately 1:6. Anticlinal and faulted anticlinal traps continue to be relied upon as the main exploration targets.

Annual production for 1989 from 52 gas fields and 37 oil fields was 5 x $10^9 m^3$ sales gas (176 BCF), 2.3 x $10^6 m^3$ oil and condensate (14.5 million bbls) and 452,000 tonnes of LPG. Petroleum currently provides 72% (42% oil, 30% natural gas) of the State's primary energy requirements for electricity generation and transport fuel.

As at 1.1.90 remaining reserves, estimated by SANTOS are; 80 x 10^9m^3 (2840 BCF) sales gas, 7.9 x 10^6m^3 (50 million bbls) oil, 8.25 x 10^6m^3 (52 million bbls or 6 x 10^6 tonnes) condensate and 6.5 x10^9m^3 (230 BCF) ethane.

SADME discovery rate analysis predicts 48 x 10^9m^3 (1700 BCF) potential risked sales gas within the Cooper Sector of PELs 5 & 6. The potential risked oil recoverable is estimated to be 4 x 10^6m^3 (26 million bbls).

Potential remains high for discoveries in stratigraphic and sub-unconformity traps which have received increasing interest in the past 3 years. Complex stratigraphic traps along the Gidgealpa-Merrimelia-Innamincka trend provide encouraging results for further gas discoveries. Pinchout plays along the margins of the Cooper Basin have been tested with commercial success. Weathered and fractured Cambrian volcanics have tested commercial quantities of oil where updip from Late Palaeozoic sediments, opening up potential for future Warburton Basin discoveries.

Otway Basin

The Otway Basin is entering a phase of intensified exploration effort and development of proven gas reserves.

Over 2000 km of seismic data have been acquired in 1990. Three wells were drilled in 1990 and another 4 are expected to be drilled in 1991.

Follow up drilling to Katnook 1 has proved up sufficient gas supplies for the local South East market. Gas production and sales will commence in the first half of 1991 and further exploration in the area may prove sufficient reserves to meet part of Adelaide's future gas needs.

High quality seismic, in conjunction with a closely spaced grid, has enabled delineation of faulted en echelon anticlinal structures within portions of the Robe and Penola Troughs. Successful exploration strategies to date have concentrated on closures within the deeper portions of these troughs. Considerable potential for oil may exist in undrilled portions of the basin.

The recent involvement of major petroleum companies, including Shell and BHP, reflects the increased interest in this region which is almost entirely under licence. Applications for two remaining areas are in the process of being granted, but additional areas are due to come available for licensing in the near future.

Bight and Duntroon Basins

The prospective but little explored Bight and Duntroon Basins have not been drilled since 1986 (BP Duntroon 1).

Five areas, comprising a total of 129 000 km^2, were gazetted in May 1990 and applications have been received for 2 areas, S90-1 and S90-2, in the Duntroon Basin. 5 wells (2 Bight, 3 Duntroon) have scarcely intersected the Cretaceous-?Jurassic sequence. 53 000 km of seismic data have enabled delineation of large anticlinal structures in the undrilled half grabenal zone of the Duntroon Basin in favourable water depths for hydrocarbon exploration.

Lake Eyre - Birdsville Track Ridge

Applications are currently being processed for five blocks covering a total of 35 000 km^2 in the Lake Eyre-Birdsville Track Ridge areas, covering the Cambro-Ordovician Warburton Basin and Mesozoic Simpson and Eromanga Basins. Eleven petroleum wells have been drilled and 6034 km of seismic have been recorded to date.

The appeal of this area is enhanced by the fact that a number of prospects have already been delineated and are ready to drill, with over 100 other prospects and leads awaiting further seismic detailing.

Eastern Officer Basin

Of major interest in the next decade will be the search for oil in Cambrian and Precambrian strata which cover large areas of South Australia. Four exploration areas totalling 44 300 km^2 are available for application in the eastern Officer Basin.

Numerous oil shows have been recorded in Precambrian and Cambrian units within the Officer Basin and elsewhere in South Australia.

60 wells (7 petroleum, 8 stratigraphic and 45 mineral) and approximately 5 300 km of seismic over the eastern Officer Basin provide a useful database for future exploration.

The Pitjantjatjara and Maralinga Tjarutja traditional landowners have maintained good relations with previous licensees and have also expressed interest in renewed petroleum exploration within their lands.

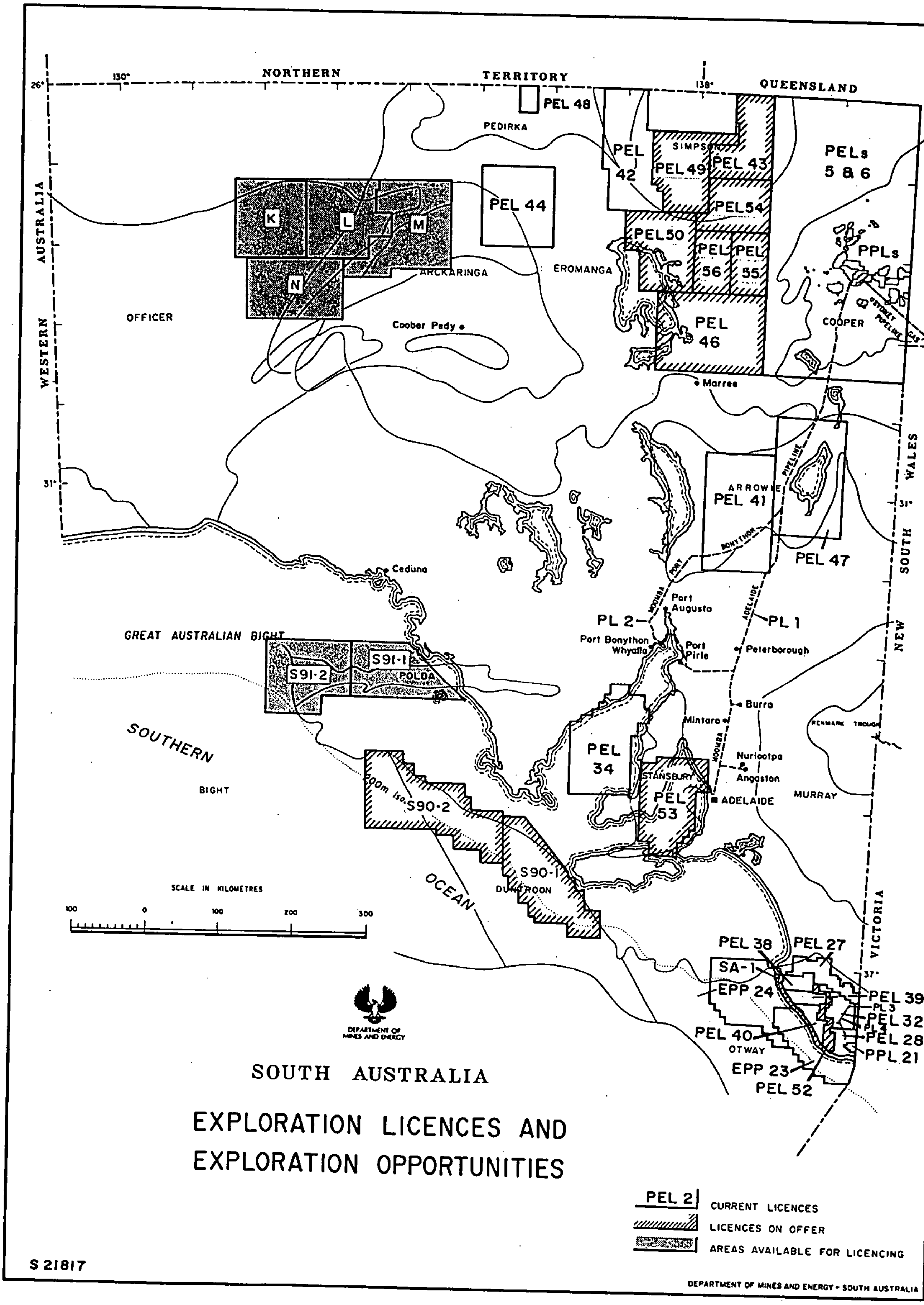

Figure 1. Exploration licences and exploration opportunities.

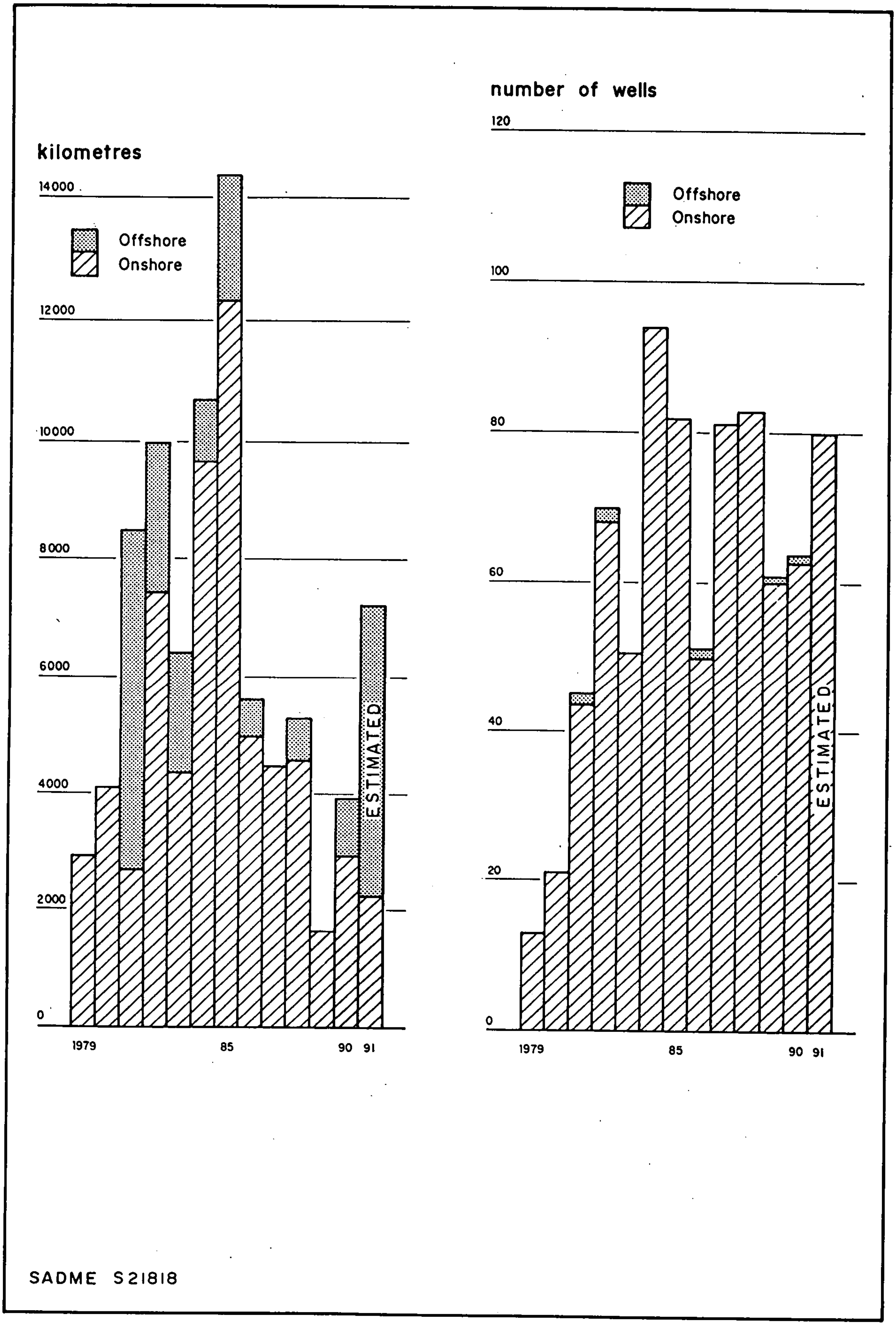

Figure 2. Seismic coverage and number of petroleum wells in SA, 1979-1990.

Otway Basin Petroleum Potential: An update of stratigraphy and discoveries, and an assessment of undiscovered oil and gas potential

JGG Morton
Oil, Gas and Coal Division

Regional setting and revised stratigraphy

The Otway Basin comprises the central to eastern portion of a series of basins formed during the rifting of Australia from Antarctica during the Early Cretaceous, and is related to the Bight -Duntroon Basins to the west, and to the Bass-Gippsland Basins to the east. Currently, the whole of the basin in South Australia, including offshore is under exploration or production licence (Fig. 1).

Stratigraphic nomenclature has recently been revised to rationalise differing company nomenclatures by Kopsen and Scholefield (1990) for the Early Cretaceous Otway Group and by Hill and Morton (1990) for both the Otway and Late Cretaceous Sherbrook Groups (Fig. 2).

The Otway Group is known mainly from the Robe-Penola Trough and comprises a sequence of fluvial and lacustrine sediments. A lacustrine, algal rich shale above or laterally equivalent to the Pretty Hill Sandstone has been termed the 'Laira Formation' and is probably the source for the numerous oil strandings encountered on SA beaches and Kangaroo Island (McKirdy, 1985). The 'Katnook Sandstone' is a fluvial unit above the Laira Formation, and a basal sand on the mid Otway Group unconformity has been termed the "Windermere Sandstone". Both are new names for the reservoir units.

The Sherbrook group consists of a southwest thickening, progradational deltaic wedge. A new shaly unit has been recognised below the Waarre Formation, and has been named the "Copa Formation".

Recent discoveries

The discovery of the Katnook Field in 1987 stimulated interest in the Otway Basin in South Australia, and was followed by the discovery of the Ladbroke Grove Field. A gas contract was signed in August, 1990 to supply industry and domestic demand at Snuggery, and Mount Gambier over the next 15 years. There exists a ready market for any additional gas discoveries, as ETSA could convert fuel in the Snuggery power station from oil to gas, and if additional gas is discovered it could be used to supplement Adelaide's gas supply. The Katnook gas is particularly rich, with only a minimum processing required before delivery to customers. In contrast, the Ladbroke Grove Field, only 2km to the south of Katnook, contains over 50% CO_2. The only other producing field in the Otway Basin in South Australia is the Caroline field, which produces nearly 100% CO_2. The CO_2 is believed to be of magmatic origin. Caroline and Ladbroke Grove are 20 and 30 km respectively from the Mt Gambier Volcanic chain, which is less than 7000 years old. It is believed that the youngest structures are the most prone to CO_2, but the presence of deep basement penetrating, field bounding faults and proximity to the volcanic chain are probably also contributing factors. In any event, CO_2 is not a valueless commodity as there are expanding markets for CO_2 in Australia and if oil were to be discovered in the Otway Basin, CO_2 could be used for enhanced oil recovery.

Hydrocarbon plays

Broadly, there are 3 plays that have proven reservoirs: Pretty Hill Sandstone (sealed by Laira Formation), Windermere/Katnook Sandstone (sealed by Eumeralla Formation) and Flaxmans/Waarre Formations (sealed by Belfast Mudstone). Existing fields have all been found in these 3 formations, in anticlines or faulted anticlines. Additional potential exists for discoveries in stratigraphic traps, the basal Tertiary sequence, or within isolated sands of the Belfast Mudstone and Eumeralla Formations, but are not considered further in this assessment.

Undiscovered petroleum potential

Estimates have been made of the undiscovered petroleum potential of the Basin using Monte-Carlo techniques. The method combines the following factors to produce an estimate of the potential reserves of the Basin:

Productive area (accounting for seal distribution, reservoir distribution, maturity, and economic drill depths)

Area of Anticlines to Productive area ratio

Closure height

Net to gross reservoir ratio

Porosity

Water saturation

Gas or oil expansion factor

Success ratio

Average fill of antielines

Recovery and shrinkage factor

Distributions are chosen for each of these factors, based on data from wells, regional seismic interpretation and discovered fields in the Otway Basin. These distributions are then sampled (1000 trials) to produce a cumulative probability distribution of the potential of each of the 3 identified plays. Because other plays are not considered, this method should be considered conservative, but is useful to give an order of magnitude estimate of undiscovered reserves. The method is in wide use by the BMR and overseas, and has been tested on the Cooper Basin in South Australia with reliable results. The method has so far been applied to onshore Otway Basin only, as economic factors differ offshore. (Table 1).

Table 1

ONSHORE S.A. OTWAY BASIN

Undiscovered Potential

Play	Probability that the ultimate potential will exceed the stated value.		
	90%	50%	10%
Waarre/Flaxman			
Sales Gas (BCF)	24	142	573
Recoverable Oil (MMSTB)	5	46	217
Windemere/Katnook			
Sales Gas (BCF)	14	271	1 736
Recoverable Oil (MMSTB)	4	41	249
Pretty Hill			
Sales Gas (BCF)	112	595	1 864
Recoverable Oil (MMSTB)	13	89	343
TOTAL			
Sales Gas (BCF)	**150**	**1 008**	**4 173**
Recoverable Oil (MMSTB)	**22**	**176**	**809**

An extension of these estimates is a determination of the maximum field size likely to exist for each play. This was determined using a rank size law (Riesz, 1978):

$$\text{Cumulative undiscovered potential} = C + \ln(1 + N) \qquad (1)$$

Where C = a constant for each play
N = total number of fields to be discovered.

Once 'C' has been determined, the maximum field size is determined using

$$\text{Field Size} = \frac{C}{1+N} \qquad (2)$$

This is the approximate derivative of equation 1, and setting N=1 the maximum field size can be estimated using Monte-Carlo techniques. Again, this should be regarded as an order of magnitude estimate only.

The results for the onshore portion of the Otway Basin are summarised in table 2.

Table 2

ONSHORE S.A. OTWAY BASIN

MAXIMUM FIELD SIZES

Play	Probability that the largest field is greater than the stated value		
	90%	50%	10%
Waarre/Flaxman			
GAS (BCF)	10	47	161
OIL (MMSTB OOIP)	4	26	93
Windemere/Katnook			
GAS (BCF OGIP)	3	54	292
OIL (MMSTB OGIP)	3	24	102
Pretty Hill			
GAS (BCF OGIP)	**38**	**179**	**469**
OIL (MMSTB OOIP)	**15**	**73**	**204**

Conclusions

Statistical analysis of the 3 main plays in the Otway Basin in South Australia suggest, a reasonable chance of finding of a further 1 TCF of sales gas and/or 200 million barrels of recoverable oil in the onshore portion of the Basin. Any gas discovered would have a ready market in supplying an ETSA power station.

The relatively small fields likely to be encountered require high resolution, and close spaced seismic (approx. 0.5 km) to ensure successes. To minimise the CO_2 risk, drilling in preference of early unfaulted structures may have the greatest chance of rich gas and/or oil.

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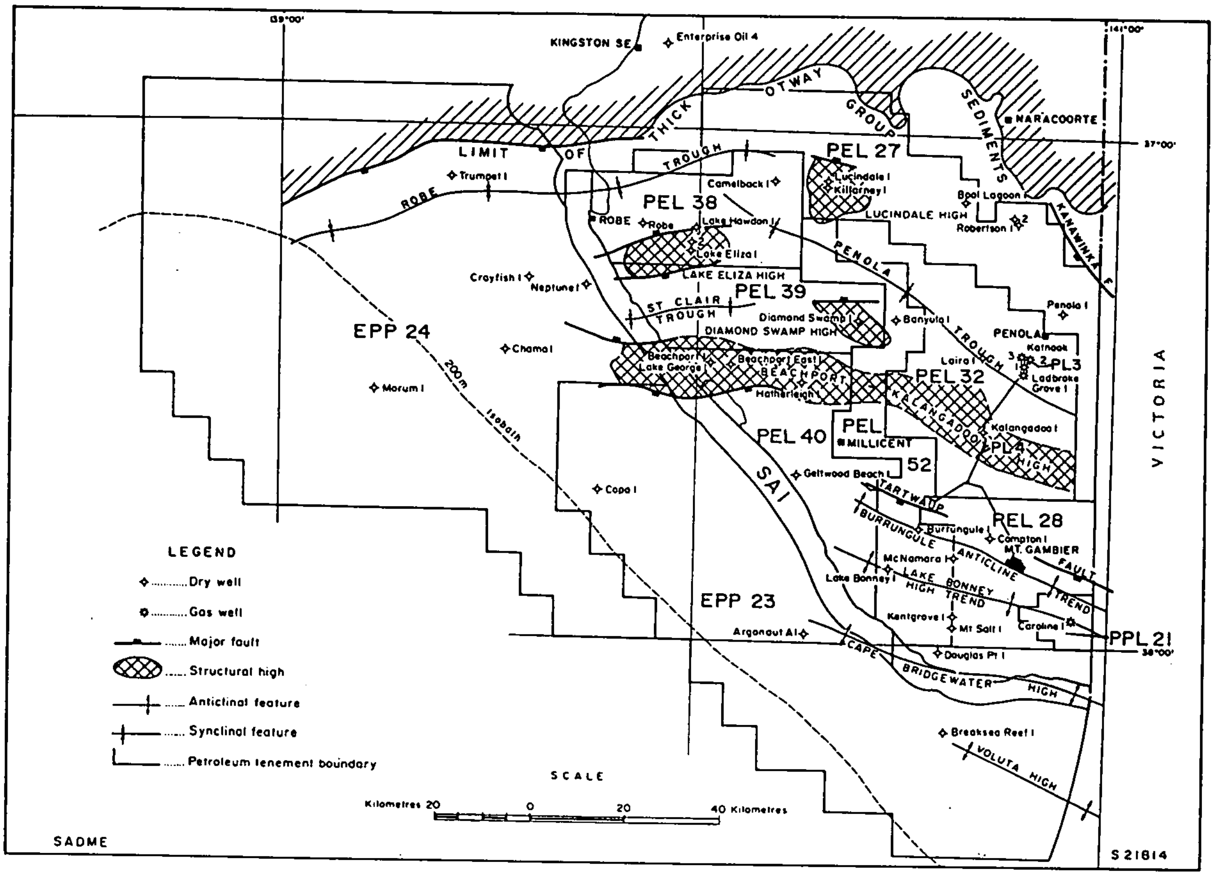

Fig 1: Structural Features and licence areas.

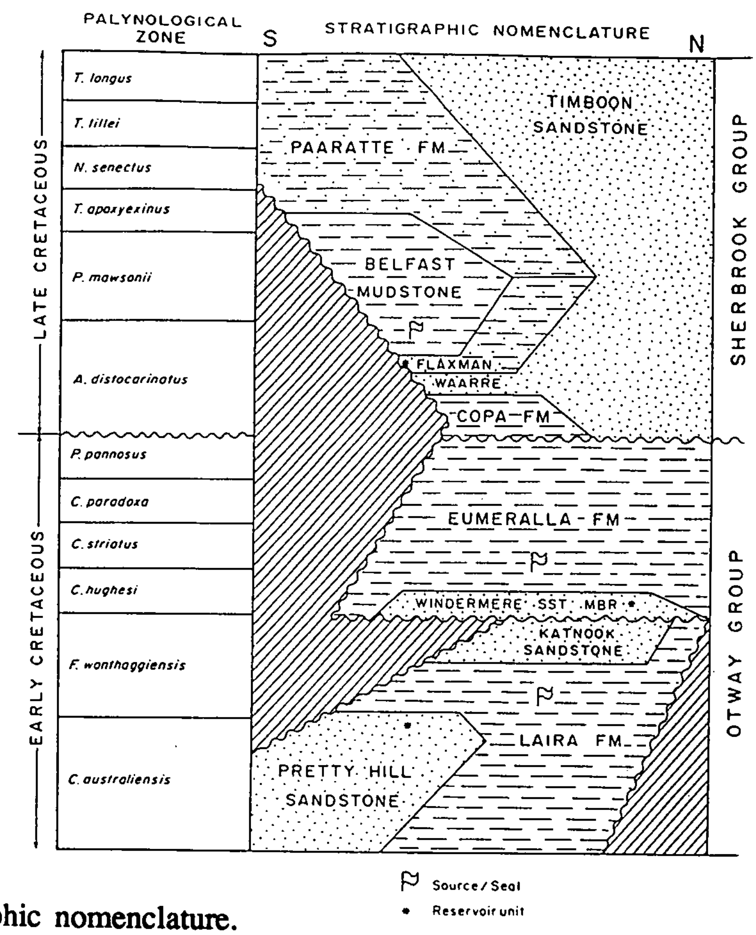

Fig. 2: Stratigraphic nomenclature.

Officer Basin petroleum potential

DI Gravestock
Petroleum Exploration Branch

Widespread oil shows at three stratigraphic levels attest to petroleum generation in Neoproterozoic (Adelaidean) and Early Cambrian sequences in the eastern Officer Basin, a region with notable similarity to the Lena - Tunguska oil and gas province of Siberia. Adelaidean strata are thickest in the Munyarai Trough and Birksgate sub-basin while Early Cambrian strata are thickest in the Wintinna Trough (Fig. 1). Adelaidean and Late Cambrian deformation (?Petermann Ranges,? Delamerian Orogenies, respectively) formed early structures capable of trapping hydrocarbons. These were enhanced, and new structures generated, during the Devonian-Carboniferous Alice Springs Orogeny.

Stratigraphic correlations (Fig. 2) are not yet secure beneath Murnaroo Formation. Basal ?Willouran clastics, carbonates and evaporites, the source of salt swells and structural décollement on seismic sections, could be remnants of a once widespread salt basin. Scattered ?Torrensian and Sturtian rocks crop out in areas beyond seismic control. Marinoan strata include Murnaroo Formation and Rodda beds, respectively the oldest known reservoir and source rocks in the basin. Shallow marine Murnaroo Formation sandstone is overlain by deeper marine shelf and slope rhythmites and basinal mudstones of the Rodda beds. Increased sediment loading led to salt withdrawal from the underlying evaporites, extensional faulting of Murnaroo Formation and growth of salt structures. Channel incision on the south flank of the deepening Munyarai Trough was followed by deposition of the upper Rodda beds. Palaeomagnetic and sequence stratigraphic studies (Flinders University) and acritarch biostratigraphy (University of Adelaide) offer promise for improved correlation with the Adelaide Geosyncline and Amadeus Basin.

Murnaroo Formation at depth (500-900m) has good reservoir character (av. porosity 15%, permeability 100-2300 md). Reservoir bitumen extracted from the sandstone is very mature, aromatic crude oil of algal/bacterial origin. Rodda beds vary from non-source to lean source rocks where sampled (av. TOC 0.16%, max. 1.47%) but oil stains and Rock Eval data suggest long-term oil generation. Sterane biomarkers are consistent with those from latest Proterozoic marine sediments elsewhere.

Early Cambrian sediments comprise five sequences in two sequence sets linked to cycles of sea-level change. Rodda beds are overlain unconformably by lowstand deposits of the first sequence Cl.1, namely aeolian-fluvial Relief Sandstone and halite-carbonate-siliciclastic salina complexes of the intertonguing and overlying Ouldburra Formation. These pass into transgressive marine deposits overlain abruptly by a carbonate breccia indicating widespread subaerial exposure. Temporary but complete withdrawal of the sea from the Wintinna/Tallaringa Troughs is suggested. Sequences Cl.2 and Cl.3 also comprise non-marine to strandline Relief Sandstone and intertonguing transgressive-regressive, cyclic Ouldburra Formation sediments.

Potential source rocks in carbonate-dominated transgressive and mixed carbonate-clastic highstand deposits are thin but widespread. Controlling factors are subsidence rate, the very low palaeoslope, arid climate and terrigenous sediment supply from the hinterland. Ouldburra Formation carbonates are mainly lean (av. TOC 0.36%, max. 0.96%) but contain oil-prone, bituminite-rich Type II kerogen. Calculated maturities of source rock extracts are greater than those of residual oils (VRcalc. 0.9% cf. 0.65%) suggesting the latter are early expulsion products. Relief Sandstone (up to 130 m thick) has excellent reservoir character in the Giles area (porosity to 26%, permeability to 4000 md) but not in the Marla area where the unit is more deeply buried. Intra-Ouldburra sands, though only 2-5m thick on average, are most frequent near sequence boundaries and are potentially good reservoirs (porosity to 27%, permeability to 600 md). Carbonates have variable reservoir character, highest in subaerial breccias and adjacent to sandstone interbeds.

A fourth sequence, C2.1 accumulated in the hinterland following regional regression and tectonic activity late in the Early Cambrian. Observatory Hill Formation alkaline playa lake and saline mudflat-sandflat facies are overlain conformably by fluvial Arcoeillinna Sandstone. Both units are widespread and intertongue with Wallatinna Formation alluvial fans in the northeast Wintinna Trough.

Bleeds of aromatic-naphthenic oil are numerous in the moderately organic-rich (TOC to 1.6%) Parakeelya Alkali Member, one of three carbonate-dominated playa lake deposits. High concentrations in the oil of isoprenoid alkanes indicate derivation from methanogenic/halophilic archaebacteria. The lacustrine source rocks contain oil-prone Type I kerogen, mainly lamalginite, and oil-source rock correlation confirms in situ generation. Reservoir potential exists in Moyles Chert Marker but is erratic (av. porosity 12%, permeability 0.01 - 400 md). Arcoeillinna Sandstone has superior reservoir character (av. porosity 22%, permeability 10 - 1200 md). Seal is provided by the Apamurra Member, which with Mt Johns Conglomerate, comprises the fifth sequence C2.2. Conglomerate represents localised alluvial fan deposits but Apamurra marks return to marine conditions which spread widely across the Gondwana supercontinent late in the Early Cambrian. Erosion has removed Arcoeillinna and Apamurra over part of the Wintinna Trough but both units extend across the Munyarai Trough and into the Birksgate sub-basin.

A third sequence set (Trainor Hill Sandstone, Wirrildar beds) may have exceeded 1 000 m in thickness, burying the prospective section towards oil - generative depth. However, erosion and mild folding before Kulyong Volcanics and the Ordovician Munda Sequence were deposited, complicate burial history of the region.

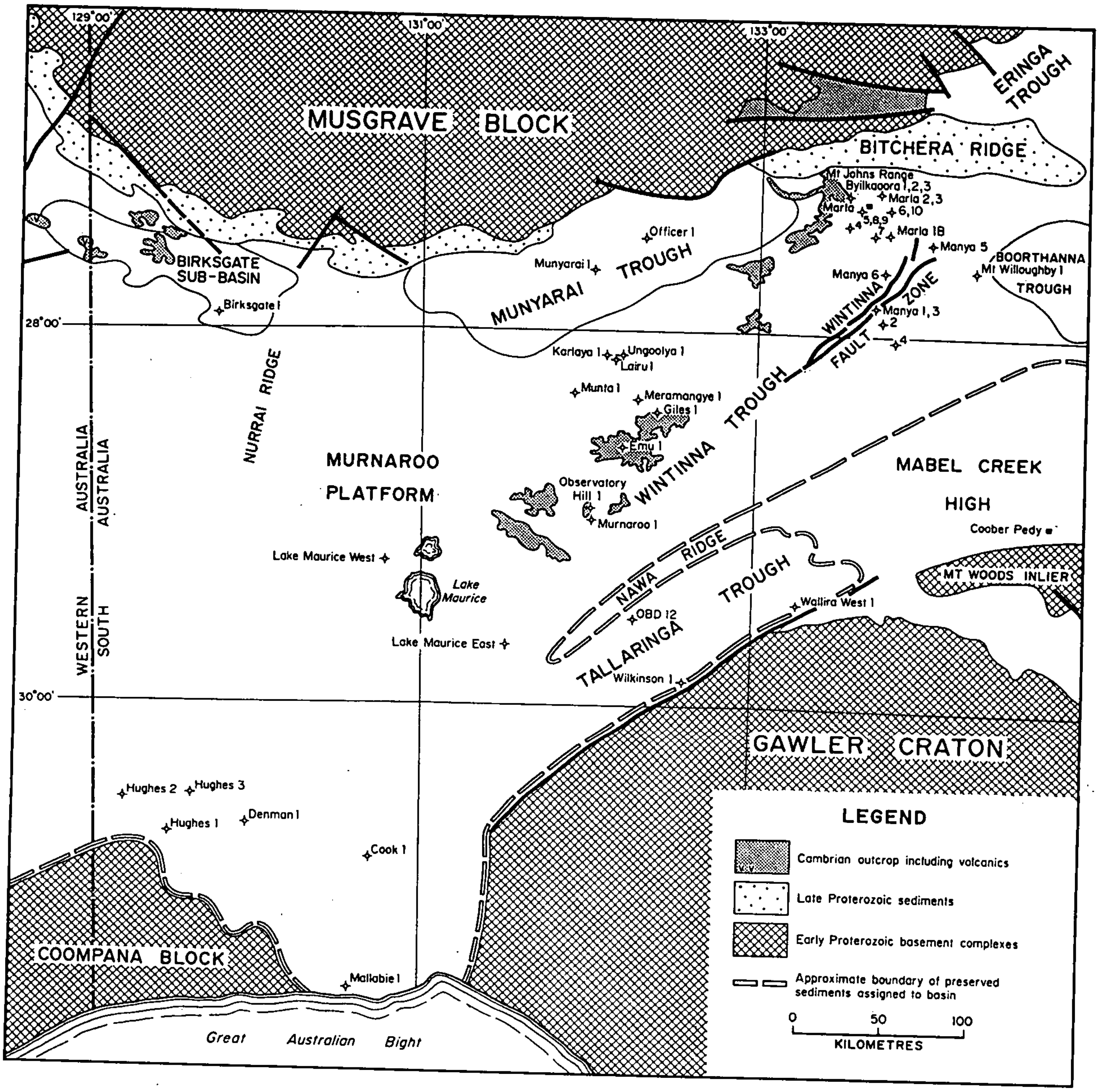

Figure 1. Eastern Officer Basin location map

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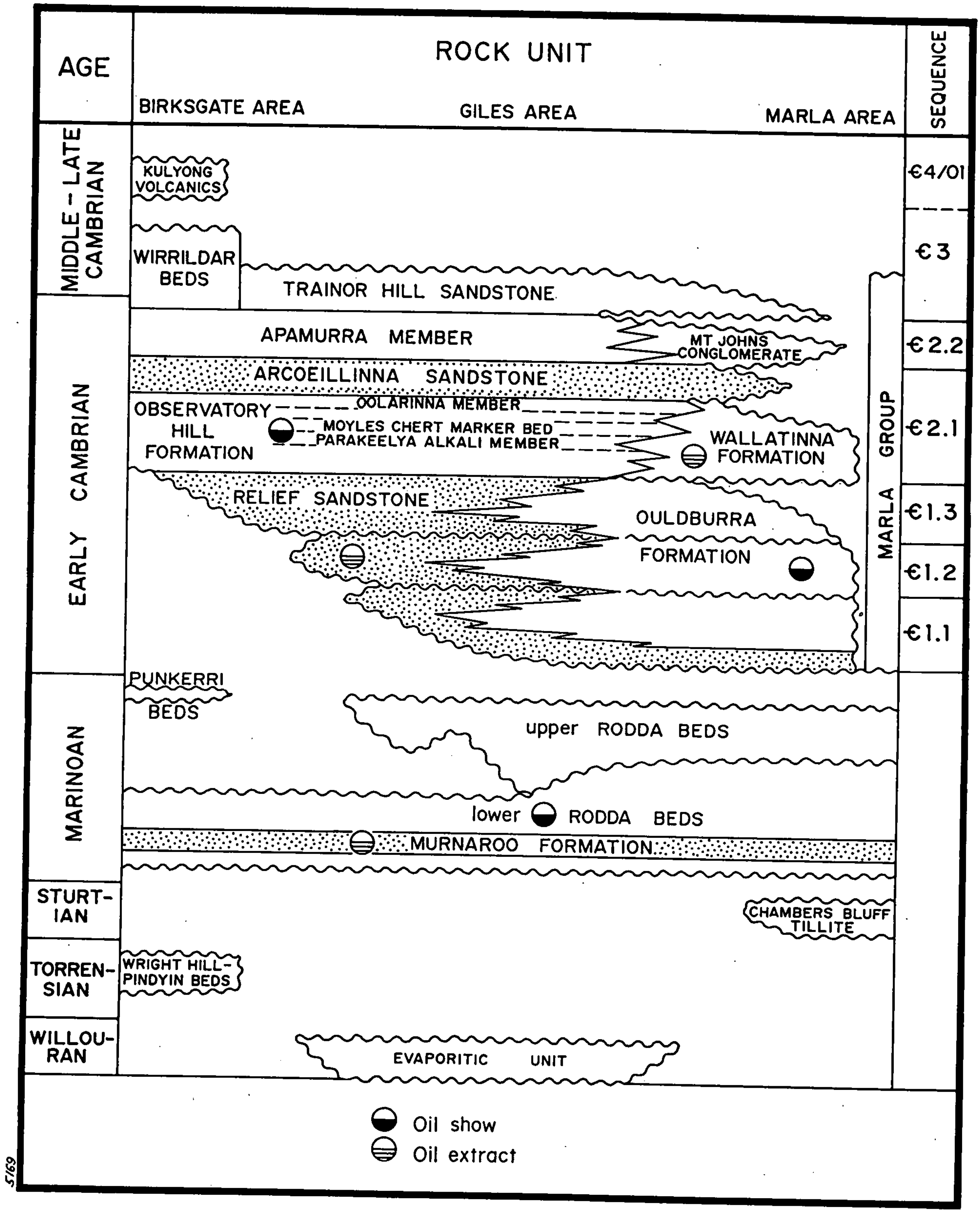

Figure 2. Eastern Officer Basin. Neoproterozoic and Early Palaeozoic stratigraphy

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Environmental Issues

M J Stone
Policy and Project Development

Five environmental issues of significance to South Australian mineral and hydrocarbon exploration will be discussed in this presentation. These are access to land; Aboriginal heritage; native vegetation clearance; environmental management; and the assessment of mining proposals. They are considered issues as they either are a subject of concern to the industry or the cause of administrative delay. Each issue is outlined and the initiatives undertaken by the Department to address each issue are defined.

The Department of Mines and Energy is mindful of the costs of environmental protection and in assisting Industry is seeking to achieve the elusive balance that makes for efficient and effective exploration and development as well as maintenance of environmental sustainability.

Access to land has been a major concern of the mining and petroleum industries throughout Australia over the past two decades. In the draft report of the Industry Commission on Mining and Minerals Processing in Australia, access to land was reported to be seen as the single most important issue facing the mining industry today. One initiative by the South Australian Government has been the 1986 Cabinet Policy on land access for mineral exploration which has led to the concepts of joint, multiple and sequential land use forming the basis for government land use decisions.

Another initiative has been the Regional Reserve park category under the National Parks and Wildlife Act. 9.3% of South Australia (see Table 1) comprises four Regional Reserves which are defined in the Act as areas "for the purpose of conserving any wildlife or the natural or historic features of that land while, at the same time, permitting the utilization of the natural resources of that land". Access provisions to parks and reserves have been carefully considered for each new park over the past decade or more and whilst an increase in park numbers and area has occurred, so to has the area of park available for access for exploration and development subject to strict environmental controls (see Tables 1 & 2).

Aboriginal land, including the Pitjantjatjara and Maralinga Lands accounts for some 18% of South Australia. Access to these lands whilst not totally denied is extremely difficult.

At this present time one company has reached agreement with the Maralinga people and is exploring on Maralinga Lands and another company is negotiating an agreement for access to Pitjantjatjara Lands. In relation to access to land the Department of Mines and Energy

- provides comments information about mineral and hydrocarbon potential for all new proposals for parks and reserves prior to their consideration by Cabinet.

Table 1

Parks and Reserves in South Australia (30/6/90)

Category	Area (ha)	Number	% of S.A.
National Park	3021190	12	3.07
Conservation Park	4453162	198	5.00
Regional Reserve	9148665	4	9.30
Game Reserve	22494	10	0.02
Recreation Park	5407	21	0.005

Table 2

Access to Parks and Reserves in South Australia for Exploration and Mining 1975 - 1990 (1/01/90)

Percentage of SA	1975	1982	1985	1988	1990
. AS PARKS & RESERVES	3.7	4.6	6.9	11.3	16.92
. SUBJECT TO JOINT PARK/MINING DEDICATION	0.7	0.8	3.0	7.4	12.36
. SUBJECT TO PARKS AND RESERVES WITHOUT ACCESS	3.0	3.8	3.9	3.9	4.56

- has drawn up jointly with the National Parks and Wildlife Service, administrative procedures to facilitate the assessment of applications to require exploration and mining rights and, secondly, to carry out exploration and mining programs on reserves.

- has held several meetings with Anangu Pitjantjatjara and Maralinga Tjarutja during the year with the aim of undertaking mapping programs on the lands as part of the National Mapping Accord and developing the understanding of these organizations of the activities associated with exploration and the benefits that could follow should there be a successful discovery.

In relation to the **Aboriginal Heritage Act, 1988** the Department has instigated a number of initiatives to assist companies and individuals in meeting their obligations under the Aboriginal Heritage Act. These have included;

- an advice note which has been sent to companies and individuals letting them know of the Act and its implications;

- an advisory service as to the appropriate Aboriginal people and communities to contact for particular areas of operation. The Department of Mines and Energy liaises with the Aboriginal Heritage Branch of the Department of Environment (DEP) and Planning to ensure that the appropriate information is provided; and

- the provision of advice to the industry regarding employment rates for Aboriginal advisers and the general format for agreements that can be entered into.

Native Vegetation clearance in the agricultural and pastoral regions of South Australia requires the consent of the Native Vegetation Authority.

Clearance incidental to exploration and mining is exempted from the provisions of the Native Vegetation Management Act under exemption (o), which states that vegetation may be cleared without application to the Native Vegetation Authority where clearance is incidental to exploratory or mining operations authorised under the Mining or Petroleum Acts.

This exemption does not give a *carte-blanche* for clearance. An integral part of exploration and mining program assessments is the investigation of alternatives to vegetation clearance, and subsequent avoidance or, where this is not possible, minimization and subsequent restoration of cleared areas.

The Department is currently jointly producing with the Native Vegetation Authority an information pamphlet for landholders, local Councils, operators and the general public which will address the rights and obligations of the explorers under the Native Vegetation Management Act.

Effective **environmental management** is the key to exploration and development activities under the Mining and Petroleum Acts which take into account the environmental protection legislation and policies in South Australia.

The Department provides an advisory service to companies regarding environmental management. Major initiatives include the provision of environmental management documents for seismic exploration and drilling in the South-East; a similar environmental management document for mineral exploration which is currently being jointly drawn up with the National Parks and Wildlife Service to cover, in the first instance, parks with joint proclamations and regional reserves in the west of the State; Tables of Contents which provide an idea of the scope and requirements of environmental assessment reports, and mineral exploration programme applications; and the provision of advice on effective restoration measures and procedures for mining leases.

The **assessment of mining proposals** is considered an issue because of the administrative delays that have occurred in processing applications when insufficient or inadequate information is provided to the Department. The lease application process will be briefly outlined in the presentation to clarify the issue.

To reduce administrative delays the Department initiated a series of meetings with DEP aimed at clarifying the roles of the two departments in the assessment process. As a result of these discussions, it has been agreed that DEP provide environmental information about the locality of the project. In order that DEP can provide pertinant environmental information, they need to have a clear understanding of the overall proposal.

To achieve this goal it is important that the proponent, when making his application, provide detailed information (including enlarged air photos and plans) on the area to be affected by the proposal and a conceptual diagram of the proposal from start to completion.

Exploration on the Maralinga Tjarutja Lands: Maralinga Tjarutja policy

A Barton
A.M. Administrator - Maralinga Tjarutja

On the 6th December 1984 the South Australian Government proclaimed the Maralinga Tjarutja Land Rights Act, 1984 and a week later Premier John Bannon handed freehold title of some 76,420 square kilometres of land to its traditional owners.

The negotiations leading to that act were largely conducted around the terms and conditions that would attach to any future mining activity on the lands. The mining provisions were based upon those contained in the Pitjantjatjara Land Rights Act with some modification.

At that time three mining companies held Exploration Licences which were deemed by the Act to have permission from the traditional owners to continue.

Comalco held Petroleum Exploration Licences over part of the Officer Basin in the Emu area in the northeast corner of the Maralinga lands. Maralinga Tjarutja and Comalco entered into site protection agreements and developed a positive and healthy working relationship and commenced negotiations into extending the land under licence and the possibility of joint venture activity. Due to an assessment of oil industry economics at the time (1988) Comalco did not pursue their licence, and in November 1988 their Exploration Manager in notifying Maralinga Tjarutja of that, thanked Maralinga Tjarutja for its 'long and willing co-operation'.

CRA Exploration Pty Ltd held a Licence area on the eastern boundary of the Maralinga lands which it surrendered in 1987 and in so surrendering expressed its thanks to Maralinga Tjarutja for the 'co-operation and help given'.

Maralinga Tjarutja had a similar successful relationship with Stockdale operating in the southeast corner of the Maralinga lands. The above three pre-existing licences have now all expired.

The first application for an Exploration Licence under the Act was by BHP who patiently and carefully negotiated access to the Ooldea Range and commenced an Exploration program in 1990. The company and community agreed on a method of site protection and compliance with the Act and even reached agreement which led to Maralinga Tjarutja performing some contract roadworks for the company.

Whilst the Act is titled 'Land Rights Act' from the point of view of the traditional owners what they do in relation to the land is discharge their responsibilities to the land. They are under social and cultural direction to ensure that the land is protected and that sites of significance are avoided. To discharge that responsibility they have to be fully informed of the works proposed and the impact of those works on the land. They have to have time, a lot of time, to ensure that they have spoken to all people with responsibilities for the land under consideration.

It is to the credit of the previous mining companies and BHP that they have accepted that, and have allowed the traditional owners to make long term decisions about the land in a responsible and unpressured manner.

Maralinga Tjarutja works closely with the Pitjantjatjara Council in relation to areas of common interest.

The traditional owners of the Maralinga lands are proud of the work they have done with mining companies and I am confident in saying that they will continue to work to balance their own sense of responsibility towards the land and the interests of those who seek to explore and mine it.

It is in the interests of potential explorers on the lands to be prepared to sit down and work patiently and carefully with the traditional owners and their advisers to ensure that reasonable balance is struck.

Our office door is always open to those of you who are prepared to meet and visit the community to discuss these things.

An address to SA-Exploration Towards 2000, Australian Mineral Foundation, 13th December 1990.

Petroleum exploration on the Pitjantjatjara Lands: Anangu Pitjantjatjara's policy

R Bradshaw
Johnston Withers, Adelaide
(former Principal Legal Officer with Pitjantjatjara Council)

On 1 November 1985, a Petroleum Exploration Licence (PEL 29) was granted to Amoco Australian Petroleum Company, Crusader Resources NL, Quadrant Petroleum NL and AP Oil Pty Ltd over part of the Pitjantjatjara freehold lands in South Australia. Under the terms of the joint venture agreement AP Oil Pty Ltd, a subsidiary of the landowning body, Anangu Pitjantjatjara (commonly referred to as "AP"), had a 20% carried interest through exploration. Unfortunately, the licence was relinquished in early 1988 after relatively little new on-the-ground work had been carried out: the cutting of the road to the proposed exploration well location at Munyarai, a geophysical survey and the "shooting" of some 400 kilometres of seismic.

There were two major reasons for the relinquishment:

(1) Amoco's "Munyarai play concept", following the reanalysis of the old seismic and Munyarai 1 data and the assessment of the new geophysical and seismic data, was no longer sustainable; and

(2) The general downturn in the industry.

AP and the traditional owners were disappointed, not least because the relationship with AP Oil's joint venture partners had been especially good.

Some of the major features of the agreements with AP and AP Oil Pty Ltd, described at the time as being "historic", were as follows:

- permission to enter the PEL 29 area to explore for and, if successful, produce hydrocarbons;
- work area clearance procedures, whereby all work areas proposed by the Operator were to be "cleared" on behalf of traditional owners by groups of senior men and women (2 groups of up to 4 in each group) in order to ensure the avoidance of any interference with sites of religious or cultural significance;
- procedures to minimize adverse environmental or social impact;
- cross-cultural orientation workshops;
- reimbursement of AP's and AP Oil's reasonable expenses incurred in connection with the exploration programme;
- AP Oil's 20% carried interest through exploration, on the basis of an election on application for a Production Licence, to take up a 20% working interest (subject to a 2 for 1 pay-back of its share of exploration costs out of production) or a 10% net profit interest;

- waiver by AP by rights to compensation for disturbance during exploration (under Section 24 Pitjantjatjara Land Rights Act 1981-87);

- AP Oil's representation (with voting rights) on the operating committee during exploration.

The Minister for Mines and Energy is about to advertise areas available for application for Petroleum Exploration Licences over parts of the Officer Basin. These include the former PEL 29 area within the Pitjantjatjara Lands. It is understood that the deadline for applications is likely to be around 30 April 1991.

As yet, AP has not fully considered its position. In particular, it has not decided whether to apply for a PEL itself as it did in September 1984. AP certainly does not wish the impression to be given to prospective applicants that permission to enter and explore will necessarily be granted. All the relevant factors provided for in the Pitjantjatjara Land Rights Act will be considered in determining whether such permission is to be granted and, if so, to whom and on what terms.

However, AP's policy regarding petroleum exploration remains unchanged since 1984-85. In general terms, petroleum exploration appears to be more readily accommodated within religious and cultural constraints than mineral exploration. This was particularly true of the PEL 29 area. Greater problems may perhaps arise in relation to those parts of the proposed application areas which lie to the west or north of PEL 29.

AP would welcome discussions with potential applicants in relation to similar arrangements to those negotiated in 1985.

Mineral sands, precious metals and diamond potential

A W Newton
Mineral Resources Branch

Coastal strandlines of Tertiary age in the Eucla and Murray Basins are high priority targets for concentrations of **heavy minerals.**

In the Murray Basin about 50 beach ridges are preserved over a distance of 100 to 300 km from the coast; some are up to 100 km long.

Late Pliocene Parilla Sand, host to the massive Wimmera and Massidon mineral sand resources in Victoria and N.S.W. respectively, is present throughout the South Australia portion of the Murray Basin. With recorded thicknesses in excess of 30 m the Parilla Sand is a prime exploration target in which a number of significant occurrences have been identified (e.g. 13 m at 1.6% heavy minerals comprising 55% ilmenite, 12% zircon, 7% rutile/anatase and 7.5% leucoxene). Underlying Early Pliocene Loxton Sands with thicknesses up to 60 m also warrant attention as a heavy mineral sand target.

Three stranded coastal dunes have been recognised on the northern and eastern margins of the Eucla Platform, adjacent to the Nullarbor Plain. The Ooldea Range, the largest of these features has a length of about 650 km. In each of the Ooldea, Barton and Paling ranges, marine and fluvial Late Eocene (possibly Early Oligocene) Hampton Sandstone is overlain by aeolian Ooldea Sand. The upper portion of Hampton Sandstone together with the basal section of Ooldea Sand constitute a prime environment for concentration of heavy minerals. Limited exploration to date has defined significant occurrences of zircon dominated assemblages. Recent work by SADME indicates the eastern margin of the Eucla Platform may extend through Eyre Peninsula to Port Lincoln significantly increasing the area of heavy mineral sand potential.

Historic **gold** production in South Australia has come mainly from quartz veins and alluvial deposits in the Mount Lofty Ranges, the Tarcoola-Glenloth area, and the Nackara Arc which extends from Burra to Olary. Significant gold has also been produced as a by-product of copper mining in the Moonta-Wallaroo region and at the Kanmantoo mine. The vein deposits in general are hosted by Proterozoic sediments and intrusive rocks.

The discovery of the massive Olympic Dam deposit has effectively put South Australia on the 'gold' map. With a total estimated gold resource of 1200t Olympic Dam rivals the Golden Mile at Kalgoorlie. Mineralisation is distributed irregularly throughout a major hydrothermal breccia pipe/dyke complex within Middle Proterozoic granite.

Similar age granites and volcanics (1580-1592 Ma) with elevated metal values, and often associated with major lineaments have been defined in a number of regions and may represent broad target zones for the development of hydrothermal and epithermal gold mineralisation. Prospective zones cover Hiltaba Suite type granites within the Gawler Craton including the Cultana Inlier and Karkaro granite near the southeast and northwest boundaries of the craton respectively, U-Ti-Th rich granites in the Crockers Well region and granites within the Curnamona Craton.

Other suggested gold exploration models include:

- Epithermal gold in the Middle Proterozoic Gawler Range Volcanics.
- Vein/stockwork mineralisation in the Tarcoola-Glenloth region with emphasis on developing a number of small deposits with a central processing plant.
- Epithermal and hydrothermal feeder/vent related mineralisation in early Palaeozoic volcanics underlying the Murray Basin.
- Telfer-style and lineament related mineralisation within Adelaidean sediments in the Nackara Arc region.
- Gold-copper associations within the Gawler Craton, Willyama Inliers and Kanmantoo Trough.
- BIF related mineralisation within Archean and Proterozoic sediments of the Gawler Craton, Willyama Inliers and the Adelaide Geosyncline.
- Vein and stockwork mineralisation on the margins of Delamerian granites on the southeast limits of the Adelaide Geosyncline.

Areas of **platinum group metal** (PGM) potential in South Australia are as follows:

- Associated with layered intrusives; Giles Complex in the Musgrave Block; Western Gawler Craton; Black Hill norite.
- Associated with carbonaceous and often metal-rich sediments; Hutchison Group graphite schists of the Gawler Craton; graphite schists in the Willyama Inliers; basal Tapley Hill Formation of the Adelaide Geosyncline and Stuart Shelf.

Diamond was discovered in the Echunga region of the Adelaide Hills in 1859, seven years before South African discoveries. Over 50 saleable diamonds have been found on this alluvial field, with one found as recently as 1987, but no kimberlitic source has yet been defined. The only other recorded occurrence of a large diamond is at Algebuckina in the Far North in 1894.

Microdiamonds have been recovered over much of the state with principal concentrations recorded at the Euralia-Carrieton dyke swarm (140) and in Triassic (?Permian) basal conglomerate of the Springfield Basin (>100). About 30 microdiamonds have been recovered from kimberlitic occurrences at Pine Creek east of Terowie and some minor/single occurrences are recorded from kimberlitic rocks near Port Augusta, from the Cretaceous Algebuckina Sandstone at Edward Creek and from other locations in the Gawler Ranges and Flinders Ranges.

Kimberlitic rocks are recorded from six distinct regions in the State with a number of these intrusives having a Jurassic age. Areas include Terowie-Whyte Yarcowie (sub-crop of dykes and pipes of micaceous kimberlite), Euralia-Carrieton (altered phlogopite-bearing kimberlite dykes), Port Augusta (micaceous kimberlite sills), Mulgathing (basic to ultrabasic mica-peridotite plugs and sills with kimberlitic affinities) and the more recently defined kimberlite discovered by Stockdale Prospecting Limited at Mount Desperate near Cleve (pipe and dyke complex, elongated N-S, comprising altered monticellite kimberlite with a weighted mean age of 183 Ma).

A new lamprophyre province has been identified by SADME between Truro and Frankton near the western margin of the Murray Basin, lamprophyre dykes have been identified at 15 localities and a 100 x 50 m ovoid diatreme, of possible alkali lamproite has been located 2.8 km north of Truro.

Apart from the areas being actively explored such as Eyre Peninsula and the Springfield Basin regions with diamond potential include:

- Truro-Frankton lamprophyre province particularly as a possible source of Echunga diamonds.

- Major deep crustal fracture systems associated with the Polda and Mulgathing troughs and possibly within the Musgrave Block.

- Northeast-trending, intracratonic fracture zones running across northern Eyre Peninsula and Bulgunnia respectively.

- Southeast margin of the Mount Painter Inlier.

- Intrusive activity associated with Jurassic basalts at Kingscote on Kangaroo Island at a flexure on the southeast margin of the Gawler Craton.

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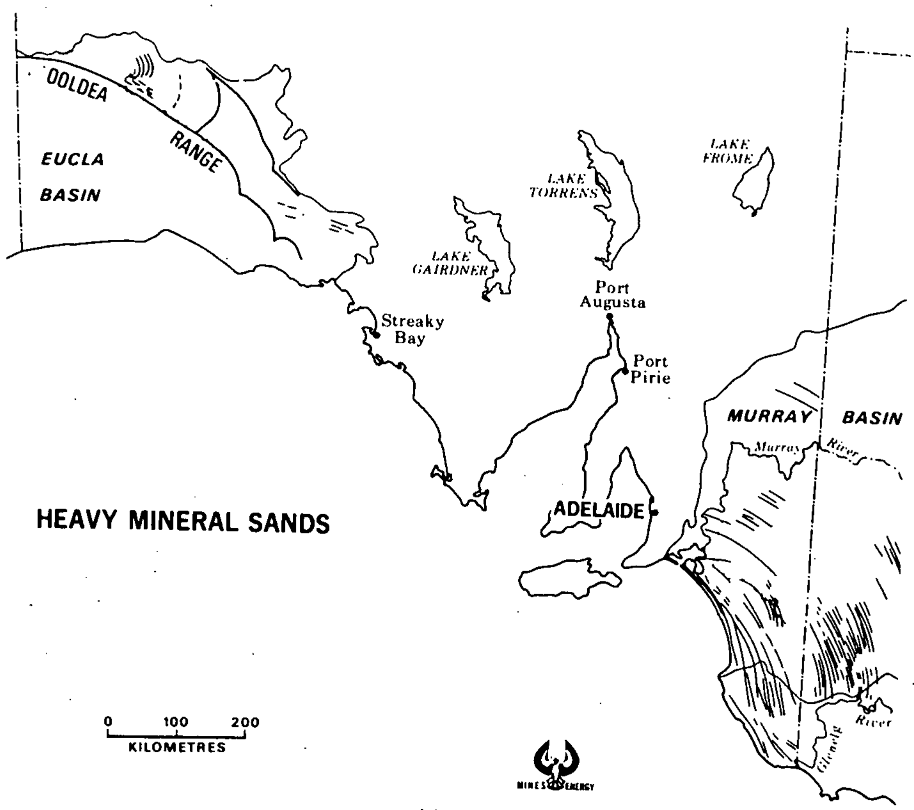
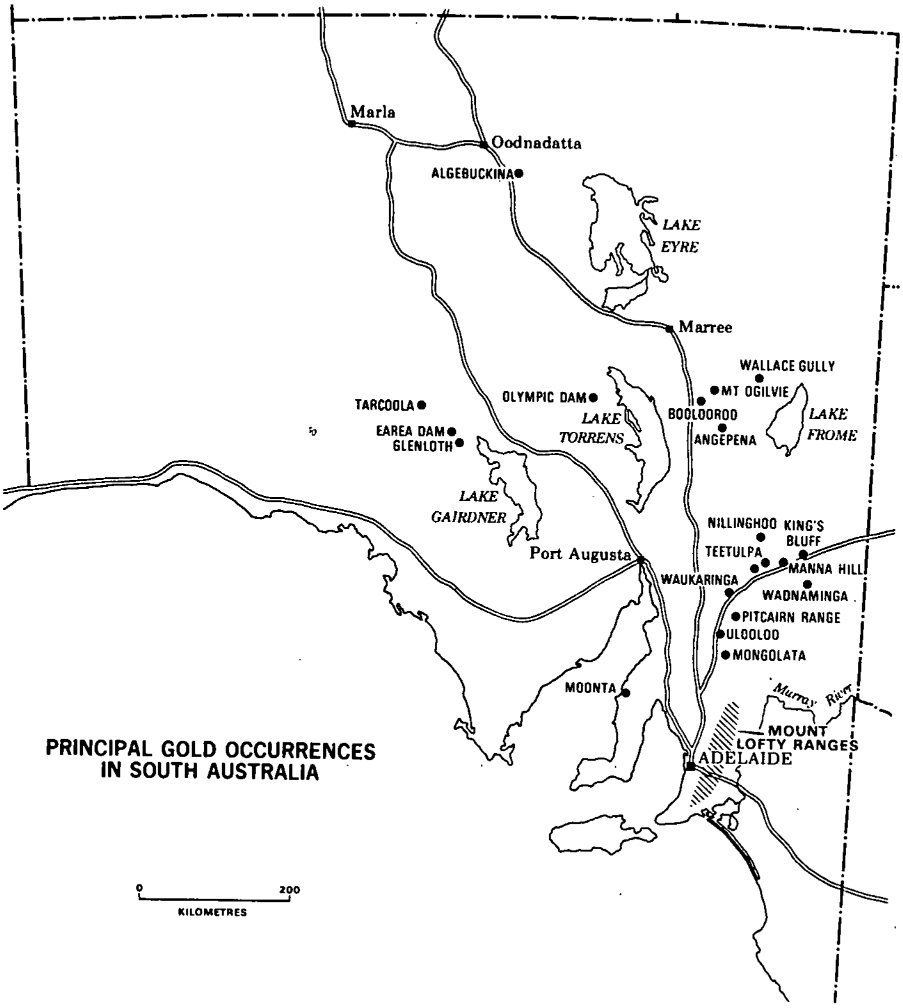
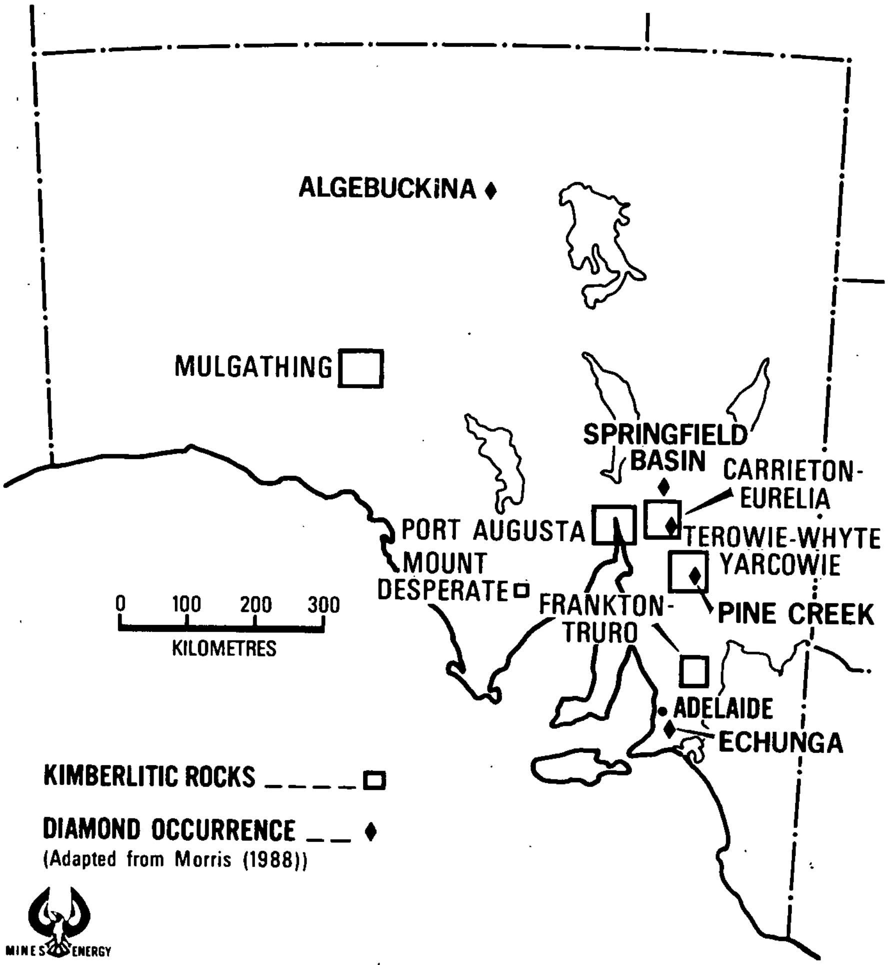




PRINCIPAL GOLD OCCURRENCES IN SOUTH AUSTRALIA



(Adapted from Morris (1988))

The lead-zinc initiative

R G Nelson (after C M Horn and B J Morris, 1988 and 1990)
Director, Mineral Development Division

"The mining industry has been one of the principal factors in the salvation and development of the colony, and there are solid reasons for the hope that much of our future prosperity will result from the same cause".

(from 'The Birth of South Australian Mining' in The South Australian Register of 19th November, 1894).

1. Historical Perspective

South Australia has abundant lead-zinc mineralisation, the known occurrences of which are scattered throughout four major geological provinces notably where there is some degree of outcrop (Figure 1). These are:

- the **Willyama Inliers**
- the **Adelaide Geosyncline**
- the **Gawler Craton**
- the **Kanmantoo Trough.**

If these provinces are taken as geographic units, then cumulative production from their combined area to date is very great, for it must logically include that from the Broken Hill district, which by its centenary year of 1983 had yielded 150 million tonnes of 15 to 28% lead-zinc-silver ore worth $A29 billion (Anon., 1983).

Strict imposition of state boundaries, however, leads to much smaller production figures. Although 100 lead-zinc occurrences have been mined or worked within the state, it has been estimated (Drexel, 1982) that only 16,000 tonnes of lead have been produced. This is not a bitter heritage, though. It is an indication of South Australia's richly metalliferous estate, and of the rewards that still remain to be won.

Australia's first metal mines were the lead-silver mines of Glen Osmond in the foothills near Adelaide. Ore from the first mine, the Wheal Gawler, was Australia's first metallic mineral export in 1841. From a struggling venture on the brink of failure, the colony of South Australia was transformed by these discoveries to a burgeoning enterprise, with a skilled population of miners who were later to spread throughout the colony and then Australia. The Glen Osmond mines in South Australia can quite rightly be regarded as the crucible of the Australian mining industry.

If the Glen Osmond mines were the salvation of the young colony, Burra, Kapunda and Moonta-Wallaroo were to follow, generally at critical economic times in its development. However, a further step towards development maturity followed the discovery of the massive lead-zinc-silver ore deposit at Broken Hill in 1883. Port Pirie on the eastern shore of Spencer Gulf was established as the seaport for Broken Hill; railway corridors were set up and in 1889 smelters were built at the port.

2. The Lead-Zinc Initiative

The Port Pirie smelter, now operated by the Broken Hill Associated Smelters (BHAS), is the world's largest combined lead smelting and refining facility. It depends primarily on concentrates from Broken Hill, which is presently thought to have a mine life of only 20 years on current ore reserves.

BHAS currently employs 1400 people, about 9% of Port Pirie's population, and is the town's major employer. At least 25% of the population is totally dependent on continuing operations at the smelter.

South Australia, through Port Pirie and other facilities, therefore offers desirable assets for base metal mining ventures:

- a skilled labour force
- complete infrastructure
- good transport and coastal communications
- a potential shortfall in supply of feedstock for smelting and refining.

These features make lead-zinc mineralisation a particularly attractive exploration target in the State. Assuming an ore grade of 8% lead, 2.5 million tonnes of ore per annum would need to be mined to provide the required 400,000 tonnes of high grade (50% lead) concentrate feed. Thus, an orebody of 50 million tonnes would be required for a mine life of 20 years. Smaller targets would require a proportionally higher ore grade.

To stimulate activity, a team of geologists and geophysicists from SADME began in 1987 to review existing information. It released reports in 1988 summarising details of 266 lead-zinc occurrences, and identifying four areas considered to have immediate prospectivity:

- **Willyama Inliers** and **Curnamona Cratonic Nucleus**
- **Gawler Craton** (Eyre Peninsula)
- **Kanmantoo Trough and Kangaroo Island**
- **Adelaide Geosyncline** and the **Stuart/Spencer Shelf.**

Other areas considered worthy of additional exploration include:

- Curdimurka Subgroup rocks in the Peake and Denison Ranges
- Boucaut Volcanics at Mutooroo Ridge
- Prospect Hill at the northern edge of the Mount Babbage Inlier
- the northeastern part of the Mount Painter Inlier.

During 1988, a regional airborne geophysical survey of the west-central portion of the Archaean-Proterozoic terrain of Eyre Peninsula was undertaken by SADME with the cooperation of the Bureau of Mineral Resources and several companies. Results from this have been extensively interpreted.

Additional geological, geophysical and drilling programmes were undertaken in 1989-90 to confirm and enhance the prospectivity of the four main areas. Details of this work are given in the papers which follow. The full suite of information is available as a set of data packages for purchase. In addition, areas of land in favourable locations are available for application as Exploration Licences.

3. A Note on Geological Environments

Base metal deposits are localised due to a combination of the following factors:

- an abundant supply of sulphur
- a source of metalliferous fluids
- a fluid transport mechanism
- a metal concentrating mechanism.

Types of lead-zinc sulphide deposits which may exist within South Australia include:

- Mississippi Valley Type (MVT) deposits
- Sediment-hosted/exhalative massive sulphide deposits, including
  - Broken Hill style
  - Mount Isa style
  - McArthur River style.

Mississippi Valley Type deposits

Mississippi Valley Type lead-zinc mineralisation has been located within Lower Cambrian strata of the northern Flinders Ranges and on Fleurieu Peninsula. At Curramulka on the **Spencer Shelf** and at Bute in the Mount Lofty Ranges, Cambrian rocks contain lead-zinc in a similar environment to that in the Flinders Ranges.

MVT ore deposits are the main source of lead-zinc in North America, where individual orebodies range from several hundred thousand to 20 million tonnes, often occurring in groups of prospects covering several hundreds of square kilometres.

Sediment-hosted Exhalative Lead-Zinc Deposits

Sedimentary-exhalative, shale-hosted, massive sulphide deposits are distinguished from MVT deposits by their location in tectonically active areas and higher initial fluid temperatures. Their size and grade are generally larger and higher respectively than MVT deposits.

Basement rocks of the Early Proterozoic **Willyama Inliers** in the Olary area are highly prospective for Broken Hill style deposits. Mineralisation within the crystalline basement is confined to specific units such as the calc-silicate of the Ethiudna Group which exhibits similarities with altered calcareous units at Broken Hill.

Rocks of the **Gawler Craton** have considerable potential. Significant stratiform base-metal sulphides were discovered recently at Menninnie Dam in carbonate-rich pelitic and psammitic sediments hidden beneath surface cover. Early Proterozoic Hutchison Group metasediments are considered a favourable host for Broken Hill style deposits.

Stratiform base-metal mineralisation similar to Mount Isa and McArthur River is a potential target in Early to Middle Proterozoic metasediments and volcanics in the Benagerie Ridge of the **Curnamona Cratonic Nucleus.**

The **Kanmantoo Trough/Kangaroo Island** province is considered to have high base metal potential, as it contains sources of sulphur and metals, favourable structural elements to control deposition, and indicated zones of heat flow which would have provided a driving mechanism. Lead-zinc-silver mineralisation occurs widely, principally confined to the Talisker Calc-silicate and the Carrickalinga Head Formation. For example, at Mount Torrens, a sub-economic deposit of 700,000 tonnes of 6.4% lead, 1.6% zinc and 41 g/t silver has been identified.

Widespread stratiform lead-zinc mineralisation occurs in the Tapley Hill Formation of the **Adelaide Geosyncline** and the partly equivalent Woocalla Dolomite on the **Stuart Shelf** (Robertson, 1988). Elsewhere within the **Adelaide Geosyncline**, Bunyeroo Formation shale hosts stratiform deposits at Puttapa and Patawarta. Evaluation of geochemical anomalies in Bunyeroo, Balcanoona and Wilyerpa Formations, and Skillogalee Dolomite, Wortupa Quartzite and Curdimurka Subgroup is recommended. Prospects adjacent to the McDonald Shear Zone east of Olary warrant further study.

Preiss (1987) has compiled an up-to-date synthesis of the Late Proterozoic Stratigraphy, Sedimentation, Palaeontology and Tectonics of the **Adelaide Geosyncline** which is extremely useful for the explorer in developing ore genesis models in this still underexplored province.

4. Summary

Lead-zinc mineralisation is widespread throughout South Australia, and the possibility of utilising smelting, refining and shipping facilities at Port Pirie makes base metal exploration within the State an attractive proposition. Localities where exploration should be directed have been outlined in the **Willyama Inliers, Gawler Craton, Kanmantoo Trough** and **Adelaide Geosyncline**. Most areas are within easy reach of transport corridors, power supplies and coastal facilities. A skilled workforce is present.

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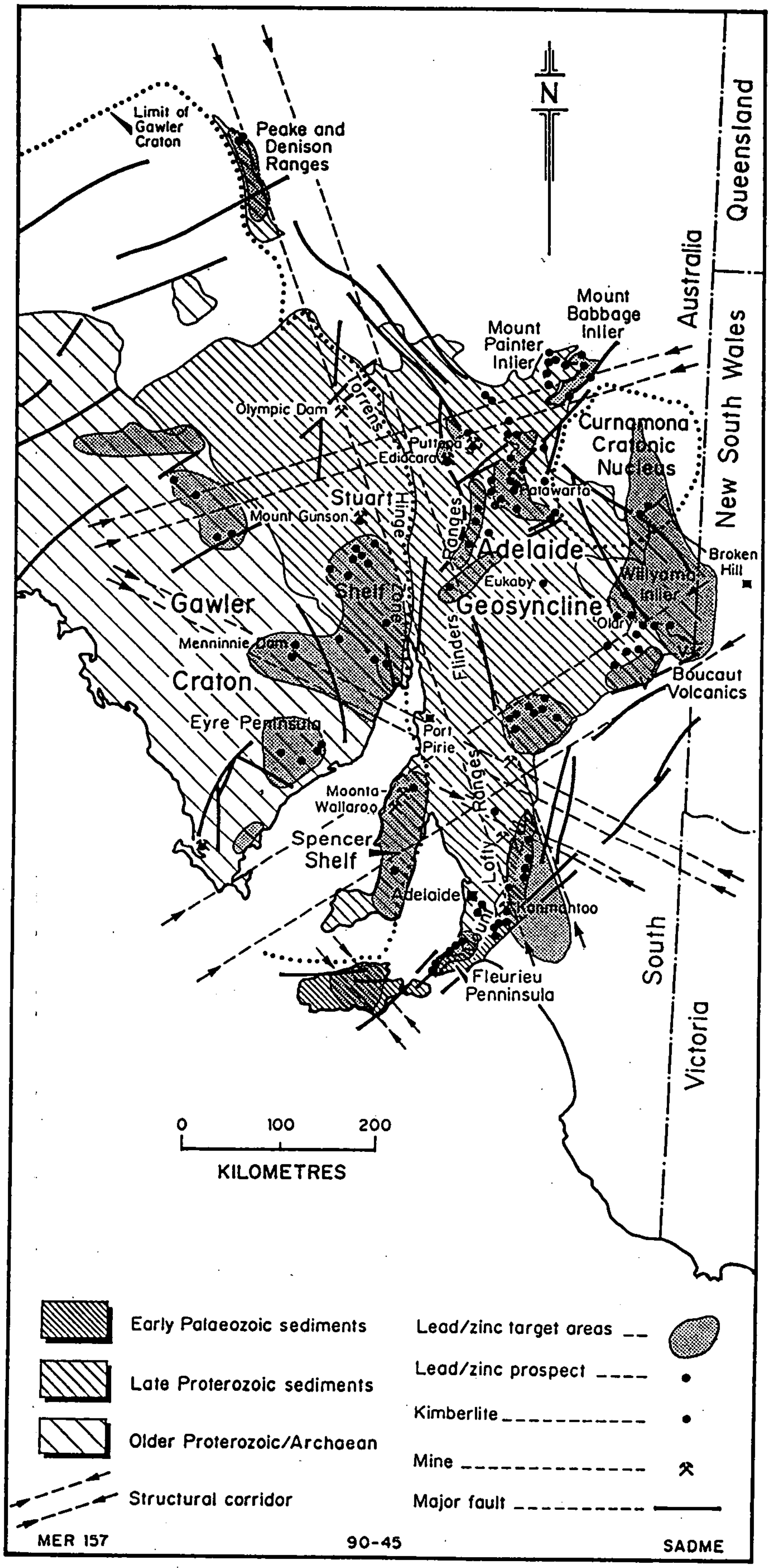
Limit of Gawler Craton
Peake and Denison Ranges
N
Queensland
Australia
New South Wales
Mount Babbage Inlier
Mount Painter Inlier
Olympic Dam
Torrens
Puttapa
Ediacara
Curnamona Cratonic Nucleus
Stuart
Hinge
Mount Gunson
Ranges
Adelaide
Patawarta
Broken Hill
Willyama Inlier
Eukaby
Gawler
Shelf
Geosyncline
Olary
Menninnie Dam
Craton
Flinders
Boucaut Volcanics
Eyre Peninsula
Port Pirie
Moonta-Wallaroo
Lofty Ranges
Spencer Shelf
Adelaide
Kanmantoo
South
Fleurieu Penninsula
Victoria
0 100 200
KILOMETRES
Early Palaeozoic sediments
Late Proterozoic sediments
Older Proterozoic/Archaean
Structural corridor
Lead/zinc target areas
Lead/zinc prospect
Kimberlite
Mine
Major fault
MER 157
90-45
SADME

Eyre Peninsula base metal potential

A J Parker
Geological Survey

Eyre Peninsula has considerable potential for base metals, particularly lead-zinc-silver, despite over two decades of modern exploration. There are numerous small copper-lead-zinc-silver mines and diggings throughout the eastern uplands, published drillcore assays at Menninnie Dam are exciting, surficial cover is generally very thin in areas of greatest potential, yet serious drilling has been very restricted. The 1988 Eyre Peninsula aeromagnetic survey has revealed new exploration targets and is providing a better understanding of the concealed structure and architecture of the Peninsula. It is not so much a question of what might be discovered but by whom, when and how big. What is the evidence?

Previous Mining

Johns (1961) provides a comprehensive summary of previous mining operations in both the Lincoln and Cleve Uplands. Discoveries leading to this mining followed closely the discovery of copper in the Moonta-Wallaroo district on Yorke Peninsula and led to numerous small or shallow workings (1870-1920) exploiting oxidised copper and lead-silver ores. There is little mention of zinc recovery from early operations reflecting the lack of interest in zinc at the turn of the century rather than the lack of zinc itself. This is demonstrated by recent assays from the Miltalie Mine where there is substantial zinc in ore samples from underground workings (Table 1) yet no recorded production.

Table 1: Selected ore assays from Miltalie Mine, NW of Cowell

Sample No.	Au(ppm)	Cu(%)	Pb(%)	Zn(%)	Ag(ppm)
6230 RS 634	0.36	15.5	5.1	3.95	118.5
6230 RS 635	0.018	1.79	31.4	1.91	27.5
6230 RS 640	0.007	3.66	61.5	1.9	56.5
6230 RS 641	0.005	4.24	9.3	10.75	57.5

Recent exploration has failed to capitalize on the opportunities in and around these old mines and prospects. In the Cowell-Cleve region there has been little or no drilling, only cursory ground geophysical surveys, and documented rock-chip, soil and stream-sediment geochemical sampling is sparse.

It is clear from only a brief examination of geological maps of the region (eg. Parker, 1983a and b) that the majority of mines are located on or immediately adjacent to serpentine marble and/or calc-silicate gneiss units. These form part of the Palaeoproterozoic (ca 1900-1840 Ma) Hutchison Group metasedimentary sequence and occur either at the base of that sequence (at the base of the Warrow Quartzite) or within Katunga Dolomite equivalents at the base of the Middleback Subgroup (Fig. 1). Massive dolomitic marble is generally barren of mineralization but serpentine-rich marble interbedded with diopside-rich calc-silicate quartzites and gneisses is often mineralized. Pyrite and pyrrhotite are ubiquitous and chalcopyrite, sphalerite and galena are common varying up to ore grades.

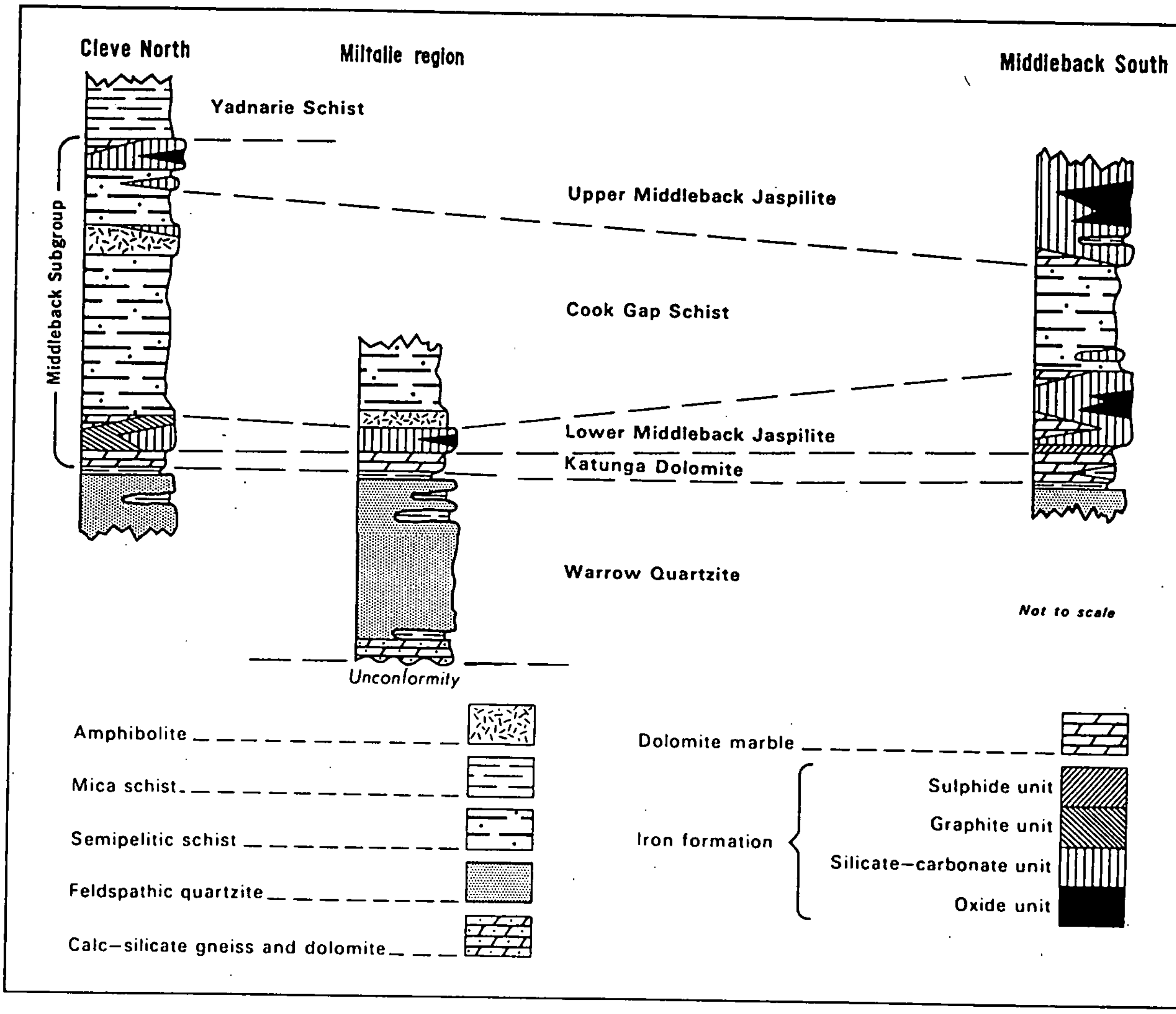

Fig. 1 Stratigraphic correlation of the Hutchison Group (after Parker & Lemon, 1982).

At Miltalie Mine, calcareous metasediments contain significant amounts of sulphides (+ magnetite + accessory sulphide-related minerals). Although much of the sulphide is stratiform and disseminated within specific serpentine-rich marbles, textural evidence (Mason, 1990) suggests that at least some pyrite, chalcopyrite, sphalerite and galena formed by replacement (of pyrrhotite and/or calcite). Much of the serpentine is after forsterite and may represent regional hydration associated with a mineralizing hydrothermal event(s). Nevertheless, some degree of mineralization is of primary origin recrystallized during regional metamorphism.

Menninnie Dam

This lead-zinc-silver prospect was discovered during a regional RAB drilling program by Billiton Australia north of Kimba immediately adjacent to the southern margin of the Gawler Ranges. Massive lead-zinc-silver mineralization occurs within a mixed sequence of ankeritic/dolomitic forsterite/serpentine marbles, calcsilicates, BIF's, pyritic graphitic schists, cherts, schists and amphibolites. The likely stratigraphic position of the sequence is within the Katunga Dolomite of the Hutchison Group and it is argued that the thick carbonate sequence here represents a lateral facies change from the thick iron formation rich sequence of the Middleback Ranges.

Mineralization comprises massive pyrite-sphalerite-galena with minor chalcopyrite in bands commonly 0.5-2 m thick (Higgins & Hellsten, 1986). Representative core assays are:

Table 2: Selected core assays from Menninnie Dam (after Higgins & Hellsten, 1986).

Interval width(m)	Pb(%)	Zn(%)	Ag(ppm)
0.65	5.8	14.0	60
0.6	23.0	12.4	108
1.92	1.5	3.65	44
0.55	13.3	38.5	180

Base metals are believed to be of sedimentary-exhalative origin deposited within an upper shelf facies or sub-tidal carbonate-mudstone sequence. The sequence has been metamorphosed leading to regional recrystallization and local migration of metal-bearing fluids.

Surficial Cover

Even in the hilly regions near Cowell, Cleve, Tumby Bay and Port Lincoln, serpentinous dolomitic marbles do not crop out continuously; outcrop is sporadic, often separated by hundreds of metres along strike, or deeply weathered and altered. Surficial cover in these areas is very thin and could easily be penetrated by electrical geophysical methods or shallow drilling programs. At Miltalie Mine, for example, a recent IP survey successfully detected chargeable (?mineralized) horizons along strike from the mine in areas where the carbonate sequence is concealed.

In areas to the west of Port Lincoln and Cleve and north and west of Kimba, superficial cover rarely exceeds 50 m in prospective areas although combined with localized deep weathering can accumulate to 100 m or thereabouts. Nevertheless, there are large areas of shallow basement that contain calcsilicate or serpentine marble units of the Hutchison Group. In the Coomunga region west of Port Lincoln, Departmental drilling this year has identified a thick (maybe > 1000 m including structural complexities) sequence of marble in the hinge zone of a major regional fold structure and, in addition, has encountered minor amounts of zinc in these rocks. Considering that detailed aeromagnetic data show this horizon(s) to continue for several tens of kilometres, this area presents an exploration prospect concealed only by clays and sands up to 50 m thick but often very thin or subcropping.

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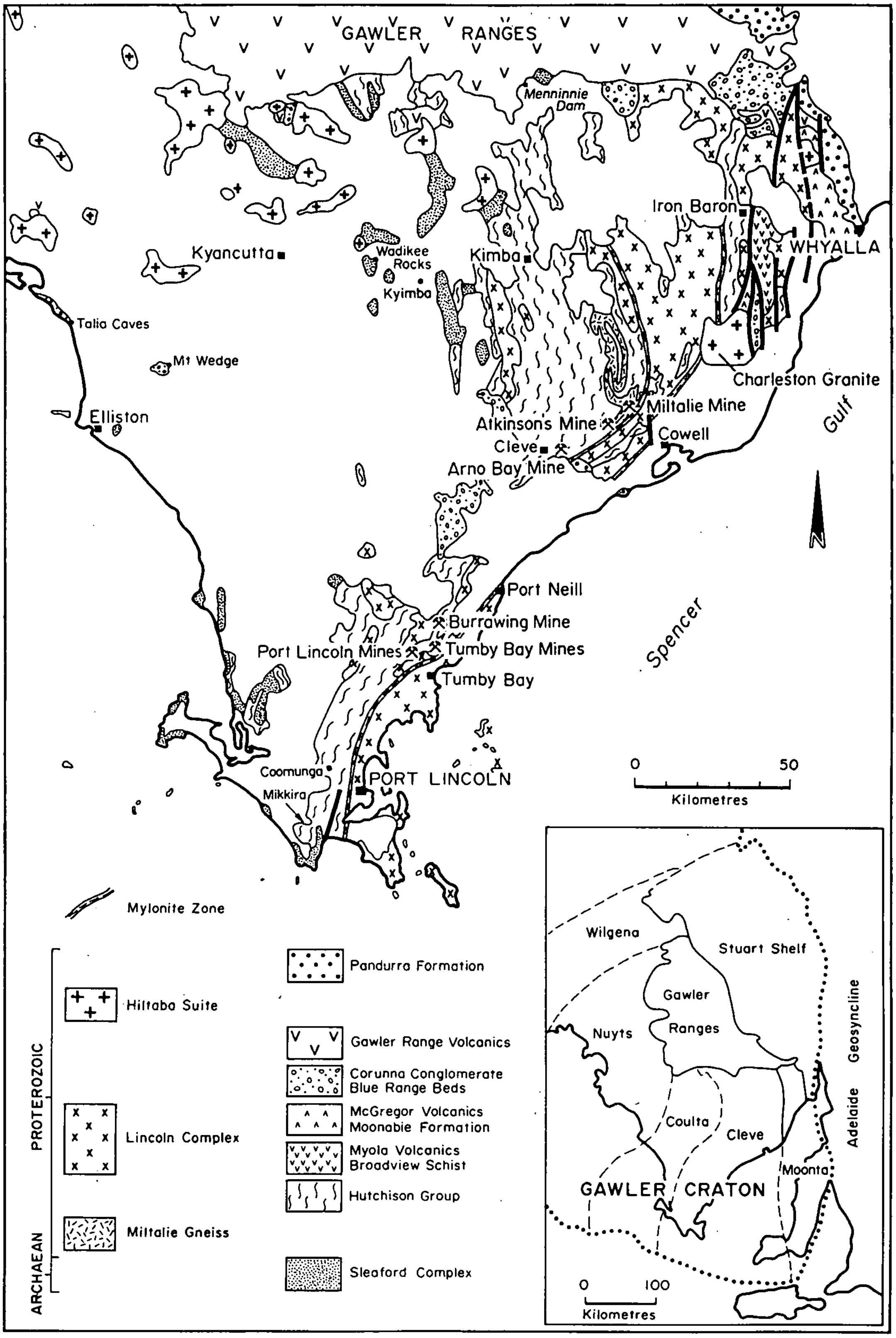

Fig. 2 Regional geological map of Eyre Peninsula and tectonic subdivisions of the Gawler Craton.

Eyre Peninsula airborne magnetic survey

David H Tucker
Consultant

INTRODUCTION

Over the Proterozoic and Archaean aged rocks of Eyre Peninsula there is an extensive cover of calcrete and transported sands and clays, and this is indicated by exploration and water bore drilling to be 10-100 metres thick. To improve knowledge of the basement and the overburden, a fixed wing airborne magnetic, gamma spectrometric and very low frequency (VLF) electromagnetic survey was conducted in the Eyre Peninsula by contract during 1988.

The survey planning was initiated by SADME and was undertaken as a cooperative project between SADME, the Bureau of Mineral Resources (BMR), Western Mining Corporation Ltd and Stockdale Prospecting Pty Ltd. The new survey replaced relatively low quality 1.6km line space data from airborne surveys dating from the 1950's, with 77 000 km of high quality digital data in the STREAKY BAY, YARDEA, ELLISTON, KIMBA and LINCOLN 1:250 000 map sheets. Geophysical data are available from SADME.

PARAMETERS OF THE SURVEY

Line length:	77 000km
Line direction:	090-270 degrees
Line spacing:	500, 1 000, 2 000 and 10 000 metres
Sampling:	Magnetic-13m, Gamma Spectro-65m, VLF-65m
Elevation a.g.l:	100 metres
Ties:	000-180 degrees

CHARACTERISTICS OF THE MAGNETIC FIELD

The survey area is one of high magnetic gradients and high amplitude range in some parts (commonly 500-1 000nT or more), and low magnetic gradients and low amplitude range in other parts (commonly 10-50nT).

Induced magnetisation is the predominant influence in producing magnetic anomalies in the area (ie. magnetic high to the north and low to the south of an anomaly source). Accordingly the magnetic data can be useful in estimating dip of magnetic bodies.

SOURCES OF MAGNETIC ANOMALIES

In general, the magnetic responses observed by this survey are caused by bedrock sources and not by the flat lying Tertiary cover. Depth to magnetic basement estimates made on several hundred anomalies over the area commonly indicate a range of 20-100 metres below surface, and this is consistent with the results of drilling.

Because of the scarcity of outcrop and the paucity of anomaly target drilling, the correlation of magnetic anomalies with lithologies is at an early stage. The magnetic anomalies seen in the new survey contour maps, pixel maps (imagery) and profiles can be classified in terms of approximately eight 'magnetic textures' as tabulated below. The textures can give a guide to inference of the likely subsurface lithologies and structures. Lithologies are inferred by correlation of anomalies with SADME 1:250 000 geological maps and SADME mapping at 1:5 000 and 1:10 000 scale along the coast near Cape Carnot and Sleaford Bay.

SOURCES OF GAMMA SPECTROMETRIC ANOMALIES

The gamma spectrometic data include Total Count, Potassium Count, Uranium Count and Thorium Count. Most of the strongest responses were recorded over Precambrian outcrop areas, particularly including the Gawler Range Volcanics, Hutchison Group metasediments and Hiltaba Suite granitoids. In addition, elevated responses were recorded over northwest-southeast striking paleochannels.

SOURCES OF VLF ANOMALIES

The Very Low Frequency data are extremely noisy and mostly reflect the highly conductive cover rocks in the survey area. Coherent VLF responses appear over Precambrian outcrop areas, and there is an indication of coherence in some of the covered areas possibly indicative of basement responses. The data show various linear cross-cutting anomalies, which indicate faults. These data warrant further processing.

METALLIC MINERAL DEPOSITS

The known large metallic mineral deposits in Eyre Peninsula and adjacent areas of the Gawler Craton have impressive size and include the iron ore deposits in the Middleback Ranges, the copper deposits of the Wallaroo-Moonta region, and Olympic Dam (Cu, U, Au). All these deposits have associated magnetic anomalies. We can speculate that if an Olympic Dam type deposit subcropped, a gamma spectrometric anomaly might be detectable. Within the new survey area, the known base metal deposits (Pb, Zn, Cu, Ag) appear to be small stratabound, stratiform and vein types and are not incipiently magnetic. However, they mostly occur adjacent to magnetic anomalies in structurally complex zones and an association may be important. The aeromagnetic data give the Eyre Peninsula a basement mapping guide and a useful guide to potential ore location.

TEXTURE INTERPRETATION OF MAGNETIC ANOMALIES IN EYRE PENINSULA

NO. & SIGN	ANOMALY TEXTURE IN CONTOURS & IMAGERY (AMPLITUDE RANGE)	INTERPRETED SOURCE	MAPPED FORMATION OR LITHOLOGY - SPECIFIC EXAMPLES
1. zero	Flat-smooth pattern (0-50nT very long wavelength)	Thick non-magnetic sediments or granite	Proterozoic and Paleozoic sediments in Polda Trough ?Archaean granitoid basement in KIMBA
2.	Long wavelength high or low back-ground (+/-200 nT)	Regional high or low magnetised terrain	Generally higher over Hiltaba Suite and lower over ?Archaean terrain & Proterozoic seds
3. +&-	Mottled &/or granular pattern (+/-50 to 100 nT)	?Gneissic terrain ?Granitoid terrain ?Acid volc terrain	?Archaean - STREAKY BAY some Hiltaba Suite Gawler Range Volcs
4. +ve rare -ve	Circular/elliptical highs, lows or annular (5-30 km across)	Plutons, plugs & stocks (acid &/or mafics). Long wave-length = deep	Mostly Hiltaba Suite granitoids. Long wavelength in Polda Trough
5. +ve or -ve	Bullseye/circular - can be on a single flight line. (5-500 nT)	Small plugs and short strike-length dykes (dolerite & kimberlite)	Gabbroic plugs eg Inkster. Quartz magnetite
6. +ve	Narrow curvilinear (very large range at least 5-100 nT)	Thin steep dipping magnetic beds - approx. 100-200 m thick mostly. Some fault zones	Hutchison Group metaseds Lincoln Complex granitoids Sleaford Complex metaseds ?Archaean metaseds
7. +ve	Broad curvilinear can be 2-5 km or more wide (200-1000 nT)	Thick and/or multi-layered magnetic beds, acid volcs.	Gawler Range Volcs Warramboo Fe fmn Middleback Ranges Fe fmns
8. +ve -ve zero	Linear cross-cutting. Pattern breaks and lineaments (5-200 nT)	Dykes, faults & fault zones, mylonite zones	Gairdner dykes (striking NW)

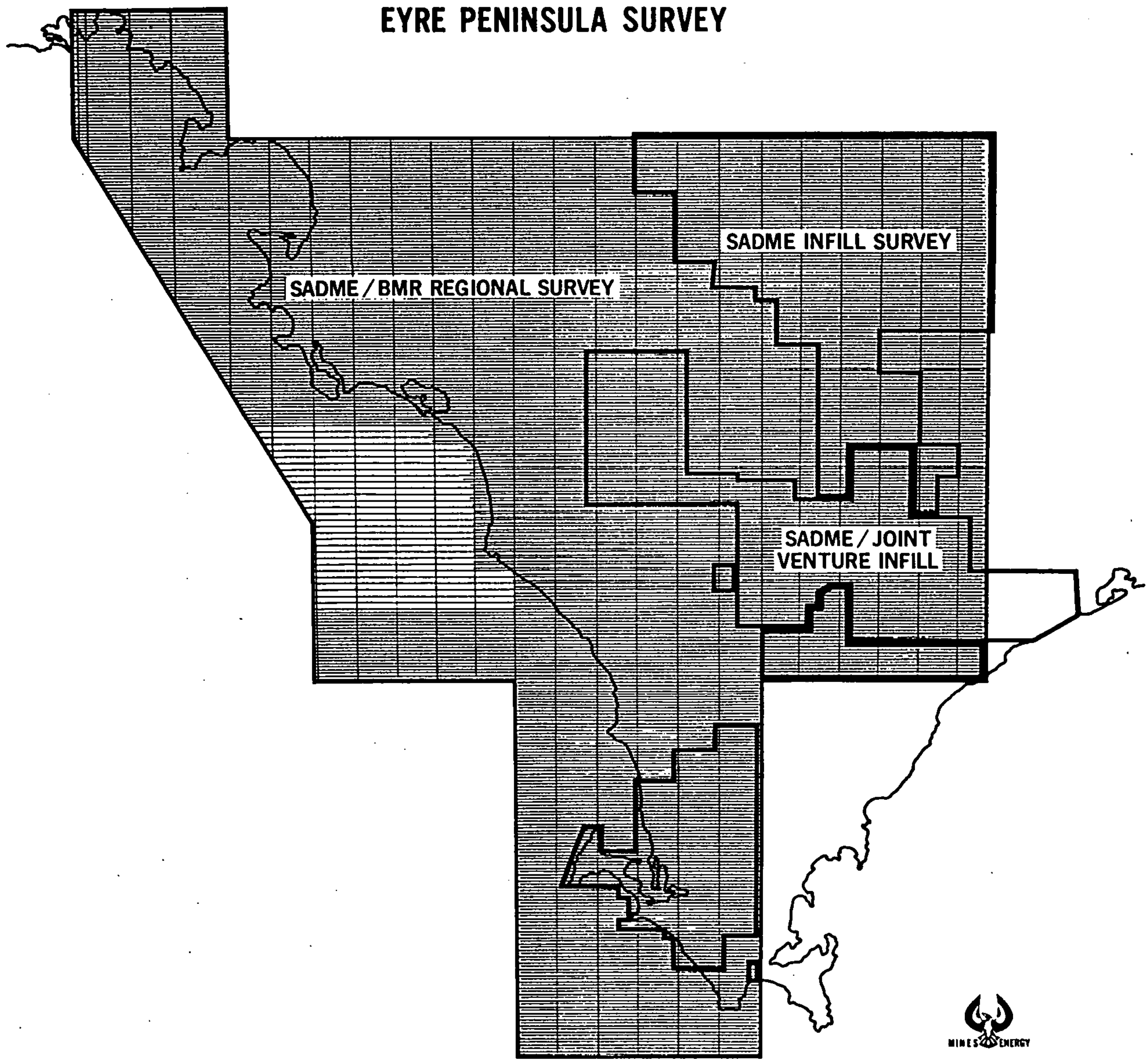

FIGURE 1. Flight line pattern for 1988 Eyre Peninsula airborne geophysical survey. Contributors to funding of the survey included SADME, BMR, Western Mining Corporation Ltd and Stockdale Prospecting Pty Ltd.

TABLE 1. Summary of maps and magnetic tapes available from SADME for the Eyre Peninsula Airborne Geophysical Survey.

1:250,000 SCALE MAPS

SHEET NAME	SHEET NUMBER	FLIGHT PATH	TMI PROFILE	TMI CONTOUR	TOTAL COUNT CONTOUR	URANIUM CONTOUR	THORIUM CONTOUR	POTASSIUM CONTOUR
ELLISTON	SI53-06	89-453	90-57	90-114	90-539	90-540	90-537	90-453
KIMBA	SI53-07	89-455	90-61	90-118	90-554	90-564	90-551	90-455
LINCOLN	SI53-11	89-457	90-58	90-115	90-534	*	90-536	90-452
STREAKY BAY	SI53-02	89-456	90-59	90-542	*	90-543	90-555	*
YARDEA	SI53-03	89-454	90-60	90-117	90-547	90-548	90-546	90-454

* PLANS IN PREPARATION

1:100,000 SCALE MAPS

SHEET NAME	SHEET NUMBER	FLIGHT PATH	TMI PROFILE
BUCKLEBOO	6132	90-229	90-279
CACUPPA	6032	90-239	90-276
COLLINSON	5632	90-245	90-278
COULTA	5929	90-235	90-293
CUMMINS	6029	90-228	90-291
CUNGENA	5832	90-241	90-294
DAMPER	5931	90-238	90-289
ELLISTON	5830	90-236	90-296
KIMBA	6131	90-237	90-286
KOPI	6031	90-240	90-288
LINCOLN	6028	90-233	90-292
MINNIPA	5932	90-234	90-277
RADSTOCK	5731	90-243	90-281
SHERINGA	5930	90-232	90-295
STREAKY BAY	5732	90-246	90-287
TALIA	5831	90-244	90-284
THEVENARD	5633	90-242	90-280
TOOLIGIE	6030	90-230	90-290
TOPGALLANT	5730	90-231	90-285
VERRAN	6130	90-226	90-282
WANGARY	5928	90-227	90-283

The base-metal potential of the Willyama Inliers, South Australia

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Aberfoyle Resources Limited

The Mid-Proterozoic Willyama Inliers straddle the SA-NSW border 400km NE of Adelaide. The inliers are separated into two blocks of different metallogenic, stratigraphic and geophysical character (Mills, 1986) by the NE Georges Mountain - Apollyon fault structure. Base-metal potential within the Olary Block on the South Australian side has traditionally rested on perceptions of the relation of the block to the Broken Hill Block and the large rich Pb-Zn-Ag deposits which have been exploited there for more than a century.

Over 50% of the possible 13,000 km^2 extent of the Olary Block is obscured by Cainozoic, Adelaidean and possibly younger Mid-Proterozoic cover (Teale, 1985). Three geomorphic terrains are defined as the northern deeply-covered area, the central well-exposed area and the southeastern weakly-exposed connection with the Mutooroo section of the Broken Hill Block. Approximately 80 metal occurrences are known, with the distribution 20% U, 10% Au, 40% Cu and 30% Zn (Pb Ag) (Campana and King, 1958, Horn and Morris, 1988). The latter are mostly modest zinc mineralisation in stratiform iron-sulphide bodies within the 10-100+m thick "Bimba Unit" of schists, calcsilicates, marbles, iron formations and cherts. This unit has over 150 km of strike extent in the block. The metal anomalism varies from Cu $\pm$ Co Au to Zn $\pm$ Pb Ag Mn Ba with lateral and vertical zoning evident. Extensive iron-sulphide units commonly assay up to 0.5% Zn over substantial widths in both gossans and drill intersections. However, intervals of higher grade (to 6% Cu and 3% Zn) are narrow and have no lateral extent.

Geological knowledge is limited, being largely derived from the work of CEC and Esso geologists (eg Ashley et al, 1978) and has been summarised and revised by various authors including Blissett (1975), Clark et al. (1986) and Callen (1990). Field mapping and research is currently being undertaken in a joint project by the universities of New England and Newcastle to improve the geological database and understanding.

The Bimba Unit is underlain by up to 500m of albitites, then psammitic gneisses. Overlying metapelites, including graphitic schists, mark a sudden change in sedimentation. The origin of the albitities is problematic: evaporitic sediments or metasomatised volcanics are favoured explanations of their sodic character. Although proven basic volcanics are comparatively rare, the stratigraphy indicates a rift-related cycle with quiescent exhalation and chemical sedimentation at the pivotal Bimba level. This sequence and subsequent history of multiple deformation and metamorphism have enabled broad correlation with the Broken Hill stratigraphy (Glen et al., 1977) however there are significant differences in detail. The albitites and Bimba Unit are respectively correlated with the Thackaringa and Broken Hill Groups.

The thinner stratigraphy and predominant carbonate and Cu ± Co associations at Olary were perceived to indicate a shallower shelf facies with lower potential for Sedex base metal deposits in comparison with the deeper rift basin interpreted for the Broken Hill environment. The iron-sulphide-rich nature of the Bimba horizon correlates better with lesser base-metal horizons at Broken Hill, although rare garnet gahnite lode rocks characteristic of the main Broken Hill ore horizon are present. However, a shallow environment is becoming more plausible for Broken Hill and the right exhalative environment is present at Olary for development of multiple "third order" exhalative or diagenetic sulphide basins as is now more evident in the Mt Isa district.

As most holes on the Olary Block are shallow (<150m), and a significant proportion failed to test their targets due to unexpected structural complications, it is likely that large bodies of mineralisation, especially with a significant plunge and small surface projection, could easily have been missed. After abundant but shallow drill testing of historical (mostly copper) deposits to 1973 by various companies, CEC recognised the stratiform zinc potential and undertook the first large scale mapping and rock chip sampling in the Olary Block. A ten-year period of gossan search and unsuccessful percussion drill testing of numerous prospects ensued. Since 1982, testing of more subtle, often geophysical targets in covered areas has progressed with abundant geochemical drilling and fewer but deeper diamond drillholes. Deep exploration coverage is estimated to be 30% as effective as that within the Broken Hill Block.

Eight major companies are currently exploring 95% of the block. The prospective albitite-Bimba position is being mapped by the magnetic contrast between the two units. Utilisation of conceptual and empirical targeting techniques along prospective strike is necessary; for example, comparison with the Skellefte field, geochemical zoning and magnetic/radiometric indicators of magnetite depletion and K-enrichment in the footwall to sulphide-filled basins. EM targetting continues to be moderately successful in discriminating iron-sulphide accumulations from graphitic schists and some gossans remain untested in more exposed areas. The potential for stratabound diagenetic-epigenetic Cu + Au mineralisation associated with silica-magnetite horizons within the albitites is also amenable to magnetic targetting.

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Kangaroo Island: Lead/Zinc Potential

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Mineral Resources Branch

Between October 1989 and late March 1990, SADME drilled 525 holes on Kangaroo Island as part of the Department's lead and zinc initiative.

Kanmantoo Group metasediments are host to stratiform Ag, Pb, Zn, Cu, and pyrite mineralization to the east and southeast of Adelaide, notably in the Strathalbyn to Kanmantoo area. Similar metasediments underlie much of Kangaroo Island, but previous exploration has been minimal. The drilling programme was designed to test the regional mineral potential of the Kanmantoo Group, in particular in areas close to major structural features.

The Kangaroo Island project was divided into the Dudley Peninsula area, and the Kingscote to Snug Cove area.

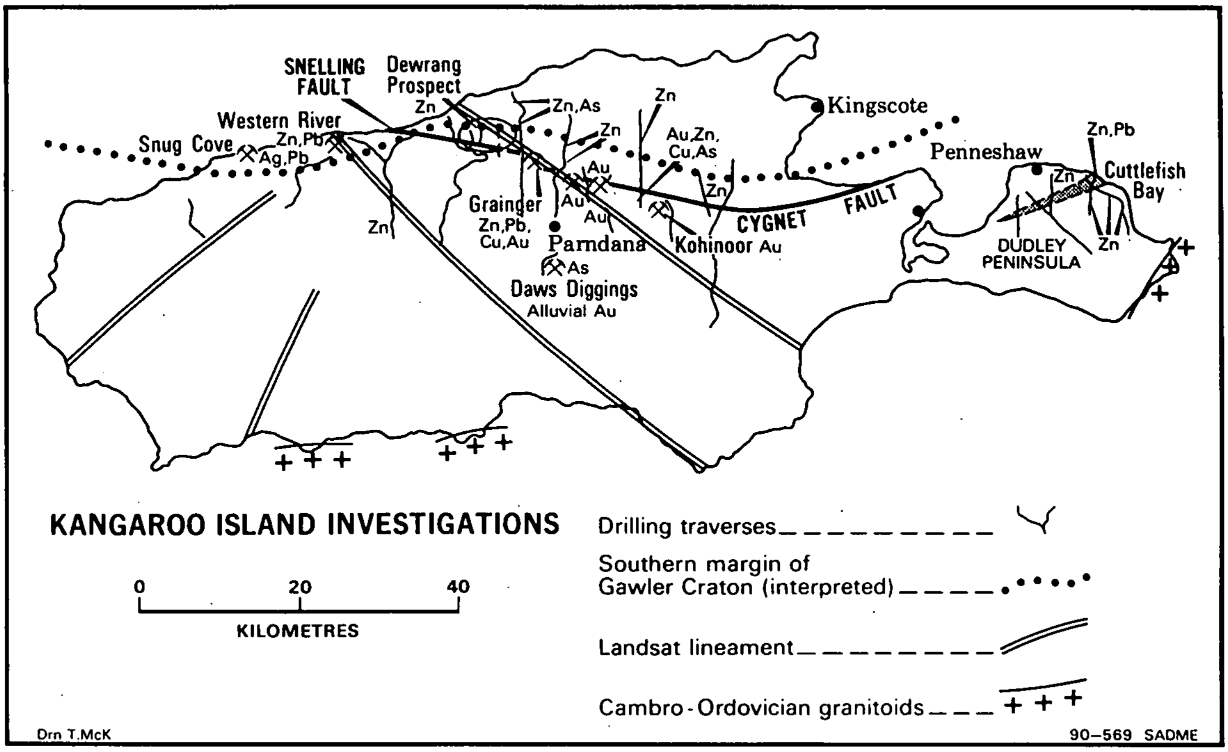
On Dudley Peninsula, Kanmantoo Group metasediments crop out around the north and northeast coast of the peninsula, and are folded into an overturned anticline which strikes east-northeast through Cuttlefish Bay, dipping steeply south, with a central core of Adelaidean metasediments. The drilling programme was designed to intersect the Talisker Calc-siltstone (Nairne Pyrite equivalent) and the overlying Tapanappa Formation, both of which include sulphide-rich interbeds, the core zone of Adelaidean metasediments, and broad anomalous geochemical zones outlined by stream sediment sampling. 78 holes were drilled at 500m intervals on 5 traverses. South of Penneshaw, Tapanappa Formation contains slightly anomalous Zn, up to 140ppm. Over and adjacent to the anticlinal core, Zn and Pb are up to 500ppm, but extremely variable.

The second and larger part of the drilling programme in the central and northern part of the island was designed to intersect Cambrian shelf sediments of the Kangaroo Island Group along the north coast, north of the Snelling and Cygnet Faults, and Kanmantoo Group trough sediments to the south.

The Cygnet and Snelling Faults are approximately coincident with the southern margin of the Gawler Craton, and a number of abandoned gold or base metal mines and prospects are scattered along, or close to, these faults.

442 holes were drilled along north-south traverses approximately across strike, totalling 6772m. In general the holes were 500m apart, but over the Snelling and Cygnet Faults hole spacing was 100 to 125m, and at some of the known prospects hole spacing was 25 to 100m.

Drilling and mapping indicated anomalous Zn with lesser Pb along the Cygnet and Snelling Faults, with higher values along the Snelling Fault and at the western end of the Cygnet Fault.



- Anomalous Zn was recorded 3km west of Kohinoor, close to the Cygnet Fault, and near Au prospects at the west end of the Cygnet Fault.

- Eight holes close to the Playford Highway, 15 km west of Parndana included anomalous Zn in a presumably stratigraphic anomalous zone.

- The Dewrang prospect is a widepread stream sediment Zn anomaly and coincident negative magnetic anomaly. The potential of this broad zone was confirmed by values from 100 to 550ppm in 9 holes; Zn is associated with fine quartz/chlorite veining in fine grained sandstone.

- At the abandoned Western River Zn-Pb Mine, mineralization is associated with a narrow east-west striking, steeply dipping silicified and brecciated and resilicified zone. Drill holes adjacent to the workings contained between 70 and 200ppm Zn, reaching a maximum of 3385ppm Zn with 1000ppm Pb over the lode.

- The abandoned Grainger Zn-Pb-Ag-Cu(?) Mine is between the Cygnet and Snelling Faults, and a west-northwest Landsat lineament has been interpreted through this zone. Three holes close to the existing shallow workings intersected massive fine sandstone with disseminated pyrite, and in excess of 1000ppm Zn. Drill hole GRA 7, 150m to the south, revealed fine anastamosing quartz, or quartz/sphalerite/galena, or chlorite/quartz veins. Assays averaged 2.69% Zn, 0.45% Pb, and 1.7 gm/tonne Ag over 16m from 10 to 26m.

Most of the gold prospects and anomalous gold are in fine grained sandstone associated with the Cygnet Fault, and gold is associated with fracturing and limonitic boxworks, and bleaching and silicification of the host rock.

- At the Kohinoor Au Mine, workings have followed quartz veins and alteration zones striking northwest or northeast, with a moderate to steep dip. The best result was 0.36ppm Au in bleached, altered and iron stained soft sandstone in a small open cut.

- Several holes on the Cygnet Fault about 3km W of Kohinoor intersected limonite boxwork and quartz veining in siltstone and shale, with up to 0.22ppm Au.

- Drilling near the alluvial workings at Daws Diggings, 10 km south of the Cygnet Fault, revealed numerous thick vughy and limonitic quartz veins in bleached and altered siltstone, but no gold was detected.

- The highest Au values, up to 0.96ppm, were recorded near the abandoned Grainger Mine, in bleached and altered fine grained sandstone, adjacent to a 1 to 2m wide silicified and brecciated and resilicified zone which strikes west-northwest for 300m, about 250m south of the old base metal workings.

Drill hole, analytical, geological and geophysical data will be available in early 1991, and the areas will be available for further exploration.

Karinya Syncline lead/zinc and diamond potential

B J Morris
Mineral Resources Branch

The Karinya Syncline, at the northern extremity of Cambrian Kanmantoo Trough, was identified by the lead-zinc task force as prospective. The main target for possible stratiform and/or stratabound base and precious metal mineralisation is the Karinya Shale, a dominantly pyritic-carbonaceous shale and equivalent to Talisker Calc-siltstone which hosts significant mineralisation elsewhere in Kanmantoo Trough.

Elements considered favourable for mineralization include:

- an abundant source of sulphur from syngeneic pyrite
- igneous activity and metamorphism to provide a source and driving force for metalliferous fluids
- major lineaments, fault and shear zones and folding to provide plumbing systems for movement and mixing of metalliferous fluids.

Regional soil sample traverses across Karinya Shale at about 2 km intervals (assayed for Cu, Pb, Zn, As, Ag and Au) along with Landsat MSS and TM interpretation defined three prospective areas:

- <u>Frankton</u>, regional soil sample results were generally low but the Karinya Shale is tightly folded with well developed axial plane cleavage. A north-westerly trending Landsat linear corridor crosses the area and several lamprophyre dykes are present.
- <u>The Gap</u>, regional soil samples were anomalous for base and precious metals. The Karinya Shale is strongly ferruginised at the closure of a secondary fold structure and a rock chip sample showed 1.4% Cu, 2105 ppm Pb, 1557 ppm Zn, 3000 ppm As, 16.5 ppm Ag and 6 ppb Au. A northeasterly trending Landsat linear corridor crosses the area.
- <u>Accommodation Hill</u>, Landsat imagery shows colour anomalies associated with ferruginous Milendella Limestone Member. Rock chip samples of the gossaneous material showed up to 1% Cu, 465 ppm Pb, 1545 ppm Zn, 2.5 ppm Ag and 0.5 ppm Au. The area is crossed by the northeasterly trending Landsat linear corridor.

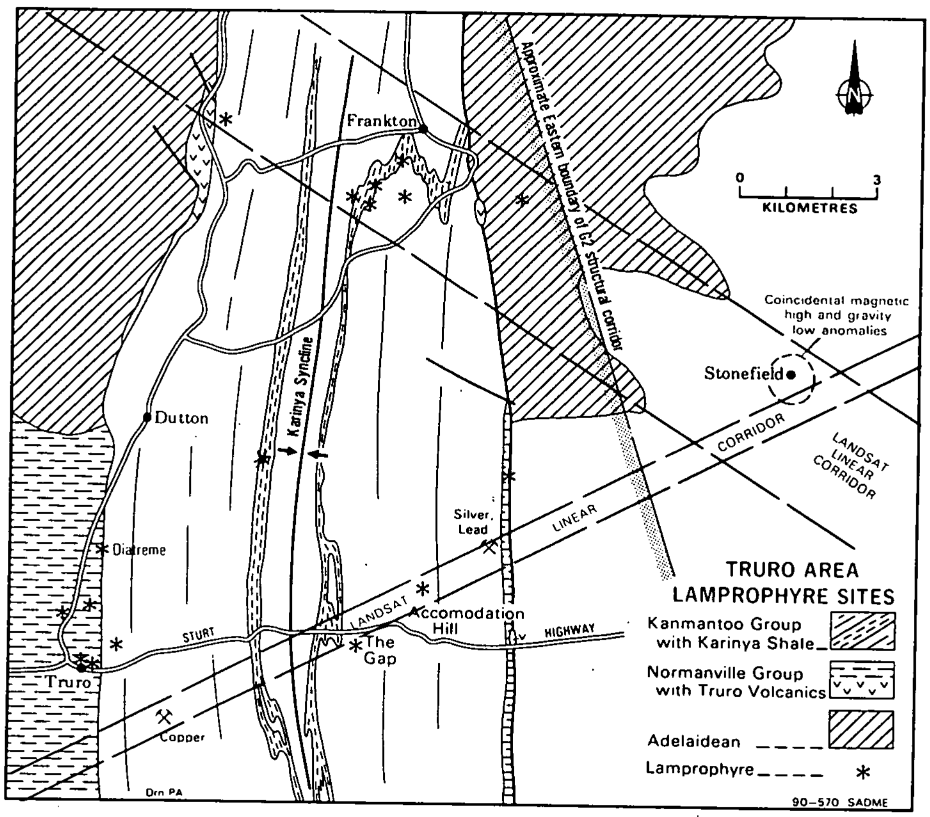
Detailed mapping, soil sampling and Induced Polarization surveys of the three prospects outlined several areas for follow-up drilling: Frankton Prospect - two angled diamond drill holes to 200 m depth; The Gap Prospect - eight angled reverse circulation drillholes to 60 m depth; Accommodation Hill Prospect - five angled reverse circulation drill holes to 54 m depth.

Drilling results showed that the base of Karinya Shale, where black shale grades to calcareous meta-siltstone, and a meta-sandstone at top of underling Backstairs Passage Formation are anomalous for base metals, with the best intersections at The Gap Prospect with up to 3.3% Pb and 1870 ppm Zn over 2m.

Many lamprophyre (minette) dykes and a lamprophyric diatreme have been identified. The dykes, about 1 m wide, are generally greyish in colour with distinctive bronze or black phlogopite phenocrysts, to 10 mm across, set in a groundmass of fine mica, felsic grains and minor apatite. Phenocrysts have either random orientation or aligned to a flow foliation.

The diatreme is ovoid in shape about 50 m by 100 m and appears to be a multiphase intrusion of lamprophyre and dolerite with a probable late stage gabbro. The margin is characterised by a pebble breccia with autolithic and heterolithic xenoliths to 0.1 m across calcareous country rock is altered to talc schist and crocidolite.

Many of the lamprophyre dykes are associated with either a northeasterly or northwesterly trending Landsat linear corridor that intersect near Stonefield where coincident magnetic high and gravity low anomalies may represent a plutonic centre. Deep seated crustal weakness is indicated with potential for base metal, precious metal and diamond mineralization.



Mineral potential of basement beneath the Murray Basin

B J Clough and L R Rankin
Geological Survey

The Murray Basin, a large intracratonic fluviatile to shallow marine Tertiary sedimentary basin, extends over a large portion of western NSW, Victoria and southeastern South Australia. The basin conceals the pre-Tertiary basement in South Australia between the Neoproterozoic to Cambrian sediments, volcanics and metasediments of the Adelaide Geosyncline, Stansbury Basin and Kanmantoo Trough in the north and west, and the Cambrian-Ordovician sediments, volcanics and metasediments of the Glenelg River and Mount Stavely Volcanic Complexes to the east in Victoria.

Interpretation of image-processed aeromagnetic data indicates the presence of several Proterozoic - Early Palaeozoic stratotectonic domains beneath the Murray Basin. These include; a) an arcuate belt of linear, and apparently folded, magnetic anomalies extending from south of the Broken Hill Block to west of the eastern Mount Lofty Ranges; b) a north-west striking belt of complex magnetic character, discordant to the above ?metasedimentary/volcanic trends, and coincident with the granitoid-rich Padthaway Ridge area, and c) the northwestern termination of the Stavely Belt (terminology of Brown *et al.*, 1988) which includes to the southeast the Mount Stavely Volcanic Complex (Buckland, 1986).

Using both the geophysical data plus previous drilling records, a programme of stratigraphic drilling was undertaken to investigate the nature of various magnetic domains and anomalies, and test the potential for Mount Read Volcanics-style bimodal volcanics and base metal mineralisation.

Combined with the results of previous exploration, this programme outlined the presence of three major zones of mafic and bimodal intrusives and extrusives.

Peebinga 1 intersected the northwestern termination of the geophysically-defined Stavely Belt, revealing the presence of an interbedded sequence of ?shallow water limestone, black shale, porphyritic and vesicular basalt, metabasic agglomerate (?altered pillow lavas) and occasional tuffaceous horizons. The sequence contains up to 3% pyrite, occurring as discordant veins, centimeter-sized nodules and fine, disseminated grains.

The sedimentary environment and lithology of this sequence closely resembles that of the Cu-bearing Truro Volcanics which are exposed, interbedded with the Heatherdale Shale of the Normanville Group, in the eastern Mount Lofty Ranges. Geochemical data support this similarity, with both volcanic sequences having within-plate continental characteristics (using the discrimination fields of Pearce and Cann, 1973), and represent slightly alkaline basaltic suites. In contrast, the Mount Stavely Volcanic Complex at the southeastern end of the Stavely Belt have calc-alkaline island-arc affinities (Buckland, 1986). The combination in Peebinga 1 of basic volcanics plus pyrite-bearing limestone and black shale indicates a high potential for volcanogenic sulphide mineralisation in this sequence.

Three drillholes to the east towards Karoonda were targeted on an elliptical anomaly and a ?fold closure in a linear magnetic high. These drillholes intersected a sequence of metadolerite intruding granodiorite, plus amphibolite which probably represents shallow ?sub-volcanic dolerite, although an extrusive origin for the amphibolite cannot be discounted. The amphibolite is weakly foliated, and is tentatively interpreted as emplaced either late in the deposition of the Kanmantoo Group, or early in the Delamerian Orogeny. In the north of the Murray Basin, a zone of similar magnetic character was found to contain ?Cambrian basic and metabasic dolerite and ?basalt (CRA, 1985; Preiss and Radke, 1988).

The geochemical signature of these metabasics is of primitive oceanic type, plotting in the MORB field of Pearce and Cann (1973). The metabasics are also geochemically similar to the pre- and syn-Delamerian Orogeny metadolerites and amphibolites, reported by Liu and Flemming (1990) that intrude the Kanmantoo Group in the eastern Mount Lofty Ranges. Undeformed post-deformation granitoids are also common in this zone.

Within Peake 1, southeast of the metabasic complex, an albititic rhyolite (intruded by metadolerite) was intersected. This felsic unit has unusual geochemical character, and does not appear related to either the post-deformation granitoids or the MORB-like metadolerites. Rhyodacite was previously intersected further north, adjacent to the metadolerite zone. The close spatial association of the metadolerites and felsic extrusives suggest a bimodal magmatic event.

All of the metabasics intersected in the 1990 drilling programme contain abundant discordant vein and disseminated pyrite mineralisation. Petrographic evidence indicates that at least part of the sulphide is primary.

The third prospective zone for bimodal volcanism and mineralisation occurs in the Padthaway Ridge area. Here, porphyritic rhyodacite and high level post-Delamerian Orogeny granitoids have been interpreted on geochemical evidence by Turner *et al.* (in press) as associated with amphibolite near Meningie and the extensive mafic-ultramafic intrusives of the Black Hill gabbro-norite complex.

In the subsurface of the Yumali-Coonalpyn area, weakly foliated basalts and basaltic andesite intersected by CSR (1986) are interpreted here as pre to syn-Delamerian Orogeny extrusives intruded by post-orogenic granitoids and preserved in a downfaulted region of the Padthaway Ridge. The Yumali-Coonalpyn basics have within-plate alkaline-tholeiitic geochemical characteristics which, combined with their foliated nature suggest correlation with the Truro Volcanics and the basalt intersected in Peebinga 1.

Other economic targets of importance in the Murray Basin basement region include potential PGE mineralisation associated with the Black Hill gabbro-norite complex intrusives, and potential Au mineralisation associated with both bimodal volcanism (similar to the Mount Stavely Volcanic Complex) and syn- to post-Delamerian Orogeny granitoids. The potential for these styles of mineralisation has yet to be tested.

In conclusion, drilling intersections and geophysical interpretation have outlined three major provinces of potential mineralisation in the basement to the Murray Basin (see Fig. 1):

1) Stavely Belt - basaltic pillow lavas interbedded with pyrite-bearing shelf-facies limestone and black shale. Possible correlation to Truro Volcanics or Mount Stavely Volcanic Complex.

2) A discontinuous arcuate zone of bimodal intrusives and extrusives extending from north of the Padthaway Ridge to south of the Broken Hill block. Possible correlation to metadolerite and amphibolite intruded in the Kanmantoo Group both during sedimentation and syn-Delamerian Orogeny, exposed in the eastern Mount Lofty Ranges.

3) Padthaway Ridge area - bimodal magmatism, including mafic intrusives and rhyolitic extrusives associated with post-Delamerian Orogeny granitoids. Also a local zone of older, deformed basalt-andesite in the Yumali-Coonalpyn area.

Each of these zones, although of slightly different ages and tectonic setting, have a high potential to host volcanogenic stratiform and epithermal feeder-zone style base metal mineralisation.

The majority of the interpreted area of mafic and bimodal magmatism lies outside of the zone of thick sedimentary cover of Devonian - Cretaceous age within the Darling and Nadda Basins, Berri Embayment.

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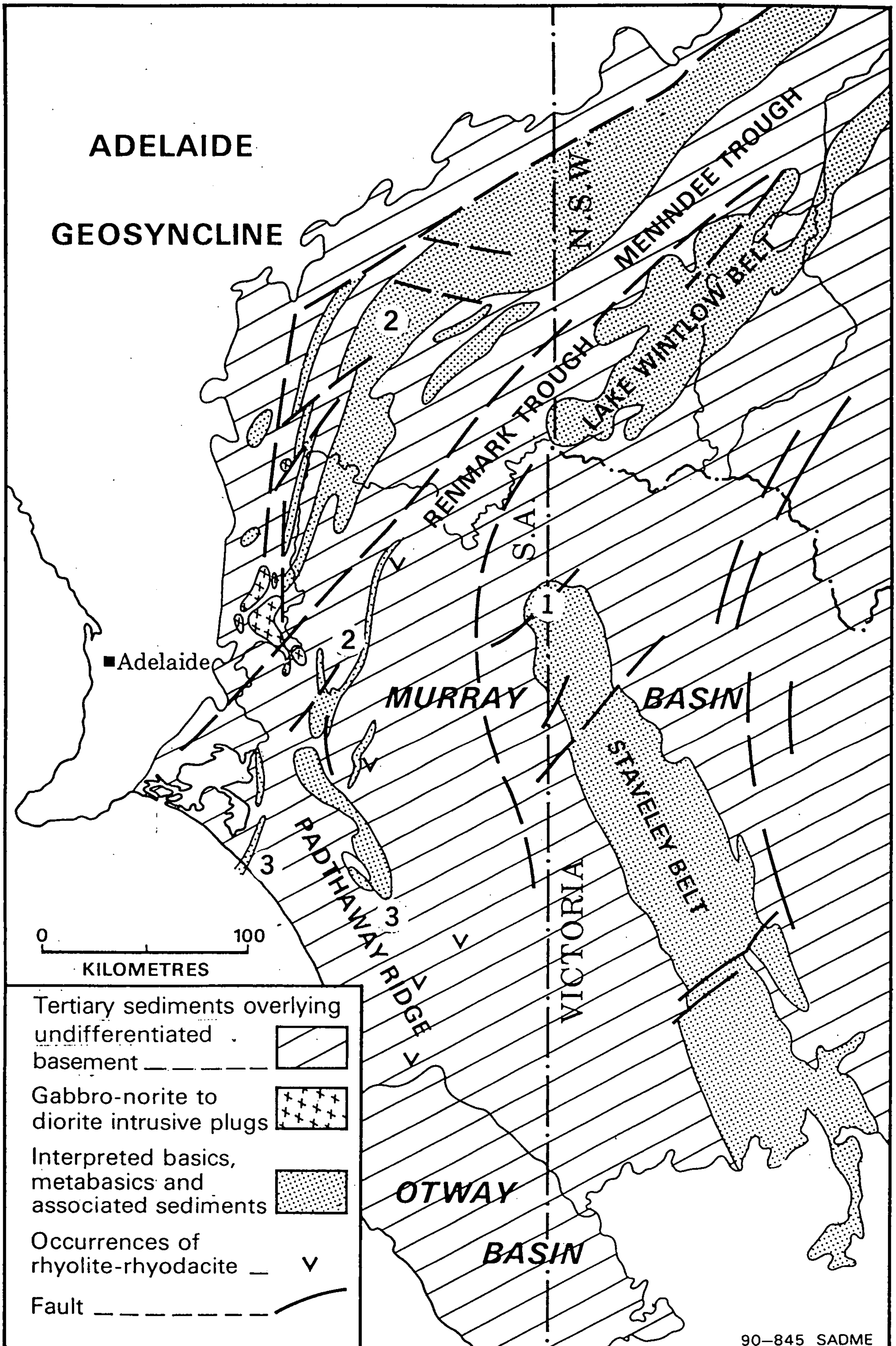

Fig. 1. Interpreted Early Palaeozoic mafic igneous associations beneath the Murray Basin. Numbers refer to provinces outlined in text. Adapted from Brown *et al.* (1988).

POSTER DISPLAYS

PEPS-SA: Petroleum Exploration and Production System - South Australia

EM Alexander
Oil, Gas and Coal Division

PEPS-SA is a comprehensive database of open file and confidential South Australian petroleum exploration, development and production data. Principal functions of PEPS-SA are:

- internal and external customer service
  - provision of data
  - index of available data (Figs. 1 and 2 illustrate PEPS-SA data screens).
- data capture and manipulation
  - data analysis
  - data management and presentation

PEPS-SA has been developed using SAS software which provides a high level of data manipulation and presentation. SAS is an industry standard and enables electronic transmission of data from Santos Ltd, operator of the oil- and gas-productive Cooper/Eromanga Basins.

PEPS-SA comprises five key data sets, each of which is subdivided into modules (numbers in brackets indicate degree of completeness of module to date):

- **wells**
  - basic well data (Fig. 1) (100% complete)
  - logs run for each well (Fig. 2) (91%)
  - index of well completion reports (69%)
- **geological**
  - formation tops (78%)
  - source rock analyses (0.1%)
  - palynology (2%)
  - cores and cuttings stored in SADME Core Library (25%)
- **engineering**
  - drill stem tests (12%)
  - liquid evaluation tests (22%)
  - perforations and treatments (14%)
  - well tests (11%)
- **production**
  - Santos gas statistics (100% to June 1990)
  - Santos oil statistics (100% to January 1990)

- **geophysics** - seismic survey data (100% to December 1988)
  - seismic line data (100% to December 1988)

PEPS-SA has developed rapidly over the past year and is now available to industry and the public for purchase. The Department has been awarded a grant of $30 000 as part of the National Geoscience Mapping Accord for development and marketing of PEPS-SA.

PEPS-SA is available in three formats, with quarterly updates provided if required (at additional cost):

- ASCII file with software to view and carry out basic searches

- SAS datasets (PC format on floppy or SAS transport format on tape)

- hard copy printout for casual enquiries

Development priorities over the next 6 months are to capture and verify data for incomplete modules (specifically engineering, geological and geophysics modules).

Over the next 12 months the following new modules will be developed:

- gas composition for each field.

- statistics - oil price, gas sales statistics, natural gas pricing history, petroleum royalties etc.

- licences - historical and current information on PELs, PPLs, EPPs and PLs

- reserves atlas - confidential SADME oil and gas reserve calculations (limited access only)

- company address list

PEPS-SA is a dynamic database that is designed to meet the current and future demands of Departmental and Industry users.

Figure 1. PEPS-SA basic well information screen.

```
South Australian Department of Mines and Energy  --  Data Package     Rec 68

                              <<<  W E L L S  >>>

Well            : BIG LAKE 27
                                                 Map         : 6941 (1:100 000)
Security        : OPEN FILE                      TD          :  9747.0 FEET
When Open       : ________                       Clarke Loc
WCR no          : 5076                              Lat      :  28.1200990 deg S
Basin           : COOPER/EROMANGA                   Long     : 140.1958300 deg E
Farmout         : MOOMBA                            Source   : SURVEYED
Tenement        : PPL 11                         ANS Loc
Operator        : DELHI                             Lat      :  28.1200700 deg S
On/Off          : ON  shore                         Long     : 140.1950330 deg E
Spudded         : 08/06/82                          Source   : SURVEYED
Rig Rel.        : 22/07/82                       Elevations
Class           : GAS APPRAISAL                     GL       :   121.1
Status R/R      : CASED & SUSPENDED GAS             KB       :   143.0
Curr Status     : CASED & SUSPENDED GAS             Units    : FEET
Drill Rig       : RICHTER 1
Object 1        : COOPER GAS
Object 2        : BIRKHEAD OIL
Comment         : Hydraulic fracturing of reservoir
```

Figure 2. PEPS-SA log index screen.

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South Australian Department of Mines and Energy  --  Data Package     Rec 13

                              <<<  L O G S  >>>

Well                 : BALCAMINGA 1

Tape Number          : 5908/1.2              Dip Meter Run ?    : NO
Sepia Box Number     :   5908                Dip Meter Tape No  : ________
Units                : FEET
Logging Company      : SCHLUMBERGER

       Type                        Run   From       To          Scales
       SLS-GR-CAL                   1     718.0     5988.0     600    240
       SLS-GR-CAL                   2    6011.0    10663.0     600    240
       DLL-MSFL-GR                  2    6011.0    10636.0     600    240
       CHECK SHOT SURVEY            1     145.0    10565.0     ___    ___
       DLL-GR-CAL                   1     718.0     5961.0     600    240
       WSS                          _   _______   _______      ___    ___
       ________________________     _   _______   _______      ___    ___
       ________________________     _   _______   _______      ___    ___

Comment   : ____________________________________________________________
```

Heavy mineral sand province of western South Australia

M C Benbow
Geological Survey

INTRODUCTION

Coastal dunes along the western and eastern coastline of Australia are a major source of the world's heavy minerals (e.g. rutile and zircon). Coastal dunes that occur many kilometres inland and which are of much greater age, are being explored in non-traditional areas in South Australia, notably in the Murray Basin and Eucla Platform*. Two large heavy mineral sand accumulations have now been located in the Murray Basin; Western Mining's Horsham deposit in Victoria and Peregrine's Massidon deposit in New South Wales. Current exploration is being driven by world demand and increased land use pressure on the sea-board.

As a result of recent systematic geological mapping by the Geological Survey of South Australia and investigations by the University of Adelaide, the heavy mineral potential of western South Australia has been dramatically increased. The targets are stranded coastal dunes and "beach" ridges flanking the Nullarbor Plain (Fig. 1). They are the oldest preserved aeolian landforms known and are believed to be ~30-35 million years old. They are of great scientific interest, providing important information about global climate when much of Australia may have been covered by rainforest (Benbow, 1986a,b, 1989, 1990).

SETTING

The coastal dunes occur on the eastern margin of the Mesozoic-Cainozoic Eucla Platform, a flat, little deformed blanket of sediments that passes seawards over the continental shelf, to the rift margin basins (Bight and Duntroon basins) where up to 12 km of sediment accumulated as Australia and Antarctica separated. Most of the Eucla Platform consists of marine limestone which outcrops as the flat, "featureless" Nullarbor Plain. Recent work indicates that there is a wide inner zone of land-derived sediments; these were deposited in marine and non-marine environments during the Cainozoic. This zone, oriented northwest-southeast, and tentatively including much of Eyre Peninsula, contains the coastal landforms. The rivers that provided the sediment for dune construction form an extensive region of palaeodrainage to the northeast.

* The Eucla Platform was previously known as the Eucla Basin (Benbow in prep., Benbow, et. al., in prep; James and Bone in prep.).

HEAVY MINERAL SAND TARGETS

Coastal Dunes

Three coastal dunes flank the Nullarbor Plain. Previously believed to be sand mantled bedrock highs, these linear features have been recently demonstrated to be dunes from their shape and the great accumulation of sand along their length.

The 650 km long Ooldea Range is the largest of the features, running along the margin of the Nullarbor Plain from Western Australia to near Ceduna. It lies 25-300 km from the modern coastline, stands 40-180 m above the Plain and has an average width of 15-20 km. The shorter, parallel Barton Range lies wholly within the Great Victorian Desert, 40-70 kms to the northeast. These two ranges are connected by the 70 km long Paling Range.

"Beach" ridges

North of the Ooldea Range there is a succession of parallel, poorly defined ridges apparent on LANDSAT satellite imagery. They may be beach ridges that formed on a marine coastal plain, as drilling indicates the presence of widespread marine sand.

Other possible targets occur northwest of the Gawler Ranges, and include "beach" ridges and bedrock-backed embayments.

STRATIGRAPHY

The major sedimentary units of the coastal dunes are the Late Eocene or Early Oligocene Hampton Sandstone and Ooldea Sand. The former is a marine to marginally marine sand, typically 20-50m thick, that forms the core of the dunes and is laterally very extensive. The aeolian Ooldea Sand caps the Hampton Sandstone; thickness is typically 25-100 m. Both formations are mantled by red brown sand sheets and seif dunes of the Great Victoria Desert.

Both the Hampton Sandstone and Ooldea Sand are mostly quartz sand. Trace to minor amounts of heavy minerals, including tourmaline, zircon and ilmenite are generally present. Intervals containing over 2.5% of heavy minerals have been noted east of Ooldea, on the western flank of the Ooldea Range.

DELINEATION OF THE COASTAL DUNES

Topographic contour data has been the principal means of outlining these landforms, and has been fundamental in recognizing their origin. There is now excellent quality data available, including Royal Australian Survey Corps 1:50 000 scale orthophoto mosaics with 10 m contour intervals (Benbow and Crooks, 1988). These data have been reduced to compile a regional topo-contour map (1:500 000 scale, 20 m contour interval) of a large part of the region (Crooks, 1984; Benbow and Crooks, 1988). A major insight into the Cainozoic geological history of the eastern Eucla Platform has been gained by the use of these maps.

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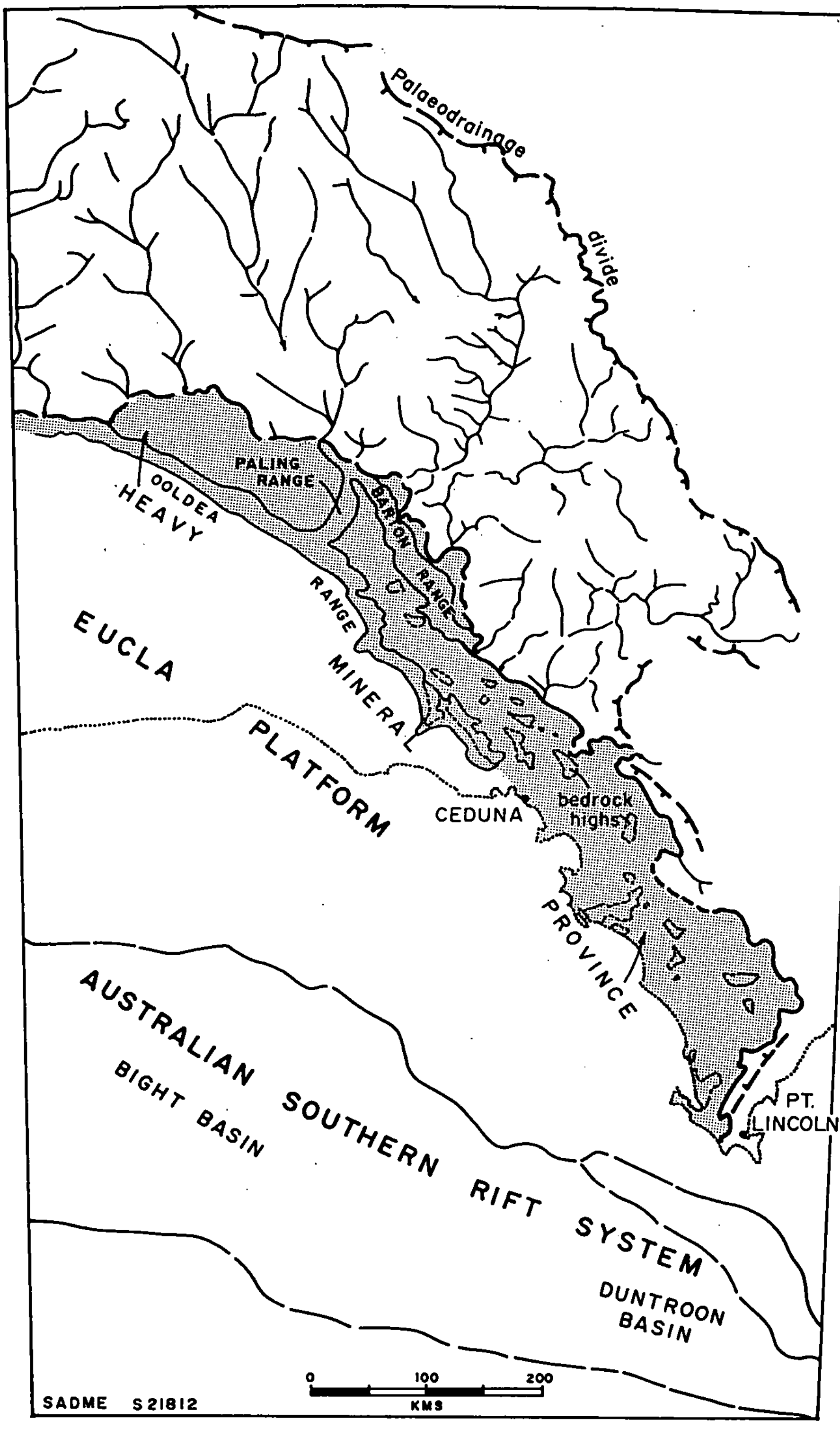

Fig.1 Setting of Tertiary coastal landforms of the eastern Eucla Platform (from Benbow et al, in preparation).

Archaean geology of the Gawler Craton, South Australia

S J Daly[1] and C M Fanning[2]
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[2]Australian National University

New isotopic data confirm that a major portion of the Gawler Craton in South Australia is composed of Archaean-Early Proterozoic continental crust. We consider the Gawler Craton to be a unique region in which to investigate the nature of the late Archaean crust not recorded elsewhere in the Australian continent. The Archaean-Early Proterozoic of the Gawler Craton has been divided into two main complexes, the Mulgathing Complex in the central and northern part of the Craton and the Sleaford Complex to the south, in Eyre Peninsula. The Mulgathing Complex is the more extensive with outcrop and subcrop exceeding 10 000 km^2. The Sleaford Complex is less extensive (~1 400 km^2) but is very well exposed along the south-west coast of Eyre Peninsula and inferred to underlie the western half of Eyre Peninsula.

The Mulgathing and Sleaford Complexes principally consist of deformed high crustal level igneous rocks (dominantly granitoids, with lesser gabbros, tonalites and minor calc-alkaline volcanics and pillow basalts), layered quartz-feldspar gneisses of uncertain origin and supracrustal sequences that have been metamorphosed to the granulite facies. The supracrustals are inferred to have been a platform sequence of shallow water sediments and volcanics deposited or extruded onto a middle Archaean basement. These include banded iron formation, calc-silicates, marble, dolomite, quartzite, pelitic sandstones, felsic volcanics and mafic dykes and sills.

The late Archaean-Early Proterozoic Sleafordian Orogeny has had a widespread effect with at least three deformational events. Peak prograde metamorphic conditions of 7-9 Kb and 700-900°C are indicated by the paragneiss assemblage; quartz - feldspar - garnet ± cordierite and quartz - feldspar ± diopside ± hypersthene ± garnet. These conditions are coincident with the third phase of deformation. Overprinting during the Proterozoic Kimban Orogeny has resulted in extensive retrogression and further deformation in many locations.

Rb-Sr total rock geochronology of granulite facies supracrustals throughout the whole Craton give isochron ages in the range 2400 - 2450 Ma with relatively high initial $^{87}Sr/^{86}Sr$ ratios of 0.704-0.706. From this data we infer that the peak metamorphic Sleafordian event occurred no later than ~2450 Ma. The timing of deposition of the supracrustal sequences can be constrained in southern Eyre Peninsula by the age of an hypersthene gneiss which is considered intrusive into the sequence at Cape Carnot. U-Pb zircon dating gives an age of 2637 ± 21 Ma which therefore is a minimum age for sedimentation. Preliminary Sm-Nd data for gneisses from both the Mulgathing and Sleaford Complexes give ε_{Nd} in the range -4 +2.5 at 2640 Ma with depleted mantle model ages (T_{DM}) between 2680 - 3070 ma. This data is interpreted as resulting from mixing of a more primitive component derived from the mantle during the early stages of the Sleaford Orogeny (~2500-2600 Ma), with an older crustal component that is inferred to form the basement to these supracrustal sequences.

Low metamorphic grade Archaean supracrustal rocks have also been identified. Calc-alkaline volcanics with tuffaceous layering and brecciated flow tops occur in one locality in the northern Gawler Craton. These volcanics have not been affected by the Sleafordian granulite facies metamorphism. U-Pb zircon dating indicates a crystallisation age of 2588 ± 6 Ma and Sm-Nd total rock analyses give T_{DM} up to ~3200 Ma with ε_{Nd} in the range -1 to +2.6 at 2560 Ma. The distribution of these little deformed volcanics and their relationship to the remainder of the Mulgathing Complex is unknown, nevertheless they provide evidence for the presence of pre-3000 Ma crust in the Gawler Craton.

Tholeiitic basalitic flows and sills, and gabbroic sills occur within the supracrustal sequences and are generally structurally concordant. The tholeiitic basalt flows contain relatively underformed relict pillows and have an ε_{Nd} value of +3.3 at 2450 Ma with a T_{DM} of 2670 Ma. The Sm-Nd data indicate that this material is a primitive addition to the crust in the late Archaean. The gabbros also have a primitive late Archaean Nd isotopic signature, with an ε_{Nd} of +1.0 and T_{DM} of 2780 Ma. The largest basalitic body is some 500m wide and 6 km long, with a subsurface aeromagnetic strike length of 16 km. Anomalous Ni and Cr contents are known for magnesium-rich metabasics. The economic potential of these mafics and the calc-alkaline volcanics has been poorly explored.

Layered quartz-feldspar gneisses are present in both the Mulgathing and Sleaford Complexes and are seen to be the dominant component of the Mulgathing Complex. These gneisses have been extensively deformed and metamorphosed to upper amphibolite grade. In places, they are interlayered with the higher grade supracrustal material and it is inferred that in these locations they represent a syntectonic intrusion of granitic composition. Elsewhere the origin of similar felsic gneisses is uncertain and metavolcanic and metasedimentary precursors have been implied. Rb-Sr rock dating records similar ages to the granulitic supracrustals and the inferred timing of peak metamorphism during the Sleafordian Orogeny, i.e. ~2450 Ma.

High crustal level granitoids were intruded during the late Archaean - Early Proterozoic. The Glenloth Granite of the Mulgathing Complex is restricted in volume and most probably derived from partial melting of the layered quartz feldspar gneisses. Preliminary single grain U-Pb zircon dating indicates crystallisation at ~2440 Ma, whilst Rb-Sr total rock analyses record an isochron age of ~2300 Ma. In southern Eyre Peninsula, the Dutton Suite was intruded into a sequence of layered quartz feldspar gneisses. The Dutton Suite has an early granodioritic phase characterised by abundant mafix xenoliths. More fractionated, megacrytic granites are dominant and form a major batholith in west south-western Eyre Peninsula. Rb-Sr total rock data have been used to imply 2300-2350 Ma ages on a regional scale, however, detailed studies on localised scales record the effects of overprinting during the Proterozoic Kimban Orogeny.

In a general sense, very broad lithological correlations can be made between the granulite facies supracrustal rocks of the Gawler Craton with those of the gneiss terrains in the Yilgarn Block of Western Australia. There are similar granitoids and calc-alkaline and basic volcanics in both, but no coherent greenstone sequence has been identified in the Gawler Craton. The age for the protoliths and timing of the dominant metamorphism do not correlate with either the Yilgarn or Pilbara Blocks and the Gawler Craton remains a unique late Archaean-Early Proterozoic terrain in the Australian shield. More importantly, direct correlations can be made with the high grade metamorphics and granitoids of Terre Adélie Land and George V Land in Antarctica. Gondwana reconstructions place the Gawler Craton in close juxtaposition with these areas and it is probable that together they formed a major Archaean terrain which to date has been little studied.

Tarcoola Goldfield

S J Daly, C M Horn and W P Fradd
Geological Survey

Tarcoola Goldfield occurs in the central Gawler Craton, 600 km north-west of Adelaide, within a sequence of folded Palaeoproterozoic sediments, c. 1650 Ma in age overlying Archaean basement. Tarcoola Formation consists of a basal pink arkosic grit, likely fluvial, with locally abundant banded iron formation fragments, overlain by laminated carbonates and thin to very thick-bedded, well-sorted quartzites, deposited on a shallow marine shelf. The quartzites are interlayered with and overlain by thin-bedded, carbonaceous and pyritic quartzites and siltstones deposited in a more restricted marine basin.

Tarcoola Formation is folded along east-west trending axes reflecting movement along Archaean basement structures. The goldfield is situated on the moderately-dipping southern limb of an easterly trending anticline. Hiltaba Suite granite c. 1580 Ma has intruded the folded sediments along a strike length of 11 kms, with a contact which crudely parallels the strike of the sediments. Large subvertical to vertical gold-bearing quartz reefs cross-cut the sediments and were emplaced following development of tension fractures, generally perpendicular to strike, by the upwardly stoping granite. The granite is locally very chloritic, may contain abundant sulphides and has been mined for gold.

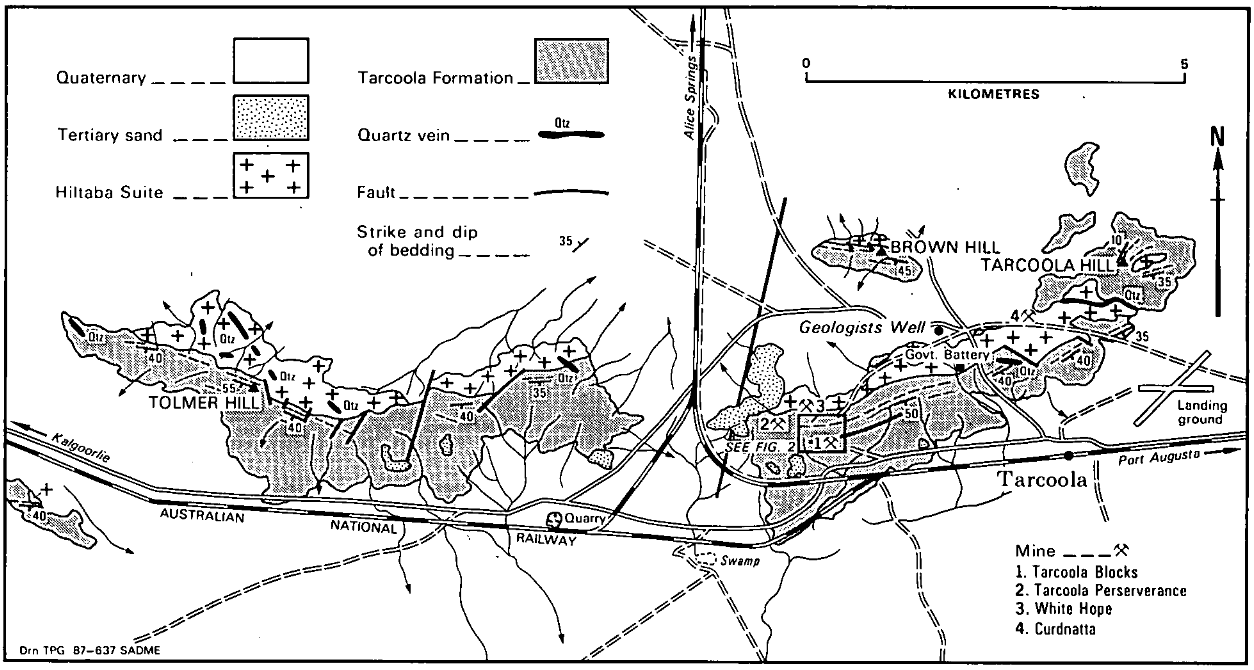
Hiltaba Suite granite, Tarcoola Formation and quartz reefs are intruded by dacitic and andesitic dykes which contain detectable gold. Gold-bearing quartz reefs are up to 2m wide, 250-300m long, with a vertical extent of at least 100m and contain abundant crushed xenoliths of quartzite and carbonaceous siltstone. Reefs have been historically described as narrower within thick-bedded quartzites and broader within thin-bedded carbonaceous siltstone and quartzites. A great deal of stoping has been done within the carbonaceous siltstones. Records suggest rich gold values have been obtained where quartz veins initially cross-cut carbonaceous siltstones. Sampling by Emperor Mines and recent drilling by Tarcoola Gold Ltd indicate gold haloes with associated sericite, chlorite and pyrite alteration also occur around quartz veins cutting quartzite. Present-day workings indicate anastomosing quartz veins of up to 20 cm width, enclosing crushed wall rock suggesting reefs were probably quartz-vein sets. Many small quartz veins which contain gold occur between the major reefs.

The ore contains not only gold but Ag, and locally abundant sulphides of Cu, Pb, Zn and As. The best recorded values are:

	Au (ppm)	Cu (ppm)	Pb (%)	Zn (%)	Ag (ppm)
Tarcoola Hill mine dump	-	2900	39.0	8.0	-
Quartz veins, Sullivan's No. 2	3.3	120	0.05	0.68	39
Quartz veins, Ward's Reef	6.8	1600	0.97	0.37	16
Quartz veins, Sullivan's No. 1	9600	670	1.6	0.07	6500

Reefs characteristically produce erratic gold values both laterally and vertically and contain both very fine-grained and coarse gold.

Between 1901 and 1986, 2.387 tonnes of gold was produced from 63 703 tonnes of ore (37.47 g/t bullion). The bulk of production occurred prior to 1918 but is still continuing on a small scale.



SAMREF: A major source of information on South Australian geoscience exploration reports

L. Gerdes, B. Eberhard and M. Griffiths
Reports Management

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SA_GEOLOGY: a digital geological map system

A J Parker
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Modern, up-to-date geoscientific maps and data sets are essential for effective exploration and land utilization. They are the fundamental database upon which all geological investigations are based, including mineral and hydrocarbon exploration, engineering site investigations, groundwater investigations, environmental management, geological research and many other forms of geological and natural resources planning and management.

Geological Map Requirements

Traditionally, geological investigations and management decisions have been based on published, multi-coloured geological maps. This is supported by a 1989 survey of map users in SA who identified, as their first priority, published geological maps at 1:250 000 and 1:100 000 scales closely followed by geological field-compilation and structure/tectonic maps.

Current manual map compilation and publication procedures within the SA Department of Mines and Energy (SADME) can only publish 8-10 geological maps per year and are inadequate to meet the growing requirement for more published geological maps. Also, there are often delays of more than two years from the time of completion of field mapping before data are readily available to the public. A further problem is that the "half-life" of a geological map is about 10 years, yet once a map is published it is generally more than 20 years before it is revised and reprinted. Therefore, to meet user requirements, we must either increase geological mapping and drafting resources or introduce new techniques, procedures and map formats.

With the ever-increasing volume of geoscientific data and the growing requirement to integrate them with various other data sets including geophysics, satellite imagery, drillhole data, soil and sediment geochemistry, mineral occurrences and vegetation, there is also an urgent need for digital geological data and data manipulation, integration and interpretation systems facilities.

A Digital Geological Map System

In 1986, SADME recognised the need for digital geological map and related data and subsequently purchased a commercial computerized geographic information system (GIS). Following preliminary data modelling and development of a pilot digital geological map SA_GEOLOGY was developed into a working system.

Creation of a digital geological map database offers a number of advantages over traditional manual mapping procedures:

- provision of digital geological map data (and GIS capability)
- greater flexibility in choice of scale, map style and attributes for output
- relatively cheap production of full-colour geological maps of publication quality
- timely provision of field compilation maps and map data
- rapid edit and update facilities
- potential time savings in map publication
- potential for rapid addition of mineral deposit data to produce a metallogenic map series
- potential for application of image processing techniques to geological map data and integration or overlaying of those data with various other data sets.

Aims

The principal aims of SA_GEOLOGY are:

- to provide a state-wide digital geological map coverage,
- to supplement published 1:250 000 geological maps, and
- to provide more detailed surficial and subsurface geological information in a form which can be easily interpreted, comprehended and integrated with other data sets.

SA_GEOLOGY must provide geological field compilation maps in a timely manner (a few months), and detailed full-colour geological maps (particularly at 1:50 000 and 1:100 000 scales) of publication or near-publication quality. It must also provide facilities for readily updating map data as new information becomes available. It is not the aim of SA_GEOLOGY to duplicate published 1:250 000 geological maps.

Digital Map Compilation Procedures

The overall geological map compilation process will remain essentially unchanged: geologists will annotate aerial photos from field observations and photo interpretation, and drafting personnel will manually transcribe that data onto photo-scale clear-film compilation maps or overlays for digitizing or scanning.

Because the primary aim of SA_GEOLOGY is to supplement 1:250 000 maps, data are captured from the most detailed source available, viz. photo-scale compilation maps. A future alternative will be to digitize directly from annotated aerial photos.

Following map digitizing and "posting" of geological linework into the main database, attribute data such as field notes, structural data, summary drillhole logs, mineral occurrences etc can be added interactively by either geologists or drafting personnel.

At any stage during the digital compilation and editing process, plots can be made either in full colour or monochrome. However, until the map database has been checked and corrected by the geologist responsible for that map, plots will not be released for public use.

Data Availability

As of December 1990, two major datasets have been compiled:

- geological map of South Australia
- detailed geological maps for the ADELAIDE and BARKER 1:250 000 map sheet areas.

The first dataset was compiled initially from the State 1:2 million Geological Map but has been substantially edited to contain not only twice as much detail as the original map but also much greater accuracy such that geological boundaries are accurate, though greatly generalized, at 1:250 000 scale. Plotted at 1:1 million scale this dataset produces a very accurate and faithful geological map of South Australia. It is also the ideal digital dataset for overlaying on or integration with Landsat TM data or regional aeromagnetic and gravity data. There is no doubt that it will be an extremely valuable dataset for anlaysis, interpretation and ground truthing of a wide range of image processed products and it may well contribute substantially to the discovery of the next major ore deposit in South Australia!

Colour plots at 1:1 million scale and digital data tapes in a variety of formats are both currently available from the Department of Mines and Energy.

Detailed computer-generated geological maps for the BARKER and ADELAIDE region are available initially as 1:100 000 scale colour plots which can be ordered from the Registration, Sales and Enquiries counter at the South Australian Department of Mines and Energy. Colour plots of specific areas at scales other than 1:100 000 can be generated on request and digital data sets are also available on request. Mineral occurrence and other information will be available shortly. Specific requests or enquiries should be directed to Dr John Parker, Chief Geologist, Regional Geology Branch (08 - 274 7615).

Research and Development

Research and development is an essential part of the SA_GEOLOGY system to investigate and/or develop new techniques and technology, for example, capturing data directly from aerial photos, producing 3-D maps/models, producing maps and associated data sets on CD-ROM, and applying image processing techniques.

The production of CD-ROM discs containing large databases to supplement published 1:250 000 geological maps and explanatory notes is seen as major goal for the future. Such discs might contain all drillhole locations and logs, all available geochemistry, geological field notes, mineral occurrence data, gravity data, aeromagnetic images, detailed digital geological map data (in vector or image form), biostratigraphic information etc and, possibly, appropriate software to access and display those data.

It is an exciting future and no doubt the 1:250 000 geological map of the year 2000 will be not only a "simple" sheet of paper but also a comprehensive computerized geoscientific information system, GEOSIS.

Copper and Gold in South Australia

R S Robertson
Mineral Resources Branch

COPPER

Production of copper has been of major importance to South Australia's economy since the discovery of the first successful metal mine at Kapunda in 1842. The Moonta-Wallaroo mines at their peak were amongst the largest copper producers in the world. Production from Olympic Dam has again made the State a significant copper producer.

Adelaide Geosyncline

Adelaidean and Palaeozoic sediments of the Adelaide Geosyncline host numerous copper occurrences, mostly vein or stratiform sulphide mineralisation. Most workings exploited concentrations of copper carbonates, oxides and secondary sulphides formed by supergene enrichment of primary sulphides.

Copper occurrences are spread through most of the stratigraphic sequence but are particulary numerous in the Callanna Group, upper Burra Group, younger Sturtian glacials, Tapley Hill Formation and early Cambrian sediments. Mineralisation is also concentrated near major faults/lineaments and diapiric breccias.

Significant deposits in the Adelaide Geosyncline include:-

Kanmantoo Chalcopyrite with minor Au and Ag occurs in a discordant, pipelike body within garnet-andalusite schist of the Cambrian Kanmantoo Group.

Production: - 4.05 million t of ore averaging about 1% Cu yielding 36 000 t of copper.

Kapunda Exploration of this historic deposit has delineated two mineralised zones in Tapley Hill formation and Brighton Limestone:

- shallow supergene oxide and sulphide mineralisation of from 9-17 million t grading 0.8% Cu
- stratiform sulphide mineralisation of tens of millions of tonnes grading less than 1% Cu.

Production: 14 500 t of copper.

Burra Secondary copper minerals occur in intensely altered Skillogalee Dolomite in faulted contact with diapiric breccia. Brecciation, alteration and emplacement of nearby syenite porphyry dykes is interpreted as Late Silurian to Early Carboniferous in age.

Production: 2.7 million t of ore yielding 90 000 t of copper.

Copper Claim Uneconomic stratiform copper sulphide mineralisation is hosted by Skillogalee Dolomite carbonaceous and pyritic siltstone, dolomite and arenite with interbedded chert and magnesite over an area of 2.5 x 1 km.

Stuart Shelf

Flatlying Adelaidean and Middle Proterozoic sediments of the Stuart Shelf host copper mineralisation and are the subject of renewed exploration interest.

At Mt Gunson copper sulphides and secondary carbonates are found in Pandurra Formation and to a lesser extent in unconformably overlying Woocalla Dolomite Member (Tapley Hill Formation) and Whyalla Sandstone, all fractured and brecciated by palaeopermafrost in a palaeoweathering profile.

The largest orebody, Cattlegrid, produced 7.5 million t of ore yielding 127 000 t of copper and 62 t of silver. Since closure of the Cattlegrid operation, Adelaide and Wallaroo Fertilizers/Adelaide Chemical Co. have produced 9300 t of copper by heap leaching of secondary ore, mostly from the 'Main' open cut.

Recently Adelaide Chemical Co. have announced their intention to mine the MG 14 orebody which contains 1 500 000 t of ore with 1.5% Cu. This orebody comprises copper sulphides in Woocalla Dolomite.

At Myall Creek uneconomic stratiform copper sulphide with lesser zinc and lead have been intersected at the base of the Tapley Hill Formation over an area of 15 x 3 km.

Willyama Inlier

High grade metamorphic rocks of the early Proterozoic Willyama Supergroup contain many copper and copper-gold occurrences. Largest of these was the Mutooroo Mine which produced about 6000 t of ore. Drilling has indicated a resource of 8.7 million t of sulphide ore with a grade of 1.8% Cu. The Dome Rock Copper Mine in the northern part of the Inlier has been the subject of recent exploration.

Gawler Craton

Moonta-Wallaroo

Situated on the eastern edge of the Gawler Craton, the Moonta-Wallaroo mining field has been the largest producer of copper in South Australia with 9 million t of ore yielding 340 000 t of copper, 3 t of gold and 5 t of silver mainly between 1860 and 1923. Mineralisation comprises copper sulphides associated with quartzose and pegmatitic veins infilling numerous fractures in Moonta Porphyry (Moonta) and Doora Schist (Wallaroo). Moonta Porphyry has been dated at 1740 Ma (Fanning et al., 1988) and Doora Schist may be of similar age.

Poona Lode (Moonta Mining N.L.)

In 1988 open cut mining commenced on the Poona copper-gold lode, found in 1985 using Sirotem near the historic Poona Mine north of Moonta. Drilling outlined 180 000 t of ore averaging 7.1% Cu and 2.0 g/t Au. Host rock is Moonta Porphyry. Primary ore consists of chalcopyrite-pyrite-bornite in a quartz-tourmaline-chlorite gangue. Chalcocite and covellite occur in a zone of pronounced supergene enrichment capping the orebody. Ore is transported to a flotation plant at Kadina which produces a copper concentrate.

Mining will commence soon on another resource of copper-gold mineralisation at Wheal Hughes, 2 km south of Poona. This mineralisation was also first located using Sirotem.

Olympic Dam (WMC - BP)

The Olympic Dam deposit is one of the largest known accumulations of metals in the world. The measured and indicated resource of 450 million tonnes contains:

- 2.5% Cu - 11 million t contained metal
- 0.8 kg/t U_3O_8 - 360 000 t
- 0.6 g/t Au - 270 t
- 6 g/t Ag - 2 700 t

Production from the mine and metallurgical plant is now nearing planned capacity.

		Copper (t)	U_3O_8 (t)	Au (gms)	Ag (gms)
Production:	Year to 30/6/89	16 868	912	65 410	-
	Year to 30/6/90	37 799	1004.5	563 804	1 315 159

Mineralisation comprises disseminated chalcocite, bornite, chalcopyrite pitchblende and minor free gold hosted by hydrothermally altered, granite-hematite breccias. These breccias are now thought to be of hydrothermal origin although clasts of laminated sediments and tuffs are present. The mineralised breccias occur within an undeformed, alkali feldspar-rich granite of the 'Olympic Dam Suite' (Olympic Dam Operations, 1988).

Zircon U-Pb geochronology of the 'Olympic Dam Suite' has yielded ages of 1613, 1590, 1576 Ma comparable to that for the Gawler Range Volcanics - (1592 Ma). and Hiltaba Suite granitoids (Mortimer, et. al., 1988).

GOLD

Gawler Craton - Willyama Inlier

Magmatism of similar age and geochemistry to the 'Olympic Dam Suite' granitoids is widespread in South Australia eg. the extensive Gawler Range Volcanics and Hiltaba Suite granites of the Gawler Craton and uranium mineralised granitoids of the Willyama Inlier. Hydrothermal systems associated with this magmatism are an obvious target for exploration for Cu, Au and U (Wyborn, et al., 1987; Mortimer, et al., 1988).

At the Tarcoola Goldfield, gold mineralisation is associated with a pluton of Hiltaba Suite granite. Gold is found in quartz veins crosscutting both Mid Proterozoic sediments and the nearby granite. A small resource (178 500 t at 5.18 g/t Au) has been defined on part of the goldfield. It is possible that a treatment plant could utilize ore from several small to medium size deposits at Tarcoola and perhaps from other deposits in the region such as the Glenloth Goldfield and Earea Dam (90 000 t at 7.84 g/t Au).

Adelaide Geosyncline

Occurrences of reef gold are found throughout the Geosyncline, particularly associated with tectonic flexures caused by deep seated fracturing, for example in the Nackara Arc. Deposits occur mainly within the Umberatana and upper Burra Groups. Many deposits are found in fractured quartzite and sandstone associated with folding and faulting and with major lineaments visible on remote sensing imagery.

Gold may have been derived from the following sources within the Geosyncline:

- hydrothermal fluids from deep seated fracture zones
- 'sweating out' of the sedimentary pile during regional metamorphism
- remobilised placer deposits derived from fluvio-glacial sediments (Morris and Horn, 1988)

Gold-Copper Association

The presence of gold in many of South Australia's numerous copper deposits has, in the past, either gone unrecognised or was of too low a grade to be of interest at prevailing prices. The exploration potential for Cu-Au orebodies at old copper mining areas is instanced by:

- Moonta-Wallaroo 9 million t ore contained 0.34 g/t Au (recovered)
  Poona Lode 180 000 t at 7.1% Cu and 2.0 g/t Au.

- Kanmantoo - recent assays of old drill core, not previously assayed for gold, disclosed 16 m of 0.9 g/t Au, including 2m of 5.1 g/t.

The Kanmantoo Trough has gold associated with many old copper, lead, zinc and silver mines. Several copper deposits of the Willyama Inlier also have significant gold.

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Note: Reference lists for many of the deposits mentioned are in SADME Special Publication, No. 8.

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