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# INDUSTRIAL MINERALS IN SOUTH AUSTRALIA, CURRENT OPERATIONS AND FUTURE TRENDS

GEOLOGICAL SURVEY

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# INDUSTRIAL MINERALS IN SOUTH AUSTRALIA, CURRENT OPERATIONS AND FUTURE TRENDS

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## ABSTRACT

The State of South Australia covers approximately one-eighth of the area of the Australian continent and has a substantial record as a major supplier of industrial minerals, mainly to Australian markets. Commodities produced from well-established operations include limestone, dolomite, salt, gypsum, dimension stone, barite and talc. South Australia has been a principal world supplier of gem opal since the 1930s and continues to maintain a high level of production from an industry based on individual enterprise. Nephrite jade is produced from deposits in the 'Cowell Jade Province' now recognised as being of world significance.

Growth in the industrial minerals industry is tied to securing additional markets, to commercial development of known deposits and the discovery of further resources. To this end, established producers have taken advantage of export opportunities for gypsum, salt and dolomite. New developments include a graphite processing plant at the former Uley Graphite Mine and trial mining of micaceous iron oxide for pigments. Proposals include building a rare earths processing plant at Port Pirie, expansion of carbon dioxide production through development of the recently discovered Katnook gasfield, and a new venture in gypsum mining for plasterboard manufacture.

Possible large resources of gypsum, kaolin, wollastonite and palygorskite, undergoing feasibility studies, require market outlets, new process technology or economic transportation to ensure development. Industrial mineral exploration in the State is focused currently on heavy mineral sands, diamonds and celestite.

## INTRODUCTION

The State of South Australia covers an area of 984 377 km$^2$, approximately one-eighth of the area of the Australian continent. The population of 1.4 million are settled mostly adjacent to the coast with over 70% residing in the capital Adelaide. In proportion to area and population, South Australia historically has been a major supplier of industrial minerals to mainly local Australian markets especially for limestone, dolomite, salt, gypsum, dimension stone, barite and talc. Total non-metallic mineral production in 1988 was $A171 million, 18% by value of all minerals produced in the State (Fig. 1). Individual commodities listed in Table 1 highlight the substantial contribution made by construction minerals and gemstones. The official figures however understate the relative value of non-metallic minerals and fail to reflect their true contribution to the economy. This arises from a more literal interpretation of ex-mine value when applied to non-metallics than to other minerals and often excludes value added by even the most basic processing. As such, values reflect substantially the costs of extraction only, irrespective of the commodity and market price, and cannot be compared directly with the delivered or ex-site value of metallic or fuel minerals which invariably include significant beneficiation or refining.

There is a growing awareness of the potential value of industrial minerals largely as a result of export successes in other Australian States, in particular the expansion of the heavy mineral sand industry, in *CRA's* developments in salt, diamonds, kaolin and heavy minerals and *WMC's* marketing of talc.

Table 1. Non-Metallic mineral production in South Australia, year 1988

| Commodity | Production (tonnes) | Value (a) ($A) |
|---|---|---|
| **Construction Minerals** | | |
| Aggregate & Rubble | 12 691 953 | 61 747 000 |
| Sand | 3 434 821 | 17 480 000 |
| Clay (b) | 621 218 | 1 756 000 |
| **Gemstones** | | |
| Opal | - | 63 600 000 |
| Jade (kgs) | 9 010 | 441 000 |
| **Industrial Minerals** | | |
| Barite | 9 842 | 421 000 |
| Carbon Dioxide | 26 600 | 322 000 |
| Dimension Stone | 34 217 | 3 344 000 |
| Dolomite | 807 680 | 3 539 000 |
| Feldspar | 3 982 | 12 000 |
| Gypsum | 1 277 183 | 3 495 000 |
| Kaolin (c) | 16 458 | 574 000 |
| Limestone | 1 917 765 | 7 687 000 |
| Magnesite | 3 117 | 27 000 |
| Mica | 128 | 14 000 |
| Micaceous Iron Oxide | 34 | 14 000 |
| Phosphate | 5 997 | 54 000 |
| Salt | 876 599 | 4 412 000 |
| Silica | 96 773 | 1 030 000 |
| Sillimanite | 64 | 7 000 |
| Talc | 18 840 | 1 413 000 |
| Total Value of Non-Metallic Minerals | | 171 389 000 |

Source - Mineral Production Statistics SADME

(a) Adopted ex-mine value.

(b) Clay and shale used mainly in brick and cement manufacture.

(c) Includes 'kaosil' (mixed kaolin and sillimanite ore)

The volume of South Australian industrial mineral exports is small by comparison and is mainly in specialised minerals such as 'kaosil' (kaolin/sillimanite ore) and in opportunity sales of bulk commodities mined principally for local consumption.

Given the strong industrial mineral base in South Australia and a favourable geological environment for a wide range of industrial minerals, it is anticipated that open-minded exploration will add substantially to the resources already identified. The discovery and development of these resources together with a reassessment of the potential of known deposits, with a view to global markets, are the challenges which are only beginning to be addressed in this State. The aim of this paper is to provide a background to the industry through a description of existing operations and a brief review of new developments and current exploration. Construction minerals while very significant to the local State economy are not discussed, but the major producers are included in Table 2.

Table 2. SUMMARY OF NON-METALLIC OPERATIONS

| COMMODITY | MAJOR DEPOSITS | COMPANY |
|---|---|---|
| CONSTRUCTION MINERALS | | |
| Aggregate | Mount Lofty Ranges | Quarry Industries/Boral, Readymix (CSR) White Rock Quarries, Southern Quarries |
| Sand | Golden Grove, Maslin Beach, Gawler | Amatek, Readymix (CSR), Christies (Hallett), Quarry Industries |
| Clay | Golden Grove | Monier PGH, Nubrik, ABC Ltd |
| GEMSTONES | | |
| Opal | Coober Pedy, Mintabie, Andamooka | Numerous syndicates and individuals |
| Jade | Cowell | Gemstone Corp of Australia. |

TABLE 2 (cont.)

| COMMODITY | MAJOR DEPOSITS | COMPANY |
|---|---|---|
| INDUSTRIAL MINERALS | | |
| Barite | Oraparinna, Dunbar | Commercial Minerals Ltd |
| Carbon Dioxide | Caroline 1 | Liquid Air Aust Ltd |
| Dimension Stone | Granite: Black Hill, Calca | Amatek Ltd, Martins Granite Quarries, Calca Granite Pty Ltd |
| | Slate/Flagstone: Mintaro, Kanmantoo, Wistow, Jones Hill | Mintaro Slate Quarries, Albern Slate, Mt Barker Wistow Slate, Parachillna Slate |
| | Limestone: Mount Gambier | Bruhn Distributors, Stafford & Earl |
| Dolomite | Ardrossan<br>Tantanoola | BHP Ltd<br>ACI Resources ltd |
| Gypsum | Lake MacDonnell | Gypsum Resources Aust (CSR/Boral) |
| | Kangaroo Island | CSR Ltd |
| | Marion Lake | Waratah Gypsum Ltd (Boral) |
| | Lake Fowler | ABC Ltd |
| | Blanchetown | David Linke Contractor Pty Ltd |
| Kaolin | Williamstown<br>Birdwood | Commercial Minerals Ltd<br>ABC Ltd |
| Limestone | Penrice<br>Klein Point, Rapid Bay<br>Coffin Bay<br>Caroline, Parham | Penrice Soda Products<br>ABC Ltd<br>BHP Ltd<br>ACI Resources Ltd |
| Magnesite | Myrtle Springs | Commercial Minerals Ltd |
| Salt | Dry Creek<br>Price, Lochiel<br>Whyalla<br>Lake MacDonnell | Penrice Soda Products<br>Cheetham Salt Ltd<br>Pacific Salt Pty Ltd<br>Diamond Salt Pty Ltd |
| Silica | Glenshera<br>Whyalla | ACI Resources Ltd<br>BHP Ltd |
| Talc | Mount Fitton | Commercial Minerals Ltd |

## GEMSTONES

South Australia has an international reputation as 'The Opal State' and has been a major supplier of gem opal since 1915. The State also boasts large reserves of nephrite jade and in recent years has carved out a reputation as a source of

premium quality black jade. Intermittent, small quantities of gem chrysoprase are mined from deposits near Mount Davies by the local Pitjantjatjara people on aboriginal lands in the State's northwest.

**Opal**

Australia produces over 90% of the world's precious opal and the bulk of this (60-70%) is mined from opalfields in South Australia (Barnes and Townsend, 1982). Production of opal rough from South Australia in 1988 was estimated conservatively at $A63 million much of which was sold on the fields direct to agents of gem processing establishments in South East Asia, principally Hong Kong. Coober Pedy (established 1915) is the heart of the opal industry and is a major outback town in the State's arid interior, 935 km north of Adelaide. Mintabie (reworked since 1976) is a further 340 km by road northwest of Coober Pedy and for the past 10 years has rivalled the more established field in production and quality, producing significant quantities of prized black opal. Andamooka (established 1930) is 640 km by road north of Adelaide and is a smaller but consistent producer of quality gem opal.

Opal is found as thin veins and cavity fillings in weathered shale and sandstone where silica, released during weathering of overlying sedimentary rocks was deposited at deeper levels where physical conditions suited silica precipitation. Depth to the opal level varies from 5 to 30 m.

Mining is mostly by small syndicates or partnerships using open cut and underground methods. Equipment ranges from heavy bulldozers to hand tools with an unusual array of purpose built or adapted equipment including large diameter (up to 1.2 m) bucket drills for shaft sinking, underground tunnelling machines and suction conveyors (blowers) to remove waste rock from underground workings (Keeling, 1980).

**Nephrite Jade**

The discovery, in 1965, of nephrite jade, 20 km northwest of Cowell on the east coast of Eyre Peninsula led to the identification of a major province of dolomite-hosted nephrite jade in Middle Proterozoic metamorphic rocks (Barnes and others, 1980). The Cowell Jade Province includes over 120 individual jade outcrops with indicated resources of 200 000 tonnes of jade to 10 m depth. This represents one of the largest jade deposits ever recorded and is currently the only source of high quality black jade. The deposits are mined by *Gemstone Corporation of Australia Ltd* using open cut methods and employing a hydraulic rock breaker to pick from the quarry face individual jade pods weighing several tonnes. Production in 1988 was 9 tonnes.

## BARITE

South Australian barite production is dominated by *Commercial Minerals Ltd* who in 1988, produced 9 560 tonnes from mines at Oraparinna and Dunbar northeast of Hawker in the Flinders Ranges. The remaining 282 tonnes were produced from 5 small intermittent operations also in the Flinders Ranges. Of 160 known occurrences or deposits in South Australia, all but a few are vein deposits hosted by Adelaide Geosyncline sedimentary rocks in the Mount Lofty and Flinders Ranges. Strata bound occurrences of low grade barite hosted by Early Proterozoic metasediments have been recorded from the Olary area, 350 km northeast of Adelaide.

**Oraparinna**

Production commenced at Oraparinna, 500km north of Adelaide, in 1940, and *Commercial Minerals Ltd* have operated the deposit since 1984, continuing the mine's long history as Australia's largest supplier of industrial grade barite. The mine, comprising seven underground levels, works a system of veins averaging 1 to 2m wide which have developed in tensional

fractures within Wilpena Group sediments of Adelaidean age in a graben structure extending from the northeastern corner of the Oraparinna diapir (McCallum, 1990a). Ore is extracted by leading stoping and is removed to stockpiles using a 20 tonne dump truck. A road train hauls the ore 160km to a treatment plant at Quorn.

**Dunbar**

The deposit is approximately 15km southwest of the Oraparinna mine and is worked by an open cut on a 35m wide sub-parallel vein system about 500m in length. Individual veins up to 9m wide have been exposed. The lode is enclosed in a 'raft' of Adelaidean sediments within the Oraparinna diapir. Iron staining is common throughout the deposit and the ore is suitable only for oil drilling grades.

**Quorn Mill**

Milling operations are carried out at Quorn, 160km southwest of the Oraparinna mine. Ore is crushed and screened into minus 8mm plus 3.2mm, minus 3.2mm plus 2.5mm, and minus 2.5mm fractions. The two coarser fractions are concentrated on a 2.1 x 0.76m May double-sided jig, and the minus 2.5mm fraction on Wilfley tables.

After de-watering, concentrates are dried by oil burner and ground in a roller mill which operates in closed circuit with a 1.2m dry cyclone. Underflow is recycled and overflow passes through a 10 cyclone filter system before bagging. Routine testing of all industrial grades is by electro reflectance photometer, and oil drilling grades by specific gravity determination (Valentine, 1989).

## CARBON DIOXIDE

*Liquid Air Australia Ltd* extracts and markets carbon dioxide from commercial flows intersected in Caroline 1, a petroleum exploration well drilled during 1966-67 by *Alliance Oil Development Australia NL* in the lower southeast of the State. Carbon dioxide is produced through perforated casing from three zones between 2516-2841 m.

The gas is thought to have originated from volcanic and post-volcanic emanations from Holocene volcanoes in the Gambier Embayment. At Caroline, entrapment of carbon dioxide in Middle Cretaceous Waarre Formation was facilitated by faulting and the presence of over 300 m of impervious caprock, the Belfast Mudstone (Wopfner and Thornton, 1971; Mulready, 1977).

Since 1968, the well has produced almost 300 000 tonnes of $CO_2$ with a current production rate of 73 tpd. The raw gas has a composition of almost 99% $CO_2$ with traces of hydrocarbons, mostly methane, and other gases. Purification and liquefaction is completed in a treatment plant on site and liquid $CO_2$ is transported in pressurised road tankers to Adelaide and Melbourne for distribution. Principal markets are aerated beverages, fire fighting, welding processes in motor vehicle manufacture and medical uses.

Natural gas flows with up to 55% $CO_2$ were recorded in Ladbroke Grove 1 exploration well drilled in May 1989 by *Ultramar Australia Inc.* The well is in the recently discovered Katnook natural gas field, 60 km north of Caroline 1. Commercial extraction of methane from the field would increase substantially available supplies of carbon dioxide.

## DIMENSION STONE

South Australian quarries currently supply about 15% of Australia's dimension stone output. They include 'Imperial Black Granite' and 'Austral Black Granite' (Black Hill) and 'Calca Red Granite' (Calca, Eyre Peninsula) as well as the bulk

of Australia's slate and limestone production. Extensive use of local natural stone in New Parliament House, Canberra and in other major developments have provided sufficient increased demand to underpin substantial modernisation of the Australian stone processing industry. Demand for a broader range of products has stimulated exploration and at least 5 new granite quarries, a green granite near Padthaway and brown, red and pink granite on northern Eyre Peninsula, are proposed for development in the State.

**Black Hill**

Since 1947, 'Black Granite' has been mined from a massive hypersthene gabbro (norite) at Black Hill, 85 km east-northeast of Adelaide. Currently, 2 companies *Amatek Ltd* and *Martins Granite Quarries Pty Ltd* account for the 6 000 tpa output which is used principally for decorative cladding. A third company, *Calca Quarries Pty Ltd* has recently commenced production. Quarry blocks up to 13 x 4 x 3 m are drilled and then freed using plug and feather. These are reduced on site to 7 tonne blocks for road transport to Adelaide or interstate for sawing and polishing.

**Calca**

Mining of red granite from Calca, 35 km southeast of Streaky Bay, commenced in 1975. Quarries operated by *Calca Granite Pty Ltd* and *Amatek Ltd* produce about 4 000 tpa which has been sold mostly to *Melocco Ltd (Boral)* in Canberra for sawing, polishing and marketing. Blocks 10 x 10 x 3 m are cut out on the quarry bench using a flame cutter. These are undercut by horizontal drillholes and loosened by electrical detonation of black powder packed in alternate holes. Drilling and wedging are used to split off marketable blocks weighing between 7-11 tonnes.

**Slate**

Production of paving slate from Mintaro commenced in 1856. The slate is a laminated siltstone of Late Proterozoic age and splits along bedding with a natural parting of between 15-50 mm. *Mintaro Slate Quarries Pty Ltd* produce traditional paving and walling slate and special architectural orders but the quarry is renowned as a source of premium slate for billiard table tops. Slate for tiles, walling and paving has been produced since 1976 from the Jones Hill mine in the northern Flinders Ranges and over 5 000 tonnes of walling and paving slate are produced annually from quarries at Wistow and Kanmantoo, 50 km southeast of Adelaide.

**Limestone**

Massive, highly permeable Tertiary bryozoal limestone from the Gambier Embayment has been quarried as a relatively low cost building material since 1842. Building blocks (ashlars) are cut in situ using carbide tipped circular saws. Five independent quarry operations, west of Mount Gambier, produce between 10-15 000 tpa of ashlars. Half the production is used in local housing and the remainder is marketed mostly in country areas of central and western Victoria.

## DOLOMITE

South Australia produces about 95% of Australia's industrial grade dolomite, mostly for use as metallurgical flux. In 1988, 808 000 tonnes were produced of which 187 000 tonnes were exported to Japan. The principal producers are *BHP Ltd* at Ardrossan on Yorke Peninsula and *ACI Resources Ltd* at Tantanoola in the southeast of the State. Small quantities of dolomite from Tantanoola and nearby Mount Gambier are sold for agricultural use.

**Ardrossan**

*BHP* commenced quarrying at Ardrossan in 1950 and the 7-bench quarry currently produces about 0.75 million tpa of lump dolomite from indicated reserves of 20 m. tonnes. The quarry is sited in a broad syncline of Early Cambrian Kulpara Limestone which comprises a pale yellow dolomite becoming grey and less dolomitic with depth. The ore is drilled, blasted, loaded and carted 2.4 km to the crushing plant adjacent to ship loading facilities. Two screened products are produced; minus 38 mm, plus 16 mm, and minus 25 mm plus 7 mm, both with a minimum MgO content of 20%. Silica is the principal contaminant and maximum $SiO_2$ content between 1.2-1.7% is specified by the customer. Fines are sold for sinter flux and for dolomite fluxed pellets. Products are shipped to basic oxygen steelmaking furnaces at Whyalla (South Australia), Port Kembla and Newcastle (New South Wales). Opportunity exports to Japan are made when exchange rates are favourable.

**Tantanoola**

*ACI's* Tantanoola quarry is sited in an irregular zone of dolomitization within Tertiary Gambier Limestone and has been worked for glassmaking flux since the early 1960s. Production of 33 000 tonnes, in 1988, is from limited reserves of 400 000 tonnes. Quarried rock is tipped over a 30 mm screen and the oversize is crushed and screened in closed circuit to produce a minus 3 mm final product. This is blended to give an average grade $CaCO_3$ 57.5%, $MgCO_3$ 42%, $SiO_2$ 0.3%, $Fe_2O_3$ 0.25%. Blended product is dispatched by rail or road to *Pilkington ACI* and *ACI Fibreglass* in Melbourne for use as a flux in manufacture of plate glass and fibreglass. The reject minus 30 mm rock is re-screened at 3 mm and sold for agricultural dolomite.

**GYPSUM**

South Australia dominates the Australian gypsum industry, with 1988 production totalling 1.28 m. tonnes. Of this, 60% was shipped to the eastern States where almost all gypsum used in plaster and cement manufacture is of South Australian origin. Overseas exports, principally to Japan, New Zealand and the United States totalled about 220 000 tonnes. Of over 40 deposits investigated within the State, 18 are currently producing. Many of these are small inland lake deposits within the Murray Basin and are worked mainly for agricultural gypsum. Blanchetown, the largest of the Murray Basin deposits, is mined by *David Linke Contractor Pty Ltd* and supplies about 35 000 tpa mainly for manufacture of plaster and cement within the State.

The largest reserves of gypsum are in barred basin deposits close to the present coastline and include:

- Lake MacDonnell on the northwest coast of Eyre Peninsula, which is mined by *Gypsum Resources of Australia Pty Ltd.*
- Marion Lake and Lake Fowler on Yorke Peninsula which are worked by *Waratah Gypsum Ltd* (a *Boral* subsidiary) and *Adelaide Brighton Cement Ltd.*
- Salt Lake and New Lake on Kangaroo Island were formerly worked by *CSR Ltd.* Reserves are now exhausted but the company draws from a large stockpile at Ballast Head with about 6 years supply.
- Bielamah deposit, 36km west of Ceduna is to be opened by *Pioneer International Pty Ltd* in a joint venture with *Lafarge Coppee* to manufacture plaster board.
- Streaky Bay deposit with reserves of 50 m. tonnes has been actively promoted by *Bay Gypsum Pty Ltd* but remains undeveloped, partly due to the lack of port facilities in the area.

**Lake MacDonnell**

Australia's largest gypsum mine is at Lake MacDonnell which produces almost 1m.tpa from an indicated resource of 575 m. tonnes. In 1984, Australia's two major plaster manufacturers *CSR Ltd* and *Boral Ltd* combined their separate operations at Lake MacDonnell to form *Gypsum Resources of Australia Pty Ltd.*

The deposit formed in an embayment between calcareous aeolian coastal dunes of Pleistocene Bridgewater Formation. The embayment was cut off from direct marine connection about 6 000 years BP and gypsum deposition commenced by solar evaporation of seawater derived brines entering through the surrounding porous aeolianite (Warren, 1983).

The deposit averages 3.9m thick with a maximum thickness of 8m. Most of this is selenite (rock gypsum) which is overlain by up to 1m of crystalline gypsarenite and 0.2-0.3m of fine gypsum silt. The gypsum silt overburden is removed by bulldozer and the exposed gypsarenite is left to be leached of salt by rainwater and is then bulldozed into stockpiles and left for further leaching. Rainfall is low and unpredictable (average 320mm pa) so a total leaching time of 2-3 years is required before gypsum meets plaster grade specifications of, gypsum minimum 93%, NaCl maximum 0.02%.

The underlying selenite is mined from a gypsum saturated brine pond of about 16% salinity by drilling, blasting and removing the shot material with a dragline which sits above the watertable atop the unmined gypsum. Selenite is crushed and screened then stockpiled and left to leach. Some is blended with gypsarenite for plaster grades but most is sold for cement manufacture. Typical rock grade is gypsum, minimum 98.5%, NaCl, maximum 0.5 -0.6%. Stockpiles are tested regularly and when sufficiently leached of salt, the gypsum is railed 70km to shipping facilities at Thevenard near Ceduna.

## KAOLIN

Two small primary kaolin deposits are currently mined in the Mount Lofty Ranges at Williamstown and Birdwood, 40 km northeast of Adelaide. Sedimentary kaolin (semi-ball clay) is mined from thin discontinuous lenses interbedded with sand and silt in remnants of Tertiary continental deposits to the north and south of Adelaide. The bulk of production is used in brick clay blends but small tonnages are used as refractory bond clay. Company exploration over the past 20 years has outlined large geological resources of moderate to high brightness kaolin in weathered Proterozoic rocks on Eyre Peninsula. Deposits near Mount Hope (*Caledon Resources Group*) and Streaky Bay (*Petroleum Engineering Services Pty Ltd*) have undergone initial evaluation for coating markets but require upgrading to improve viscosity characteristics. Methods of beneficiation are being investigated.

### Williamstown

This unusual mineral deposit comprises an elliptical, pipe-like body of hydrothermally-altered sillimanite. The resulting mixture of sillimanite and kaolinite ore 'kaosil' (40-48% $Al_2O_3$) has been mined since 1900 and has produced almost 200 000 tonnes for refractories (Barnes and Olliver, 1989). The deposit also produces by-product white, filler-grade mica and massive sillimanite. Annual 'kaosil' production of some 5 500 tonnes is mostly exported principally to the UK (*MPK Insulators Ltd*) and to Taiwan and New Zealand. Massive sillimanite boulders are calcined using a 'top hat' kiln and air quenched to aid decrepitation before crushing, milling and screening. The entire output of 300-500 tpa is purchased under agreement by *Refcrete Services Pty Ltd*, a Western Australian refractory manufacturer. The Williamstown mine was recently acquired by *Commercial Minerals Ltd* following an asset selloff of the *Ausmintec Group* in October 1989.

**Birdwood**

Crystalline, massive kaolinite formed by intense weathering of folded biotite schist is selectively mined at Birdwood by *Adelaide Brighton Cement Ltd.* Kaolin is blended with white marble from Penrice quarry to manufacture a specialty off-white cement marketed throughout Australia as 'Brightonlite'. Small tonnages of kaolin from adjoining tenements held by *Hallett Brick Industries* have in recent years been mined and dry milled by the *Ausmintec Group* for local and interstate filler markets. Production from Birdwood deposits averages 5-6 000 tpa.

## LIMESTONE

In 1988, South Australia produced 1.9 m. tonnes of limestone for industrial use. Of this:

- 70% was used to manufacture cement clinker, representing about 15% of Australia's cement production
- 25% was used in the manufacture of soda ash at Australia's only Solvay process plant at Osborne, Adelaide
- 5% was used as metallurgical and glassmaking flux, as a filler in paint and plastic, and as agricultural lime.

Principal limestone operations are:

- Penrice (*Penrice Soda Products)*
- Klein Point (*Adelaide Brighton Cement Ltd)*
- Rapid Bay (*Adelaide Brighton Cement Ltd)*
- Coffin Bay (*BHP)*
- Caroline (*ACI Resources Ltd)*
- Parham (*ACI Resources Ltd)*

**Penrice**

In 1950, *ICI* opened a quarry in white marble at Penrice, near Angaston as a source of carbonate for their Solvay process, soda ash plant at Osborne, Adelaide. The coarse, crystalline

Cambrian marble is steeply dipping and comprises a high-grade central zone ($CaCO_3$ 95-98%) flanked by narrower, lower grade zones ($CaCO_3$ <95%) containing interbedded calcsilicate units (Scott, 1982). Annual production exceeds 1 m. tonnes of which about 50% is railed to Osborne and 20% is sold to *ABC Ltd* for cement and lime manufacture at their nearby Angaston plant. The remainder is sold to *Commercial Minerals'* Beverly plant for fillers, to *ACI Pilkington* for glass flux, to *BHP* and *Mitsubishi* for foundry flux and elsewhere for agricultural uses and roadmaking. In 1989, *ICI* withdrew from soda ash manufacture, and the Osborne plant, Dry Creek salt deposits and Penrice quarry were sold to *Penrice Soda Products Pty Ltd*, who have continued the operation.

**Klein Point**

The *Adelaide Cement Co* opened limestone quarries in the Stansbury-Klein Point area in 1914. The company merged with the *South Australian Portland Cement Co* in 1971 to form *Adelaide Brighton Cement Ltd* which in 1988 quarried 840 000 tonnes of Tertiary fossiliferous calcarenite at Klein Point from indicated resources of some 200 m. tonnes. The deposit is variably consolidated and is worked to produce an average grade of total carbonates 88% with maximum $SiO_2$ 12%, MgO 2% and Chloride 0.08%. The limestone is mined in four benches by cross-ripping and dozing down 25° faces for recovery on a lower bench. This is fed to a hammer mill and the crushed rock is stored or loaded directly to ship. Shipments, averaging 5 000 tonnes are made across St Vincent Gulf, in *ABC Ltd's* ship MV *Accolade II*, to the company's Birkenhead cement plant.

**Rapid Bay**

Rapid Bay quarry, formerly operated by *BHP* for metallurgical flux, was purchased by *ABC Ltd* in 1981 to supplement shipments from Klein Point to the Birkenhead works. The deposit is in Cambrian marble of average grade $CaCO_3$ 90.5%

but the hard rock has higher mining costs than those at Klein Point and as a result only 91 000 tonnes were produced in 1988. Reserves of marble are large, and upgrading existing wharf and berthing facilities is under consideration so that 30 000 tonne displacement vessels could be loaded for shipment interstate for local cement production.

**Coffin Bay**

Limesand from enormous reserves in coastal dunes at Coffin Bay has been worked by *BHP* since 1966, originally for blast furnace flux at Whyalla steelworks and today as flux for the Port Pirie lead-zinc-silver smelters. Limesand of average grade $CaCO_3$ 91% is dug directly from the dune with an RB54 electric shovel, and railed to shipping facilities at Proper Bay near Port Lincoln. Production in 1988 was 17 000 tonnes.

**Caroline and Parham**

*ACI Resources Ltd* mine Tertiary limestone at Caroline in the State's southeast and shellgrit from coastal deposits at Parham, 60 km north of Adelaide primarily as a source of low iron limestone for glass manufacture. At Caroline, fossiliferous calcarenite is mined by elevating scrapers and crushed and milled on site before dispatch by road to *Australian Glass Manufacturers* (*AGM*) and *ACI Fibreglass*, Melbourne plants. Crushed limestone is sold to *Commercial Minerals Ltd* for milling to produce filler grades and small quantities are sold for agricultural uses. In 1988, 40 000 tonnes of glass grade limestone was produced.

At Parham, unconsolidated, Holocene, shellgrit beach deposits are mined by scraper and screened, dried and crushed on site using a hammer mill and rolls crusher. Product is dispatched by road to Adelaide for glass manufacture at *AGM's* Croydon plant. In 1988, 14 000 tonnes were mined.

## MAGNESITE

In 1988 South Australia produced 3 117 tonnes of magnesite, about 4% of Australia's production. The Myrtle Springs deposit near Copley in the Flinders Ranges is the State's most important deposit, accounting for about 40% of total production. The deposit is mined for *Commercial Minerals Ltd* who mill the ore at Gillman and produce caustic magnesia in Melbourne.

In the past this and other deposits in the vicinity have been used as a source of magnesite for pharmaceuticals and refractories.

The Myrtle Springs deposit is within the Skillogalee Dolomite, a unit which is widespread in the Adelaide Geosyncline and in which thin interbeds of sedimentary magnesite or magnesite conglomerate are relatively common. Thickest magnesite development is in a zone extending for 110km northwesterly from Leigh Creek. Individual magnesite beds are relatively thin, generally less than 4m thickness, but can be traced for several kilometres along strike (McCallum, 1990b). Geological mapping of one deposit near Leigh Creek recorded 60 beds ranging from 50mm to 3m thick in a zone 300m wide.

Development is hampered by remoteness of the deposits and their thinly bedded nature. The principal impurity is silica, which commonly comprises between 1 and 15% of the magnesite beds.

## SALT

All South Australian salt is produced by solar evaporation of sea water or saline lake water. In 1988, 0.88 m. tonnes were produced, of which almost 0.6 m. tonnes were consumed in soda ash production and 0.2 m. tonnes exported in bulk to Japan, New Zealand and Malaysia (Valentine, 1989). South Australia only produces about 12% of Australia's salt but supplies about 60% of domestic requirements. Western Australia is the major producer, about 80% of Australian production, almost all of which is

exported to Asia, United States, Nigeria and Brazil. Principal South Australian producers are:

- Dry Creek (*Penrice Soda Products)*
- Price and Lochiel (*Cheetham Salt Ltd)*
- Whyalla (*Pacific Salt Pty Ltd)*
- Lake MacDonnell (*Gypsum Resources of Australia Pty Ltd and Diamond Salt Pty Ltd)*

**Dry Creek**

*ICI* began salt production at Dry Creek in 1940 and after almost 50 years production, sold the operation, in 1989, to *Penrice Soda Products*. The saltfields cover some 4 000 ha on the coast north of Adelaide. Harvested salt is re-dissolved and pumped as brine to Osborne for manufacture of soda ash by the Solvay process.

**Price and Lochiel**

Salt has been produced at Lochiel since 1912 and at Price since 1919. The Price operation incorporates 1 064 ha of evaporators and crystallizers and a processing plant which produces bagged and packaged salt for industrial and household use. Bulk salt (about 75% of total production) is sent to *Cheetham's* Geelong refinery (Victoria) or is shipped to Tasmania or New Zealand from *BHP's* port facilities at Ardrossan. At Lochiel, salt is dissolved from saline mud by winter rains filling Lake Bumbunga, an inland lake covering 1 500 ha. Lake brine is pumped into three, 25 ha crystallizers, which in 1988 produced 16 000 tonnes of salt for processing at the Lochiel plant. Markets are mainly in New South Wales, Northern Territory and Adelaide for tanning, metallurgical uses, water treatment and food processing.

**Whyalla**

*BHP* began salt production at Whyalla in 1951. In 1979, *Pacific Salt Pty Ltd* built a processing plant on site and took over salt production in 1988. Some 52 000 tonnes were produced in 1988 from 240 ha of brine ponds and 20 ha of crystallizers. Salt is packaged for the supermarket trade and shipped to distribution centres in all eastern Australia States including Tasmania.

**Lake MacDonnell**

Salt has been produced at Lake MacDonnell since the early 1920s and production is now maintained by *Gypsum Resources of Australia Pty Ltd (CSR/Boral)*. Production, in 1988, was 100 000 tonnes from 680 ha of concentrators and 70 ha of crystallizers. In that year, *Diamond Salt Pty Ltd* completed a processing plant on site to produce bagged salt. Bulk salt is railed 70 km to Thevenard for shipment to Japan, Malaysia and to *Diamond Salt's* plant at Geelong, Victoria. Bagged salt is trucked to the eastern States for water softening, swimming pool treatment and aluminium processing.

## SILICA

Silica sand is mined at Glenshera near Mount Compass, south of Adelaide by *ACI Resources Ltd* for manufacture of amber and colourless container glass, and for foundry sand. Lump silica from a massive quartz reef, 37 km northwest of Whyalla has been quarried by *BHP Ltd* since 1949 for use in blast furnace slag control at the company's Whyalla steelworks and for ferro-alloy manufacture by *TEMCO* (a BHP subsidiary) at Bell Bay in Tasmania.

**Glenshera**

Production of silica sand from Glenshera commenced in 1987 and replaces *ACI's* former beach dune mining operations at Normanville. The new mine is in Permian fluvioglacial sand. Up

to 10 m of yellow and orange sand, which is upgraded for amber glass and foundry sand, overlies cream coloured sand which after processing is used for colourless container glass. The mineable thickness of white sand is between 10 and 80 m depending on depth to the water table. Processing is geared to minimal use of chemicals. Trommels and vibrating polyurethane screens remove oversize, twin attritioning cells remove surface coating from grains and triple start primary and secondary spirals remove heavy minerals. Product is dewatered using hydrocyclones and process water is recycled after passing through a Delta-stack clarifier. Annual output of some 50 000 tonnes of glass sand is used in manufacture of container glass for wine, brewing, dairy, food and soft drink industries. Over 60% of glass containers produced are wine bottles, most of which are used in South Australia which packages 60% of Australia's wine.

**Whyalla**

*BHP's* silica quarry is at the southern end of a 15-20 m wide band of quartz which can be traced as a series of discontinuous ridges for almost 8 km. The resistant quartz crops out up to 15 m above the surrounding plain and cuts across Proterozoic bedrock of volcaniclastic grit and sandstone. Quartz is mined on a single quarry bench by drilling and blasting. Quarry feed is reduced by jaw crushers to give 2 products; plus 38 mm, and minus 38 mm plus 12.5 mm. About 20-30 000 tonnes of plus 38 mm product averaging $SiO_2$ 98% and maximum $Al_2O_3$ 0.7% is shipped each year to Bell Bay (Tasmania) for ferrosilicon and silicomanganese manufacture. The finer product with an average $SiO_2$ 96% and maximum $Al_2O_3$ 1.6% is used at Whyalla steelworks to control blast furnace slag chemistry.

## TALC

Although South Australia produces only about 9% of Australia's talc, it supplies most of Australia's domestic requirements. In 1988, 19 000 tonnes were mined, of which 70% was shipped to the eastern States mainly for use in the pharmaceutical and paint industries.

About 90% of South Australia's talc including all pharmaceutical grade is mined by *Commercial Minerals Ltd* from deposits near Mount Fitton in the Flinders Ranges, 755km north of Adelaide.

Small quantities of lower grade fillers are mined from deposits near Lyndoch and Gumeracha in the Mount Lofty Ranges, and have in the past been won from deposits on Eyre Peninsula.

### Mount Fitton

Over 40 deposits within an area of 60km$^2$ have produced a total of about 300 000 tonnes since production commenced in 1945. *Commercial Minerals Ltd* have been the operators since 1984 and are currently producing from open cuts in three of the deposits. Faces are established by drilling and blasting and talc is selectively loosened and dropped from the faces using a hydraulic rock breaker. The talc is screened and plus 80mm material is conveyed under water spray to a picking belt where it is manually separated into four grades. The minus 80mm plus 20mm material is stockpiled for later sorting. Impurities include dolomite, marble, tremolite and chloritic schist. Product is transported by road train to Copley then by rail to Adelaide for milling and blending to specifications of fineness, bulk density, colour absorbance and reflectance.

The Mount Fitton deposits are hosted by dolomite and marble of the Balcanoona Formation of Adelaidean age and were formed by hydrothermal replacement in fold cores at the contacts with enclosing siltstone. The larger deposits are 10-15m wide, 20m

deep and several hundred metres long with plunges parallel to regional fold axes (McCallum , 1990c).

**Mt Lofty Ranges**

Talc deposits near Lyndoch, 45km northeast of Adelaide and Gumeracha 35km east of Adelaide have formed in shear zones within tightly folded Undulya Quartzite and dolomitic sediments of Woolshed Flat Shale of Adelaidean age. Albite commonly constitutes up to 30% of the ore zones which are worked intermittently by operators including *Commercial Minerals Ltd* for filler grades.

**Eyre Peninsula**

Small lodes of talc hosted by Lower Proterozoic Katunga Dolomite produced a total of about 11 000 tonnes of mainly filling grade talc between 1910 and 1980.

## RECENT DEVELOPMENTS AND EXPLORATION TARGETS

**Celestite**

Occurrences of celestite are widespread in the Lake Eyre drainage basin with some significant concentrations as veins and modules within limestone and siltstone of Cretaceous age. The only recorded production of 125 tonnes was in 1941-42 for munitions manufacture and was mined from veins up to 0.2 m wide at Fossil Creek, 50 km northwest of Oodnadatta. *Status Minerals NL* are currently exploring an area south of Lake Eyre where similar occurrences have been reported.

**Diamond**

During the late 1800s, over fifty saleable diamonds were recovered from alluvial gold workings at Echunga, east of Adelaide. Serious exploration for diamonds however did not commence until the late 1960s with the introduction of bulk sampling methods for kimberlite indicator minerals by *Stockdale*

*Prospecting Ltd*. Numerous small kimberlite dykes and sills have been identified subsequently, near Terowie and Port Augusta and over 150 small fine-coloured diamonds have been recovered from alluvial samples. So far, exploration has failed to locate diamond-bearing kimberlite. In 1984, 35 diamonds weighing a total 1.5 carats were recovered from 80 tonnes of Triassic conglomerate from the Springfield Basin, 60 km northeast of Port Augusta. Current exploration by *Matlock Mining NL* and *Poseidon Minerals Ltd* is directed to locating the source of the Springfield Basin diamonds. *Stockdale Prospecting Ltd* have an active exploration programme to test possible kimberlite targets on Eyre Peninsula. *Reedy Lagoon Corporation NL* is exploring in the Kingoonya area and *Metana Minerals NL* in the Warrina region.

**Graphite**

A deposit of flake graphite at Uley, 23 km southwest of Port Lincoln is being re-developed by *Graphite Mines of Australia Pty Ltd* a wholly-owned subsidiary of Perth based *Solution Mining Pty Ltd*. The company purchased leases from *CRA Ltd* in 1987 and have since constructed a treatment plant to process indicated resources of 1 m. tonnes of ore at cutoff grade 8% carbon. Processing includes crushing, milling, flotation and electromagnetic separation, and trials are proceeding to optimise recovery and product grade to give an estimated 40% recovery of graphite in the size range 150-500 microns. Production is anticipated to commence in early 1990, reaching 5 000 tpa within 5 years, and contracts for 75% of initial output have been negotiated for sale to Japan with the remainder to be marketed within Australia.

**Heavy Mineral Sands**

The discovery by *CRA Ltd* in 1986-87, of the WIM 150 orebody near Horsham, Victoria firmly established the prospectivity for heavy minerals in stranded coastal deposits of Tertiary and Pleistocene ages. In South Australia, exploration has targeted

stranded beach ridges in the Murray Basin and the northern and eastern margins of the Eucla Basin. The principal explorers are *Aberfoyle Resources Ltd, BHP Minerals Ltd., Peregrine Resources (Aust.) NL, CRA Exploration Pty Ltd* and *National Mineral Sands (SA)*.

**Micaceous Iron Oxide**

Since the mid 1970s, a number of micaceous hematite deposits in South Australia have been investigated. The deposit with greatest potential is at Warrakimbo in the Flinders Ranges, 92 km by road north of Port Augusta. A steeply dipping micaceous hematite breccia zone with a maximum width of 6.5 m occurs within Etina Limestone, an iron-rich carbonate of the Willochra Subgroup of Late Proterozoic age. Laboratory tests show that the ore can be beneficiated to produce all grades of micaceous hematite specified for anti-corrosive paint manufacture.

**Palygorskite (Attapulgite)**

Palygorskite is widely developed in Miocene sediments of inland South Australia, but only limited reconnaissance sampling has been carried out to date because of remoteness of the areas. Of particular interest are the Lake Eyre Basin, the Tarkarooloo Basin near Lake Frome, and the Garford Palaeochannel, a 150 km long palaeodrainage channel to the southwest of Coober Pedy. Deposits in the latter area are under investigation by *Roebuck Resources NL*.

**Rare Earths Processing**

In 1988, *SX Holdings Ltd* announced a proposal to construct a rare earth extraction plant on the site of a former uranium treatment plant at Port Pirie. Feedstock for the plant will be initially from retreatment of the 200 000 tonnes of uranium tailings buried on site which contain an estimated 1 500 tonnes of rare earth oxides. Later expansion of the plant is proposed

to enable extraction of rare earths from Australian monazite ore and from clays to be imported from China. An EIS covering the monazite operations is being prepared by *Kinhill Engineers Pty Ltd* and is expected to be released in early 1990.

**Wollastonite**

The *Adelaide Chemical Company* is currently investigating a deposit of wollastonite at Ethiudna, 40 km north of Yunta in the Olary region. The deposit is hosted by the Ettlewood calcsilicate Member of Early Proterozoic, Willyama Complex and contains an indicated resource of 1 m. tonnes of ore grading >40% wollastonite.

J L KEELING
SENIOR GEOLOGIST

A M PAIN
PRINCIPAL GEOLOGIST

J T VALENTINE
SENIOR GEOLOGIST

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FIGURES

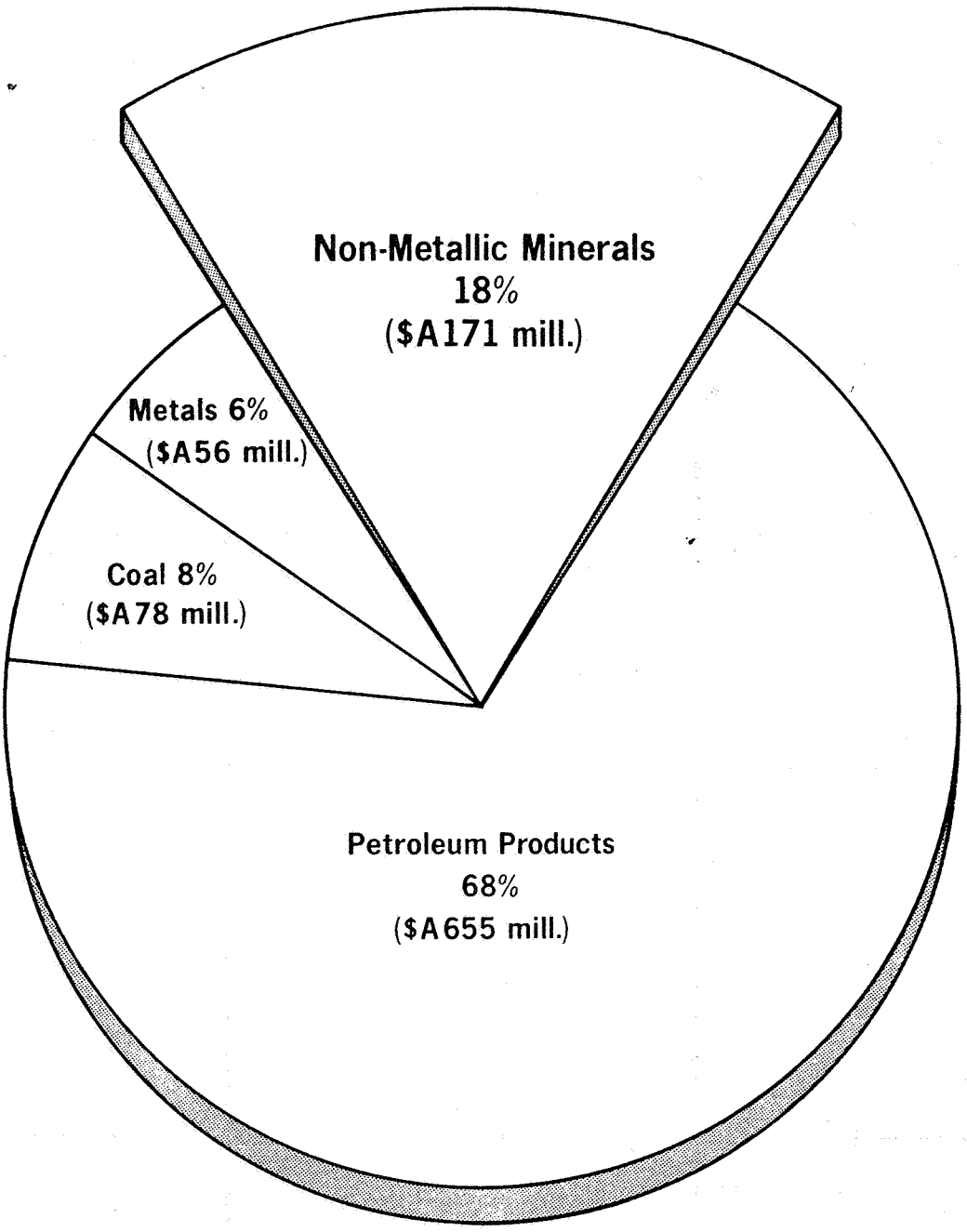


Figure .....1

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| INDUSTRIAL MINERALS OF SOUTH AUSTRALIA | DRAWN M.R. | SCALE |
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4984

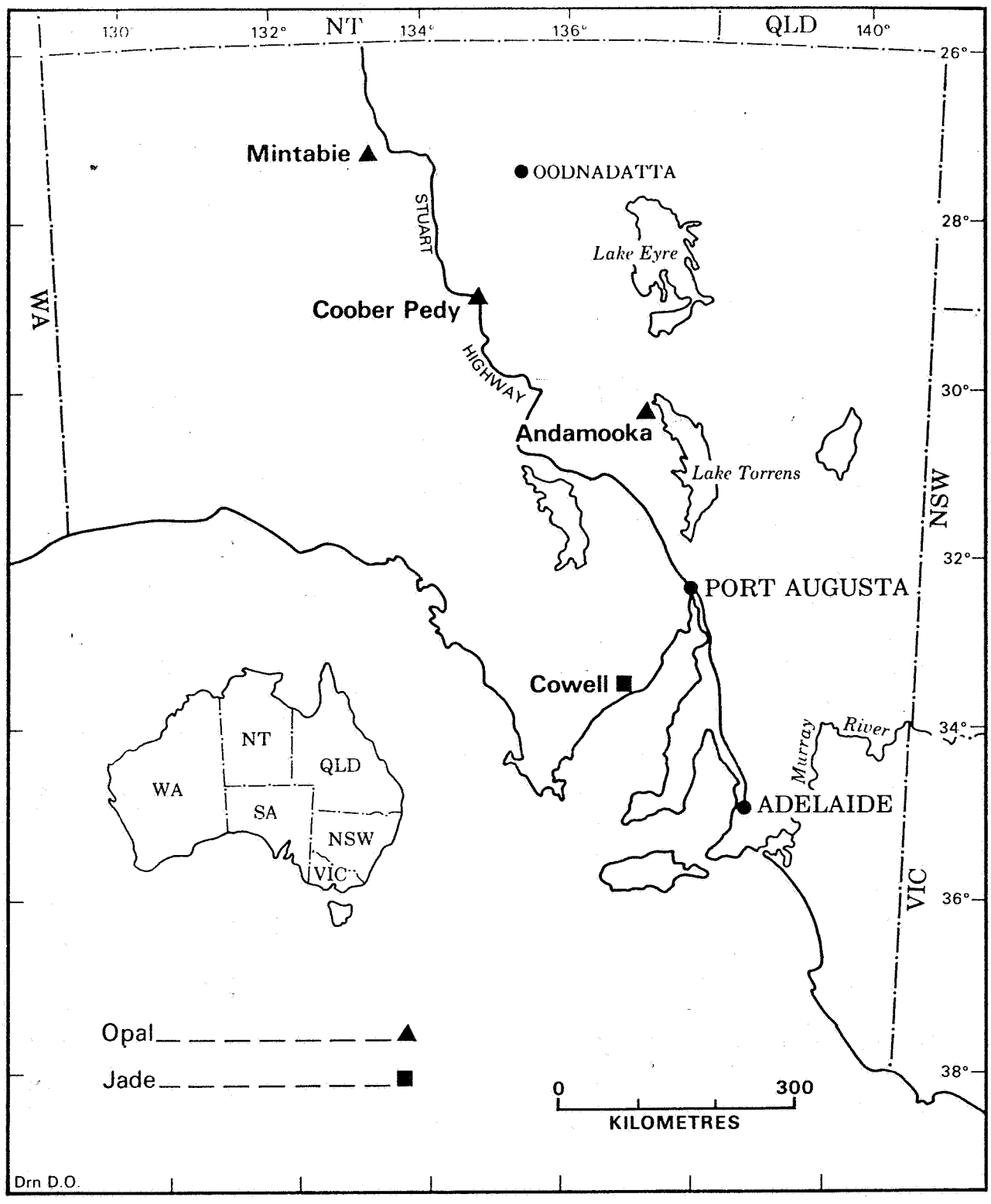


Figure....2

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|---|---|---|---|
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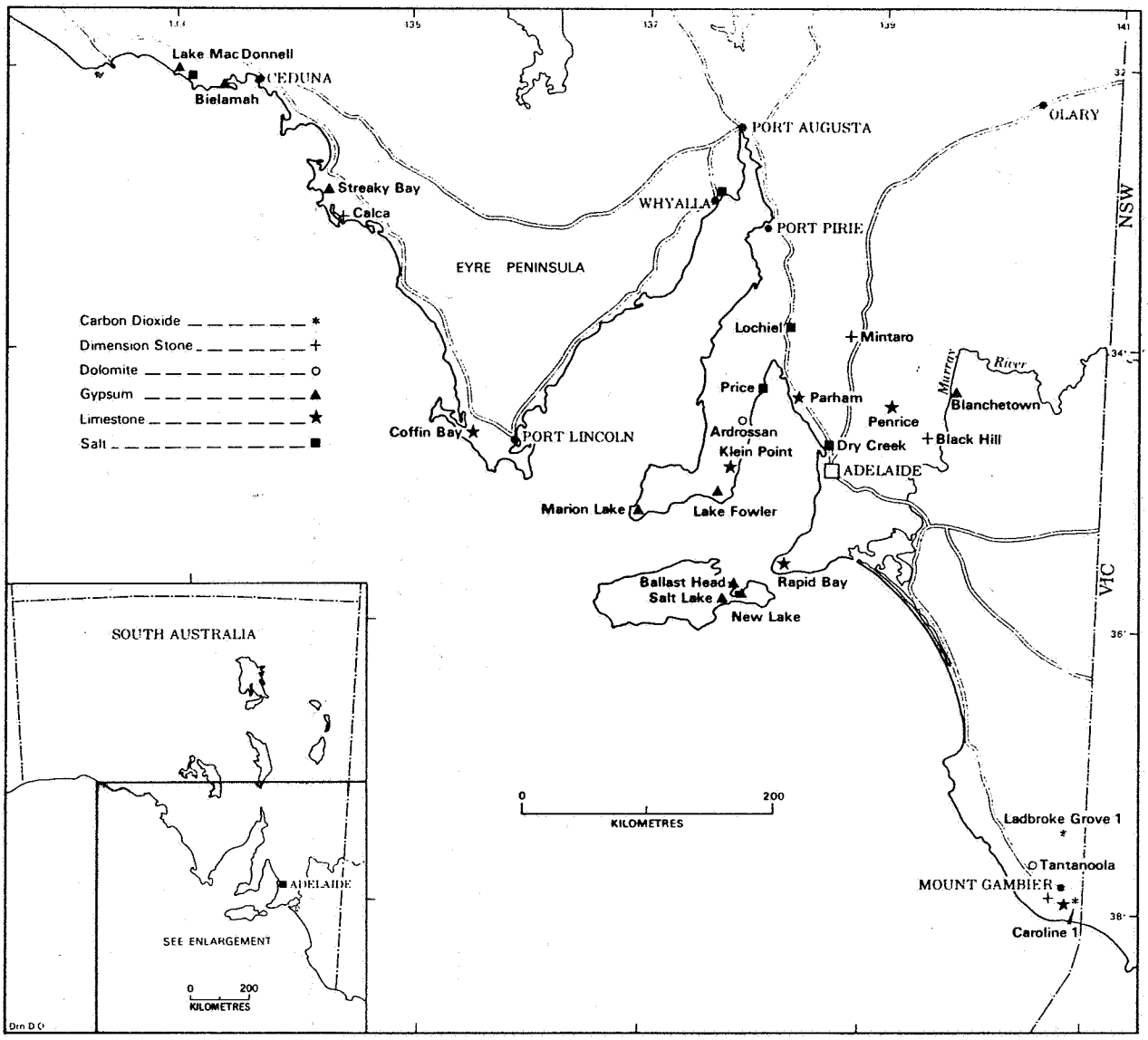


Figura .....3

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| INDUSTRIAL MINERAL IN SOUTH AUSTRALIA | DRAWN M.R. | SCALE |
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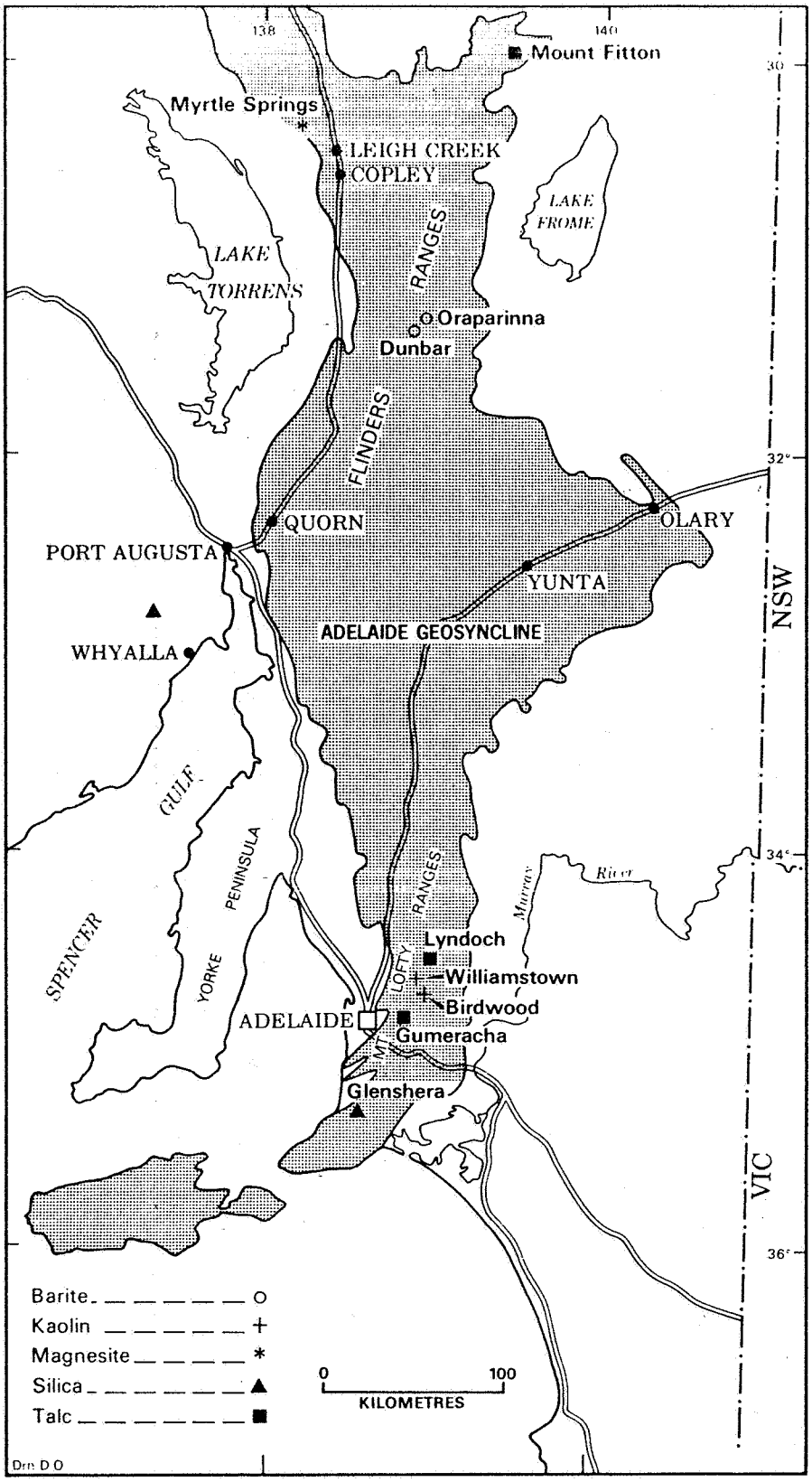


Figure ..... 4

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# PLATES

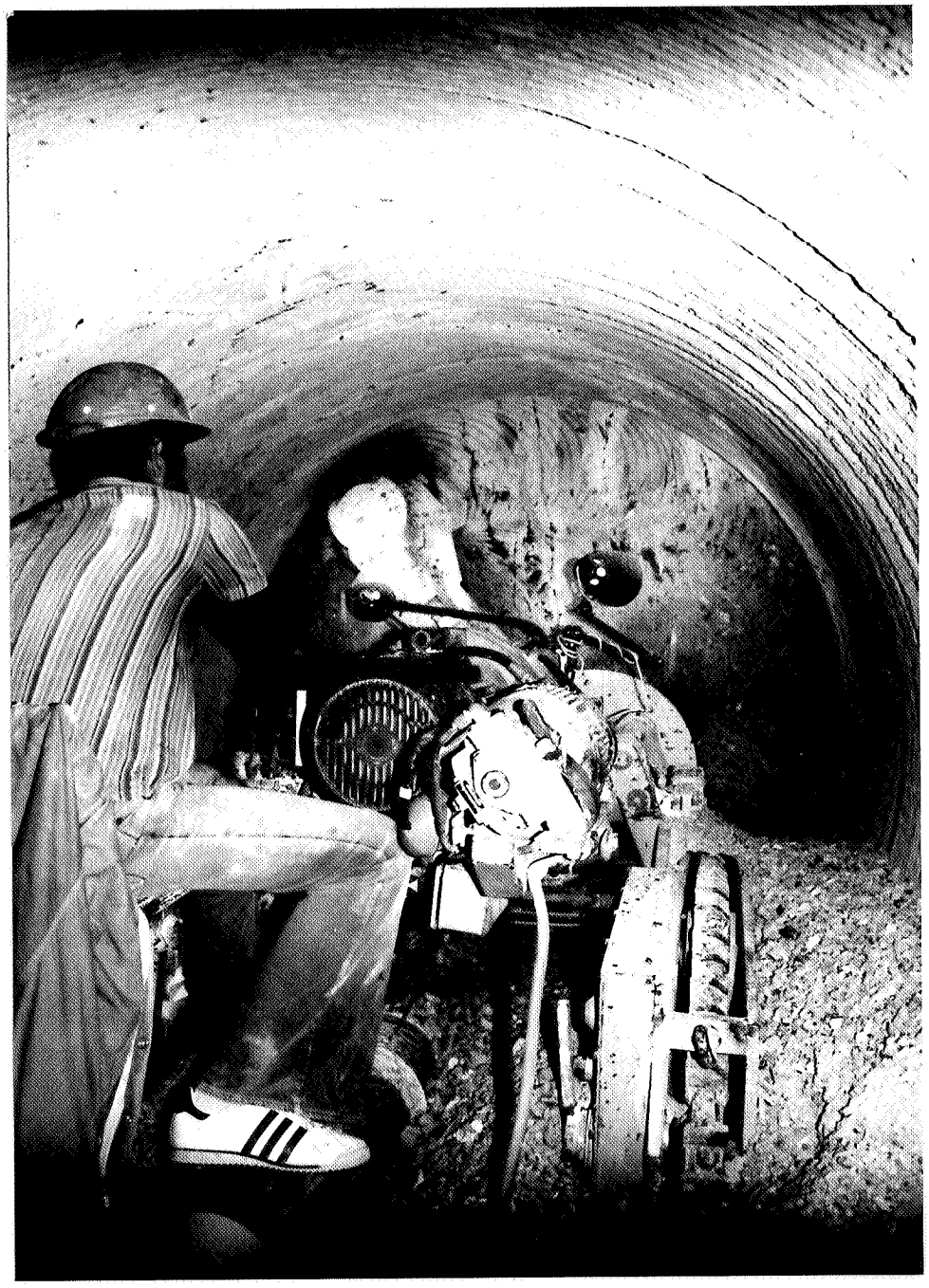

Plate 1. Underground mining using a disc-type tunnelling machine, Coober Pedy opalfields.

Neg. No. 38636

Plate 2. Decline portal to the Oraparinna Barite Mine.
Neg. No. 38637

Plate 3. 'Imperial Black Granite' quarry, Black Hill.
Neg. No. 38638

Plate 4. Penrice marble quarry.

Neg. No. 38639

Plate 5. Limesand mining, Coffin Bay.

Neg. No. 38640

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Plate 6. Mining of thin magnesite beds at Myrtle Springs.
Neg. No. 38641

Plate 7. Saltfields at Dry Creek, Adelaide.

Neg. No. 38642