DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

Rept.Bk.No. 80/26

OPAL IN SOUTH AUSTRALIA

GEOLOGICAL SURVEY

By

L.C. BARNES

I.J. TOWNSEND

and

G.J. NICOL

MAY, 1980.

D.M. No.: 227/80

CONTENTS PAGE

INTRODUCTION	1
WHAT IS OPAL	3
COLOUR IN PRECIOUS OPAL	4
PRESENTATION OF OPAL	6
HISTORY	8
THE GEOLOGY OF OPAL	11
MINING METHODS	13
ANDAMOOKA	17
STUART CREEK	21
MINOR OPAL DIGGINGS IN THE STUART CREEK AREA	25
Charlie Swamp	25
Yarra Wurta Cliff	26
Coward Cliff	26
COOBER PEDY	27
MINOR OPAL DIGGINGS NORTH OF COOBER PEDY	34
England Hill	34
Oulburra Hill	34
Sarda Bluff	35
Vesuvius	35
Lambina	36
MINTABIE	37
MINOR OPAL DIGGINGS IN THE MINTABIE AREA	41
Wallatinna	41
Granite Downs	41
THE VALUE OF OPAL	43
THE OPAL INDUSTRY	45
SELECTED BIBLIOGRAPHY	50
TABLE 1- Estimated value of opal production in South Australia 1916 - 1970	46
TABLE 2- Estimated value of opal production in South Australia 1971-1977	47
TABLE 3- Data and Production	48

Figures		Plan No.
1.	Methods of finishing opal	76-27
2.	Australian opal deposits	S14752
3.	Opal occurrences in South Australia.	S14249
4.	Stratigraphy of opal bearing rocks	S14753
5.	Regional geological plan, Andamooka Precious Stones Field	76-101
6.	Regional geological plan Stuart Creek-Coward Cliff	80-238
7.	Geological sections Andamooka-Stuart Creek-Charlie Swamp	S14754
8.	Regional geological plan - Coober Pedy Precious Stones Field	S14755
9.	Topographic plan Coober Pedy Opal Fields	80-268
10.	Schematic cross section Coober Pedy	S14756
11.	Far north regional geology and location of opal occurrences	80-269
12.	Schematic cross section Mintabie opal diggings	S14757

Plates		Neg. No.	Slide No.
1.	Opal doublet and triplet	31290	14997
2.	Scanning electron micrograph of Coober Pedy precious opal X 10 000	31291	14998
3.	Scanning electron micrograph of Coober Pedy red fire opal X 20 000	31292	14999
4.	Scanning electron micrograph of Mintabie green opal X 20 000	31293	15000
5.	Scanning electron micrograph of Mintabie black potch X 20 000	31294	15001
6.	Scanning electron micrograph of Mintabie white potch X 20 000	31295	15002
7.	Scanning electron micrograph of Coober Pedy precious opal X 10 000, showing colour grain boundary	31296	15003
8.	Opal solids	31297	15004
9.	Opal triplet	31298	15005

Plates		Neg. No.	Slide No.
10.	Treated, polished Andamooka matrix	31299	15006
11.	Gilson synthetic opal	31300	15007
12.	Marree Formation, Coward Cliff	31301	15008
13.	Shaft sinking by hand, Andamooka	31302	15009
14.	Hand windlass	30235	13754
15.	Calweld drill, Mintabie	31303	15010
16.	Calweld drill starting hole	31304	15011
17.	Calweld drill emptying bucket	30917	15012
18.	Calweld drill hole	30251	13771
19.	Underground mining, Mintabie	31305	15013
20.	Underground mining, Coober Pedy	31306	15014
21.	Yorke hoist, Andamooka	30237	13757
22.	Self unloader, Andamooka	30239	13759
23.	Blower, Andamooka	31307	13685
24.	Tunnelling machine, Coober Pedy	30920	13671
25.	Tunnelling machine, Coober Pedy	30914	15015
26.	Large blower working tunnelling machine, Coober Pedy	30921	15016
27.	Rubber-tyred bogger, Coober Pedy	31308	13679
28.	Bucket elevator, Coober Pedy	30909	15017
29.	Backhoe, Stuart Creek	30752	15018
30.	Bulldozer, Coober Pedy	30919	15019
31.	Open cut mining, Mintabie	31309	15020
32.	Open ccut mining, Mintabie	31310	15021
33.	Aerial view, Andamooka, 1976	29888	13455
34.	False "levels", Andamooka	31311	15022
35.	"Level", Andamooka	30252	13772
36.	Rough matrix opal, Andamooka	31312	15023
37.	Painted lady, Andamooka	30244	13764

Plates		Neg. No.	Slide No.
38.	"Slide", Andamooka	30245	13765
39.	Divining a "slide", Andamooka	30249	13769
40.	Prospecting, Andamooka	30236	13756
41.	Bulldozing, Andamooka	31313	13755
42.	General view, Stuart Creek Nov. 1978	31314	15024
43.	Marree Formation, Stuart Creek	31315	15025
44.	"Level", Stuart Creek	31316	15026
45.	"Level", Stuart Creek	31317	15027
46.	"Level" boulder, Stuart Creek	31318	15028
47.	Gibber, Stuart Creek	31319	15029
48.	Silcrete capped mesa, Stuart Creek	31320	15030
49.	Opal, Stuart Creek	31252	15031
50.	Opal, Stuart Creek	30761	15032
51.	General view, Charlie Swamp	31321	15033
52.	Opal, Charlie Swamp	31253	15034
53.	Brecciated opal, Charlie Swamp	31254	15035
54.	Collection of opal, Stuart Creek area	31251	15036
55.	Opal, Coward Cliff	31322	15037
56.	Aerial view, Coober Pedy Sept. 1972	31323	15038
57.	Track to Hans Peak Field, Coober Pedy	31324	15039
58.	Radeka's dugout, Coober Pedy	30907	15040
59.	Residential area, Coober Pedy	30906	15041
60.	Marree Formation, Coober Pedy	31325	15042
61.	Tubule "level", Coober Pedy	31326	15043
62.	Tubule "levels", Coober Pedy	31327	15044
63.	Alunite "level", Coober Pedy	31328	15045
64.	Gypsum "level", Coober Pedy	31329	15046

Plates		Neg. No.	Slide No.
65.	"Slide", Coober Pedy	31330	15047
66.	"Verticals", Coober Pedy	31331	15048
67.	Opal in "level", Coober Pedy	31332	12369
68.	Opal in "levels", Coober Pedy	31333	15049
69.	Opal in "vertical", Coober Pedy	31334	15050
70.	"Skin" shells, Coober Pedy	31335	15051
71.	"Full" shells, Coober Pedy	31336	15052
72.	"Alluvial" opal, Coober Pedy	31337	15053
73.	Auger drill, Coober Pedy	30916	15054
74.	Aerial view of prospecting activity, Coober Pedy	31338	15055
75.	"Blowers", Coober Pedy	30905	15056
76.	Equipment at Hans Peak, Coober Pedy	30912	15057
77.	Bulldozing, Coober Pedy	30918	15058
78.	Noodling machine, Coober Pedy	30915	15059
79.	General view, England Hill	31339	15060
80.	General view, Vesuvius	31340	15061
81.	General view, Lambina	31341	15062
82.	Aerial view, Mintabie, Sept. 1979	31342	15063
83.	Workings on scarp, Mintabie	31343	15064
84.	Mining and residential area, Mintabie	31344	15065
85.	Canteen, Mintabie	31345	15066
86.	Cretaceous unconformably overlying Mintabie Beds, Mintabie	31346	15067
87.	Mintabie Beds, Mintabie	31347	15068
88.	Cross bedding in Mintabie Beds	31348	15069
89.	Opal on cross bedding, Mintabie	31349	15070
90.	"Vertical", Mintabie	31350	15071
91.	Opal seam, Mintabie	31351	15072

Plates		Neg. No.	Slide No.
92.	"Semi-black" opal, Mintabie	31352	15073
93.	Top quality Mintabie opal	31353	15074
94.	Red fire opal, Mintabie	31354	15075
95.	Third grade Mintabie opal, for triplets	31355	15076
96.	Bulldozing, Mintabie	31356	15077
97.	Blast hole drilling, Mintabie	31357	15078
98.	Blasting, Mintabie	31358	15079
99.	Bulldozing, Mintabie	31359	15080
100.	Bulldozing mullock over scarp edge, Mintabie	31360	15081
101.	Aboriginals noodling, Mintabie	31361	15082
102.	Hopto digger, Mintabie	31362	15083
103.	Open cut, Mintabie	31363	15084
104.	Underground mining, Mintabie	31364	15085
105.	Aerial view, Mintabie Sept. 1979	31365	15086
106.	Aerial view, Wallatinna diggings	31366	15087
107.	General view, Granite Downs No. 1 diggings	31367	15088
108.	Collection of polished opal	31368	12366

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

Rept.Bk.No. 80/26
D.M. No.227/80

OPAL IN SOUTH AUSTRALIA

INTRODUCTION

The Mineral Resources Section of the South Australian Department of Mines and Energy has been closely involved with the opal industry since 1975. The Section has been mapping the various opal fields in an attempt to understand the geology of opal, and monitoring mining activity to determine the value of the opal being mined. Involvement started at Andamooka with a geological mapping program in 1975 in conjunction with a subsidised mining scheme, followed by mapping and drilling at Stuart Creek in 1977. In 1976 Mintabie became a major opal mining centre and geological mapping was carried out in 1979. The Department sponsored an M.Sc. project at Coober Pedy in 1977 and co-operation with Adelaide University has continued with sponsored student projects in the Stuart Creek area in 1978, and 1979.

This report summarises the results of these investigations and embraces the geology of opal, its occurrence and mining methods and represents many years work by a number of Departmental officers. The report is an enlarged written version of a talk on opal prepared for presentation to Gem and Mineral Clubs, High schools, Universities or interested clubs and associations. A simplified version of this report will eventually be presented in audio-visual form for use in the Department of Mines and Energy Demonstration Caravan.

The text is designed so that each section is complete in itself. This will permit talks which highlight different aspects of opal mining, or different fields, to be presented. The selection of slides shown herein, that have been used to illustrate various aspects and fields, can be modified or enlarged from the comprehensive collection held by the Mineral Resources Section.

All photographs shown as prints in this report are taken from slides, a set of which is retained in the Department's Technical Information Section along with a complete set of internegatives. A duplicate set of slides is kept in the Mineral Resources Section.

WHAT IS OPAL

Opal is a common mineral. It is a form of silica chemically similar to the very common mineral, quartz, but containing a variable amount of water within the mineral structure. The formula can be expressed as $SiO_2.n\ H_2O$ where n varies between 2 and 20%. Precious opal generally contains 6 to 10% water.

Precious opal is composed of small spheres of amorphous silica arranged in a regular pattern. Plate 2 clearly shows this regular array of silica spheres and voids, magnified about 10 000 times. Partial cementation of the silica spheres entraps water, probably in vapour form, within the voids. Fractures develop, and the opal crazes and turns white if the sample is dried quickly or completely.

The silica spheres are considered to have been deposited from a colloidal suspension, due to evaporation and/or filtration and to have accumulated in regular horizontal layers, predominantly in a cubic close packed structure.

In a geological sense, the term opal is used for all forms of the mineral, whereas opal miners restrict use of the word opal to the precious variety, other forms with little or no colour being referred to as "<u>potch</u>".

Opal is found as two types, <u>volcanic</u> opal where it infills vesicles and cracks in intermediate igneous rocks, and the more familiar <u>sedimentary or sandstone</u> opal. Apart from the main Australian fields, almost all other opal is found as volcanic opal. Volcanic opal generally contains more water than sedimentary opal and when mined from fresh lava has a tendency to dry out and crack. With the exception of some Brazilian opal and some Mexican fire opal, most volcanic opal crazes and many of the occurrences throughout the world are of little more than mineralogical interest.

COLOUR IN PRECIOUS OPAL

The origin of the colour in opal has given rise to as many theories as there are stories concerning the stone's history. However it has now been demonstrated that the regular array of spheres and voids diffracts white light by breaking it into the complete range of spectral colour (Darragh et al 1976). The colour observed is primarily dependent on the layer spacing, which is determined by sphere size.

In opal which shows dominant red fire, the spheres are approximately 4 000 A^{O} in diameter, whilst in green opal the spheres are about 2 500 A^{O} diameter. Plates 3 and 4, both at 20 000 magnifications show this difference.

The colour observed also depends on the angle of incidence of light and the position of the observer. This can be readily demonstrated by rotating red fire opal and noting one particular area of colour which changes from red through green to blue as the angle of incidence to observer is increased. Green opal will show only green to blue colours on rotation as the sphere size controls the highest order colour observed.

Likewise, blue opal will show only blue-black colour on rotation as the sphere size does not produce the higher green or red colours.

In Plate 4, the silica spheres are cemented more than those shown in Plates 2 and 3. If the silica spheres are strongly cemented the porosity is greatly reduced; thus light passes through the specimen without being diffracted to produce colour. The end result is clear potch.

In potch, which shows no play of colours, the silica spheres are either of assorted sizes and do not produce the regular array required for colour diffraction (Plate 5), or are too small to produce blue colour even when arranged in a regular pattern (Plate 6).

Faults in stacking or growth of silica spheres create grain boundaries (Plate 7) which result in differences and abrupt changes in colour at these boundaries. In natural opal, each grain boundary is sharp and straight sided, and the texture of each colour flake is uniform. In synthetic opal (Gilson opal) however, crenulated boundaries are obvious and subgrains can be seen inside most colour grains (Plate 11).

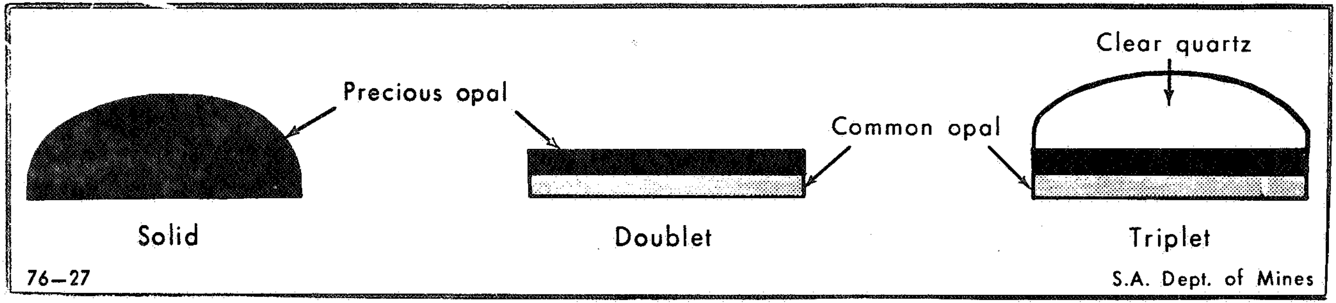

Precious opal
Clear quartz
Common opal
Solid
Doublet
Triplet
76—27
S.A. Dept. of Mines

Fig. I

PRESENTATION OF OPAL

Opals are presented as cut and polished stones in a number of ways, depending on the nature and thickness of the colour band within the raw material (Fig. 1).

1. Solid - (Cabochon)

   If the opal is sufficiently thick most cutters prefer to produce the opal as a solid or "en cabochon" such as those shown in Plate 8.

2. Doublet

   A thin veneer of opal may show enhanced colour with a dark backing. This can be achieved either by cementing a thin slice of common dark opal, or of black plastic (vitrolite) to the back of the opal with expoxy resin.

3. Triplet

   To protect the opal from abrasion a slice of quartz, or clear plastic may be used to cap the thin opal veneer producing a 3 tiered gemstone known as a triplet (Plate 9). Because very thin brilliant colour bands can be used, this type of stone can display beautiful colours.

   Variations of the above can be produced by substituting matrix, synthetic opal or imitation opal for precious opal.

4. (a) Matrix.

   Andamooka matrix comprises precious opaline silica as an infilling of the pore spaces in silty claystone and generally shows fine pinfire colour in the natural state. The colour may be enhanced by soaking the specimen in a sugar solution and then boiling in acid to deposit carbon in the available pore spaces, resulting in a dark background (Plate 10).

   Matrix opal is generally cut and sold as solids. When such processing was originated in the 1950's the product was sold at a premium as black opal but dealers are now generally aware of such treatment and recognise matrix as a distinct type of opal.

(b) Synthetic Opal.

Synthetic opal, such as Gilson opal, is opaline silica produced in the laboratory and having a similar structure to that of precious opal (Plate 11).

The following may be used to differentiate between natural and synthetic opal -

- Synthetic stones generally show brighter than normal colours, and colour patches are often larger than in natural opal.
- Colour grain boundaries are generally highly irregular in synthetic opal.
- Within each colour grain in synthetic opal, there are numerous sub-grains that produce a distinctive snakeskin pattern.
- Synthetic material generally shows a more ordered pattern of colours since artificial material does not duplicate the numerous stacking faults of natural opal.

As detection of synthetic opal is reasonably simple, there is no threat to good quality natural solids, but synthetics have captured part of the triplet market.

(c) Imitation Opal.

This includes any non opaline silica material such as coloured "tinsel" which may be set in clear plastic or epoxy resin. It is normally obvious that it is synthetic, and does not threaten the natural opal market.

HISTORY

The anthropologist, Louis Leakey, reported opal and jade artifacts, dated from about 4 000 B.C., in a cave in Kenya. The Romans established opal as a gemstone, being introduced to the Roman Empire in about 100 B.C. The Romans obtained their stones from traders in the Middle East and believed that the gem came from India. Their name for this gem was Opalus, which is based on the ancient Indian word, Upala (precious stone).

The Romans valued opal above all other gems, believing it to combine the beauty of all other precious stones.

In the 1st Century, the scholar Pliny wrote: "Of all the precious stones it is the opal that presents the greatest difficulty of description, it displaying at once the piercing fire of ruby, the purple brilliancy of amethyst, and the sea-green of emerald, the whole blended together and refulgent with a brightness that is incredible" (Plate 1).

It is now known that the stones so eagerly sought after by Rome came from open cut workings in andesitic volcanics in Eastern Czechoslovakia, which was then part of Hungary.

The Hungarian mines remained the only source of opal for Europe until the 16th century. Although in fairly short supply, opal was a popular gemstone amongst the rich, upper class.

The Spaniards returned from the New World with many fine examples of Aztec opal. Volcanic opal is widely, but sporadically, distributed throughout northern South America, central America and North America, and the Aztecs probably mined the gem from several sites.

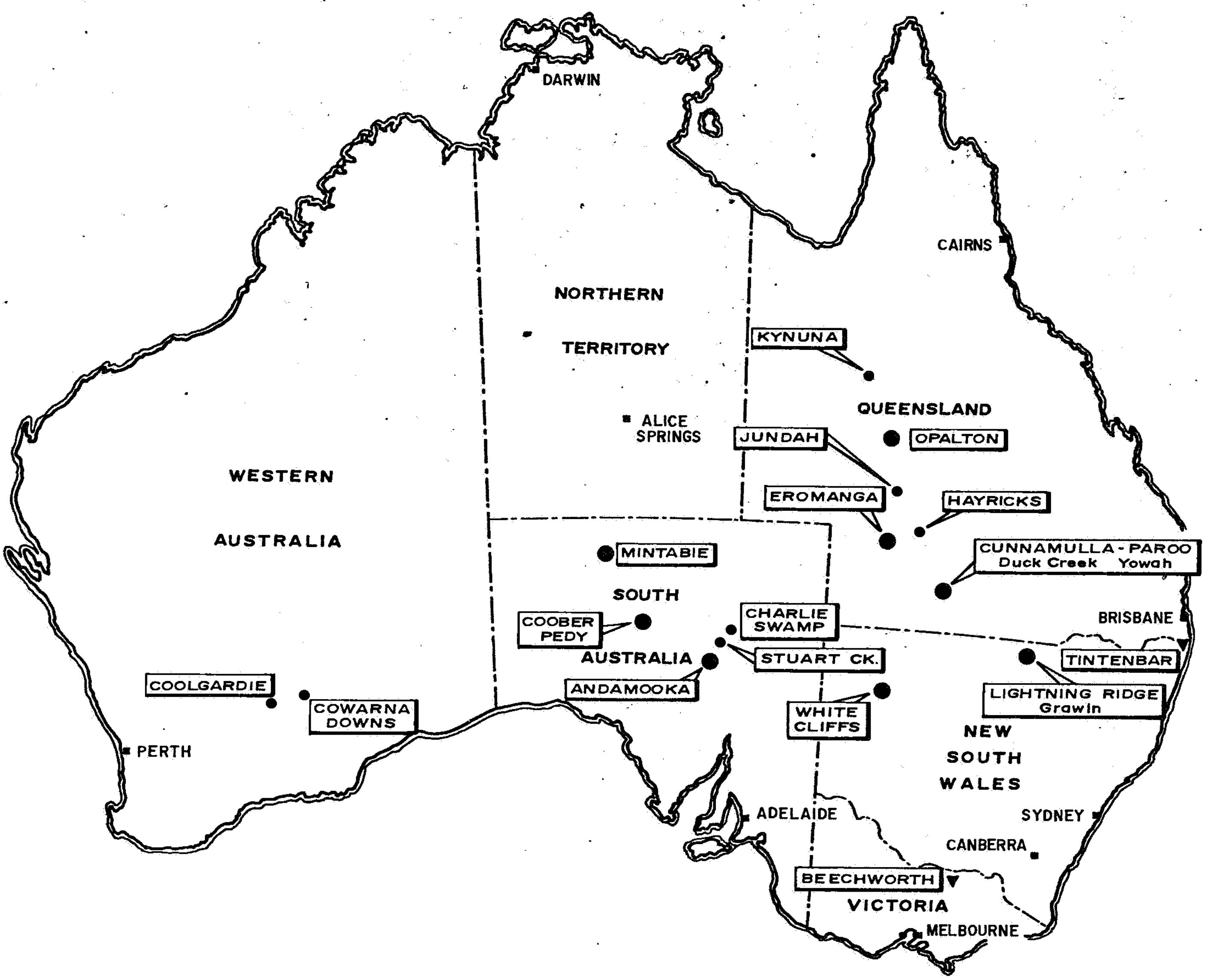
In the late 18th and early 19th Century, opal fell out of favour and inherited a reputation as a harbinger (bad luck stone) of ill fortune. There are numerous stories (fall of kings, pestilence, famine) that blamed opal as a bearer of bad luck but in all probability the main factor contributing to its decline in popularity was the fact that much of the opal found at this time tended to crack badly. This coincided with the start of underground mining at the Hungarian deposits where the opal won from fresh lava dried out too quickly and crazed. The reputation of the stone deteriorated and prices became so low that the Hungarian mines closed for many years. They were re-opened by a few individuals in the mid 1800's and very slowly opal regained some popularity.

When Australian opal appeared on the market in the 1890's, the Hungarian mines, in a last desperate attempt to remain viable, tried to promote the idea that Australian opal was not genuine, probably because gems with such brilliant fire had not been seen before. The Hungarian mines finally closed in 1932.

The Mexican opal deposits at Queratoro were discovered in 1835 and have been worked to the present day. The dominantly yellow and red fire opal is found in cavities in volcanic lavas rich in silica. In the early 1970's an Australian syndicate worked volcanic opal deposits in Brazil. Some Brazilian opal shows fire and colour comparable with Andamooka opal and for a while competed actively with Australian stones. These operations were closed with the death of the foreman in 1976. Other deposits of volcanic opal have been occasionally worked in Indonesia, Honduras, Guatamala and in several places in the United States of America. As far as is known the Mexican deposits are the only volcanic opal deposits being worked at present and they remain the only significant, but very minor, source of opal outside Australia.

In Australia the first discovery of precious opal was by gold panners in Victoria in the 1860's, and there followed rapidly a number of discoveries of both "volcanic" and "sedimentary" opal throughout eastern Australia.

AUSTRALIAN OPAL DEPOSITS



● .... MAJOR OPAL OCCURRENCE

• .... MINOR OPAL OCCURRENCE

▼ .... VOLCANIC OPAL OCCURRENCE

FIG. 2

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED I.J. Townsend	C.D.O. DATE 21/5/80
OPAL IN SOUTH AUSTRALIA	DRAWN M. R.	SCALE
AUSTRALIAN OPAL DEPOSITS	DATE April 1980	PLAN NUMBER
	CHECKED	S 14752

1875

Notable dates in the development of the Australian opal mining industry include the following (for locations see Figure 2).

1849 -	Discovery of common opal by the German geologist Menge near Angaston in South Australia.
1863 -	Recovery of waterworn pieces of precious opal by gold panners in the Beechworth district, Victoria.
1872 -	Discovery of "sedimentary" opal at Listowel Downs, near Jundah in central Queensland.
1877-78 -	Discovery of opal in the Eromanga and Cunnamulla area, Queensland.
Late 1880's -	Discovery of White Cliffs where production began in 1890.
1896 -	Start of production from Opalton, Queensland.
1903 -	Discovery of Lighting Ridge where production began two years later.
1904 -	Discovery of opal "with a play of colours similar to precious opal" at Charlie Swamp in South Australia, the first recorded discovery of semi-precious opal in the State.
1915 -	Discovery of the Stuart's Range field - now Coober Pedy.
1930 -	Opal found at Andamooka.
1931 -	White men find black opal at Mintabie, although aboriginals had previously collected pieces of opal from this area.
1947 -	Probable date of discovery of Stuart Creek opal field.

Since the Australian stones have been on the market, opal has regained its former popularity and is now one of the most appreciated and valuable of gems. Hence, the price has increased slowly at first, but in the last 20 years it has escalated rapidly.

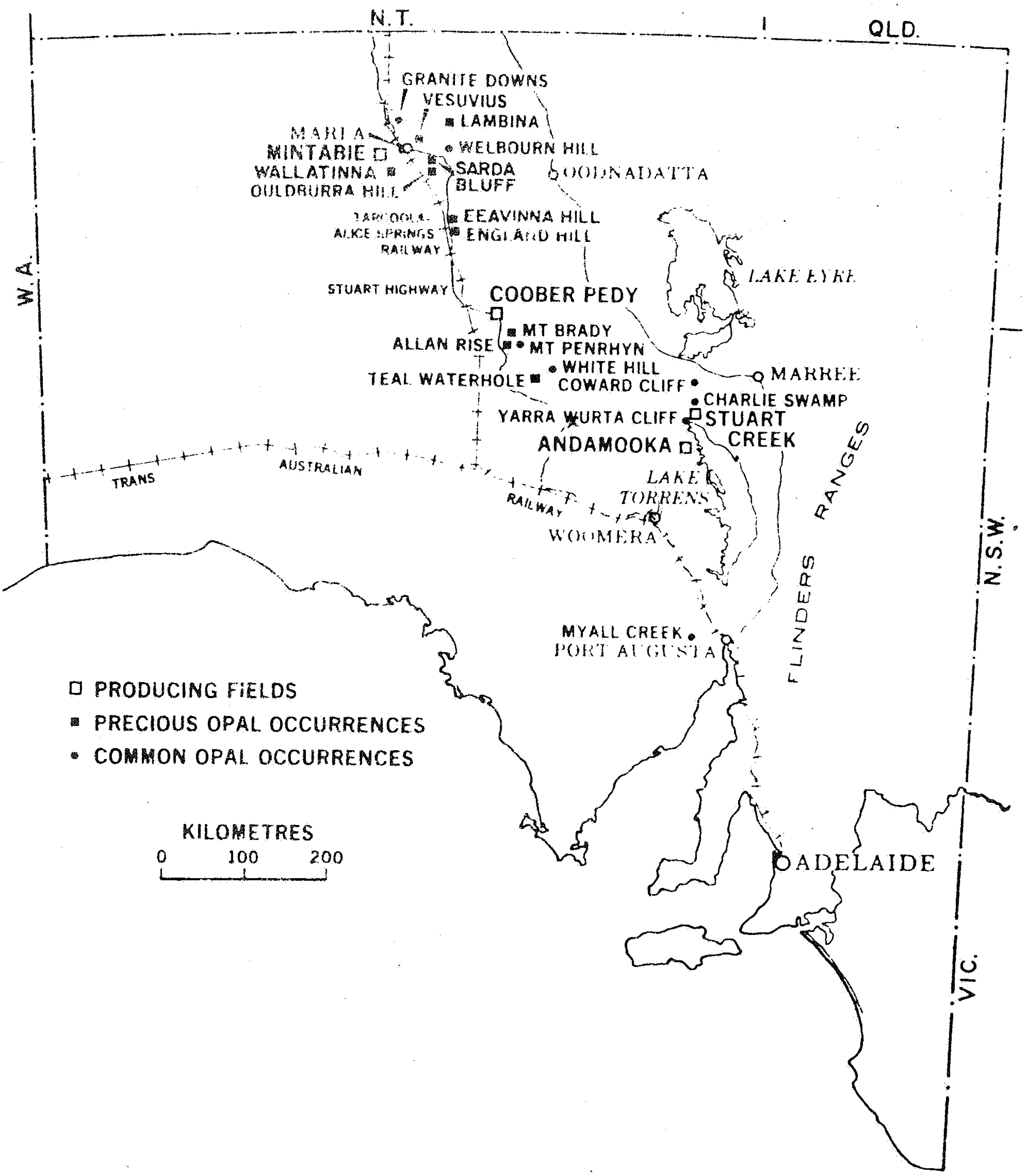


Fig.3

	DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	SCALE 1:7400000
L.C.B.		DATE 12·9·79
	OPAL OCCURRENCES IN SOUTH AUSTRALIA	PLAN NUMBER
		S14248

THE GEOLOGY OF OPAL

Opal is widely distributed in South Australia, Figure 3 showing the principal opal localities. The geology of the opal bearing rocks is summarised in Figure 4.

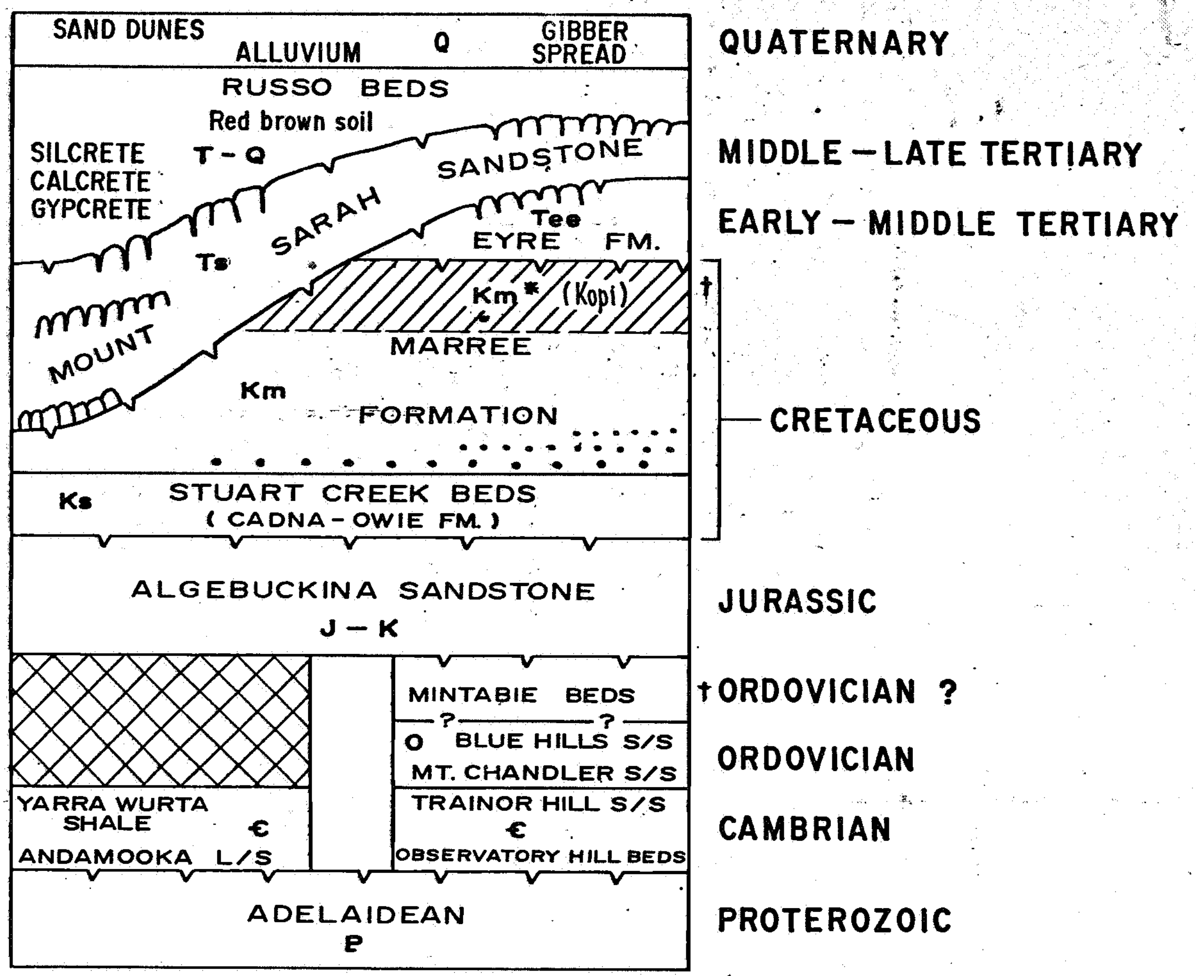
The most important rock unit is Marree Formation of Early Cretaceous age. To avoid confusion, this name is used throughout this report although other names are used for rocks of the same age in different parts of the state. Marree Formation comprises marine mud, sand and conglomerate. In outcrop, these rocks are almost everywhere strongly bleached, by weathering and alteration post dating deposition, to a light porous claystone erroneously called "kopi" or "sandstone". A typical exposure of this bleached profile is shown in Plate 12.

The Marree Formation is generally overlain by Early Tertiary Eyre Formation, a fluviatile sequence of sand and silt on which a silcrete, a hard tough silicified rock, is often developed.

Wopfner (1974) considered that silcrete and the deep weathering profile to be related, and to be associated with development of a widespread peneplain-like land surface during the Middle Tertiary.

Sediments of the Eyre Formation, and the first phase of silcrete development are succeeded by a younger fluvial sand sequence which has eroded the older silcrete, in places completely removing it. The younger sand sequence, Mount Sarah Sandstone, is strongly silcreted to comprise the major silcrete formation over northern South Australia. It may be overlain by various younger units including:

- Russo Beds (a sequence of red silt, silcrete, calcrete and gypcrete, extensively developed on the Stuart Range plateau.
- Sand dunes.
- Creek alluvium.



† - prominent host rock of precious opal

FIG. 4

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED L.C. Barnes	C.D.O.	DATE
OPAL IN SOUTH AUSTRALIA	DRAWN M.R.	SCALE	
STRATIGRAPHY OF OPAL BEARING ROCKS	DATE April 1980 CHECKED	PLAN NUMBER S 14753	

1875

- Red brown clay and extensive gibber spreads.

Formation of sedimentary opal

Sedimentary opal may be deposited in -

- cracks
- fissures
- pore space in sediments
- cavities resulting from dissolution of shells
- pore space in tree trunks, or even completely replacing wood fragments.

The common factors in sedimentary opal formation are -

- association with the fluctuating silica-rich water table
- infilling of voids that are either stratigraphically or structurally controlled.

In South Australia, the host rocks are principally weathered Cretaceous siltstone and shale but Tertiary, Palaeozoic and Pre-cambrian rocks may also contain opal. Host rocks are often deeply weathered and only occasionally are they fresh. Weathered rocks are brittle and fractured and, together with an enhanced porosity resulting from leaching, permits movement of silica-rich waters, and the deposition of opal in suitable open spaces.

Although there are many theories, the formation of opal is generally considered to be related to the process of silicification which produced the siliceous cap rocks or silcretes common in the north of South Australia. Wopfner (1978) related opal formation to silification associated with the Warrina Surface of Pliocene-Pleistocene age. Barnes and Scott (1979) and Nicol (1979) however suggest a relation to silicification of the Mount Sarah Sandstone, an older event.

Others including Carr et al., (1979) support a genetic connection with a major weathering profile and intense bleaching whilst Barker (in prep.) suggests a diagenetic origin associated with deposition of sediments of the Marree Formation.

MINING METHODS

The simplest form of mining is through shaft sinking with a pick and shovel (Plate 13). When the hole gets too deep, mullock has to be hauled out and this can be done with -

Hand windlass - a simple, hand operated winch used to lift buckets of mullock out of the shaft (Plate 14). There are still a few old timers who use this method.

Power winch - works on the same principal as the windlass but powered by compressed air, or small stationary petrol or diesel engines.

The most popular method of shaft sinking is by use of the -

Caldweld drill - drills a hole about 1 m in diameter to depths of 30 m (Plate 15). A telescopic shank holding a steel bucket (Plate 16) is mounted on the rear of a truck. The bucket has a hinged base with two slots fitted with cutting teeth. The base is locked; the bucket lowered down the hole and filled by rotary action. When full, the bucket is brought to the surface and pulled away from the drillhole by a boom and pulley system. The hinged base is opened to dump the mullock about 5 m from the drillhole collar (Plt. 17). As each bucket is emptied, miners search for signs of opal or a "level". The drillhole is deepened 1-1.5 m beyond the proposed drive to facilitate driving. Caldweld holes can be reamed out to approximately 2 m diameter to allow boggers and tunnelling machines down the shaft.

Plate 18 shows a completed Caldweld drill hole with a miner descending to check the position of the opal indicated by chips at the surface.

Driving on the "level" or "vertical" is usually undertaken with jack-picks (Plate 19) and explosives. When traces of opal are found, a hand pick (Plate 20) or a screw driver are used in preference to a jack pick. The mullock from underground mining is removed in a number of ways, some of them unique to the opal fields.

These include:-

Yorke hoist - is mounted on a vertical pipe which is stayed by wires from the top enabling free rotation (Plate 21).

A full bucket is hoisted to the surface, swung away from the shaft and emptied by operator at the surface. An operator underground fills buckets at the face and slides them to the shaft along lengths of water pipe on the floor lubricated by sump oil. A safety hook is used to prevent the bucket dislodging. The shaft collar is built up by boxing with galvanised iron or wooden frames to prevent mullock falling into the shaft.

Self unloader - or automatic bucket tipper allows the entire operation to be controlled by one miner from underground. A full bucket is strapped to a cradle at the base of the shaft. The miner pulls a lever which engages the winder motor. The bucket is hauled to the surface along two parallel rails which above ground are curved such that the bucket empties the mullock about 5 m from the shaft collar (Plate 22). At the point of tipping, an automatic reversing switch is tripped, returning the bucket underground.

Blower - is a truck mounted machine which is similar to a vacuum cleaner (Plate 23). A fan or blower, driven by a stationary diesel engine draws mullock out of the shaft through a series of metal pipes to collect in a bin at the surface, which is emptied as necessary. A pressure type "plenum" blower system has been developed, but none are yet in operation (Calbert, 1972).

In recent years there has been a dramatic upsurge in the use of sophisticated mining machines, particularly at Coober Pedy.

These machines, usually electric powered, include tunnelling machines which are of two principal types. One has a revolving boom on the front with a circular cutting head which cuts a circular tunnel (Plate 24). The mullock is generally extracted using a blower. On the other type, two parallel booms on either side of the machine support a revolving drum with teeth at the front (Plate 25). The drum is raised and lowered on the booms to cut a rectangular drive and waste is fed by an auger to either blower pipes or conveyor behind the machine.

Blowers used with tunnelling machines are generally of large capacity, sufficient to remove considerable amounts of mullock excavated (Plate 26) and may combine with conveyor systems to dump dirt well away from the shaft.

Bogger - small, air powered, front end loader, which is generally rubber tyred (Plate 27). After blasting underground the bogger scoops and discharges broken mullock into a bin. The bin is emptied into a sump below the mine floor for removal by bucket elevator.

Bucket elevator - a series of buckets on endless chains (Plate 28).

For open cut mining operations either backhoes, or bulldozers are used.

Backhoe - used for digging trenches where the opal is close to the surface, or for working in abandoned bulldozer cuts (Plate 29). Larger machines are used for open cut mining.

Bulldozer - operates more efficiently on amalgamated claims where there is adequate area for disposal of overburden by pushing from one claim to the next, allowing maximum exposure of opal-bearing ground. The operator pushes overburden from the cut to the expected depth of a "level", often with "spotters" watching for opal (Plate 30). When opal is spotted the ground is worked over by hand, first with a pick and shovel (Plate 31) and, when the opal seam is located, by a screwdriver (Plate 32).

A significant amount of opal may be crushed, broken or overlooked by careless operators. Hence, bulldozed heaps are the preferred target for noodling machines rather than the dumps resulting from underground mining. Bulldozing is often on a commission basis with the contractors receiving a percentage of the find.

ANDAMOOKA

Andamooka Opal Fields, 640 km by road north of Adelaide, near the western margin of Lake Torrens, (Fig. 3) are reached by 140 km of graded, unsealed road which leaves the Stuart Highway at Pimba. This stretch becomes impassable to two wheel drive vehicles after light rain. Andamooka was discovered in 1930 when Sam Brooks and Roy Shepherd found "floaters" below what is now Treloar Hill. The first miners were Treloar and Evans, and the first recorded production, in 1933, was valued at 962 pounds.

In the ensuing 45 years the workings have expanded over an area of 13 km by 5 km (Fig. 5 and Plate 33). Until 1972, Andamooka was a major producer of precious opal with output equalling and, occasionally, exceeding in value that from Coober Pedy.

Despite the discovery of two small fields in 1976 during a subsided mining programme (Carr et. al., 1979; Olliver et. al., 1978), the failure to locate a major new field since 1971 has resulted in a steady decline in population from a peak of 3,000 to approximately 400 in May 1979. Several big finds in the White Dam area have stimulated increased activity at Andamooka, and the population increased slightly late in 1979.

Geology (see Fig. 5)

Rock units within the area of the Precious Stones Field comprise -

- the opal bearing Early Cretaceous Marree Formation, as a thin outlier resting on flat-lying Adelaidean and Cambrian sediments of the Stuart Shelf.
- Early Tertiary Eyre Formation and silcrete cap the central plateau with opal working's scattered around the dissected margins.

A section across the main area of workings (Fig. 5) shows:-

- deeply weathered and bleached Marree Formation, ("kopi").
- near the base of the Marree Formation an extensive sandy boulder bed, the conglomerate band.
- beneath the conglomerate band and seperating it from unbleached Marree Formation, ("mud") is the "level" (Fig. 5).

In some places, there are "false levels" higher in the section within the "kopi" (Plate 34). These are not laterally extensive but may contain opal in some areas, notably at White Dam. However, the main "level" is the important one.

Plate 35 shows the "level" underground, with "kopi", at the base of which is the conglomerate band with boulders that overlies "mud". A second "level" is developed below.

Opal

Opal may occur as follows -

- in a thin seam on the contact of the conglomerate bed and underlying "mud"; this is generally of the best quality;
- as matrix cementing sand and clay (Plate 36). This is called matrix opal and, when chemically treated, produces stones as shown in Plate 10.
- as a thin film developed on joints in quartzite boulders (Plate 37) called "painted ladies", which command high prices as specimens.
- as "concrete" cementing the conglomerate.
- in minor amounts in "verticals" above and below the "level", and in "slides".

Prospecting

Geological mapping has defined the depth of the "level" throughout the Andamooka Precious Stones Field with reasonable accuracy. However, within the "level" opal is randomly distributed infilling voids and cracks and its presence or location cannot be predicted.

Because of its random distribution, miners have evolved a number of theories to explain the occurrence of opal. The most popular theory relates opal to the presence of nearby small scale faults, or "slides". The "slide" in Plate 38 shows a bigger than normal displacement of the "level" of about 1.2 m. No evidence was found in the 1976 investigation of any constant relationship between these "slides" and opal occurrence. There are many hundreds of these slides throughout the opal fields and any opal find can be related to one "slide" or another. Many miners use "wires" (Plate 39) to divine for "slides". This method is no more successful than any other. One miner is reported to have sunk 60 shafts based on divining, without disclosing opal, before leaving the field. In a total of 66 shafts sited on Marree Formation and collared above the "level", during the 1976 subsidised scheme, precious opal was found in four, and potch, or dead matrix, was found in another nine.

The Calweld drill provides the most effective method of prospecting at Andamooka. As holes are drilled, the spoil heap is searched for whatever particular opal indicators a miner prefers (Plate 40). When such indications are found, the shaft is already dug and the miner drives the "level" in search of opal.

Preferred Mining Methods

The most popular method is underground mining; that is sinking a shaft and driving along the "level" searching for opal. Most miners prefer to use a Yorke Hoist or a self dumper to remove the mullock from the shaft. There are few blowers at Andamooka, probably because only a few miners shift enough dirt to warrant the expense. Blowers cannot handle the large boulders in the "level".

Open cut mining, using a bulldozer, is popular in shallow ground (Plate 41). This exposes a large area of "level" that is then worked over by pick and shovel.

Potential

The potential of Andamooka, must be considered as unlimited. The conglomerate band, and hence the "level", is an extensive unit and throughout the Marree Formation, above the "level", must be considered prospective for opal occurrence.

The limiting factor is probably the depth of the "level". In the central part of the Precious Stones Field, there is about 40-50 m of "kopi" overlying the "level", and this makes mining difficult within a 50 m x 50 m claim.

STUART CREEK

This small field, (Plate 42) 58 km north of Andamooka, is reached either via a poorly maintained track through sandhills from Andamooka; or by station tracks from Farina on the Leigh Creek-Marree road (Fig. 3). The field was probably discovered in 1947 (Barnes and Scott, 1979). However, difficulty of access, absence of water, and the generally poor quality of the opal made this area much less attractive than Coober Pedy or Andamooka. The field has only been worked intermittently, although rumours of a major find sparked a rush in mid-1977. An inspection in November 1979 showed the field to be deserted again.

Geology

Geology of the Stuart Creek-Charlie Swamp area is shown on Figure 6.

Basement, underlying Mesozoic and Cainozoic rocks comprises Adelaidean and Cambrian sediments. Folded Adelaidean rocks crop out east of Stuart Creek whilst flat-lying Cambrian sediments extend westward beneath younger cover.

Mesozoic "Stuart Creek Beds" crop out west of Stuart Creek at Yarra Wurta Dam (Fig. 6) where the basal part of a 6 m section comprises stiff red-brown brecciated clay, probably a regolith developed on Cambrian Yarra Wurta Shale. This is overlain by clay chip breccia, green clay chips in a sandy matrix, with thin interbeds of gypsum cemented, cross-bedded sand.

"Stuart Creek Beds" were intersected in a Calweld drill hole and backhoe trenches at Stuart Creek. At the opal workings, they comprise 9 m of friable pebbly sand and clay lenses containing carbonaceous material, with a basal regolithic red clay. On the southern margin of the Precious Stones Field, the unit comprises lenses of clay chip breccia in carbonaceous sand and mud.

"Stuart Creek Beds" which crop out southeast of Charlie Swamp comprise predominantly fine sand.

"Stuart Creek Beds" infill depressions in the basement topography. They frequently contain glauconite indicating a marine influence. Their distribution and lithology suggest a transitional unit, of Early Cretaceous age, at the base of the marine Marree Formation. They may be equivalent to units described elsewhere in a similar stratigraphic position, e.g. Cadna-Owie Formation, Pelican Well Formation, or Woolpoorinna Breccia Member of Marree Formation.

Early Cretaceous Marree Formation, which crops out at Stuart Creek and Charlie Swamp overlies "Stuart Creek Beds", in places with an erosional contact. The extent of this disconformity is unknown, as elsewhere the contact is apparently conformable.

Marree Formation comprises a basal conglomerate bed overlain by mud with 'erratics', and sandy conglomeratic interbeds.

The basal conglomerate bed at Stuart Creek is more than 1 m thick and packed with pebbles, cobbles and boulders, mostly of well rounded quartzite lithologically identical to ABC Range Quartzite which crops out near Stuart Creek. This conglomerate, within which boulders obtain 2 m in length, represents a lag deposit; a product of reworking by the transgressing Early Cretaceous sea.

Grey-brown mud exposed in the opal diggings at Stuart Creek (Plate 43) includes numerous sandy conglomeratic interbeds (Plate 44). Large clasts within such beds and isolated 'erratics' in the mud have long been an enigma, and many theories have been advanced for their origin.

It is now considered that these boulders were derived locally, rounded on the shoreline of the Early Cretaceous sea and transported by shore-ice-rafting to the sea floor where mud was being deposited under quiet, shallow marine conditions (Plate 45).

The main conglomerate band, the "level"; at Andamooka can be correlated with a similar bed, at a similar elevation, in the Yarra Wurta Cliff - Stuart Creek area and the Charlie Swamp area (Fig. 7). The deposition of a single conglomerate sheet, generally no more than 0.5 m thick, developed on a horizontal surface up to 30 m above the base of the Marree Formation over a distance of 80 km, could only have been accomplished by widespread ice-rafting. This is supported by the presence of numerous large boulders in the bed; one having a length in excess of 2.6 m (Plate 46).

Erosion of the Marree Formation results in the present land surface being littered with rounded quartzite boulders (Plate 47). Boulders with Devonian fossils have been found suggesting that Permian glacial deposits containing Devonian quartzite, and possibly other exotic clasts, were reworked into the Cretaceous sequence.

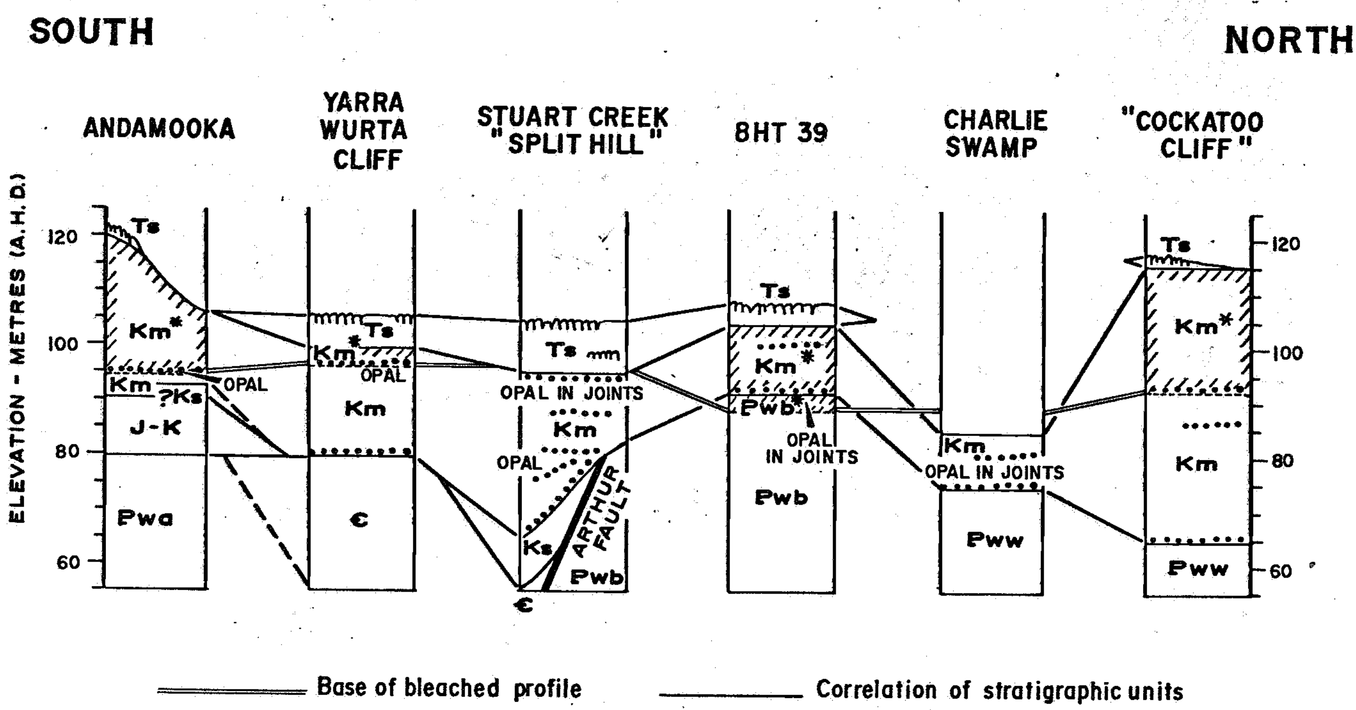
The upper part of the Marree Formation is intensively weathered to "kopi". As at Andamooka, the base of the "kopi" generally coincides with the major conglomerate bed.

Marree Formation is overlain by ?Middle Tertiary Mount Sarah Sandstone (Plate 48), a fluviatile-lacustrine deposit of coarse sand, clay and limestone, modified by ferruginisation and silicification. A hard, dense silcrete caps most of the mesas in the area.

Opal

At Stuart Creek, precious opal is confined to sediments of the Marree Formation. The main diggings are in a valley, but opal has also been taken from a nearby mesa, giving a 20-30 m vertical distribution of opal, all found in fresh "mud".

Like Andamooka, opal is found in "levels", the contact of a sandy conglomerate bed with underlying "mud" (Plate 49). Opal is also found, frequently associated with gypsum, in vertical



NOTE:- For legend see plan no. 80-238

FIG. 7

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

OPAL IN SOUTH AUSTRALIA
ANDAMOOKA — STUART CREEK — CHARLIE SWAMP
GEOLOGICAL SECTION

COMPILED G. Nicol	C.D.O. 21/5/80	DATE
DRAWN M.R.	SCALE —	
DATE April 1980	PLAN NUMBER	
CHECKED	S 14754	

1875

and horizontal veins apparently deposited in open cracks and within homogeneous sediment, usually "mud" (Plate 50).

Because the opal is found in fresh, moist "mud", it has not dried out naturally over a long period of time and much Stuart Creek opal crazes on exposure. Some opal is "gypsum shot", with fine needles of gypsum entrapped inside the opal which also causes cracking. However, in the last few years enough good quality opal has been found to maintain interest in this area.

Preferred mining methods

The soft, moist fresh "mud" dries and crumbles quickly on exposure, making underground mining extremely hazardous and several fatalities have resulted from collapse in excavated ground.

Recently, bulldozers have been extensively used to remove overburden above the opal "levels". Backhoes (Plate 29) figure prominently in the mining activities because the soft dark brown "mud" is easily dug by this machine which is used to expose opal "levels" after being reached by bulldozer. Once opal traces are found, the "level" is worked by pick and shovel. There has been limited prospecting with a Calweld drill.

Potential

Although the Marree Formation is less extensive than at Andamooka and Coober Pedy, only a very small area has been intensely prospected. The field is limited on the northern and eastern sides by outcropping Adelaidean sediments but the potentially opal-bearing rocks extend for several kilometres west and south of the present diggings. Further prospecting in this area is warranted.

MINOR OPAL DIGGINGS IN THE STUART CREEK AREA

CHARLIE SWAMP

These diggings, 20 km north of Stuart Creek (Fig. 6), comprising several bulldozer cuts on a low ridge and a few dozen scattered shallow trenches (Plate 51)mark the site of the first find of semi-precious opal in South Australia. In 1904, Brown reported:

> "A discovery of opal, possessing a certain amount of "fire", but not sufficient to allow of its being classed as precious opal, has been made at Charley's Swamp, about 30 miles South of Bopeechee Railway Siding, in the Hergott district. Common opal, white black and translucent chalcedony and agatised wood occur with it. It is possible that precious opal may yet be found at this place, the rock formation being favourable, and the stone already found may be considered an approach towards the precious variety".

Geology

The geology is similar to that at Stuart Creek. The workings are in fresh, grey-brown mud of Marree Formation. There are lenticular sandy conglomerate interbeds, as well as scattered "erratic" boulders within the mud. Marree Formation outcrops poorly, being everywhere covered by grey soil and boulders weathered out from the unit; silcrete being absent.

Opal

Black common opal, in veins of varying orientation up to 4 or 5 cm thick (Plate 52), is abundant in homogeneous fresh mud. There is evidence of at least two phases of common opal formation (Plate 53), the black material being brecciated and recemented by white common opal.

South of Charlie Swamp, at backhoe trench 39, (Fig. 6) Adelaidean Bunyeroo Formation forms a basement high extending up into the bleached profile. It has been altered to a grey indurated massive mudstone overlying soft, moist, fissile, laminated "mud". Within the soft "mud", very poor quality, amber coloured, common opal is present in vertical and horizontal veins up to 7 mm thick.

YARRA WURTA CLIFF

Scattered diggings, of unknown age and origin, are centred on Yarra Wurta Cliff, 9 km southwest of Stuart Creek where Marree Formation overlies Cambrian Yarra Wurta Shale. A bleached profile, only a few metres thick, remains at the top of the Marree Formation and is overlain by 6 m of Tertiary sand. An adit in the side of the mesa has been dug below the conglomerate bed ("level") marking the "kopi/mud" contact. Immediately below the "level" common opal is present within joints in the mud.

COWARD CLIFF

Several small diggings are scattered around the base of a prominent mesa known as Coward Cliff, 35 km north of Stuart Creek, where dark grey, fresh mud is overlain successively by yellow mud, and "kopi" (Plate 12). The basal conglomerate of the Tertiary sandstone, which overlies Marree Formation with sharp contact, contains cobbles of reworked silcrete and bleached shale clasts derived by erosion of the bleached profile. The top of the Tertiary sequence is strongly silicified to massive silcrete.

Opal is found in joints and horizontal partings in the "kopi" (Pl. 55) and in joints in fresh grey mud, as at Charlie Swamp.

Plate 54 shows the various types of opal found in the Stuart Creek area: black common opal from Charlie Swamp; black and white laminated, and yellow common opal from Yarra Wurta Cliff; precious opal and white potch from Stuart Creek; and white common opal from a mesa between Yarra Wurta Cliff and Stuart Creek.

COOBER PEDY

Coober Pedy Opal Fields are 935 km by road north of Adelaide, (Fig. 3) on the Stuart Highway. The highway, which is unsealed for all but two sections of 48 km each between Pimba and Pt. Augusta becomes impassable to two wheel drive vehicles after rain.

The opal workings, extending 30 km northwards and up to 8 km southwards of the town centre (Plate 56), are serviced by several major roads and hundreds of constantly changing, inter-connecting dirt tracks (Plate 57 and Fig. 9).

The first significant discovery of precious opal in South Australia was in 1915 at Stuart's Range. The discovery, by 14 year old Bill Hutchinson, was reported in Review of Mining Operations No. 22 (1915) p. 13. thus:

> "A prospecting party sent out by the New Colorado Prospecting Syndicate to prospect some of the Far North-Western country between Lake Phillipson and the railway made a discovery of opal, which proved to be of the precious variety and similar in character to that found at White Cliffs. The locality is at Stuart's Range, about 70 miles west of Anna Creek Station. Very little work has been done so far, the country is destitute of water, and on account of the war the market is disorganised".

The original name "Stuart's Range Opal Field" was later changed to Coober Pedy. The name is derived from the aboriginal kupa (or goober) meaning uninitiated person or white man, and piti, waterhole or hole. Hence Kupa Piti; white man's hole or burrow, (Briand, 1971) referring to the underground habitat of miners in "dugouts" (Plate 58). The shortage of ground suitable for dugout construction has since resulted in erection of more conventional surface dwellings (Pl. 59).

In the early days, methods of mining were simple and inexpensive, with prospectors' tools consisting of pick, shovel, pocket knife and pliers. Selecting the area to mine involved locating "coloured floaters" and searching for the main vein indicated by the presence of "bleached opal" in the soil. The area was gouged with care and the opal extracted. Workings consisted mainly of burrows and shallow trenches less than one metre deep along the escarpment edge. The first recorded production was valued at 750 pounds in 1916.

The next major development was the discovery of opal at shallow depth by an aborigine in 1946 at Geraghty Hill (Eight Mile), west of the present town. This heralded the beginning of underground mining on the plateau behind the escarpment. A spectacular increase in production resulted, from 96 pounds in 1945 to 54 797 pounds in 1946. By the early 1950's, Geraghty Hill was considered worked out. However, in 1957, an Italian partnership sank shafts to 16 m and discovered "levels" with high quality opal below the old workings. A major rush followed, and this level of activity has been maintained, and increased, since.

Geology

The geology is shown on Figure 8 in simplified form. The oldest unit cropping out is Early Cretaceous Marree Formation, which is overlain by various Tertiary and Holocene units.

Figure 10 shows a schematic section from Oolgelima Creek, on the northeastern boundary of the Precious Stones Field to the 14 mile Opal Field. Marree Formation, identical to that at Stuart Creek crops out in Oolgelima Creek as dark grey, fresh mud with lenses of sandy conglomerate (Plate 60). Nearby, lenticular limestone interbeds are packed with shelly fossils. Near the base of the Stuart Range escarpment, the fresh grey mud changes, rather abruptly, to brilliant white bleached silty claystone, the "kopi", or "sandstone" as it is called at Coober Pedy. This "kopi" crops out extensively throughout the length of the Stuart Range escarpment.

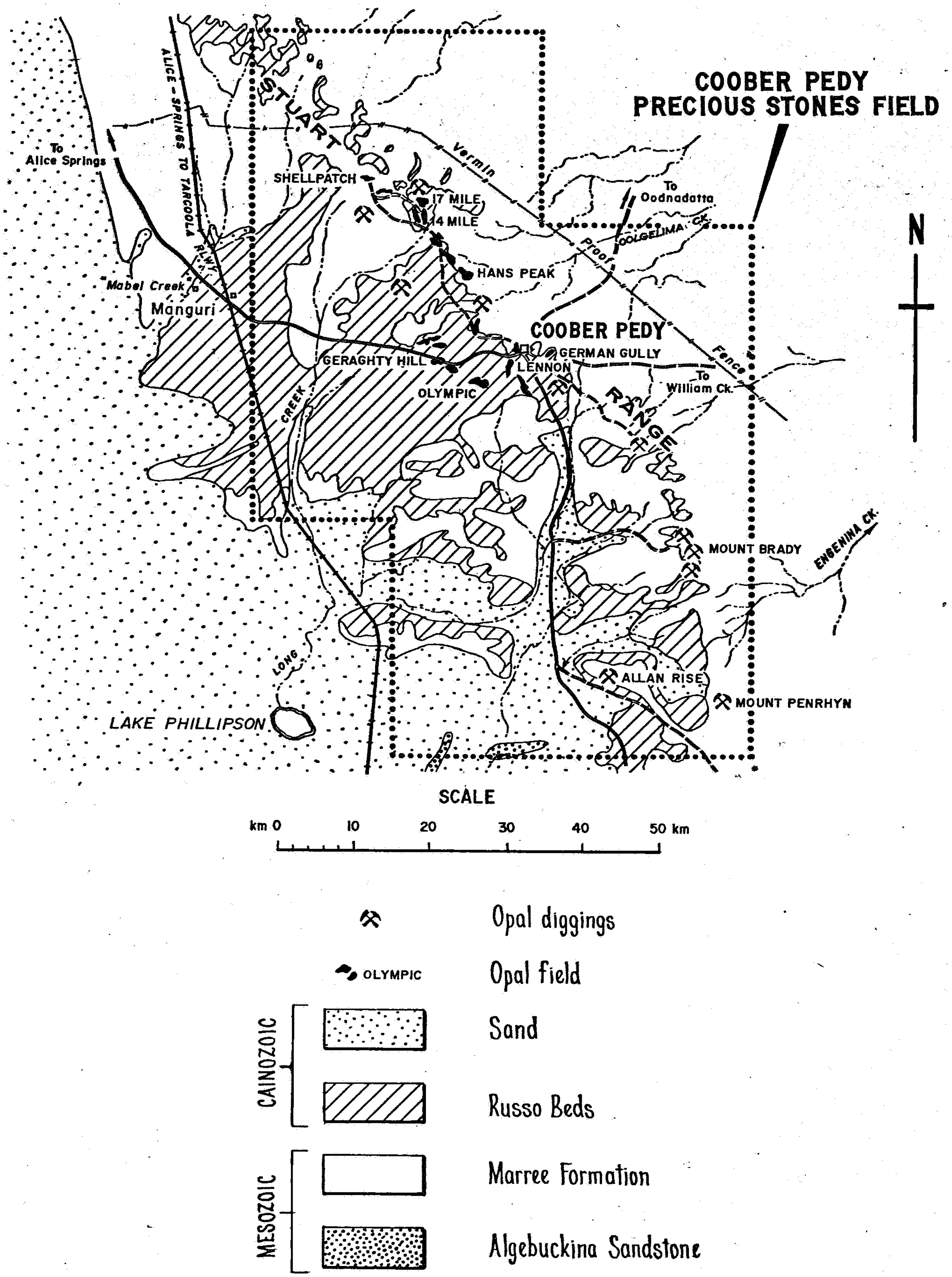


FIG. 8

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED L.C. Barnes	C.D.O. 21/5/80 DATE
OPAL IN SOUTH AUSTRALIA COOBER PEDY PRECIOUS STONES FIELD **REGIONAL GEOLOGY**	DRAWN M.R.	SCALE As shown
	DATE April 1980	PLAN NUMBER
	CHECKED	S 14755

1875

Up on the scarp, "kopi" is overlain by a complex sequence of silcrete, soil and sediment the Russo Beds, comprising -

- red silt
- red jasper breccia
- conglomerate

and . calcrete

Small areas of grey billy silcrete remain on the bleached Marree Formation, but it has been largely reworked into the Russo Beds.

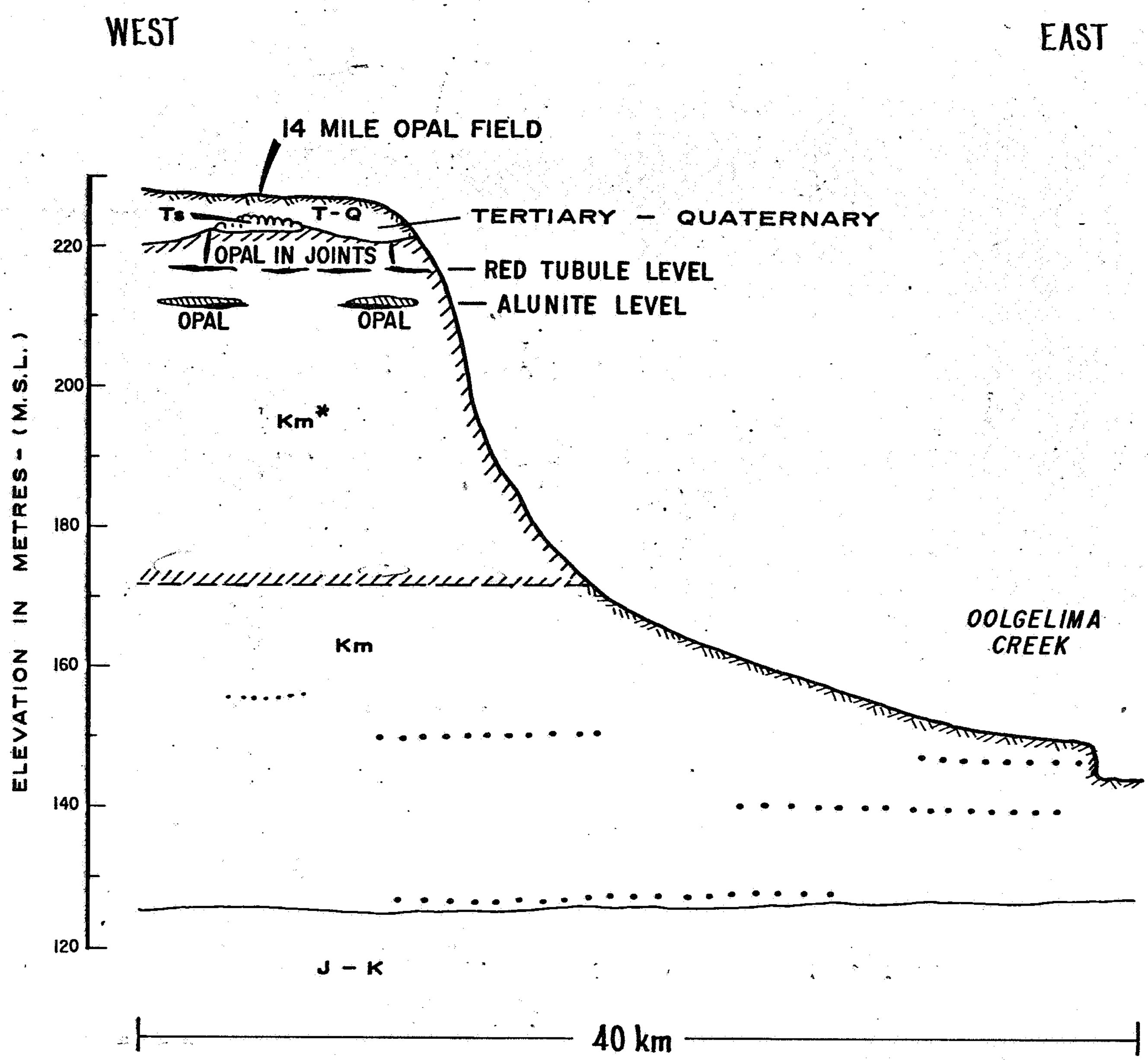
Opal

Opal is found in "kopi" in horizontal and vertical structures called "levels", "verticals" and "slides", which are often defined by various infillings, most of which postdate formation of opal.

Red tubule "levels" are so called because of the concentration of circular tubules, about 10 mm across, infilled with red silt. In some places intense concentrations of tubules form vertical structures extending down from the surface before spreading out along horizontal "level" structures (Plate 61).

Barker (in prep.) has interpreted these tubules as being due to termite activity. Termites are considered to have built mounds and burrowed downwards through the soil and "kopi" and spread out along favourable horizons, presumably related to water table. Although tubules are found up to 15 m below the top of the Marree Formation, this depth is not excessive, as modern mounds have tunnels down to a depth equal to four or five times the height of the mound above the ground.

There are numerous tubule "levels" throughout the opal fields. "Levels" cannot be traced for any great distance laterally. Although restricted to the upper 10-15 m of the "kopi" any section may show a number of red tubule "levels" about 2-3 m apart. Plate 62 shows two tubule "levels", the lower one obviously having been worked for opal.



NOTE: For legend see plan no. S14753

FIG. 10

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

OPAL IN SOUTH AUSTRALIA
COOBER PEDY 14 MILE OPAL FIELD
SCHEMATIC SECTION

COMPILED L.C. Barnes	C.D.O.	DATE 21/5/80	
DRAWN M.R.	SCALE		
DATE April 1980	PLAN NUMBER	S 14756	
CHECKED			

1875

Another type of horizontal structure is the alunite "level" (Plate 63). Large masses of cream, white or pale green alunite irregularly impregnate and replace "kopi" to produce a horizontal "level" which is found down to the deepest workings, but again are discontinuous. In many places, alunite is restricted to minor spotting, with small spots of alunite 5-10 mm across immediately below the "level".

Horizontal cracks may be infilled with massive satin spar gypsum which may be up to 0.5 m thick. Gypsum also infills joints in which opal has previously been deposited, in many cases breaking up the opal. In Plate 64, opal was gouged from immediately below the gypsum seam.

A fourth type of "level" is the yellow-brown limonite "level" or "ironstone band". Limonite impregnates cracks staining "kopi" on either side yellow-brown (Plate 67). Although formed later than opal, many miners regard the presence of an "ironstone band" as a good opal indicator.

Another type of opal bearing structure is the "vertical", or "slide". Theoretically, a "slide" is a minor fault but because all traces of bedding have been obliterated by weathering, relative movement is difficult to detect and many so called "slides" may not actually represent a fault. "Verticals" and "slides" i.e. non horizontal cracks, may be defined by the same materials that define a "level", either opal, red tubules, alunite, gypsum or yellow limonite. In Plate 65, the "slide" is defined by red tubules; a parcel of opal was found where this "slide" flattened out.

In Plate 66, red tubule "verticals" radiate from a red tubule "level". There is a second red tubule "level" about 0.4 m below the first. Adjacent to the tubules, the pale purplish "kopi" has been bleached white by a second generation bleaching, which post-dates development of opal.

Relationship of opal to geological features

At Coober Pedy, opal infills horizontal and vertical cracks. Plate 67 shows opal in a horizontal fracture or "level", immediately overlying an "ironstone band" of yellow-brown limonite which impregnates many opal bearing structures. In Plate 68, two sub-horizontal "levels" converge to "make" opal. In Plate 69, a limonite infilled "vertical", contains earlier formed opal in the centre of the structure.

In general, the best opal is found in "levels", but more than 50% of all opal is found in "verticals".?

Opal is occasionally found infilling space left when carbonate shells have been dissolved out during the bleaching process. These are called "skin shells" (Plate 70). Opal can also form internal moulds of fossils where the space between the shell valves, or inside snail shells, is infilled with opal. These "full" shells, (Plate 71) fetch high prices as specimens.

Opal in seams and veins in the "kopi" can be broken up and incorporated into rocks and soils which post-date formation of opal. Plate 72 shows silicified Russo Beds containing reworked clasts of opal. This type of rock is worked in several areas, notably Mount Brady and Teal Waterhole, where the miners call it "alluvial opal".

Deposition of opal must post date development of horizontal and vertical structures in which it is found. These structures were developed probably by tectonic activity (minor faulting and gentle folding) following the major period of bleaching. The relationship of opal to alunite is ambiguous; some opal predates development of alunite whilst in other places opal appears to be later than alunite. This suggests either:-

- several periods of alunite formation

- several periods of opal formation,
- or both.

Opal clearly predates satin spar gypsum, the red tubule infillings and accumulation of the Russo Beds.

Prospecting

At Coober Pedy, unlike Andamooka, the depth and spatial distribution of the "levels" is unpredictable and, indeed may not persist from one claim to the next. Likewise, the numerous "verticals" are unpredictably distributed. Thus at Coober Pedy opal is randomly distributed and its occurrence quite unpredictable.

Prospecting at Coober Pedy is effectively undertaken with an auger rig (Plate 73) which drills a hole about 0.1 m diameter to depths of 30 m. The cuttings brought up by the drill are searched for chips of opal and if good "trace" is found, a shaft is sunk or a bulldozer commences work. Because the only indication of an opal bearing "level" is chips of opal, the more holes that are drilled the greater the chance of finding opal (Plate 74). Capital and operating costs for auger drills are much less than for Calweld drills, although the latter are used for prospecting.

Preferred Mining Methods

Most mining is by underground methods using mechanised equipment. There are few, if any, traditional miners left at Coober Pedy. There are many Yorke Hoists and self-dumpers in operation but the favoured machine is the blower, being the most efficient method of bringing mullock to the surface from relatively deep "levels". When clustered together (Plate 75), they create their own micro-environment and dust is spread for miles.

Usually, the face of the drive is either drilled and blasted or dug with a jack hammer, and the mullock shovelled into blower tubes by hand. However, there is an increasing trend to mechanisation with more sophisticated equipment being used for driving. These include continuous bucket elevators which are used in conjunction with underground bogger and tunnelling machines.

Plate 76 shows the equipment associated with a medium sized underground operation at Coober Pedy:

- a Calweld drill to prospect, drill a shaft and ream out the hole to 1.8 m diameter,
- crane to lower the tunnelling machine down the hole,
- large blower to remove mullock, and
- small bulldozer to spread mullock piles.

In open cut mining, the most popular machines are bulldozers (Plate 77) which cut down to a "level", the depth of which is determined by either the depth where opal was found in nearby claims, or the depth of opal traces found during prospecting. Unless great care is taken during the dozing operation, any opal in higher "levels" or "verticals" is pushed into the dumps.

Large dumps generated by bulldozers are a haven for noodlers and, more recently, for noodling machines (Plate 78). Dump material is loaded into a hopper, to feed by elevator into a revolving screen. Screened rock fragments pass through a small, darkened cabin on a moving belt on which an Ultra-violet light shines. Most opal fluoresces white under long wave length (3150-4000 A^{O}) ultra-violet light and hence opal can be recognised and picked from the belt. The rest of the rock goes to waste.

Backhoe machines are best suited either to shallow ground or areas where the Russo Beds are thin or absent.

<u>Potential</u>

The potential at Coober Pedy is unlimited. Opal is found in horizontal, oblique and vertical structures throughout the "kopi" down to at least 200 m elevation (A.H.D.). Hence all parts of the Marree Formation above about 200 m are potentially opal bearing.

MINOR OPAL DIGGINGS NORTH OF COOBER PEDY

Many small opal diggings scattered along the Stuart Range for 300 km north of Coober Pedy (Fig. 3) are worked only sporadically and, in all cases, the limited production is unknown.

ENGLAND HILL

The workings comprise several bulldozer cuts and backhoe trenches on the flanks of England Hill (Plate 79), 110 km north-northwest of Coober Pedy (Fig. 3), in bleached Marree Formation "kopi" about 150 m stratigraphically above the base of the unit.

Small amounts of precious opal have been recovered from alunite "levels" and "verticals" similar to those at Coober Pedy.

OULDBURRA HILL

These diggings, described by Nichol (1973), are located 185 km north-northwest of Coober Pedy (Figs. 3 and 11) on a small plateau forming part of the western escarpment of Ouldburra Hill, approximately 20 m above general plain level.

The workings comprise one shaft approximately 25 m deep, five bulldozed trenches and 57 small open pits.

Host rock is bleached claystone and shale of the Marree Formation. There are several coarse grained sandstone beds, up to 1 m thick, interbedded with the claystone suggesting that the exposed rocks are near the base of the Marree Formation. Upper portions of the Cretaceous sequence are strongly silicified in part, and are overlain by red colluvial silt and reworked silcrete. In the sandy clay and shale, opal is found as thin seams, veinlets or lenses, generally within 3 m of the surface. In the sandstone, opal occurs as a cement surrounding the detrital quartz grains. White potch, grey potch, hyalite, semi-precious and small fragments of precious opal are common on the dumps.

SARDA BLUFF

These workings, 15 km north of the Ouldburra Hill diggings (Fig. 11) are located on the western scarp slope of a hill, approximately 20 m above the general plain level. The workings, described by Nichol (1973), comprise one adit in the hillside, two bulldozed areas and 72 small open pits.

The geology of the Sarda Bluff diggings is similar to that at Ouldburra Hill. Thin, coarse grained sandstone beds are interbedded with white claystone. Opal is found in horizontal cracks and vertical joints, as thin seams on the contact between sandstone and claystone, and as a matrix cementing the sandstone.

VESUVIUS

Located, 225 km north-northwest of Coober Pedy and 15 km northeast of Marla (Fig. 11) Vesuvius was worked in 1977 by miners en route to the Mintabie diggings.

The workings comprise two groups, one of bulldozer and backhoe trenches on the flanks of a low hill (Pl. 80) and the other of bulldozing and trenching, 1 km to the north on the slopes of a long mesa (McCallum, 1980).

Geology is similar to Sarda Bluff and Ouldburra Hill, with interbedded coarse grained sandstone and bleached white claystone near the base of the Marree Formation. Several quartzite boulders, similar to those in the conglomerate beds at Andamooka and Stuart Creek, have been observed on the dumps. Cretaceous rocks are overlain by massive quartzose silcrete and red brown silt and clay.

Most of the opal at Vesuvius was found in an arcuate joint or "slide" that flattened out to become a "level". Other horizontal cracks contain thin seams of opal, and abundant glassy potch cements sandstone.

LAMBINA

Lambina opal diggings, 230 km north of Coober Pedy and 10 km south of Lambina Homestead (Fig. 11) on the Granite Downs-Oodnadatta road, and have been worked intermittently for at least 20 years until 1977.

The workings, described in Flint and Barnes (1980), comprise eight bulldozer cuts, a number of backhoe trenches, and a few shallow auger holes. They extend for 1.5 km along the northern slopes of a low silcrete capped rise (Plate 81).

The workings are in bleached Marree Formation. Coarse grained sand interbeds and lenses are common, and evidence of bioturbation abundant. Cretaceous rocks are overlain by massive quartzose silcrete on the top of the rise but in the workings 1 to 2 m of red silt and colluvium with soft platy calcrete overlies the "kopi". In some areas, this red colluvial silt is silicified to a brittle jasper breccia.

Opal is found in joints within the claystone, and as thin seams immediately beneath the sandy interbeds. Clasts of opal reworked from primary veins in the Marree Formation are found in the colluvial silt and jasper breccia.

MINTABIE

In 1931, precious opal was discovered at Mintabie, 400 km northwest of Coober Pedy (Fig. 3), although there is a report of black opal being found in 1919 (O'Leary, 1937). Because of remoteness and hard rock, mining was intermittent until large bulldozers arrived in late 1976 and there was a major strike in 1977.

The workings are clustered together on the edge of a north-easterly facing scarp (Plate 82). The area, in contrast to the other opal fields is thickly vegetated with mulga and mallee trees (Plate 83).

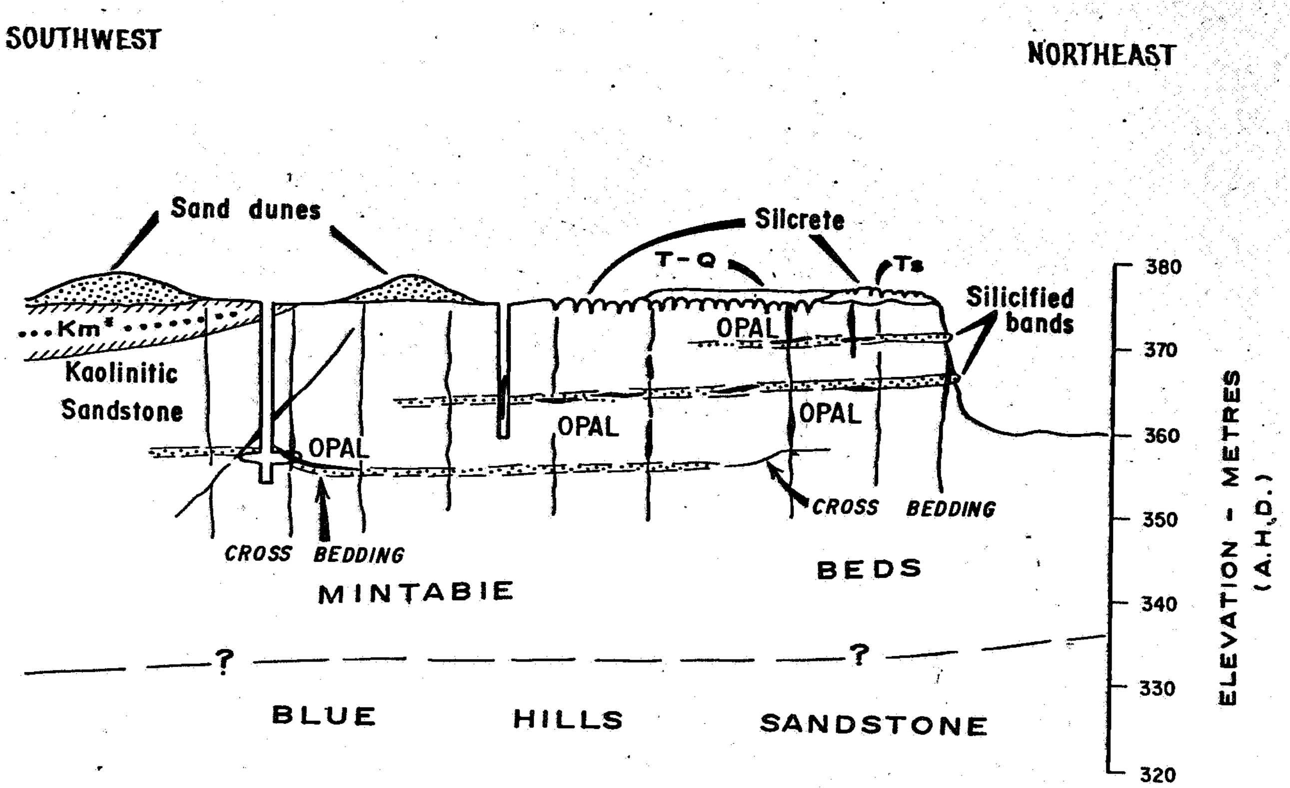
Living conditions at Mintabie are still fairly primitive. There have been up to 250 residents on the field, mainly housed in caravans or tents, although there is a steady rise in the number of more permanent residences, many of which are scattered through the mining area (Plate 84).

A residential area with a canteen (Plate 85) has been established below the scarp. An airstrip, reported to be one of the best in the outback, a bore fitted with an electric pump and an equipped medical aid caravan have also been established. The Flying Doctor calls once a month. The Department of Mines and Energy has established an Area Office and the Area Officer's wife handles the medical sessions.

At present the population varies markedly, with many of the miners returning to Adelaide, or their dugouts in Coober Pedy during the hot summer months. As the town grows, the population may become more stabilised.

Geology

Figure 11 shows the geology of the Mintabie area. The workings are in Ordovician-Devonian Mintabie Beds, a sequence of massive and kaolinitic sandstone with minor shale bands (which as an aquiclude may be important in opal formation). Mintabie



NOTE :– For legend see plan no. S 14753

FIG. 12

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

OPAL IN SOUTH AUSTRALIA
MINTABIE OPAL DIGGINGS
SCHEMATIC SECTION

COMPILED I.J. Townsend	C.D.O.	DATE 21/5/80
DRAWN M.R.	SCALE —	
DATE April 1980	PLAN NUMBER	
CHECKED	S 14757	

1875

Beds crop out extensively along the escarpment conformably overlying Blue Hills Sandstone of ?Ordovician age (Fig. 12), and overlain in places either by Cretaceous shale with a thin basal sandstone (Plate 86), or by Tertiary sandstone.

In many areas, both Tertiary and Palaeozoic sandstone is silicified to massive hard quartzose silcrete.

Mintabie Beds are gently folded and, at Mintabie, dip southerly at about 5^{o} (Plate 87). The upper part of the Mintabie beds are generally strongly jointed and the earlier miners stopped when they reached less jointed, poorly bedded, massive sandstone.

<u>Opal</u>

As in other fields, both vertical and horizontal structures are sought for the elusive opal. Abundant potch has been found in horizontal structures or "levels" and, in places, this potch makes colour and becomes precious opal. The horizontal partings probably represent parting along the bedding planes. Thin shale bands may also act as aquicludes to form a "level". "Levels" are generally silicified by opaline silica and potch, or precious opal infills the partings.

Mintabie Beds often exhibit large scale cross bedding (Plate 88), a feature typical of sand deposited in a fluviatile environment. The opal "levels" are often arcuate and reflect development along cross bedding (Plate 89). Opal also forms in oblique or near vertical joints (Plate 90).

Plate 91 shows a typical opal seam in the Mintabie Beds. Mintabie opal often exhibits distinct dark and light bands with colour generally being present in the lighter bands. Opal is cut so that a thin light colour band with play of colours is backed by dark opal forming a natural doublet (Plate 92). This is called Mintabie "semi-black" opal. Normal black opal with colour flash in the black is also found.

Plates 93 and 94 show good quality Mintabie opal; inferior material (Plate 95) is made into triplets.

Preferred Mining Methods

Open Cut

Large bulldozers, mostly D9's, scrape off top soil, (Plate 96) and rip carefully through the upper blocky silicified sandstone. Where silcrete is thicker or less jointed, drilling (Plate 97) and blasting (Plate 98) is required.

Once through the harder layers, the big machines can handle the underlying softer, more uniform sandstone. Spotters follow the ripping operation throughout (Plate 99) to check for signs of precious opal, as it has been found as shallow as 1.5 m. Mullock is pushed out into huge dumps, (Plate 100) which are a paradise for noodlers, particularly aboriginals from Indulkana (Plate 10).

Other large mining equipment capable of handling the hard ground included a 95 tonne Hopto trench digger with a 5 m^3 bucket (Pl. 102). This machine which, with bulldozers, dug the hole shown in Plate 103, has since been sold because of high operating costs and limited use.

Underground mining is gradually replacing expensive open cut operations. The ever increasing cost of repair to the big machines, plus the cost, and difficulty with regard to supply of diesel fuel means that miners increasingly use conventional underground methods and Calweld drilled shafts, Yorke hoists, (Plate 104), self dumpers, or blowers.

As is the case at other fields, miners are reluctant to move far from areas of known production. Prospecting is confined to margins of the producing area and the field enlarged by slow peripheral growth (Plate 105). Opal has been recorded in Mintabie Beds up to 8 km distant from Mintabie, but only recently have miners been prepared to actively prospect any distance from the main workings.

Potential

The potential for opal is high in the area of outcropping Mintabie Beds and in the overlying Cretaceous sediments south of the present workings.

MINOR OPAL DIGGINGS IN THE MINTABIE AREA

WALLATINNA

The diggings, comprising about 40 backhoe trenches scattered over a low hill (Plate 106) are 15 km south of Mintabie and 8 km southwest of Wallatinna Outstation (Fig. 11). The period of working is unknown although there was some activity in 1977 (Townsend and Robertson, 1980).

Geology

The workings are in Cambrian "Wallatinna Beds", a sequence of white, kaolinitic, medium to coarse grained sandstone with interbedded siltstone and conglomerate, with cobbles and boulders of deeply weathered crystalline basement.

The sediments trend northeast and dip 30° northwest. Siltstone, with irregular chert development more typical of the Observatory Hill Beds, crops out 300 m northwest of the workings.

Opal

In one cut in the central part of the workings, a sandy conglomerate bed 0.2-0.3 m thick overlies a 0.05 m thick layer of brown clay (or "mud"). It is presumed that some opal has been found at this sand-"mud" interface, similar to Andamooka. However, this "mud" is only present in one digging and the number of diggings suggests that opal is not restricted to this "level", but is also in joints in Cambrian rocks.

Because of the restricted distribution of kaolinitic conglomerate, the potential of this area is considered to be low.

GRANITE DOWNS

Two groups of abandoned opal workings have been located near Granite Downs homestead (Fig. 11) (Nichol, 1975)).

A third group of workings, is reported to be about 3 km south of Granite Downs and average quality opal has been won from these workings (Hiern, 1967, p. 37). Small exploratory diggings are common over a wide area around Granite Downs. There is no record of amount or value of opal recovered from these abandoned workings.

Granite Downs Opal Workings No. 1

The diggings are located on the eastern edge of a wide, salt bush covered gibber plain, 4 km east of Mount Chandler and 300 m east of the Alice Springs railway line (Plate 107).

The diggings are on the gentle slopes of a low rise, the main group of workings being on the western flank, with a few diggings on the eastern side. Workings comprise four shafts 4-5 m deep, four large bulldozed trenches and 13 small open pits.

Host rock is deeply weathered Precambrian crystalline basement. Gneissic banding strikes easterly and dips 75^{o} southwards. Opal is found as thin seams, veinlets and lenses in joints and minor faults in the weathered gneiss. White potch, grey potch, hyalite semi-precious and small fragments of precious opal are common on the dumps.

Granite Downs Opal Workings No. 2

The diggings are near the base of a silcrete capped mesa adjacent to the main road to Oodnadatta, 3 km southeast of Granite Downs Homestead, (Hiern, 1967; Nichol, 1975). The workings comprise one shaft, 7.5 m deep, and 41 small open pits.

Country rock is light grey, deeply weathered gneiss, striking northeast and dipping 70^{o} northwestwards.

A trace of pale coloured potch opal was found as a thin seam in the weathered gneiss. A pale pink variety of chalcedonic quartz is common on the surface in the immediate area and may have been taken to be an opal floater by prospectors.

THE VALUE OF OPAL

Opal is by far the most valuable of the many precious and semi-precious varieties of silica, but value of individual stones varies widely. Although attempts have been made to establish guide lines for determining opal prices (O'Leary, 1977), they have been largely unsuccessful because of the infinite variation in colour pattern and brilliance exhibited by the gem.

Thus the price paid for any stone, or parcel of stones, is subjective, and dependent on the whim of individual buyers.

However, the main factors influencing the price paid for opal are:

- background colour: - Black opal (a stone with a dark background) is more valuable than clear opal (crystal opal) which in turn is generally more valuable than white or milky opal.
- dominant fire colour: - A red fire opal is generally more valuable than a predominantly green opal, which in turn is more valuable than a stone showing only blue colour.
- colour pattern: - Harlequin opal, where the colour shines as patches is generally more valuable than pinfire opal where the colour is in small specks.

There is a marked difference between the value of uncut opal compared with the value of cut and polished stone. The opal miner receives between one fifth and one hundredth of the final value of the stone. Because of this extreme variation in prices, quoting prices for opal may be misleading.

The best black opal from Lightning Ridge fetches up to \$3000/carat. At 155 carats per ounce, that equates to \$450 000/ounce or \$16 billion/tonne.

In South Australia, the highest prices are received for stones from Mintabie, with cut and polished opal being valued at up to \$1 200/carat. Good quality Mintabie opal fetches \$500-\$7 000/ounce in the rough. Top quality crystal opal from Andamooka also commands very high prices and much of the opal from this field brings over $100/carat when polished. A high proportion of opal from Coober Pedy is of lesser quality, being worth only a few dollars, or tens of dollars, per ounce and hence is used mainly for doublets and triplets (Plate 108). However, because the amount of opal found at this field is much greater than at all other fields combined, Coober Pedy is the world's major producer of precious opal.

THE OPAL INDUSTRY

Estimation of the value of opal production is difficult. There is no royalty payable on opal and there are no production returns submitted by miners to the Department of Mines and Energy, as is required for all other minerals.

From 1916 to mid 1970, annual returns submitted by opal buyers provided the only record of production (Table 1). These returns were considered unreliable and grossly understated, and the amount of either rough or cut opal sold privately was not known.

TABLE 1

ESTIMATED VALUE OF OPAL PRODUCTION IN SOUTH AUSTRALIA, 1916-1970 ($)

YEAR	COOBER PEDY	ANDAMOOKA	STUART CREEK	MINTABIE
1916	1 500			
1917	1 000			
1918	143 350			
1919	40 000			
1920	48 000			
1921	14 000			
1922	11 000			
1923	7 000			
1924	8 000			
1925	18 140			
1926	20 660			
1927	18 350			
1928	23 080			
1929	22 112			
1930	2 284			
1931	6 254			
1932	6 120			
1933	4 588	1 924		
1934	1 722	1 312		68
1935	4 290	2 098		170
1936	16 422	2 134		-
1937	16 400	7 374		-
1938	4 624	4 516		-
1939	3 942	8 002		96
1940	5 284	18 044		-
1941	4 030	19 106		-
1942	2 372	9 580		-
1943	4 488	23 274		-
1944	2 150	17 594		-
1945	1 934	22 634		-
1946	109 584	34 584		-
1947	40 484	42 360	294	-
1948	60 788	35 964	-	-
1949	35 148	44 430	-	10
1950	45 424	62 238	-	-
1951	80 370	47 864	-	-
1952	87 754	37 212	-	-
1953	108 340	44 580	-	-
1954	97 006	46 474	-	120
1955	74 130	68 240	-	30
1956	98 850	142 188	40	-
1957	210 834	153 964	-	-
1958	206 024	171 108	-	2 500
1959	498 826	344 308	-	1 000
1960	826 496	366 918	1 600	-
1961	824 566	500 888	-	4 650
1962	1 136 074	754 172	-	7 708
1963	1 472 488	810 574	-	3 850
1964	1 362 146	1 266 496	-	3 260
1965	1 742 352	1 274 402	-	1 950
1966	1 970 001	1 655 362	-	-
1967	1 020 624	1 814 311	-	-
1968	1 940 369	2 068 160	-	6 150
1969	3 449 718	3 693 912	-	183 775
1970	4 000 000	3 300 000	-	400 000
Totals	$21 832 502	$18 918 301	$1 934	$615 337

Since 1971, overall value of production has been estimated by Departmental officers. The miners are reticent about their turnover in the belief that figures will be used as a check against taxation returns. Annual, official value of opal production in South Australia from 1971 to 1977, listed in Table 2 is taken from the Annual Reports of the Department of Mines and Energy.

TABLE 2

ESTIMATED VALUE OF OPAL PRODUCTION IN SOUTH AUSTRALIA 1971-1977

Year	Coober Pedy	Andamooka	Stuart Creek	Mintabie
1971		11 000 000		
1972	Total	20 000 000		
1973	Estimated	30 000 000		
1974	for all	22 000 000		
1975	fields.	20 000 000		
1976		30 000 000		
1977		30 000 000		
	Total	163 000 000		
Grand Total 1916-1977		204 368 074		

As the figure of $30 million adopted for 1976 and 1977 was believed to understate the value of opal production a detailed survey of machinery and equipment on each opal field was undertaken in 1978. The results were used in an attempt to estimate more realistically the value of opal production and a formula based on the capital investment of mining equipment, operating costs and the cost of living was devised.

$$\$\ \text{Annual Production} = 24\,400\,x + y + 0.25z$$

where x = number of miners

y = annual operating cost

z = capital investment

The constant of $24 400 is derived by assuming that each miner supports himself and two dependents and that the cost of living on or off the field is $150/week/person. In addition, a "bonanza factor" was included assuming that 1% of miners make a significant find of $100,000/year.

Thus the constant was

$$(3 \times 52 \times 150) + (.01 \times 100,000) = \$24,400$$

The figures used in calculations and the resultant estimates for 1978 are listed in Table 3.

TABLE 3

DATA AND PRODUCTION

	No. of miners (x)	Operating costs $ million (y)	Capital investment $ million (z)	Value of Production $ million
Coober Pedy	1 000	3.13	17.83	32
Andamooka	50	0.5	3.17	2.5
Stuart Creek	20	0.1	0.8	.75
Mintabie	150	1.07	7.83	6.5
Total	1 220	4.80	29.63	41.75

Based on a similar survey in 1979, opal production for that year amounted to $42.6 million.

Of that $42 million a large proportion of the opal is exported, particularly to Hong Kong, and some of the money earnt from opal is sent to relatives in the miner's home country. However, a considerable proportion of the money earned by the miner stays within the State and is expended on new equipment, and into the ever increasing costs of operating and purchase of explosives. The high cost of living on the opal fields absorbs much of the miner's earnings.

Opal mining has been responsible for considerable associated development, including -

- Opal jewellery - much of the better quality opal is cut and polished in Australia, and the mining industry supports a number of cutters and jewellers throughout the country.
- development of regional centres - Coober Pedy is an established town, the largest settlement north of

Port Augusta. The town, which only a few years ago was a frontier mining town, is now a fully established regional centre boasting most of the amenities of the southern city such as school, hospital, post office, police station and many government offices. Of a population of 5 000-6 000, only about 1 000 are miners. The town would now probably be viable without opal mining.

- air transport - the airline, Opal Air, originally financed by money from opal mining has now established a network incorporating most of the towns in the north of the State and including Alice Springs (N.T.). Several independent aircharter companies exist solely on the carriage of opal miners and families and buyers.
- tourism - the tourist industry is increasing dramatically in Coober Pedy, and to a lesser extent in Andamooka and Mintabie. Many tourists include the towns in their holiday itinerary instead of regarding them as names en-route to or from Ayers Rock and Darwin.

South Australia, producing about 80% of the world's precious opal, is the main supplier to the world, and opal is the only mineral product for which this State is renowned. For this, South Australia is surely entitled to be called THE OPAL STATE.

L. Barnes. I. J. Townsend. G. J. Nicol per LCB.

L. C. BARNES I. J. TOWNSEND G. J. NICOL

SELECTED BIBLIOGRAPHY

Anonymous, 1966. Matrix Opal - South Australia's own gemstone. The Fossicker Sept. 1966.

Armstrong, A.T., 1962. Andamooka and Coober Pedy Opal fields. Aust. Dept. of Mines report 55/3 (unpublished).

Armstrong, A.T., 1978. Handbook on Small Mines. Sth. Aust. Government Printer, 206 pp.

Ball, R.A. and Malin, A.S., 1973. The Australian Gemmologist Nov. 16-19.

Barker, I.C., Barnes, L.C. and Benbow, M.C., 1979. The Russo Beds, Q. geol. Notes, geol. Surv. S. Aust., 71.

Barker, I.C. The Stratigraphy and Opal Occurrences of the 14 and 17 Mile Opalfields, Coober Pedy, South Australia. M.Sc. thesis, University of Adelaide, (in prep.).

Barnes, L.C., and Pitt, G.M., 1976. Silcrete, sediments and stratigraphy. S. Aust. Dept. Mines report 76/119 (unpublished).

Barnes, L.C., and Pitt, G.M., 1977. The Mount Sarah Sandstone. Q. geol. Notes geol. Surv. S. Aust., 62: 2-8.

Barnes, L.C., and Scott, D.C., 1978. Opal at Stuart Creek, Charlie Swamp and Yarra Wurta Cliff. Report No. 1: Geological investigations and Calweld drilling of the Precious Stones Field. S. Aust. Dept. Mines report 79/6 (unpublished).

Berrington, M.D., 1958. Stones of Fire. Robertson and Mullens, Melbourne.

Briand, R., 1971. White man in a hole. Abbot Litho Arts. Melbourne, 155 pp.

Brown, H.Y.L., 1894. Report on the geology of the country along the route from Strangways Springs to Wilgena, and on the gold discovery near Wilgena: Adelaide, South Australian Govt. Geologist Ann. Rept. 10-12.

Brown, H.Y.L., 1904. Opal. A short review of Mining Operations in S. Aust. 2, 12.

Brown, H.Y.L., 1908. Record of the Mines of S. Aust., (4th Ed.) p. 360.

Calbert, B.L., 1978. Use of Pneumatic Conveying System ("Blowers") on the Opal Fields. Min. Ind. Q., S. Aust. Dept. Mines Energy, 12, 17-24.

Campbell, K.S.W., Rogers, P.A., and Benbow, M.C., 1977. Fossiliferous Lower Devonian boulders from the Cretaceous of South Australia. Q. geol. Notes, geol. Surv. S. Aust., 62: 9-13.

Carr, S.G., Olliver, J.G., Conor, C.H.H., and Scott, D.C., 1979. Andamooka Opal Field. The geology of the Precious Stones Field and the Results of the subsidised Mining Programme. Rep. Invest. geol. Surv. S. Aust., 51.

Croll, I.C.H., 1950. The opal industry in Australia. Bull. Bur. Miner. Resour. Geol. Geophys. Aust., 17:47 p.

Daly, S.J. and Coats, R.P., 1971. CURDIMURKA map sheet, Geological Atlas of South Australia 1: 250 000 series (Preliminary edition) Geol. Surv. S. Aust.

Darragh, P.J., Gaskin, A.J., Terrell, B.C., and Sanders, J.V., 1966. Origin of Precious Opal. Nature, Jan. No. 5018: 13-16.

Darragh, D.J., and Pendix, J.L., 1973. Precious Opal - Development towards synthesis. The Australian Gemmologist 11(11): 17-21.

Darragh, P.J., Gaskin, A.J., and Sanders, J.V., 1976. Opals Scientific American, 234 (4): 84-95.

Darragh, P.J., Gaskin, A.J. and Sanders, J.V., 1977. Synthetic Opals. The Australian Gemmologist. 13 (4).

Dorman, F.H., and Gill, E.D., 1959. Oxygen isotope palaeotemperature measurements of Australian fossils. Proc. Roy. Soc. Vict., 71: 73-98.

Emery, K.O., 1955. Transportation of rocks by driftwood. J. sedim. Petrol. 25 (1): 51-57.

Eyles, W.C., 1964. The Book of Opals. Charles E. Tuttle Co. - Inc.

Falconer, A., and Watkins, D.C., 1978. Survey of principal mining operations in South Australia in 1977. S. Aust. Dept. Mines report 78/94 (unpublished).

Flint, D. and Barnes, L.C., 1980. Lambina Opal Diggings. S. Aust. Dept. Mines report (in prep.) (unpublished).

Forbes, B.G., 1966. The geology of the Marree 1: 250 000 map area. S. Aust. Dept. Mines. Report of Investigations 28, 47pp.

Freytag, I.B., 1966. Proposed rock units for marine Lower Cretaceous sediments in the Oodnadatta region of the Great Artesian Basin. Q. geol. Notes. geol. Surv. S. Aust., 18: 3-7.

Geraghty, V.T., 1947. Andamooka Opal field. S. Aust. Dept. Mines Report 23/225 (unpublished).

Geraghty, V.T., 1961. Andamooka and Coober Pedy Opal Fields. Min. Rev. Adelaide, 111: 18-25.

Geraghty, V.T., 1963. Andamooka and Coober Pedy Opal Fields. Min. Rev. Adelaide, 115: 38-45.

Gourlay, A.J., and Noakes L.C., 1970. Developments in the Australian Opal Industry. Australian Mineral Industry Review 23(1) Sept. 1970.

Hannah, M.J. and Lindsay, J.M., 1977. Foraminiferal biostratigraphy of the Andamooka Opalfields. S. Aust. Dept. Mines report 77/10 (unpublished).

Harris, W.K. and Cooper, B.J., 1978. Micropalaeontology of selected samples from the Stuart Creek Opalfield. ANDAMOOKA 1:250 000 map sheet S. Aust. Dept. Mines report 78/95 (unpublished).

Hiern, M.N., 1965. Opal deposits in Australia. Q. geol. Notes, geol. Surv. S. Aust., 16:3-6.

Hiern, M.N., 1967. Coober Pedy Opal Field. Min. Rev. Adelaide, 122:5-27.

Hiern, M.N., 1967. Mintabie Opal Field. Min. Rev. Adelaide, 122:33-36.

Hiern, M.N., 1967. Opal Deposits in Northern South Australia. Min. Rev. Adelaide, 122:373-9.

Hiern, M.N., 1967. Opal Occurrence - Myall Creek Station. Min. Rev. Adelaide, 122:40-43.

Hiern, M.N., 1974. Opal - South Australia. Geol. Surv. S. Aust. report 74/26 (Unpublished) also: Economic Geology of Australia and Papua New Guinea 1976 A.I.M.M. monograph series No. 4. Industrial Minerals and rocks.

Howchin, W., 1919. Geological Memoranda - Salt a cause of mechanical disintegration of rocks in arid regions. Trans. Roy. Soc. S. Aust., 43:54-55.

Idriess, I.L., 1967. Opals and Sapphires. Angus and Robertson, Sydney.

Jack, R.L., 1926. Notes on two occurrences of Archaeocyathinae near Lake Torrens. Trans. Roy. Soc. S. Aust., 50:317.

Jessup, R.W., 1960. The lateritic soils of the southeastern portion of the Australian arid zone. J. Soil Sci., 11: 106-113.

Jessup, R.W., and Norris, R.M., 1971. Cainozoic Stratigraphy of the Lake Eyre Basin and Part of the Arid Region Lying to the South. J. geol. Soc. Aust., 18: 303-331.

Johns, R.K. Hiern, M.N. and Nixon, L.G., 1966. Andamooka map sheet, Geological Atlas of South Australia, 1: 250 000 series Geol. Surv. S. Aust.

Johns, R.K., 1967. Water supply - Andamooka opal field. Report on recent drilling Min. Rev. Adelaide 122: 44-46.

Johns, R.K., 1968. Geology and mineral resources of the Andamooka-Torrens area. Bull. geol. Surv. S. Aust. 41.

Johnson, W., 1958. Coober Pedy Opal Field. Min. Rev. Adelaide, 105: 62-63.

Johnson, W., 1958. Andamooka Opal Field. Min. Rev. Adelaide, 105: 65-66.

Jones, J.B., Segnit, E.R., and Nickson, 1963. Differential Thermal and X-ray Analysis of opal. Nature 198: 1191

Jones, J.B., Sanders, J.V., Segnit, E.R., 1964. Structure of Opal. Nature 204: 990-991.

Jones, J.B., and Segnit, E.R., 1966. The occurrence and formation of opal at Coober Pedy and Andamooka. Aust. J. Sci., 29: 129-133.

Jones, J.B., and Segnit, E.R., 1971. The nature of opal. Nomenclature and constituent phases. J. Geol. Soc. Aust., 18: 57-68.

Kalokerinos, A., 1967. In Search of Opal. Ure Smith, Sydney.

Kalokerinos, A., 1971. Australian Precious Opal. Thomas Nelson and Sons (Canada) Ltd. 1971.

Leechman, F., 1961. The Opal Book. Ure Smith, Sydney. 255 pp.

Lindsay, J.M., 1975. Foraminiferal biostratigraphy of an Aptian Shale from Giddinna, MURLOOCOPPIE 1: 250 000 sheet. Dept. Mines report 75/176 unpublished.

Ludbrook, N.H., 1961. Outline of the biostratigraphy of Andamooka opal field. Trans. R. Soc. S. Aust. 84: 129-137.

Ludbrook, N.H., 1966. Cretaceous biostratigraphy of the Great Artesian Basin in South Australia. Bull. Geol. Surv. S. Aust. 40.

Mansfield, L.L., 1949. Andamooka Opal Field. Min. Rev. Adelaide, 87: 199-201.

Mayer, W., 1972. Opal <u>in</u> Myatt, W.J. (Ed.) Australian and New Zealand Gemstones, how and where to find them. Paul Hamlyn Pty. Ltd. (Pub.) 237-243.

McCallum, W.S., 1980. Vesuvius Opal Diggings. S. Aust. Dept. Mines report 80/38 (unpublished).

Murrell, B., 1977. Stratigraphy and Tectonics across the Torrens Hinge Zone between Marree and Andamooka, South Australia. Ph.D. thesis University of Adelaide (unpublished).

Nicol, G.J., 1979. Geology of the Stuart Creek - Charlie Swamp Area, Northern South Australia. S. Aust. Dept. Mines Energy open file Env. 3463 (unpublished).

Nicol, G.J., 1979. The Tertiary geology of the Coward Cliff area, between Lake Eyre and Lake Torrens, South Australia. University of Adelaide Honours thesis S. Aust. Dept. Mines Energy open file Env. 3600 (unpublished).

Nichol, D., 1973. Opal Occurrences near Welbourn Hill Homestead. <u>Mineral Resour. Rev. S. Aust.</u>, 135: 164-168.

Nichol, D., 1975. Opal Occurrences near Granite Downs Homestead. <u>Mineral. Resour. Rev. S. Aust.</u>, 139: 99-101.

Nixon, L.G.B., 1960. Andamooka opal field <u>Min. Rev. Adelaide</u>, 109: 13-23.

O'Driscoll, E.P.D., 1959. The possibility of augmenting groundwater supplies, Andamooka opal field. <u>Min. Rev., Adelaide</u>, 107: 42-44.

O'Leary, B., 1977. A field guide to Australian Opals. Rigby Ltd.

Olliver, J.G., Carr, S.G., Conor, C.H.H., and Scott, D.C., 1978. Andamooka Opalfields, A Geological guide for the opal prospector. S. Aust. Dept. Mines report 78/86 (unpublished).

Osterstock, A., 1976. Andamooka Opal. Austaprint, Hampstead Gardens, South Australia.

Parkin, L.W., 1947. The Opal Industry in South Australia. Min. Rev. Adelaide 84: 151-153.

Parkin, L.W., 1956. Notes on the younger glacial remnants of northern South Australia. Trans. Roy. Soc. S. Aust., 79: 148-151.

Parkin, L.W., ed. 1969. Handbook of South Australian Geology. Geol. Surv. S. Aust. Adelaide, 268 pp.

Pitt, G.M., 1978. MURLOOCOPPIE, South Australia. Explanatory Notes, 1:250 000, geological series. Sheet SH32-2 Geol. Surv. S. Aust.

Reynolds, W.R., 1970. Mineralogy and stratigraphy of Lower Tertiary clays and claystone of Alabama. J. Sedim. Petrol., 40: 829-838.

Sanders, J.V., 1964. Colour of Precious Opal. Nature, 204:1151-1153.

Sanders, J.V., 1968. Diffraction of Light by Opals. Acta Crystallographica Section A. A24 (4): 427-434.

Segnit, R.W., 1935. Andamooka Opal Field. Min. Rev. Adelaide, 62: 51-56.

Segnit, R.W., 1939. The Precambrian-Cambrian succession Bull. geol. Surv. S. Aust. 18: 143-164.

Segnit, E.R., Anderson C.A. and Jones, J.B., 1970. A scanning microscope study of the morphology of opal. Search Vol. 1 No. 6 Dec. 1970.

Thomson, B.P., 1978. Geological Map of South Australia, 1:1 000 000 (Preliminary edition) Geol. Surv. S. Aust.

Townsend, I.J. and Robertson, R.S., 1980. Wallatinna Opal Diggings. S. Aust. Dept. Mines report (in prep.) (unpublished).

Vnuk, M.F., 1978. Geology of the Stuart Creek Area, North of Lake Torrens. University of Adelaide, Honours Thesis S. Aust. Dept. Mines. Energy open file Env. 3425 (unpublished).

Wake, P.V., 1969. Opal Men. Halstead Press, Sydney.

Ward, L.K., 1917. Stuart Range opal field. Min. Rev. Adelaide, 25: 36-44.

Webb, B.P., and Wopfner, H., 1961. Plio-Pleistocene Dunes North-West of Lake Torrens, S.A. and their Influence on Erosional Pattern. Aust. J. Sci. 23(11): 379-381.

Webster, R., 1975. Gems. Their sources, descriptions and Identification. Camelot Press. England. 931. pp.

Winton, L.J., 1925. Coober Pedy (Stuart Range) opal field. Min. Rev. Adelaide, 42: 72-77.

Winton, L.J., 1928. The Coober Pedy opal field. Min. Rev. Adelaide, 47: 58.

Winton, L.J., 1933. General Notes. Min. Rev. Adelaide, 57: 39.

__________, 1934. General Notes. Min. Rev. Adelaide, 59: 44.

__________, 1949. Charlie Swamp or Stuart Creek opal field. Min. Rev. Adelaide, 87: 23.

__________, 1950. General Notes, Opal Industry. Min. Rev. Adelaide, 90: 8-9.

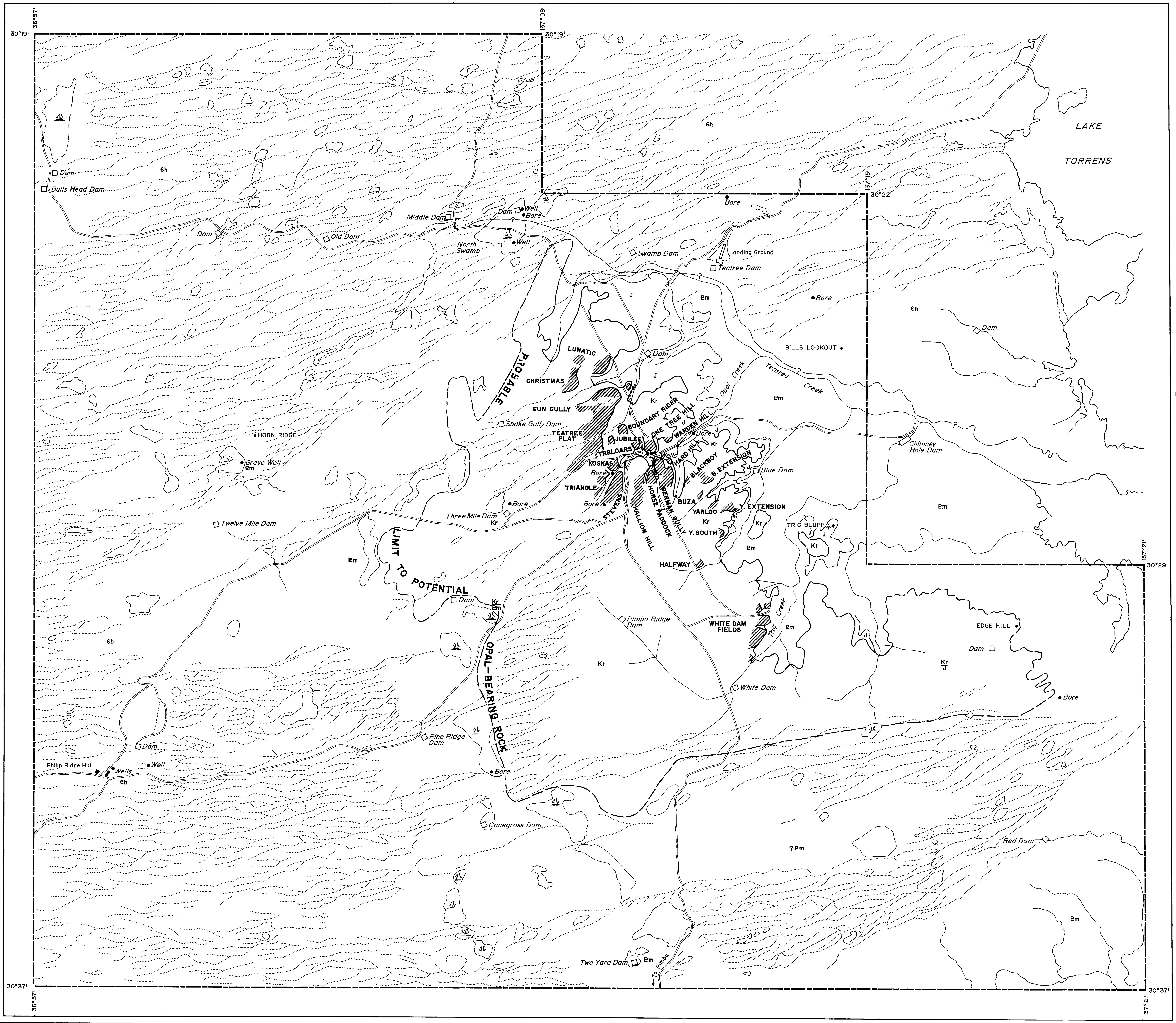
Wollaston, T.C., 1924. Opal: The Gem of the Never Never, Thomas Murby and Co., London.

Woolnough, W.G., and David, T.W.E., 1926. Cretaceous glaciation in Central Australia. Q. J. Geol. Soc. London 82: 332-351.

Wopfner, H., 1974. Post-Eocene history and stratigraphy of north-eastern South Australia Trans. R. Soc. S. Aust., 98(1): 1-12.

Wopfner, H., Freytag, I.B., and Heath, G.R., 1970. Basal Jurassic - Cretaceous rocks of western Great Artesian Basin, South Australia. Stratigraphy and Environment. Bull. Am. Assoc. Petrol. Geol., 54(3): 383-416.

Wopfner, H., Callen, R.A., and Harris, W.K., 1974. The Lower Tertiary Eyre Formation of the southwestern Great Artesian Basin. J. Geol. Soc., Aust., 21(1): 17-51.



ANDAMOOKA

PRECIOUS STONES FIELD

REGIONAL GEOLOGY PRIOR TO SUBSIDISED EXPLORATION

REFERENCE

QUATERNARY		SAND DUNES
CRETACEOUS	Kr	CADNA-OWIE FORMATION. Slightly sandy white kaolinised clay overlying iron oxide stained clay. Opalization at interface. "Erratic" boulders, cobbles throughout.
JURASSIC	J	ALGEBUCKINA SANDSTONE. Coarse sands, grits, ferruginous sands, conglomerates. Occasional plant remains.
CAMBRIAN	Єh	ANDAMOOKA LIMESTONE. Laminated and massive brown and grey limestone, Archaeocyatha.
UPPER PROTEROZOIC	Pm	TENT HILL FORMATION. ARCOONA QUARTZITE MEMBER. Cross bedded brown flaggy and platy quartzite and sandstone. YARLOO SHALE MEMBER north of Teatree Creek not differentiated.

Geological boundary
- Observed
- Approximate
- Inferred

Plant fossil

Major creek

Swamp

Claypan

Dam

Bore, Well

Road

Track

Hill

Approximate extent of workings as at 21·11·75 with downhill (outcrop) limits shown

Boundary of Precious Stone Field

SCALE 1:50000

KILOMETRES 1 0 1 2 3 4 5 KILOMETRES

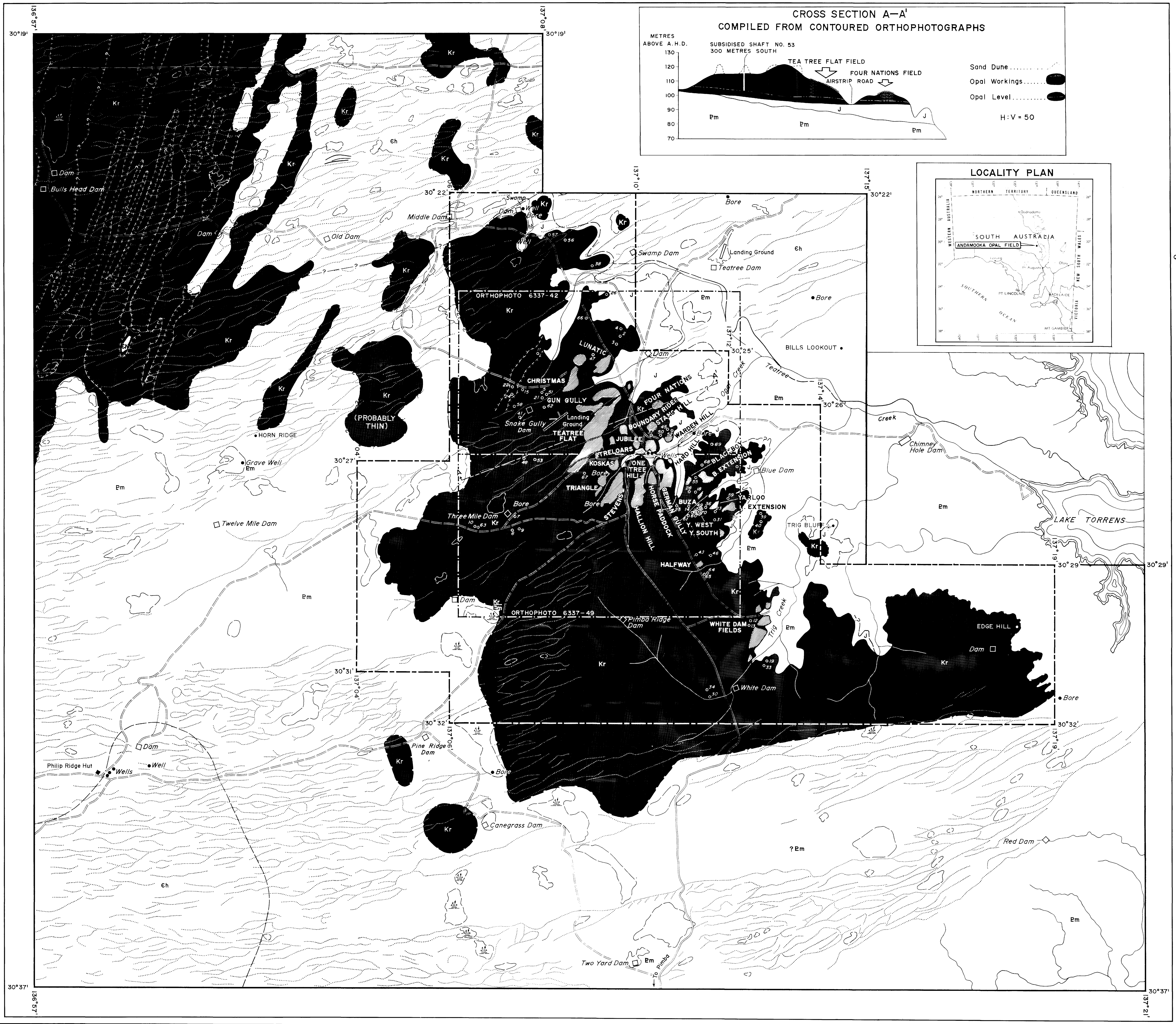
Geology by S.G. Carr

Map information interpreted from aerial photo surveys 1857 & 1439

S.A. Dept. of Mines

6336

76-101



ANDAMOOKA PRECIOUS STONES FIELD

REGIONAL GEOLOGY

REFERENCE

QUATERNARY		SAND DUNES
TERTIARY		Form lines of Tertiary dune system. Fine grained, ferruginous, aeolian sandstone remains on most ridges.
CRETACEOUS	Kr	MARREE FORMATION. Basal part – slightly sandy white kaolinised clay overlying iron oxide stained clay. Opalization at interface. "Erratic" boulders, cobbles throughout. (previously called Cadna-owie Formation.)
JURASSIC	J	ALGEBUCKINA SANDSTONE. Coarse sands, grits, ferruginous sands, conglomerates. Occasional plant remains.
CAMBRIAN	Єh	ANDAMOOKA LIMESTONE. Laminated and massive brown and grey limestone, Archaeocyatha.
UPPER PROTEROZOIC	Ꞓm	TENT HILL FORMATION. ARCOONA QUARTZITE MEMBER. Cross bedded brown flaggy and platy quartzite and sandstone. YARLOO SHALE MEMBER north of Teatree Creek not differentiated.

Geological boundary
Observed
Approximate
Inferred

Plant fossil

Major creek

Swamp

Claypan

Dam

Bore, Well

Road

Track

Hill

Approximate extent of workings as at Dec. 1976 with downhill (outcrop) limits shown

Present Boundary of Precious Stone Field (Gov. Gaz. 22·7·76)

Former Boundary of Precious Stone Field (Gov. Gaz. 29·6·72)

Subsidised Shaft (Numbered as in Appendix) — o 18

Dept. of Lands contoured orthophotographs (6337-49, 6337-42)

SCALE 1:50000

KILOMETRES 1 0 1 2 3 4 5 KILOMETRES

Geology by S.G. Carr

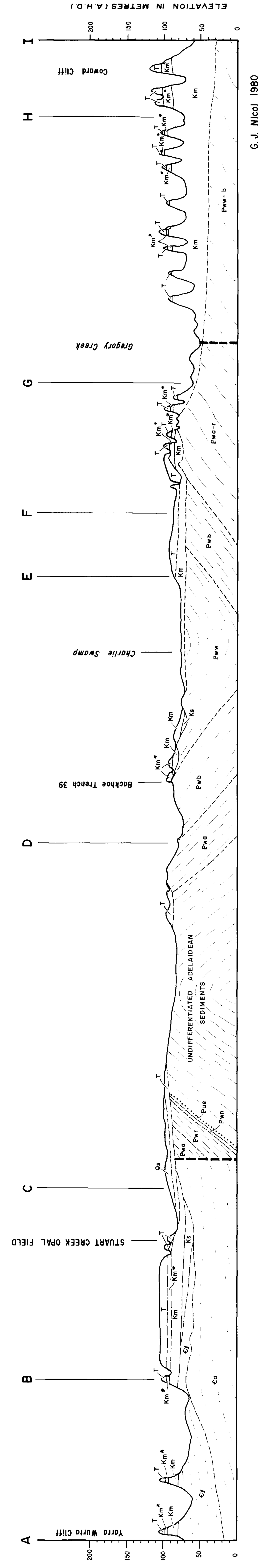
Map information interpreted from aerial photo surveys 1857 & 1439

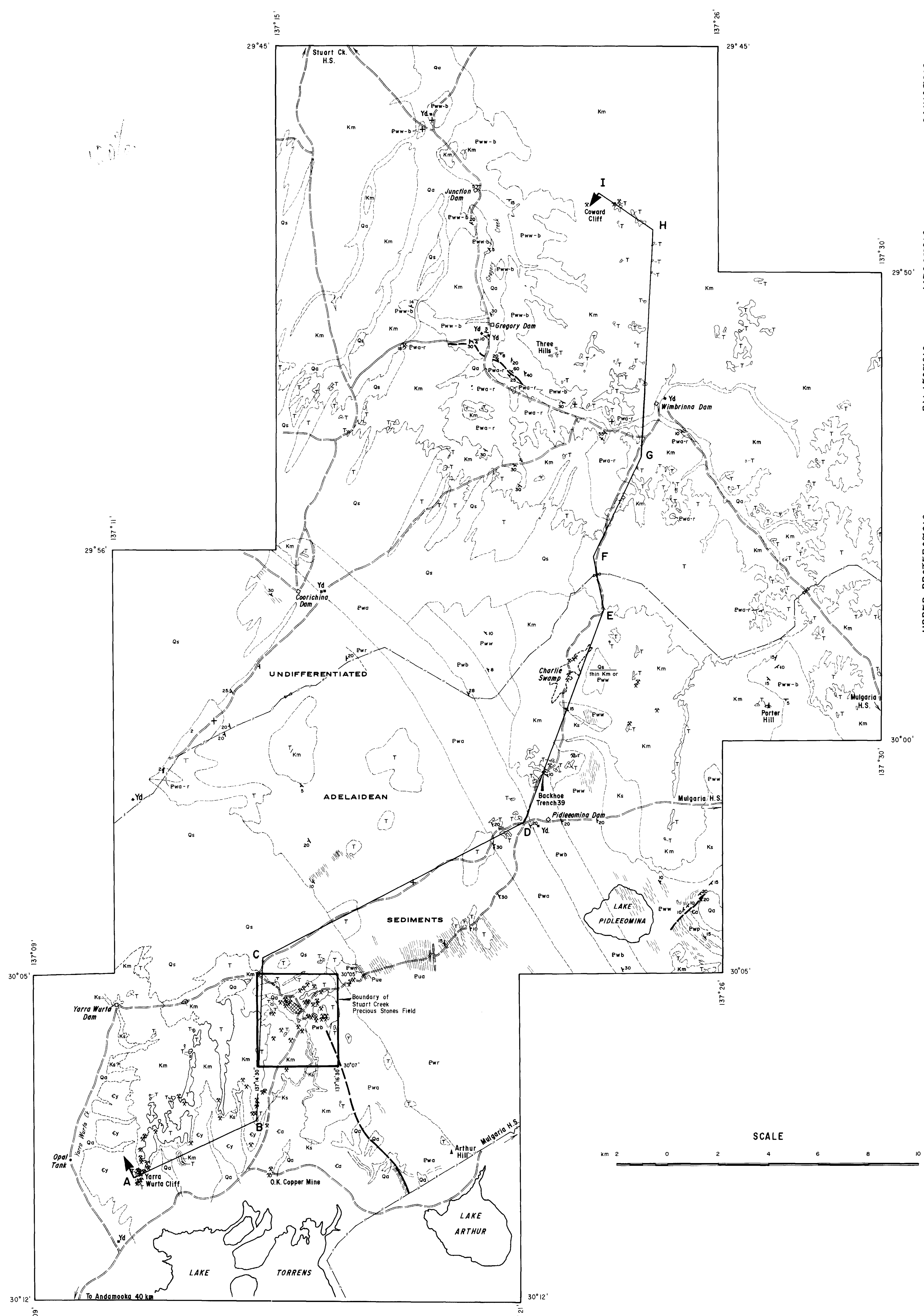
S.A. Dept. of Mines

FIG. 19

76-101a

6336





REFERENCE

CAINOZOIC	QUATERNARY	Qa	Alluvium, conglomerate, sand, silt and clay of creeks and floodplains.
CAINOZOIC	QUATERNARY	Qs	Sand. Pale reddish-brown, fine to medium quartz sand ridges and spread with claypans.
CAINOZOIC	TERTIARY	T	Upper part. White, reddish-brown and yellow cross-bedded pebbly fine to medium quartz sand and minor sandy limestone. Lower part. Flat-bedded, grey, clayey silt and very fine sand to cross-bedded medium sand, minor very coarse silcrete sand and conglomerate. Thin basal layer of silcrete and quartzite pebbles to boulders. Silicified, ferruginised and gypsified in part.
MESOZOIC	LOWER CRETACEOUS	Km* / Km	MARREE FORMATION. Dark brown to grey mud with randomly distributed exotic pebbles, cobbles and boulders with thin lenticular silt, sand and conglomerate interbeds. Upper parts may be altered to white mudstone or friable alunite (Km*)
MESOZOIC	LOWER CRETACEOUS	Ks	"STUART CREEK BEDS" Varied lithologies, including regolithic or reworked Yarra Wurta Shale at base (may contain glauconite), pale green, clay cast conglomerate, brown sand, silt and clay with abundant lignitic wood fragments, pebbles and cobbles in friable silty sand, and poorly bedded greenish clay, silt and sand. Poorly outcropping.
PALAEOZOIC	LOWER CAMBRIAN	Ꞓy	YARRA WURTA SHALE. Red and green, laminated shale and siltstone.
PALAEOZOIC	LOWER CAMBRIAN	Ꞓa	ANDAMOOKA LIMESTONE. Massive to laminated, grey to brown limestone with chalcedonic nodules.
UPPER PROTEROZOIC	ADELAIDEAN, Wilpena Group	Pwp	POUND QUARTZITE. White, red and purple thin bedded quartzite and sandstone with ripple marks and shale casts.
UPPER PROTEROZOIC	ADELAIDEAN, Wilpena Group	Pww	WONOKA FORMATION. Laminated, green and brown, micaceous and calcareous siltstone. Purple and green limestone near the top.
UPPER PROTEROZOIC	ADELAIDEAN, Wilpena Group	Pwb	BUNYEROO FORMATION. Red and green micaceous shale and siltstone.
UPPER PROTEROZOIC	ADELAIDEAN, Wilpena Group	Pwa	A.B.C. RANGE QUARTZITE. White to grey, flaggy quartzite interbedded with sandstone, siltstone and shale.
UPPER PROTEROZOIC	ADELAIDEAN, Wilpena Group	Pwr	BRACHINA FORMATION. Green and purple micaceous shale and siltstone.
UPPER PROTEROZOIC	ADELAIDEAN, Wilpena Group	Pwn	NUCCALEENA FORMATION. Yellow weathering dolomite, purple shale.
UPPER PROTEROZOIC	ADELAIDEAN, Umberatana Group	Pue	ELATINA FORMATION. Brown, calcareous, coarse feldspathic sandstone.
UPPER PROTEROZOIC	ADELAIDEAN, Umberatana Group	Pua	AMBEROONA FORMATION. Green and yellow laminated and micaceous siltstone. Some coarse calcareous sandstone. Yellow weathering dolomite.

- A I .... Geological section
- .... Geological boundary - observed
- .... Geological boundary - inferred
- .... Fault - observed
- .... Fault - inferred
- .... Bedding trend
- .... Strike and dip of bedding
- + ... Horizontal bedding, vertical bedding
- .... Digging (s)
- .... Area of intensive digging
- .... Fence
- .... Gate
- .... Track
- Yd. .... Stockyard

FIG. 6

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

OPAL IN SOUTH AUSTRALIA

STUART CREEK – COWARD CLIFF

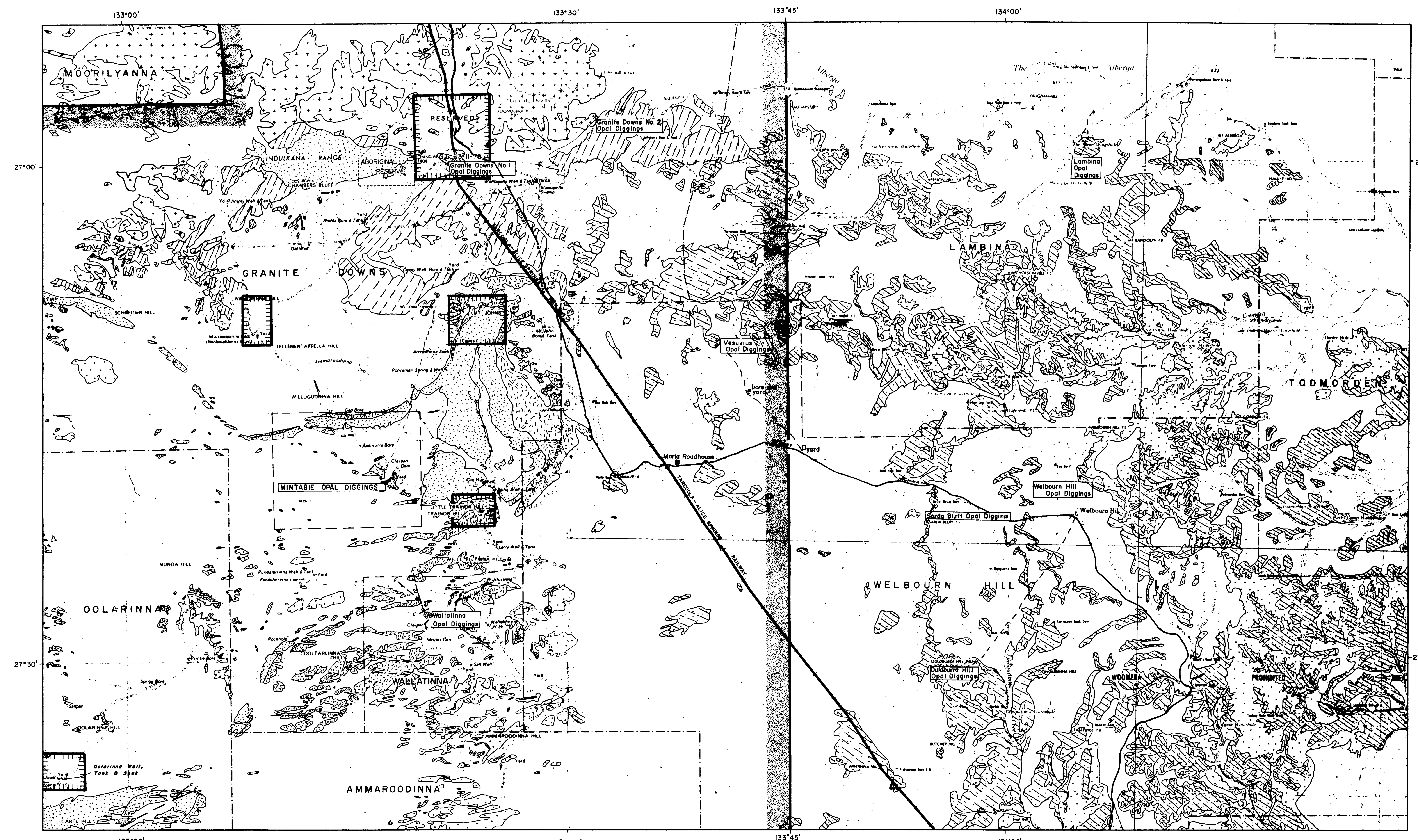
REGIONAL GEOLOGICAL PLAN

DIRECTOR GENERAL	COMPILED G. Nicol	DRN M.R. / CKD	SCALE As shown / DATE April 1980	PLAN NUMBER 80-238

1875

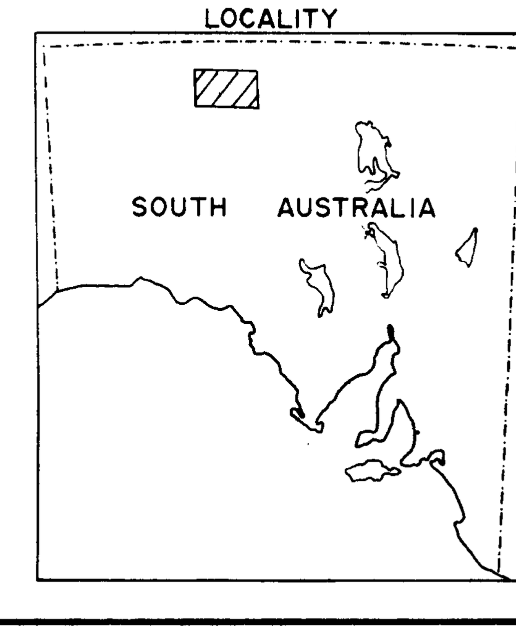
DEPARTMENT OF MINES AND ENERGY - SOUTH AUSTRALIA
COOBER PEDY OPAL FIELDS
TOPOGRAPHIC PLAN
SCALE 1:50 000
KILOMETRES 1 0 1 2 3 4 5 KILOMETRES
Transverse Mercator Projection, Australian Map Grid.
REFERENCE
Highway
Secondary road
Track
Minor track
Proposed highway re-alignment
Fence
Dog Fence
Bore
Ephemeral stream
Ephemeral stream with flood plain
Waterhole
Claypan
Cliff or escarpment
Hill, peak
Contour (10 metre interval)
Opal Field and Name
OLYMPIC
Superseded Opal Field Name
(Quail)
Areas Reserved from the Operation of the Mining Act
Steel Peg
Reserved nominally 50m either side of centreline
25m reserved either side of fence line
DINGO
RESERVE
SHELL PATCH
(Whiskey Field)
Shellpatch Bore & Tank
SEC. 752
SEC. 751
Giddigiddinna Bore
PILE HILL
JOHN DEERE
SEVENTEEN MILE
VINO
(Yellow Hill (9 Mile)
(Hard Hill 10 Mile)
BROWNS FOLLY
FOURTEEN MILE
KIMBA
FOR
Magpie W.H.
UNKNOWN
SEC. 753
Sputnik Bore
SEC. 756
THE BREAKAWAYS
MINISTER
FRANKS FOLLY
DORA GULLY
(Twelve Mile)
GREEK GULLY
Rock Hill Bore
Honeymoon Bore
Cottonbush Bore
SEC. 754
(Steinbiss)
HANS PEAK
(Stony Hill)
Oolgelima
Creek
DEAD MANS GULLY
Willows Bore
LANDS (GG 2.2.78)
PIPING LANE
(Avlis)
DIGGERS GULLY
DEAD HORSE GULLY
Cottonbush W.H.
SATURN
Long Creek
Cottonbush Creek
Goat W.H.
Salty Bore
OLD FOUR MILE
KENDA FLAT
HELLENIC HILL
RUSSOS FOLLY
(Ten Mile)
(Two Boys)
LARKINS FOLLY
(Nine Mile)
TURKEY RIDGE
(Butcher)
(Pitcher)
(Zorba Extension)
ZORBA
HOPEFULL HILLS
(Icecream Hill)
(Hypo Hill)
PERFETTO
RYANS HILL
BIG FLAT
COOBER PEDY
Jewellers Shop
BLACK POINT
GERMAN GULLY
POTCH GULLY
SADDLE
GERMAN VALLEY
Centipede Ck. W.H.
VENUS
GERAGHTY HILL
(Eight Mile)
SOUTH PACIFIC
(Seven Mile)
EAST PACIFIC
(Six Mile)
(Jasper)
(Painters)
SEC. 59
PROSPECT
LENNON
BLACK FLAG
WILLOW
SEC. 60
DEADMANS DUGOUT
JUNGLE
COMPANY
(Quail)
Top Box W.H.
Middle Box W.H.
Bottom Box W.H.
Finger Post W.H.
OLYMPIC
EMU
BENITOS FOLLY
CRATER
Top W.H.
(Five Mile)
STUART HIGHWAY
STUART RANGE
To "William Creek"
28°48'
28°55'
29°05'
134°29'
134°30'
134°45'
134°55'
80-268

FIG. 9



SCALE 1:250,000

KILOMETRES 5 0 5 10 15 20 25 KILOMETRES



CAINOZOIC

Quaternary – undifferentiated: alluvium, soil and sand sediments overlying older rock units

Tertiary – undifferentiated: silicified sand and gravel; limestone and ferruginous gravel

MESOZOIC

Cretaceous – Marree Sub-Group (Bulldog Shale and Oodnadatta Formation): clay and silt with lenticular sand interbeds; Algebuckina Sandstone: fluviatile sand

PALAEOZOIC

Ordovician – Mintabie Beds: white kaolinitic arkosic sandstone; Blue Hills Sandstone: Indulkana Shale, Mount Chandler Sandstone

Cambrian – Trainor Hill Sandstone; Mount Johns Conglomerate; Observatory Hill Beds

PROTEROZOIC

Adelaidean – undifferentiated: siltstone, shale, sandstone, tillite and basalt

Lower Proterozoic – undifferentiated: granite, adamellite, dolerite and gneiss

Areas reserved from Part VII of the Mining Act 1971 - 1978

Mintabie Opal Diggings: Area allowed for the prospecting for opal

Areas reserved from Parts IV to VIII of the Mining Act 1971 - 1978

Fault

Pastoral Boundary

Fig. 11

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

OPAL IN SOUTH AUSTRALIA
FAR NORTHERN AREA
REGIONAL GEOLOGY AND LOCATION
OF OPAL OCCURRENCES

	COMPILED P. Crettenden	DRN E.C.	SCALE 1:250,000	PLAN NUMBER
DIRECTOR GENERAL		CKD	DATE Oct. 16, 1979	80-269

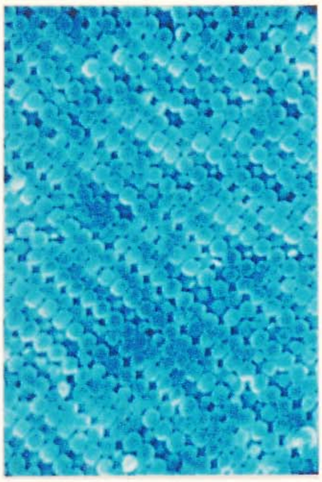
1921

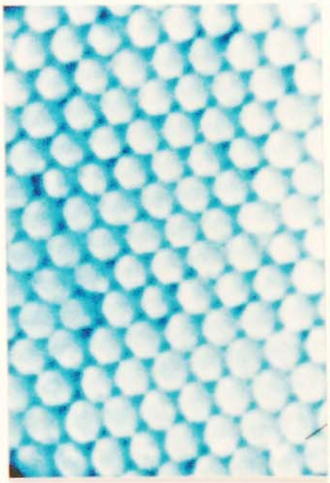
Facing Page I

Plate	Title
1	<u>Opal</u> - Doublet and triplet - Coober Pedy
2	<u>Opal</u> - Scanning electron micrograph of Coober Pedy precious opal X 10 000
3	<u>Opal</u> - Scanning electron micrograph of Coober Pedy red fire opal X 20 000
4	<u>Opal</u> - Scanning electron micrograph of Mintabie green opal X 20 000
5	<u>Opal</u> - Scanning electron micrograph of Mintabie black potch X 20 000
6	<u>Opal</u> - Scanning electron micrograph of Mintabie white potch X 20 000
7	<u>Opal</u> - Scanning electron micrograph of Coober Pedy precious opal X 10 000, showing colour grain boundary.
8	<u>Opal Solids</u> Selection of cut and polished Coober Pedy cabachons.
9	<u>Opal Triplet</u> Triplet of Coober Pedy opal. (Specimen loaned by Solo of Mintabie)
10	<u>Treated, polished Andamooka matrix opal</u> After cutting and shaping, the rough matrix is treated by soaking in sugar solution, and carbonizing in concentrated sulphuric acid to turn background black and highlight colour.
11	<u>Gilson synthetic opal</u> Note irregular colour grain boundaries (compared with plate 9) and sub-grains within the colour grains. Specimen loaned by Tibor Shelley, Opal Exporters, Adelaide).

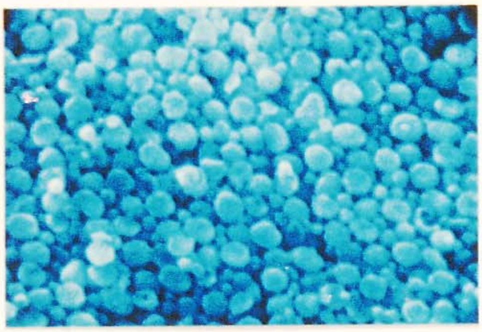
I

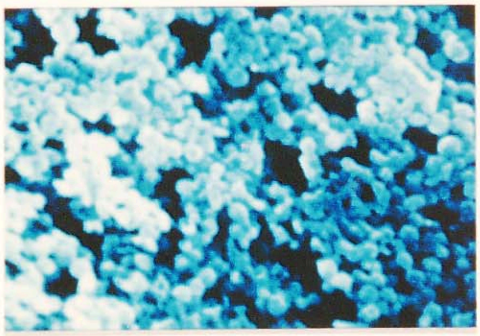

1

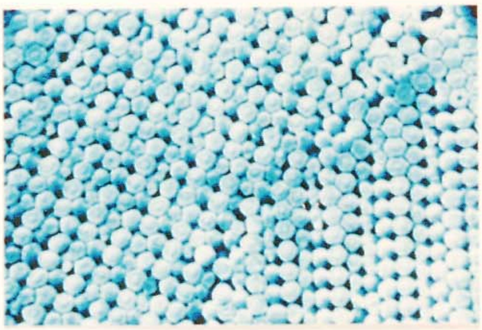

2


3


4


5


6


7


8

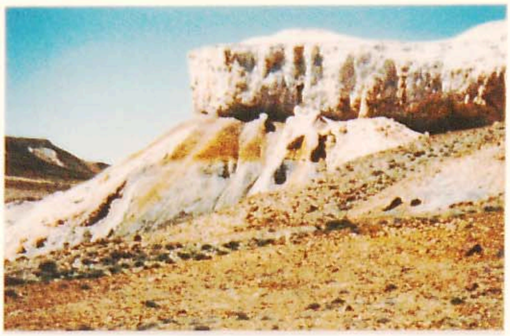

9


11


10

Plate	Title
12	Marree Formation - Coward Cliff Intensely bleached claystone overlies yellow and purple claystone, which sits on fresh, dark grey clay. Mesa capped by Tertiary sand.
13	Shaft sinking Old timer sinking shaft with pick and shovel, Andamooka.
14	Hand windlass Hauling "kopi" by hand windlass, White Dam Field, Andamooka.
15	Calweld drill Shaft sinking at Mintabie.
16	Calweld drill Starting the hole.
17	Calweld drill Emptying the bucket.
18	Calweld drill hole Going down shaft to inspect for "levels" or indications of opal.
19	Underground mining Miners using jackpick to drive a "level", Mintabie.
20	Underground mining Miners using a hand pick to chase a seam of opal, Coober Pedy.
21	Yorke hoist Small petrol driven winch pivoted on a vertical pipe so bucket with mullock can be swung away from the shaft. Yarloo West Field, Andamooka.
22	Self unloader Bucket empties automatically whilst miner works underground.
23	Blower Hallion Hill, Andamooka.

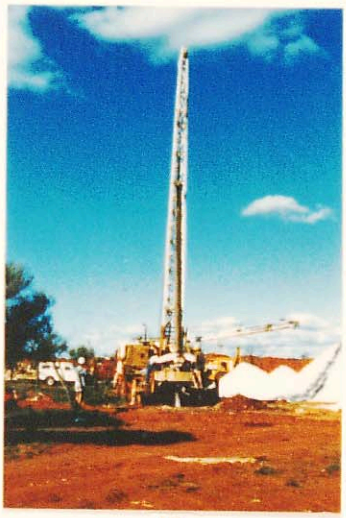
II


12


13


14


16


15

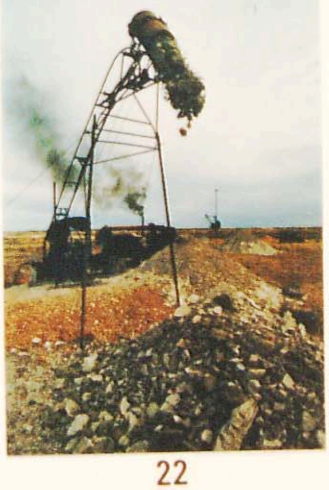

17


18


19

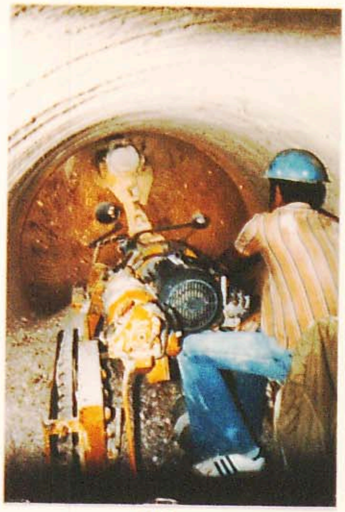

20


21


22


23

Plate	Title
24	Tunnelling machine Cutting head on rotating boom cuts circular drive. Mullock fed into blower pipes at operator's feet. Olympic Field, Coober Pedy.
25	Tunnelling machine Rotating cutting heads on boom that moves in vertical plane to cut the drive. Hans Peak Field, Coober Pedy.
26	Large blower working with a tunnelling machine Mullock brought to surface, collects in the bins and is fed onto a conveyor belt which dumps the mullock away from the shaft. Kenda Flat Field, Coober Pedy.
27	Rubber-tyred bogger Mullock is shovelled into bin, transported to shaft, unloaded into sump and taken to surface by bucket elevator. Bogger is operated by compressed air. Olympic Field, Coober Pedy.
28	Bucket elevator Mullock lifted to surface in buckets and dumped away from shaft. Olympic Field, Coober Pedy.
29	Backhoe Backhoe digging shallow trenches in bull-dozer cut to expose "level", which is then worked over by pick and shovel. Stuart Creek.
30	Bulldozer Spotters following bulldozer looking for signs of opal. Fourteen Mile Field, Coober Pedy.
31	Open cut mining Spotters chasing opal seam after traces revealed by ripping with bulldozer. Mintabie.
32	Open cut mining Chipping opal from seam revealed by bulldozing, Mintabie.


24


25


26


27


28


29


30

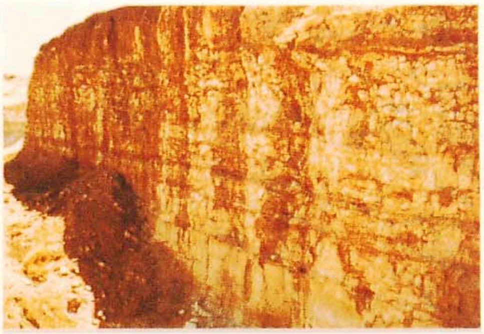

31


32

Plate	Title
33	Andamooka Aerial view of distinctive land form created by confusion of shafts and bulldozer cuts. Tea Tree Flat Field, August 1976.
34	False "levels" - Andamooka Several thin sandy boulder beds in "kopi", above the main "level". Yarloo Field.
35	"Level" - Andamooka White "kopi", conglomerate band at base resting on brown "mud". Interface between conglomerate and "mud" is the "level". Stans Hill Field.
36	Matrix opal Rough matrix opal from Andamooka.
37	Painted lady - Andamooka Opal coating a fracture in boulder of Arcoona Quartzite.
38	"Slide" - Andamooka The steep fault displaces the "level" 1.2 m from top right to bottom left. Yarloo West Field.
39	Divining-Andamooka Miner divining a "slide", or "slip", in the opal level to decide where to sink shaft.
40	Prospecting - Andamooka Calweld drilling rig on Stans Hill Field. Material brought up by bucket is inspected for signs of the "level".
41	Bulldozing - Andamooka Bulldozed "level" west of Christmas Field being inspected by miners.
42	Stuart Creek General view east across the workings, November, 1978.
43	Marree Formation - Stuart Creek Grey brown fresh "mud" with several conglomerate "levels" exposed in open cut.
44	"Level" - Stuart Creek Sandy interbed with pebbles and boulders within fresh brown "mud".

IV

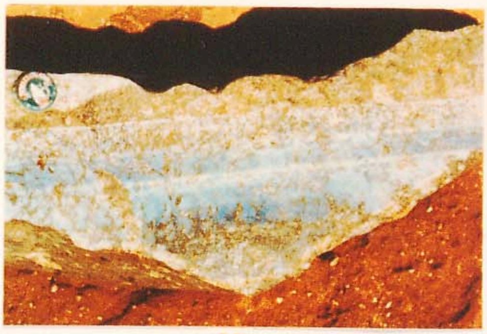
33



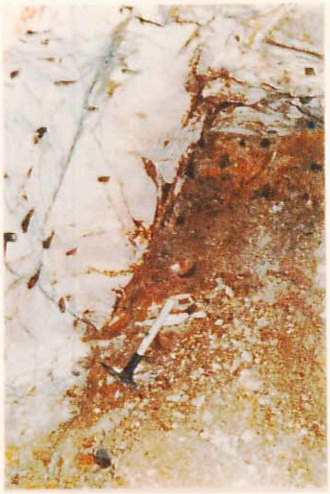
34

35

36

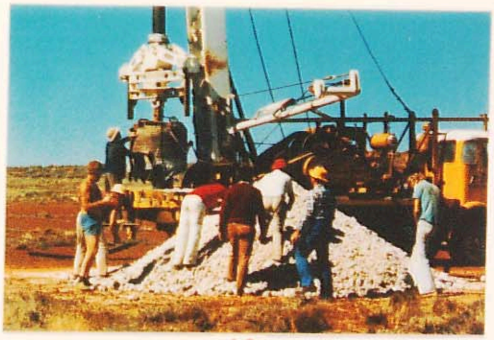


37



38

39



40

41

42

43

44

Plate	Title
45	"Level" - Stuart Creek Large boulder with smaller cobbles in lenticular sand bed within brown "mud".
46	"Level" boulder - Stuart Creek Large boulder 2.6 m across, eroded from the major conglomerate bed.
47	"Gibber plain" - Stuart Creek Numerous quartzite boulders left as lag after erosion of conglomerate beds. Devonian fossils were found in quartzite boulders in this area.
48	Silcrete capped mesa - Stuart Creek Patchily silicified ferruginous, Tertiary sand overlying Cretaceous "mud".
49	Opal - Stuart Creek Thin opal seam on contact between sand and "mud".
50	Opal - Stuart Creek Thin opal seams, with gypsum, irregularly developed in brown, silty "mud".
51	Charlie Swamp General view south from northern group of workings, October, 1978.
52	Opal - Charlie Swamp Black potch opal in veins and joints through brown "mud".
53	Opal - Charlie Swamp Brecciated black potch recemented by white potch.
54	Opal Selection of opal from Stuart Creek area. Clockwise from top right. Black potch cabachons, Charlie Swamp; black and white laminated opal and amber potch, Yarra Wurta Cliff area; precious opal and blue potch, Stuart Creek; grey porcelain potch, small scrape between Stuart Creek and Yarra Wurta Cliff.
55	Opal - Coward Cliff Horizontal veins of opaque white opal, with red staining on fracture surfaces, in joints in Marree Formation mudstone near base of bleached profile.

Gibber or gibber plain

V

45

46

47

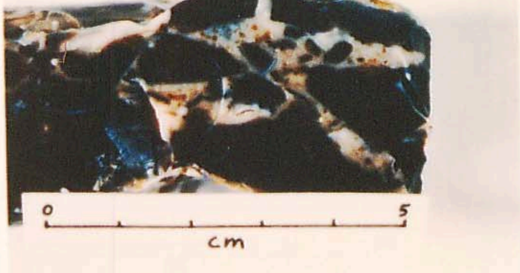
48

49

50

51

52



53

54

55

Plate	Title
56	Coober Pedy Aerial view of town centre, September, 1972.
57	Coober Pedy View northwards to Hans Peak Field, March 1979.
58	Radeka's dugout - Coober Pedy Underground motel accommodation.
59	Coober Pedy Numberous platforms on mesas in background mark dugout sites. Shortage of suitable dugout sites has led to increase in construction of surface dwellings (foreground).
60	Marree Formation - Coober Pedy Grey mud with sandy, boulder bed outcropping in banks of Oolgelima Creek 10 km north of town centre.
61	"Level" - Coober Pedy Mass of red tubules extending down from surface as a pipe, then running horizontally along a flat surface, probably defining an old water table.
62	"Levels" - Coober Pedy Two red tubule "levels", the lower one having been worked for opal, in "kopi", Shellpatch Field.
63	"Level" - Coober Pedy Alunite "level". Patchy development of alunite in "kopi" below a line that may mark an old water table. Hans Peak Field.
64	"Level" - Coober Pedy Satin spar gypsum on "level". Opal was found immediately below gypsum band. Hans Peak Field.
65	"Slide" - Coober Pedy Near-vertical fracture infilled with red silt and red tubules. Hans Peak Field.
66	"Verticals" - Coober Pedy Near-vertical fractures, infilled with red silt and tubules radiate from a red tubule "level". Second level about 0.3 m below. Note second generation bleaching, adjacent to the red tubule infilling.
67	Opal - Coober Pedy Precious opal in horizontal seam, immediately above a yellow brown ironstone "level". Fourteen Mile Field.


56


57


58


59

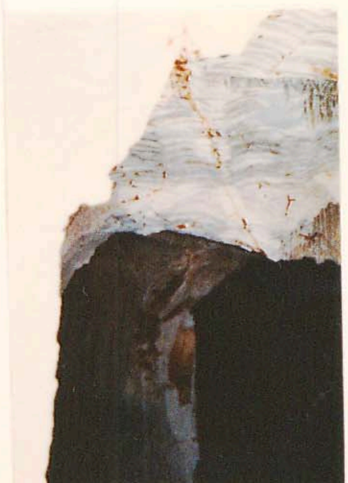

60


61


62


63


64


65


66


67

Plate	Title
68	Opal - Coober Pedy Two near horizontal fractures come together to "make" a seam of opal. Fourteen Mile Field.
69	Opal - Coober Pedy Limonite infilled "vertical" with seam of opal 10-15 mm thick in the centre. Note "vertical" peters out with depth.
70	"Skin shells" - Coober Pedy Opal infills space in "kopi" where bivalve shells have been dissolved out. Fourteen Mile Field.
71	"Full shells" - Coober Pedy Solid precious opal forms internal moulds of bivalve and gastropod shells. (Specimens loaned by W. Turner, Coober Pedy).
72	Alluvial opal - Coober Pedy Pieces of opal broken up and incorporated in a gypcrete of the Russo Beds. Fourteen Mile Field.
73	Auger drill - Coober Pedy Use for prospecting a claim before underground or open cut mining. Olympic Field.
74	Prospecting - Coober Pedy Aerial view showing intense prospecting drilling adjacent to the area of workings.
75	Blowers - Coober Pedy Intense activity at Hans Peak Field. Note dust spread over the gibber plain.
76	Hans Peak - Coober Pedy Equipment belonging to one partnership. Crane, for lowering tunnelling machine down shaft; D6 bulldozer for shifting mullock dump; generator for powering blower, tunnelling machine and lighting; and Calweld drill for prospecting, drilling and reaming shafts.
77	Bulldozing - Coober Pedy "Level" being inspected by miners as "mullock" is removed. Fourteen Mile Field.
78	Noodling machine - Coober Pedy Mullock fed into hopper, screened, and oversize material is passed through a dark room under an Ultra-Violet light. Black Flag Field.

68

69

70

71

72

73

74

75

76

78

77

Plate	Title
79	England Hill General view from the west. March 1979.
80	Vesuvius General view of southern group of workings from the east. October 1978.
81	Lambina General view of central group of workings, Silcrete capped rise in background. August 1979.
82	Mintabie Aerial view southwest of the scarp and workings. Canteen and soccer ground centre right. September 1979.
83	Mintabie General view of scarp and workings. Mallee eucalypts in foreground.
84	Mintabie General view of main area of activity showing caravans and mining operations next to each other. October 1978.
85	Mintabie Canteen, October 1978.
86	Mintabie Cretaceous clayey sand and claystone, silicified at top, unconformably overlying the Mintabie Beds.
87	Mintabie Beds Open cut on top of scarp showing gently southerly dipping kaolinitic sandstone. Note blocky nature at top highlighted by parting along bedding.
88	Mintabie Beds Large scale cross bedding in the upper part of Mintabie Beds.
89	Opal - Mintabie Seam of precious opal developed along arcuate bedding plane within Mintabie Beds. Note yellow brown limonitic staining.

79

80

81

82

83

84

85

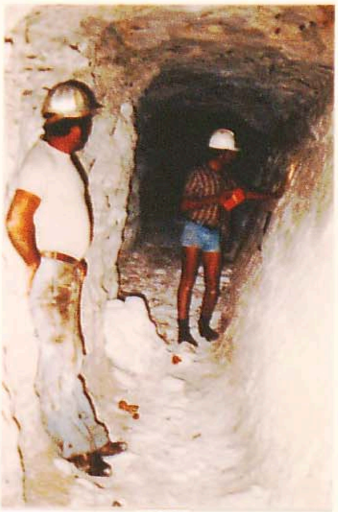
86

87

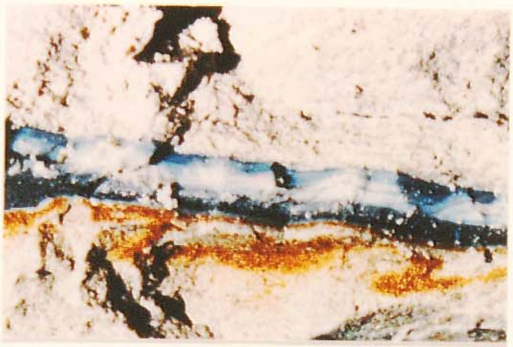
88

89

Plate	Title
90	"Vertical" - Mintabie Near vertical joint in Mintabie Beds along which opal has been found in several places.
91	Opal - Mintabie Opal seam in Mintabie Beds. Seam of white opal showing abundant colour flashes with black potch on either side.
92.	Opal - Mintabie Mintabie "semi-black" opal. Thin colour bar, backed by black potch cut along length to form a natural doublet. Specimen 4.5 cm long. (Kindly donated by S. Billings, Mintabie).
93	Opal - Mintabie Top quality Mintabie opal. Piece in centre of bottom row is 2.5 cm across. (Specimens loaned by S. Billings, Mintabie).
94	Opal - Mintabie Red fire opal. Specimen 4.5 cm across, (loaned by Tom of Mintabie).
95	Opal - Mintabie Parcel of third grade Mintabie opal, mainly used for manufacture of triplets. (Specimens loaned by Marko of Mintabie).
96	Bulldozing - Mintabie D9 bulldozer having scraped off topsoil starts to rip upper silicified portions of Mintabie Beds. Note smoke coming from ripper tynes.
97	Drilling - Mintabie Blast hole drill pattern in silicified upper part of Mintabie Beds.
98	Blasting - Mintabie Breaking up the hard silicified sandstone so that it can be ripped and dozed.
99	Bulldozing - Mintabie 2 D9 bulldozers ripping kaolinitic sandstone, followed by spotters.

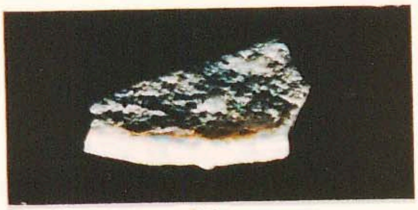


90

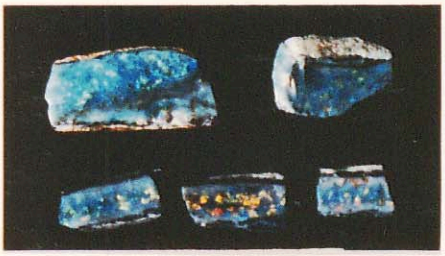


91

92



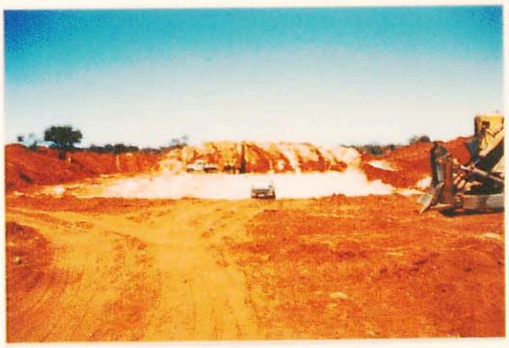
94



93

95

96



97

98

99

Facing Page X

Plate	Title
100	<u>Bulldozing</u> - Mintabie D9 Bulldozer pushing mullock over edge of scarp.
101	<u>Noodling</u> - Mintabie Aboriginals noodling the dumps from underground mining.
102	<u>Hopto digger</u> - Mintabie Large trench digger with $5m^3$ bucket. All up weight 95 tonnes.
103	<u>Open cut</u> - Mintabie One of the deepest open cuts at Mintabie, 22.5 m deep. Dug by bulldozer and then Hopto machine.
104	<u>Underground mining</u> - Mintabie Spoil heaps from underground mining adjacent to open cuts. Note Yorke Hoist on shaft.
105	<u>Mintabie</u> Aerial view of workings showing underground mining around the outskirts of the main area of open cut workings. September, 1979.
106	<u>Wallatinna</u> Aerial view of group of backhoe trenches on flanks of hill. September 1979.
107	<u>Granite Downs No. 1 workings</u> Small group of workings on salt bush plain, 4 km east of Mount Chandler (in background). August, 1979. The Alice Springs railway crosses the plain in the middle distance.
108	<u>Opal</u> Collection of cut and polished stones, mainly doublets and triplets. Most of the stones are Coober Pedy opal. (Collection loaned by Kiwi Bob of Coober Pedy).

X

100

101

102

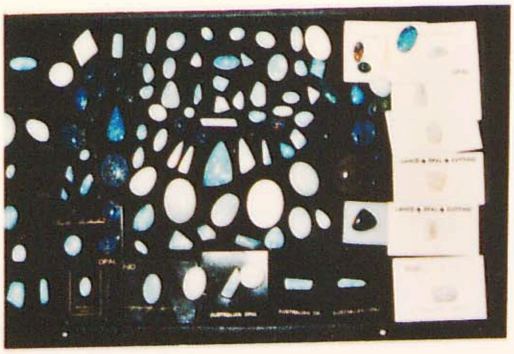
103

104

105

106

107



108