THE WHITE CLIFFS OPAL FIELD, NEW SOUTH WALES

by R. E. RELPH

INTRODUCTION

Precious opal has been known to occur within Cretaceous sediments in the north-western portion of the State since 1884, when it was first discovered on Momba Pastoral Company's property in the locality later developed as the township of White Cliffs. Subsequently a number of nearby occurrences, such as Barclay's Bunker and Gemville, 8 and 12 miles south-west, Welsh's Knob, 9 miles south, and Turner's and Purnanga, 10 and 30 miles north of White Cliffs were discovered. These latter areas have been embraced within the White Cliffs opal field which was visited in company with Geologist G. Rose during the week ending 2nd May, 1959.

White Cliffs is situated at latitude 30° 48′ south, longitude 143° 6′ east, approximately 60 miles by road north-north-west from Wilcannia, 170 miles by road north-east from Broken Hill and is in parish Kirk, county Yungnulgra. The average annual rainfall is 8·61 inches.

HISTORY

The first record of opal-mining at White Cliffs is contained in the 1890 Report of the Department of Mines. Opal was first discovered about 6 years previous to this, and by 1890, 600 acres had been taken up under lease, a shaft had been sunk to a depth of 50 feet and a large quantity of opal had brought (for then) a very high price. As much as £5 per ounce was offered locally for good specimens and an English company had been formed to work some of the claims. By 1893 the population was estimated at 700, a township had been developed, and a regular coach service was running from Wilcannia. By the time of the Royal Commission into the leasing and marketing conditions on the White Cliffs field in 1901, the town had 2,300 inhabitants and opal valued at £576,000 had been won. From this peak the number of miners and the amount of opal won gradually decreased until by 1911 when the leases of the White Cliffs Opal Mining Company were cancelled only 150 men were left on the field. With the start of the first World War the market suffered by the withdrawal of German buyers and by 1916 there were only a few men on the field. There was a slight resurgence in activity in 1919 when 100 men won opal worth £1,900, but since then only a few miners have found employment in the area, and since 1940 the recorded value of opal won is £30.

At the time of inspection in May, 1959, there were only two miners on the field, one on the Blocks Area near Sullivan's Hill (see plan B392—plate 1) and one at Barclay's Bunker (plan PA 166—fig. 1). There were also five itinerant prospectors in the vicinity. The 1954 census showed the population of White Cliffs as 33.

ROYAL COMMISSION

The White Cliffs Opal Mining Company and owners of the other leases let out portions of their leases to miners on tribute. The amount of tribute paid by the miners varied from 50 per cent. of all opal won when the system first started (and when easy ground was worked as at the "open cut"), to 25 per cent., then 15 per cent. and then to a weekly rental of 2s. 6d. as applied when the Company ceased operations. This method of working proved unsatisfactory and led to a lot of dissention amongst the miners and enmity between them and the owners, so much so, that a Royal Commission was appointed in 1901 to enquire into the opal mining industry at White Cliffs.

The findings of the Commission were:—

(1) That the Government should offer to redeem the unexpired portion of the leases now held by the White Cliffs Opal Mines, Limited (300 acres in all).

(2) That if this be effected the land be revested in the Crown, and thrown open for mining in small areas under the miner's right or mineral licence.

(3) That in the event of the company not coming to terms with the Government, it be a recommendation to the Company that in lieu of the tribute system a small weekly rental should be charged for the privilege of working on its blocks under agreement, which agreement should not be made for a shorter term than three months.

(4) That a rigid system of registration of all opal buyers, cutters, and polishers, be enforced under conditions outlined by the Commissioners, and that the fee for registration should be nominal.

(5) That provision be made in the new Mining Bill for the proper registration of all business or residence areas, claims, or shares in claims, upon the White Cliffs Opal Field, at a nominal fee, say 1s., and within two months of possession.

(6) That no opal buyers, cutters, or polishers, be allowed to hold claims or interest in claims on the field.

(7) That prospecting under Government aid should be encouraged in the district.

(8) That no more mineral leases be under any circumstances issued in the White Cliffs opal-bearing district, and that no claim be allowed in excess of 100 feet square.

Since cancellation of the leases held by the company in 1911, all mining has been carried out under 100 feet by 100 feet mineral claims.

GEOLOGY

Sediments of Lower Cretaceous age, having a general slight dip to the east, rest upon a basement of highly folded Proterozoic strata which have been termed the Torrowangee Series by Kenny (1934). Tertiary deposits have been developed over the Cretaceous beds.

The succession is as follows:—

Recent—Alluvium, silt, sand, rock waste.

Tertiary—Greybilly, conglomerate, shale.

Lower Cretaceous—Claystone, sandstone, conglomerate.

Proterozoic—Slate, sandstone.

Proterozoic

These rocks do not crop out in the White Cliffs area, their presence beneath the Lower Cretaceous sediments here being determined by bores. Bores 9894 (732) and 13098 (754) detected slate and sandstone as basement rocks, and evidence west of White Cliffs, on the margin of the Cretaceous sediments, shows that they are composed of well-cleaved sandstone, slate and phyllite which are cleaved in directions of 285° and 290° (M). They have been liberally intruded by narrow quartz veins, form gentle slopes, are deeply weathered, and are covered by large amounts of quartz scree.

Lower Cretaceous

Claystone and sandstone having a gently easterly dip have been eroded by tributaries of the Paroo and Bunker's Creek so that a number of low flat-topped mesas have been formed. The sediments which crop out along low scarps 20 to 100 feet above the general level of the country, are light in colour and show white scars on the eroded surface, or where minor slumping has occurred.

Shafts at the opal diggings have proved a thickness of 80 feet, while bore 732 some $2\frac{1}{2}$ to 3 miles west of the northern extension of the Blocks area shows 320 feet to basement rocks. Another bore (754) in parish Yerndambool near Bunker's Creek penetrated 208 feet of Cretaceous sediments, while Jaquet (1893) records the occurrence of basement rocks at depths of 127 feet and 143 feet in two wells on Tarella Station some 14 miles south of White Cliffs.

Within the area covered by the White Cliffs diggings the sequence is dominated by claystone members. In Quin's Block a thickness of 26 feet is exposed in one shaft which yielded the following section:—

"*Londoner*" *Shaft*

	From ft.	in.	To ft.	in.	
Tertiary ..	0	0	10	3	Greybilly and ironstone gravels, sand, loosely cemented. Pebbles up to 8 inches, average 1 to $1\frac{1}{2}$ inches.
	10	3	11	5	Conglomerate, fine grained, pebbles average $\frac{1}{8}$ inch, some to $\frac{1}{2}$ inch with occasional to 2 inch. This bed is locally termed " geyser ".
Lower Cretaceous ..	11	5	12	4	Claystone, hardened, silty, containing angular fragments of quartz in an argillaceous matrix. Some regrowth of quartz grains and some secondary chalcedonic growths are present. Stained with iron oxide. At 12 ft. 4 in. prominent horizontal joint.
	12	4	16	4	Claystone, hardened, silty with some siliceous material. Closely jointed. Joints open and approximately $\frac{1}{10}$ inch wide.
	16	4	16	6	Claystone, hardened, open joint between this and overlying bed.
	16	6	27	0	Claystone, sandy, off-white, thinly bedded, well jointed, ironstained with occasional vertical joints filled by iron oxide, some finely divided muscovite. Fracture in part hackly and in part conchoidal.
	27	0	37	0 +	Claystone, silty, containing 15 per cent. quartz in a clayey matrix. A little chloritic material and some secondary silica. Slight iron staining. Opal occurs in vertical and horizontal joints.

It will be noticed that the Cretaceous sediments exposed here are all claystones, with only one horizon, between 16 ft. 6 in. and 27 feet being typified as sandy. The horizon below the 27 feet level has been worked for opal, and is termed " opal-dirt ".

Similar claystones occur at Purnanga where the topmost bed of the Cretaceous is a compact, hard white claystone of very fine grainsize, which contains approximately 5 per cent. of fine angular quartz grains in a very fine groundmass. It breaks with a sub-conchoidal fracture, and is similar to the " shincracker " of Lightning Ridge. Beneath this is another white, silty claystone containing about 5 per cent. angular to sub-rounded grains of quartz in a fine argillaceous matrix. It is compact and shows iron oxide staining on the cleavages. Below these two beds is a white silty claystone which shows a breccia effect in hand specimen. There are included within the rock small compact finer-grained areas which do not show iron oxide staining as markedly as the remainder of the bed and these are regarded by D. R. Pinkstone, Petrologist, as being due to intraformational sub-aqueous gliding or slumping.

Similar, but slightly coarser, material is in evidence at Turley's Hill, where there is 3 feet of sandstone and claystone breccia overlying 11 feet of fine-grained soft sandstone which has numerous small claystone pieces enclosed within it. Gypsum in the form of vughs and veins has formed within the top 2 feet of the latter bed. These beds are on comparable horizons with the claystones described from Quin's Block, and claystones from the southern margin of the Blocks Area, suggesting that the beds have suffered fairly rapid lateral facies changes in this area.

Kenny (1934) tabulates some analyses of fine-grained shaly sandstones from the area (and gives analyses of a ceramic and a brick clay for comparison purposes). This table is repeated below:—

Reference No	1	2	3	4	5	6	7	8
Moisture at 100°C.	5.40	3.98	3.83	1.90	2.37	4.81	1.07	1.10
Combined Water	5.91	7.30	8.27	7.89	9.33	8.23	7.11	8.35
Silica	68.12	63.55	61.60	66.14	59.64	62.83	66.76	59.00
Alumina	15.25	21.89	23.32	21.45	25.44	20.00	22.21	26.32
Ferric Oxide	0.76	0.57	0.80	0.78	0.59	0.27	0.35	1.00
Ferrous Oxide	0.27	0.21	0.18	..	0.27	0.28	0.04	0.27
Lime	0.42	0.32	0.48	0.41	0.74	0.35	0.28	0.47
Magnesia	0.77	0.57	0.70	0.45	0.47	0.48	0,22	Trace
Soda	0.77	0.71	0.24	0.46	0.38	0.43	0.40	0.27
Potash	0.73	0.64	0.27	0.68	0.35	0.71	1.20	2.10
Titanium dioxide	0.74	0.24	0.72	..	0.57	0.96	..	0.90
Chlorine	1.29	0.64	..	0.17	0.02	1.17	..	0.02

Localities:

1. Nine miles north-west of White Cliffs.
2. Bunker Creek near White Cliffs.
3. Material below seam of opalised bivalve shells, White Cliffs.
4. Bunker Creek near White Cliffs.
5. Above third opal seam, White Cliffs.
6. Gritty rock, Bunker Creek near White Cliffs.
7. Ulan ceramic clay.
8. Kuringai brick clay.

Evidence from bores within parishes Elder and Kirk, immediately north of White Cliffs, shows that between 180 feet and 420 feet of claystone was penetrated before any sandy members were encountered. From these bores it appears that the main sandstone members of the Cretaceous would lie at a depth approximating 180 feet beneath the Blocks Area.

Fossil evidence suggests that the beds have been laid down under littoral conditions. David (1950) states "..... the beds are largely of the kaolinic type ..... This rock in addition to veins of opal contains thin veins and concretionary nodules of gypsum and nodules of barytes, together with curious aggregates of pointed crystals of glauberite pseudomorphed by common and precious opal—the so-called " fossil pineapples ". The beds have yielded crinoids, lamellibranchs, brachiopods, cephalopods and some reptilian bones which, with fossil wood, suggest estuarine or littoral deposition ".

Erratics composed chiefly of Devonian quartzite occur throughout the claystone at White Cliffs. They vary in size up to 5 feet in length, are not limited to any one horizon, and their presence suggests that glaciation has occurred during the Lower Cretaceous period. David says of them ".... and though generally rounded may have one flat face. They were evidently dropped by floating ice ". Further glacial deposits within this geological period are known in South Australia. Fossiliferous evidence exists to prove the age of the erratic boulders as Devonian.

F. G. de V. Gipps (1894) collected from the White Cliffs area the undermentioned fossils which were identified by R. Etheridge, Jnr.

Maccoyella reflecta, Moore;
Tellina sp.;
Modiola;
Natica varialsilis, Moore; and
Belemnites canhami, Tate.

With these were some crinoid stems and a bone of a plesiosaur.

E. F. Pittman (1901) records the following fossils identified by W. S. Dun:—

Lucina (?) *bonythoni*, Tate.
Platopsis (?) *currugata*, Tate;
Tellina;
Maccoyella barklyi, Moore;
Glycimeris;
Cytherea, cf. *moorei* Eth. fil.;
Cimoliosaurus leucoscopelus, Eth. fil.;
Crinoid ossicles;
Brachiopod fragments;
Coniferous wood.

Practically all the above have been found in an opalized condition.

Spence (1958) collected samples from "the highest beds at White Cliffs, in which the opals are found . . . a microfauna identified by Dr. Ludbrook as belonging to the Tambo formation. The spoil heap of a shaft which began at a horizon not more than 50 feet below the fossiliferous Tambo beds, and which is reputed to be about 100 feet deep, contained pieces of grey, glauconitic, sandy shale in which Dr. Ludbrook identified an Aptian (Roma) microfauna".

Samples collected during the present survey and submitted to I. Crespin for microfossil determination gave the following results:—

777. *Top band in underground workings in shaft on eastern edge of the "Blocks Area" White Cliffs.*

Cream to pinkish siltstone with (?) foraminifera.

780. *West side of "Blocks Area" (on dump), White Cliffs.*

Cream sandy siltstone with bands of opal and opal replacement of shell fragments. Washings contained arenaceous and calcareous tests of foraminifera, opalized shell fragments and ostracoda. The arenaceous tests of foraminifera were crushed, whilst the calcareous ones were replaced with opal.

Foraminifera: *Bigenerina* sp.
Haplophragmoides chapmani Crespin.
Haplophragmoides aff. *excavata* Chapman.
Lenticulina australiensis Crespin.
Marginulinopsis australis Crespin.

Ostracoda: Genus indeterminate.

781. *Locality as for* 780.

Cream silstone with opaline patches and indeterminate shell fragments. No foraminifera were present in the washings.

793. *Bottom of south tractor cut on Turley's Hill, White Cliffs.*

Sandy siltstone with arenaceous foraminifera, very crushed.

Haplophragmoides cf. *chapmani* Crespin.
Spiroplectammina sp.
Trochammina aff. *raggatti* Crespin.
Trochammina aff. *depressa* Lozo.

Crespin states "All species recognisable are characteristic of the Lower Cretaceous deposits of the Great Artesian Basin . . . . ". All arenaceous tests were crushed and distorted as is frequently the case with the foraminifera found in the Lower Cretaceous deposits. However, the calcareous species *Marginulinopsis australis* and *Lenticulina australiensis* have become opalized and have retained their original shape.

TERTIARY

Deposits of greybilly, conglomerate and shale which have been assigned to the Tertiary period have been formed over the Cretaceous sediments. Kenny (1934) gives the following section:—

Siliceous material (greybilly), pseudo-conglomerate, maximum thickness 20 feet.

Clays, in part sandy, usually reddish in colour, with nodules of "greybilly" in the upper portions. As much as 10 to 12 feet in thickness where best developed, but may be absent in some places.

"Geyser" or "Geaser". Siliceous material of pisolitic nature closely resembling "greybilly".

The uppermost siliceous material, commonly termed "greybilly" is a secondary deposit which has a widespread distribution over the Cretaceous sediments, and forms the capping to the flat-topped mesas which occur in the area.

It is very hard, has a distinctive sheen on its weathered surface, and has a blocky or nodular habit. Its mode of formation is discussed by Andrews (1922), who states:

> "It would appear that during arid conditions obtaining in the Kainozoic Period, there was a steady rise of underground water to the arid surface. This ascending water contained a percentage of silica which was thrown down upon reaching the surface through rapid evaporation of the water, and the silica thus raised was deposited, generally as replacement, in the form of segregations at the surface."

Nothing was seen during the present survey to discredit this theory and it appears to be the most logical answer to the formation of this type of deposit. Kenny (1930) collected leaf impressions within greybilly from the top of Smith's Hill. He stated that they resembled Tertiary leaves, but the results from the palaeontologist were unknown when he went to print. These impressions have since been determined by K. G. Wood, Palaeontologist, to be the forms *Elaeocarpus muelleri* and *Cassia phaseolitoides*, which are referable to the Tertiary Period (see Appendix A). Sections measured during the present survey did not reveal any leaf impressions, and gave thicknesses of the material varying between 1 ft. 10 ins. and 10 ft. 3 ins. Mixed with the greybilly, boulders of which averaged 1 inch to 1½ inches diameter with occasional to 8 inches, were ironstone gravels. Both the greybilly and ironstone had been loosely cemented by sand in some areas.

The clays mentioned by Kenny are not revealed in the sections on plate B392 and they were not seen by the writer.

Where sectioned, the greybilly directly overlies a band of conglomerate. Pebbles consist of small pieces of greybilly, white quartz and claystone, averaging ⅛ inch in diameter, with some to ½ inch and only an occasional pebble to 2 inches. A sample of this material taken from Welsh's Knob was described by D. R. Pinkstone, Petrologist, Mining Museum, as being a "conglomerate consisting of sub-rounded to sub-angular pebbles of silty claystone, claystone and quartz in a matrix of silty claystone. The quartz grains of the matrix are angular to sub-angular and the matrix as a whole is impregnated with iron oxide".

Another sample of "geyser" was taken from the Purnanga diggings and this was described by D. R. Pinkstone as "conglomerate consisting of sub-rounded to rounded pebbles of quartz wacke ("greybilly", R. E. R.) in a siliceous cement impregnated with iron oxide. The quartz fragments of the quartz wacke pebbles are markedly angular and unsorted". This latter type of conglomerate is the most common on the field. It has been placed within the Tertiary Period, and it has been suggested by Kenny (1934) that it may represent an older development upon the surface of the Cretaceous rocks prior to deposition of Tertiary sediments.

Pleistocene to Recent

Deposits of sand, clay, sandy loam, ironstone scree, and gypsum overlie the Tertiary sediments in part.

Wind-blown sand covers both Tertiary and Cretaceous rocks on the plateau to the west of White Cliffs, while deposits of sand, sandy loam and clay occur along the creek banks. Ironstone scree covers both the Tertiary greybilly and the gentle slopes of the Cretaceous sediments where they are exposed. Gravels which cover Lena's Hill consist mainly of greybilly with some sandstone and have been greatly ironstained. Some, if not all, of these were formed within Tertiary time, and now cover the other rocks as a weathered mantle.

Gypsum is a common occurrence within and on top of the Cretaceous. It is possible that there has been more than one age of formation for this mineral.

MINING AREAS

White Cliffs

Precious opal has been won from a number of localities in the immediate vicinity of the town of White Cliffs (see plan B392). These are:—

1. The Blocks Area.
2. Sullivan's Hill.
3. Moffat's Hill.
4. Clancy's.
5. Turley's Hill.
6. Smith's Hill.
7. Lena's Hill.

The Blocks Area

By far the greatest amount of activity has been centred in that area known as the "The Blocks", the south-east corner of which is situated 20 chains north-west of the Post Office, and which is approximately 1½ miles long and ½ to ¾ mile wide. It was here that opal was first mined and by 1890 some 600 acres had been secured under lease. The leases became known as "Blocks", seven of which aggregating 300 acres being owned by the White Cliffs Opal Mining Company with others being owned by McKenzie (Block 2), Brady (Block 9), Grady & Co. (Block 11), Ronald and Dromgoole (Block 14) and Barrett (Block 25).

The seven blocks held by the White Cliffs Opal Mining Company proved popular with the miners as the opal-bearing claystone cropped out at the surface and did not have the hard capping of grey-billy that covered the other blocks. In 1901 there were 440 men working on these blocks, with 80 men on Block 11, 30 on Block 9, 40 on Block 2, 70 on Block 14, 5 on Block 25, and about 100 men working on claims outside these leases. There were over 900 men on the field during this year.

Depth of sinking varied throughout the Blocks Area, with good quality opal at the surface in the vicinity of the open-cut and dug-outs and at depths down to 80 feet in Block 6. Most driving has been carried out on the 9, 13, 18, 24, 32 and 40-ft. levels, however, and there is a difference of opinion as to whether the opal improves or deteriorates in quality with depth. In the Annual Report of the N.S.W. Department of Mines for 1895, p. 68, it is stated: "It is also encouraging to learn that the patches of opal met with appear to improve in quality with depth and to become more regular and frequent than that met with in the higher levels. In Block 5 the shaft is down 50 feet in first class country and splendid opal is showing in the drives. On Block 7, a patch of stone was found which realised over £3,000 and good stone is still being got. In one of the shafts on this block there are three distinct veins of opal—one at 10 feet, another at 20 feet and a third at the 30 feet level. The work done on Block 8 has proved very satisfactory, the quality of the opal obtained being very good. In a shaft on this block large pieces of petrified wood and opalised shells were obtained at a depth of 30 feet. Block 6 is on the brow of a hill where the country is much harder and the opal-bearing veins dip into the hill. Some valuable patches of opal have been taken from this block".

Sullivan's Hill

This is an extension to the east of the main Blocks area and is towards the margin of outcrop of the Cretaceous sediments. It is separated from the Blocks by an area which is covered by a thickness of greybilly and ironstone gravels that has discouraged prospecting to any degree, and only random holes have been emplaced there. More activity has taken place near the edge of the scarp where the Tertiary capping is not so severe.

One shaft afforded the following section:—

From ft. in.	To ft. in.	
0 0	1 10	Surface debris—greybilly, ironstone and ironstained soil.
1 10	4 6	Sandstone, fine-grained, platy, well jointed with ironstone concretions and iron-staining prevalent.
4 6	7 10	Claystone, slightly hardened—ironstained, slight conchoidal fracture.
7 10	22 0	Clay, soft, white with sandy facies. Ironstained, some vertical jointing. Bedding indistinct—some gypsum.

There are reputedly three opal levels here, with the lowest level at a depth of 40 feet. Fifty men were mining in this area in 1901.

Moffat's Hill

This is a small outlier of Cretaceous rocks, half a mile north-east of the main Blocks area. It is covered by a capping of Tertiary greybilly and most of the activity has been directed to two areas, one on the south and the other on the north side of the hill, so that the greatest depth of Tertiary cover is by-passed.

Depths of 15 and 20 feet have been sunk to opal dirt along the southern margin of the hill.

Clancy's

This is an area which forms the northern limit of workings along the line of the Blocks area, from which area it is separated by approximately 1½ miles within which distance several sporadic holes have been sunk. It is 6 miles north of the Post Office.

The Tertiary capping of greybilly has been eroded here and thus exposed the Cretaceous sediments. Without the greybilly sinking was easy and upwards of one hundred shafts are in evidence. Depths of the shafts are not known, but from the dumps it does not appear that many, if any, exceed 40 feet.

Turley's Hill

This is an outlier situated ¼ mile east of the Post Office. It is capped, especially on its southern margin, by a bold outcrop of greybilly which has discouraged any great amount of shaft sinking, and in consequence a great deal of driving has been carried out from the outcrop of the Cretaceous rocks. Most of this driving has taken place immediately below the junction of the Cretaceous sediments with the overlying Tertiary conglomerate. On the periphery of the hill a number of shafts have been started within the Cretaceous, and on the western margin two bulldozer cuts have been made over a length of approximately 50 feet and to a depth of 22 feet within loose Tertiary-Recent material and soft Cretaceous sediments. Only a small amount of opal was won by this method and the project was abandoned.

A section within this bulldozer cut is as follows:—

From ft. in.	To ft. in.	
0 0	8 0	Tertiary gravels loosely cemented to completely free—average size 1 inch with occasional to 5 inches—mostly greybilly.
8 0	11 0	Sandstone and claystone breccia.
11 0	13 4	Gypsum associated with fine-grained sandstone. Gypsum occurs in veins and vughs.
13 4 (Sample 793).	22 0	Sandstone, light, fine-grained, soft, with clay blebs. Well jointed, bedding well displayed, ironstained.

In 1901, 50 men found employment on this hill, which was then called Farley's, and by 1907 precious opal had been recovered to depths up to 42 feet which was quoted then as the range of productiveness.

Smith's Hill

This is situated 1¾ mile south of the Post Office, and is very similar to Turley's Hill in that the overlying Tertiary has discouraged any great amount of shaft sinking. Some activity has been directed to the margins of the hill, but not nearly so much work has been undertaken here as at, say, Turley's. Twenty men were mining on the hill in 1907.

Lena's Hill

This is ¾ mile south-west of the Post Office. It is capped by gravels consisting mainly of greybilly and ironstone which have been cemented in part. Small quantities of sandstone and a few Denovian boulders make up the remainder of the gravels. Only a few shallow shafts have been sunk here, and there are a small number of prospecting pits along the margin of the hill. Some boulders of quartzite which carry Devonian fossils are in evidence near the dumps.

Other Localities

Gemville

This area was originally called the Bunker Field and is referred to as such in early Annual Reports of the Department. It is situated 12 miles south-west of White Cliffs, and is approachable through either Tarella or Whipstick Stations. Greybilly covers some of the Cretaceous here, but it is not nearly so extensive as at White Cliffs. Shaly sandstone and claystone with some gypsum are associated on the dumps, and some clear and slightly milky potch occurs.

The workings averaged about 20 feet in depth and seldom exceeded 35 feet. The sinking is described as easy, with the opal being well distributed throughout the sediments. The opal is of good quality, comparing with any on the field, and some hundreds of shafts have been sunk.

Barclay's Bunker

This is situated 8 miles south-west of White Cliffs. Here Cretaceous sediments are exposed in a scarp caused by erosion along Bunker Creek, and shafts have been sunk close to the scarp through Tertiary greybilly, and along the edge of the scarp in Cretaceous sediments. This area has not received as much attention as the Gemville diggings due to a more extensive greybilly cover, but more than one hundred shafts have been sunk. Here, again, the average depth would be of the order of 30-40 feet.

Welsh's Knob

12-15 shafts have been sunk on Welsh's Knob which is 9 miles south of White Cliffs beside the road to Tarella Station and Wilcannia. There is a strong greybilly outcrop on the crest of the hill with some fine-grained Tertiary conglomerate underlying it. The Cretaceous appears to be more sandy than at White Cliffs and it is doubtful, by the few shafts here, that any opal of consequence was discovered.

Purnanga

About 50 shafts have been sunk on the scarp of a Cretaceous plateau five miles west of Purnanga Homestead which is some 30 miles north-north-east of White Cliffs.

This field was discovered in 1896, when between 10 and 15 men were shaft-sinking. However, scarcity of water was apparently the main deterrent to further exploitation and little activity has taken place since.

A section here is as follows:—

		ft.	
Tertiary		2	Greybilly—average size of pebbles 3 inches, an occasional one to 12 inches.
		2	Conglomerate consisting of sub-rounded to rounded pebbles of quartzwacke in a siliceous cement impregnated with iron oxide. The quartz fragments are markedly angular and unsorted.
Lower Cretaceous	Approx.	4	Claystone, compact, hard, white, of very fine grainsize, containing approximately 5 per cent. of fine angular quartz grains in a very fine groundmass. The rock breaks with sub-conchoidal fracture.
	Approx.	4	Claystone, white, silty, containing approx. 5 per cent. angular to subrounded grains of quartz in a fine argillaceous matrix. Iron oxide staining on cleavage only.
		6 +	Claystone, white, silty, with intraformational sub-aqueous gliding or slumping to give a breccia effect in hand specimen.

These sediments are of similar type to the White Cliffs sediments, but no true " opal dirt " was seen on the dumps or *in situ*. The opal was no doubt associated with the white silty claystone showing a breccia effect in hand specimen. There is a considerable amount of gypsum on the dumps.

Two shallow bulldozer cuts have exposed the top hard claystone (similar to the " shincracker " of Lightning Ridge) band here. This has been apparently too difficult to break by bulldozer and the project was abandoned.

Some prospecting has been carried out a few miles north-west of the homestead.

Turner's

Nothing is known of this locality which is situated 10 miles north of White Cliffs, and apparently little opal of value was won from here.

OCCURRENCE OF OPAL

Any of the claystone members that have so far been observed within the Lower Cretaceous at White Cliffs have proved to be opal-bearing, and small but uneconomical amounts have also been recorded from the bed of Tertiary (?) conglomerate, locally termed " geyser ", which immediately overlies these beds. It has also been noted in one or two instances in the overlying porcellanite (greybilly) in Queensland (Jackson 1902). This suggests that the opalisation of these sediments took place either during the late Tertiary or a post-Tertiary period.

Opal may occur either as (*a*) potch or common opal which does not display the brilliant colours of the precious opal, being on this field mainly clear to white. A small amount of black potch is formed with the white to form " magpie " potch in one locality on Sullivan's Hill, or (*b*) as precious opal which has been divided on type into " pin-fire " in which the colour is shown as many small pin-points of fire; " flash " in which the colour is shown as broad, irregular flashes of one colour; or " harlequin " in which the colour is shown as small regular-sized squares.

It occurs in the following forms:—

(1) As thin horizontal and vertical veins.

(2) As irregular nodules.

(3) As wood opal.

(4) Replacing shells and pseudomorphous after gypsum (?).

(5) Penetrating, or as crusts to, Devonian erratics and other boulders within the Cretaceous.

Potch is the more abundant form. It may have bands of precious opal through it and when it is struck in the workings it is usually followed to determine if any colour will make along the vein. Horizontal veins are better to prospect than verticals. They are usually thicker, and if colour does occur it forms in horizontal layers so that the colour runs " true ", and it is possible to cut large stones. The " verticals " have the colour running across them, and only the thickest of veins can be utilised, for the " grain " of the colour being horizontal means that only horizontal cuts of the material will give the best display of colours.

If a stone is cut at right angles to the " grain " it will not show an overall flash of many colours, but will have bands of various colours running across it.

Kenny (1929) records the existence of a " bandstone ", described as " rock of indefinite composition, but usually resembling a fine-grained sandstone, in part silicifed " as an important marker horizon, as opal had been noted to occur in many places beneath it. This " bandstone " was not recognised during this survey, and it apparently is a bed which is non-persistent. The presence of this band is not a criterion for the formation of opal, however, for the opal itself does not persist along any one horizon, but occurs spasmodically throughout the claystone. There is a concentration, however, along some levels such as at the junction of the Cretaceous and Tertiary rocks, and within some workings up to three and possibly six levels have been prospected. There is no reason why more than six levels could not be present in some localities.

COLOUR OF OPALS

Chalmers (1955) points out that in 1932 Dwyer and Mellor (1934) showed that opal contains crystallites of crystobalite and hence is not an amorphous substance as had been thought up to that date. Also that Raman and Jayaraman (1953) elucidated by X-ray examination that the colour is caused by the finely stratified nature of crystalline structures within the opal. These structures consist of alternate layers of two crystalline varieties of silica (alpha-tridymite and beta-crystobalite) which have slightly different refractive indices.

Chalmers states:—" spectroscopic examination of the play of colours reflected from these stratified structures prove them to be pure monochromatic hues, and therefore not caused by interference. It is pointed out that the high degree of perfection of the reflections from opal show that the alternate layers occur in great numbers and are spaced regularly, the magnitude of the spacing being of the same order as the wave length of light. The magnitude of the spacing indeed corresponds more to the smaller wave lengths of light, which explains why the smaller wave length colours, violet, blue and green, are seen more frequently than the higher wave length colours, red and orange. One of the most convincing proofs that the colours of opal are caused by the inherent structure of the mineral was first afforded by Dwyer and Mellor (1932), who found that heating opal at 100° C. for eight hours did not destroy the colours. Raman & Jayaraman proved this also by heating opal to such an extent that it disintegrated and yet the colours were not destroyed ".

FUTURE PROSPECTS

Because of its isolation, unpleasant living conditions and the fact that the less popular white or light coloured opal is found here, it is considered that the field would need either some major economic upheaval, coupled with some form of Government aid, or a breakdown of present supplies of opal, before it is likely that new life would be instilled into it. That there is still quite a large amount of opal to be won on the field and in the surrounding districts seems obvious when one considers that opal has been won from a number of places over a length of approximately 50 miles in this locality within Cretaceous sediments which are potential sources of opal, and that the known fields could be still further prospected with every chance of securing economic deposits.

PRODUCTION

The following figures can only serve as a guide to the amount of opal that has been taken from the field. The difficulty of proving accurately the amount of opal that was taken out especially during the days when the tribute system was working can be easily realised, and figures such as £50,000 and £20,000 speak for themselves.

PRODUCTION

Year	Value
	£
1890	15,600
1891	..
1892	2,000
1893	12,315
1894	5,684
1895	6,000
1896	45,000
1897	75,000
1898	80,000
1899	135,000
1900	80,000
1901	120,000
1902	140,000
1903	100,000
1904	56,000
1905	55,000
1906	50,000
1907	66,000
1908	31,000
1909	21,800
1910	20,000
1911	17,700
1912	8,828
1913	10,121
1914	4,898
1915	2,327
1916	663
1917	600
1918	600
1919	1,900
1920	600
1921	400
1922	100
1923	40
1924	..
1925	30
1926	..
1927	..
1928	..
1929	30
1930	..
1931	..
1932	80
1933	..
1934	25
1935	550
1936	10
1937	15
1938	44
1939	30
1940	102
1941	..
1942	..
1943	10
1944	20

No production has been recorded from this date.

TOTAL	£1,166,922

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Appendix A

Leaf Impressions in a Silicified Sediment from White Cliffs, N.S.W.

The specimens of " greybilly ", collected by E. J. Kenny, from the top of Smith's Hill, White Cliffs, have been examined.

The material consisted of two large irregular pieces of silicified gritty sediment containing two leaf impressions on one piece and one undeterminable fragment on the other. Preservation of part of one leaf was particularly good and the venation and nervation was readily observed. However, the edges of the leaf were obscured and the outline could not be determined. From a consideration of the venation and nervation the form is probably *Elaeocarpus Muelleri.* The other leaf is referred to *Cassia phaseolitoides.*

These genera have been found in the Tertiary sediments of the New England district.

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Palaeontologist.
Geological and Mining Museum.

Appendix B

Petrological Determinations

WHITE CLIFFS AREA

Specimen No. — Location and Description

782. *22 foot Shaft, middle of eastern fall from Sullivan's Hill.*

Soft white silty claystone containing approximately 10 per cent. angular to sub-angular silt size quartz grains in a fine clayey matrix. Occasional chert fragments, weathered felspars, grains of zircon and iron oxide are present.

783. *7 ft. 10 in. below surface, in above shaft.*

Fine-grained white silty claystone having approximately 20 per cent. of fine angular quartz in a very fine-grained argillaceous matrix. The rock is ironstained on cleavages only.

776. *Bottom of shaft on eastern edge of Blocks area.*

Silty claystone containing approximately 15 per cent. quartz (finer than 782) in a clayey matrix. A little chloritic material and some secondary silica is discernible. The rock is slightly stained with iron oxide.

775. *From the above* (776) *shaft,* 11 *ft.* 5 *in. to* 12 *ft.* 4 *in. below surface.*

Hardened silty claystone containing angular fragments of quartz in an argillaceous matrix. Regrowth of quartz grains may be noticed and secondary chalcedonic growths appear to be more prevalent than in the above samples. Staining with iron oxide also appears to be more prevalent.

787. *Welsh's Knob near White Cliffs.*

Conglomerate consisting of sub-rounded to sub-angular pebbles of silty claystone, claystone and quartz in a matrix of silty claystone. The quartz grains of the matrix are angular to sub-angular and the matrix as a whole is impregnated with iron oxide.

PURNANGA OPAL FIELD

774. *Purnanga Opal Field.*

Conglomerate consisting of sub-rounded to rounded pebbles of quartz wacke in a siliceous cement impregnated with iron oxide. The quartz fragments of the quartz wacke pebbles are markedly angular and unsorted.

789. *Purnanga Opal Field.*

Compact hard white claystone of very fine grainsize, containing approximately 5 per cent. of fine angular quartz grains in a very fine groundmass. The rock breaks with a sub-conchoidal fracture not unlike that of chert.

772. *Purnanga Opal Field—from tractor cut.*

White silty claystone containing approximately 5 per cent. angular to sub-rounded grains of quartz in a fine argillaceous matrix. The rock is compact and shows iron oxide staining on cleavages only.

771. *Purnanga Opal Field.*

White silty claystone similar in composition to 772. The brecciation effect seen in hand specimen is not sharply defined as such under the microscope and is to be regarded as intraformational sub-aqueous gliding or slumping. The finer more compact areas have little or no silt-size quartz fragments.

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Petrologist.
Geological and Mining Museum.

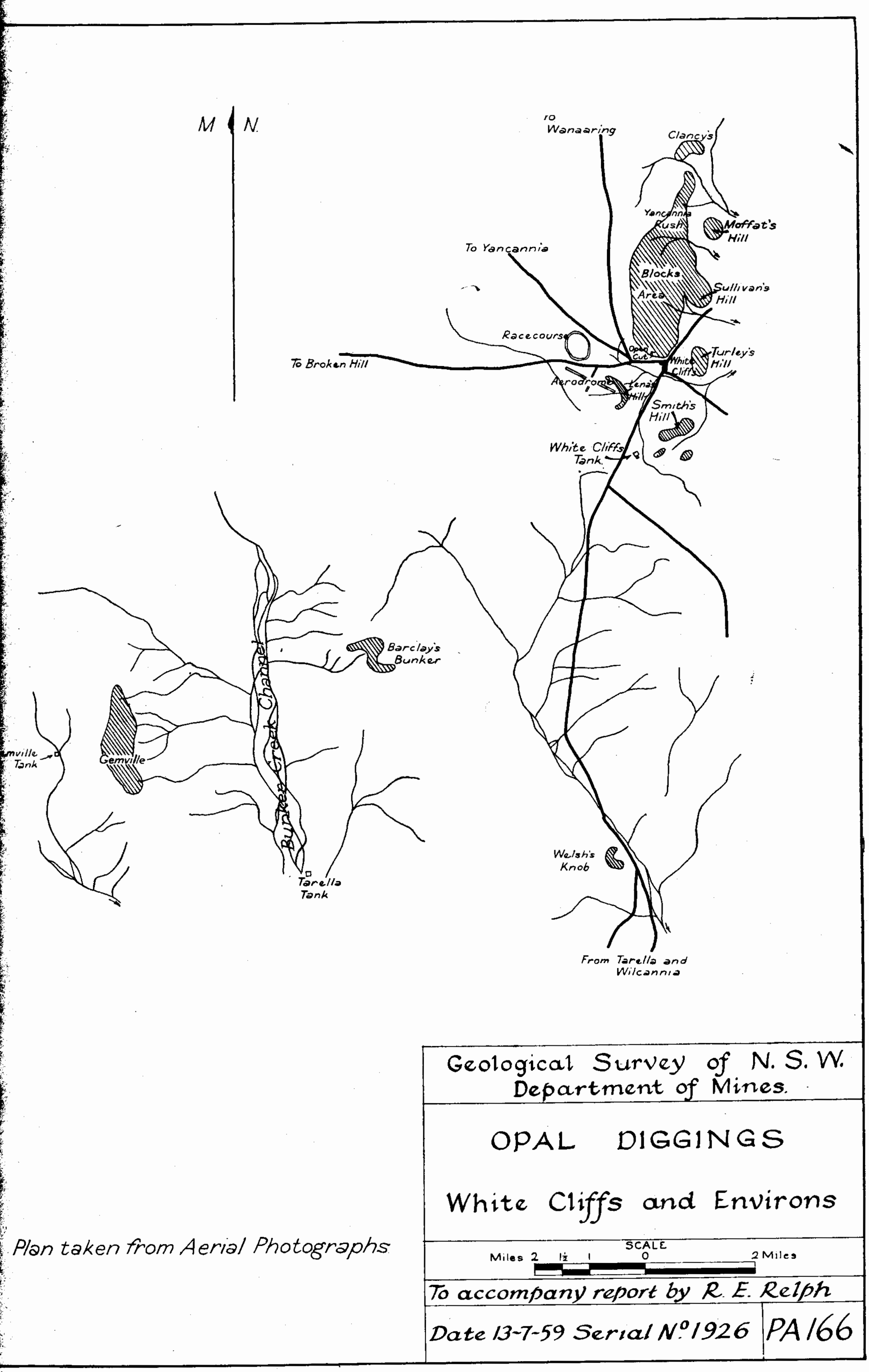
M N.
To Wanaaring
Clancy's
Yancannia Rush
Moffat's Hill
To Yancannia
Blocks Area
Sullivan's Hill
Racecourse
Open Cut
Turley's Hill
To Broken Hill
White Cliffs
Aerodrome
Smith's Hill
White Cliffs Tank
Barclay's Bunker
Bunker Creek Channel
Gemville
Tarella Tank
Welsh's Knob
From Tarella and Wilcannia
Plan taken from Aerial Photographs
Geological Survey of N. S. W.
Department of Mines.
OPAL DIGGINGS
White Cliffs and Environs
SCALE
Miles 2 1½ 1 0 2 Miles
To accompany report by R. E. Relph
Date 13-7-59 Serial Nº 1926
PA 166

Fig. 1