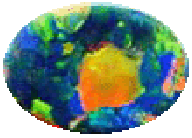
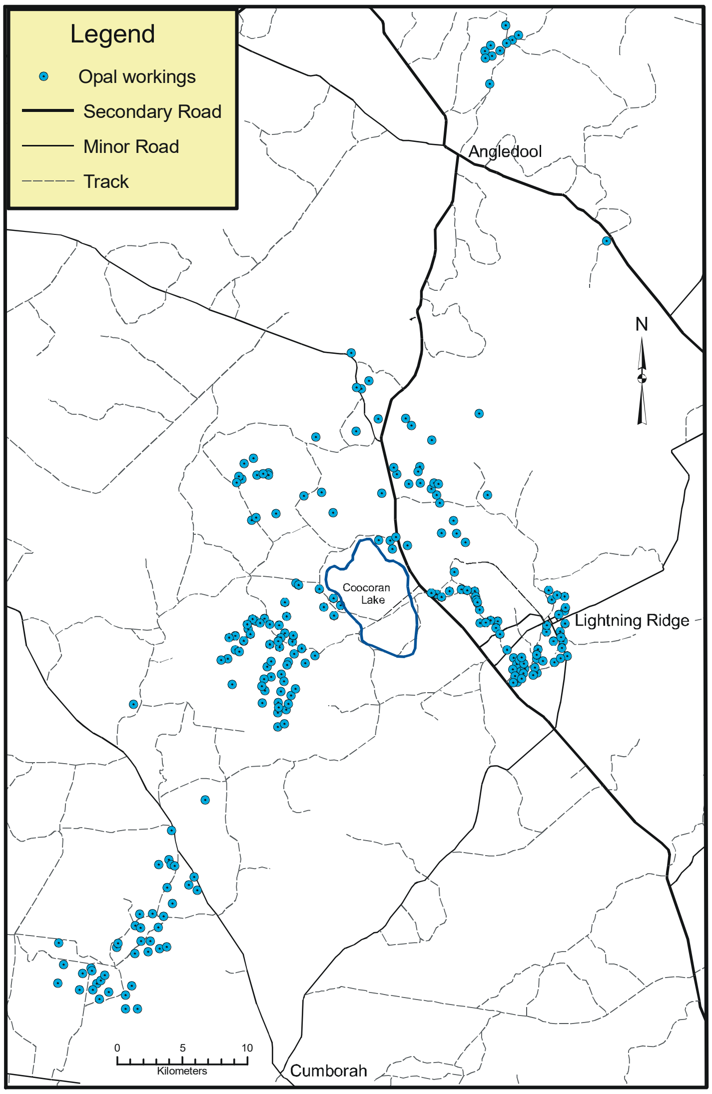
GEOLOGICAL TOUR OF THE LIGHTNING RIDGE AREA



The Lightning Ridge area is situated in central northern New South Wales, about 76 km north of Walgett. The area of known opal occurrences are closely associated with low hills of sedimentary rocks which generally extend in a northerly-trending belt 82 km long and 30 km wide. The opal belt commences near Cumborah at its southern end, and continues to the north of Angledool, with Lightning Ridge located approximately centrally. The opal produced from this field is unique, displaying a dark blue to black matrix and strongly contrasting, vivid colours. It is known as *black opal*. Most opal occurrences from elsewhere in Australia and overseas exhibit a pale matrix which produces less contrast with the opal's colours.



The area is unfortunately not endowed with particularly instructive outcrop or unique rock types. There are a number of adequate localities where the geology of the opal-bearing rock sequence can be examined, and where the geomorphology of the dry Coocoran Lake can be visited. Maps of the major opal fields are included here as an assistance to fossickers.

The geological observations and conclusions of geoscientist Gary Burton of the New South Wales Geological Survey are acknowledged as a major contribution to this guide. This guide is derived from the enthusiasm of local authority Warwick Schofield who is thanked for his support and positive contribution.

Figure 1. The opal mining areas of the Lightning Ridge district.

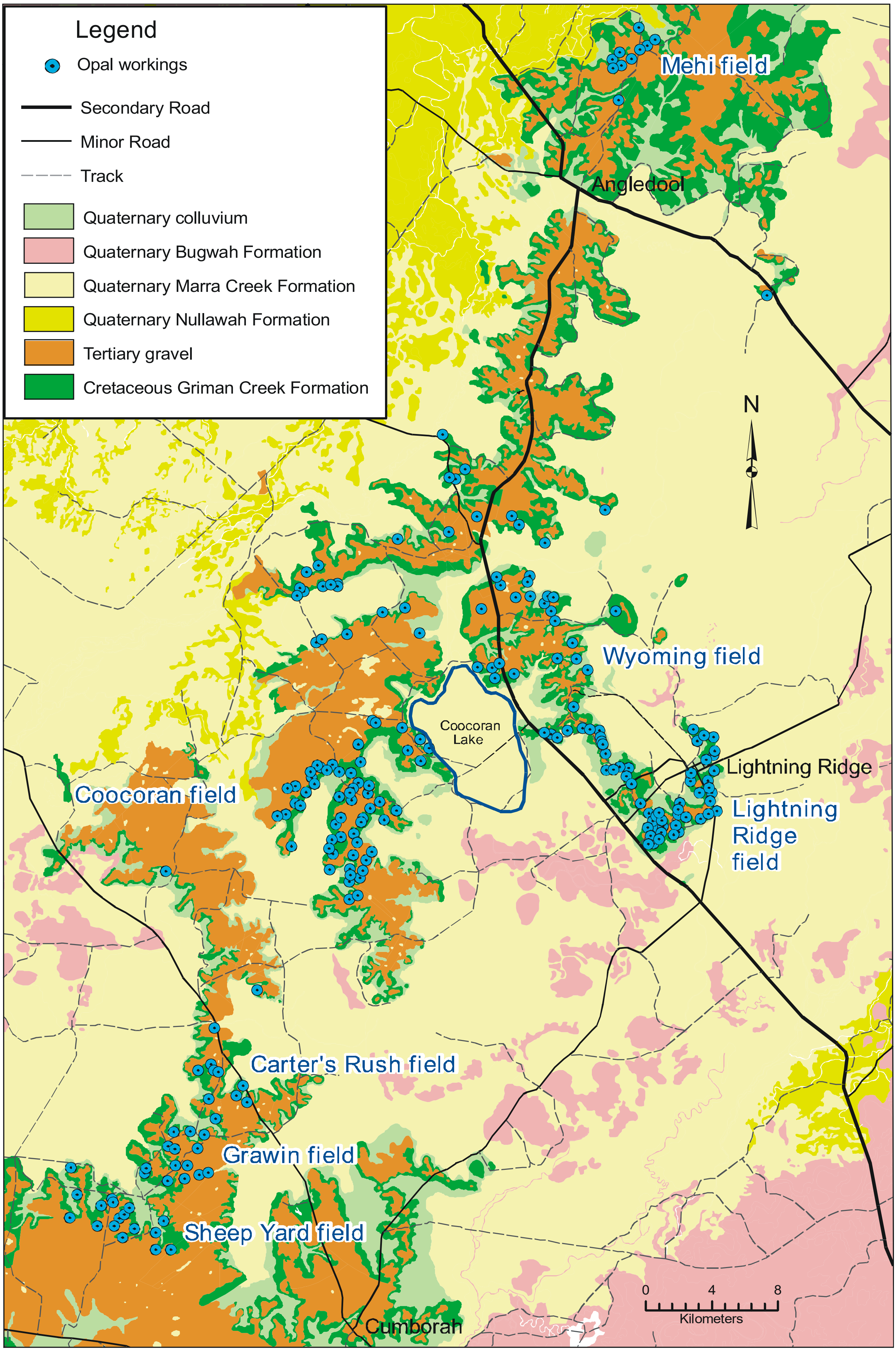


Figure 2. Simplified geology and the distribution of opal workings in the Lightning Ridge area. Geology and opal mine locations after Gary Burton.

The Lightning Ridge area is situated upon rocks of the Great Artesian Basin (Figure 3). This enormous accumulation of sedimentary rocks was laid down on land and in a shallow marine sea between between 100 and 250 million years ago (see table, page 4), at a time when the Australian continent was close to the Antarctic pole. The basin covers a total area of over 1 711 000 square km and it has an estimated total water storage of 64 900 million megalitres.

The Great Artesian Basin consists of alternating layers of water-bearing (permeable) sandstone aquifers and non-water-bearing (impermeable) siltstones and mudstones. The thickness of this sequence varies from less than 100 metres on the basin extremities to over 3 000 metres in the deeper parts of the basin. Individual bore depths vary up to 2 000 metres with the average being 500 metres. Some of the sandstone sequences contain oil and gas where conditions are suitable. The water supply for Lightning Ridge and many other inland towns is derived from aquifers within the basin. The Lightning Ridge opal deposits also occur within sedimentary rocks of the basin (the Griman Creek Formation, Figure 2).

Figure 3. The regional extent of the Great Artesian Basin .

The Griman Creek Formation is the only geological unit of the Great Artesian Basin outcropping in the Lightning Ridge area. It consists of interlayered fine- to medium-grained and rarely coarse-grained sandstone, claystone and siltstone. In outcrop the rocks are weathered to clay (kaolinite) and are white in colour. Clay-rich weathering extends to a depth of at least 50 m. Fossils are locally abundant (see page 4 for photos), and include common cylindrical cavities after reeds and sedges, locally sparse plant fossils, and the remains of various types of shellfish, turtles, lungfish, crocodiles, pterosaurs, plesiosaurs and dinosaurs. Opalised animal and plant fossils have been found within opal mines. The fossils indicate that the Griman Creek Formation is of Cretaceous age and was deposited between 100 and 110 million years ago by fresh water streams.

In places the upper part of the Griman Creek Formation has been silicified (silica, or quartz, has been added to the rock). Silicification took place during a period of deep weathering in the Tertiary period (see above). Where the silicified rock is very hard, particularly where claystone has been converted to *porcellanite* (a white, flinty rock showing curved fracture surfaces), the rock is locally referred to by miners as *shincracker*. In places, not far above the opal-bearing levels, silicified sandstone, or *steel band* occurs, ranging in thickness from several millimetres to about one metre. *Steel band* is not always associated with opal, but it probably formed at the same time as opal deposits.

SIMPLIFIED GEOLOGICAL HISTORY OF THE LIGHTNING RIDGE REGION

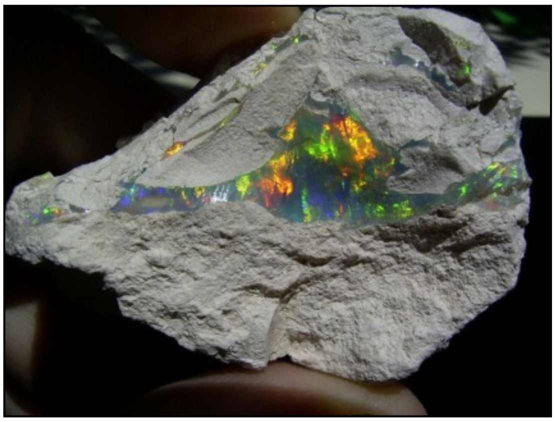
PERIOD	YEARS AGO	LIFE FORMS ORIGINATING	GEOLOGICAL EVENTS
QUATERNARY	0 2,000,000	Human Beings	Deposition on land by wind and extensive river systems
TERTIARY	65,000,000	Grazing and carnivorous mammals	Tropical conditions produced widespread sandy deposits from abundant rivers. Groundwater movement produced silcrete and opal . Erosion of silcrete formed thick gravel beds. Local faulting of silcrete and older rocks.
CRETACEOUS	145,000,000	Last dinosaurs First flowering plants	Polar conditions. Widespread inundation beneath a shallow marine sea and on land close to the shoreline. Uplift of seafloor and deposition on land prevailed by end of Cretaceous
JURASSIC	200,000,000	First birds	No rocks at surface from this period in local area
TRIASSIC	251,000,000	First dinosaurs and mammals	
PERMIAN	299,000,000	Mammal-like reptiles, last Trilobites	
CARBONIFEROUS	359,000,000	First reptiles; fern forests	
DEVONIAN	416,000,000	First amphibians and insects	
SILURIAN	443,000,000	Vascular land plants	
ORDOVICIAN	488,000,000	First corals, fish with vertebrae	
CAMBRIAN	542,000,000	Shellfish, Trilobites	
PRECAMBRIAN	700,000,000 1,500,000,000 3,500,000,000 4,500,000,000	Algae Complex cells Primitive cells Formation of the Earth	

Opalised 110 million year old Cretaceous fossils (left) and 45 million year old Tertiary plant leaf fossils (above) from the Griman Creek Formation. Photos by Warwick Schofield.

In places throughout the Griman Creek Formation linear zones of angular, fractured rock (breccia) occur. Local miners refer to these as *blows.* The *blows* are generally vertical and range from a few millimetres to about two metres in width and extend to over twenty metres in depth. They consist of fragments of the Griman Creek Formation and/or silcrete and/or quartz pebbles, supported by a matrix of white, quartz-rich sand and grey clay. *Blows* are exposed at the surface at numerous localities and are commonly observed within mine workings. Some opal miners believe that *blows* are good indicators for opal. However, research has shown that *blows* post-date both opal formation and the silicification event. Some *blows* cross-cut opal/potch seams and contain angular opal/potch fragments confirming that they post-date the seams. The fact that the 'blows' are rich in present-day surface material indicates that they are recent features. Their origin is uncertain, but they may represent deep surface fractures which have repeatedly opened by small amounts, allowing the in filling by surface sand and gravel.

Opal occurs within the Griman Creek Formation in distinct areas or *fields* (see Figures 2, 4, 5, 6, 7). The main fields where opal is mined are the Coocoran, Lightning Ridge, Carters Rush–Grawin–Glengarry, Wyoming, Muttabun–Allawah and Mehi areas. Opal occurs as horizontal seams, nodules (nobbies) and as replacements and cast fillings after fossils. It is commonly developed within the upper parts (approximately the upper one metre) of claystone lenses which are referred to by miners as *levels* and the claystone itself is referred to as *opal dirt*. The opal-bearing claystone is always overlain by a thick sandstone layer. Recoverable opal is found within 30 m of the surface and has been worked mainly by underground methods, though some open cut mining has been carried out. Generally a single claystone layers is mined, although in some places two or more opal-bearing claystones (referred to as *levels* by miners) are present.

Seam opal consists of mainly horizontal seams of *opaline silica* (see photo at right).



Nobby type opal consists of nodular masses of opal (see photo below). The nodules may be rounded or have various conical shapes, and they vary in size from a few millimetres to several tens of centimetres in diameter. Nobby type opal is particularly common in the opal fields around Lightning Ridge and in the Coocoran area, while to the south in the Grawin–Glengarry area nobbies are rare and seam opal dominates.

Opalised fossils (see photo below) are plant, shell, bone or teeth fossils which have been replaced by opaline silica.

There have been a number of theories to explain the origin of opal. The most strongly favoured is the deep weathering model which involved silica mobilisation during weathering. This model proposes that deep weathering altered the original feldspars in the sandstones to kaolin, liberating silica. The silica-rich ground water migrated downward via fractures and other permeable pathways until it reached an impermeable barrier. In most cases this barrier was provided by claystone lenses, though voids after fossils and various fractures also acted as fluid traps. Once trapped, the water evaporated, creating a silica gel. Microscopic silica spheres then precipitated from the gel to form opaline silica. Where the spheres were of uniform size and were regularly packed, precious opal was formed. Where the spheres were variable in size and not regularly packed, potch, or common opal, developed.

The opal-bearing Griman Creek Formation is overlain locally by silicified sandstone and conglomerate of Tertiary (Eocene) age. This sandstone, the Eyre Formation, was deposited between about 37 and 55 million years ago across much of inland central Australia by creeks and in lakes similar to those in the Channel Country of southwest Queensland. The pebbles are characterised by their small size, high degree of rounding, dominance of white quartz, and very glossy surfaces. The sandstone and conglomerate was subjected to at least one deep weathering event during the Tertiary (about 33 million years ago) which resulted in the movement of large volumes of dissolved silica. Some of this silica formed opal within the underlying Cretaceous rocks, whilst the bulk of the silica precipitated closer to the surface in porous sandstone and conglomerate layers. The resulting, hard, silica-rich rock is known as *silcrete*. The natural erosion-resistant qualities of this rock has resulted in its preservation on the crests of hills and ridges.

Erosion since the production of the silcrete has resulted in extensive mantling of the ground surface with residual gravel and sand. Pebbles derived from the Eyre Formation and elsewhere have been concentrated into locally thick gravel beds. The gravels comprise mainly quartz, but also include agate, chalcedony, petrified wood and rare topaz (see photos below). A variety of quartz pebble with numerous red-brown

Examples of pebbles from the residual gravel beds in the Lightning Ridge area. Pebbles include agate (above), and petrified wood, quartz, brainstone and colourless topaz (right).

intersecting cracks is locally referred to as *brainstone*. Opal pebbles have also been found very rarely. The most recent sedimentary deposits of Quaternary age comprise wind blown sands and extensive sand and clay resulting from deposition by stream systems and in lakes. A number of distinct groups of Quaternary sediments have been recognised by geoscientists (see Figure 2):

Marra Creek Formation - youngest
Bugwah Formation
Nullawah Formation - oldest

These units occur as an essentially flat plain surrounding the ridges. The oldest is the possible Late Pleistocene Nullawa Formation, which is characterised by a dendritic pattern of numerous branching, meandering stream channels and associated floodplain material. This unit is considered to be gradational to the overlying Bugwah Formation, which is characterised by wide, large wavelength, meandering channels. The Marra Creek Formation overlies both of these formations and constitutes the current drainage pattern, characterised by narrow, tightly meandering channels and a broad floodplain. Flow in all three alluvial systems was from northeast to southwest. Silty sediment in the nearby Coocoran Lake is of Marra Creek Formation.

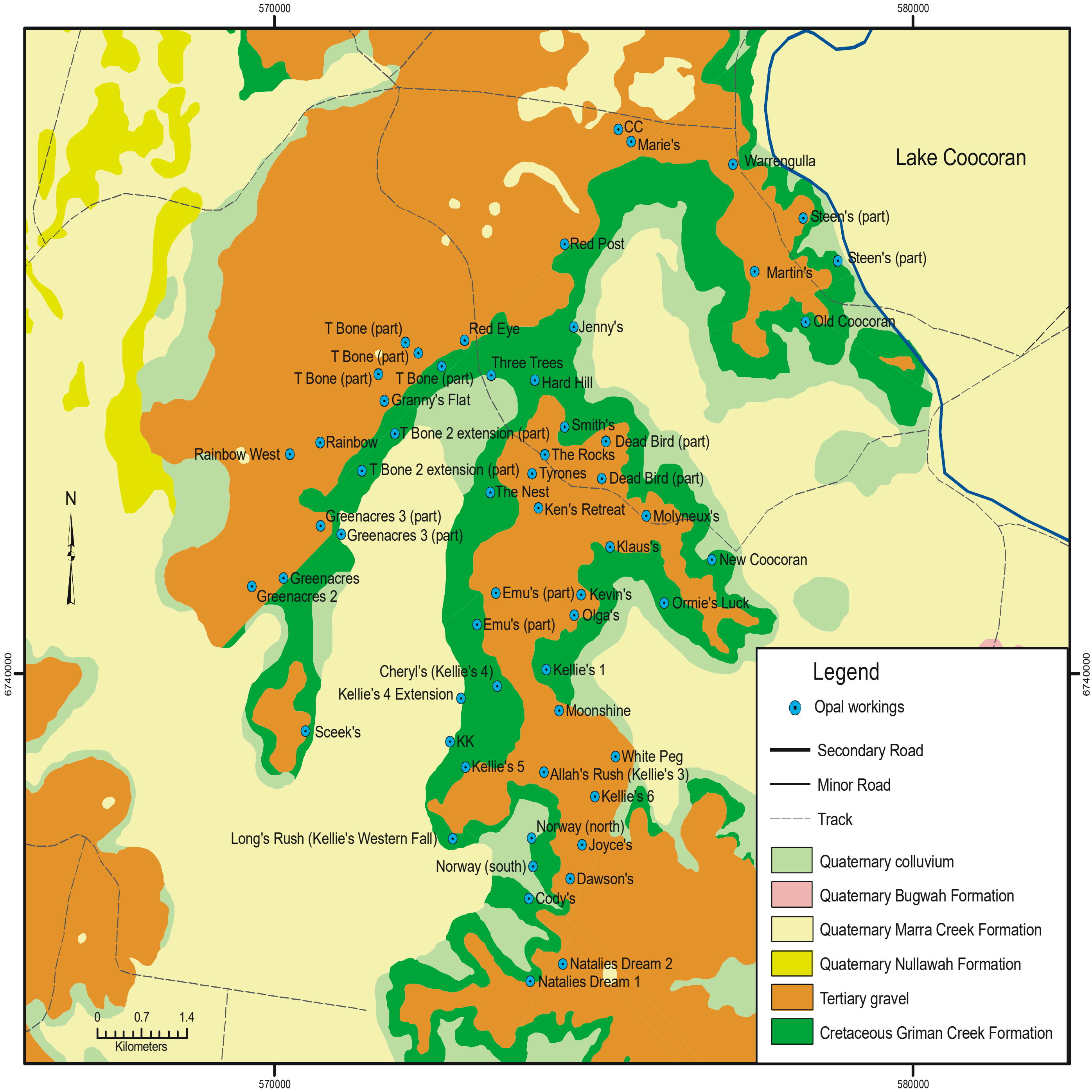
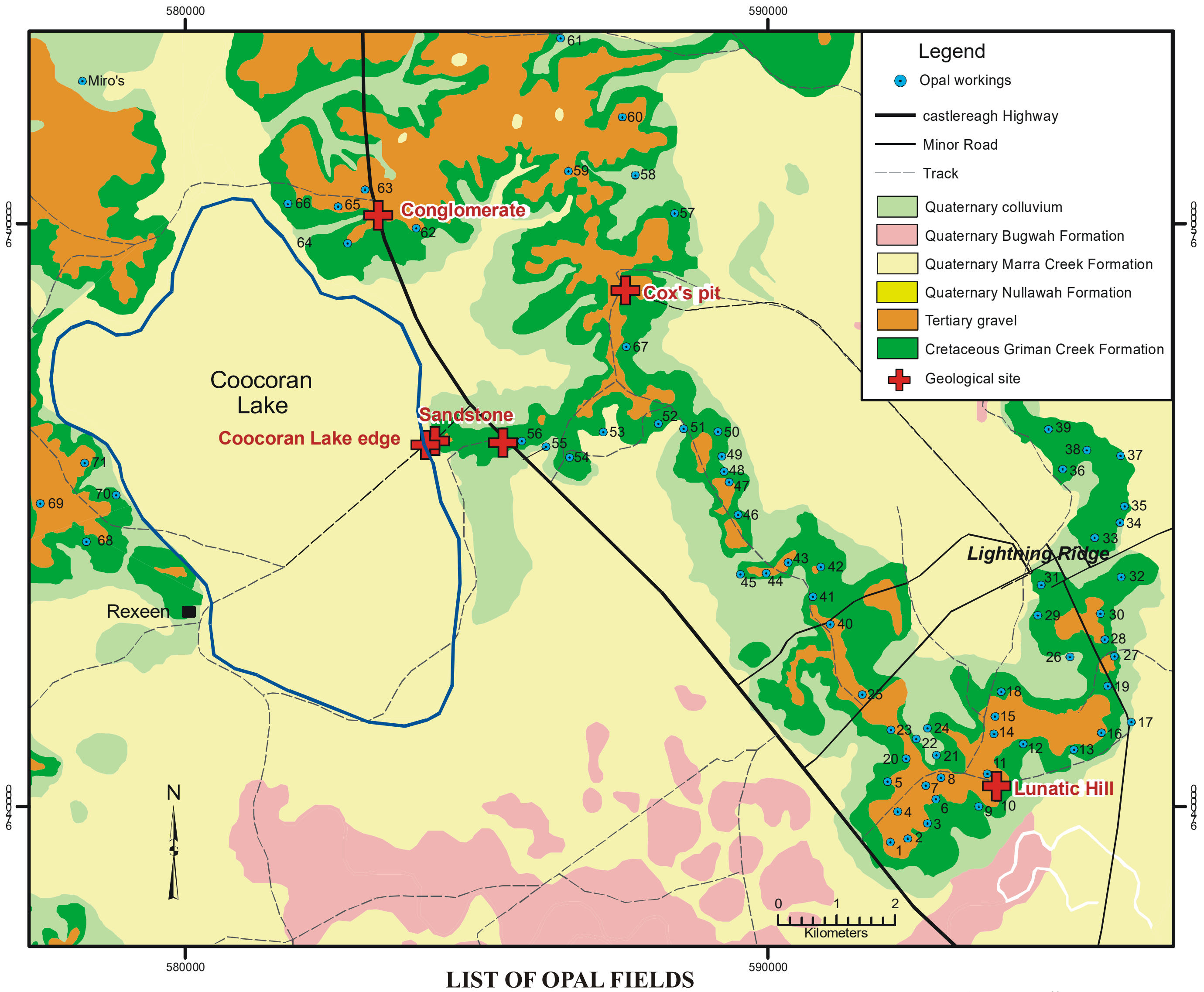


Figure 4. The distribution of opal workings in the Coocoran field.



LIST OF OPAL FIELDS

1. Snowy Browns
2. Deep Four Mile
3. Shallow Belar's & Four Mile Flat
4.New Four Mile
5.Hawk's Nest & Frying Pan
6.Holden's
7.Canada's
8.Hart's & Spicer's
9.Three Mile Western Falls
10. Frog Hollow
11. Three Mile
12. Three Mile Flat
13. Bullock's Head
14. The Gully
15. Vertical Bill's
16. Palestine
17. Bullockies
18. Airport Rush
19. Old Nobby
20. Grassy Hollow
21. McNamara's
22. Hidden Valley
23. Deep Belar's
24. Phil Herbert's Rush
25. Pig Hill
26. Water Tower & Reward Rush
27. Dry Rush
28. Walshe's
29. Darby's
30. Telephone Line & Pony Fence
31. Newtown & New Year's Rush
32. Sim's Hill (Hatter's Flat, Old Town, Butterfly, Indian Lookout, Kingfisher)
33. Canfell's
34. Angledool
35. Pumpkin Flat
36. Old Chum & New Chum
37. Bald Hill
38. Potch Point, Bill the Boer & Hornet's Rush
39. unnamed
40. Rosso's
41. Nebia Hill
42. Beckett's
43. Thorley's Six Mile (part)
44. Thorley's Six Mile (part)
45. McDonald's Six Mile
46. Con's Rush
47. Shearer's Rush
48. Red Robin
49. Jim Taylor's Rush
50. Foley's Six Mile
51. Seven Mile
52. Matson's Rush
53. Berlin Rush
54. Nine Mile
55. Bishop's Rush
56. Dentist Hill
57. Wyoming
58. Bee eaters
59. JC
60. Ironbark
61. Great Eastern Extension
62. Power Pole
63. Tom's Gully
64. Dave's
65, 66. Steve's (part)
67. Ten Mile
68. Old Coocoran
69. Martin's
70, 71. Steen's (part)

Figure 5. The distribution of opal workings in the Lightning Ridge field, showing geological sites described below.

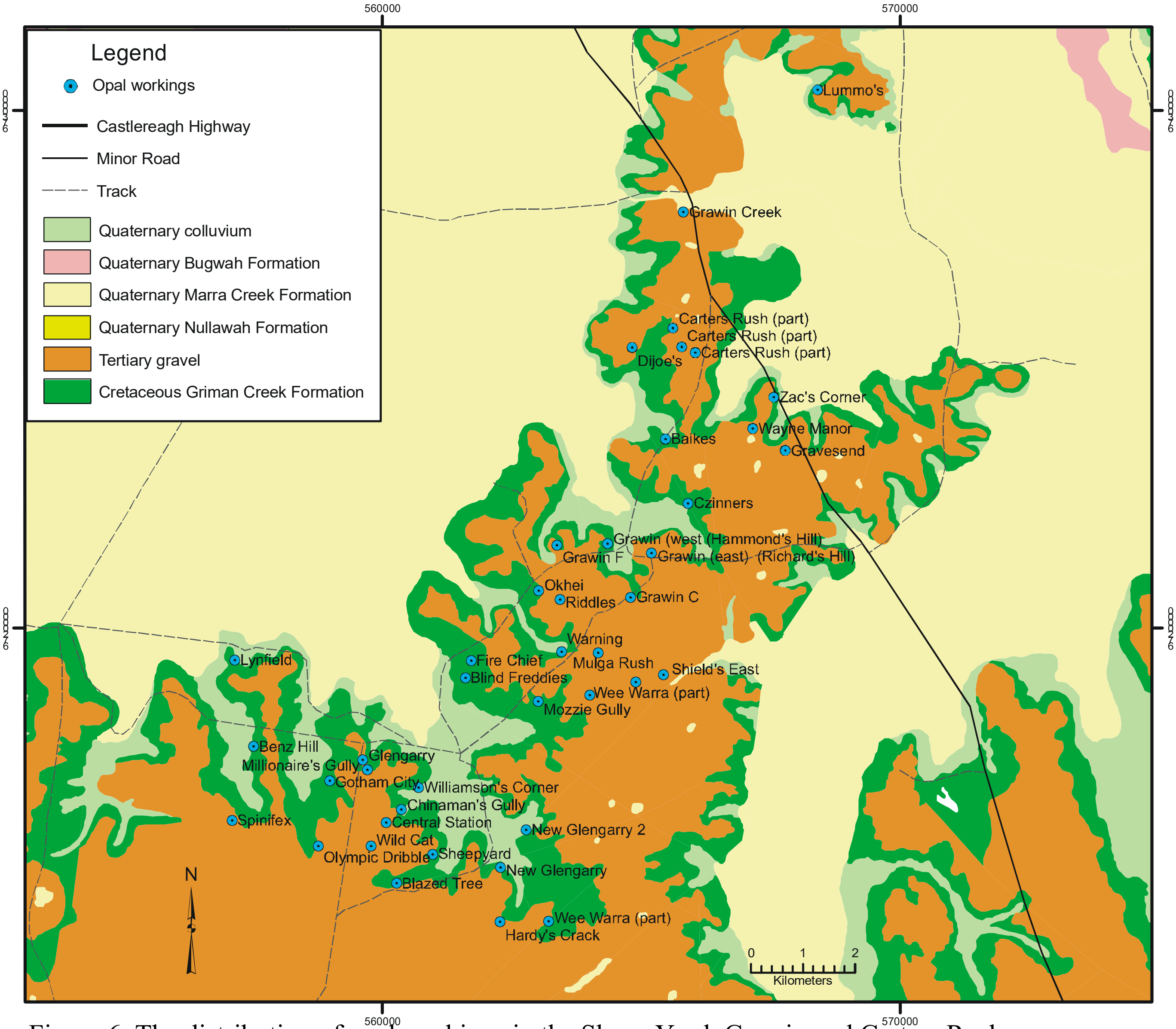


Figure 6. The distribution of opal workings in the Sheep Yard, Grawin and Carters Rush area.

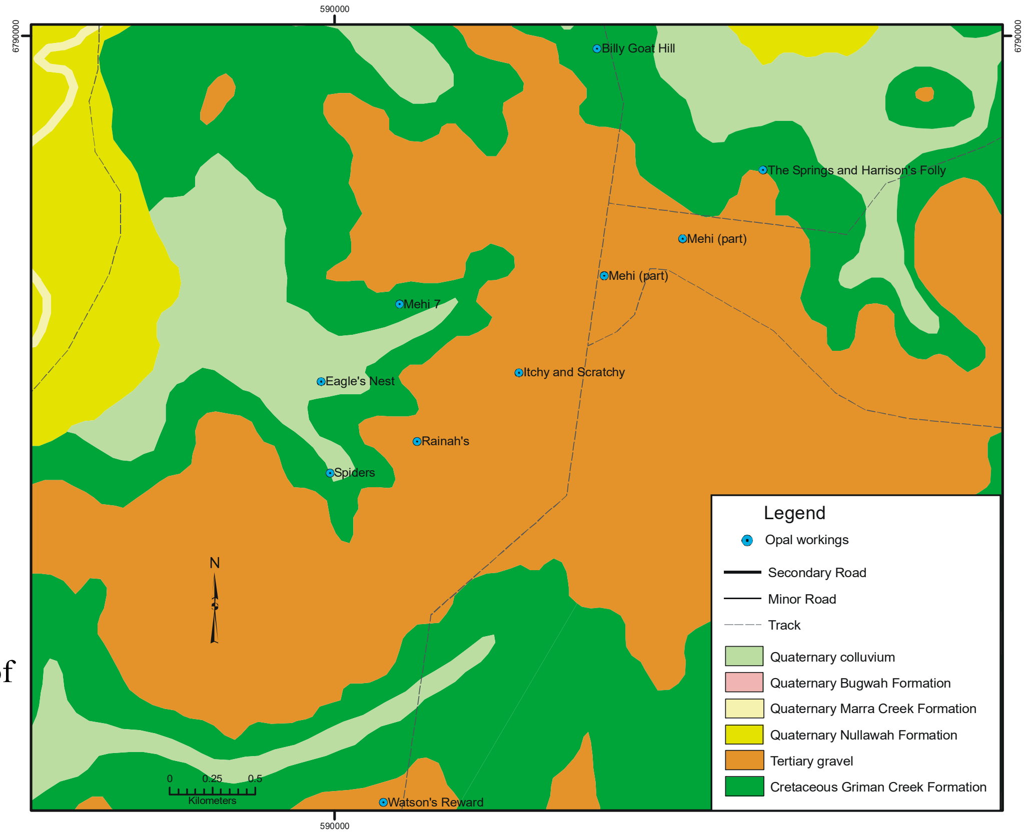


Figure 7. The distribution of opal workings in the Mehi area.

GEOLOGICAL SITES

A number of sites have been selected (see Figure 5) to exhibit some of the significant aspects of Lightning Ridge geology:

1. Lunatic Hill (Three Mile) open cut
2. Cox's pit
3. Griman Creek Formation sandstone
4. Coocoran Lake landforms
5. Tertiary silcrete and conglomerate

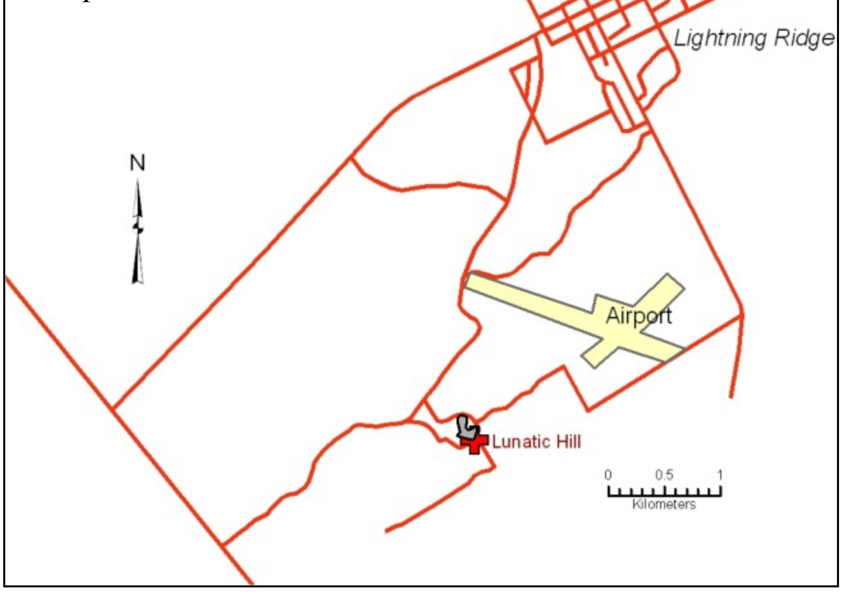
LUNATIC HILL (THREE MILE) OPEN CUT

(MGA Grid Reference 593917 6740354). Take Three Mile Road (see Figure 8) and proceed for 3.6 km until reaching The Black Hand. Turn left and follow the track about 250 m until the chain link fence around the open cut is observed. Follow the rough track around the northern perimeter of the open cut until the sign posted lookout sign is reached.

This lookout provides great views of the open cut with a viewing platform and security fence. Here you can view a section from surface to the opal-bearing level. Old underground workings are visible in the base of the vertical face, and representative rocks from the open cut are scattered near the viewing platform.

The ground surface here is covered with pebbles of quartz, many of which have a brown iron oxide coating. The iron oxide is intermixed with fine clay which has been pulverised against the pebbles by millions of years of blowing winds. Some iron oxide has coated the pebbles whilst they

Figure 8. Location of the Lunatic Hill open cut.



Three Mile open cut, showing old underground workings exposed in the relatively soft siltstone and claystone (locally known as *Finch clay*. Above this is a thick sandstone layer (locally known as *Wallangulla sandstone*). The dark brown surface layer comprises iron oxide coated gravel and soil. Photo by Warwick Schofield.

were buried in the weathering profile, where iron oxide rich groundwater precipitated iron oxide into the weathered rocks.

Beneath the surface soil and gravel are white sandstone, siltstone and claystone beds. Samples of these rocks are available on the ground to the west of the open cut viewing area. The sandstone (which is locally known as *Wallangulla sandstone*) is white and relatively coarse grained (see photo at right). Lenses and beds of grey claystone (locally known as *Coocoran claystone*) occur within the sandstone. Some of the claystone has been silicified, forming *porcellanite* (locally referred to as *shincracker - see photo below*). The silicification possibly occurred during the weathering event which produced the silica-bearing groundwater responsible for the development of silcrete (probably eroded away from this site) and opal.

White sandstone with grey claystone layer (above), and tough, silicified claystone or *shincracker*, (left) similar to material from the Three Mile open cut. Photos by Warwick Schofield.

COX'S PIT

MGA grid reference 587545 6748870. Turn into Onyx Street (on the western end of town) and follow the mainly unsealed road for 9.2 km. The road passes across floodplain mud of the Quaternary Marra Creek Formation (see Figure 5) before crossing poorly exposed Griman Creek Formation and Tertiary silicified conglomerate and gravels. This road is dry weather only. The pit is on private land, so do not stray from the pit, and when finished here, return via the same route.

This road material pit is developed in Tertiary conglomerate. The site covers a large area, and offers the potential to fossick for agate, chalcedony, attractive quartz pebbles, and possibly topaz. Note the iron oxide veneer on many pebbles, and the boulders of silicified quartz pebble conglomerate.

GRIMAN CREEK FORMATION

MGA grid reference 585434 6746262. Proceed west from Lightning Ridge to the Castlereagh Highway. Turn right and continue for 7.7 km, passing through flat-lying floodplain and watercourse sands, silts and muds of the Marra Creek Formation (Figure 5), before ascending a gentle slope into Griman Creek Formation sandstones. Park off the side of the road near the road cutting in white sandstone.

This long cutting has exposed a section through layered, white sandstone of the Griman Creek Formation. The sandstone has been altered to a white, clay-rich rock by deep weathering during the Tertiary period, when prevailing tropical conditions produced strong, shallow groundwater flows. The groundwater altered the volcanic feldspar component of the sandstone to kaolin and removed soluble elements such as iron and some silica. Theses were deposited in rocks overlying the Cretaceous sandstones, forming silcretes and iron oxide-rich layers. The silcrete has been eroded away from the surface in this immediate area.

The sandstone at this site shows few sedimentary structures. Original bedding planes (layering) are evident, and some low amplitude ripple marks are visible on some bedding planes. Careful examination may reveal some siltstone and claystone layers where the possibility of finding fossil remains is highest.

COOCORAN LAKE

MGA grid reference 584256 6746305. Continue through the road cutting for a further 830 m and turn left into Rexeen Road. Cross the grid and follow the unsealed road for about 880 m, stopping near the next grid. The road passes across low outcrops of Griman Creek Formation before descending towards Coocoran Lake.

The grid approximately marks the boundary between intermixed colluvial fan debris originating from the hill to the east, and wind blown sand from the lake bed. Gully faces adjacent to the road show the intermixed sand and rock debris from the eroding hill. The abrupt change in hill slope where the grid is positioned marks the toe of the colluvial outwash fan, and marks the start of wind blown dune sand deposits. The colluvial fan has formed during periods of heavy rainfall when material has rapidly washed from the hill and been dumped near the base of the hill. Over time the colluvial fan will move slowly away from the hill towards the lake.

Continue along the road until the end of the vegetated area, where the flat lake bed commences. The sandy wind-derived deposits west of the grid are heavily vegetated with communities of eucalypts (including Coolabahs) and other native species. These sandy deposits encircle the dry lake bed and have been slowly built up by ongoing windy conditions. The bed of the lake is a rich cultivated area, with high quality soil rich in organic matter and no anomalous salinity. The lake is fed from the north by Weetalibah Creek. Coocoran Lake would only flood after anomalous high rainfall.

Return to the highway and turn left. Continue for about 3.6 km. The road passes mainly through thickly vegetated watercourse deposits of sand and silt of Marra Creek Formation derived from low ridges to the east (Figure 5). Park carefully on the northern end of the road cutting.

TERTIARY CONGLOMERATE AND SILCRETE

MGA grid reference 583284 6750128. This road cutting shows hard, silicified quartz pebble conglomerate on the western side of the road, and hard, white silcrete on the opposite side of the road. The rocks are associated with a veneer of iron oxide coated pebbles which are common throughout the region.

The rocks present here represent silicified Tertiary conglomerate and sandstone (probably Eyre Formation), both of which are regarded as variations of silcrete. They overlie Cretaceous Griman Creek Formation rocks, the weathering of which produced the silica which has converted these Tertiary rocks to silcrete.

This completes the geological guide to the Lightning Ridge area. A more comprehensive description of the geology of the area was produced by Gary Burton for the NSW Department of Primary Industries. His unpublished report, GS2003/183 can be viewed online using the following URL and using the Report Number field as the search criterion:

http://digsopen.minerals.nsw.gov.au/