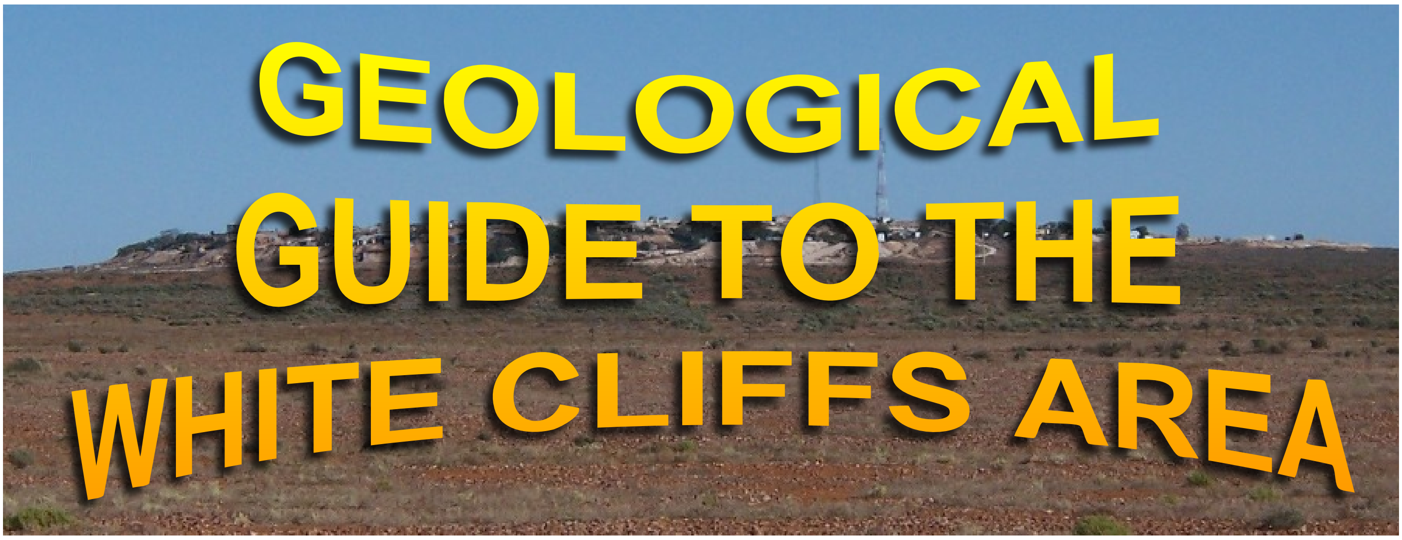
GEOLOGICAL GUIDE TO THE WHITE CLIFFS AREA



The initial discovery of opal in 1884 by a shepherd on Momba Station, in what was to later become known as *White Cliffs,* attracted no local attention due largely to the strong interest in silver mining throughout the Barrier Ranges near Broken Hill. Those original pieces of "coloured glass" were the surface indications of the frustratingly elusive, yet incredibly rich deposits of opal amongst the white Cretaceous sandstones of this remote area. It was not until 1889 when four kangaroo shooters observed the brightly coloured stones and one of their number, Charlie Turner, dispatched a sample to Adelaide for examination. The shooters became the first opal miners on the site, taking out two twenty acre (8 hectares) claims under the title *Wilcannia Blocks Syndicate*.

The syndicate subdivided the "blocks" into areas 45 x 45 feet (13.7 x 13.7 metres) which were taken up by tributors. The syndicate provided the men with tools and equipment and received half the proceeds of the opal sold. In later years the tribute was reduced to one quarter of the proceeds, but from the onset there was abuse of the system with underhanded dealings between miner and buyer commonplace.

By about 1894, not long after the ramshackle village of White Cliffs was developed, many families began converting the deserted adits (a horizontal mine tunnel) and stopes (an underground area from which ore has been removed, often cavernous) about the hillsides into homes. The environment in these quarters was vastly preferable to the climatic extremes suffered by those living in the corrugated iron dwellings in the village. The trappings of civilisation soon followed the increasing population, with a post office in 1893, a school in 1895, a hospital and doctor and water supply dams. About 1000 people were present on the field by 1897, and the population peaked in 1902.

Intensive mining continued until World War I when the market slumped and many men went to war, resulting in the virtual abandonment of the field. Since then mining has been relatively sparse. Total production of opal is unknown, but conservative estimates report well in excess of $150 million worth of opal, with much of this produced prior to 1911.

The opal deposits of the White Cliffs area occur within sedimentary rocks of the Cretaceous period. These were deposited in a shallow marine sea within the Great Artesian Basin between 125 and 115 million years ago. This inland sea had formed as a result of high sea levels and regional-scale downwarping of the continent. The Australian continent had formed from the breakup of the Gondwana supercontinent about 125 million years ago, and separated from India about 7 million years later. Australia was within polar latitudes during the Cretaceous period and had begun to separate from Antarctica about 80 million years ago. The continent was undergoing glaciation, and ice sheets and drifting ice masses were common on the sea. Boulders, pebbles and sands derived from rocks far to the east (possibly about Cobar) were transported into the present area by floating ice, dropping to the bottom as the ice melted. These ice rafted rock types (known as *glacial erratics*) will be examined at Stop 1 of this field guide.

The Great Artesian Basin

Cretaceous - 130 million years   Cretaceous - 120 million years   Tertiary - 40 million years

SIMPLIFIED GEOLOGICAL HISTORY OF THE WHITE CLIFFS 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	
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	No rocks at surface from this period in local area
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	

During the following 30 million years the sea level dropped and the marine sands and muds were overlain by sands deposited on land. The Australian continent moved slowly northward and temperatures increased. At the end of the Cretaceous period, about 65 million years ago, a mass extinction event occurred (the *Cretaceous-Tertiary* or *K-T event*) which resulted in about 70% of all species on Earth disappearing within a very short period. This has been variously attributed to a cataclysmic asteroid impact or increased volcanic activity.

The incoming Tertiary period was hot and wet, with local conditions probably similar to the Amazon Basin. The Cretaceous sands and muds had been converted to sandstone and shale, and these were eroded and deeply weathered by the wet environment. This resulted in bleaching of the Cretaceous rocks (due to removal of soluble elements, particularly iron). The erosion products included gravel, sand and clay which were deposited over the Cretaceous rocks. The movement of groundwater through the Cretaceous rocks and Tertiary sands dissolved silica (quartz) from the minerals, redepositing it in the porous Tertiary sands to form "*geyser*" (a local term for silicified gravel) and *silcrete* (locally known as "greybilly") about 34 million years ago. At about 24 million years ago, much of inland Australia underwent long wavelength warping, forming low, broad dome- and basin-like structures. One research model suggests that opal formed in the tops of dome structures. Since then the tough, durable silcrete has slowly eroded away to form extensive gibber plains. Remnants of the silcrete form resistant caps on some mesa-like hills, preserving the softer, bleached Cretaceous sandstones beneath.

Since the Tertiary period inland Australia has developed typical desert-like landforms and geology. Flat-topped, steep sided mesas contrast with the flat and rolling gibber plains and areas of wind blown sand. Braided watercourses with complex, shifting gravelly channels cut across the region, in some cases winding their way towards the Darling River, whereas others dissipate in the flat, dry plains or in internally-draining lakes.

OPAL OCCURRENCE


Opalised shelly fossils

Opal at White Cliffs is formed within Cretaceous sandstone and sandy to silty claystone. White Cliffs opal is predominantly common opal (potch) which occurs in horizontal seams 1 to 75 mm thick. Some seams are also vertical. In some cases horizontal seams of potch thicken and become precious opal. Opal also occurs as flecks filling voids in claystone, as an in-filling of fossil casts (shells, bones, plant remains), and as replacements of gypsum crystals and glauberite crystal clusters (the latter are locally known as *pineapples*). Some opal also occupies cracks and fossil voids in glacial erratics, and forms coatings on erratic boulders (the latter referred to locally as *painted lady)*.


Opal "pineapple"

Perhaps the most famous and unusual opalised fossil is that of a Plesiosaur which was discovered in 1976. This fossil is nearly 2.6 m long.

Many miners at White Cliffs consider that fault planes are important indicators of the presence of opal. In places lines of workings demonstrate that shafts have been preferentially sunk on faults. Opal has certainly been found both within and adjacent to fault planes, and some opal seams have been crushed and broken up by movement on faults, and other seams have been moved and rotated by fault movement. This indicates that opal has formed after faults were developed and confirms that some faults have been active after opal formation.

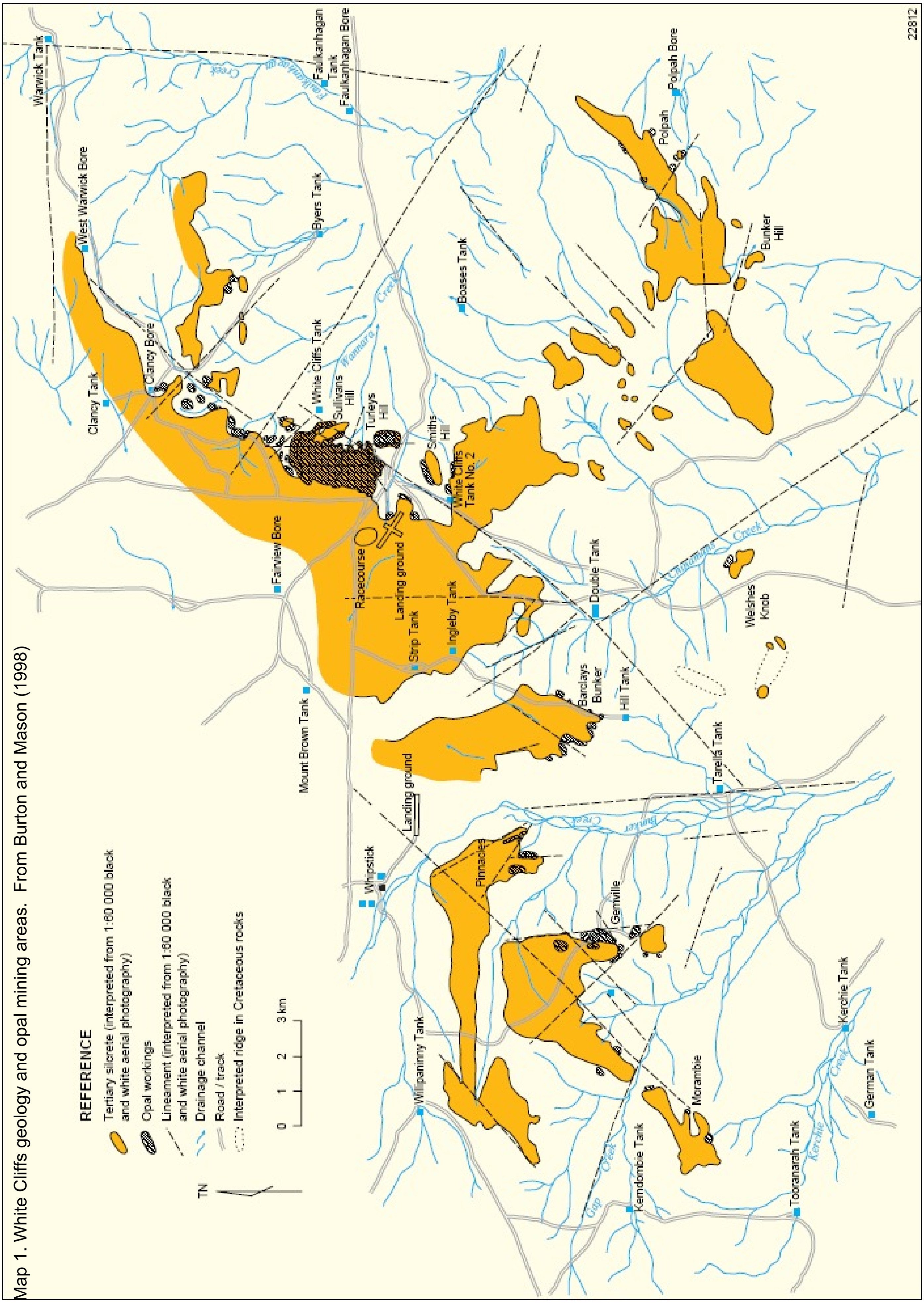
OPAL FORMATION

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, acid 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 weathering event which produced the opal-forming silica occurred during the Tertiary period. There is no consensus on the age of opal formation, with various researchers suggesting that this event took place during major weathering between 65 and 55 million years ago or in association with warping and silcrete formation about 24 million years ago.

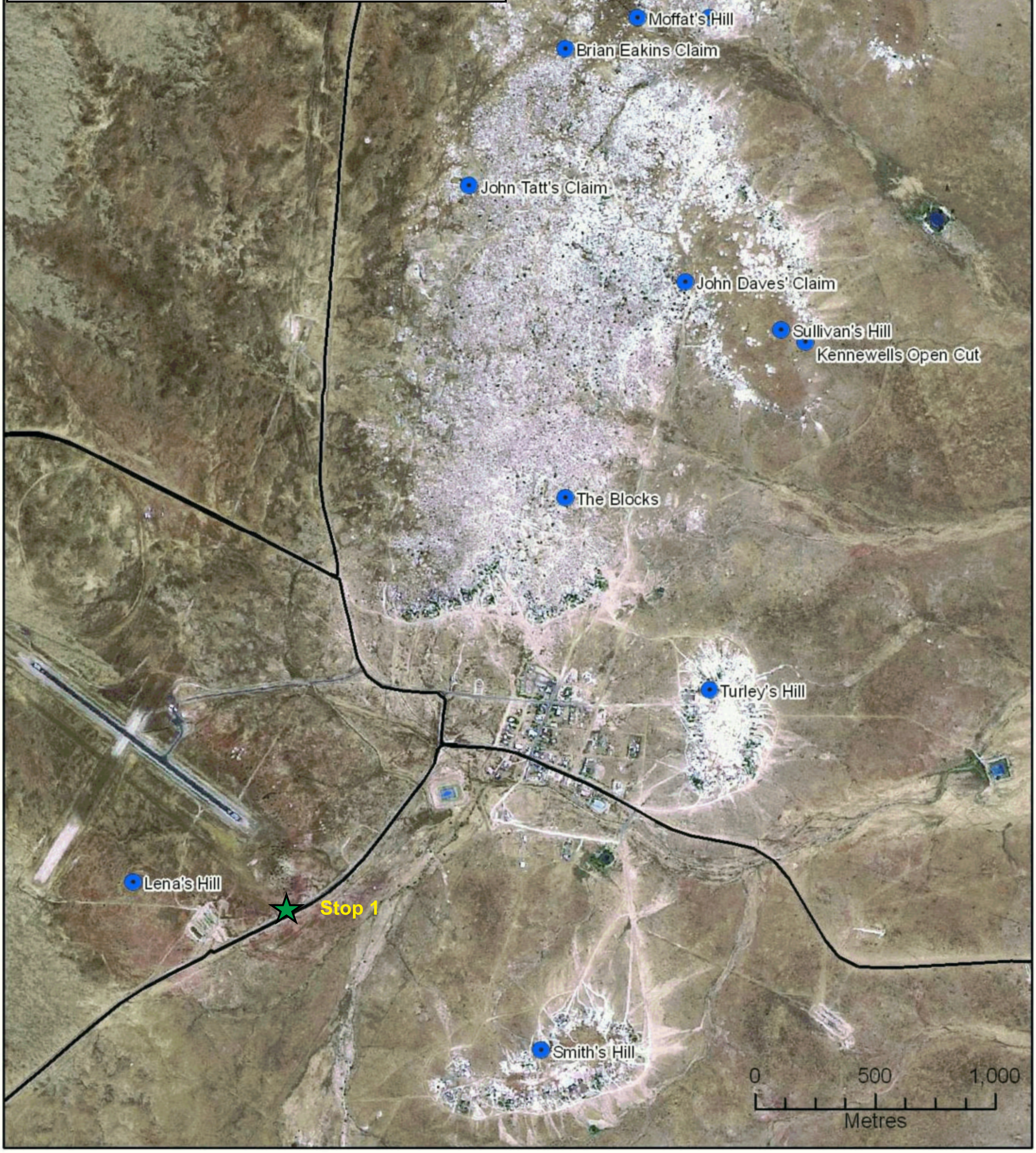
WHITE CLIFFS GEOLOGY

Surface exposures of rocks at White Cliffs are limited to hills of sparsely outcropping Cretaceous sedimentary rocks, with a local capping of hard, bouldery Tertiary silcrete (See Map 1). Opal diggings coincide with



Map 1. White Cliffs geology and opal mining areas. From Burton and Mason (1998)

Satellite image of White Cliffs, showing major workings as white mottled areas.



these hilly outcrops, as the prospective Cretaceous rocks are only preserved on the hills, having otherwise been eroded away. The low areas of the field are covered by gibber plains and sand plains, with local areas of alluvium along major watercourses.

Viewed from several kilometres away the major geological features are clearly evident. Flat topped, mesa-like hills (see Photo1) are capped with erosion-resistant silcrete, their slightly northern downward dip indicating local tilting of the land surface since the Tertiary period. The contact between the Cretaceous and Tertiary rocks can be found just below the tops of these flat ridges. This contact is an *unconformity*, the land surface during the tropical Tertiary period prior to it being covered with the sand and gravel which is now silcrete. The rocks below this surface are white, with local brown iron oxide accumulations close to the

Photo 1. Smiths Hill viewed from the west, showing a tilted, silcrete-capped mesa to the south.

Photo 2. Flat topped Turleys Hill has remnants of a silcrete cap, with dugouts excavated into the underlying Cretaceous rocks

unconformity. Further down the slope the iron oxides become less abundant despite the white rocks remaining constant. This indicates that iron was leached from the Cretaceous rocks by groundwater movement and was then carried upward and deposited near the Cretaceous-Tertiary unconformity, which would have been covered by a blanket of sand and gravel during that time. The movement of silica through these leached rocks would soon lead to the formation of opal in the Cretaceous rocks, and silcrete in the Tertiary sands.

The Cretaceous host rocks to the opal deposits can be viewed at Stop 1. To travel there, proceed to the intersection of the Opal Miners Way with Keraro Road and turn left (south). Continue for 970 metres, stopping near the low hill on the right (west) of the road. If you pass a small quarry or cross a grid you have come too far! Examine the rocks exposed in the gutter before climbing the hill. **Beware of open boreholes near the top of the hill!**

The rocks exposed in the gutter (Photo 3) are leached, white Cretaceous sandstones with a little iron oxide present. Pebbles of quartzite (metamorphosed sandstone) are present, representing glacial erratics. Fossils found in some of these erratics from elsewhere indicate a Devonian age (more than 360 million years old).

Photo 3. White Cretaceous sandstone with Devonian glacial erratics and local iron oxide accumulations.

Photo 4. Outcrop of Cretaceous sandstone with abundant iron oxides.

Photo 5. Iron oxide pebbles cover the hilltop. Beware of these open boreholes.

Ascending the hill it is apparent that iron oxide becomes more abundant (Photo 4). A number of boulders of quartzite erratics are present along the sides of the hill.

At the top of the hill the ground surface is littered with iron oxide pebbles (Photo 5). The flat surface of the hill suggests that it is not far below the original unconformity surface. No silcrete is present here, having been eroded millions of years ago.

An examination of some of the other accessible hills in the region will show similar rocks with the same style of leaching beneath a Tertiary silcrete cap. The rocks found on most opal mine dumps are the same leached Cretaceous sandstones, in some cases with blocks of silicified claystone.

REFERENCE

Burton G.R. & Mason A.J. 1998. Controls on opal localisation in the White Cliffs area. New South Wales Geological Survey Quarterly Notes 107.

This reference can be obtained online using the following URL and using an author name and White Cliffs as search criteria:
http://digsopen.minerals.nsw.gov.au/