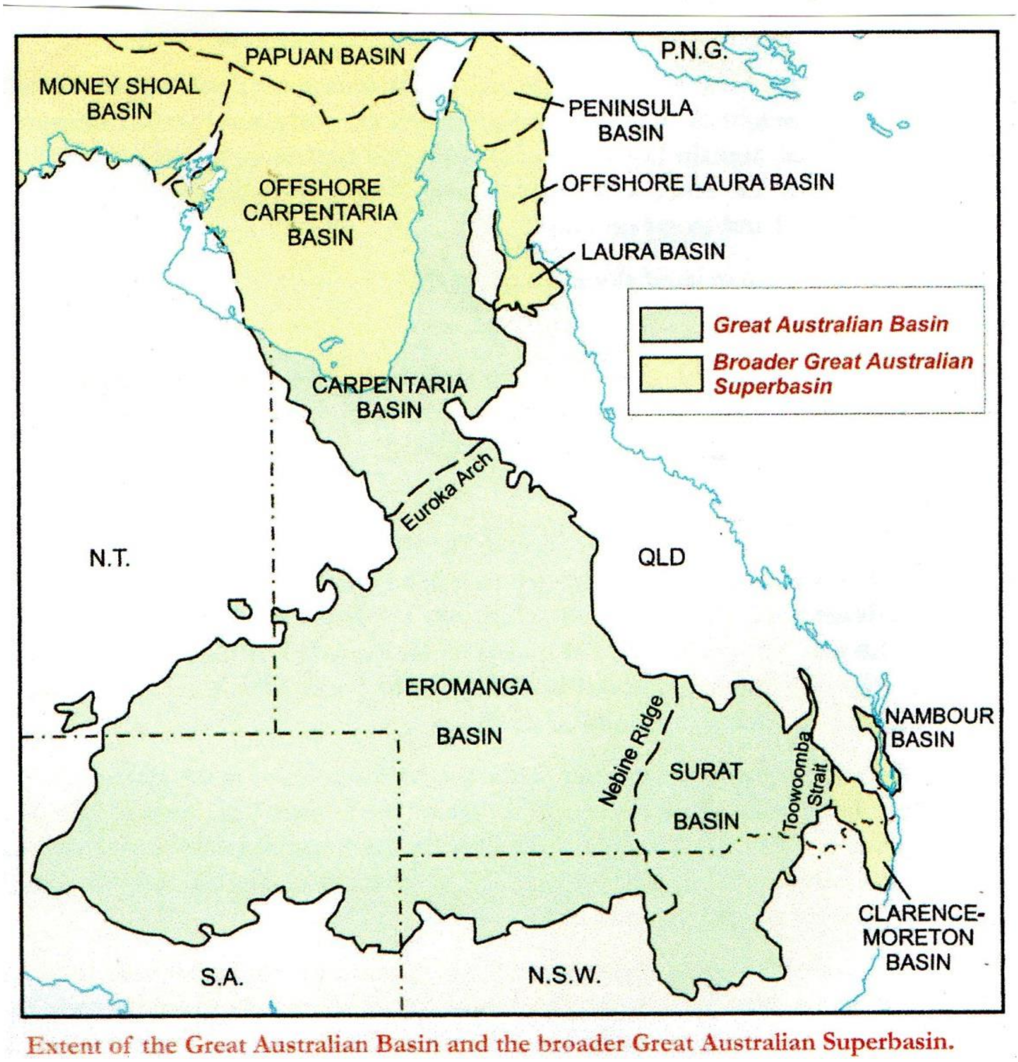
Natural Sciences Loop Safari 2023- Field Notes.

Introduction: The AGSHV Safari for 2023 gives members a chance to examine the features of the Eromanga Basin which is part of the Great Australian Basin. The predominantly Jurassic and Cretaceous sediments of the basin give rise to a number of features such as artesian bores, mound springs, boulder opal fields, fossilized dinosaur and megafauna bones, Mitchell grass plains, jump-ups, dune systems and gorges.

The expedition follows the Natural Science Loop in the SW Region of Queensland a 995 km circuit connecting the Paroo, Bulloo, Quilpie and Murwah Shires.

Features of the Great Australian Basin: Between 145 and 100 Ma vast inland seas covered most of the eastern parts of the continent in what was now Queensland, N.S.W and South Australia. Sediments deposited in these seas and on earlier river plains gradually accumulated and were hardened to rock. These rocks covered a broad area which is now known generally as the Great Artesian Basin.



Extent of the Great Australian Basin and the broader Great Australian Superbasin.

Figure 1 Willmott, Cook, Neville (2017) p 4

This basin occupies one fifth of the Australian land mass and is one of the world's largest sedimentary basins and artesian systems. 1.7 million km^2 is in Queensland, from Cape York to the Simpson Desert.

Its most characteristic landscapes are flat topped "mesa" country, semi-arid rolling downs and channel and lake country to the south west.

The supply of artesian water from the Basin has allowed the development of a vast pastoral industry-at first sheep and now cattle. Resources of oil, gas, and coal have been exploited as well as the more controversial coal seam gas in recent times.

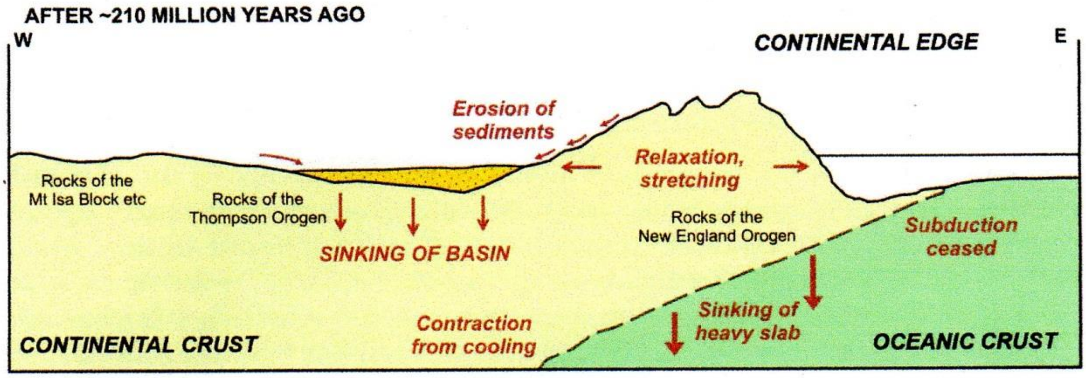
Deposits of opal, Australia's national gem stone have been extracted in several remote areas. World renowned fossils of dinosaurs and giant swimming reptiles are another feature of the area and continue to be discovered.

Figure 2Source: htpps://www.friendsofmoundsprings.org.au/wp-content/uploads/2015/11/Map-of-the-Great-Artesian-Basin-Australia.pdf.

Formation of Basin: Before the most recent part of the Triassic Period, 210 Ma, the eastern edge of the Australian continent was periodically compressed, squeezed and heated by subduction of oceanic crust under the continental edge. After 210 Ma the subduction ceased or moved eastward.

The continental edge then relaxed, the oceanic crust sank and the continental crust cooled and contracted. The continent behind the edge sagged over a long period of time, from 200 Ma until 90 Ma.

This subsiding area became a basin for the accumulation of sediments.



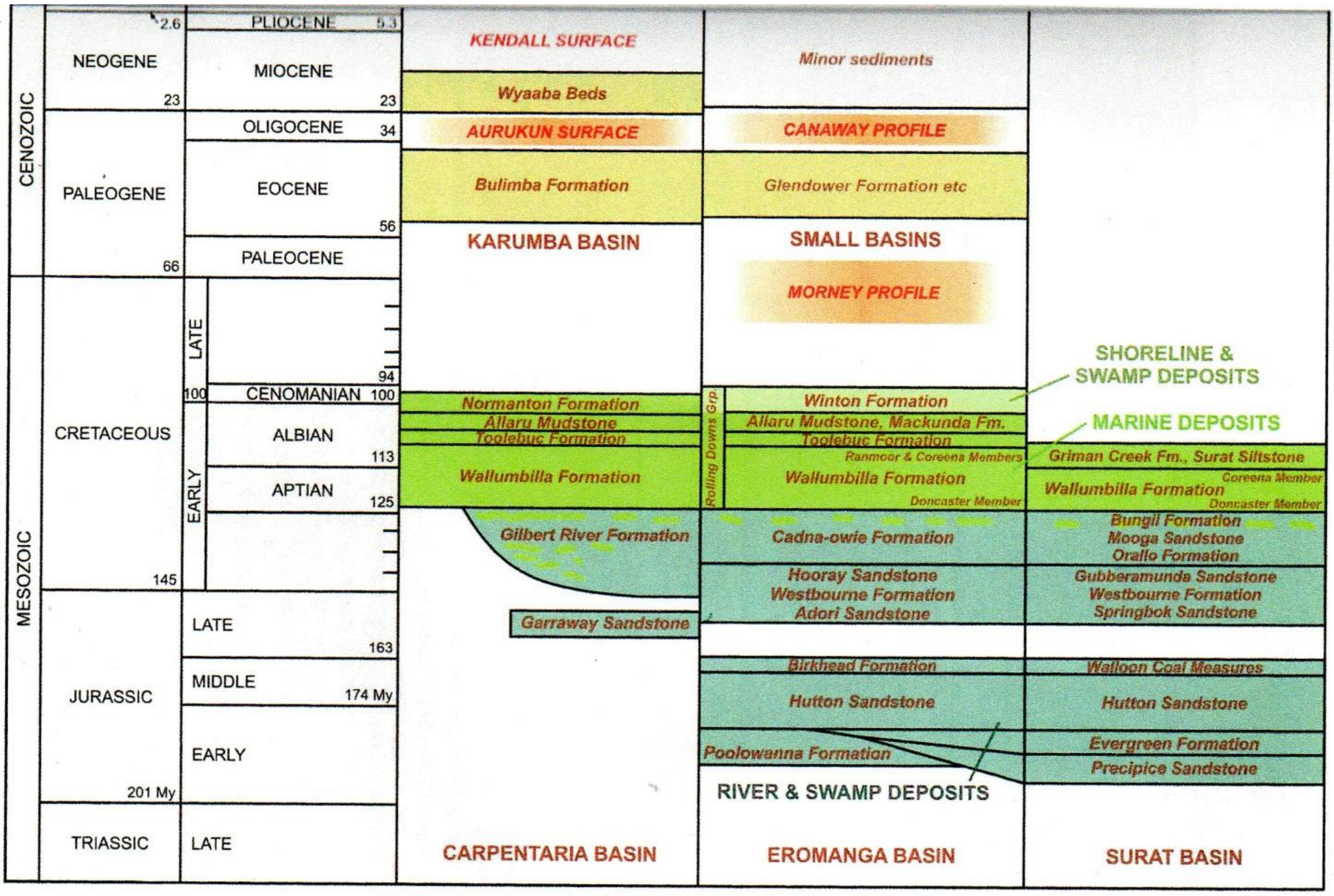
Possible mechanism for the sinking of the Great Australian Basin.

Figure 3 Willmott, Cook, Neville (2017) p6

Formation of the Sedimentary Rocks. The earliest sediments in the basin came from rivers in the south and southwest in the early Jurassic period (205-175 Ma.) These formed extensive plains with a few low hills in the basin area. Quartz rich sand up to 150 m thick was deposited. Soon the plains filled up and the rivers became more widespread and sluggish. In the Eromanga Basin siltstone, sandstone, shale and minor coal, the Poolowanna Formation were laid down. These are only known from oil and gas exploration wells and do not outcrop at the surface. About 175 Ma the soft sandstone of the Hutton Sandstone was deposited. This was a continuous and thick blanket of sand. In the mid Jurassic (174-163 Ma) finer grained sediments of floodplain and swamp environments was laid down. In the Eromanga Basin this is the Birkhead Formation which has no significant coal deposits. After a break during which there was some erosion of the accumulated sediments towards the end of the Jurassic, widespread sandstones were again deposited in rivers and lakes in the Eromanga Basin. The Adori Sandstone, Westbourne Formation and Hooray Sandstone were formed in the Eromanga Basin. This non-marine sedimentary pattern was to continue across the Jurassic- Cretaceous boundary. By the late Jurassic the Great Australian Basin was joined as a united system. The extensive sandstone units throughout the Jurassic rock sequence are the important water-bearing aquifers of the basin.

Global changes in climate and sea level and the continuing sinking of the Basin soon resulted in the first major invasion of the sea about 135 Ma. Australia at the time was located in the higher latitudes and it was a relatively warm period in the Earth's history. In the Eromanga Basin marine conditions began with the uppermost Cadna-owie Formation. There were five inundations by the sea through the Gulf of Carpentaria into the continent till about the mid- Cretaceous (90 Ma).

The third inundation of the Eromanga Sea (about 116-113 Ma) formation was the most extensive with mudstones deposited in the shallow seas to form the Doncaster member of the Wallumbilla Formation. These mudstones are very fossiliferous in places. During the fourth inundation (about 108-105 Ma) deposits of siltstone and sandstone formed the Ranmoor Member of the Wallumbilla Formation.



Main rock units of the Great Australian Basin and their ages.

Figure 4 Willmott W., Cook A. & Barry N (2017) page 15

The fifth and final inundation occurred after millions of years of erosion. The sediments from this time, outcrop widely. They are from earliest to latest the Toolebuc Formation (contains organic-rich black shales and limestone concretions) formed in an oxygen-poor sea floor; Allaru Mudstone (materials derived from volcanic activity) mudstone, fossil-rich sandstone and limestone deposited in a shallow sea environment and Mackunda Formation dominated by sandstones derived from increased volcanic activity, mudstone and calcareous siltstone. The rocks of this formation contain the last marine fossils known from the Basin. They underlie the Winton Formation.

The Winton Formation. From 100 to 93 Ma the inland sea retreated never to return. The sediments of the Winton Formation were laid down in the late Albian to early Cenomanian of the Cretaceous. Widespread freshwater lake, swamp and floodplain sediments were built up across the old sea bed. The Winton Fm rests unconformably on the older Mackunda Fm of the Eromanga Basin. The Winton Fm has maximum thickness of 1100m and forms the uppermost part of the Rolling Downs Group. The Winton formation is a heterogeneous package of sedimentary rocks that include lithic and feldspathic sandstone, mudstone, siltstone, coal, minor conglomerate and layers of volcanic deprived detrital material. (GA and ASC, 2014) These rocks are the last rock formation of the Eromanga Basin and cover much of the surface. The Winton Formation contains many plant fossils, with rarer insects, fresh

water mussels and bones and tracks of dinosaurs. Weathered sections also contain important boulder opal deposits. The Winton Formation is part of the Rolling Downs Group which underlies the Mitchell-grass plains in the centre of the Eromanga Basin. Faults and folds have altered and interrupted these broad zones adding to the irregularities. Cook A. (2017) pages 9-18.

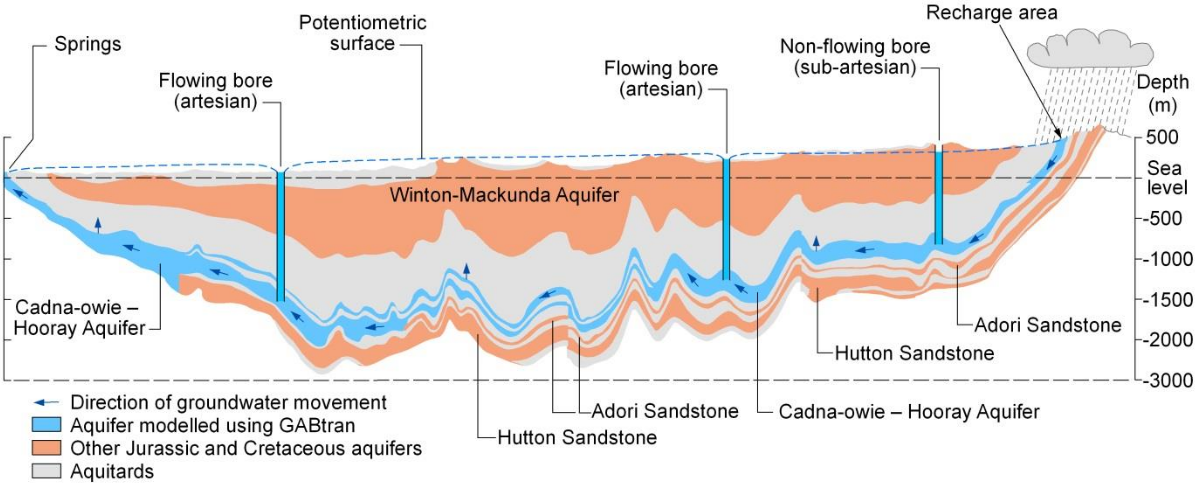
Figure 5 Duricrusted deeply weathered Winton Formation. This has a silcrete cap and talus slopes. Pediments with lag gravels overlie clay soil developed in situ. Source Wilson & Taylor (2012) page 27

The Erosion Processes of the Winton Formation. It is estimated that over 3000 m of sediment has been eroded away during a long era of weathering.

Australia broke away from Antarctica and drifted northwards to lower latitudes. Climatic conditions changed from warm moist conditions to a more arid environment. (Wilmott W. page 27).

Periods of deep weathering have been identified. During these periods hardened crusts enriched in silica and iron oxides have grown just beneath the land surface. These crusts sit above a leached mottled or white clay-rich layer. Later erosion of the surface and lowering of the landscape has resulted in these hard crusts remaining as the tops of plateaus, ridges and mesas known locally as jump-ups.

Underground Water

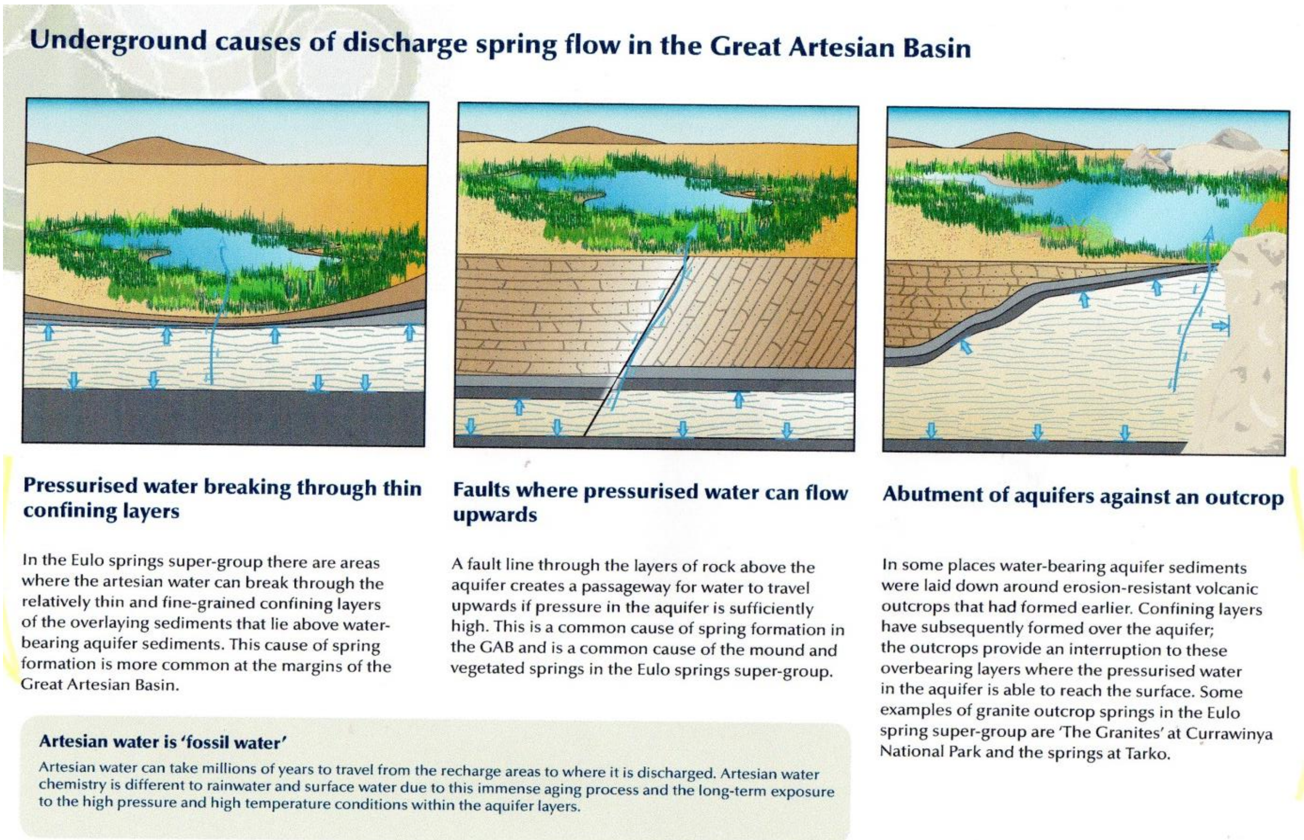


Schematic slice through the Great Artesian Basin illustrating predominant aquifers in the Jurassic and Cretaceous beds in blue, confining layers in grey, and other aquifers in orange. The slice represents schematic layering from major spring zones in South Australia (left side of figure) to major recharge areas in Queensland (right side of figure) and therefore the vertical scale is exaggerated **(Source: Radke et al., Hydrochemistry and implied hydrodynamics of the Cadna-owie – Hooray Aquifer, 2000).**

“The Great Artesian Basin (GAB) contains about 65 million gigalitres of water. It is one of the largest natural underground water reservoirs in the world. It consists of layers of aquifers and aquitards ranging from 65 to 250 million years old, deposited in the Triassic, Jurassic and Cretaceous periods. The aquifers can be up to 3000 m deep, with water moving laterally through the Basin between 1-3 m per annum. The waters are up to two million years old.

From the perspective of the whole GAB, water from rain and some rivers enters the groundwater along the elevated margins (Great Dividing Range). From these areas of recharge, groundwater is driven by topographic gradient to lower-lying parts of the landscape where it can discharge back to the surface. In the GAB, groundwater discharge occurs through springs, artesian bores, extraction bores and very slowly by a diffuse seepage process across broad sections of arid land.

The mechanics of groundwater flow in the GAB, or hydrodynamics, are governed by the structure and nature of the sequence of aquifers. Across much of the GAB, the Jurassic and Cretaceous beds that form aquifers are confined by nearly impervious rock layers. These confining beds and relative elevation difference with the more elevated recharge areas results in the artesian groundwater pressure.



Source: Conceptual Model Case Studies: Eulo springs super group page 5

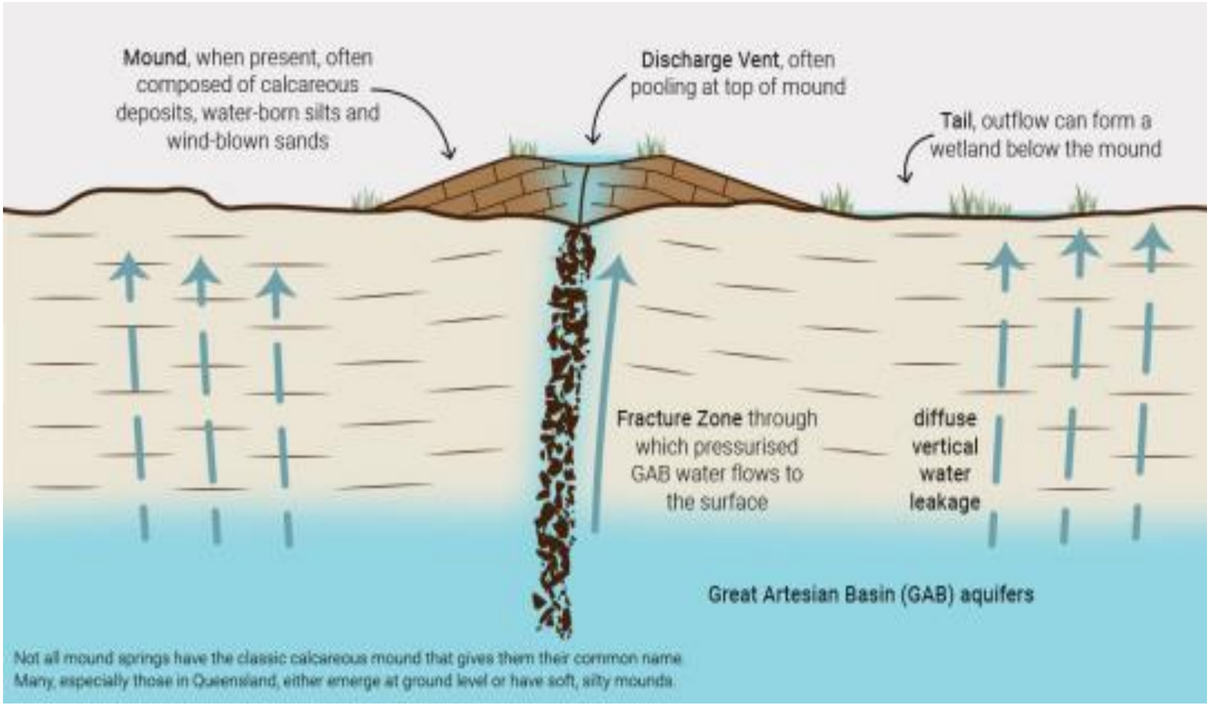
Since the 1880s, groundwater pressure has decreased, largely due to uncontrolled bores and open bore drains. Rehabilitating (capping) artesian bores and upgrading them with closed pipe systems was the focus of the GAB Sustainability Initiative (GABSI), which commenced in 1999. "Source: The Great Artesian Basin and CSG – GISERA (csiro.au)

The most important aquifers of the Eromanga Basin are the combined strata of the Cadna-owie Formation and the Hooray Sandstone, the youngest Jurassic sandstones, as they are the highest of the artesian aquifers. (Willmott W page 42) Deeper aquifers are the Adori, Springbok and Hutton Sandstones which stretch across the width of the basin. Sub- artesian aquifers are present in the Cretaceous marine sediments from the inland seas (Wallumbilla Fm, Alluri Mudstone and Mackunda Fm) and in the later swamp sediments of the Winton Fm. The bores in these units require pumping.

Artesian springs result from pressurised water breaking through thin confining layers, from water being forced up faults in the strata, or from the abutment of aquifers against impervious bedrock. (Willmott W page 44).

The first bores sunk in Queensland date from 1886 and by 1998 there were about 4,700 flowing bores drilled across the basin. In Queensland 74% of the bores are extinct because of the large amount of water that has been extracted.

Mound or Mud Springs



Source: friendsofmoundsprings.org.au

Most mound (sometimes called mud springs) occur on the margins of the GAB in the Far North of South Australia, NW N.S.W. and SW Queensland. The term mound springs reflects the characteristic mounds that have developed at many but not all springs. In some areas the mounds have been building for thousands of years. Spring flows were stronger in the geological past.

The Eulo supergroup consists of 53 active and inactive spring complexes. This super-group of the GAB formed around the town of Eulo in SW Queensland. The Mud Springs we will visit are located nine kilometres west of Eulo.

The mound springs of the Eulo region are composed of mineral-rich clay mud that has slowly been transported to the surface by the pressurised artesian water from the sandstone aquifer. The mound is quite hard on top and sounds hollow if you jump on it.

The likely source aquifers of the Eulo Springs groups are considered to be the Wyandra Sandstone Member of the Cadna-owie Fm and /or the Hooray sandstone, although it is likely that some of these waters mix with shallower aquifers on route to the surface.

Abutment of Aquifers Against An Outcrop. The Eulo springs complex, overlies the Eulo Ridge, an area of granitic bedrock exposures and regionally shallow depth to the granitic basement. The Eulo Ridge is characterised by a marked thinning of the Eromanga Basin sedimentary sequence (Senior et al 1971). The Granite and Eulo Town spring complexes are situated directly adjacent to granite outcroppings, and may be considered as discharge spring complexes emanating from contact between onlapping sediments and outcropping basement structures.

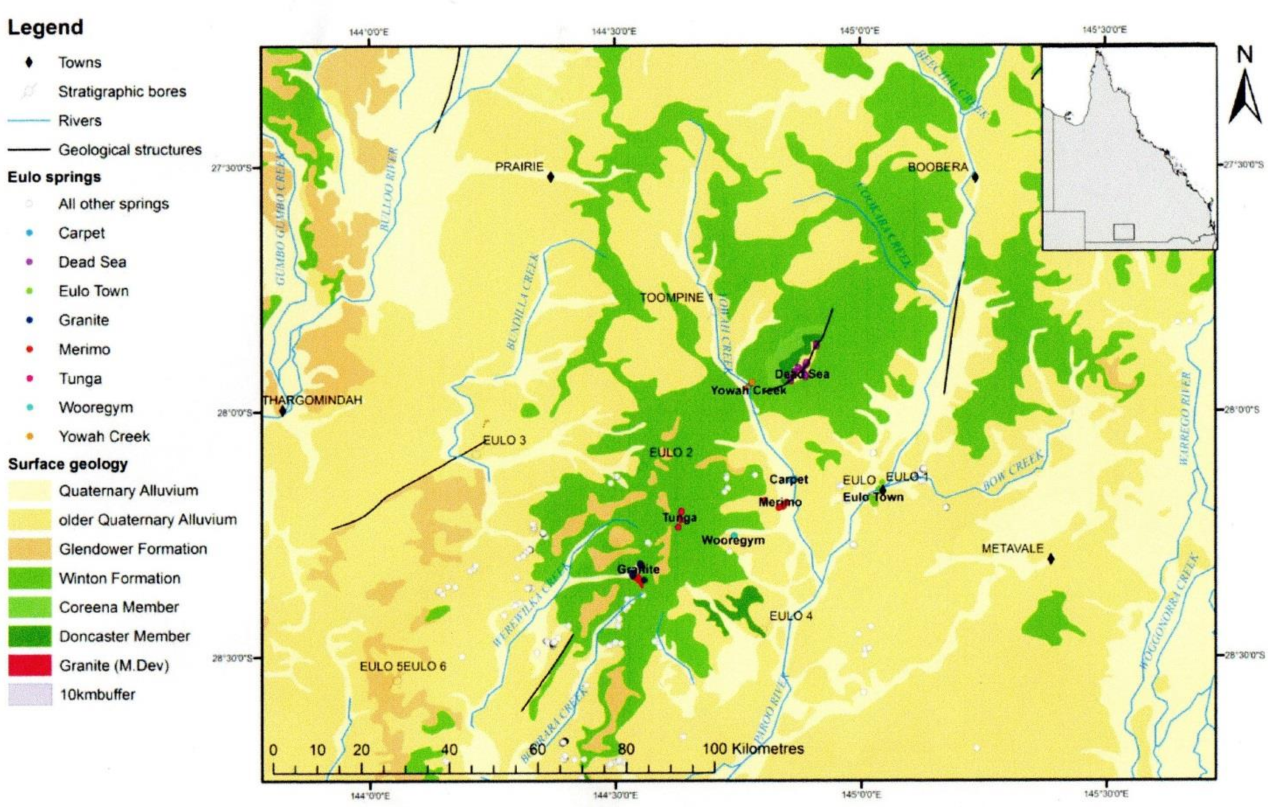


Figure 58 The Eulo supergroup springs in the Eromanga Basin investigated in this report.

Source: Ecological and Hydrogeological survey of the Great Artesian Basin Springs Volume 1 page 102.

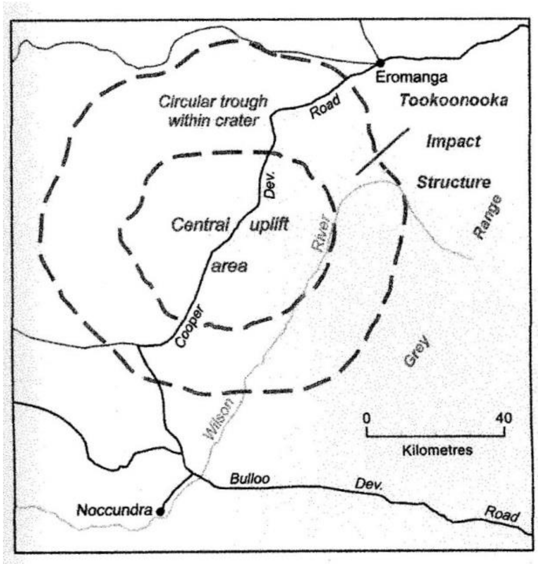
The Yowah Opal Fields are formed in a syncline and have an estimated age of 35Ma +or – 7 Ma, that is late Eocene to early Oligocene, the age of the ironstone formation. They were first discovered by Bryan Rossiter in the 1880's. He was an opal dealer.

Figure 6 Display of Yowah Nuts. Photo taken by Barbara Dunn (2018)

The Yowah mining area is well known for a brown opal called the Ironstone Matrix Opal and the Yowah Opal Nut, a siliceous ironstone nodule, an opal type only found in this part of Queensland. These nuts range in size from about 5 mm to 200 mm across. They have a spherical or ellipsoidal shape, and show alternate concentric rings or bands of light and dark brown siliceous ironstone. There is sometimes a kernel of precious opal. Yowah opals are often cut as cabochons (round shapes without faces)

The Yowah nuts are found in layers (150-600 mm in thickness) at depths of up to 20 m in a ferruginous sandstone, and are commonly associated with mudstone fragments or clay pellets.

The main layer is located near the contact between the sandstone and the underlying mudstone/claystone, but scattered nodules, and in some cases, a second band may occur above.



In Queensland open cut mining is the norm and bulldozers and 20-40 tonne excavators are widely used.

Impact Craters

Between Noccundra and Eromanga town a meteor crater has been detected by seismic profiling called the Tookoonooka Crater. It is about 66 kms across. Drilling for oil and gas in the vicinity has provided the following information. Source: Willmott W page 83

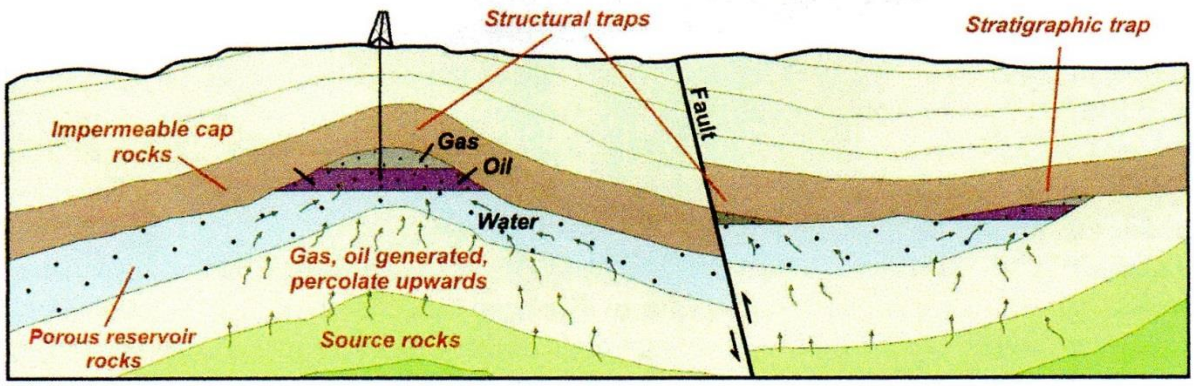
"A hole near the centre of the crater encountered quartzite and schist of presumed Ordovician Age belonging to the basement beneath the basin which has been brought up at least 450 m from the elastic rebound strike. This central dome is 22 km across and is surrounded by a ring of debri and later rocks, whilst a significant thickness of eroded ejected debri extends out to a diameter of 130 km" (Willmott W. page 83).

Scientists believe that the meteorite crashed into the first Eromanga Sea when the Cadna-owie Formation was being deposited around its shores, in about 128 Ma. Some researchers believe that the Wyandra Sandstone Member deposited just after, is part composed of sediments from giant tsunamis generated by this huge plunge into the sea. The resulting crater is thought to have been at least hundreds of metres above the sea. The Wallumbilla Formation of marine sediments were then deposited in the Basin. Erosion of the crater rim and deposition covered over the crater so that it is no longer visable on the surface..

Cooper – Eromanga Basins, Gas and Oil Fields.

These are the largest conventional petroleum fields in Queensland and the largest onshore in Australia.

Gas was discovered in the Cooper Basin in 1963 at Gidgealpa, SA and piped to Adelaide in 1969. Reservoirs were located in the Cooper and overlying Eromanga Basin. There are now 150 separate gas fields with 700 producing wells, and 90 oil fields with 360 producing wells. Pipelines transmit the gas from processing hubs in Moomba, SA and Ballera, Qld.to Adelaide, Sydney, Mt Isa and Brisbane. The gas has also been used by several small gas-fired power stations along the pipeline to Brisbane. Oil from the Jackson South-Naccowlah field and Kenmore field was once transported by pipeline to Moonie and then to Brisbane. Because of declining volumes the remaining oil is now taken to Moomba and then Adelaide. (Willmott W (2017) page 53).



Generation and entrapment of oil and gas.

Source: Willmott W. page 51

Oil and gas deposits occur where a significant accumulation of organic matter in the sediments is converted under heat and pressure to hydrocarbon molecules. Light ones are gaseous, heavier ones are liquid (oil) and very heavy ones are almost solid (tar or bitumen). A permeable rock layer beneath and an impermeable cap are needed for these products to accumulate. The permeable layers are called reservoirs and the sites of accumulation are called traps. See the diagram above.

The permeable layers are also water aquifers but the gas and oil being lighter will float to the top of the water in any trap. The traps can be structural such as where a rock layer is folded or faulted or stratigraphic where a permeable layer pinches out against an impermeable layer. This is shown in the diagram above. A series of stacked traps may occur where more than one permeable layer is present. Initially the oil and gas will be under pressure and will gush out when a well is drilled. Eventually pumping will be required. Injection of water and fracturing of the rock by water pressure may be used to flush out the remaining oil and gas.(Willmott W. page 51)

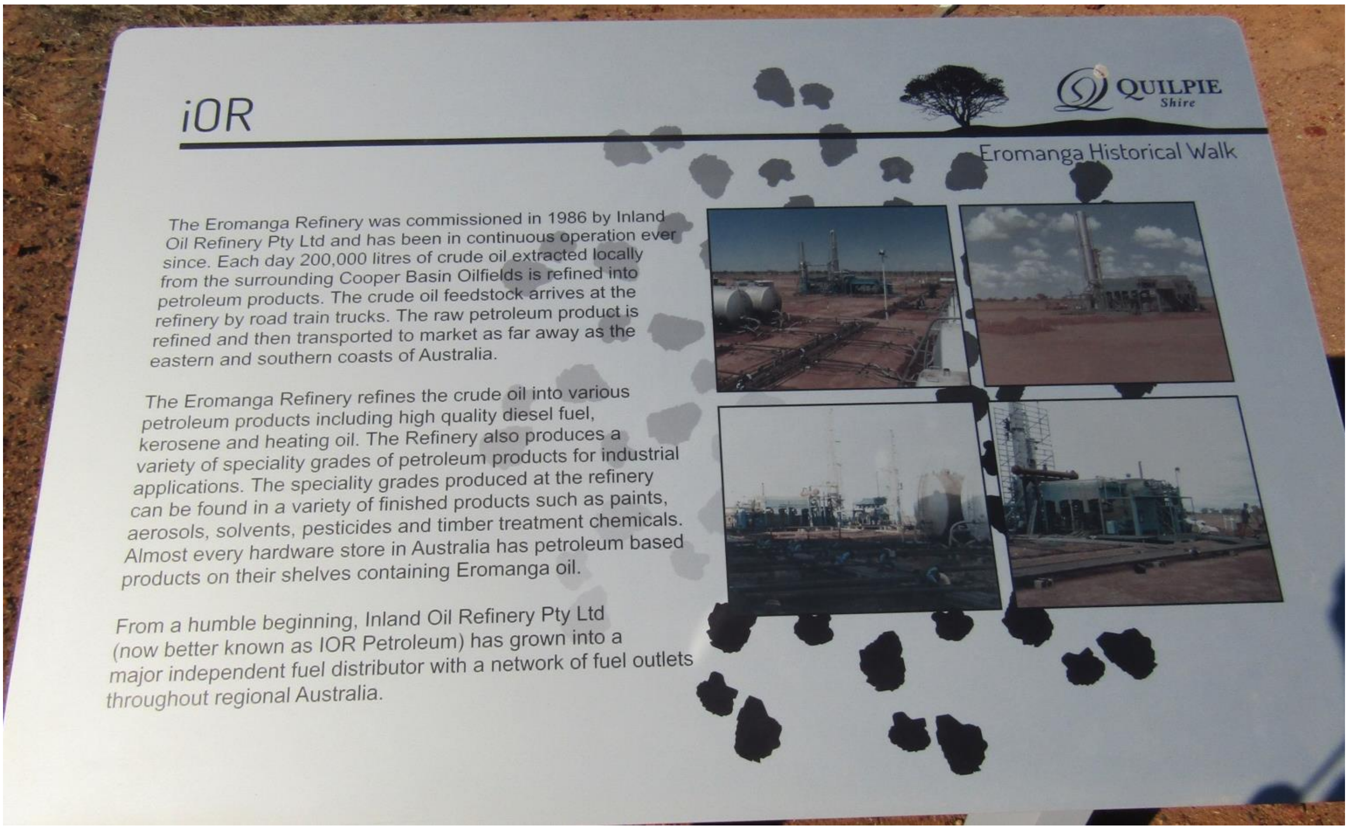


Figure 7 Photo taken at iOR Refinery, Eromanga (2018) by Barbara Dunn.

Some oil is refined as diesel at Eromanga.in a small refinery.

The source rocks are primarily Permian coal seams and mudstones of the Cooper Basin. Reservoirs are found in all sandstone layers of this basin and may be stacked above one another. The gas and oil have also migrated higher into the rocks of the Eromanga Basin in the SE. The main reservoir there is the Jurassic Hutton Sandstone beneath a seal of the Birkhead Fm. rocks. There are also higher reservoirs in the Adori and Westbourne Fms, the Namur and Hooray Sandstones and the Mura and Cadna-owie Fm. Again, here may be stacked pools in the various reservoirs in any one trap.

The Channel Country is in south-western Queensland, extending into South Australia and NSW. 280,000 km^2 or 70% is located in Queensland. It is defined by having braided channels, flood and alluvial plains. In flood times the watercourses overflow into distributaries and channels sometimes reaching 80 km across. The main water courses west to east are the Georgina and Diamantina Rivers, Cooper Creek and the Bulloo River.

On the rare occasions of massive floodwaters, the watercourses discharge into Goyder's Lagoon, Lake Eyre and Coongie Lakes.

The Channel Country is found covering the Cooper and Eromanga geological basins that form part of the GAB. It is interspersed with flat-topped ridges, sand dunes and ancient floodplains. The flat basin-like expanse of land is a result of erosion over millennia, but also the 'continental sagging' that occurred between 120-98 Ma when

Figure 8 Channel country alluvium of the Diamantina River after flood. Source Wilson & Taylor (2012) page 49

Australia was connected to Gondwana near the South Pole. At this time the Channel Country was occupied by a vast inland sea populated by strange pre-historic sea life. Today it has around 770 residents and the major land use is cattle grazing

Permanent waterholes and periodic pulses of substantial water allowed Aboriginal people to live in great numbers in Channel Country. 25 tribal groups have occupied the Channel Country for approximately 20 000 years. It was the heart of an extensive network of trade routes and dreaming pathways that linked this part of the land with the rest of the continent. Pituri, stone, ochre and pearl shell, were traded.

A succession of explorers travelling through Channel country in the middle of the 19th century were Charles Sturt (1844-45), Augustus Gregory (1858), Thomas Mitchell (1846), Burke and Wills (1860-61, John McKinley (1861) and William Hodgkinson (1861,1877). They were variously looking for an inland sea long gone; looking for pastoral lands and looking for territorial advantage for the states that had sponsored their trips.

The pastoralists followed in the 1870's, bringing sheep to the Channel Country but the ravages of the 1890's drought and attacks by dingoes saw cattle replace wool and lamb. Aboriginal people tried to resist the pastoral invasion of their lands and there were many conflicts. Eventually the Aboriginal people were reduced to roles as station hands and house-help. Leading pastoralists were John Costello, Robert Collins, Patrick Durack, Sidney Kidman and Oscar de Satge.

Birdsville and Windorah are the most prominent towns in the area while other settlements include Betoota and Bedourie. It is estimated that between 500,000 to one million head of cattle can be found in the Queensland section alone of Channel Country.

Quaternary Inland Dunefields

In Queensland the dunes are restricted to the south-western corner of the state and form part of the Simpson and Strezlecki Dunefields. The dunes follow the direction of the prevailing south-easterly winds with the mobile crests being steeper on the eastern side due to the westerly winds in winter. That is they trend from south-east to north-west.

The sand in the dunes is derived mainly from the weathering of ancient laterites, and partly from sandstones or from alluvial deposits laid down along watercourses or in basins.

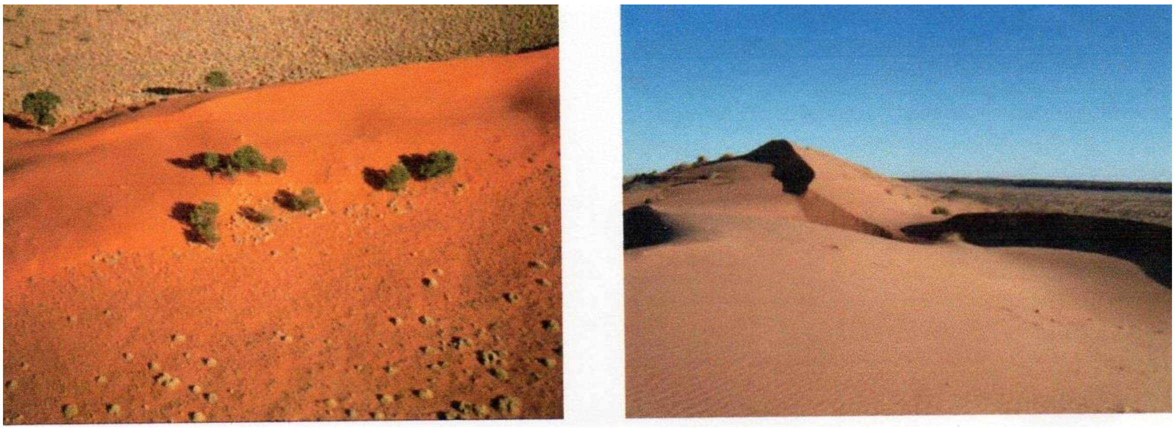


Figure 9 Longitudinal dunes of western Queensland. Source Wilson & Taylor (2012) page 59

Erosion of the Tertiary landscape and quartz-rich substrates has deposited large amounts of sediments containing sand that have been reworked by wind to form sand dunes and associated sandplains. In general dunes are predominantly pale coloured on the north western side of the large alluvial plains of the Channel Country where the sand originates and becomes redder in colour to the north-west. The red colour is due to the gradual oxidation of the iron minerals coating the sand grains. Isolated semi-stable and mobile dunes are associated with many river systems in western Queensland.

Boulder Opals are those found in concretionary ironstone and are mined in Queensland from numerous localities in a zone extending from Eulo to Cunnamulla district in the south and NW for a distance of 700 km to Kapuna in the north. The towns of Quilpie, Yowah and Winton are the main opal mining and wholesale centres.

Figure 10 Boulder Opal, Quilpie, Qld Photo taken by Barbara Dunn 2018

The opal is found in a 300 km wide belt of sedimentary and Cretaceous rocks of the Winton Formation.

Boulder opal was first found in Quilpie around 1870. It was formed millions of years ago from a solution of silica from decomposing rocks mixed with, water, which flowed into seams cracks and cavities into a type of sandstone known as ironstone. The solution hardened in underground cavities and fissures where temperature and pressure fused it into ironstone.

The ironstone matrix enhances the stones durability and vibrancy of colour, often increasing the desirable effects of play of colour and opalescence.

Boulder opals are mainly found in freeform shapes and slabs that maximize and preserve the weight of the opal strip.

The main difference between the matrix opal and the boulder opal which are very similar is the width of the veins. They are larger in the boulder opal.

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