

Sturt's expedition to discover the mythical great inland sea of the hitherto poorly explored Australian continent arrived in the Broken Hill area from Adelaide via Menindee in 1845. The party of men, oxen, sheep, horses and the whaleboat which was to be used for expeditions on the inland sea camped on Stephens Creek (east of what is now Broken Hill) whilst exploring the Barrier Range to the north. The party finally set off to the northwest, crossing the range and then heading northward. A number of large watercourses draining westward from the Barrier Range provided welcome water sources for the thirsty men and animals.

The explorers arrived at a large waterhole on what is now known as Depot Glen in early summer. Hot, dry conditions resulted in the party remaining in this camp for more than 6 months before they set off on further exploration to the north. The party hastily retreated to Menindee in December 1845 after suffering one casualty and enduring unbelievable hardships. Although they failed to discover any inland sea, they were successful in acquiring knowledge on the conditions and geography of this remote region. It was to be almost 15 years before other explorers reached this area, and a further 20 years before the alluvial gold riches of the area about Sturt's Depot Glen base were discovered.

This geological drive is a reference for those modern explorers who chose to follow the approximate path of Sturt's expedition. Although it is not feasible to closely follow Sturt's overland route, a number of gravel roads pass in reasonably close proximity to his passage to and from Depot Glen.

The guide provides some insight into the general geology and landforms of the route between Silverton, through Wilangee, Mount Woowoolahra, McDougalls Well, Pine View, Sanpah, Pine Ridge, Yelka, Pimpara Lake, Pincally, Mount Shannon, Mount Browne and finally, Milparinka. The route is promoted as *Sturt's Steps* which is in accordance with a tourism initiative of the Milparinka Heritage and Tourism Association. The terminology used in the guide is aimed at the layman, although some scientific jargon is inescapable.

The route described here comprises gravel roads with local sand drifts, numerous gates, generally no surface water, no commercial fuel outlets, and few, scattered homesteads. Some of these isolated properties offer accommodation or camping. A reliable, appropriate vehicle with an adequate fuel supply is necessary to safely undertake the journey. Adequate food and water, first aid equipment, spare tyres, and emergency communication (satellite phone, UHF radio) are essential. Conventional mobile phones are useless here.

The reward for making the journey is great. The road travels through isolated, largely flat terrain which is dominated by seemingly endless gibber plains and sand dunes. Steep, high ranges of ancient rocks emerge from the plains abruptly, creating awesome backdrops. Mesa-like hills appear in places, capped with tough, erosion-resistant rocks. Camping along the few large creeks or amongst the well vegetated dunes is memorable for the scenery, peace and quiet, and wildlife. Most graziers in this region are welcoming, knowledgeable about their patch of Australia, and replete with tales of the outback. This is a memorable drive which will take you into a part of Sturt's world, which despite the passing of more than 150 years, retains much of the character and scenery that those hardy explorers would have experienced.

The tour route generally passes across the sand and gravel products resulting from the prolonged erosion of this ancient continent. Central Australia is relatively flat, because the ancient rocks which make up the crust have been planed downward by hundreds of millions of years of erosion by wind, water and ice. Those rocks are covered by up to several hundreds of metres thickness of sand, gravel and silt which has been transported into its present position by rivers, creeks and the relentless wind. Erosion is constant, and elevated landforms are slowly reducing in height and extent, their erosion products either blown away on the wind, or dispersed onto the planes via watercourses and alluvial fans. The flat tops of mesas (technically known as *cordillos*, but locally referred to as *jump ups*) demonstrate the land surface during the Tertiary period (about 33 million years ago - see Table 1). These give some idea of the erosion which has taken place due to natural processes since those Tertiary rocks were deposited.

The earth's crust in this region comprises very ancient rocks which have been faulted against one another, folded many times, and fractured and cleaved by the enormous energies involved in constructing a continent. Those rocks were originally sands, gravels and silts, limey muds, lavas, tuffs (volcanic ash), and a variety of rocks resulting from magmas intruding the crust, such as granite. Heat and pressure associated with major periods of crustal instability (known as *orogenies*, or *mountain building*) changed those rocks into a range of metamorphic rocks (meaning *rocks changed by heat and pressure*) that we find today.

The oldest rocks present are the metamorphic rocks of the Barrier Ranges about Broken Hill. These rocks were deposited in a variety of environments between 1710 and 1640 million years ago in the Palaeoproterozoic period (Table 1), including on land, in a shallow sea, and in deep oceanic waters. They formed as part of a continent which was subsequently amalgamated into the supercontinent (i.e. a mass of land comprising more than one continent) *Rodinia* during the Neoproterozoic. These rocks were folded and metamorphosed about 1600 million years ago, and shortly after intruded by granite during the Mesoproterozoic period about 1596 to 1591 million years ago. Over the following millions of years during the Neoproterozoic period (between 840 and about 590 million years ago) these metamorphic rocks were eroded into a shallow sea, after which they were uplifted and folded, possibly as a result of the breaking apart of *Rodinia* about 600 million years ago (see Table 1).

During the Cambrian period, about 500 million years ago, and into the following Ordovician period, sands and muds were deposited into the sea. Volcanic eruptions contributed lavas and ash to the sediment. About 430 million years ago in the following Silurian period, those rocks were folded and disrupted by a major period of mountain building (known as an *orogeny*). Following this, the mountains were weathered and eroded, and the resulting sands and gravels formed extensive deposits over the older rocks. Another orogeny about 410 million years ago during the Devonian period uplifted and folded those rocks. The cycle of erosion and deposition continued into the following Carboniferous period, during which time the land was once again covered in the sand and gravel resulting from the breakdown of the older, exposed rocks. This deposition was halted in the latter parts of the Carboniferous (about 310 million years ago) by yet another orogeny which was probably related to the collision of the continents remaining from *Rodinia's* destruction. These were brought together in a different configuration by plate tectonic movement, their collision resulting in the formation of a new supercontinent, *Pangea* about 255 million years ago. *Pangea* stretched almost from pole to pole and gave the opportunity for widespread movement of life across this vast area, thereby spreading the local evolutionary and species variations. *Pangea* began to split apart about 240 million years ago, separating into two supercontinents - *Laurasia* and *Gondwana*. *Gondwana* included what was to later become the Australian continent, and was the scene of distinctive and unique development of animal species. *Gondwana* remained intact until 180 million years ago when it started to break up in the Jurassic period to form the Australian and other continents after which evolution continued on a continent scale.

Large areas of the new Australian continent were submerged by the ocean during the Jurassic and Cretaceous periods. This was a time when the Australian continent was within polar latitudes, resulting in the glaciation of the landmass, and the prevalence of ice sheets and drifting ice across the inland sea. The sedimentary rocks deposited at the time reflect this environment, with large blocks of ice-rafted rock in local abundance. As the sea shallowed toward the start of the Tertiary period, the continent continued to move toward equatorial latitudes. The resulting sands and gravels deposited during the Tertiary period (about 33 million years ago) were formed on land across most of inland Australia, and reflect the alternating hot, dry and very wet conditions of this environment. Extensive layers of *silcrete* (a hard, siliceous rock) were formed in the soil by groundwater movement, and the underlying Cretaceous rocks were bleached and robbed of their soluble minerals.

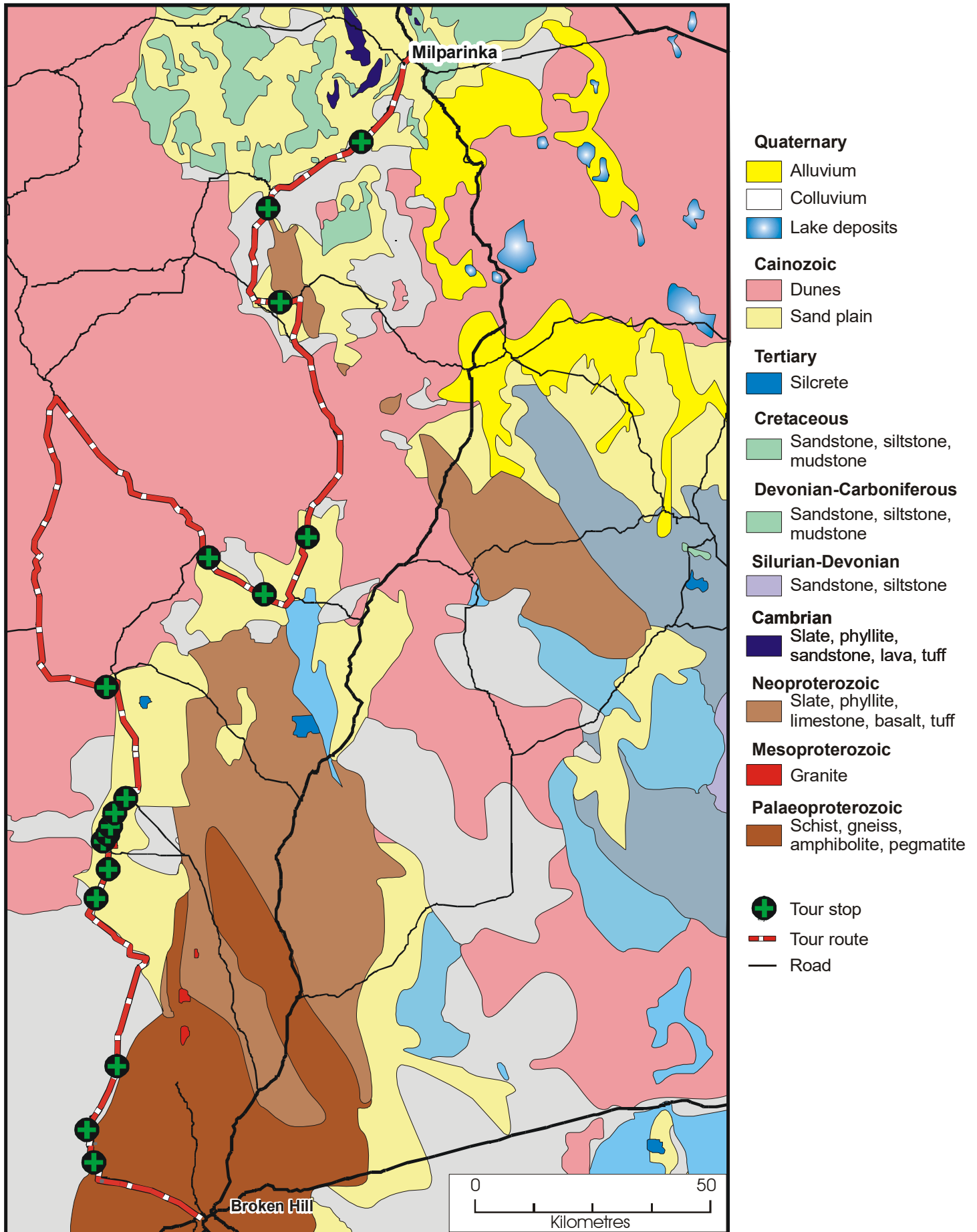


Figure 1. Simplified geology of the Sturt's Steps geological drive. The tour route is highlighted, and tour stops shown.

Table 1. Simplified geological history of the region beneath Sturt's Steps.

PERIOD	YEARS AGO	LIFE FORMS ORIGINATING	GEOLOGICAL EVENTS
QUATERNARY	0 2,000,000	Human Beings	Deposition on land by wind and water
TERTIARY	65,000,000	Grazing and carnivorous mammals	Tropical conditions produced widespread sandy deposits from abundant rivers. Groundwater movement produced silcrete
CRETACEOUS	145,000,000	Last dinosaurs First flowering plants	Polar conditions. Widespread inundation beneath a shallow marine sea. Uplift of seafloor and deposition on land by end of Cretaceous. Australian continent moving northwards.
JURASSIC	200,000,000	First birds	No rocks preserved from this period in local area. Gondwana breaks apart – Australian continent formed
TRIASSIC	251,000,000	First dinosaurs and mammals	No rocks preserved from this period in local area Pangea breaking apart – formation of Gondwana
PERMIAN	299,000,000	Mammal-like reptiles, last Trilobites	No rocks preserved from this period in local area. Continents collide to form new supercontinent, Pangea
CARBONIFEROUS	359,000,000	First reptiles; fern forests	Sand and gravel deposited across land Remains of Rodinia moving together.
DEVONIAN	416,000,000	First amphibians and insects	Period of major fracturing and faulting
SILURIAN	443,000,000	Vascular land plants	Major period of folding followed by deposition of sand and silt across land
ORDOVICIAN	488,000,000	First corals, fish with vertebrae	Deposition of sands and muds in ocean about 500 million years ago. Lavas and ash introduced periodically
CAMBRIAN	542,000,000	Shellfish, Trilobites	Supercontinent Rodinia broken apart.
Neoproterozoic	700,000,000	Algae	Silt, mud, limestone and basalt in shallow sea. Formation of Rodinia supercontinent
Mesoproterozoic	1,500,000,000	Complex cells	Granite intruded older rocks
Palaeoproterozoic	3,500,000,000 4,500,000,000	Primitive cells	Sand, silt and volcanic rocks deposited on land and in shallow to deep sea
		Formation of the Earth	

Following the Tertiary period central Australia settled into a relatively quiescent period. Erosion and deposition of the erosion products by wind and water have persisted, resulting in the extensive sand dunes and gibber plains of the region. The land underwent local uplift due in some cases to crustal readjustment (*isostatic uplift*), whilst many ancient fault lines were also periodically reactivated. These ancient faults have influenced the deposition of rocks for millions of years, and have also resulted in the uplift of ancient rocks against their younger counterparts. Many of the spectacular ranges in central Australia have been elevated in comparatively recent times by uplift on such faults. The products of this uplift are very evident on the Sturt's Steps drive.

The Stops listed in this guide are identified by distance and by grid reference. Distances are approximate. Grid references are in Geographic Datum Australia 1994, Map Grid Australia Zone 54 (GDA 1994, MGA56).

Stop 1. Mundi Mundi Plain lookout. Grid reference 519303; 6476187.

For many visitors, the sight of the vast Mundi Mundi Plain from the elevated edge of the Barrier Ranges is a unique sight never to be forgotten. However, for most residents of central Australia, this sight is not unique, despite its abrupt, awesome character. Like many of the central Australian ranges, the Barrier Ranges are bounded by a major fault which has been active in relatively recent times, uplifting one side relative to the other. In the case of the Mundi Mundi Plain and the Barrier ranges, a very long-lived, lengthy, north-trending fault has elevated the eastern block upwards, forming the Barrier Ranges. This fault is known as the Mundi Mundi Fault. The fault plane is buried beneath eroded gravels and sand to the west of the escarpment.



Researchers have determined that the Mundi Mundi Fault was probably active during the Palaeoproterozoic and has been sporadically reactivated since that time. A significant movement in the Tertiary period elevated the Barrier Ranges, stripping off the covering of Cretaceous rocks and dumping them westward into the topographically lower region. Thicknesses of about 200 m of overburden are present immediately adjacent to the fault scarp, thinning to about 50 m near the South Australian border. Evidence from along the scarp indicates that the last major movement was somewhat more than 53,000 years ago. Dislocated alluvial fans and terraces along the scarp also support the assertion that significant movement has taken place thousands of years ago.

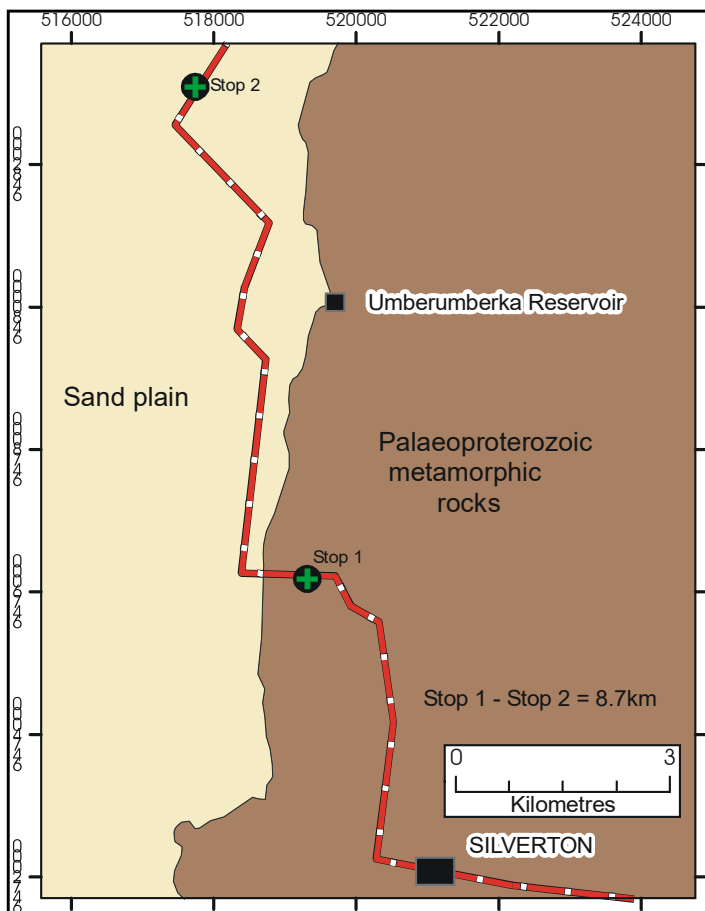


The Mundi Mundi fault scarp viewed from the sand plain to the west.

Many similar faults are present throughout the region of Sturt's Steps. As we will see, the Grey Range near Mount Arrowsmith (Stops 15 and 16) has been elevated along faults. The Cambrian ranges near Milparinka are similarly fault-bounded. A geological tour of the Milparinka area which examines these rocks is available from the Tourism and Heritage Association in Milparinka and from our web site..

The drive to Stop 2 is reached by descending the road onto the Mundi Mundi Plain and traveling for about 8.7 km. The road passes across a broad sand plain with the Mundi Mundi fault scarp on the east. Stop by the ruined buildings near the roadside.

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Stop 2. Early settlement. Grid reference 517732 6483093.

VIEW THE RUINS FROM THE ROAD. DO NOT VENTURE ON TO PRIVATE PROPERTY. In the early years of European settlement in the region many buildings were constructed of local stone. The advantage of this was that the cost was less than importing alternative materials, there was little local timber suitable for constructing external walls, and

the stone was a very good insulator against the extremes of summer heat and winter cold.

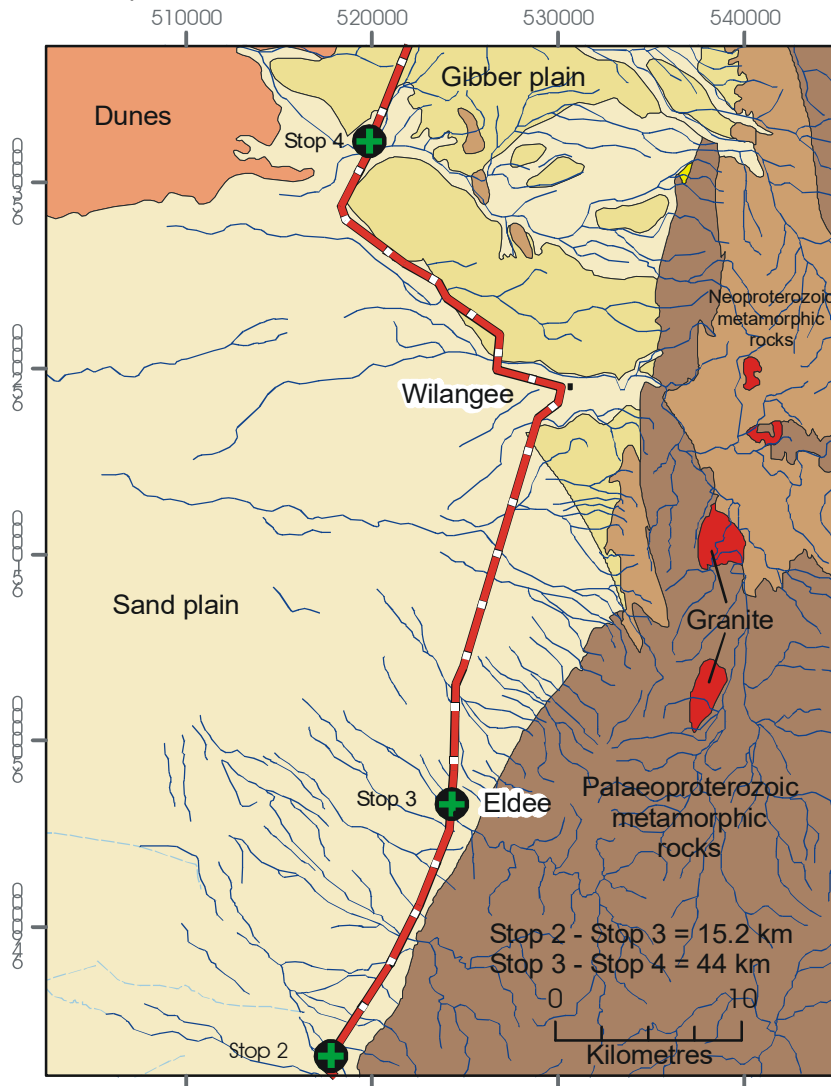
The ruins at this stop represent an original community of a farm house and outbuildings. These were probably constructed in the late 1800s, well after Sturt's party passed through this way.

The ridge to the east of the buildings comprises Palaeoproterozoic rocks of the Barrier Ranges. The Mundi Mundi Fault lies between the road and the edge of the ridge, but is buried by up to 200 m of material eroded from the ridges over millions of years.

Continue along the road for about 15.2 km, passing the turnoff to Eldee Homestead, crossing Eldee Creek and stopping with a superb view of the Mundi Mundi fault scarp set behind the Eldee woolshed.



Ruins at Stop 2



Stop 3. The Mundi Mundi Fault scarp and pegmatite dykes. Grid reference 524254 6496603.



VIEW THE ROCKS AND SCARP FROM THE ROAD. DO NOT ENTER PRIVATE PROPERTY.

The ancient rocks of the Barrier Ranges mainly comprise what were sands, silts and muds. The high pressures and temperatures that these rocks were subjected to during orogenic events has melted some parts of the rocks, resulting in masses of molten rock which intruded through the adjacent metamorphic rocks. What was the molten rock is now rich in pale coloured minerals such as quartz and feldspar, which contrast with the darker

metamorphic rocks around it. The intrusive bodies are known as dykes. Several dykes are visible on the hills behind the woolshed (see photo). The pale, quartz- and feldspar-rich rock is known as pegmatite. As a reminder of the rich mining heritage of the Barrier Ranges, a number of mine shafts are visible on the flanks of the ridge (represented by dark grey dumps on the hillside).

Looking northward along the Mundi Mundi Fault scarp, it is apparent that the scarp changes direction abruptly. This is illustrated on the geological map above, where a major, north-trending fault has intersected the Mundi Mundi Fault and offset it, locally changing the trend of the escarpment from north-northeast, to north-northwest and north.

Continue along the road toward Stop 4 for a distance of about 44 km, passing the turnoff to Wilangee Homestead and for a while driving away from the fault scarp. Note that the road continues to cross sparsely vegetated sand plain, although gibber plains are present a short distance to the east. Cross the major creek bed and halt at the top of the bank where the first pebbles of the gibber plain are encountered.

Stop 4. Gibber plains. Grid reference 519803 6532273.

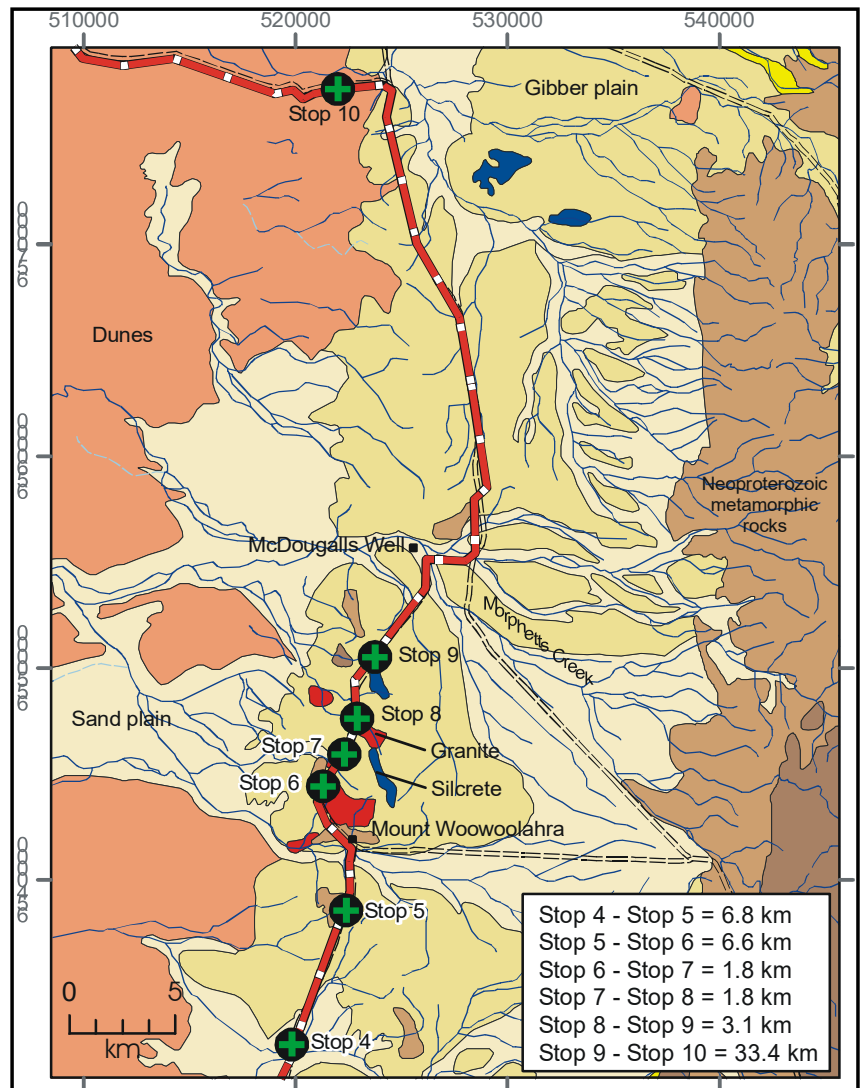
This is the first of many gibber plains which will be encountered on the drive. Gibber plains such as this make up a large part of the ground surface in central Australia. They are composed of smooth, round pebbles and cobbles of weathering-resistant, tough rock types which have survived millions of years of abrasion from wind and water. Chief amongst the pebble types is silcrete, a grey, fine-grained, quartz-rich rock which will be examined later on the drive. Pebbles of quartz, petrified wood and ironstone are also present in places.

Gibber plains have resulted from the erosion of older rocks, with the tough, residual component of those rocks remaining on the land surface as a veneer. The gibbers are too large to be blown away, and occur on flat to gently sloping surfaces above watercourse channels. Consequently, the gibbers tend to remain relatively stationary, whilst the sand and silt about them washes or blows away over time. In places the gibbers become covered by wind-blown sand, and may be found in the low ground between sand dunes.

Continue along the road for approximately 6.8 km. As you travel across the gibber plain you will observe that the road is approaching a low ridge. The rocks which comprise this ridge are metamorphosed sedimentary rocks of Neoproterozoic age. After crossing the crest of the ridge, continue toward the base of the hill and stop near the prominent outcrops on the eastern side of the road.

Stop 5. Neoproterozoic rocks with devil's dice. Grid reference 522371 6538583.

The rocks on these low hills are metamorphosed sedimentary rocks which were deposited in a shallow ocean between 840 and 590 million years ago. They were deposited off the coast of the supercontinent Rodinia. Most of the rocks here were sandstones, pebbly sandstones and shales. The ocean basin that the rocks formed in was not prone to strong currents or wave activity. We know this because the rock layers are very continuous and regular in form over large distances. We also know that the absence of currents resulted in the conditions on the seafloor becoming oxygen-starved. In oxygen-poor environments certain bacteria (*anaerobic bacteria*) thrive which use sulphates for respiration rather than oxygen. The bacteria result in the accumulation of sulphurous compounds which eventually form pyrite (iron sulphide). Pyrite is a mineral which exists as cubic crystals in sedimentary rocks. When the pyrite is exposed to atmospheric water it breaks down to form iron oxides, which in some cases exactly replace the pyrite crystal. The resulting black to dark brown cubes or intergrown cubes are known as *devil's dice*. In the rocks and soil on the eastern side of the road beautiful specimens of devil's dice can be found ranging in size from about 1 mm to several centimetres across. The sedimentary layer containing the devil's dice probably extends toward the top of



Devil's dice in rock from Stop 5



Devil's dice from Stop 5.

Granite boulder in conglomerate at Stop 5.



the hill and should therefore provide plenty of scope for finding good specimens.

There are many layers of conglomerate on the hill to the west. The conglomerate was a mixture of sand and pebbles eroded from the land. There are pebbles and small boulders of granite in the conglomerate. The granite may be derived from the same intrusion which will be examined at Stop 8.

In the distance to the north you can see Mount Woowoolahrah homestead. Continue from Stop 5 to the road intersection near the homestead and turn left (west), following the road around the prominent hill that the homestead takes its name from.

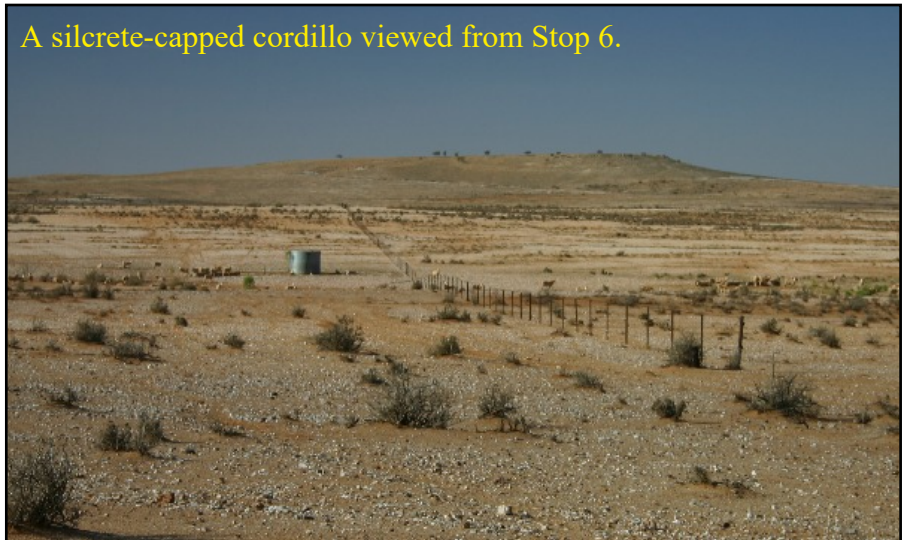
The distance from Stop 5 to Stop 6 is about 6.6 km.

Most of this distance is spent crossing gibber plain, with a little sand plain and some alluvium bear the major watercourse. Stop where you achieve a good view of the mesa-like hills to the east.

Stop 6. Tertiary silcrete-capped cordillos. Grid reference 521271 6544440. See geological map on previous page.

This is the first silcrete-capped ridge encountered on the drive. The gently sloping, relatively flat top of the ridge is the hard, silica (quartz) rich rock silcrete which forms most of the gibbers on the nearby gibber plains. We will examine some of this rock in subsequent stops, and its significance and origin will be described. Millions of years ago the region would have been uniformly blanketed with this rock. However, normal erosional

A silcrete-capped cordillo viewed from Stop 6.



processes are carving downward into the Earth's surface, leaving remnants of the silcrete on ridges, and covering the ground with tough silcrete pebbles. The ridge is known as a *cordillo*, a landform which shows a mesa-like top and leading edge, but which commonly slopes into a plain.

Continue for about 1.8 km along the road until some low, prominent outcrops are apparent on the eastern side of the road.

Stop 7. Mesoproterozoic granite. Grid reference 522273 6545952.

The low hills to the east of this stop are composed of Neoproterozoic granite. This rock formed about 1591 million years ago. The granite has intruded the Palaeoproterozoic rocks of the Barrier Ranges but is older than the metamorphosed sedimentary rocks examined at Stop 5. Possible boulders and pebbles of this granite were eroded from the granite more than 600 million years ago.

The granite is composed of white

Granite outcrops at Stop 7.



quartz, yellow rectangular feldspar and colourless mica crystals. The granite intruded as a molten magma into the Palaeoproterozoic rocks as a result of melting in the Earth's crust. It would have been emplaced to a final depth of several kilometres. Following this, the steady processes of weathering and erosion stripped the overlying rocks from the granite, exposing it so that it could be eroded and incorporated into the sedimentary rocks which formed during the Neoproterozoic period.

Note how the granite has been cut by white quartz veins in places. The veins may have been emplaced late during the cooling of the granite, or in the subsequent millions of years of crustal disturbances.



Granite outcrop surface

Continue along the road, gradually ascending until the crest of the hill is reached, a distance of about 1.8 km.

Stop 8. Silcrete and granite outcrops. Grid reference 522864 6547646

This site includes numerous scattered, low granite outcrops in the foreground, and isolated, scattered knolls

Scattered silcrete outcrops viewed from Stop 8



of silcrete in the distance. Within the past few million years the silcrete layer which would have covered these granite outcrops has been eroded away, leaving behind the abundant silcrete gibbers on the local ground surface. As erosion continues, more of the granite will become exposed, and the silcrete gibbers will slowly scatter away from the granite.

Continue along the road for about 3.1 km until a prominent silcrete ridge is close to the eastern side of the road (see geological map on page 7).

Stop 9. Silcrete ridge. Grid reference 523727 6550556.

This is a typical example of silcrete. Tough, pale grey- to buff-coloured bouldery silcrete outcrop is surrounded by an outward-sloping surface of angular pebbles of silcrete. These pebbles will eventually become smooth and rounded on a mature gibber plain due to the processes of weathering and erosion.

Silcrete is one of the most widespread and common rocks in

Blocky outcrops of silcrete surrounded by angular silcrete gibbers - Stop 9



central Australia. It forms a layer associated with rocks of the Lake Eyre Basin. It is known as the *Cordillo Silcrete*, and is present throughout northwestern NSW, Queensland, South Australia and the Northern Territory. Silcrete has formed from the crystallisation of silica in the pore spaces of what was originally a quartz-rich sand or sandstone. The silcrete resulted from movement of groundwater through the sand, with silica being introduced from the deep weathering of older rocks beneath. This process took place during the Tertiary period, about 33 million years ago, a time when Australia was subjected to a hot, wet environment. The underlying rocks aren't exposed here, but are probably Neoproterozoic metamorphic rocks. The Tertiary environment was ideal for producing plentiful groundwater, then drawing it through the rocks by rapid evaporation, resulting in the precipitation of the dissolved iron, silica or lime. In places the original structure of the sandstone or sand can be seen, with small, very glossy, white quartz pebbles being a common feature.

In some places the silcrete shows a columnar structure. This is one of the common forms of silcrete. The edges of each column show an interesting texture which resembles candle wax drippings. This is a product of the groundwater movement and silica precipitation which formed the silcrete.

Continue along the road, crossing Morphetts Creek after about 6 km. This was one of the main water

Morphetts Creek with the northern end of the Barrier Ranges in the background.
Note the silcrete gibbers in the foreground



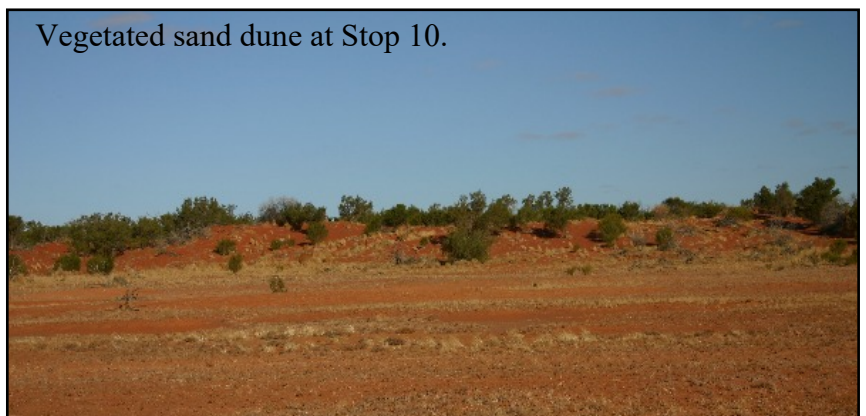
supply creeks Sturt's party used on their outward and return journeys. They sourced water where the creek entered the range to the east, where rock holes and basins trapped the creek's flow before it seeped under the thick gravels of the creek. The journey from Stop 9 to Stop 10 is about 33.4 km, passing through gibber plain country. At the intersection near Teilta, take the left fork, and continue driving westward toward Stop 10. You have now entered an extensive region of sand dunes.

Stop 10. Dunefield. Grid reference 521955 6577352.

Vast areas of inland Australia are covered by dunefields. This part of the drive travels through a very large expanse of dunes, which make a beautiful, well vegetated contrast with the earlier part of the drive.

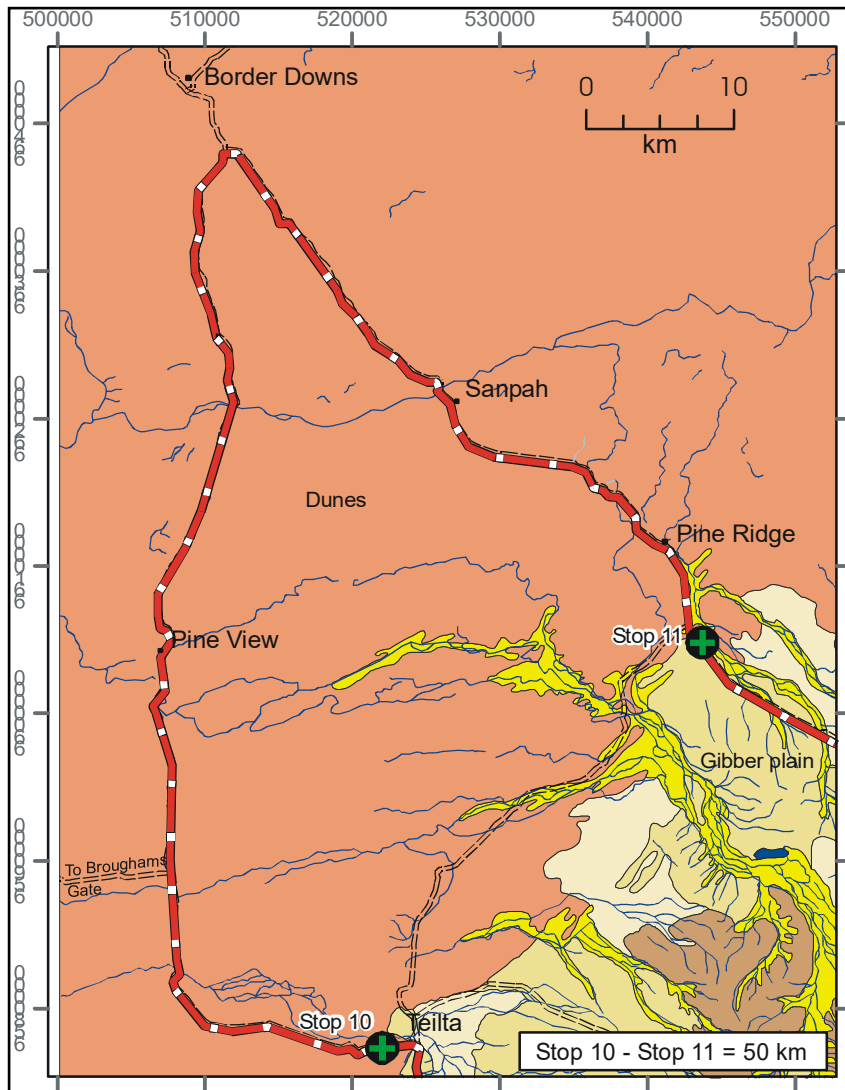
Shifting dunes were a major feature of inland Australia from about 500,000 years ago, with the last period of significant dune formation occurring during the last ice age which ended about 17,000 years ago. After this time the

Vegetated sand dune at Stop 10.



dunes were stabilised by the return of vegetation which has helped preserve their ancient structure. The dune colour is probably related to small amounts of iron oxide amongst the sand and clay which comprise the dunes. The northeast to east-northeast strike of the dunes preserves evidence for the prevailing winds more than 17,000 years ago. Frigid southerly winds prevailed, but with the end of the ice age the winds shifted to the present average westerly trend. If it weren't for the vegetation cover on the dunes, they would either be blown away and converted to sand plains, or reoriented into north-south dunes.

The relatively rich population of shrub and tree species is produced by the ability of the dunes to absorb moisture, and by the relatively high fertility of the dunes. After adequate rain in spring and summer these dunes support a rich carpet of flowering perennial plant species. The relatively thick vegetation also supports a populous and diverse range of animal life. The dunes are pleasant places to camp amongst when there is no significant wind, otherwise the wind-blown sand



Satellite image of dunefield about Stop 10. Note the northeast strike of the dune crests, indicating a wind direction from the southeast.

becomes very unpleasant for the tent camper.

As you drive through the dunefield, note the changes in vegetation style, the relative height of the dunes (some can be very high), and the relative spacing of each dune. It is apparent that some dunes have been devegetated and almost totally blown away, whereas in other places the road travels through regularly spaced dunes which are relatively intact.

There are really only two significant intersections on the road: the road to Broughams Gate, and the major intersection to Border Downs and Sanpah. Turn right towards Sanpah and Pine Ridge. The total distance between Stop 10 and Stop 11 is about 50 km. Stop 11 is marked by the abrupt cessation of the dunefield, with the resumption of gibber plains.

Stop 11. Break between dunes and sand and gibber plains. Grid reference 543688 6604854.

Stop 11 is remarkable for the abrupt change in landforms and vegetation. This is the local edge of the extensive dunefield. The drive from this point eastward is through sand plains initially, then gibber plains and eventually into silcrete ridges.

This may once have all been covered by dunes, but natural erosion has flattened the dunes and scattered the sand through the atmosphere to the east.

Continue along the road toward Stop 12, a distance of about 14.6 km. Stop on the gibber-covered hillside by the gravel pit on the northern side of the road.

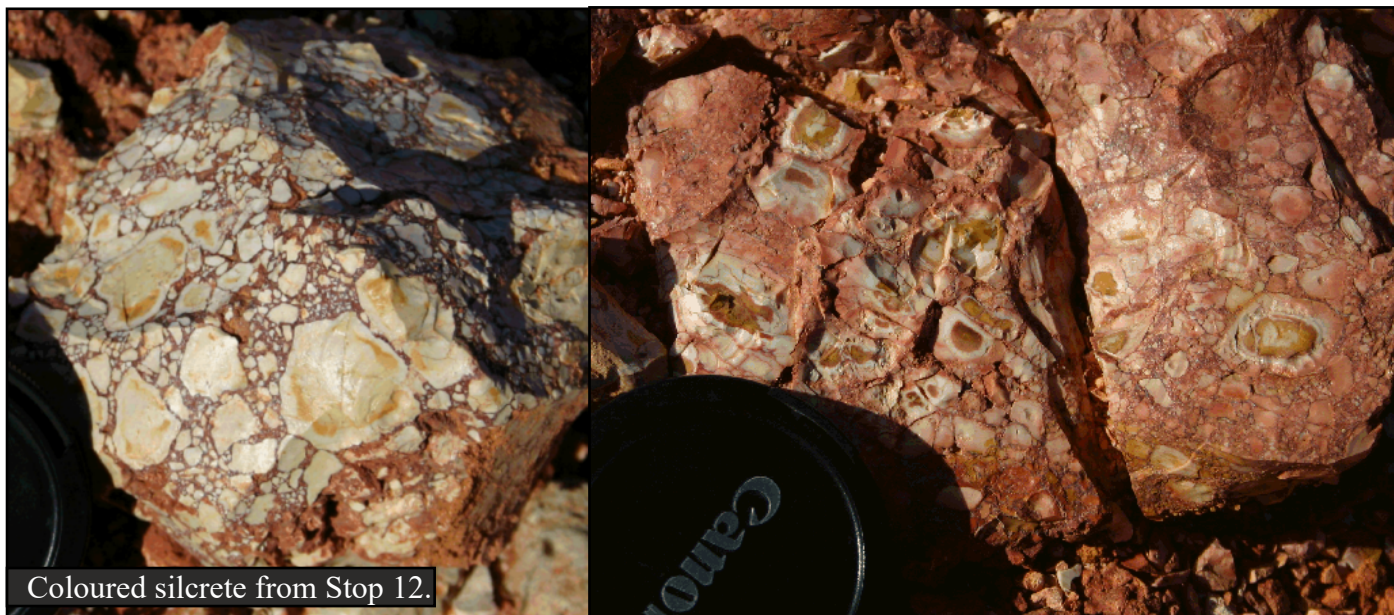


The scene viewed east after emerging from the Dunefield - flat sand and gibber plains.

Stop 12. Exotic patterns and colours in silcrete. Grid reference 555567 6597094.

This locality is a road aggregate pit which has been excavated into silcrete. This is particularly unique silcrete, as it shows a variety of red, yellow and brown colours, and a range of textures somewhat similar to agate. The silcrete is *chalcedonic*, meaning that the silica is extremely fine-grained, which gives the silcrete a very glassy texture which breaks with razor-sharp, curved edges. It should be an excellent material for slabbing and producing decorative jewellery.

Why is this silcrete different to other silcreted? Because of the conditions in the ground where the silcrete was forming during the Tertiary period. The composition of the groundwater included dissolved metals (including iron) which precipitated out in differing amounts to give a range of yellows, browns and reds. The groundwater composition was influenced by how wet the local area was, by how permeable and porous the rocks were to allow that water through, and by how long the conditions appropriate for precipita-



Coloured silcrete from Stop 12.

tion of the pigmenting elements remained active. There was also an adequate local iron source. The concentric layering is a *concretionary* phenomenon, meaning that the iron-rich silica built up about a nucleus, much like a pearl grows. The different colour bands indicate changes in composition of the groundwater.

Very attractive samples of coloured silcrete occur throughout the floor of the pit and on the stockpiles. Hopefully future extraction for road works will replenish easily accessible supplies. Silcrete is abundant on the surrounding hills. A search of the area may unearth more interesting and different silcrete variations.

Continue along the road for about 5 km until the intersection near The Veldt homestead is reached. Take the northern fork (left) towards Pimpara Lake. The total distance between Stops 12 and 13 is about 21.7 km. Much of the road passes through gibber plains, with low silcrete-topped hills to the north. The extensive, well vegetated dunefield is visible in the distance, swinging eastward toward and paralleling the road as Stop 13 is approached. The Stop is recognisable where the road bends and approaches a prominent, low, continuous outcrop of silcrete which looks like a wall. The silcrete crosses the road, and a pinnacle-shaped hill is on the eastern side of the road.

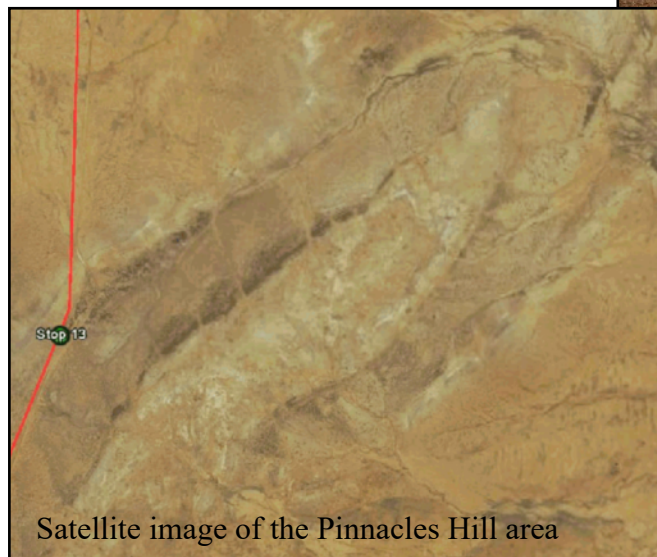
Stop 13. Folded silcrete ridge - Pinnacles Hill. Grid reference 564733 6608977.

This location is worth investigating for several reasons. Its claim to fame is as a recorded observation point for Sturt on his journey northward - so this is an opportunity to really walk in his steps.

The continuously outcropping, grey silcrete layer is tilted towards the south. From the top of the hill you can see it folding around in an arc to the south before disappearing under the gibbers. This silcrete has been slightly folded, possibly by local faults kinking the rocks in this area. Tilted silcrete layers are common, and it is also common to see them tilted at different angles near one another. This satellite image shows the fold in the Pinnacles Hill area.

To travel to Stop 14, continue along the

Dipping silcrete layer, Pinnacles Hill (Photo by Ruth Sandow)



road, entering the area of dunes. The road passes the entrances to Yelka homestead, then Pimpara lake homestead then passes across the largest watercourse for many kilometres, Packsaddle Creek. Stop on the northern side of the creek and walk down stream for a few tens of metres to the gravel pits developed in the northern bank of the creek. The distance from Stop 13 to Stop 14 is about 34 km.

Stop 14. Bleached Cretaceous rocks in contact with Tertiary rocks. Grid reference 566953 6638881.

This small gravel pit shows one of the most interesting and well exposed geological contacts throughout inland

Australia. This is the *unconformity* (a surface in the rock record which indicates a significant break in time across that surface) between the Cretaceous and Tertiary sedimentary rocks.

Following the retreat of the Cretaceous ocean from this part of the continent, the region has been subjected to land-based depositional processes (see Table 1). In some places large thicknesses of the Cretaceous rocks were eroded during the 40 million years preceding the development of the next major depositional basin, the Lake Eyre Basin. Sedimentation commenced in the Lake Eyre Basin about 60 million years ago, at a time when most of the continent was experiencing tropical conditions involving high temperatures and wet conditions. This environment resulted in deep weathering of the surface rocks,

associated with large rates of erosion from the basin margins, and consequently large amounts of sediment deposited in the basin. Exposure of the sandy and gravelly rocks to large groundwater movements

Stop 14 - Packsaddle Creek viewed from the northern bank above the gravel pit.



resulted in the precipitation of large amounts of quartz to produce the silcretes which have been examined previously on the tour.

The gravel pit at this site shows bleached, white sandstone at the foot of the hill. These are the deeply weathered Cretaceous rocks which have been leached of their soluble elements by weathering during the Tertiary period.

About half way up the pit the rocks abruptly become darker and harder, and some pebbly layers are present. These are rocks of the Tertiary period. You can identify the actual contact of the Cretaceous and Tertiary rocks - this is the unconformity surface, which represents a depositional break of about 40 million years! Silica from the underlying rocks has been incorporated into the Tertiary rocks, making them much harder. Some have been completely converted to grey, very hard silcrete.

At the top of the hill some of the rocks show smooth surfaces with etched patterns. These rocks have had calcium carbonate (lime) added by the same process that silica was introduced into the rocks lower down the hill.

Continue northwards, finally exiting the dunefield into sand plain and gibber plain country. The road passes to the west of the Grey Range, before branching at a major intersection. Take the western (left) fork towards Pincally. Stop about 3 km along the road past the intersection, with a view of the ridge to the north.

Stop 15. Grey Range and Mount Arrowsmith. Grid reference 558948 6659275.

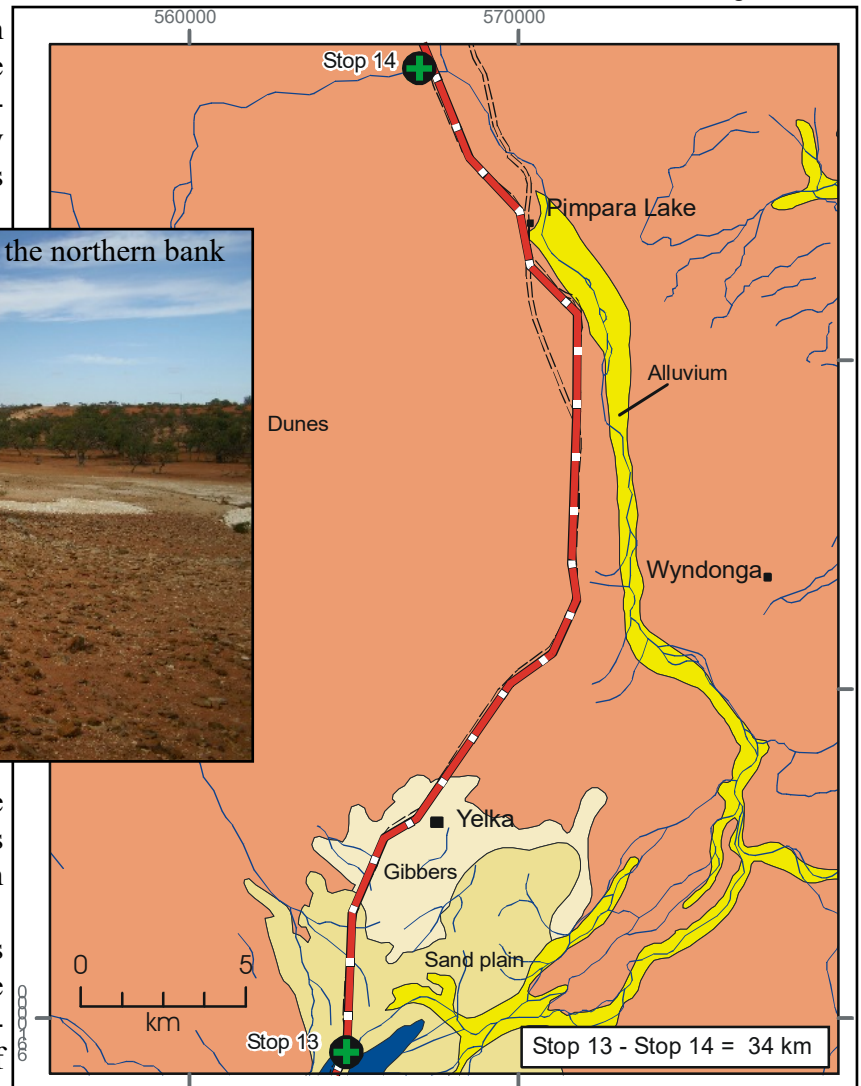
Sturt traveled through the Grey Range on his journey to and from Depot Glen. The high ridge offered views of the region, and the possibility of water trapped in gullies on its flanks.

Similarly to many other prominent ranges, the Grey Range is elevated by bounding faults with a north-northwest trend. The range is made up of Neoproterozoic volcanic rocks and slate. These are faulted against Cambrian to Ordovician age sandstone and shales on the eastern and western flanks of the range. Younger, northeast-striking, cross-cutting faults have offset the range in a number of places.

The highest point on the range is Mount Arrowsmith. This is an excellent lookout across the varied arid zone geographic features of this area.

Pincally is one of several homesteads in the area which offers farm stay accommodation. This would provide an excellent base for exploring the amazing rocks of the Grey Range. Detailed maps of the geology of this area are available from the Department of Primary Industries office in Broken Hill.

To continue to Stop 16, continue along the main road, passing Pincally Homestead and travelling parallel to



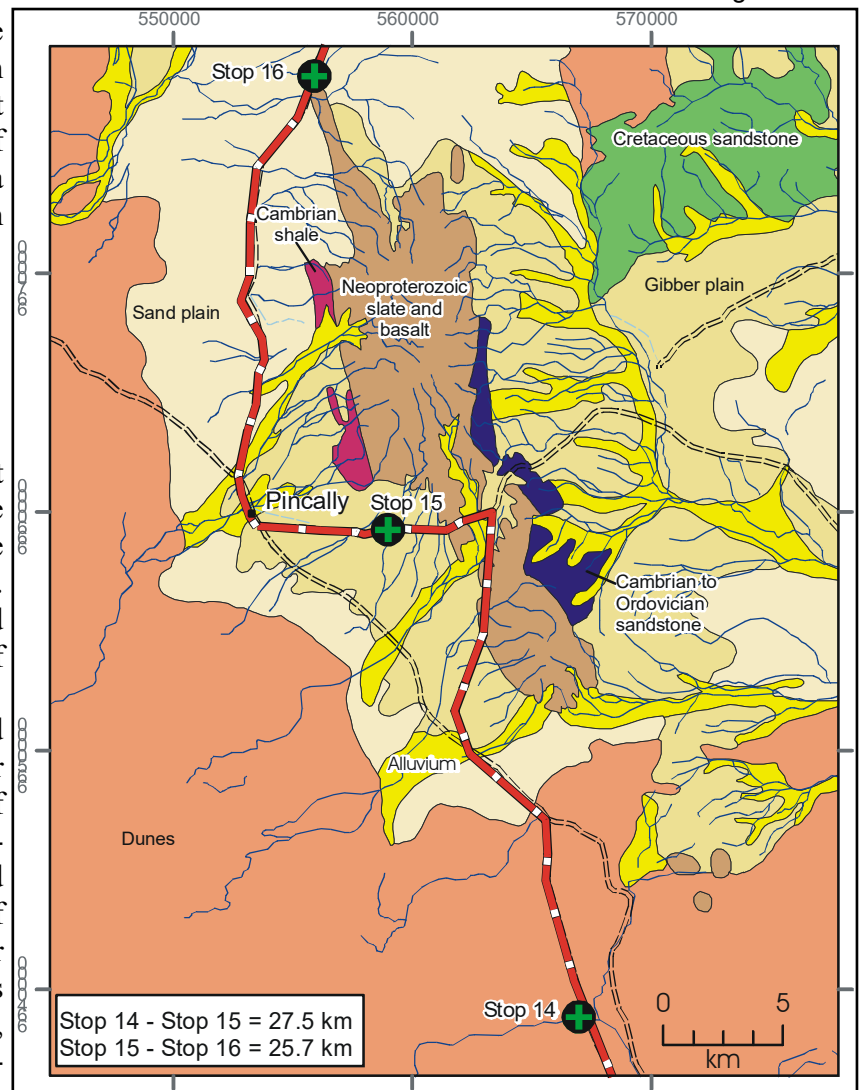
Sturt's Steps

the Grey Range for about 25.7 km. The road passes mainly across sand plain, with gibber plain evident close to the point where the road crosses the northern end of the range. Stop where the road crests on a low rise with dark Neoproterozoic rocks in outcrop.

Stop 16. Neoproterozoic rocks with surrounding quartz pebble gibbers. Grid reference 555889 6678297.

At this point the Grey range has almost completely fallen away into the plain. The northern-most vestiges are shown in the low, nondescript outcrops at this locality. What is significant here is the local spread of white quartz pebbles along the edges of the metasedimentary rock outcrop.

The white pebbles were derived from erosion of quartz veins in the older rocks by wind and water over millions of years. The pebbles were concentrated during the Cretaceous period by widespread streams, which formed thick blankets of quartz pebble-rich gravel and sand over the entire region. The pebble-rich gravels were the first deposited, with subsequent, overlying sand and silt lacking these peb-



View from Stop 16, showing white quartz gibbers in the near distance.



bles because the source of the pebbles (the older rocks) was buried under the gravels or stripped of the pebbles. Erosion since the Cretaceous is re-exposing the pebbly gravels (which are now conglomerate) which are tilted away from the edges of the older metamorphic rocks. Thus the quartz pebbles are being exposed around the edges of the ridge, because the conglomerate composed of those pebbles mantles the older rocks. As we go further from the ridge, the pebbles cease, because the source conglomerate is no longer present.

This is a very common feature about the Milparinka-Tibooburra region. In those areas, gold has been mined from the conglomerate, as some of the original quartz veins (which produced the pebbles) were gold-bearing. Many fossickers successfully and profitably use metal detectors to locate gold nuggets amongst the quartz gibbers in those areas.

Continue along the road, passing across sand plains and watercourses, and passing Mount Shannon Homestead. Stop 17 is a prominent, low hill with a gravel pit on the right of the road, about 26.8 km from Stop 16.

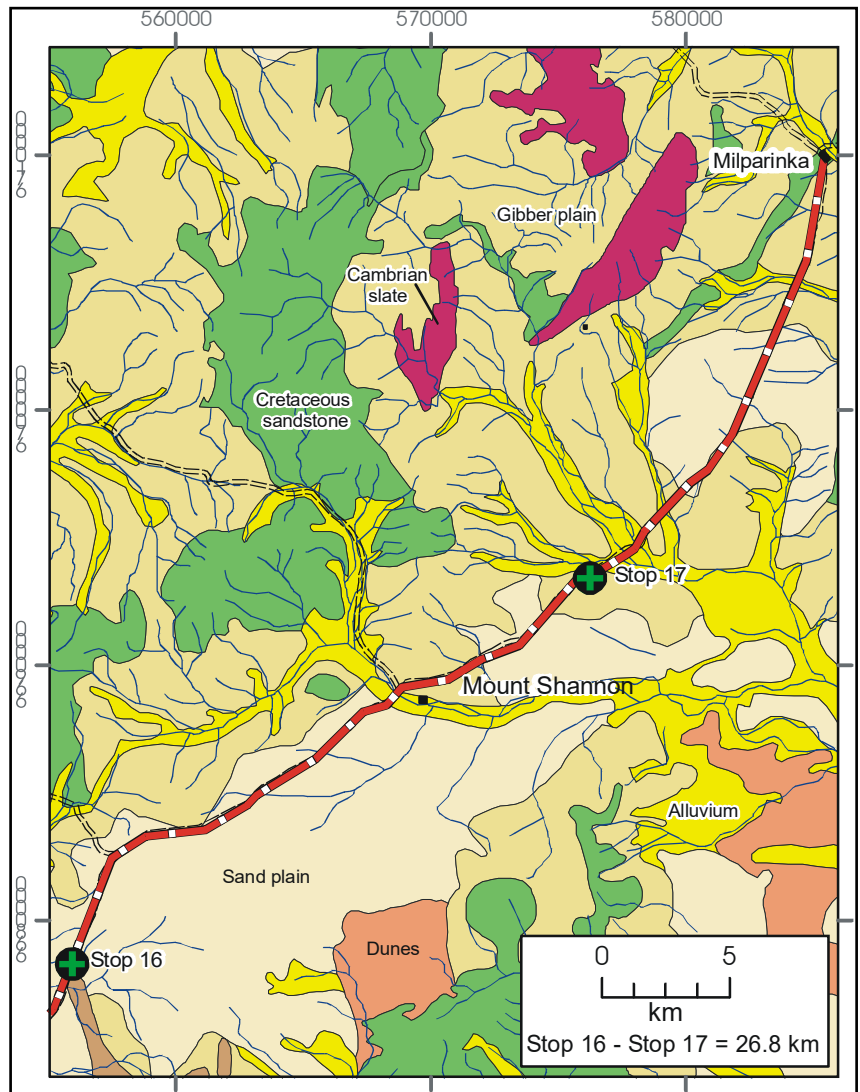
Stop 17. Views of Cambrian inliers. Grid reference 576193 6693432.

This is the final stop on the tour. It presents a view of the Cambrian ridges to the west and north of Milparinka.

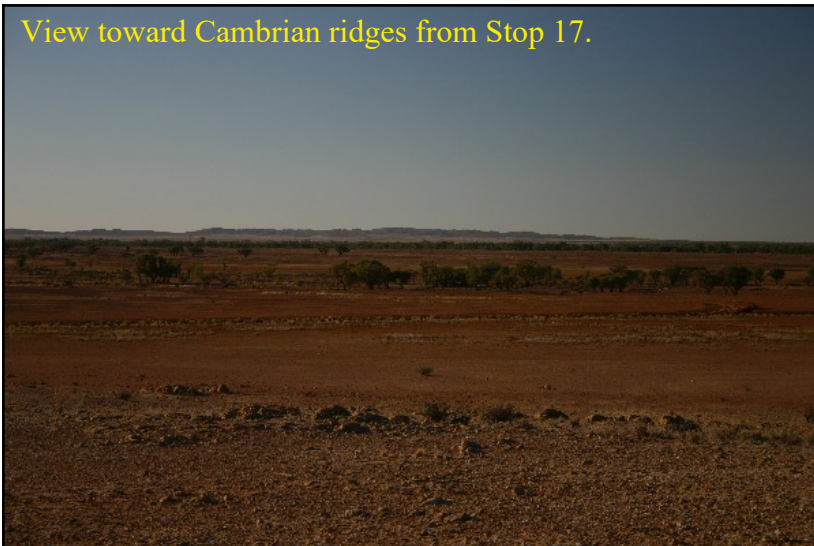
The ridge is composed of calcareous (lime-rich) sandstone of Cretaceous age. Large areas of outcrop of similar Cretaceous rocks are shown in green on the geological map at right. These sandstones are common in the Tibooburra-Milparinka region, and in central South Australia and Queensland. They are part of the Cretaceous *Eromanga Basin*, a major area of sedimentary rocks which make up the Great Artesian Basin. In Queensland and South Australia rocks of this basin host the major oil and gas fields which supply much of southern and eastern Australia with domestic gas supplies, and continue to produce petroleum. And of course, so much of central Australia derives its permanent water supplies from deep artesian bores driven into these rocks.

To the north we can see ridges of Cambrian rocks which have been forced upward through the Cretaceous rocks along faults. These Cambrian ridges are encircled by quartz pebble conglomerates similar to those present at the previous stop. Alluvial gold occurs with the conglomerate adjacent to the ridges visible to the north.

To continue to Milparinka, follow the road for a final 20 km into the village. You have now successfully travelled through the general route followed by



View toward Cambrian ridges from Stop 17.



Sturt's party in 1845. Their prolonged summer haven, Depot Glen, is located just to the north of the ridge on the skyline.

To learn more of the region to the north, there are some informative geological tours of the Cambrian and younger rocks near Sturt's Depot Glen available from the visitor's centre at Milparinka. Self-drive geological and landform tours are also available from there on the Tibooburra region.

We hope that you have enjoyed this commentary and guide, and perhaps learned something about the geology and landforms of the area you have journeyed through. We welcome any constructive comments and criticisms you may wish to pass on to us regarding this guide, and invite you to partake of the other self-guided tours we have produced for other interesting areas.