'Geo-Log' 2022 - 2023

Journal of the Amateur Geological Society of the Hunter Valley

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President's Introduction.

Hello members and friends.

2022-2023 has been an interesting time. After surviving droughts and Covid lockdowns we have had to endure severe rain and floods. During this time the Society has continued to offer opportunities for activities to be run and I thank the people who have come along and supported the Society in so many ways.

I have been given the privilege to serve as the President of the AGSHV during this time. I thank the members who have organized and run the activities and social events.

The foundations of this Society have been built on knowledge and enthusiasm of past presidents and I am grateful for the help from Ron Evans, Brian England and Chris Morton. Thank you to Richard Bale and John Hyslop for continuing in their roles as Secretary and Treasurer. Also, a thank you goes to Chris Morton for taking on the role as Vice President. Their professionalism and dedication is appreciated by everyone. The Social Committee run by Sue Rogers has been active and is the glue that holds us together.

The New Members that have joined us are most welcome while, sadly, there have been others no longer able to continue. David Atkinson has been a passionate and exuberant member since the earliest days of the Society. His many contributions have been appreciated.

A variety of activities have continued during the year. The AGM was a chance to reset for the year ahead.

The annual safari run by Barbara and Brian Dunn and Sue Rogers was a chance to study the features of the Adelaide Geosyncline in the regions of Quorn, Wilpena Pound, Blinman, Nilpena, Arkaroola and Copley. After two previous attempts had been thwarted by Covid lockdowns there was the chance to explore this part of South Australia that has an iconic status. The Nilpena-Ediacara site is currently going through the process of World Heritage recognition so to see this unique place before the official opening was a highlight.

Barry Collier stepped up with an excellent Strickland Falls walk on short notice when Kitchener was not possible. The Christmas Party C=cruise on the Hawkesbury River was a relaxing way for members to catch up in beautiful surroundings. The talks organized by Richard Bale in January and February were interesting and informative. Chris Morton's trip to Forster was eagerly anticipated but the weather gods were not kind but the group still soldiered on. Rick Miller's trip to the Windsor region gave a great insight into the interaction between the geology of the area and the use of the area especially related to the Indigenous peoples. Chris Morton's May activity combined the knowledgeable senior members of the Society with a group that we hope will join us as new members so the Society can continue as a vibrant, social and knowledge seeking society.

Thank you to all of the members who have been actively involved in organizing and participating in activities during the year. The connections across the Society are still strong and this gives us an exciting 2023-2024 to look forward to.

Kind Regards,

Brian Dunn

Bunurong Coastal Park & Mallacoota Coastal Walk

Leader: Barry Collier.
Date: Saturday 19th to Sunday 27th March 2022.
Attendance: 10 members.

Aim of Trip.

The aim of this safari was to explore the fascinating rock formations in Bunurong Coastal Reserve/Park and along the Mallacoota Coastal Walk.

Saturday 19th March, 2022.

The activity started when we met at Bombala to camp for one night. Some people visited the local show, while others explored the surrounding countryside. Places visited were the walking trail along the river, Bombala Lookout *(photo 1)* with fascinating sedimentary rock formations, wonderful botanical environment and Platypus Reserve *(photo 2)*. Platypus Reserve is on a very attractive section of Bombala River, but no platypuses were observed. Locals have told us that platypuses have been quite rare since the recent floods.

Sunday 20th March, 2022.

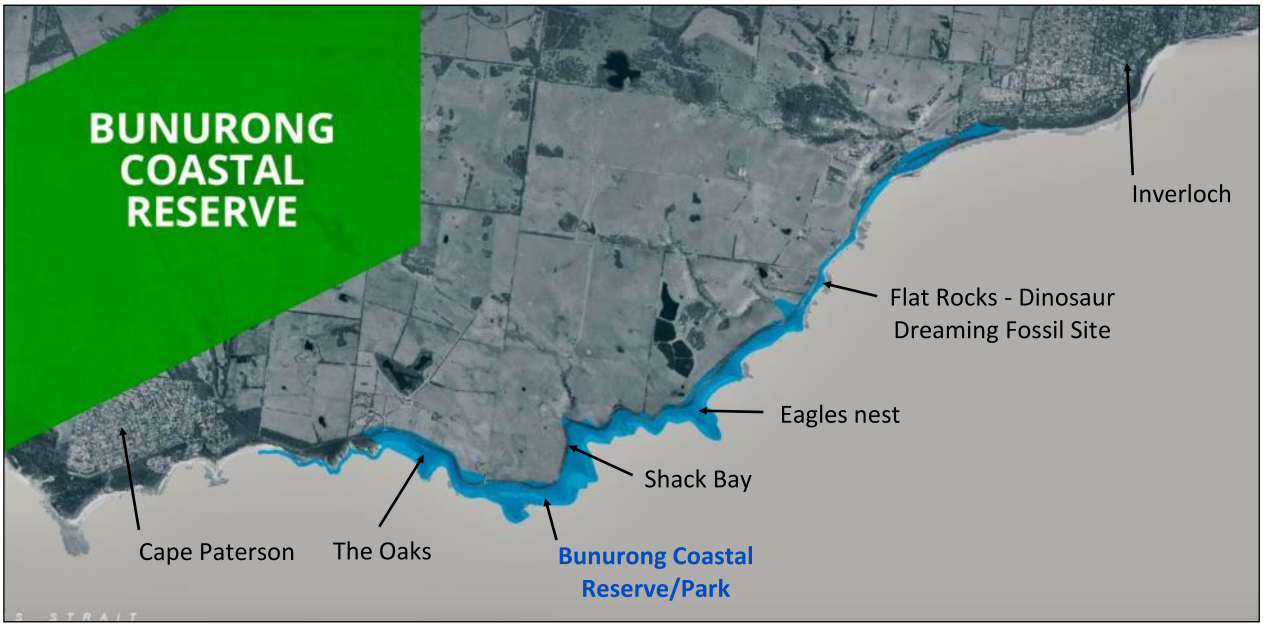
We all drove to Inverloch, a small coastal town a few of kilometres east of Bunurong Coastal Park. On arrival, all just worked on settling in for the next few days and a 5 pm happy hour.

Bunurong Coastal Reserve/Park *(Map 1)* consists of a series of headlands and beaches, although at low tide most of the beaches become expansive rock platforms. Tidal variation is much greater than in NSW. The park is bounded by the sea to the south and a main road to the north. There are 8 entries from the road, 7 of which are staircases. The plan was to visit foreshore areas each morning, with low tides and spend the afternoons in nearby interesting areas.

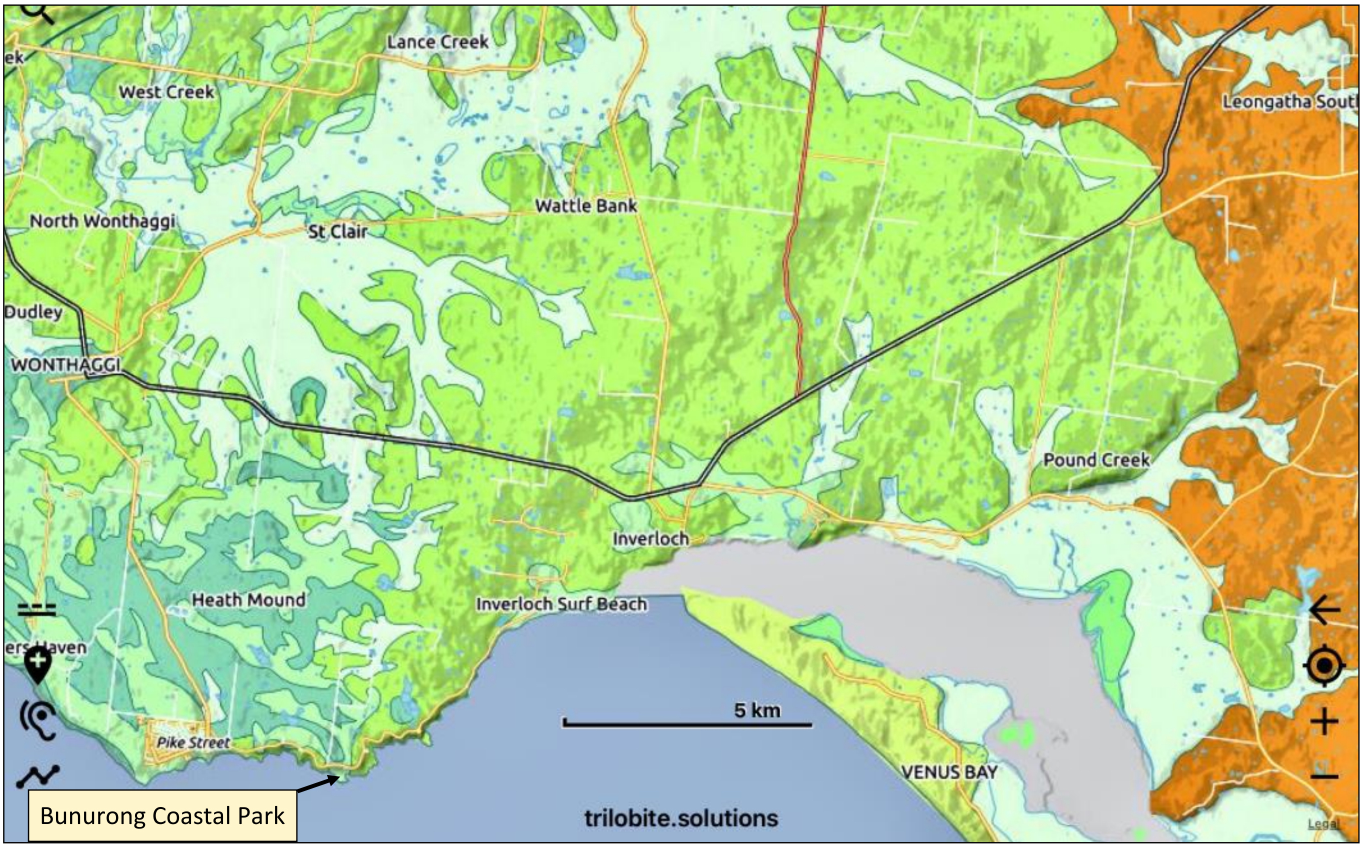
Rocks outcropping along the Bunurong Coastal Park belong to the Wonthaggi Formation *(Map 2)* and are of early Cretaceous age (some 125 Ma). Sediments forming the rocks were deposited in a fluvial environment comprising channelled stream flows and over-bank (flood) deposits. They comprise lithic volcaniclastic sandstone, arkose and siltstone with minor conglomerate and coal. Sandstone forms the major proportion of outcrops along the coast being faulted and tilted in places.

Some 15 km to the east volcanic rocks of the Thorpdale Volcanic Group outcrop. Alkali and tholeiitic basalt are the main rocks found. They were deposited as lava flows from the Paleocene (66 Ma) to the Miocene (23 Ma).

The rocks of the Inverloch region are Cretaceous age, much younger than around home. The rocks near the coast are mostly sandstone, with numerous faults, tilted strata and fairly level topography. Around 10 km inland the topography changes dramatically to very steep -sided hills, in spite of the fact that geological maps show the same geological formations on both sides of the dramatic topography change. With the rich soil, most of the area has been cleared for agriculture, providing beautiful scenery *(photo 3)*.



Map 1. Location of Bunurong Coastal Reserve shown in **blue**.



Map 2. Regional geology of the Inverloch area.

Wonthaggi Formation

Thorpdale Volcanic Group

Pleistocene to Holocene alluvium

Monday 21st March, 2022.

In the morning we went to Shack Bay and walked down 128 steps to the middle of a beach. We then walked to the western end where there was an interesting headland, surrounded by a broad rock platform with numerous areas of fascinating tessellation and at the end an amazing collection of concretions. There were also a lot of interesting formations in the cliffs.

After exploring that area for a while, we walked to the other end of the beach where there was a slightly narrower platform, with slippery surface and lots of fallen boulders. The end of the headland consisted of rock quite different to all the other headlands I have visited, but access was too difficult, but some got close enough to get a reasonable photo. At the carpark, a clifftop walk headed west to a lookout platform, so we did the short walk. The views were to the east and all the headland details were hidden in shadow, so we decided to come back on a cloudy day if we were in the locality.

By then it was too early for lunch, so we had morning tea at the Eagles Nest carpark and then walked around the top of the headland before heading back to camp, stopping at Inverloch Jetty to see if there were any of the giant Stingrays we had heard about, but there weren't any.

After lunch we went to Bunurong Environment Centre, at Inverloch *(photo 4)*. They have one of the most amazing shell collections I have seen and information on local dinosaurs. While looking at the shells, I was approached by Mike Cleeland *(photo 5)*, an Education Officer who leads a lot of school groups on dinosaur tours and even had the largest local dinosaur named after him and a colleague. He heard we were a geology group and he would be happy to lead us to the local dinosaur site. As tides were so important and the lowest tide of the week was on Thursday, around 11 am, we agreed to go with him on Thursday morning.

We then went for a drive to Korumburra, driving through the dramatic change of topography as mentioned above. We had afternoon tea at a bakery in Korumburra and headed back to camp.

Tuesday 22nd March, 2022.

We headed to The Oaks and walked down a track with 78 steps to a beach and then headed east to one of the most amazing headlands I have seen. While walking along the beach, with low tide and calm seas, we walked close to the water with firmer sand and during that walk saw a number of millipedes on the sand, something none of us had ever seen. The headland was surrounded by a broad rock platform with a variety of tessellations and numerous large concretions. There were also some amazing rock patterns and concretions in the cliff faces. Around on the eastern side, the cliff had a number of

1. Rock formation at Bombala Lookout.

2. Bombala River at Platypus Reserve.

3. Typical scenery inland from Inverloch.

fascinating tessellated cliff faces, the like of which I don't recall seeing anywhere else.

To the east of the headland was a small beach before another headland which was surrounded by a similar rock platform. In front of the end of that headland was a hump, a bit like a miniature Eagles Nest, so we all walked out there, past more fascinating rock formations. At the foot of the hump was a petrified log about 5 metres long and surrounded by about 10 cm of

4. Shell display at Bunurong Environment Centre.

5. Mike Cleeland with *Koolasuchus cleelandii* at Wallace Ave Park in Inverloch.

6. Petrified wood on headland east of The Oaks Bunurong Conservation Park.

sandstone *(photo 6)*. There were two gaps in the sandstone cover, so we were able to see that there was a petrified log inside it.

After morning tea at the carpark, we went to the Wonthaggi Coal Mine. The mine stopped working in 1969 and since then has been managed by Parks Victoria, the Victorian equivalent of our NSW NPWS. Up until the COVID outbreak, regular underground tours were organised, but have since been cancelled. While I was preparing the outing, a bit over 12 months ago, I asked if they would be resumed and the lady I was talking to said no. But then, when I mentioned I was planning a geological activity she said "oh yes, we would love run a tour for you. Please let me know when you are running the activity".

The mine *(photo 7)* site is now being managed as a tourist site and visitors are welcome to wander freely through the site and most buildings, including a couple of museums and tours of the above-ground sites are regularly made for school groups. When planning the activity, I wasn't sure how long we would be on the foreshore, so I booked the tour for 2 pm. We arrived in time for an early lunch and most purchased lunch which was absolutely delicious. We then wandered around the site until 2 pm.

At 2 pm we met our guide, Steve, who was as keen as we were because it was 2 years since had had the opportunity to lead a group down there. He turned out to be a very informative person and we all seemed to enjoy a very interesting tour.

Wednesday 23rd March, 2022.

We woke to a cloudy day with quite a few showers, but by the time we started the showers were out to sea and stayed there. In the meantime, the cloudy conditions were great for geological photography.

Our first stop was Eagles Nest *(photo 8)*, probably the number one feature of our trip. From the carpark, we descended 120 steps to the beach on the east side of the headland. We then walked out along an even bigger rock platform with many varieties of tessellation and concretions *(photo 9)*. Last time I was there I found a type of concretion I had never seen before, but this time couldn't find it. On my last trip I also found a concretion weathered to look like a dinosaur about to attack, but I couldn't find it either. Maybe violent seas have caused some changes to the platform. There were still plenty of interesting features and as we walked around the Eagles Nest, a huge geological tower, it kept looking different, so lots of photos were taken.

Towards the western end of the headland were three caves. All relatively small, but two had interesting formations in them. Access was somewhat difficult so only around half the group walked into the caves *(photo 10)*.

After exploring that headland, we walked to the headland at the eastern end of the beach, where there were more fascinating formations, including groups of concretions each about 2 to 3 m in diameter. A few walked on to the next headland which contains 'The Caves'. There is a parking area and staircase with signage indicating The Caves, but the only access is from Eagles Nest. There are 3 caves. One is about 10 metres high and deep and about 15 metres wide and is the only accessible one. The other two are about the same height, but much narrower and with floor level well below sea level.

7. Buildings at Wonthaggi Coal mine.

8. Eagles Nest in Bunurong Conservation Park.

9. Concretions near Eagles Nest in Bunurong Conservation Park.

10. Small cave west of Eagles Nest in Bunurong Conservation Park.

11. *Eucalyptus viminalis* subspecies *pryoriana* along Screw Creek Walk.

12. Messmate forest in Carl Hamann Reserve.

After morning tea, we all went back to camp for lunch, but a few detoured to Shack Bay to get better photos from the clifftop track.

After lunch, we drove to the end of The Esplanade, through the adjoining caravan park, to a carpark at the start of The Screw Creek Nature Walk. The walk starts through vegetated dunes, then a boardwalk over a wetland to a bridge over Screw Creek.

With the tide fairly low, numerous foreshore crabs were seen below the bridge. About 150 metres from the bridge is the start of a loop over Townsend Bluff, providing some nice views and passing some amazing trees. The more spectacular ones were a variety of *Eucalyptus viminalis* or Ribbon Gum *(photo 11)*, which only occurs on the Gippsland coast in southern Victoria. About 50 metres from the bridge a track goes off to the left, leading to two viewing platforms over Screw Creek and a cul-de-sac off the Inverloch-Venus Bay Road.

Thursday 24th March, 2022.

On Thursday we went to the Bunurong Environment Centre to meet Mike Cleeland at 9.30 am. There he gave us an interesting talk about the local dinosaurs and then led us out to The Caves carpark. We descended about 30 steps to the rock platform. Then Mike led us to the east to what must have been an amazing fault. The rocks on both sides of the fault line were quite different and, particularly to the west, quite interesting. He then took us to a dinosaur footprint, which, unfortunately had been damaged by vandals. Nearby he showed us the original dinosaur dig site where many rocks had been removed during early studies. Not far from there he showed us some petrified ferns and some petrified wood.

After that he took us back to near the fault line, where numerous fossils had been found in broken rocks at the base of the cliff. Some important ones had been found by school children on tours, but none of us were lucky to find any.

We then went back to the cars and drove back to the middle of town to a small park in which a life size sculpture has been created of the largest local dinosaur, *Koolasuchus cleelandii (see photo 5)*. It looked to have been an amazing creature and even looked a bit scary as a sculpture.

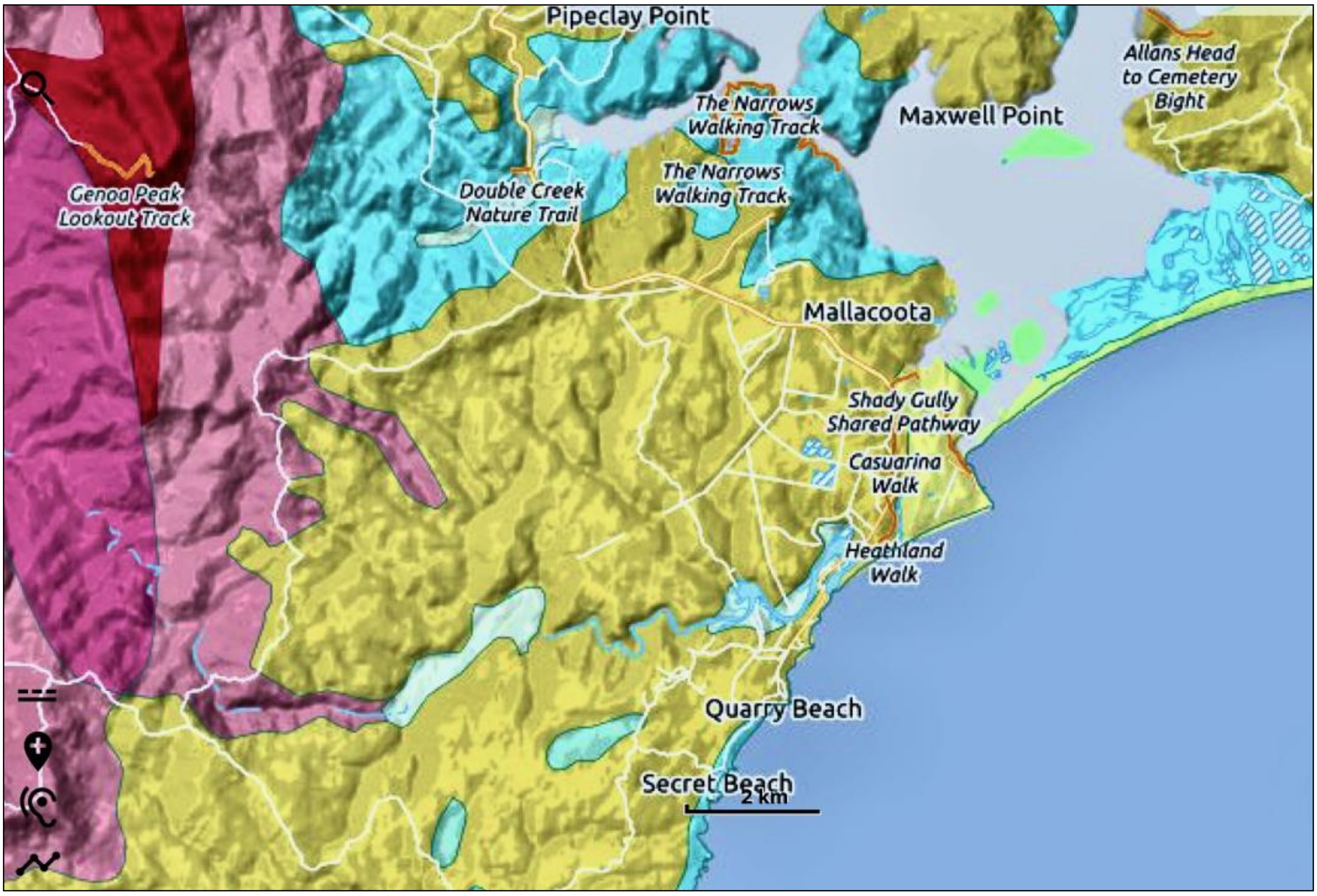
From there it was back to camp for lunch and then we drove to a reserve in an area of the steep hills that had never been cleared. In that reserve was a loop of about 1 km through the most beautiful Messmate (*Eucalyptus obliqua*) forest *(photo 12)* I have seen. Forests of that species are quite common in higher areas in NSW, south from the Barrington Tops, but although often very attractive, not as great as in this reserve. Halfway around the loop was a side track to a creek, but recently fallen trees had blocked that track.

As some of the group were unable to go to Korumburra on Monday, I decided to return to camp via Korumburra so all could see that scenery and others could see a bit more.

Back at camp we had a happy hour to discus the trip to Mallacoota.

Friday 25th March, 2022.

After packing up, we drove to Mallacoota. Most of the places worth visiting along the way had access unsuitable for caravans, so we just drove through and



Map 3. Regional geology of the Malacoota area.

Lower Devonian Granites.

Miocene to Pliocene Sale Group.

Lower Ordovician Pinnak Sandstone.

set up camp. I went to the information centre and found that Secret Beach was now accessible and got some more detail on the Mallacoota Coastal Walk.

To the west of Mallacoota, granitic rocks of Lower Devonian age outcrop (pinks and reds on Map 3) while Lower Ordovician rocks of Pinnak Sandstone (blue on Map 3) outcrop along the shoreline and to the north of Mallacoota. Sandstone is the dominant rock found with minor siltstone and rare cherts that can be seen at Quarry Beach.

Miocene to Pliocene clastics and carbonate sediments (gravels, siltstone, claystone and sandstone) of the Sale Group (yellow on Map 3) cover much of the land south west of Mallacoota.

Pinnak Sandstone rocks have been folded and faulted in the past by a subduction event where an oceanic plate slides beneath a continental plate, causing the earth to buckle into folds.

Saturday 26th March, 2022.

With a low tide at 10 am, we made sure we got away early and headed straight to Secret Beach. It was so named because it was supposed to be inaccessible, but a stairway has been constructed through a steep valley and we walked down 67 steps to a track through a hind dune forest to the middle of the beach.

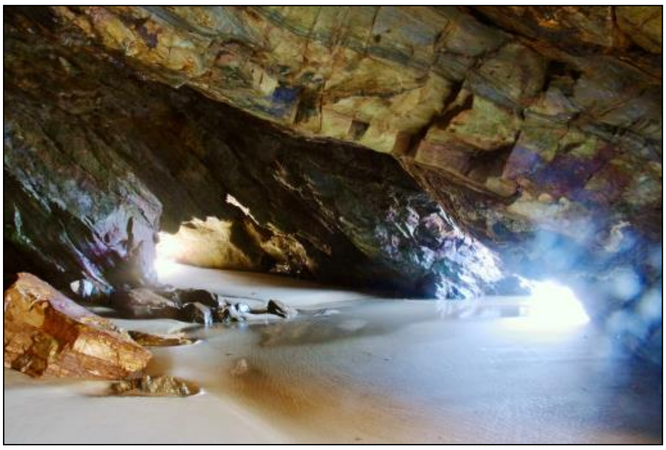
At the beach, we headed east to a headland *(photo 13)* which was supposed to have a cave, or caves, in it. As it turned out there was one cave with three entrances. The middle one was in water, so we walked into the western entry. Inside the cave *(photo 14)* were some amazing rock formations. To exit the eastern entrance, we had to get on our hands and knees and crawl out. Through the cave was a small beach less than 100 metres long leading to another headland. The rocks on that beach and in the water were absolutely amazing, so plenty of photos were taken.

We then walked down to the western end of the beach where there were more interesting rocks and a fascinating rock platform composed of vertical strata *(photo 15)*. On my last trip I found similar formations on Pebbly Beach, a little further to the west.

We then went to Quarry Beach for morning tea. The carpark is in a small former quarry, with some interesting rock formations in the wall. After morning tea, we walked east about 100 metres to another former quarry on the foreshore. How they got the machinery in or the rocks out is totally mystifying, but they obviously did and the rock formations in the wall were amazing. They are highly deformed turbidites of Ordovician age. *(photo 16)*. Last time I was there, I was able to

13. Headland containing cave at Secret Beach.

15. Rock formations at west end of Secret Beach.



14. Other two entrances to cave at Secret Beach.

walk around the eastern wall of the quarry to a beach where there were even more amazing rock formations, but recent beach erosion has made that impossible.

We noticed that the Mallacoota Coastal Walk now comes down to the carpark, so we decided to walk up the 47 steps and see if there were any viewpoints above the quarry. As it turned out there weren't, but we walked almost all the way to Geology Point, to a viewpoint with great views to the west.

We then decided to drive to Betka Beach for lunch, but when we got there some decided it was too early for lunch, so we decided to do an anticlockwise walk around the Betka Loop. It was a 1.9 km walk along the Betka River foreshore, then over the road to the coast and clifftop or beach walk back to the cars. Along

16. Folded and faulted turbidites, Quarry Beach.

the coastal foreshore were more fascinating rocks. Much of the walk was through former paperbark forest but the recent bushfire was severe enough to kill all the trees, so much of the walk was fascinating, through leafless, black trees in a carpet of bright green regrowth about 1 metre high *(photo 17)*.

After lunch we decided to do a car shuffle and walk the Mallacoota Coastal Walk to Geology Point *(photo 18)*. Along the way the vegetation was similar to the loop walk and there were some fascinating rock formations along the foreshore. There were also some fascinating views along the coastline in both directions.

At Geology Point the rock formations were amazing, with fascinating patterns and two tunnels. The Point is a headland with a valley in it. A lookout platform has been constructed to provide an amazing view of the rock formations on the western side of the valley.

I decided to lead a group along some faint tracks on the top of the headland to the east of the valley to where we could look through the tunnel on the western side of the valley.

I then led the group along similar faint tracks on the western side of the valley to where we could look through the tunnel on the eastern side of the valley and get a great view of the coastline to the west.

After that we headed back to camp, but it was only mid afternoon, so most of the group joined me on the Double Creek Nature Walk, a 1 km loop along Double Creek and through incredibly tall forest. I couldn't find any fruit or buds, but, as the trees were so tall, I assume they were Southern Blue Gum.

At 6.30 we were picked up by a courtesy bus and taken to the golf club for dinner, which turned out to be a rather large, but very delicious meal.

Sunday 17th March, 2022.

At 2 am, the whole of the town was blacked out and no power was returned until 11 am, so we had to pack up without power or lights and then the group all made their own way home.

Photographs by Barry Collier.

Edited by Ron Evans and Brian England.

References.

Bunurong Coastal Reserve. www.parks.vic.gov.au

Australian Geology Travel Maps - Vic geology detailed.

17. Mallacoota Coastal Walk near Point Difficult.

18. Western side of bay at Geology Point.

Members of the AGSHV being given an explanation by Mike Cleeland, of how a piece of petrified wood formed.

Pokolbin Inlier Field Trip Part 2

Leaders: Ron Evans and Brian England.
Date: Saturday 6th August 2022.
Attendance: 17 members, 1 visitor.

Attendees met at 9:30 am at the Hunter Valley Gardens top car park picnic area where carpooling was arranged to allow a maximum of five vehicles. The purpose of the excursion was to examine some of the structures and rock types to the north of the Pokolbin Inlier, which was explored in June 2021 (Evans and England, 2021). Local geology of the area is shown in Maps 2 and 3.

The structure and geomorphology of the area has been influenced by the Lochinvar Anticline and transpression *(see footnote)* along a complicated fault array (Willey, 2010). Willey (2010) suggests that the Pokolbin Inlier "popped up" as a restraining bend positive flower structure. This dextral transgression is thought to have occurred pre Bimbadeen Basalt, with further movement before deposition of the Singleton Super Group. It had ceased before deposition of the Narrabeen Group.

We set off in convoy and returned to McDonalds Road, turning right at the intersection. After 5.6 kilometres we turned right into Pokolbin Mountains Road and proceeded past Baringbah Winery and Tinkler's Wines. The convoy followed this steep narrow dirt road up the side of the ridge and after 2.3 kilometres reached the saddle connecting this ridge with the Broken Back Range. Here we turned right into Broken Back Road and continued along this unsealed all-weather road through private land for a further 11.6 kilometres up the thickly wooded northern side of the range and then along the ridge top to the parking bay at the communication towers at the northern edge of the Broken Back Range. The route taken is shown in *Map 1* and follows that outlined in Gilmore and Greenfield (2012). Unsurprisingly, we passed several small landslides and fallen trees which had been cleared from the road after the recent heavy rains to allow access to the towers.

Arriving at the base of the towers people made preparations for morning coffee while Brian explained the local stratigraphy *(Table 1)* and geology using several maps and diagrams pinned by bluetac to the side windows of Ron's vehicle *(photo 1)*. During our return to Hunter Valley Gardens Brian gave a running commentary on the geology over the radios.

Site 1/Stop 1.

The Communication towers are located on a ridge of Banks Wall Sandstone Member in the Triassic Narrabeen Group. Views are restricted by trees but looking to the northwest through a gap in the forest the relatively flat undulating topography in the foreground can be seen, formed over Late Permian sediments with Dalwood Group rocks in the foreground to the east and Maitland Group rocks to the west. The high ridge on the horizon is composed of Carboniferous rocks of the New England Orogen *(photo 2)*.

The convoy then returned along Broken Back Road passing bouldery outcrops of Banks Wall Sandstone along the ridge top on the left, before pulling in to a prominent cutting on the left after 6.4 kilometres. This was the first opportunity to park and examine the Banks Wall Sandstone up close at what proved to be the best outcrop of this formation anywhere along the road.

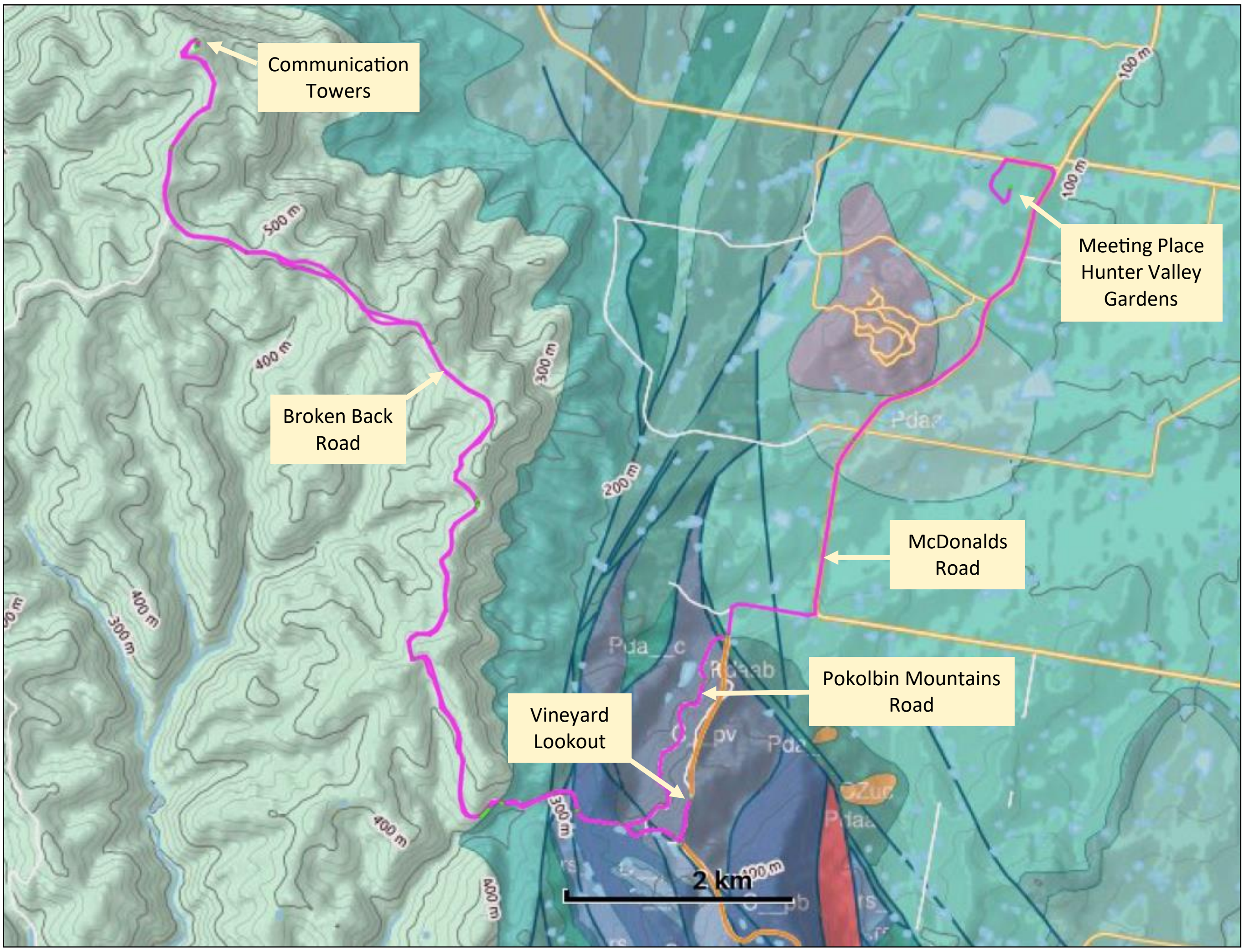
Site 2/Stop 2.

The sandstone here is thickly bedded, fine grained and massive with no obvious intraformational structures such as cross bedding *(photo 3)*.

In this area the Banks Wall Sandstone is the highest unit visible in the Triassic Narrabeen Group. Paleocurrent direction is generally from the northwest, unlike in the overlying Hawkesbury Sandstone where it is from the southwest *(Figure 1)*. The rock is generally relatively fine grained and quartzose with only a small

1. Brian, with the aid of diagrams, explaining the local stratigraphy.

2. View north into the Hunter Valley from the Communication Towers on Broken Back Range.



Map 1. The route taken on the field trip shown by the pink line.

3. Outcrop of Banks Wall Sandstone in a road cutting.

4. Cross bedding in an outcrop of Banks Wall Sandstone.

number of lithic fragments. There are numerous greenish claystone horizons which probably give rise to the abundance of small caves at certain levels in the outcrops. These sediments were deposited on a fluvio-deltaic plain sandwiched between the New England Fold Belt and the Lachlan Fold Belt *(see Figure 2)*. Maximum thickness in the western Blue Mountains is 115 metres with the unit thickening gradually and uniformly eastwards (Herbert & Helby, 1980).

Site 3.

Ten kilometres from the towers the road cutting on the left shows excellent examples of cross bedding in the Banks Wall Sandstone *(photo 4)*. It was not possible to park here without blocking the road so each vehicle paused only briefly.

PERIOD	FACIES/SETTINGS	STRATIGRAPHY IN THE MOUNT VIEW AREA			CORRELATIVES
Triassic	Terrestrial (fluviatile) to deltaic	Narrabeen Group			
Permian	Terrestrial (fluviatile), deltaic, minor marine	Singleton Super-Group	Wollombi Coal Measures	Newcastle Coal Measures	
			Wittingham Coal Measures	Tomago Coal Merasures	
	Shallow marine, marine transgression	Maitland Group		(Mulbring Siltstone)	
				Muree Sandstone)	
				Branxton Formation	
				Cessnock Sandstone Member	
	Alluvial to deltaic	Greta Coal Measures			
	Shallow marine	Dalwood Group		Farley Formation	Basalts in Lochinvar Formation & Gunnedah, Weribee & Myall Synclines
				Rutherford Formation	
				Allandale Formation	
				Lochinvar Formation	
				Unit VI (Bimbadeen Basalt)	
		Ungrouped		Unit V	
				Unit IV	
				Unit III	
Carboniferous	Periglacial	Seaham Formation		Unit II	
				Unit I	
		Pokolbin Hills Volcanics		Mount Bright Rhyolite Ignimbrite Member	Paterson Volcanics (308±4 Ma, K-Ar, Roberts et al 1991
				Flying Fox Trachyte Member	
				Matthews Gap Dacitic Tuff Member (309±3 Ma, U-Pb, Gulson et al 1990)	
				Vineyard Lookout Volcanic Agglomerate Member	Mount Johnson Formation
					Gilmore (~331 Ma, K-Ar, Roberts et al 1991 & Nerong V0lcanics
	I-type intrusion	Mount View Range Granodiorite (349±2.1 Ma, U-Pb, Jeong 2012)			

Table 1. Stratigraphy in the Mount View area covered by the field trip. Yellow shading indicates the rock units encountered. Modified from Gilmore and Greenfield (2012).

Site 4.

After a further 0.2 kilometres the road crosses the boundary between the Banks Wall Sandstone and the underlying Singleton Super-Group. The boundary is not visible on the ground so the convoy kept moving.

The Singleton Super-Group is the time equivalent to the Newcastle Coal Measures that lie west of the Lochinvar Anticline. These rocks were formerly grouped under Singleton Coal Measures because direct correlation with the Newcastle area was lacking. But more recently the Wittingham and Wollombi Coal Measures have been recognised as Tomago and Newcastle equivalents within the Singleton Super-Group. The deposition of these sediments was contemporaneous with the development of the Lochinvar Anticline and lap onto it (Herbert & Helby, 1980).

Site 5.

At 10.7 kilometres from the towers the road crosses the Mathews Gap Fault which runs along the base of the ridge the road has just descended. This fault separates the Singleton Super-Group from the underlying Branxton Formation Member of the Maitland Group which was deposited during a steady marine transgression following deposition of the Greta Coal Measures from a north to northwest source area. The actual location of the fault is not visible so the convoy did not stop here. Note that there is no outcrop

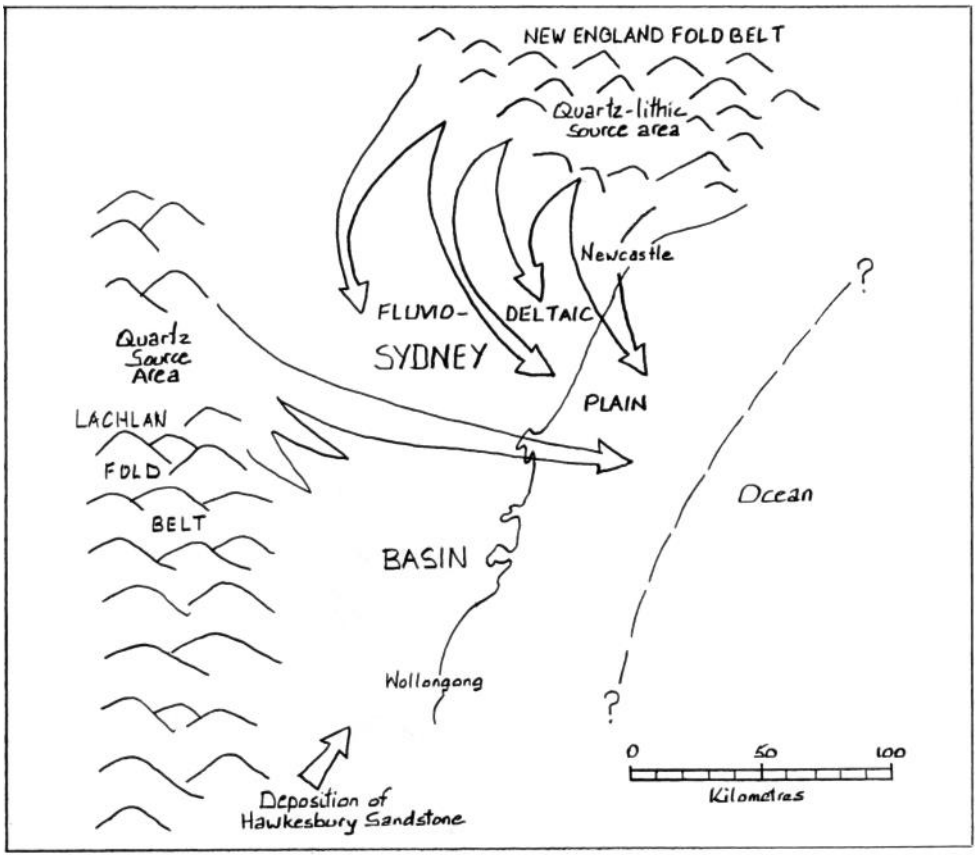


Figure 1.

Palaeogeography of the Sydney Basin during deposition in the middle of the upper Narrabeen Group showing sediment sources for the Banks Wall Sandstone and later Hawkesbury Sandstone. Modified from Herbert & Helby, 1980.

of the underlying Dalwood Group (Rutherford and Allandale Formations) here, suggesting the area was either emergent or a basement high at that time.

Site 6.

At 10.9 kilometres lies the boundary between the Permian Branxton Formation and the underlying Late Carboniferous Seaham Formation, here exposed as a silicic mudstone. But the outcrop is very poor so the convoy continued on to Stop 3 where the Seaham Formation is better exposed.

Site 7.

At 11.1 kilometres from the towers lies the boundary between the mudstone and silicic (acid) conglomerate components of the Carboniferous Seaham Formation. There is no outcrop here so we continued on to Site 8.

Site 8/Stop 3.

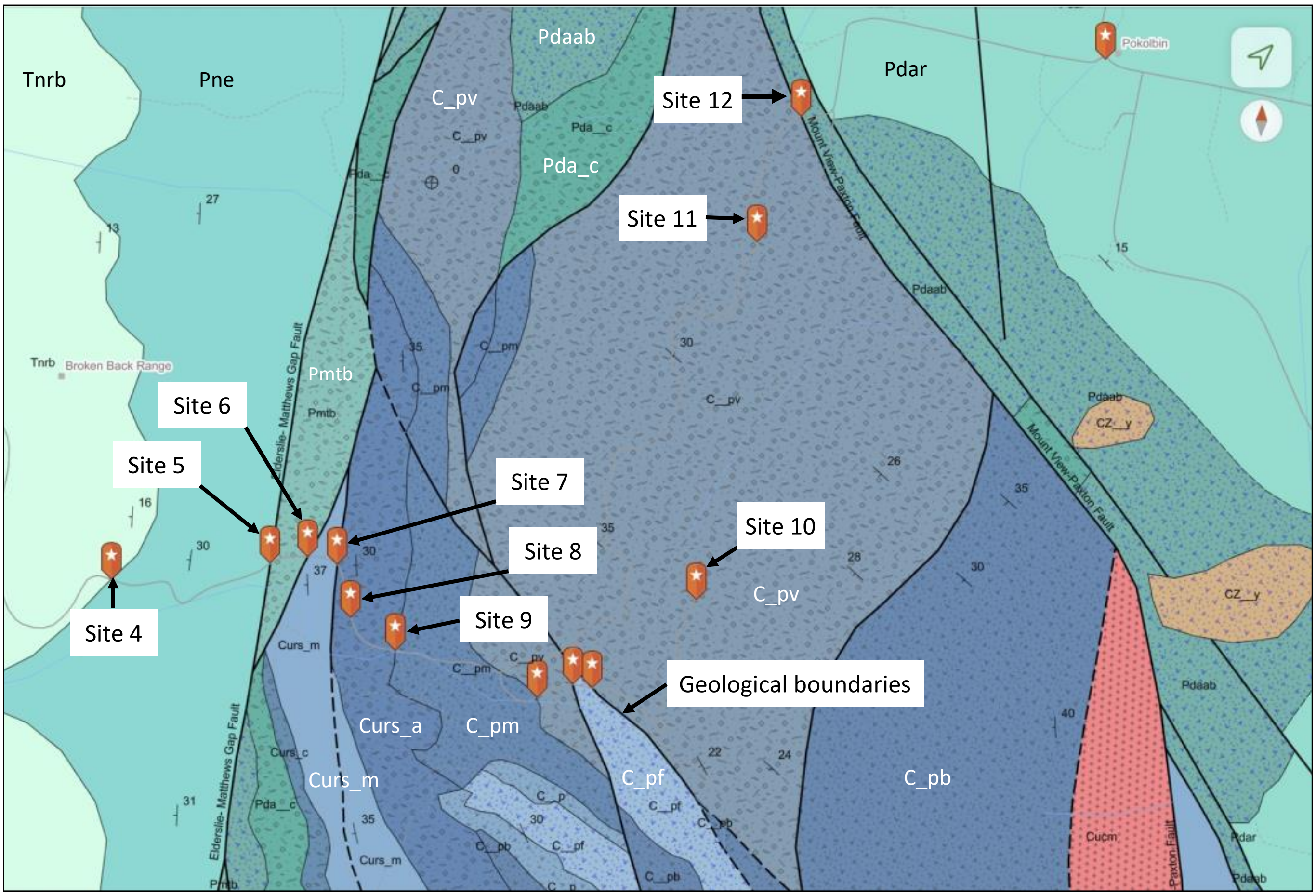
At 11.2 kilometres, just beyond the cattle grid, the convoy found ample parking on the right side of the road. Here the silicic conglomerate component of the Seaham Formation is well exposed in the cutting on the left *(photo 5)*.

Paleocurrent studies in these conglomerates show that clastic detritus from mountain glaciers was fluvially transported in a northern to eastern direction from highlands trending northwest to southeast, 80 to 320 kilometres away. These highlands existed immediately to the south of the present Hunter Valley and are now covered by Sydney Basin sediments (Herbert & Helby, 1980). Gravels derived from these glaciers were deposited by braided streams in river valleys entrenched in the Pokolbin Hills Volcanics while finer sediments (such as varved shales) were deposited as outwash in lakes across the Paterson Volcanics further to the east *(Figure 2)*. The Paterson Volcanics are correlative with the Pokolbin Hills Volcanics.

Site 9.

At 11.2 kilometres the Mathews Gap Dacitic Tuff Member of the Pokolbin Hills Volcanics outcrops but here is very limited outcrop so the convoy did not stop.

The end of Broken Back Road was reached at 11.6 kilometres and the convoy turned right towards the Vineyards Lookout. After 0.6 kilometres the road swung sharply to the left towards the lookout. The track to the



Map 2 - Indicates sites visited (4 - 12), geological boundaries and structures.

Key:

Tnrb	Banks Wall Sandstone.	Pne	Singleton Super Group
Pmtb	Branxton Formation	Pdaab	Bimbadeen Basalt
Pda_c	Dalwood Group - Conglomerate	Pdar	Rutherford Formation
Curs_m	Seaham Formation - Mudstone	Curs_a	Seaham Formation - Acid Conglomerate
C_pm	Matthews Gap Dacitic Tuff Member	C_pf	Flying Fox Gully Trachyandesite Member
C_pv	Vineyard Lookout Volcanic Agglomerate	C_pb	Mount Bright Rhyolitic Ignimbrite Member

right at this point is the west end of the Watagan Fire Trail from Mount Bright Lookout which was visited on the first Pokolbin Inlier excursion but this trail is blocked to vehicle access by a gate part way along.

Site 10/ Stop 4.

The parking bay on Vineyards Lookout lies on an outcrop of the Vineyard Lookout Volcanic Agglomerate at the base of the Pokolbin Hills Volcanics. Outcrop here is poor but the lookout provides excellent overview of the geomorphology of the Lower Hunter Region. The tree-shrouded white cliffs of the Mount Bright Rhyolitic Ignimbrite *(photo 6)* in the Pokolbin Hills Volcanics at the west end of the Mount View Range are visible to the east. The view to the north and northeast overlooks the Early Permian Dalwood Group on the north flank of the Lochinvar Anticline. The hills in the distance are Carboniferous rocks of the New England Orogen on the north side of the Hunter Thrust fault. To the west and northwest are high ridges capped by the early Triassic Narrabeen Group represented by the Banks Wall Sandstone.

We then returned to the Broken Back Road intersection and continued through on Pokolbin Mountains Road.

5. Seaham Formation - outcrop of acid conglomerate.

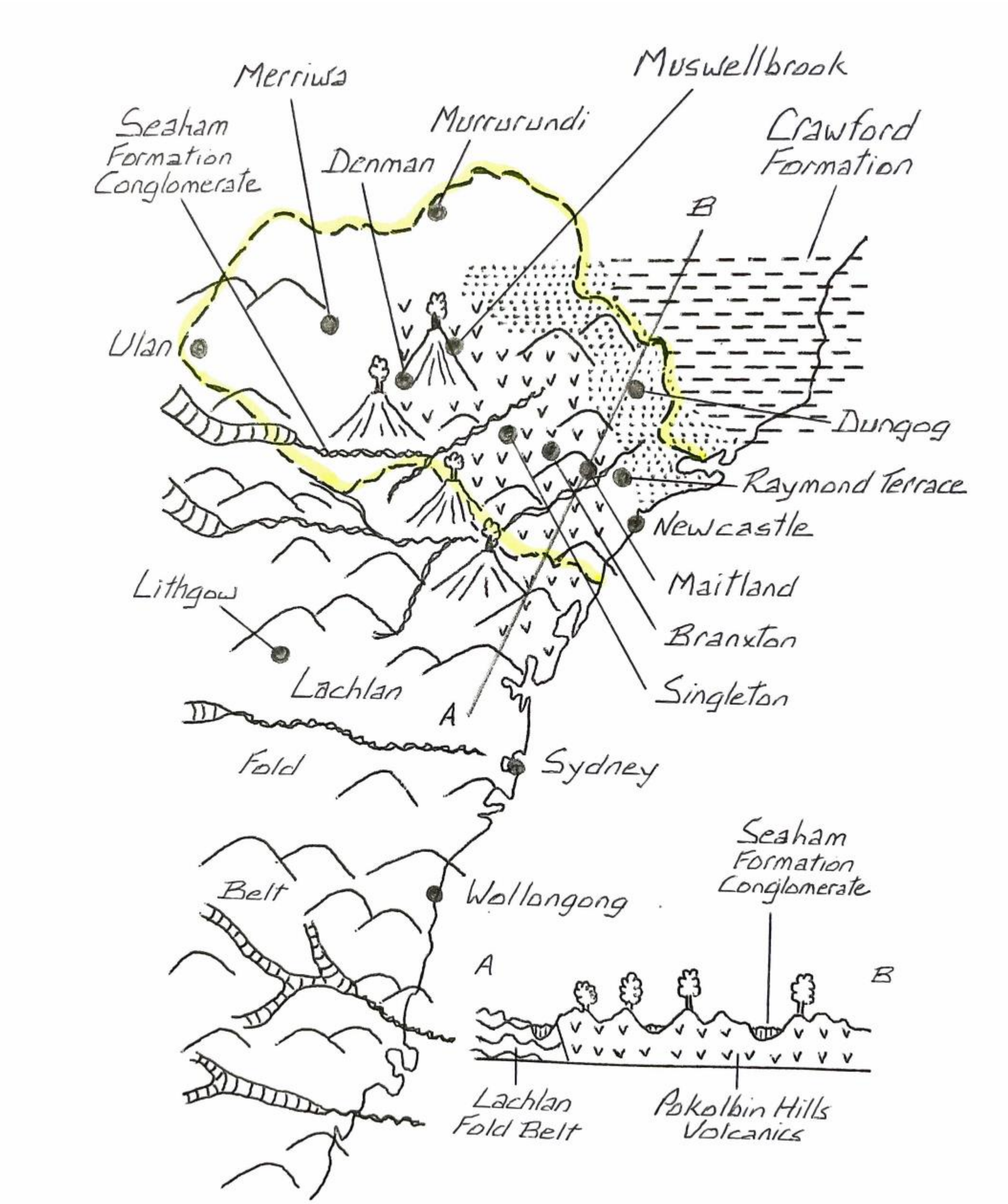


Figure 2.

In the Late Carboniferous to Early Permian the presently defined outline of the Sydney Basin had not yet evolved. The area consisted of a glaciated mountain terrain with an active volcanic rift zone to the north and marine conditions in the northeast with Early Permian pro-deltaic, intertidal to swamp sediments deposited across a broad continental shelf, transgressing the Lachlan Fold Belt. Seaham Formation conglomerates were laid down by braided streams coming from alpine and valley glaciers to the west, between the Late Carboniferous volcanic peaks of the Pokolbin Hills Volcanics, which have been correlated with the Paterson Volcanics. The Pokolbin Hills Volcanics are underlaid by the Mount View Range Granodiorite which today is only seen in faulted contact with the more recent overlying rocks.

On the way the road crosses a narrow patch of Flying Fox Trachyte in the Pokolbin Hills Volcanics but there is no outcrop. A crystal-rich hornblende ignimbrite, also within the Pokolbin Hills Volcanics, outcrops at the road intersection and at other places back down Pokolbin Mountains Road but although outcrop is good the rock is deeply weathered and not worthy of close inspection.

Site 11/Stop 5.

At 1.8 kilometres from the road intersection the convoy was able to pull in to a small parking bay on the right *(photo 7)*. In the road gutter here are better exposed outcrops of the Vineyard Lookout Agglomerate Member of the Pokolbin Hills Volcanics, clearly showing the angular to sub-angular nature of the rock fragments *(photos 8 & 9)*.

Site 12.

At 2.2 kilometres from the road junction the Pokolbin Mountains Road crosses the Mount View/ Paxton Fault into the Permian Bimbadeen Basalt but outcrops are very poor.

The boundary between the Bimbadeen Basalt and the overlying Rutherford Formation occurs 100 m further on at 2.3 kilometres, just before the track leading off to the right at the pepper trees. There is no outcrop here.

The Rutherford Formation consists of fine sediments and sporadic basalts. Soils developed on this formation support many of the Hunter Valley vineyards.

At the end of Pokolbin Mountains Road we turned left into McDonalds Road.

Site 13.

At the white gates forming the entry into the Pokolbin Community Recreation Reserve lies the boundary between the Allandale Formation and the overlying Rutherford Formation. Outcrop here is very poor *(see Map 3)*.

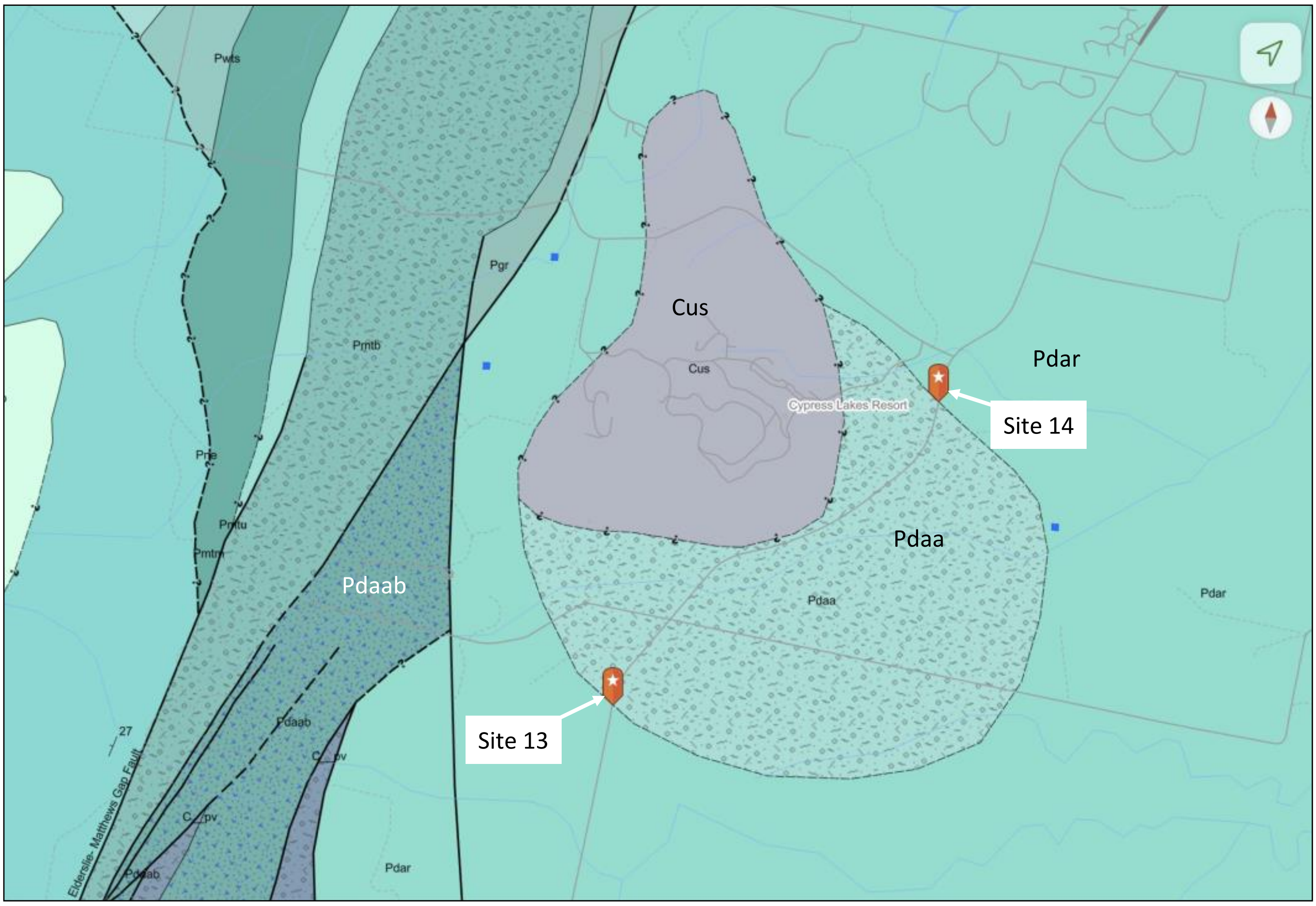
The upper Dalwood Group rocks were deposited around the edge of the Pokolbin Inlier which was a basement high at that time and so dip away from the inlier. Hence here the Rutherford Formation overlies the Allandale Formation, which overlies the Bimbadeen Basalt.

Cyprus Lakes Resort occupies the wooded hill on the left. This is an inlier of ungrouped Carboniferous rocks within the Upper Permian Dalwood Group. This may have been another topographic high at that time.

6. View south to the white cliffs of the Mount Bright Rhyolitic Ignimbrite in the Pokolbin Hills Volcanics.

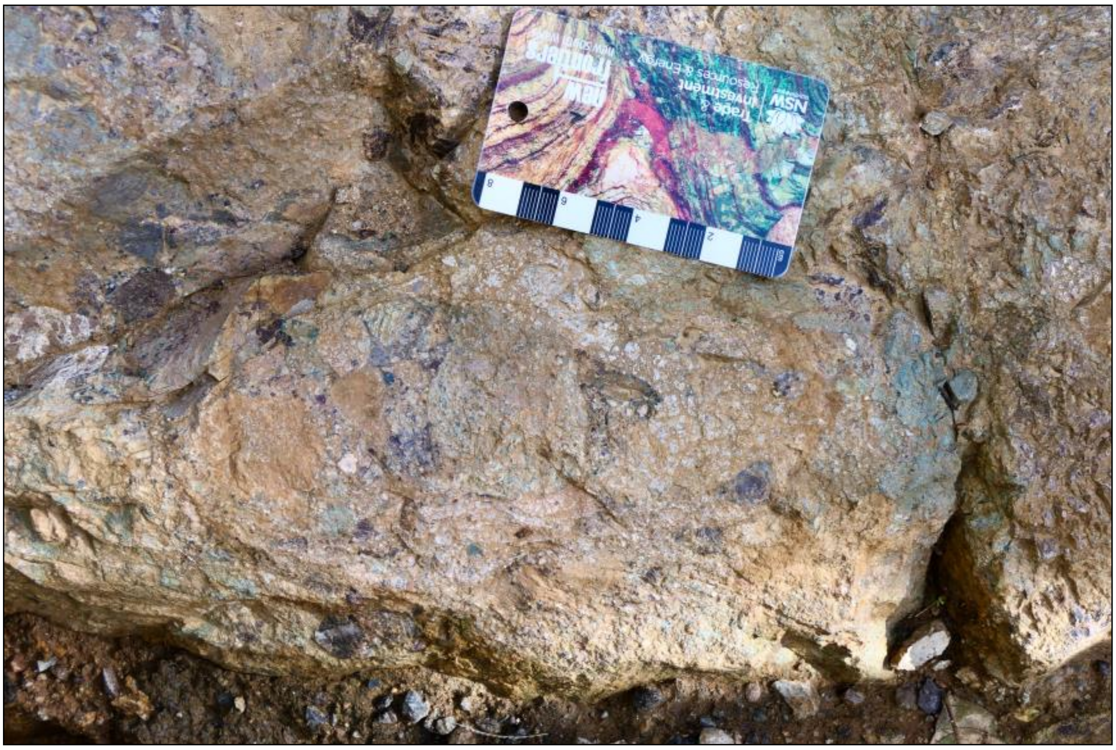
7. Stop 5 on Pokolbin Mountains Road. Vineyard Lookout Volcanic Agglomerate Member exposed in the gutter on the right-hand side of the road.

8. Vineyard Lookout Volcanic Agglomerate exposed in the gutter. Note the mixture of different sized angular rock fragments.



Map 3. A small inlier composed of older Carboniferous rocks (Cus) and Permian Allandale Formation (Pdaa) overlying younger Rutherford Formation (Pdar) rocks.

Key:				
	Pdar	Rutherford Formation	Pdaa	Allandale Formation
	Pdaab	Bimbadeen Basalt	Cus	Ungrouped Carboniferous units



9. Sample of Vineyard Lookout Volcanic Agglomerate, an agglomerate of angular trachytic and trachyandesitic fragments.

Site 14.

At 4.1 kilometres from the Pokolbin Mountains Road intersection at the Pokolbin Estate and just before the Thompsons Road sign lies the boundary between the Rutherford Formation and the underlying Allandale Formation, but outcrop is poor.

Report by Brian England and Ron Evans.
Photographs by Ron Evans.

Acknowledgements.

Figure 3 modified from Figure 2.6 in Herbert and Helby *(1980).*

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Footnote.

Transpression is a type of strike-slip deformation that deviates from simple shear because of a simultaneous component of shortening perpendicular to the fault plane. This movement ends up resulting in oblique shear (Wikipedia).

Geological Tour - Flinders Ranges

Geological Safari 2022

Saturday 10^{th} to Friday 30^{th} September

Leaders: Brian and Barbara Dunn and Sue Rogers.

Attendance: 14 members.

Preamble.

The first Geological Safari conducted by the AGSHV occurred from Saturday 20^{th} May to Sunday 4^{th} June 1995 in the Flinders Ranges (see England, 1995).

The trip was organised by John Cater and ably led by Brian England. 12 members participated.

Participants flew to Adelaide on Saturday 20^{th} May arriving at 12:15 pm. An 18 seater coach minus the last two rows of seats (making room for luggage) was transport for the trip. John Cater and Bob Bagnall who were licensed to drive a bus shared the driving.

Accommodation was a motel in Adelaide on the first and last nights, caravan park cabins in Melrose, Quorn, Rawnsley Park, Arkaroola Village and a night in the Blinman Hotel.

The group bulk-catered for breakfast and lunches and snacks with the evening meal in a nearby hotel or restaurant.

Most days started early; breakfast and preparing lunch, morning and afternoon teas before departing for the days activity around 7-8 am and returning around 5 pm.

Many of the activities involved lots of walking. Brian was getting us fit for a BIG walk at Arkaroola, some 22 km return to and from Mt. Painter via Radium Creek, the old prospectors route.

Some of the comments on the attendance sheet by the end of the trip included:

"Well- you nearly killed me mate. But I loved every minute of it".

"I've learnt to climb rocks, slip on rocks, fall on rocks, but seriously thanks a million for showing us something unique".

"To Captain Bligh. A hard taskmaster, but fair, hard walks, early mornings, late afternoons, but for all that very interesting, great scenery, rocks and company".

"Well, we did it - I don't know which was the most horrid, Rawnsley Bluff or the trek up to Mount Gee. They were both horrendous".

AGSHV Members at Arkaroola.

Brian England and John Cater standing.

Joan Robinson, Barry Collier, Stan Madden, Norm Rabbet, Jill and Bob Bagnall, Elaine Collier and Ron Evans.

Janet Cater and Ellen Evans sitting.

Introduction.

The following was extracted from the field notes for the safari that were prepared by Ron Evans.

Formation of the Flinders Ranges.

The Flinders Ranges form part of an eroded mountain chain some 600 km long stretching from Kangaroo Island in the south through the Mt Lofty Ranges and Flinders Ranges to Maree and beyond. The elevation of almost all of the ranges is above 300 m, and locally peak elevations exceed about 1100 m.

The Flinders Ranges began their formation in a subsiding sedimentary basin called the Adelaide Geosyncline (also known as Adelaide Rift Complex), a major geological province in central South Australia *(Figure 1).* It is a great belt of sediments, deposited in depressions (rift valleys) during a time of lithospheric stretching in an arc approximately a thousand kilometres long and several hundred kilometres wide. The thickest parts of the belt are approximately 24,000 m thick. Limestones, shales, and sandstones indicate a predominantly marine environment *Figure 2).* The crystalline basement rocks that the sediments were deposited on were formed 1.5 billion years ago and are exposed near Arkaroola.

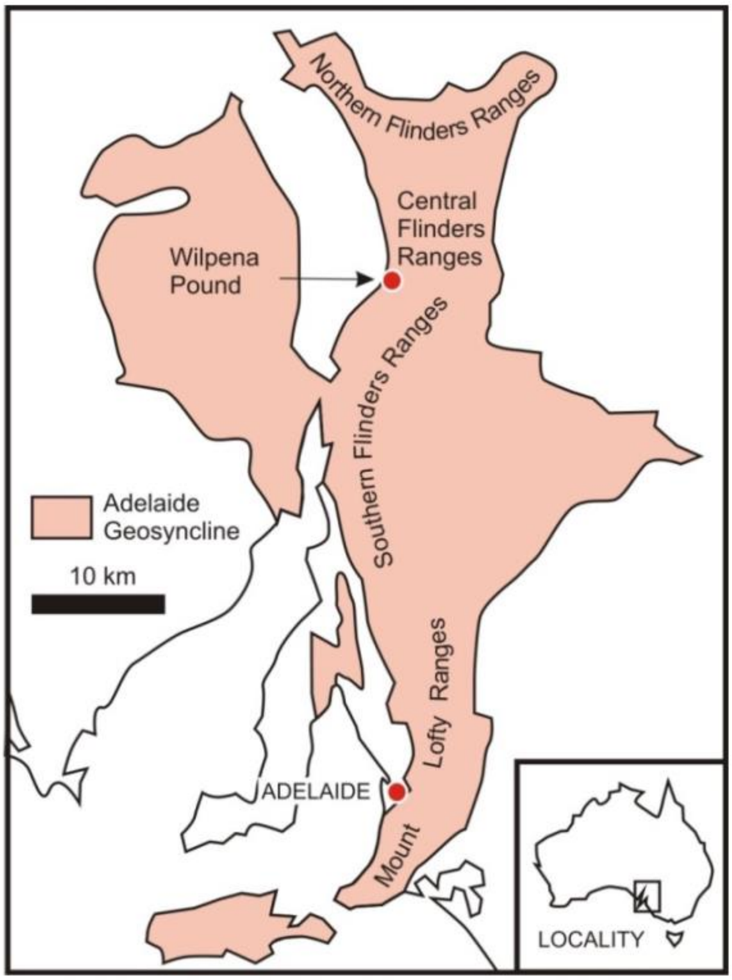


Figure 1: Location of the Adelaide Geosyncline and the Flinders Ranges (Abbott).

The sediments in the rift complex were deposited between about 870 Ma (the middle Neoproterozoic) to ~500 Ma (the end of the Cambrian). They consist of a thick pile of sedimentary rocks and minor volcanic rocks that were deposited on the eastern margin of Australia during the time of breakup of the supercontinent Rodinia.

Rodinia, meaning "to give birth", is the name of a supercontinent that comprised most or all of Earth's landmass when the Neoproterozoic era began. It existed between 1.1 billion and 750 million years ago.

Sedimentation in the geosyncline ended towards the Cambrian, when plate movements changed and the area experienced an orogeny (mountain-building period) extending into the Ordovician. Foden et al. (2006) suggest that this orogeny lasted from ~514 ± 3 Ma and persisted for ~24 Ma to 490 ± 3 Ma.

This event is called the Delamerian Orogeny, named after Delamere, a small town on the Fleurieu Peninsula where evidence was found for the event. The orogeny caused substantial folding, buckling, and faulting of the strata, and resulted in the creation of a major mountain range, the eroded stumps of which can today be seen as the Mount Lofty and Flinders Ranges.

The formation of the Adelaide Geosyncline is poorly understood. However, some geologists believe at least 5 phases of rifting occurred.

Initially, stretching and thinning of the crust caused depressions which, due to faulting, formed troughs into which the sea eventually flowed. Because there was no vegetation on land, unrestricted erosion occurred washing huge volumes of sediment into the shallow seas and lakes to form sandy plains, alluvial fans and river deltas *(Figure 3).*

A severe climate cooling about 700 Ma (Cryogenian Epoch) caused a major ice age over much of Australia. Glaciers in the area disgorged their loads of rock debris into the sea and icebergs occasionally dropped boulders into the fine-grained marine sediments which formed tillites *(Figure 4).*

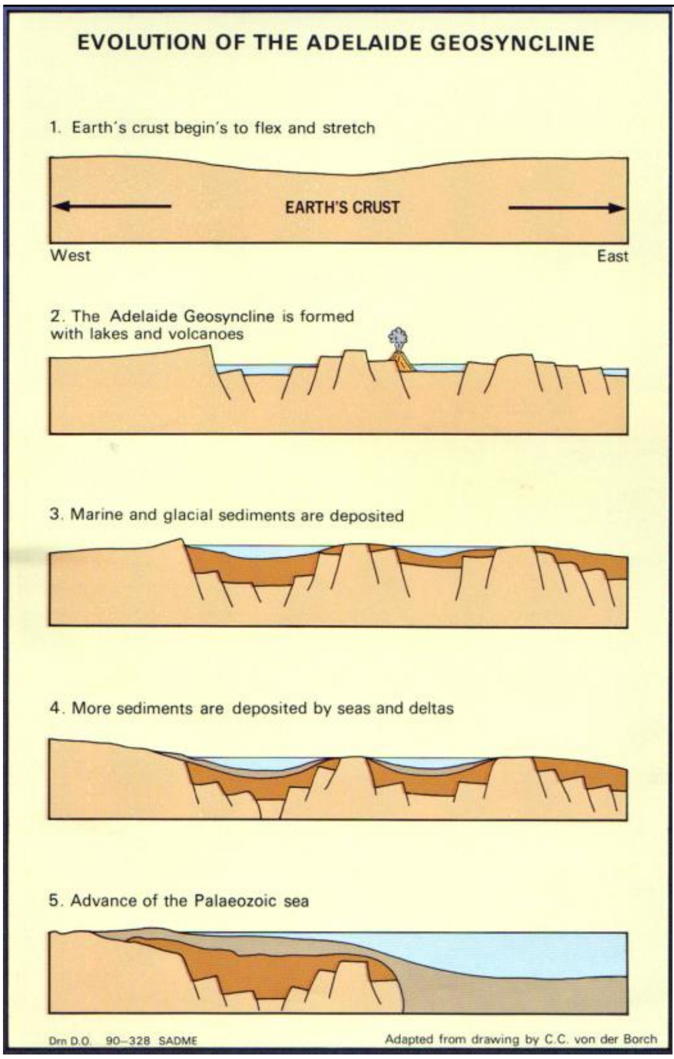


Figure 2: Summary of the Adelaide Geosyncline formation. (Selby, 1990).

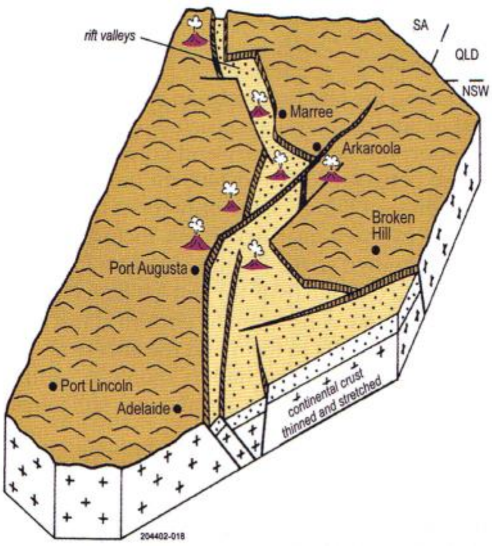


Figure 3: Stretching and thinning of the crust formed depressions and rift valleys into which the sea flowed. Due to crustal thinning, some volcanic activity occurred. (Barker, et al., 2019).

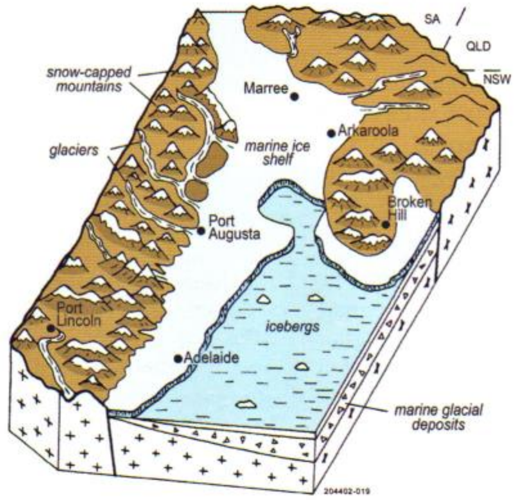


Figure 4: Glaciers, sometimes in the form of an ice sheet deposited loads of scoured rock debris into the sea while icebergs dropped stones into the marine sediments which later formed tillites. (Barker, et al., 2019).

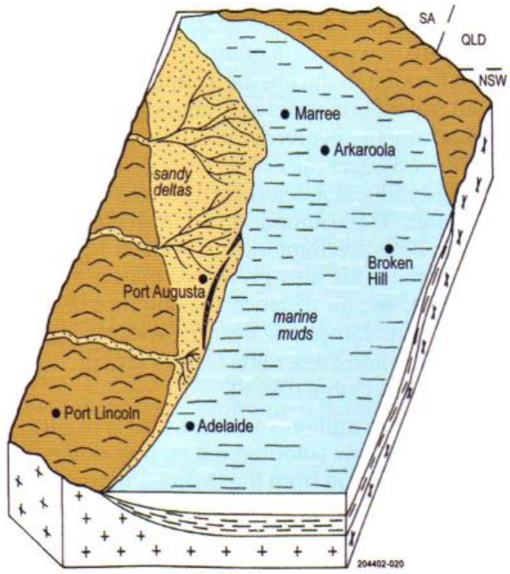


Figure 5: Late in the development of the of the Adelaide Geosyncline, sandy deltas formed from flowing rivers. These sediments now form the ABC Range Quartzite. (Barker, et al., 2019).

The climate again then warmed, ice sheets melted and the sea inundated the area. Silts and other fine sediments were deposited in the basin.

A second, probably less severe ice age then occurred about 650 Ma associated with a drop in sea level. Again, the climate warmed, ice sheets melted, the sea level rose and the whole basin was inundated with renewed deposition of silts, clays and sands from deltas.

Sedimentation ended about 500 Ma. The sediments that had accumulated in the geosyncline had been compacted and cemented into sedimentary rock (mudstone, siltstone, sandstone, conglomerate, tillite, limestone and dolomite) 10-15 km thick.

The Delamerian Orogeny then occurred, folding, faulting and uplifting these rocks. Weathering and erosion immediately began to wear away the mountains as they rose. Large rivers carried vast amounts of the eroded rock away and deposited them in developing sedimentary basins in eastern Australia.

The majority of the mineral deposits scattered throughout the Flinders Ranges are associated with the action of diapirs and then a folding event during the late Cambrian. These provided fracture zones in the rock where minerals could be deposited.

By the Mesozoic era (230 to 65 Ma) the climate was generally wetter and warmer than today and the ancestral ranges had probably been reduced to a low gently undulating landscape. Coal seams formed (such as Leigh Creek).

Then during the Cretaceous (145 to 66 Ma) the sea inundated central Australia several times to form the Great Australian Basin.

During this time Australia was separating from Antarctica which caused further uplift of the ancestral ranges. During the last 45 million years, the Flinders Ranges have been rising steadily.

During this uplift, softer rocks such as mudstone were eroded to form valleys while harder rocks such as sandstone remained as peaks and ridges e.g. Wilpena Pound with a cliff-line of Rawnsley Quartzite.

If you require more information, read the Introduction *(page vi)* and Histories - The legacy of Time *(page 1to 5)* and Discovery 5 - the space connection *(page 33)* in the book, Explore the Flinders Ranges by The Royal Geographical Society of S.A. Inc.

An Example of how Rocks can Indicate Past Environments and Events.

The Bunyeroo Formation is composed of reddish-brown passing up to grey-green shale and siltstone formed from deep-water marine deposits. Within these rocks is a thin (10-30 mm) unusual layer containing abundant fragments of a distinctive red porphyritic rock, called the Gawler Range Volcanics, which is about 1000 million years older and found only about 300 km to the west in the Gawler Ranges on Eyre Peninsula.

This layer is interpreted to be fallout from the impact of the giant meteorite which crashed onto Eyre Peninsula at Lake Acraman about 600 million years ago throwing vast quantities of Gawler Range Volcanic debris into the atmosphere for hundreds of kilometers around (Figures 6 and 7).

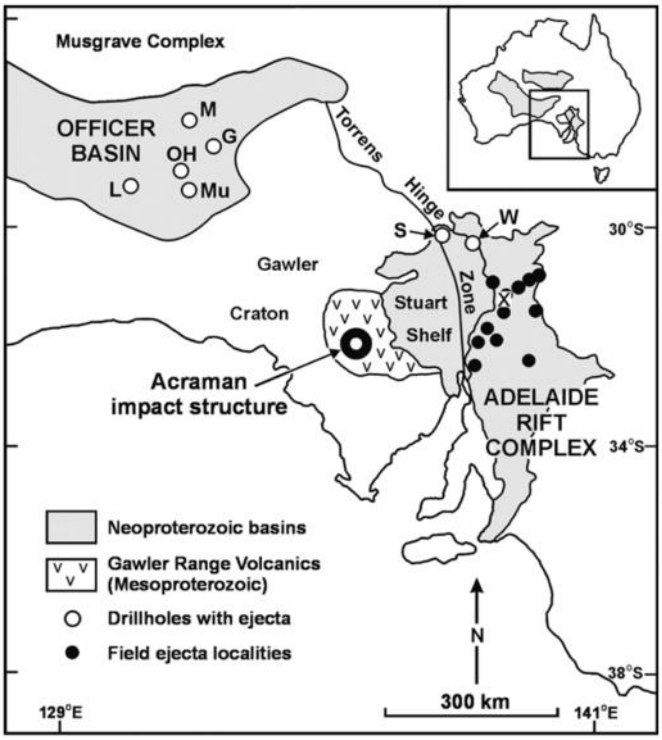


Figure 6: Location of Acraman Crater and surface exposure of volcanic rock debris in the Flinders Ranges. (Abbott).

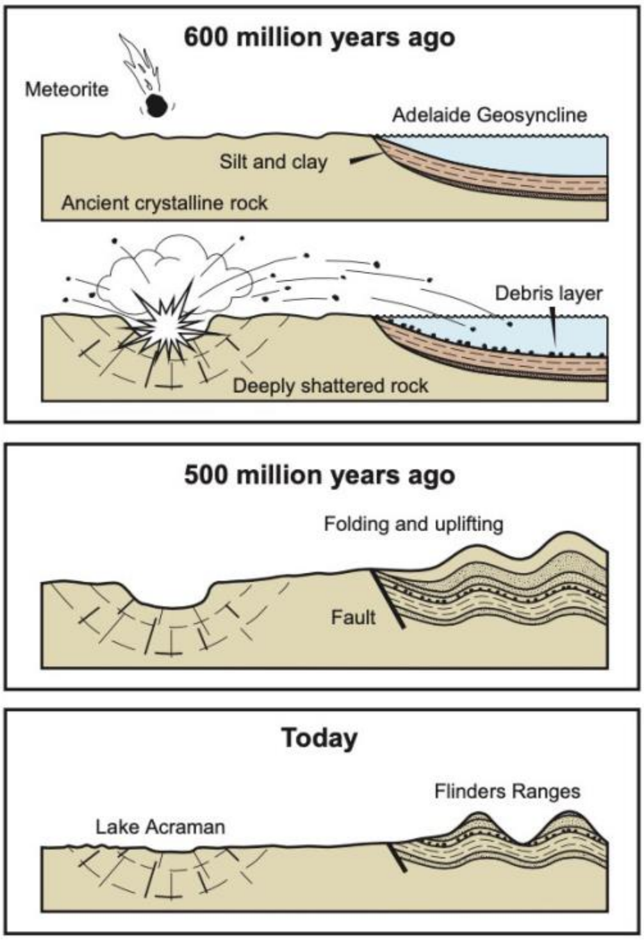


Figure 7: Diagram indicating how volcanic rock fragments from the Gawler Ranges became incorporated into the Bunyeroo Formation. (Selby, 1990).

Figure 8 **below shows the rock types exposed along Brachina Gorge, the relative sea level that existed during sedimentation and fossil evidence used to support these deductions**.

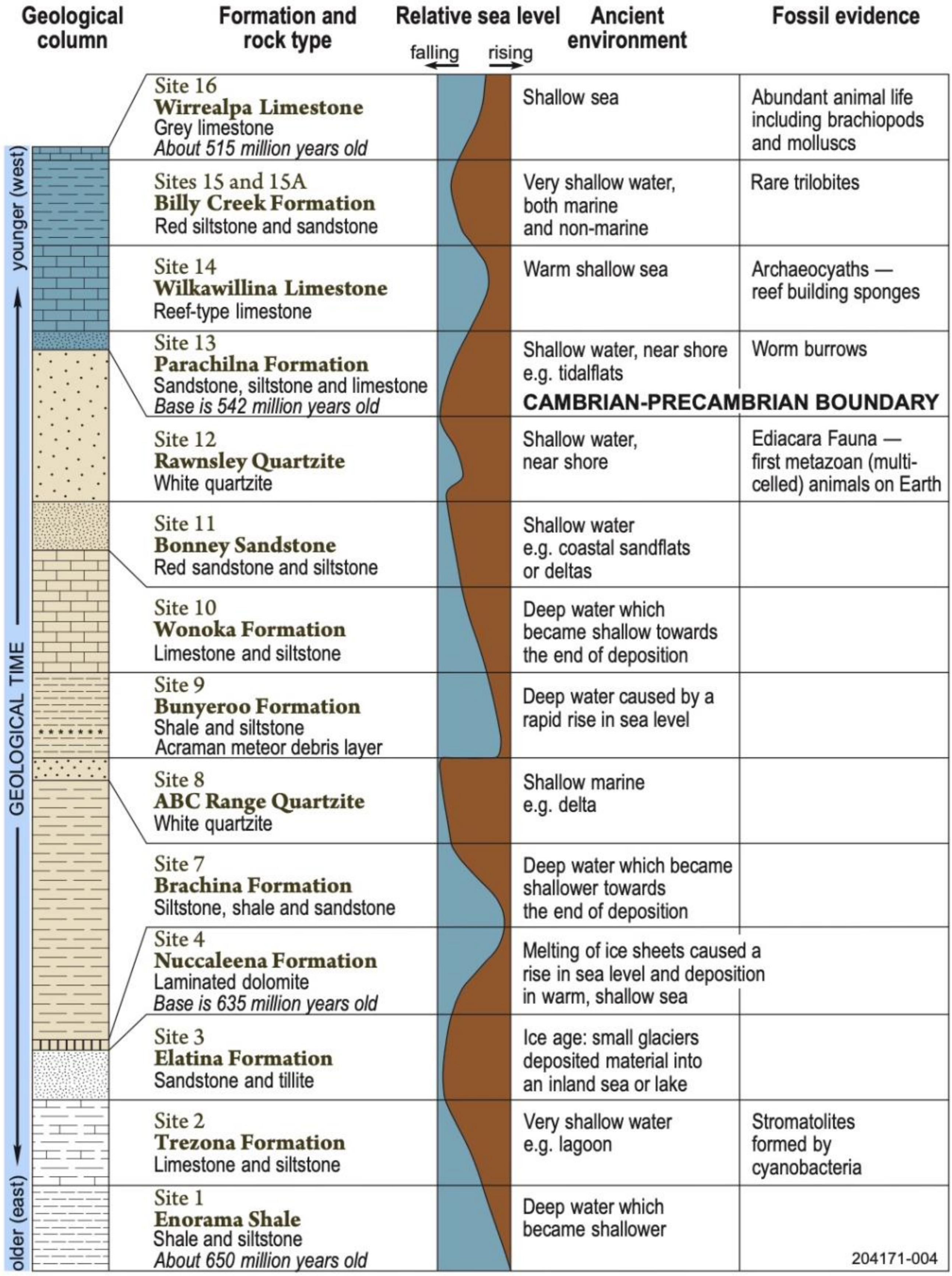
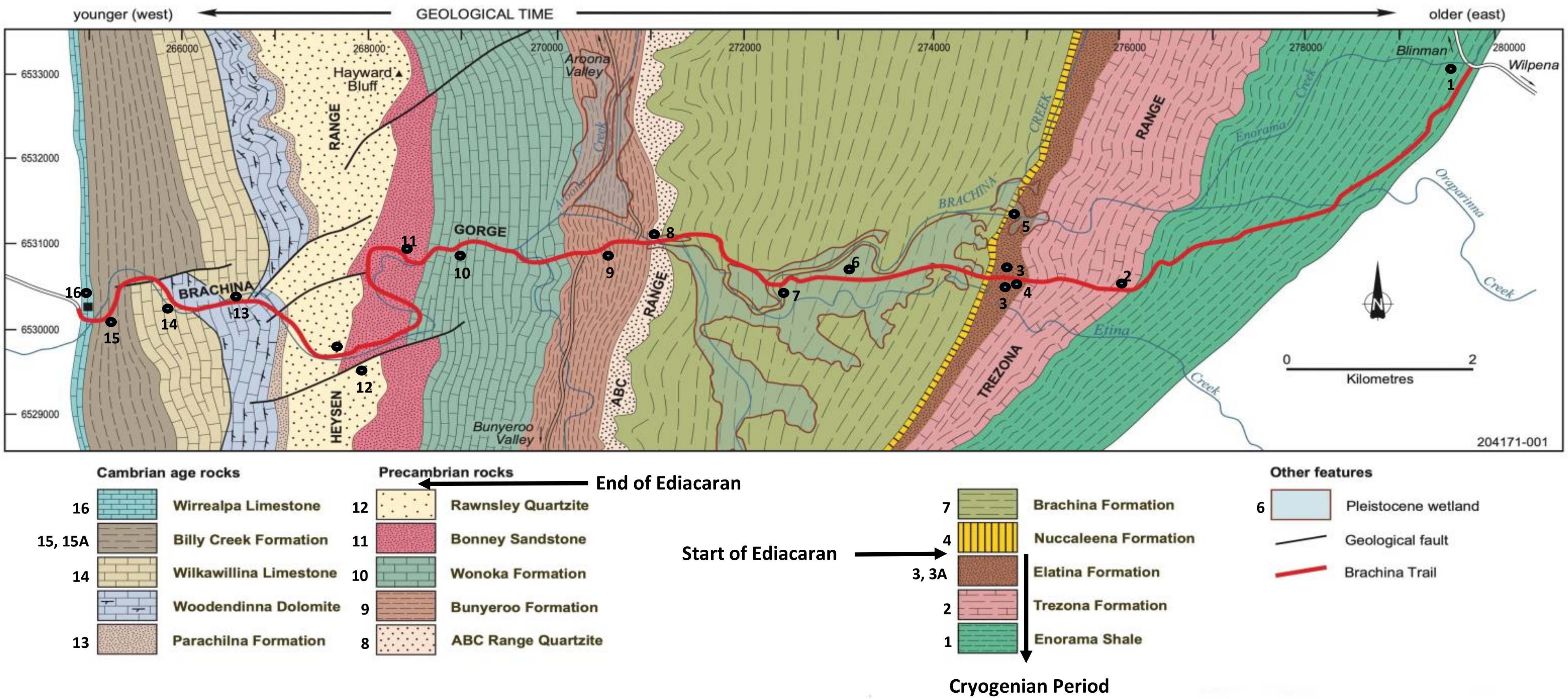


Figure 8: Cambrian and Precambrian environments in Brachina Gorge. (Selby, 1990).

Figure 9: Brachina Gorge Geological Sequence.



An unconformity is a buried erosional or non-depositional surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous. e.g. The boundary between the Precambrian Rawnsley Quartzite and the Cambrian Parachilna Formation.

(Brachina Gorge Geological Trail 2015).

Geological Column of some rocks found in the Southern & Central Flinders Ranges.

This information provides greater detail to the Stratigraphic Column on page 24 (Figure 8).

Younger:

Wirrealpa Limestone: Limestone, medium grey, micritic; basal dolomite. Abundant trilobites, brachiopods and small shelly fossils. Shallow seas containing abundant marine life.

Paleozoic Era, Cambrian Period, Series 2 Epoch (early Cambrian - 509 to 521 Ma).

Billy Creek Fm: Red siltstone and sandstone, deltaic. Rare trilobites. Shallow water both marine and fresh.

Paleozoic Era, Cambrian Period, Series 2 Epoch (early Cambrian - 509 to 521 Ma).

Mernmerna Fm: Limestone; bioherm complexes - slope, platform; turbidites; nodular wackestone; black laminated lime mud.

Paleozoic Era, Cambrian Period, Series 2 Epoch (early Cambrian - 509 to 521 Ma).

Wilkawillina Limestone: Archaeocyath-calcimicrobe limestone. Warm shallow seas encourage reef building organisms to flourish.

Paleozoic Era, Cambrian Period, Series 2 Epoch (early Cambrian - 509 to 521 Ma).

Woodendinna Dolomite: Dolomite, shale, conglomerate.

Paleozoic Era, Cambrian Period, Start of Series 2 Epoch (early Cambrian - 521 Ma).

Parachilna Fm: Sandstone, upward-fining; with siltstone and minor carbonate interbeds. Trace fossils include *Diplocraterion* (vertical U-shaped worm burrows) and *Bemella* (small mollusc). Shallow water near shore, mudflats. Sea slowly becomes deeper.

Paleozoic Era, Cambrian Period, Terreneuvian Epoch (early Cambrian - 541 to 521 Ma).

Cambrian - Precambrian Boundary

Rawnsley Quartzite: containing the Ediacara Member: Quartzite and sandstone, white or light grey, locally flaggy and fossiliferous. Shallow seas.

Neoproterozoic Period, Cryogenian epoch, Marinoan glaciation age.

Bonny Sandstone: Sandstone, fine to medium grained, occasionally coarse, flaggy to medium bedded, silty and feldspathic, cross bedded, ripple marks, small scale slumps, mudcracks, interclasts; siltstone; quartzite. Shallow seas, deltas, coastal mudflats.

Neoproterozoic Period, Cryogenian epoch, Marinoan glaciation age.

Wonka Fm: Shale, grey, calcareous; flaggy dolomite, limestone and silt. Seas become shallower due to deposition.

Neoproterozoic Period, Cryogenian epoch, Marinoan glaciation age.

Bunyeroo Fm: Siltstone, shale, grey-red to grey-green, partly calcitic, minor fine grained sandstone, dolomite, grey; limestone, grey lenses, thin beds. Contains Acraman meteor debris layer of Gawler Volcanics. Seas become deep due to rapid rise in sea level.

Neoproterozoic Period, Cryogenian epoch, Marinoan glaciation age.

ABC Range Quartzite: Quartzite, slightly feldspathic, fine to medium grained, pale pinkish grey, clay interclasts, flaggy to medium bedded, heavy mineral lamination, minor siltstone. Shallow marine- deltaic.

Neoproterozoic Period, Cryogenian epoch, Marinoan glaciation age.

Brachina Fm: Siltstone, shale, fine grained sandstone. Contains Moolooploo Siltstone Member and Bayley Range Siltstone Member. Seas become shallower due to deposition.

Neoproterozoic Period, Cryogenian epoch, Marinoan glaciation age.

Nuccaleena Fm: Dolomite, thin, laminated, micritic, with interbedded shale near the top. Warm shallow seas became deeper as glaciers melted.

Neoproterozoic Period, Cryogenian epoch, Marinoan glaciation age.

Elatina Fm: Sandstone, arkosic, medium grained, red-brown, slumped, ripple cross laminated; siltstone, sandy, red dropstones and minor beds of diamictite with cobble to boulder size clasts of dolomite, tillite, basalt, dolerite, tuff. Shallow water - glacial.

Neoproterozoic Period, Cryogenian epoch, Marinoan glaciation age.

Trezona Fm: Limestone, interclastic and stromatolitic; with beds of calcareous siltstone. Shallow water - glacial.

Neoproterozoic Period, Cryogenian epoch, Marinoan glaciation age.

Enorama Shale: Shale, grey-green and minor red, laminated; silty shale, rare fine grained sandstone. Deep water - glacial.

Neoproterozoic period, Cryogenian epoch, Marinoan glaciation age.

Etina Fm: Limestone, sandy, grey, oolitic, stromatolitic, trough cross bedding; interbedded grey-green siltstone. Local diapir derived conglomerate.

Neoproterozoic Period, Cryogenian epoch, Marinoan glaciation age.

Sunderland Fm: Siltstone - grey-green; sandstone - fine to medium interbedded with coarse pebbly sandstone and oolitic conglomerate, stromatolite limestone.

Neoproterozoic Period, Cryogenian epoch, Sturtian glaciation age.

Tapely Hill Fm: Siltstone - grey to black, dolomitic and pyritic grading upwards to calcareous, thinly laminated and locally cross bedded; dolomite - grey, flaggy to massive; limestone conglomerate, intraformational; greywacke.

Neoproterozoic Period, Cryogenian epoch, Sturtian glaciation age.

Older:

Geological Time Scale showing the times that the rocks in the Flinders Ranges were deposited.

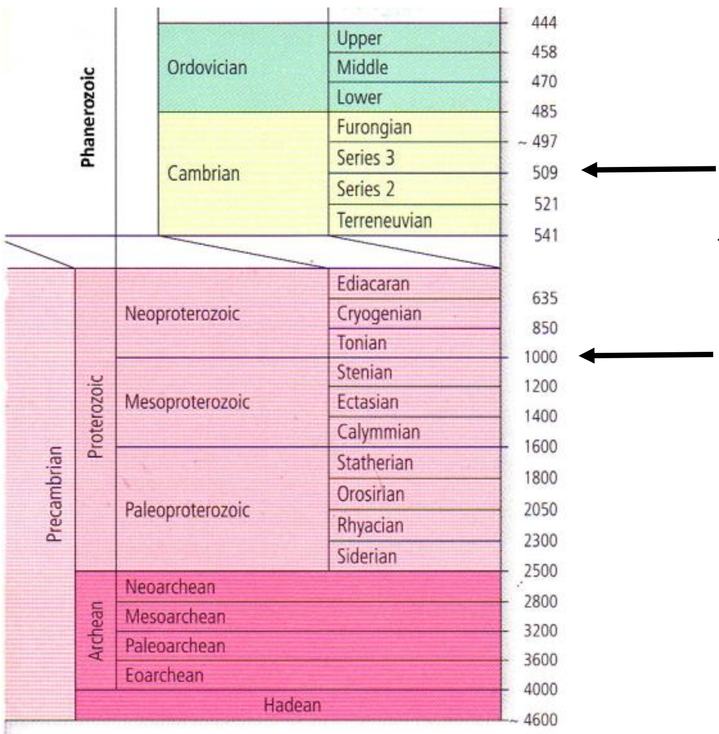


Figure 10: Time period of most deposition

www.ga.gov.au. Timescale Bookmark.

Diapirs.

A diapir is a geological structure consisting of mobile material that was forced into more brittle surrounding rocks, usually by the upward flow of material from a parent rock or rock layers.

The flow may be produced by gravitational forces (heavy rocks causing underlying lighter rocks to rise), tectonic forces (mobile rocks being squeezed through less mobile rocks by lateral stress), or a combination of both.

Diapirs may take the shape of domes, waves, mushrooms, teardrops, or dykes. Because salt flows quite readily, diapirs are often associated with salt domes or salt anticlines. In some cases the diapiric process is thought to be the mode of origin for a salt dome itself.

There are several diapirs within the Flinders Ranges such as the Blinman diapir, Arkaba diapir south west of Rawnsley Bluff and the Oraparinna diapir north-north east of Wilpena Pound.

During folding and faulting that occurred during the Delamerian Orogeny, soft ductile sediments near the floor of the geosyncline were so severely squeezed that that they became plastic and flowed upwards and outwards to form massive bodies called diapirs. Brittle rocks were broken into fragments to form clastic rocks called breccias.

The Blinman mine is worked on a copper orebody within one massive breccia-block in the Blinman Diapir.

The usually soft broken nature of breccias often give diapirs in the Flinders Ranges a subdued topography. This is best seen immediately east of Oraparinna and in the well known hills of Arkaba.

Diapirs in the Flinders Ranges occur in rocks belonging to the The Willouran-aged Callanna Group (ca. 850–800 Ma).

The Callanna Group is an assemblage of highly brecciated to commonly layered siliciclastic, carbonate and mafic intrusive to volcanic rocks originally interbedded with evaporites (they are now absent at the surface). It represents the lowermost strata of the Adelaide Fold Belt sedimentary sequence and nonconformably overlies Archean and Mesoproterozoic crystalline basement.

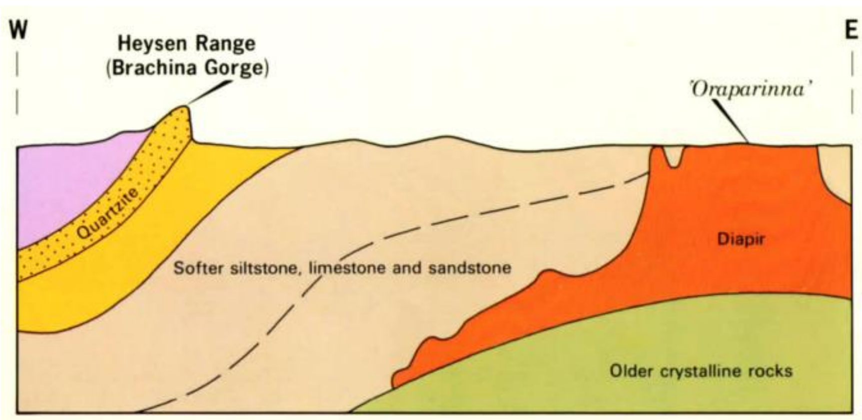
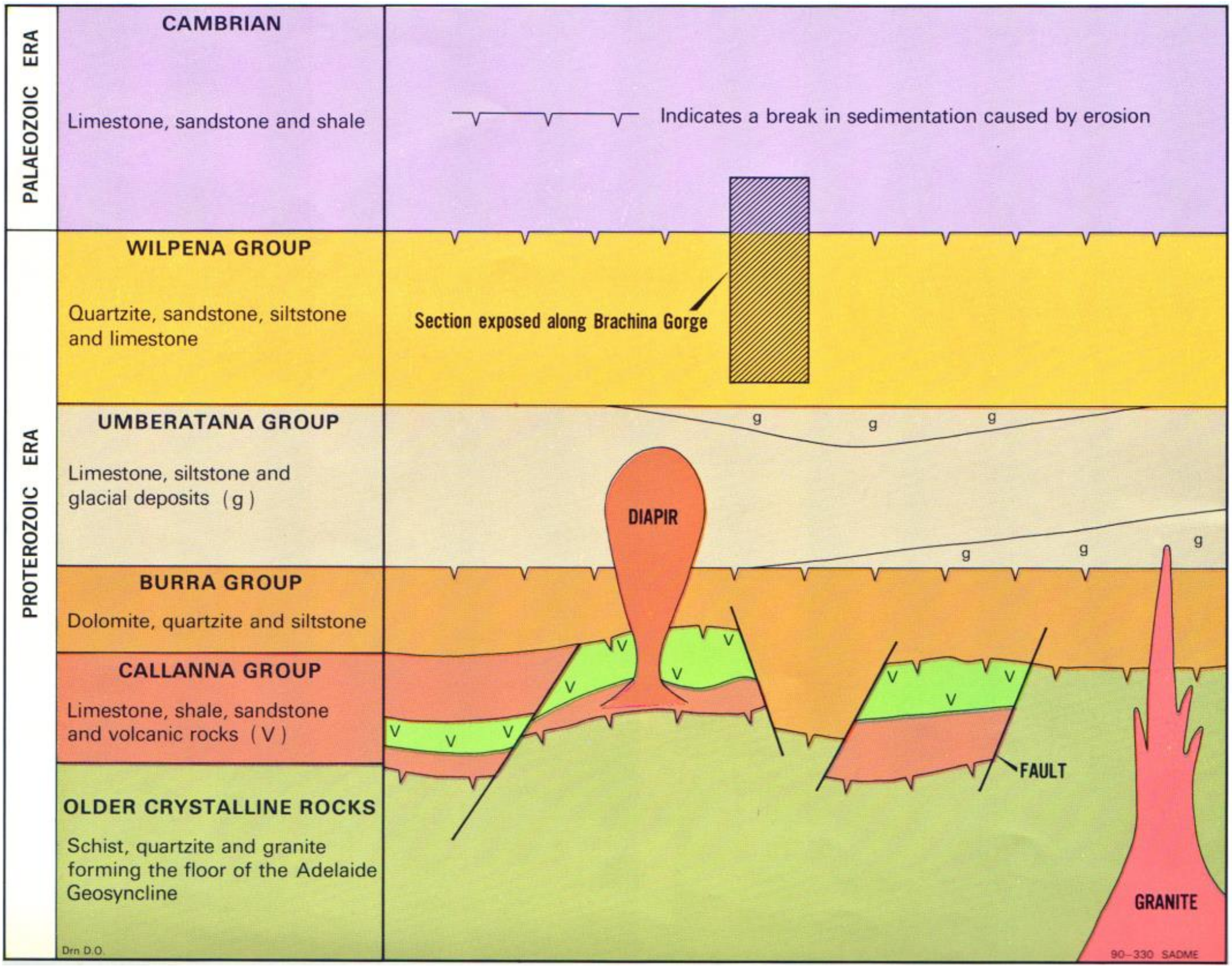


Figure 11: Location of the Oraparinna Diapir in relation to the Heysen Range.
(Selby, 1990).

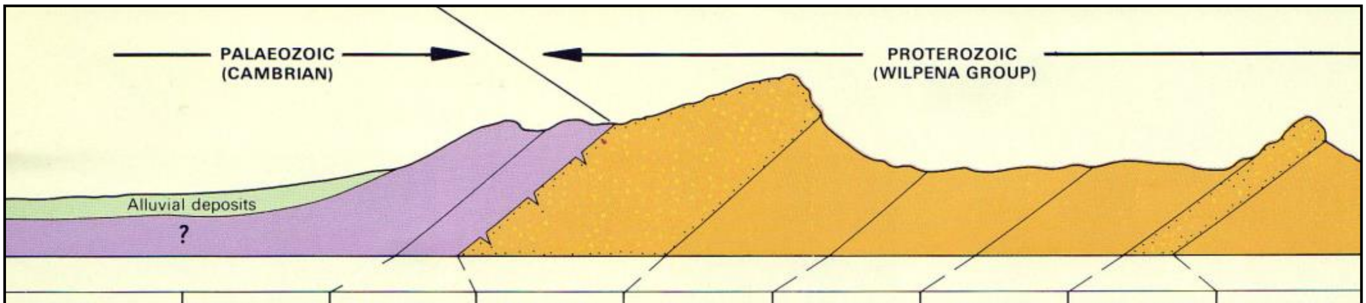
Figure 12: Major rock groups in the Flinders Ranges.



Note where the rocks seen in Brachina Gorge are situated in relation to the complete rock sequence.

(Selby, 1990).

Figure 13: Cross section showing the rock sequences seen in Brachina Gorge.



NAME OF ROCK UNIT	WILKAWILLINA LIMESTONE	PARACHILNA FORMATION	RAWNSLEY QUARTZITE	BONNEY SANDSTONE	WONOKA FORMATION	BUNYEROO FORMATION	ABC RANGE QUARTZITE	BRACHINA FORMATION
ROCK TYPE	Sandy limestone	Shaly sandstone	Quartzite	Sandstone	Shale and limestone	Shale	Quartzite	Shale and sandstone
ENVIRONMENT OF DEPOSITION	Open marine	Near shore marine	Shallow marine	Tidal delta	Shallowing marine	Deep marine	Shallow marine	Intertidal zone
GEOLOGICAL NOTES	Contains fossil molluscs, trilobites, and reefs of sponge-like archaeocyatha		Forms the walls of Wilpena Pound. Contains fossils of the Ediacara fauna			Distinctive maroon colour with greenish layers	Contains mudcracks and ripple marks	

YOUNGER ← GEOLOGICAL TIME → OLDER

(Selby, 1990).

The Geology of the Northern Flinders Ranges, including Arkaroola, is very complex with some aspects of the geology still unresolved. This information should be read in conjunction with Discovery 24 - Arkaroola Wilderness Sanctuary, page 53 and Reference and Special Interest, page 193 in the book 'Explore the Flinders Ranges' by Barker et al. (2019).

For the purpose of this excursion we will divide the geology into sections; the Mesoproterozoic Inliers, the Neoproterozoic Formations from the Adelaide Geosyncline, the Mesozoic and Cenozoic sediments from the erosion of these basement rocks, the Paralana Fault Zone and the Minerals found near the Fault Zone.

Section 1: **The Mesoproterozoic Inliers - Mount Painter Inlier (MPI), Figure 14.**

This region is centred around the Mt Painter Inlier and the rocks are the oldest in the region. There are outcrops of metasediments and quartzite from the Radium Creek Group. They are Mesoproterozoic (1590 Ma) to Paleoproterozoic (2500 Ma). Examples found in the region include schist, gneiss, amphibolite, marble, quartzite and migmatite. They are the crystalline basement rocks for the region.

These metasediments have been intruded by granites. One example is the Mount Neill granites which are reddish in colour due to the red feldspars they contain. They are early Mesoproterozoic ~1580 Ma.

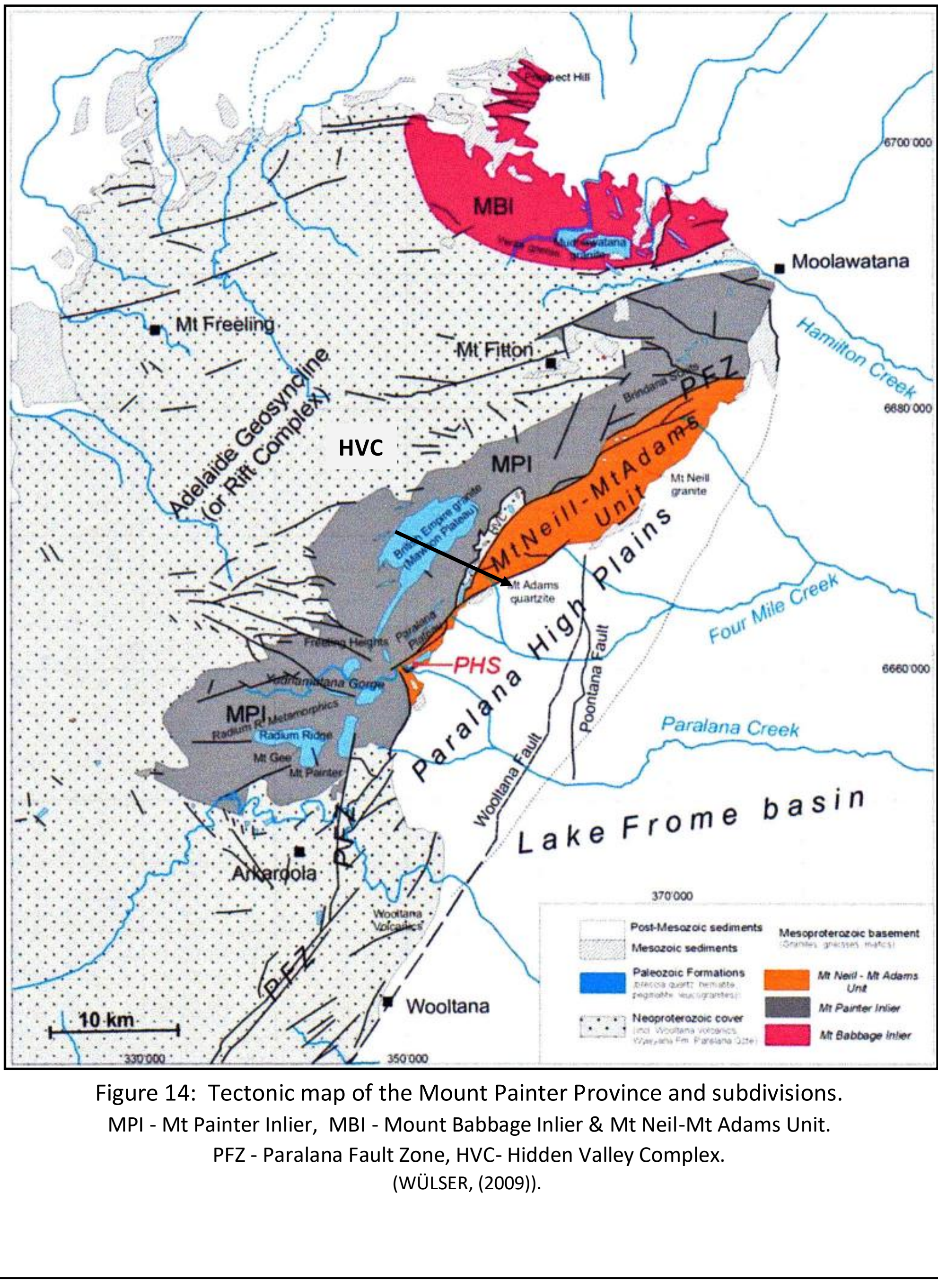


Figure 14: Tectonic map of the Mount Painter Province and subdivisions.
MPI - Mt Painter Inlier, MBI - Mount Babbage Inlier & Mt Neil-Mt Adams Unit.
PFZ - Paralana Fault Zone, HVC- Hidden Valley Complex.
(WÜLSER, (2009)).

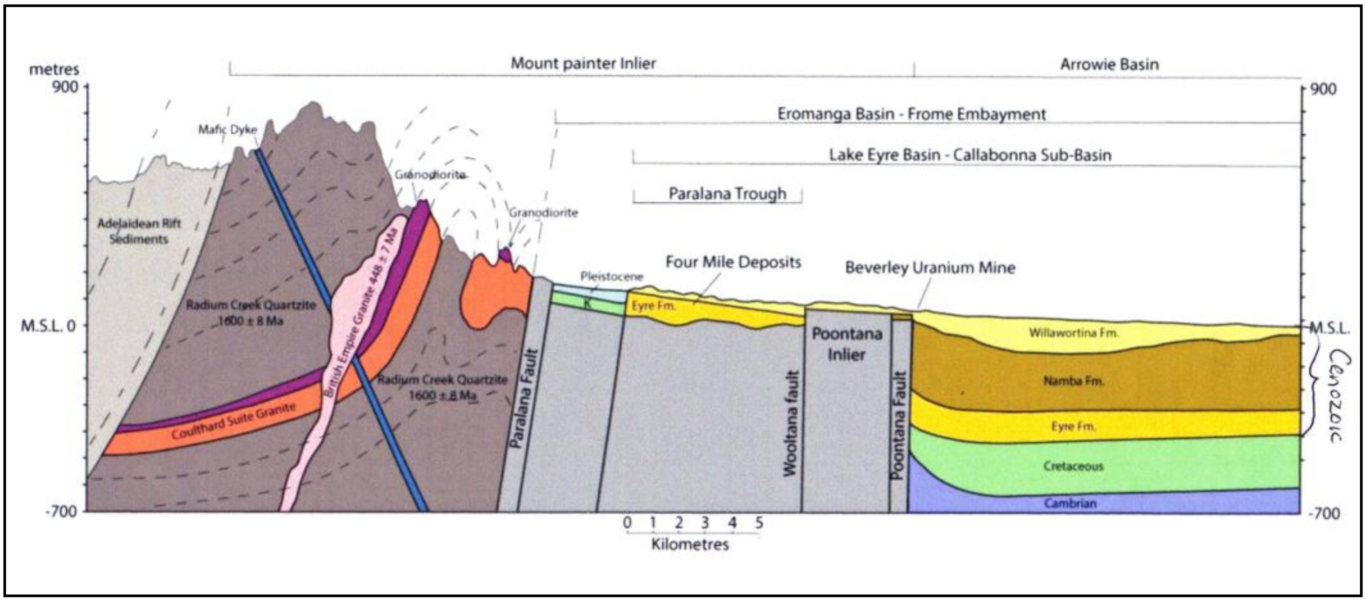


Figure 15: Cross section of Arkaroola geology. (Berthiaume, (2018))

Section 2: **The Neoproterozoic Formations from the Adelaide Geosyncline.**

Overlaying the basement rocks and outcropping in the west and south are the Adelaidean metasediments that were formed in the Adelaide Geosyncline. The deposition of the sediments cover the Neoproterozoic period of (830 Ma to 500 Ma). The processes for the formation of these rocks is covered in Figures 2 to 5. Examples found in the Arkaroola region include basalt from the Wooltana Volcanics, Blue Mine Conglomerate, siltstone from the Opaminda Formation and Amberoona Formation.

Section 3: **The Mesozoic and Cenozoic Sediments.**

The East Region contains sediments from the Mesozoic (140 Ma) and the Cenozoic (65 Ma). During the Paleozoic there were some intrusions through the basement rocks to produce granites. The British Empire Granite of the Mawson Plateau (448 Ma) is one example of this. The pegmatite plugs such as Sitting Bull, The Pinnacles, The Needles and Tourmaline Hill are also from this time (450 Ma).

After a large break in time significant sedimentation began again during the Cretaceous period (145 Ma to 65 Ma) of the Mesozoic Era. There are few places where these rocks are exposed in the region. Recent uplift ~5 Ma has shed these rocks as eroded material onto the eastern plain and here they are covered by Cenozoic sediments. The Cenozoic Formation consists of sediments laid down in the basin to the east. The Eyre Formation is Paleogene (33 Ma to 55 Ma), the Namba Formation is Neogene (5 Ma to 23 Ma) and is carbonate rich. Gypsum and stromatolites can be found. Covering this in places are Quaternary sediments (< 1 Ma) from the most recent erosion processes.

Section 4: **The Paralana Fault Zone. (PFZ on Figure 14).**

The Paralana Fault Zone has been a major crustal scale feature through each of these periods of time (1500 Ma to 5 Ma). It is considered to be a Reverse Fault with the western side rising. At the start of the Neogene (5.3 Ma) evidence suggests that there was uplift of more than 150 m. The fault zone runs tens of kilometres on either side of Arkaroola to produce the Mt Painter Inlier. The uplift on the eastern side has exposed the crystalline basement rocks of the Radium Creek metasediments. The eastern plains contain an enormous amount of eroded material from the inlier due to the erosion of the uplifted rocks. Close to Paralana Hot Springs the ranges to the west were covered by Eromanga Basin sediments (~145 Ma) and Lake Eyre Basin sediments (~55 Ma) but these have been eroded away and are only found in isolated locations. Many earth tremors are recorded in the region due to the stresses derived from rock movements in the region.

Section 5: **Mineralisation and Mines.**

Located at the north eastern end of the Flinders Ranges of South Australia, Arkaroola is an area rich in a variety of minerals. Close to the Paralana Fault Zone the rock movements have brecciated the rocks which has allowed fluids to intrude and to concentrate minerals, metals and their ores. The fluids, at times, have been iron-rich, silica-rich, potassium-rich, sodium-rich with some uranium-rich.

Exploration of the area for minerals dates back to the 1860's when copper deposits were discovered around the western edge of the most rugged part of the property. The many mines that opened up form an arc from the Wheal Turner mine to the Stanley mine and include the Yudnamutana, Black Queen, Cockscomb, Daly, Blue, Wheal Frost, Wheal Austin, Wheal Gleeson, Wealthy King and Sir Dominick mines. Another line of copper deposits is located along the eastern edge of the property following the major fault line between the highlands and the Lake Frome plain. This line includes the Welcome, Great Boulder, White Ants and Lady Buxton mines. The central granite domain of Arkaroola was first prospected in 1898 by Bentley Greenwood who ventured up Radium Creek to discover the uranium deposits around Mount Gee and Mount Painter.

At Arkaroola Bore on the edge of the granite domain is in a zone of altered basalt. This rock contains cavities and seams of mineralised material, the most common being stilbite which occur as radiating crystal clusters. Other minerals found in the Bore area include ilmenite (as tabular crystals), hematite (as flat plates and roses), actinolite, quartz, calcite and at least 40 other species.

One of the more notable mineral occurrences is at Mt. Gee which is a Registered Geological Monument. The basement reddish granite was brecciated and recemented to form granitic breccia. The rock was again brecciated and cemented with siliceous fluids. Cavities in the rock are often lined with quartz crystals. This 'fossil' geothermal/ epithermal system is considered by some to be the longest duration geothermal site in the world, existing for ~100 million years.

Preamble by Ron Evans and Barbara Dunn.

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The 2022 Safari.

<u>Day 1</u>: *Saturday 10th September – Preliminary Meeting at Quorn.*

We all met up at the camp kitchen in the Quorn Caravan Park to discuss our travels so far as some had spent a number of days travelling to get to Quorn while others had travelled in just three days from home via Broken Hill. Brian welcomed everyone and then gave an outline of the geology of the southern Flinders Ranges.

Sue then discussed the details for Sunday's steam train ride and pub lunch.

<u>Day 2</u>: *Sunday 11th September – Pichi Richi Railway.*

Because most of us had spent several days travelling (except Sue who had flown from Tasmania to Adelaide), this was deemed a non-driving day. We walked across the road from the Quorn Caravan Park to the railway precinct around 9:30 am and had roughly an hour to investigate the railway museum, visitor's centre where shirts and Quandong treats were purchased, and take photos of our steam train *(photo 1)*.

Tickets were distributed and at around 10:30 am we all boarded Wandana, a timber carriage that was around 100 years old. Soon after the whistle blew we were on our way over the narrow-gauge tracks. This railway dates back to 1878. The journey took us 32 kilometres past the Quorn flour mill that was built in 1879, spectacular cuttings *(photo 2)*, over dry stone walls that were built by British stone masons using Chinese labourers, around Devil's Peak that was formed of Pound Quartzite about 700 Ma, the ghost town of Pichi Richi to Woolshed Flat where we disembarked for morning tea.

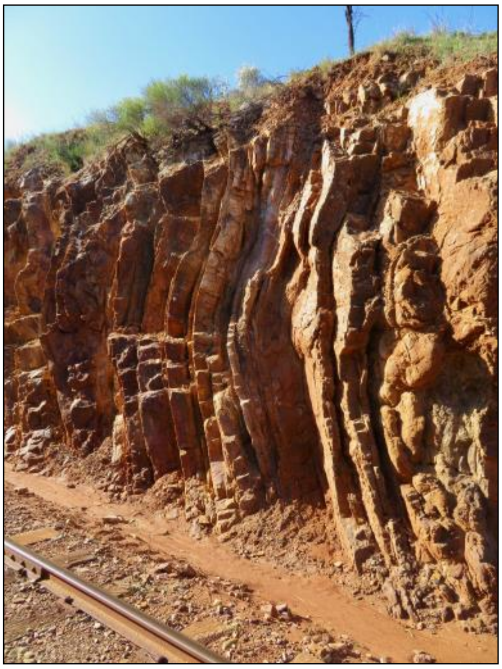
The train had nearly twice as many passengers and hence carriages than usual as Saturday's train had to be cancelled, so it was a rush to get the scones, jam and cream. Many settled for sausage rolls or lamingtons when the supply of scones had been sold out.

The Ghan traveled this track from 1923 to 1956 with the Pichi Richi section having the steepest gradients of the route from Port Augusta to Alice Springs as it was positioned to service the promising copper prospects of the region rather than adhere to the advice of the engineers who wanted the line west of the Flinders Ranges where it is currently located.

After our cuppa we watched the locomotive turn on the triangle and recouple ready for our return journey. A volunteer discussed the history and restoration of the railway with us as we travelled as well as the points of interest along the way *(photo 3)*. We arrived back at Quorn at 1:15pm and walked to the heritage listed Transcontinental Hotel which was built in 1879 for lunch.

It was then a free afternoon but at 6:45 we congregated at the silo to watch Quorn's light show that gave us a great overview of the area including information about how the CWA ladies made thousands of meals during WW2 for the troops travelling on the train to Darwin and the families evacuated from the north when their town was bombed or deemed at risk.

1. AGSHV participants waiting to board train in Quorn.



2. Folded strata exposed in a cutting near Pitchi Ritchi.

3. Plate Girder bridge near Woolshed flat.

<u>Day 3</u>: Monday 12th September - Gorges Drive.

Today our convoy of four vehicles got away from Quorn Caravan Park a little later than scheduled as tyre pressures had to be adjusted on the vehicles. It was a gorgeous sunny day with no wind just perfect for today's adventure. The aim of our trip was to give an overview of the geology of the Flinders Ranges and an appreciation of the challenges of European settlement outside the Goyder Line of demarcation for agricultural pursuits.

We followed Arden Vale Road out of Quorn and turned right to our first stop in the Yarrah Vale Gorge to examine an outcrop of red-layered Bonney Sandstone. We travelled past an outcrop of the Rawnsley Quartzite of the Ragless Range on our way to a lookout point. Here we had a view over the Willochra Plain which is composed of Quaternary sediments from the erosion of the range.

Next we travelled to Warren Gorge (Stop 2) where the gorge cuts through steeply dipping ABC Range Quartzite. We examined some very detailed and informative panels on the geology of the area. Our walk into the gorge began at the western end in the Nuccaleena Formation. The dolomite here was mined in the past and little of it was seen. Walking east we came to the vertical beds of Moolooloo Siltstone *(photo 4)* and then the impressive vertical cliffs of the ABC Range Quartzite *(photo 5)* that made most of the rest of the gorge. We were in awe of a rock climber we saw there negotiating a vertical rock face. After examining the geological features of the gorge we had morning tea *(photo 6)*.

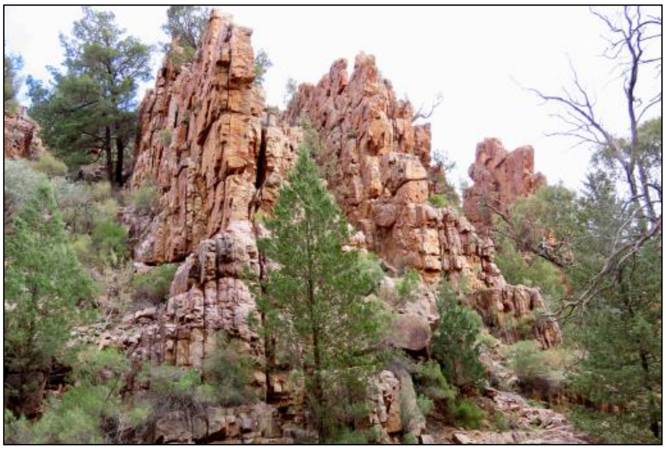
Stop 3 was Buckaringa Gorge *(photo 7)* and Middle Gorge, now a Wildlife Sanctuary which is gated. Here we admired at a distance the rampart of the ABC Range Quartzite which had a ribbed appearance.

The grave of Hugh Proby was Stop 4. He was the third son of a Scottish nobleman who was swept from his horse and drowned in flooded Willochra Creek while trying to round up his cattle after they stampeded during a violent thunderstorm. He was only 24 years of age. He died on 30th August, 1852.

Stop 5 was Buckaringa Lookout where we walked up a steep pinch to the lookout which provided extensive views north east across the northern Willochra Plain towards Hawker, Elder, Chase and Druid Ranges and part of Wilpena Pound. Hopbush, emu bush, silver senna, silver mulla mulla and ruby saltbush were some of the plants we saw here. We also walked to the crest of the hill to take in the sweeping landscape to the west.

As we progressed towards Kanyaka Station (Stop 6). The landscape became progressively drier and the vegetation responded to this. We sited several ruins and were surprised to find water across the ford at Willochra Creek *(photo 8)*. We had a photo stop at the ruins of Simmonston which was surveyed in 1872 *(photo 9)*. A different route chosen for the Great Northern Railway gave Simmonston the title of "the town that never was".

4. Vertical beds of Moolooloo Siltstone Warren Gorge.



5. Almost vertical layers of ABC Range Quartzite, Warren Gorge.

6. Morning tea at Warren Gorge.

7. Buckeringa Gorge.

8. Fording Willochra Creek.

10. Kanyaka ruins.

9. Simmonston ruins.

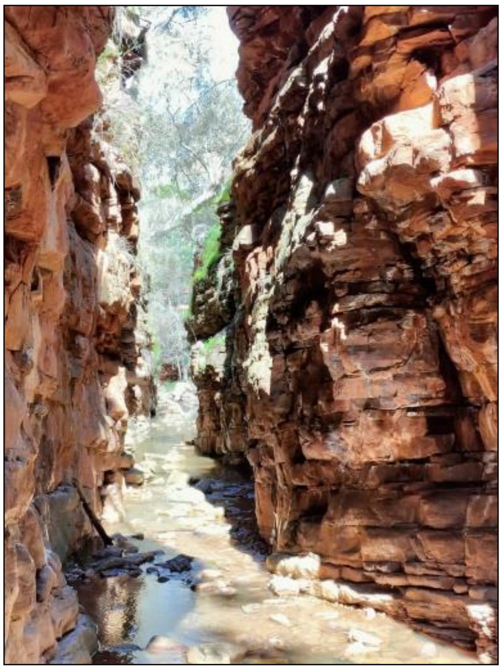
11. Death Rock and dolomite outcrop.

We reached Kanyaka Station ruins *(photo 10)* in time for a late lunch and then spent time wandering around the historical site and the cemetery. This cattle station was established by Hugh Proby in February, 1852 and grew in size to be the largest in the district with 70 families living and working there under the management of John Randall Phillips. Some of the group made a stop at Death Rock and Kanyaka Waterhole *(photo 11)* on their return trip to Quorn. This was a resting site for Aboriginal people prior to European settlement and was a permanent water supply for the station. Death Rock consists of a younger quartzite than the nearby ranges and is a resistant remnant of sediment beneath Willochra Plain. The embankment of the Old Ghan Rail Line passed close by and we observed the stonework of the culverts.

Day 4: Tuesday 13th September – Free Day.

Our third day in Quorn was a designated rest day but most of us had a busy day. About half of the group went to Alligator Gorge, a quartzite gorge in the Mt Remarkable National Park near Wilmington. We checked out the lookout first and then I walked from the Blue Gum Flat picnic area to the valley floor to walk to the narrows *(photo 12)* and then the terraces *(photo 13)* and then further into the gorge and up the cliff face to a fire track that was 5 km from the starting point. This was a fantastic walk and is rated by many as the best walk in South Australia. After lunch we enjoyed an ice cream in Wilmington and then visited Hancock's Lookout which provided views from Port Pirie to Port Augusta.

Others spent the day in Port Augusta gathering supplies for the days ahead and exploring the Australian Arid Lands Botanical Gardens that were established in 1993 and focuses on arid zone ecosystem research and conservation.



12. The narrows - you have to negotiate the stepping stones here unless you want wet feet.

13. The terraces in the gorge.

Day 5: Wednesday 14th September – Relocate from Quorn to Rawnsley Park Station Caravan Park.

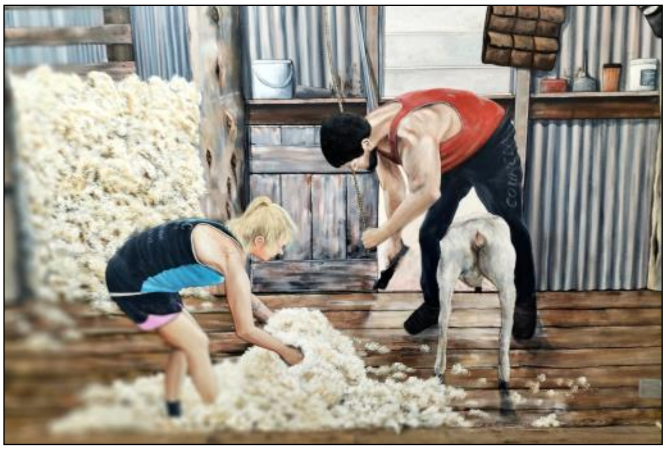
We left Quorn today and experienced some light rain as we drove north to Hawker, another old railway town that relies on tourism today.

The main attraction is the superb Jeff Morgan gallery that has many paintings of the local area *(photo 14)* as well as one of the largest displays of rocks that we have seen plus model cars and a 1926 model T ford. Jeff's panoramas of various scenes in the Flinders Ranges were magnificent and really enticed you to want to see the landscape with your own eyes.

His first circular panorama painting was 30 m in circumference and 3.5 m high and was completed in 2003. Jeff finished his second circular panorama in 2017. This one is 46 m in circumference and 5.5 m high and required him to expand the gallery. Jeff is currently adding a shearing shed to the gallery and some in our group observed him painting the shearing operations *(photo 15)*.

A number of the group saw the seismograph station that records the Earth's movements in and around Hawker. Most of the group enjoyed the chance to have a delicious morning tea at the Flinders Food Company in Hawker before the drive to Rawnsley Park

14. Painting of Rawnsley Bluff with fading sunlight.



15. Part of the shearing scene painting in the Gallery.

Station to set up camp. We caught up with each other at 5 pm to discuss the next few days of our itinerary.

<u>Day 6</u>: *Thursday 15th September - Brachina Gorge Geological Trail.*

Today was a special day of geology for the group. We were to explore Bunyeroo Valley and gorge to see the Acraman impact debris and travel the Brachina Gorge Geological Trail including seeing the Golden Spike, the global position of the designated point marking the base of the Ediacaran Period.

The group gathered in convoy to travel firstly to Wilpena Pound to obtain day passes for the Ikara National Park. The sun was shining on the outer walls of the pound *(photo 16)*, which are composed of white Rawnsley Quartzite at the top with red Bonney Sandstone below emphasizing the palette of colours.

Entering the pound we came across a group of young emus grazing by the road. Once the passes were obtained we drove north east to travel through a gap in the ABC range of quartzite. Here we came across an emu family on the road. The seven chicks still had their striped feathers.

After 6 km we turned into Bunyeroo Valley Road, a gravel rocky road of corrugations and washaways about 30 km in length. We travelled through grassy plains of Etina Formation limestone covered with native pines and surrounded by rolling hill country covered in a whitish lily-type flower which is a type of onion weed and an invasive pest, to reach Bunyeroo Valley and Razorback Lookouts. A few Euros were seen.

The Bunyeroo Valley Lookout gave sweeping views south up the valley of Bunyeroo Creek to Wilpena Pound *(photo 17)*. The silver mulla mulla was the dominant ground cover with some hopbush and silver senna. Close by was our second stop at Razorback Lookout. The view to the Heysen Range was stunning *(photo 18)*.

Next we descended steeply down the Razorback into Bunyeroo Gorge and followed Bunyeroo Creek through the ABC Range. Tilted red beds of quartzite and ripple marks were seen here. We pulled into the Bunyeroo Valley carpark for morning tea before heading out along the trail to Stop 1. We walked along a small creek to locate the Acraman Debris signpost. It stated *"A 5 km diameter meteorite collided with the earth at the site of present day Lake Acraman 580 Ma. 10 trillion tonnes of rock were thrown into the atmosphere. Some landed here, 280 km away, in the sea floor mud of Bunyeroo Formation siltstones"*.

A 5 cm maroon layer was found in the grey siltstone. Jagged fragments of debris were embedded in the fine ash layer *(photos 19 & 20)*.

Leaving the carpark we entered the Wilcolo Creek Valley where steep hills, sheer gullies and pyramidal peaks were the dominant features. The Heysen Range was on our left and the ABC Range on our right as we travelled to Cambrian Campground to have lunch. Another emu family with chicks was seen here. River red gums lined the stony creek bed.

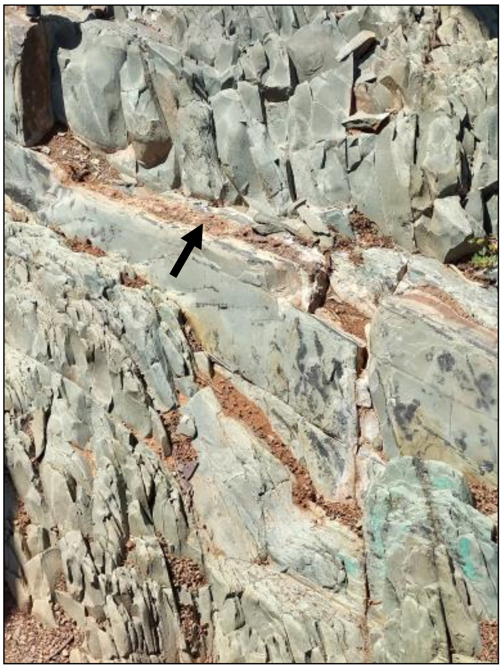
16. Outer wall of Wilpena Pound.

17. Bunyeroo Lookout.

18. Heysen Range from Razorback Lookout.

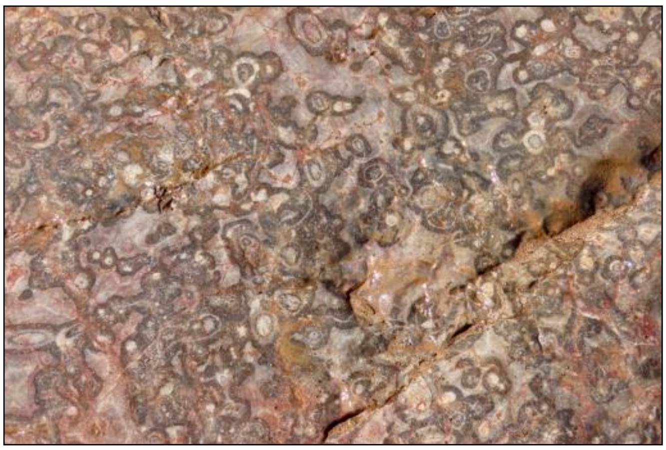
After lunch we continued through more open and flat country to the T intersection with Brachina Gorge Trail and turned right, driving 9 km to the western end to read the relevant information panels and to take in the stunning views. The gorge was used in 1862 as a means of carting copper ore by bullock wagon from the Blinman mine to the coast.

The rocks of the gorge were once sediments deposited in a shallow elongate basin called the Adelaide Geosyncline. These sediments were transported by rivers and sometimes glaciers and deposited on the sea



19. Location of Acraman meteorite debris situated within grey siltstone shown by arrow.

20. Jagged fragments embedded in ash from the Acraman meteorite impact 280 km away.



21. *Archaeocyatha* fossils in Wilkawillina Limestone.

22. Fossilised worm burrows Parachilna Formation 540 Ma.

23. Golden Spike.

24. Group at Golden Spike indicated by walking pole.

floor 650-500 Ma. For a period of 150 million years the area was flooded by the sea for much of the time with the sea level rising and falling many times. By 500 million years ago Earth movements caused the sedimentary rocks to be compressed, folded and uplifted into a high mountain range. This took many millions of years. Weathering and erosion has reduced the height of the mountain range by many kilometres leaving the present ranges and exposing the edges of the folded layers. The geo-trail passes across the edges of these

25. Stromatolite Reef in Enorama Creek.

26. Bonny Sandstone near Ferntree Falls.

exposed layers with the youngest rocks in the west and the oldest to the east of the trail. It is the western part of a 50 km fold that is exposed in Brachina Gorge.

The trail covers 150 million years of Earth history. In the gorge we travelled over a sequence of 12 formations that have a total thickness of about 9 km.

After leaving the information panels the first section of the gorge was lined with massive limestone cliffs built from microbes and the skeletons of ancient sponges. Our first stop 2 km into the gorge, was at the Wilkawillina Limestone. Water was sprayed on sections of the limestone to reveal the coral-like archaeocyathids *(photo 21)*. The rock revealed wagon wheel like cross sections or V- shaped sections parallel to their body axis. These are index fossils for the Cambrian Period world-wide. They became extinct half way through this period.

The next stop was at the Parachilna Formation (540 Ma). Here we walked along a gully representing the boundary between the Ediacaran and Cambrian Periods. The sloping sandstone layer on the east side had no fossils while the crumbling red sandstone on the west side shows the U-shaped burrows of worms *(photo 22)*.

We returned to the vehicles, crossing Brachina Creek several times which contained pools of water. One car group was lucky to see a yellow footed rock wallaby drinking from the creek. In the deepest and narrowest part of the gorge Ediacara fossils can be found where the thin red layers of sandstone joins thicker layers of cream-coloured sandstone. Progress was slowed by the work of graders trying to improve the trail. Another stop was made at a talus slope where an active fault has shattered the sandstone. This is the habitat of the yellow footed rock wallabies and is fenced off to protect them. However, no wallabies were seen here. A not so friendly magpie bombarded Richard and Barbara as they endeavoured to take photos of signage on the wallabies.

At the Aroona Valley Lookout we made a stop to read further information about the Acraman debris which settled in the sediment of the Bunyeroo Formation 680 Ma and to view the wide valley floor between the Heysen and ABC Ranges. The ruins of Old

27. Morning tea at Ferntree Falls.

Aroona Homestead built in the 1850's are located here but we ran out of time to investigate these.

Driving into Trezona Campground we walked about 300 m along the southern bank of Enorama Creek to locate the Golden Spike *(photos 23 & 24)*. This GSSP (Global Boundary Stratotype Section and Point) is one of 64 around the world and the only one in the Southern Hemisphere. A GSSP is an internationally agreed upon reference point on a stratigraphic section which defines the lower boundary of a stage on the geologic time scale. This Ediacaran GSSP location marks the base of the Nuccaleena Formation (pink dolomite) overlying the Elatina Formation (crimson glacial diamicite). Small holes have been drilled in successive layers to measure magnetic pole positions during deposition of the rock at the beginning of the Ediacaran Period. This period began 635 Ma and ended 542 Ma with the Cambrian explosion of life. The Ediacaran fossils were the basis for defining the first new geological period in over a century.

Our last stop of the day was at Youngoona, the shepherd's hut ruins, where a short walk to Enorama Creek and along the creek bed revealed a reef of stromatolites *(photo 25)*. These were the only visible fossils in the Cryogenian Period. These layered structures with a dome shaped top about 10-30 cm across are formed by the trapping of sediments in microbial layers (blue-green algae or cyanobacteria). The layers, although weathered, can be easily identified. They are evidence of some of the earliest life on earth. From Youngoona the convoy dispersed to return the 36 km to Rawnsley Park at its own pace. It had been a long day but was thoroughly enjoyed.

Day 7: Friday 16th September - Rawnsley Bluff Walks.

Today was another walking day but some had a rest day. We left the Rawnsley Bluff car par around 8:40 am and headed along the creek bed for 600 m to the fork of the Ferntree Falls track and Rawnsley Bluff track. We turned left to follow the relatively flat trail that was lined with pine trees towards the Ferntree Falls. We didn't see any of the yellow footed wallabies that are supposed to reside there nor water coming over the rocks but were impressed with the colours in the Bonny Sandstone *(photo 26)*.

We had morning tea *(photo 27)* and then Richard and Sue headed back to go up the Bluff track while the others gradually returned to their cars.

Rawnsley Bluff is named after surveyor H.C. Rawnsley who worked in the Flinders in 1851. He was poorly qualified for the position. The trail to the Bluff gradually got steeper *(photo 28)* and the rocks that you needed to maneuver yourself over got bigger but we were taken in with the diverse range of wild flowers and the views over the ranges.

After the Lone Pine Lookout the track levelled out and we made our way across the Rawnsley Quartzite to the Bluff to find the survey cairn *(photo 29)* constructed by Samuel Parry in 1858 and views to the south and east overlooking Chace and Elder Ranges.

After numerous photos we walked back to take the trail out to the Wilpena Pound Lookout. This provides an excellent view down the centre of Wilpena Pound. We then started the long journey back to Richard's car *(photo 30)*, stopping for lunch before we undertook the steep descent. We arrived back at our vans just before it started to rain around 3 pm.

Day 8: Saturday 17th September - Huck's and Stokes Lookouts and Arkaroo Rock.

After rain on and off during the night it was decided to delay our departure until 9:30 instead of 8:30. We had planned to do the walk to Arkaroo Rock first up but as it still looked like it could rain, driving seemed a better option, so we headed to the Cazneaux Tree. This is a *Eucalyptus camaldulensis* or river red gum with the backdrop of the northern side of Wilpena Pound that was made famous by the New Zealand photographer, Harold Cazneaux, Dick Smith's grandfather. In 1937 Cazneaux won an international competition with a photograph of this tree entitled The Spirit of Endurance.

Next stop was the very windy Huck's Lookout

28. Track to Rawnsley Bluff.

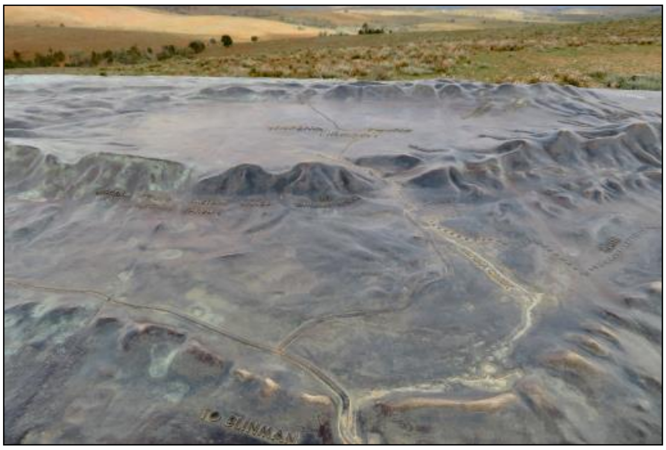
29. Cairn at Rawnsley Bluff.

30. Looking up to the cliffs on Rawnsley Bluff from about half-way down the track.

(photo 31). Unfortunately it was still too misty to see the ranges properly but the mountains with mist over their peaks are probably a rare sight in this arid climate. The rocks around here include siltstones, sandstones

31. Grass trees growing on the limestone at Huck's Lookout.

34. Grass trees and wattles along the Arkaroo track with Rawnsley Bluff in the background.



32. Model of Wilpena Pound at Stokes Hill.

35. Art in the cave at Arkaroo Rock.

33. Old Wipena Station surrounded by some magnificent River Red Gums.

(massive, flaggy) plus oolitic and stromatolitic limestones deposited during the Marinoan glacial age (650 to 621 Ma) and older Sturtian glacial age (715 to 680 Ma) that occurred during the Cryogenian epoch (715 to 680 Ma). These ancient rocks have weathered more rapidly than the harder and younger quartzite producing the undulating landscape.

We then travelled a short distance to turn right off the highway to drive up the winding gravel road to Stokes Hill Lookout which at 750 m, offers spectacular panoramas of Wilpena Pound, Mt Patawarta, and the Druid, Chace, Elder, Heysen and Bunker Ranges in favourable weather. Interpretive signs at the site include a 3D model of Wilpena Pound *(photo 32)* and explanatory panels for Adnyamathanha dreamtime legends, traditional plant uses and pictorial symbols. However the severe wind and cold forced everyone to spend minimal time here. The lookout is named after F. W. Stokes who managed Coonatto Station from 1851.

We then travelled to Wilpena Pound for morning tea in the car park of the old shearing shed. This gave us some respite from the wind, the convenience of toilets and a chance to view the art show that was on in the shearing shed exhibiting various paintings of the Flinders Ranges scenery.

36. Track from Visitors Centre towards Wilpena Pound.

It had stopped raining so Barbara gave a talk on the history of the Old Wilpena Station *(photo 33)* and then we wandered around the various station buildings before driving to the Wilpena Pound Visitors Centre to consume our lunch at the picnic area. You can now only go into the pound by walking over 2 km which adds at least 4 km to any of the walks you do there. They sometimes run shuttle buses every second hour but they were not running when we visited.

We therefore gave walking in the pound a miss and went to Arkaroo Rock via Rawnsley Lookout instead. The 3 km circuit walk up to the cave paintings at Arkaroo was challenging for some of our group but rewarding with beautiful scenery *(photo 34)* and then a viewing the traditional story of how Wilpena Pound was formed. It is a significant cultural site for the Adnyamathanha people of the Flinders Ranges as the rock paintings *(photo 35)* feature ochre and charcoal images that depict the Yura Muda (Dreaming, or creation story) of Ikara (Wilpena Pound).

<u>Day 9</u>: Sunday 18th September - Free Day.

Today was a free day so it was a chance to do the washing or rest. A number of the group drove to Wilpena Pound. The shuttle was still not running so we had to walk into the pound along a track *(photo 36)* to the Hill's stone homestead that was built in 1904 and renovated from ruins in 1995. Interpretive signs display information about the early pioneer families, native flora and fauna of the pound and the Adnyamathanha dreamtime story.

The lower and upper Wangarra Lookouts gave spectacular views of the inside of the pound *(photo 37)* and an appreciation of the size of the pound - 80 square kilometres or roughly 8000 hectares. We had lunch at the Visitors Centre before returning to Rawnsley Station. At 5 pm we had a meeting with the rest of the group to discuss our drive to Angorichina and the Blinman underground copper mine tour.

37. View from Wangarra Lookout.

Day 10: Monday 19th September- Relocate from Rawnsley Park to Angorichina Tourist Village.

We left our scenic campsite at Rawnsley Station and drove north-east passing the Great Wall of China on the way. We arrived at Angorichina Tourist Park around 11 am and quickly noticed it was going to be an outback experience with no drinking water, outside toilets with hand basins in the sun and only 8 powered sites.

Most of the group went to Blinman Miner's Crib Cafe or the North Blinman Hotel for lunch and then explored the historic town that has buildings dating back to the 1860s. A number of the buildings are constructed of buff-coloured sandstone from a quarry north of the town. The original miners huts were pine and pug. Blinman is the highest town in South Australia sitting at 616 m above sea level and has a population of about 20 permanent residents. There is no council controlling it so residents do not pay rates but are responsible for their own garbage disposal.

Blinman is the only town left from all the mining townships that were surveyed across the Flinders Ranges in the 19th century. Blinman's population has been reflective of the prosperity of the mine. At the peak of mining in 1869 the town had a population of 1500. When the drought and low copper prices closed the mine in 1882 the population fell to less than 200 but was back to 500 in 1888 when mining activity recommenced.

Just before 2 pm we collected our tickets and drove 1 km out of town for a wonderful underground tour of the historic copper mine. Our guide, Mike, explained that copper was discovered at here in 1859 by a one-legged shepherd, Robert 'Peg Leg' Blinman. The discovery occurred on land owned by a Dr Hayward. Blinman was given the job of watching the sheep and one day broke a chunk off the rock he was sitting on and found that it was good quality copper ore. Two butchers in Adelaide, Henry and Thomas Martin, contacted Blinman and by 1861 they had a mineral lease on the land. The copper mining occurred from around 1862 through to 1874 and then on and off until its final closure in 1918. In total around 10,000 tonnes of copper were removed from 200,000 tons of ore. It was the longest operating mine in the Flinders area. Mining initially involved quarrying the outcropping orebody and sinking shafts along its length. A smelter works was built in 1863 and this produced high grade copper ingots that were shipped overseas.

We placed our name at the entrance and collected a hard hat and torch to follow our guide through the many tunnels *(photos 38 & 39)*. Along the way we listened to various sounds that enabled you to appreciate the extreme hardship the early Cornish miners and families experienced working and living here. Mike explained how it was a family affair with sons working above ground from the age of 10 and then underground as soon as they turned 14. It was extremely dangerous with virtually no light and shafts up to 60 m deep and 15 m wide. Water was not found until the 90 m mark so few pumps were required and as most of the area was solid rock, little timber was needed so the operation was fairly economical. The big problem was the cost of transporting the copper to Port Augusta for shipment. This was reduced when the railway was constructed. We saw exhibits of different equipment, clothing, tools, explosives and lighting devices.

After the informative tour most walked around the site and spent time photographing the top of the main shaft, the boiler, water tanks and the remnants of numerous other buildings such as the smelter, winding house and workshops *(photos 40 & 41)*. The impressive stone wall dam was built in 1885 and still holds water. It was amazing to think of the resilience of the mining families but also the determination and dedication of the current 20 odd residents of Blinman that took on the opportunity to restore the mine and volunteer to operate the tours for tourists to breathe a new life into their remote village.

38. Blinman mine underground tour.

39. View of the open stope from underground.

40. The water storage tanks at Blinman Copper mine.

42. Entry into the new Nilpena Ediacara National Park.

41. Vegetation is gradually replacing the remnants of Blinman Copper mine buildings.

43. Visitor Centre for the Nilpena Ediacara National Park in restored Blacksmiths Shop.

Day 11: Tuesday 20th September.

Today was one of the highlights of the Flinders Ranges trip with a visit to the Ediacara Fossil sites on Nilpena Station with owner and amateur paleontologist Ross Fargher. It was an early start, just after 8 am. The convoy of three vehicles, travelled west 18 km on gravel along Parachilna Gorge, onto the Outback Highway. At this T intersection we turned north to travel 25 km to Nilpena on bitumen. After crossing a section of the Old Ghan rail line we turned west and travelled onto Nilpena Station for about a kilometre on gravel to a carpark. A very impressive stone wall and security gate announced our arrival at Nilpena Ediacara National Park *(photo 42)*. This park was formed in June, 2021 with the purchase of two thirds of Nilpena Station west of the homestead (60,000 ha) and including historic stone buildings (1860) the Shearing Shed, Blacksmith's Shop and Shearers Quarters (old Evan's family homestead).

Ross collected us in a 4 wheel drive coach and we travelled across the property to the Blacksmiths Shop *(photo 43)* and on to the Shearing Shed. Ross was a very accomplished and informative speaker and gave us a background firstly to Nilpena Station, then to the discovery of the Ediacara Biota fossils by Reginald Sprigg at the Ediacara Mine site north of Nilpena Station and his own involvement in the discovery of the fossils on Nilpena. He also spoke of the work involved in getting Nilpena fossil site recognised as a World Heritage site. This is still a work in progress.

We were privileged to meet Dr. Mary Droser who with her team, has been excavating the sedimentary fossil beds on Nilpena Station during the months of June and July for many years. Her presence at this time of year (September) was due to her involvement in liaising with National Parks concerning access to the fossil sites for the public and Sandpit Media, an audio-visual production company responsible for developing the presentation in the National Parks Interpretative Centre. The park is not open to the general public at this stage with construction work still to be completed. It is due to be opened in the first half of 2023.

A 7 News TV crew consisting of a cameraman and presenter Ron Kandelaars, interviewed Ross *(photo 44)* on the significance of the fossils to science and the impact of climate change in the Flinders. Our members became the extras for the production. We were also part of a testing phase for delivery of guided tours to the fossil sites when the National Park finally opens. After inspecting the shearing shed containing 20 shearing stands where up to 47,000 sheep were shorn we boarded the coach to travel across the property to Mt Michael in the distant ranges. Crossing the creek we saw the permanent spring which provides vital water to the station and travelled past remnants of Aboriginal campfires.

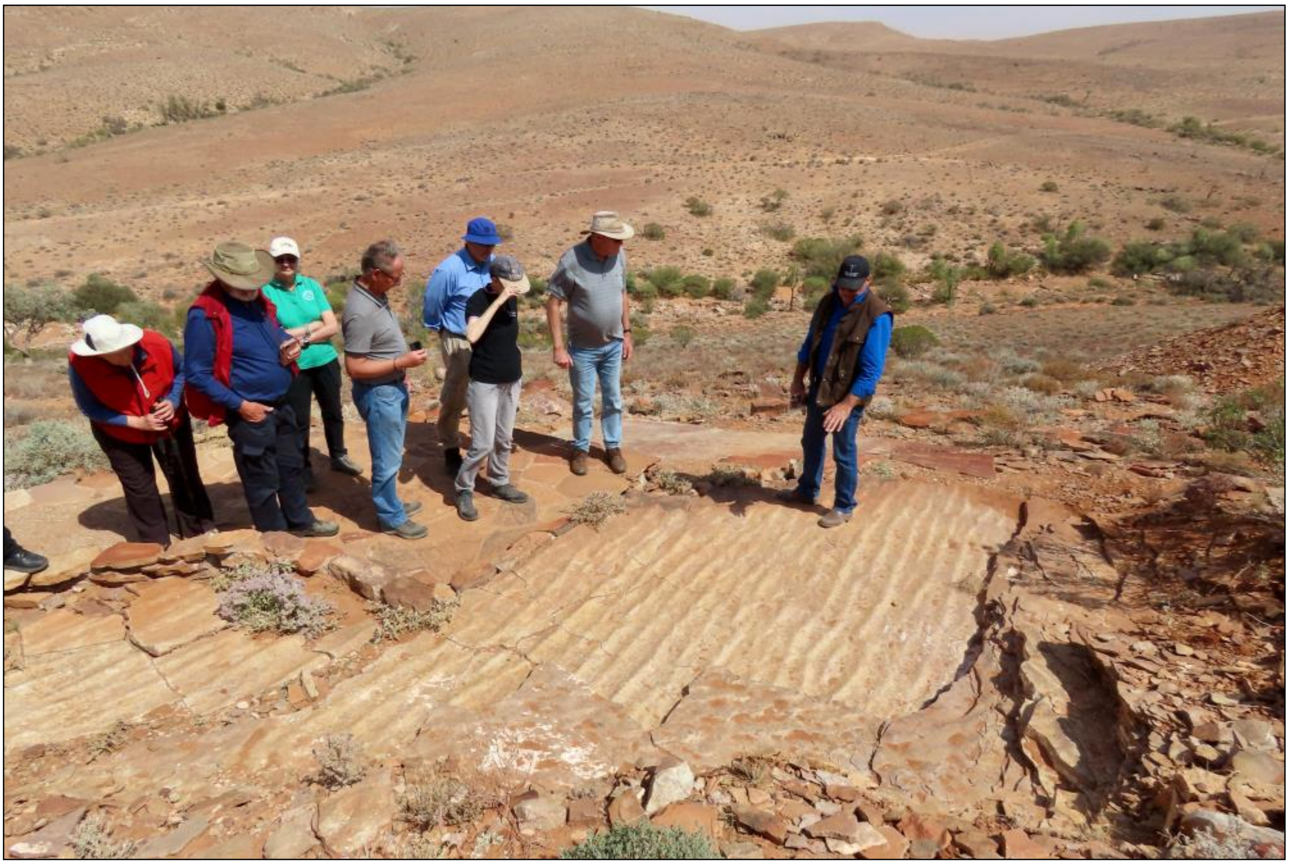
The Farghers bought Nilpena in the 1980's and ran sheep and cattle, then only cattle which they bred on the property. The cattle were transported to a south eastern property owned by the family in the Coorong to be fattened before sale. Since the end of the drought in 2019 the family has totally destocked the property. This has allowed rejuvenation of the native vegetation in the form of summer grass, bluebush, saltbush, acacias and gums. With the effective use of calisivirus to rid the land of rabbits, foxes and cats have also been reduced with the loss of their food source. Echidnas, lizards and small ground dwelling mammals have returned in numbers. Emus and kangaroo numbers have always been good.

We reached the fossil site where a team of Mary's students from the University of California were working on the fossil beds *(photo 45)*. Ross led us down a formed pathway to where the team has exposed, excavated, flipped and reassembled large samples of fossil covered seafloors so they can be studied for their fossil ecology *(photo 46)*. Everything else is retained on site for current and future research. The desert climate does not impact on the fossil impressions. Nilpena is uniquely important as a field laboratory for researchers to use to try and understand this critical time in Earth history, when large life bloomed for the first time.

We were able to examine the various fossils exposed on the slabs and Ross was able to show us

44. TV Crew interviewing Ross Fargher.

45. Students at work at the Ediacara site.



46. Ross describing how the Ediacara fossils are discovered and studied.

Nilpena Rossi, a fossil named after him. The relentless gale force wind blowing from NE to SW stirred up the dust so visibility was greatly reduced. Lightning shafts perpendicular to the ground were seen.

We returned to the Blacksmith's Shop to enjoy morning tea and watch another interview being recorded by the TV people. Next Ross led us into the fossil display area for an audio-visual experience like no other we had seen. As the National Park is not officially open, we were unable to take cameras into the room.

A large slab of fossil-bearing seafloor called Alice's Restaurant Bed was bolted to a table with the red desert sands bordering the edges. A narrator outlined the ecosystem of the Ediacaran geological period (560 Ma to 542 Ma) and explained the environment in which each animal lived, fed, moved and reproduced. After an animation showing details of each creature, the fossil was highlighted on the table *(photo 47)* as it was described by the narrator and we had the opportunity to touch each one. It was a very engaging experience enjoyed by all. The room temperature is kept at 22 degrees.

By 12.30 pm we were returned to our vehicles in the carpark and the group dispersed to follow their own interests. Some went to the historic town of Beltana, some to Leigh Creek and some to Parachilna before returning to Angorichina.

47. *Aspidell* fossil.

<u>Day 12</u>*: Wednesday 21st September - Free Day.*

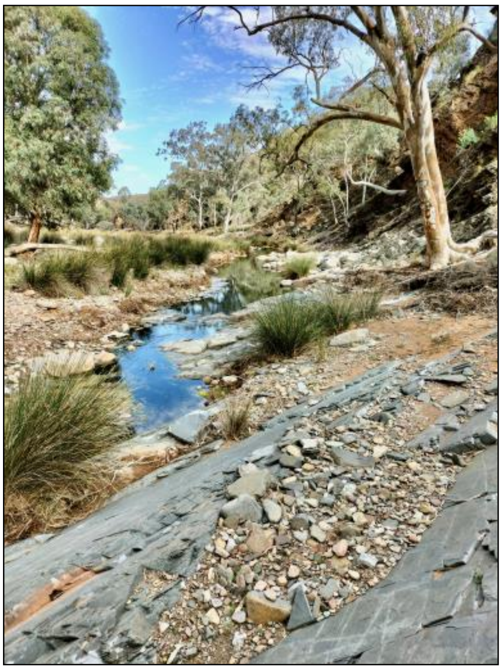
It rained overnight and as the gravel roads around Angorichina were wet and slippery, it was decided to make this a free day. Many took the chance to study their photos, read or do some craft work. There was no internet or phone coverage at the tourist village *(photo 48)* so some risked the roads and drove till they had reception to be able to catch up with friends or families. It finally cleared in the afternoon and meant some explored the area around Angorichina including the creek bed walk towards Blinman Pools *(photo 49)*.

48. Angorichina Village.

<u>Day 13</u>: *Thursday 22nd September - Glass Gorge and Parachilna.*

We couldn't have had a more perfect day weather -wise today. The sun was shining, the sky was azure blue and there was no blustery wind. The convoy assembled outside the caravan park and we departed at 8.30 am on the road for Blinman 15 km east of camp. This road is the divide between north and south Flinders Ranges. It was churned up and very muddy yesterday but had dried out surprisingly quickly. There was one quick stop on the way at a very weathered, sedimentary outcrop of the Umberatana Group. Reaching Blinman most headed for the Miners Crib Café to stock up on Cornish pasties, lemon myrtle cheesecake tarts, carrot cake and chocolate brownies for morning tea.

After driving through town we set off along Glass Gorge Scenic Drive, a 30 km drive on gravel and



49. Blinman Pools walk.

50. Gneiss pushed up by a diapir from great depth.

51. Dry stone wall long Glass Gorge Drive.

52. ‘Geology Girls’ on safari.

along creek beds to reconnect with Parachilna Gorge Road. Our first stop was at an outcrop of gneiss boulders about 1 km past the first grid and close to the north edge of the road. The gneiss *(photo 50)* is a high grade metamorphic rock which has been carried up from great depths in the Blinman Diaper. The rocks into which it has intruded are diapiric breccia.

The second stop was just past the Glass Gorge sign where we searched for grey-green Mt Caernarvon Greywacke. It forms a prominent ridge through which the gorge passes. The cypress pine covered ridge forms

53. Heysen Trail Walk.

a rim around the diaper.

We kept our eyes peeled for the hut George Glass lived in when he worked as a station hand in the area. The gorge is named after him. Apparently he built part of the gorge road. The ruins of two stone chimneys and another building were seen through the trees. It is on private property so we could only view these ruins from a distance. On a rise which was cleared of vegetation just over the creek we stopped for morning tea and enjoyed our bakery treats and the views.

Stop 3 was at a creek crossing where we viewed magnificent river red gums and in the creek an outcrop of what appeared to be dolomite above which was a deposit of grey-green siltstone that was at a different angle to the rest of the rock formations. Some mallee ringneck parrots were seen in the trees above.

We passed the turnoff to Moolooloo Station where access can be gained to Nuccaleena copper mine ruins. The mine operated for only 6 years from 1860-66. Access is for experienced 4 wheel drivers, particularly the last few kilometres of the track, so we did not attempt this. We crossed Oratunga Creek, the name made famous by Hans Heysen in his painting “Patawartal land of the Oratunga”. The next grid we crossed was on the Tapley Hill Formation. Our next stop was at a 10 m wide bed of the Nucaleena Formation dolomite in the road cutting. It was highly weathered. Red brown sandstone of the glacial Elatina Formation lies to the east. Nearby was a well preserved dry stone wall which supports the road running along and above the creek bed *(photo 51)*. It was a popular subject for the photographers in the group including the ‘Safari Girls’ *(photo 52)* in the safari participants. From here we drove towards the Heysen Range and made numerous photo stops to capture the colours in the magnificent ranges. The last part of our journey was along the creek bed, where the creek cuts through red Brachina Siltstones.

Once we reached the Parachilna Gorge Road we drove 11 km to the Prairie Hotel where we had booked in for lunch. We had made this booking by telephone from Blinman. Unfortunately the hotel was closed because of the nation’s official day of mourning for

Queen Elizabeth 11. The booking was on the answering machine and had not been read. A touring coach group were the priority. We did get access to see some of the Ediacaran fossils displayed and to sample some Fargher Lager brewed on site.

Disappointed we returned to camp for a quick lunch before walking a section of the Heysen Range led by Sue Rogers *(photo 53)*. This was a pleasant walk amongst splendid red river gums along the creek bed.

Day 14: *Friday 23rd September 2022 – Blinman to Arkaroola via Chambers Gorge.*

The group packed up to move on to Arkaroola. Most stopped at Blinman for phone and internet access and to purchase some of the tasty treats available at the café before heading north east to Arkaroola.

A number stopped at Mt Chambers Gorge *(photo 54)* to view the numerous petroglyphs, rock engravings that are about 6000 years old *(photo 55)*. We came back to the main road, had lunch and continued the drive to Arkaroola arriving around 4 pm. It was gravel roads for the whole trip so a few screws came undone and things were shaken up in the van but no real damage.

However Ross and Glenda drove their vehicle to the Arkaroola reception and after checking in found that the engine would restart but not keep running. This led them to being towed to the camping area so they could set up with the understanding that the mechanic would not be available to look at it until Monday. This was the beginning of their vehicles dramas that lead to them having an extensive extra holiday in Adelaide while awaiting for the vehicle to be roadworthy again.

Day 15: *Saturday 24th September - The Pinnacles Drive and Walk.*

The weather was perfect today for the Acacia Ridge walk *(photo 56)* along the Blue Mine Conglomerate that was laid down 800-900 Ma resulting from the erosion of older granite. The coarse clear quartz was highly visible but the rocks have been moved over time and are often vertical rather than horizontal. This 5.2 km walk saw us climb to 560 m to the lookout for wonderful 360° views *(photos 57 & 58)*. We saw numerous wildflowers as well as various species of acacia. Others not keen on the steep walk examined the enormous rock samples that make up Arkhenge at the park entrance and about 500 m of the ridge walk to observe the two geosites and dam wall.

At 1.30 pm the convoy of 3 vehicles set off from the Arkaroola Caravan Park to The Pinnacles. The distance travelled to this geo-site was only 4 km but we made a few stops along the way. Stop 1 was at the Miniremarkable Range. This was an ancient slab of seabed quartzite broken away from the Griselda Hill which overlooks the camping area. Stop 2 was at Copper Creek Bore, the earlier water supply of the village. The water is very saline and is no longer used.

54. Mt Chambers as seen from the gorge.

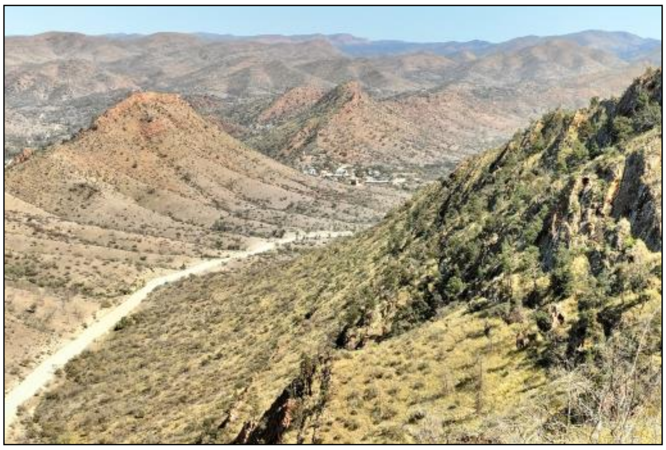
55. Some of the numerous petroglyphs in Chambers Gorge.

56. Acacia Ridge track.

Last Chance Bore is currently in use. We passed a water storage facility and noted a solar array and satellite dish on a high ridge to our left. At Stop 3 we noted the regeneration of mulgas, acacias and native pines seen on the southerly slopes of the ranges.

We made a right hand turn off the Bolla Bollana Track to travel 500 m up to elevation 430 m to a carpark which gave an overview of two of the pegmatite plugs called The Pinnacles *(photo 59)*. The walk around the plugs and back to Arkaroola Village is along the

57. Acacia Ridge track View from Summit towards Lake Frome.



58. Acacia Ridge track view from the summit over Arkaroola.

59. The second pinnacle surrounded by colourful wildflowers.

Mawson Valley. Three distinct rock types are found here. On the northern side there is the Blue Mine Conglomerate. It was laid down 900 Ma as a coarse grained marine shoreline deposit. It is up to 355 m thick. It has mudcracks and ripple marks. The valley floor is the Opaminda Formation. It is 300 m thick and was sand and mud deposited on tidal flats. The southern side is a resistant ridge of Worturpa Quartzite 200 m thick, formed by beach sand which settled on mudflats. From the carpark we followed a section of the Mawson-Spriggina Trail to the base of the main Pinnacle. Spinifex, brilliant hopbush, yellow flowering gums and mauve bush fushia were the main flora.

Sue and Laurel walked back along the Mawson Valley which is named after Sir Douglas Mawson, Antarctic explorer, geologist, and teacher who spent a considerable time at Arkaroola. The trail takes you to Sitting Bull that was named by Mawson in 1945. Sitting Bull formed about 450 Ma. The magma from which it cooled is thought to have reached the surface as an explosive silicic volcano. From this pegmatite plug the trail follows the creek back to the village. Others did the short walk to the main and smaller pinnacles and returned via the same track to the vehicles. The main pinnacle is home to a small colony of yellow footed rock wallabies.

<u>Day 16</u>: Sunday 25th September - Ridge Top Tour.

We had another great day today with perfect weather. The group had a free morning before doing the very scenic and informative ridge top tour. After some argument as to who was to travel in which vehicle our whole group were finally allowed to sit in one of the three troop carriers *(photo 60)*.

Our French guide, Pierre, explained the history, geology, vegetation, management and importance of Arkaroola while he drove us safely along the 4WD tracks in the open sided troop carrier. The roads were originally made in the 1960s by the mining company Exoil searching for uranium and have to be reconstructed after any heavy rain. We were surprised as to how good they were to travel on, proof that money is being invested in improving them. We stopped at Coulthard's lookout *(photo 61)* which gave us views of the Mount Painter Inlier and its various rock types . We could see Lake Frome, Mount Painter, Mount Gee and Radium Ridge.

Our second stop was the Split Rock Lookout *(photo 62)*. Pierre explained how Reg Spriggs had purchased the Arkaroola Pastoral lease in 1968 and established it as a wildlife sanctuary and tourist resort. He had to remove all of the farm animals – cattle, sheep, pigs and horses that were grazing on the steep hills and gullies.

We ascended the narrow rocky knoll known as Sillers Lookout for our final stop and of course a group photo *(photo 63)*. After a few minutes we were given lamingtons and a cuppa. This lookout provided views towards the plains *(photo 64)* and Beverley Uranium mine as well as the Gammon Ranges. The difference between the rugged mountain landscape that we had travelled through and the plains that we viewed from here was stark. The still active Paralana Fault is responsible for this marked difference in the landscape. We overlooked the Beverley uranium mine and Mawson Plateau. The lookout is named after Bill Siller (Exoil Consortium Chief) and the mine after his wife, Beverley. We returned in time to view the yellow-footed wallabies descending Mount Griselda.

60. Aboard a troop carrier for the Ridge Top Tour.

62. Split Rock - brecciated granite.

61. View from Coulthard's Lookout.

63. Group photo at Sillers Lookout.

65. Ochre deposit with old stream deposit above.

64. View from Sillers Lookout towards the plains and Lake Frome.

66. Lively's gold mine.

Day 17: Monday 26th September - Paralana Hot Springs.

Overcast skies and showers of rain led the leaders today to delay the departure of the group convoy by 1 hour. Amazingly the sky cleared and the sun was brightly shining by 9.30 am when we departed. We collected some members at Reception and drove out along the Arkaroola Road for 5 km to the turn off to Paralana Hot Springs.

Our destination was some 26 km distant over a gravel road of a reasonable standard for two wheel drive vehicles to Stubbs Waterhole and then became a four wheel drive track for about 20 km. The first photo stop of the morning was at ripple marks in Blue Mine Conglomerate exposed in a rock face as we approached the Ochre Wall. After parking we alighted from the vehicles and crossed the dry creek bed to the bank of exposed ochre *(photo 65)*. The Ochre Wall is located on the eastern side of the Paralana Fault. It consists of highly weathered laminated red silts and shales of the upper section of the Angepena Formation. The colours are formed from hydrated iron oxide mixed with clay and sand. Above the ochre is a 1 m thick capping of Quaternary creek bed alluvium. The ochre was used for painting and decorating the Adnyamathanha peoples' bodies in ceremonies. Many wildflowers were seen and photographed here.

Next stop was Lively's Gold Mine *(photo 66)* found by Allan Lively about 1946. 203 oz were produced and was the richest gold find in Arkaroola. The gold occurs as fine wires, crisscrossing an ochreous seam in crushed slate. The mine is located within the deeply weathered and brecciated laminated siltstones and shales of the Blue Mine Conglomerate proximal to the Paralana Fault. We walked to the ruins of his bush camp and climbed over the mine mullock heaps to peer down into the mine tunnels in the hillside nearby.

We drove between the Jasper Twins *(photo 67),* two imposing boulders of silica coloured by iron oxides and part of the brecciated Balcanoona Formation which have been altered and cemented by silica-rich fluids. These rocks have probably rolled downslope to their present location. This was a photo stop only.

Our next stop was at the Welcome Mine which consisted of a patchy high grade copper deposit. It was owned by H.C. Gleeson of Adelaide. Mining began in 1862 with three men raising 23 tons of ore which they bagged and dressed. The ore contained 40% copper and was valued at £35 per ton. It was carted to Port Augusta and then shipped to smelters in Wales. The high grade copper ore soon petered out and during four years of drought mining ceased. The mine closed in

1867 after 19 tons of ore was removed in that same year. The copper was found in the brecciated Tapely Hill Formation in the form of the copper carbonates, malachite and azurite.

Driving on we climbed the track to a lookout point over Welcome Pound. The pound was a valley, surrounded by hills with no exit. It was favoured by pastoralists to hold livestock. Here in the road cutting we saw the Tapely Hill slates made from fine grained mud in the deep ocean. Under heat and pressure these muds had been changed to slate.

Shade was a priority so morning tea was had at Stubbs Waterhole *(photo 68)* which was a very picturesque location in Arkaroola Creek. This semi-permanent waterhole was a favourite stopover for the group. Here we studied the Merinjina Tillite which was carried by glaciers, crushed and cemented together to form rock. It was formed about 650 Ma. It was found in the dramatic high walls above the creek bed. From here we travelled through Claude's Pass (named after Reg Sprigg's father). The rocks here were dated at 700 to 900 Ma. The track crossed very hard rock and it was an uncomfortable ride. One carload returned to Stubb's Waterhole for lunch finding the rough ride too much. They then returned to camp.

The rest of the convoy progressed to the Lady Buxton Mine site where we viewed a reverse thrust fault. This is evidence of the neotectonic activity of the region. The light-coloured Neoproterozoic formation has been thrust over much younger dark brown Cenozoic sediments.

Eventually we reached the eastern plains crossing over alluvial fans. The group was delighted to see substantial flowering of the Sturt's Desert Pea *(photo 69)* growing in its natural environment. By 2 pm we had reached Paralana Hot Springs. Out came the picnic lunches which we very much enjoyed in the shade of the trees. After a short respite we walked along the 140 m track to find the springs. They were silted up under layers of sediment. The water in the creek was hot below the springs but cold above them.

The springs issue from fault fissures associated with the Paralana Fault in rocks heated by radioactive decay. They are the only radioactively-heated hot springs in the world. Helium, carbon dioxide, hydrogen sulfide and radon gas bubble out continuously. The rocks in the area are 1580 Ma Mesoproterozoic granite and gneiss. Near the springs are basement boulders of breccia and jasper. The water temperature is 60 degrees.

Cynobacteria and Proteobacteria are the primitive life supported by the warm water. The walls of the valley are lined with jasper, crushed and sheared in fault movements that continue the process of uplift in the nearby ranges. We headed back to Arkaroola Campground at 2.55 pm and arrived back at camp just after 5 pm.

67. Road passing between the Jasper Twins.

68. Stubbs Waterhole Fault Zone and tillite.

69. Sturt's Desert Pea grew along the roadside.

Day 18: Tuesday 27th September - Bolla Bollana Waterhole and Smelter Site and Nooldoonooldoona Waterhole.

The activity today was a half day to allow members to prepare for onward travel to Copley the next day. Only five intrepid explorers today ventured out in two vehicles. From the campground we travelled on the Bolla Bollana track about 6 km to Bolla Bollana Springs. Bolla Bollana means "where they got up and ran". This refers to the Aboriginal Dreaming ancestors who fled from Arkaroo's (the serpent) fury.

After negotiating a tricky creek crossing of very sharp pointed rocks we found a park under some shady trees. We then walked along a well- worn track along the creek where the opposite rock wall was composed of great sliding dip faces of Griselda Hill Sandstone *(photo 70)*. Brian and Terry spotted a yellow footed rock wallaby bounding across the rock face with great agility. The creek bed contained some very weathered pale-coloured dome shaped rocks which proved to be popular with the photographers amongst us. Soon we reached the spring and waterhole located behind a narrow pinch between dipping beds. We climbed up to the top of a large dipping outcrop to get an overview of the waterhole and the creek beyond *(photo 71)*. A number of corellas flew in to drink while we watched on.

Returning to the vehicles we had morning tea before progressing a few km further to the Bolla Bollana Smelter Site in the Gammon Ranges National Park. This site was about 300 m off the track. Here we saw the brick round house kiln *(photo 72)*, the ruins of the storeroom, the slag heaps, the two shaft furnace ruins, the 50 m flue joining a collapsed chimney stack *(photo 73)* and several slate floors where the copper ore was sorted by hand and bagged.

Smelting operations ceased in 1874. The smelter was the grand plan of Alfred Frost in the 1870's to provide a central smelter for the scattered copper mines in the area. The site was chosen because of the permanent water supply nearby and the timber available. The design was based on the Blinman Smelter which we had visited earlier in the trip. Bullock wagons brought the ore to the site from the copper mines. The miners were Cornish.

The last stop of the morning was at Nooldoonooldoona Waterhole *(photo 74)*. On the way we passed a tremolite deposit (greyish white, brittle asbestos) and passed around Greenwood Hill where Bentley Greenwood had a gold prospecting location. Haematite Hill and Bob's Knob were seen and we drove into the region where Mount Neill Granite is exposed. We parked before a very nasty looking drop off where large high boulders deterred us from crossing.

We walked about 800 m to the carpark of the waterhole seeing many beautiful wildflowers along the way. Once at the carpark the waterhole was only a further 200 m away. Here the Dreaming ancestors rolled down great boulders in an attempt to block the passage of the serpent Arkaroo. The rocks in the creek bed at this site were biotite, muscovite and quartz schist *(photo 75)* and they glittered in the sunlight. The waterhole held the reflections of the wildflowers and white rocks behind. The red cliffs towered above. It was a beautiful location.

Brian walked back to the vehicle and brought it out to save us the long walk back. Terry returned in his vehicle to camp while the rest of us had a picnic lunch in the shade. We then made the return to camp ourselves.

70. Steeply dipping beds of Griselda Hill Sandstone.

71. Bolla Bollana Waterhole.

72. Round house brick kiln at Bolla Bollana Smelter site.

73. 50 m flue with collapsed roof looking towards collapsed chimney.

74. Nooldoonooldoona Waterhole.

75. Biotite, muscovite and quartz schist.

Day 19: Wednesday 28th September - Relocate from Arkaroola to Copley.

We left Arkaroola around 8:20 am and drove mainly west on gravel roads to the old railway town of Copley. We drove through Italowie Gap near where R. M. Williams began his Bushman's Outfitters business. We also passed through Nepabunna where the Adnyamathanha people were relocated to in 1929. It was a tidy town that appeared to have modern services.

The road was far better than we expected and we arrived just after 10:30, perfect time to have morning tea at Copley Bakery which is in the caravan park. After unhitching we drove the 5 km to Leigh Creek, a coal mining town that is nearly empty now as the mine closed in 2016. However it houses an impressive supermarket that sells nearly everything you would ever need - clothing, shoes, electrical goods, gardening products, hardware, basic furniture as well as groceries so we could get fresh bread, milk and vegetables. None of these were available at Arkaroola and the general store at Copley has been closed for a while.

It was an opportunity to explore Copley after lunch and relax before our safari dinner *(photo 76)* at Leigh Creek pub located in Copley, about 200 m from the caravan park. The husband ran the bar and the wife looked after the food. Their specialty was deep fried battered onion rings that were served layered onto a skewer of hot chips. The meals were more than adequate and a few needed to ask for a container to take the excess for lunch on the following day.

Day 20: Thursday 29th September - Ochre Pits, Farina and Aroona Dam.

Another bright sunny day for the last day of our safari was enjoyed by all. The convoy formed up at 8.30 am with a slightly delayed start. We set off hoping that the missing group would catch up before too long.

From Copley we travelled some 33 km to Lyndhurst. Just 5 km past this town of population 30 on a good day, we turned into the Ochre Pits. This was our first stop of the day. Here we found a 1 km square quarry dug over thousands of years by the Yantruwanta

76. Safari Dinner at Leigh Creek Hotel, Copley.

peoples *(photo 77)*. The ochre is an earthy pigment containing ferric oxide typically in clay within Quaternary alluvial sediments. Brown, red, orange, yellow and white ochres were seen at the site. The ochre was used for ceremony, medicine, art and burial. It was widely traded for native tobacco, stone axe heads and spinifex resin. The site is considered a sacred site of great significance.

We returned to the main road and travelled a further 20 km north to Farina historic ruins *(photo 78)*. "Farina" in Latin means flour. The town was first called "Government Gums" and was established in 1878. We stopped first at the information panels, to get a copy of the town layout map before travelling 2 km further to the campground. Here we found a suitable picnic table in the shade for morning tea.

Next we walked to the War Memorial and read the information panels that told us that 33 local men had enlisted in World War 1, 5 were killed in action, 19 were wounded and 1 died on the voyage to England. In World War 2, 35 had enlisted, 26 joined the AIF and 9 joined the RAAF. The memorial was built in 2010 and the first Anzac Service was held in 2012 with over 100 participants.

Next stop was Well No 1 built in 1864. Budgerigars, wood swallows, cockatiels and sparrows were some of the birds seen in the trees nearby. Black kites circled overhead. The well originally was an open timber well with a windlass and bucket and water was transferred to a stone built storage tank *(photo 79)*. The supply of wells along the stock routes was the idea of George Goyder. Workers on the construction of the Overland Telegraph also drew water from this well.

Getting back into the vehicles we drove 2 km through two gates to the Historic Cemetery. The cemetery tells the tale of high infant mortality, women dying in childbirth, men dying from accidents, thirst, heat stroke and unsanitary conditions. A challenge was set to find the grave of French woman Ernestine Adrienne Lesire whose Arabic name was Miriam Bebe. Miriam married an Afghan cameleer, Gool Mohamet. In the furthest corner of the cemetery far away from the rest of the burials Sue found the grave.

From the cemetery we returned to the main area of the Farina ruins and spent an hour and a half walking around the site reading the information boards. The underground Bakery, the Patterson Homestead, the Police Stations old and new, the hotels (Exchange and Intercontinental), the Post Office, the railway fettlers and guard cottages, cattle and sheep rail transport carriages and the rail infrastructure were all viewed during this time.

Back in the campground at 12.30 pm we shared a lunch together in the shade. From the Farina ruins people dispersed to follow their interests. Maree and Richard travelled to Marree, Rob, Helen, Ian and Sue returned to Copley, Colleen left for the long drive back to Sydney and Brian, Barbara and Sue visited Talc Alf's gallery just out of Lyndhurst *(photo 80)*. Here we were met by the character himself and he explained the significance of his talc sculptures in his open-air gallery.

Returning to Copley one vehicle continued out to Aroona Dam *(photo 81)* located a few km south of Leigh Creek. The dam was built by the Electricity Trust of South Australia from 1952 to 1957 by damming Aroona Creek. The aim of the dam was to supply water to the township of Leigh Creek and the coalmines 10 km to the north of the town. The dam is a concrete gravity dam 24 m in height and 236 m in width. Its maximum capacity is 7500 mega litres. The lake behind the dam extends for 3.5 km. The catchment area of the dam is 730 km square. It was a very picturesque location with some amazing rock formations.

In 1995 a wildlife sanctuary was established and yellow footed rock wallabies were reintroduced to the area after the eradication of feral pests such as rabbits, foxes and goats. Unfortunately a mob of feral goats was seen by us within the area as we left to return to Copley. They were very robust and healthy in appearance.

Report by Sue Rogers and Barbara Dunn.
Photographs by Ian and Sue Rogers, Brian and Barbara Dunn.

77. The Ochre Pits 5 km north of Lyndhurst.

78. Transcontinental Hotel ruin at Farina.

79. Holding tank for the Farina well.

80. Examples of Talc Alf's work at his gallery.

81. Aroona Dam near Leigh Creek.

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Strickland State Forest Walk

Leader: Barry Collier.
Date: Friday 4th November 2022.
Attendance: 12 members.

This was a walk I have planned for some time, but can only be appreciated on a cloudy day. There are so many fascinating cliffs, which, on a sunny day are in heavy shadow and with bright sky in the background, finer details are hard to see and appreciate.

On the 4th of November, a planned geology outing had to be cancelled as road damage from recent bad weather made accessing the site impossible.

When I checked the weather forecasts, they predicted that the 4th should be very cloudy with little if any rain, so I decided to run the Strickland State Forest walk as an alternative to the planned activity.

Strickland State Forest is relatively compact with an area of 5 km^2. However, an impressive variety of plants and animals live there (350 plants, 98 birds, 29 reptiles, 27 mammals, 20 amphibians and 4 fish species recorded to date). The diverse ecosystem within the forest contributes to this with wildflowers and dry heath woodland in the north, tall eucalypts on its slopes through to lush rainforest in the south.

Rocks present in the forest consist mostly of Terrigal Formation with a narrow spur of Hawkesbury Sandstone extending into the forest from the west which contains the main entrance and picnic area.

The Terrigal Formation rocks are more susceptible to erosion than the Hawkesbury Sandstone, so, as the Terrigal Formation weathers, large sections of Hawkesbury Sandstone collapse, leaving relatively high cliff lines especially on south facing hillsides, which receive more severe weather.

Strickland has extensive walking tracks through varying forest types'; past waterfalls, under cabbage tree palms and along creeks

One of these walking tracks is the Strickland Falls Loop. The southern half of the loop descends into the Terrigal Formation, through some absolutely beautiful forests. The second half of the southern side of that loop is only a few metres below the junction of the Hawkesbury Sandstone and Terrigal Formation, and is thus just below the base of some spectacular cliff lines, which look so much better in cloudy conditions.

The loop goes within 100 metres of the falls, with a side track leading to the base of the falls. However, during the recent severe weather, a huge gum tree has been blown over and blocks the track. After heavy rain the falls are spectacular, but for most of the time there is virtually no water going over the falls.

Past the falls, the loop goes up numerous steps to the top of the sandstone ridge and returns to the picnic area through some interesting vegetation, including fascinating orchids, and past spectacular weathering on some of the rock outcrops. On the way up from the falls there were some displays of minerals deposited from water seeping out of the rocks

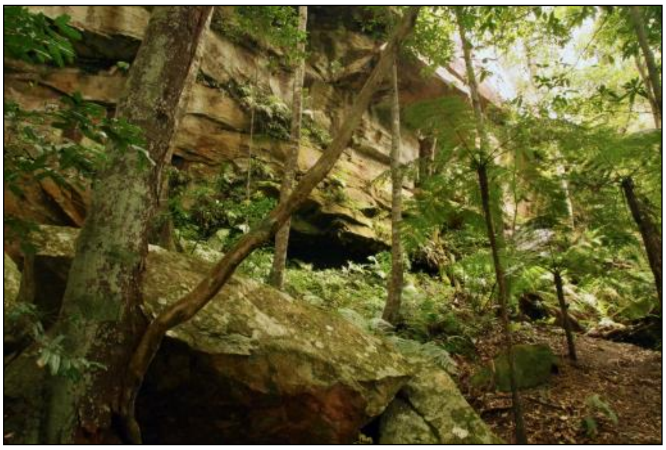
Apart from the fascinating Hawkesbury Sandstone cliffs, the Stoney Creek valley has some really beautiful forests which look better on cloudy days. After lunch, we decided to undertake a car shuffle and do the Stoney Creek Trail down to the Stoney Creek Carpark.

That was a most enjoyable walk for half an afternoon, but as soon as we finished, the clouds started to disappear, so we just made the best of the weather conditions.

Report by Barry Collier.
Edited by Ron Evans.

Photographs by Barry Collier and Shane Kerr.

Barry outlining the days activities at the Banksia Picnic area.



Impressive sandstone cliffs beside the Strickland Falls Loop track.

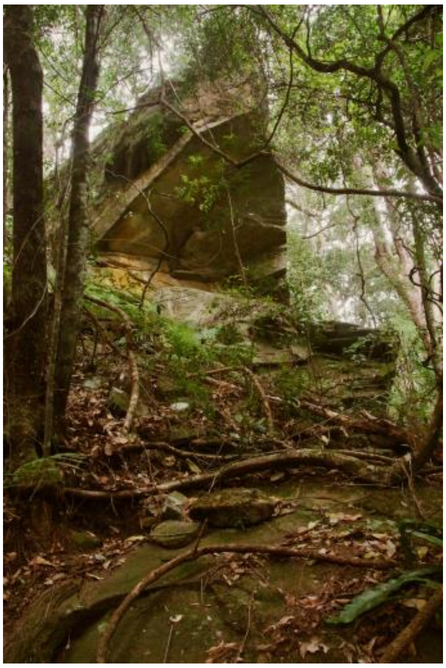
Track passing below Strickland Falls.

Track passes sandstone cliffs. Note people standing on the outcrop of Hawkesbury Sandstone.

Honeycomb weathering in sandstone. Note the Liesegang rings above the weathered section.

Group enjoying lunch back at the Banksia Picnic area.

Stony Creek trail (above) and Stony Creek (below).



Outcrop of Hawkesbury Sandstone above sandstones of the Terrigal Formation.

AGSHV Christmas Activity Hawkesbury River Cruise

Leader: Brian Dunn.
Date: Wednesday 7th December, 2022.
Attendance: 32 members.

On Wednesday 7th December 2022, 32 Society members gathered at Brooklyn Public Wharf to board the "Seven Islands of the Hawkesbury River" cruise which departed the wharf at 10.30 am for the Society's annual Christmas Party. The duration of the cruise was about 3 hours.

There was time for a quick coffee at the Brooklyn Marina while we waited for everyone to arrive.

Brooklyn is a small riverside settlement occupying the narrow strip of land between the river's southern bank and the extensive bushland of the Ku-Ring-Gai Chase National Park and Muogamarra Nature Reserve. It is sometimes referred to as "the gateway to the Hawkesbury".

Once we were welcomed aboard and were made familiar with the layout of the boat and safety procedures, morning tea was served. This consisted of Ben's Anzac biscuits, (the recipe courtesy of his grandmother) and tea or coffee. The biscuits were large, thin, crunchy and tasty.

The Captain gave us an informative commentary as we cruised down river around Dangar Island. The island is the only residential island in the Hawkesbury River. It was originally called Mullet Island by Captain Arthur Phillip in March 1788. Engravings and rock shelters on the island reflect Aboriginal occupation before white settlement. It was known as a gathering place.

The island covers an area of around 29 hectares, with a 3 kilometre long shoreline. It lies between Little Wobby and Brooklyn. It has around 300 residents. Private cars are not allowed on the island. It was connected to electricity in 1948 and to water in 1971. The island now boasts a cafe and shop, a bowling club and a community hall. A ferry service runs regularly between Brooklyn, Wobby and Dangar, seven days per week. Most residents have their own boat.

In 1864 the island was purchased as a country estate by Henry Cary Dangar, a prominent politician who later became a member of the Upper House of New South Wales.

Dangar leased the island to the New York based Union Bridge Company during the construction of the Hawkesbury River rail bridge between 1886 and 1889.

A community of around 400 Americans lived on the island. Following Dangar's death in 1917 the island was subdivided into residential allotments and named Dangar Island. During the Second World War, Army and Navy personnel used Dangar Island as a base to protect the railway bridge from potential Japanese attacks.

Surrounded by National Parks and reserves the Lower Hawkesbury River offers spectacular scenery,

AGSHV Members enjoying their "Seven Islands of the Hawkesbury River" cruise as the boat heads upstream towards the Hawkesbury River road bridge.

1. Upstream view of the Hawkesbury River estuary past Milson Island. The estuary is situated in a drowned river valley, hence the steep cliffs with V-shaped hanging valleys bordering the river behind Milson Island.

despite its proximity to the State's largest city, Sydney. These are the traditional lands of the Dharug and Guringai people whose name for the Hawkesbury was "Deerubbun".

The estuary is a drowned river valley with deep V -shaped valleys bordered by steep cliffs of Hawkesbury Sandstone *(photo 1)*. From the earliest days of colonial settlement the river was the lifeline between the fertile farmlands of Windsor and Richmond and the struggling settlement at Sydney Cove.

After rounding Dangar Island the boat headed upriver passing by the old rail bridge buttresses. The historic rail bridge was built in 1889 by the Union Bridge Company of New York, USA. Its completion was used by Sir Henry Parkes as a symbol for his campaign for the Federation of the Australian colonies as every colony was now joined by a rail link. Deterioration of the piers and the load limitations led to this rail bridge being replaced in 1946 by the current rail bridge.

The boat then passed between Spectacle Island and Long Island. Spectacle Island is located near the junction of Mooney Mooney Creek and the Hawkesbury River. It is 36.4 hectares in size. It was originally known as Goat Island, named after the herd of goats that were kept on the island.

Long Island is an elongated island of 73 hectares in area and is a nature reserve. It is joined to the mainland at its south eastern edge by the railway causeway across Sandbrook Inlet to Brooklyn.

Passing by Long Island to Kangaroo Point we travelled underneath the road bridges across the Hawkesbury. The Peats Ferry Bridge is a steel truss bridge that carries the Pacific Highway (B83) between Kangaroo Point and Mooney Mooney Point. It was constructed between 1938 and 1945. The adjacent Brooklyn Bridge carries the M1 Motorway and was officially opened in 1973.

The old stone quarries were viewed after passing underneath the road bridges as well as the remnants of the historic Peats Ferry Wharf. This ferry service was operated between 1847 and 1890's by George Peat and was the only way to cross the Hawkesbury River till the rail bridge was built in 1889.

Beautiful outcrops of Hawkesbury Sandstone were viewed closely, revealing cream, orange and red coloration. This rock is the dominant rock in the area and is resistant to erosion. Its upper surface is preserved on the ridgetops, the level of a former plain warped upwards to form the Hornsby Plateau. The vertical joints in the sandstone cause blocks of rock to break away forming vertical cliff faces. The NE and NW joint orientation controls the direction of flow of the Hawkesbury River and its tributaries.

The Hawkesbury Sandstone formed on top of the Upper Narrabeen Group when there was a paleocurrent shift from the southeast to the east and then to the northeast. Coarse quartzose detritus was transported northeastwards into the Sydney Basin by energetic braided streams to eventually form a sand sheet up to 300 m thick. Fine-grained floodplain deposits are rarely found in the Hawkesbury Sandstone. Mostly it was deposited in the main alluvial channels.

The Hawkesbury Sandstone is a Triassic relatively pure quartzose sandstone. It contains minor shale beds rich in fossils. The quartz sand grains developed overgrowths that extend into porosity between the grains. Thus the sand grains have minute faces which sparkle in the sunshine. Current bedding is common. Iron oxide has been mobilized by ground water and then precipitated to form red-brown concentric bands called Liesegang rings *(photo 2)* which give attractive patterning and patchy colouration. However, the sandstone weathers to a dull grey colour on its exterior surface over time as seen on the top of Pedestal Rock *(photo 3)*.

The history of Peat Island was explained as we passed by. The eight-hectare island has an infamous recent past, and has been sitting unused for the last 12 years. It officially became known as Peat Island in 1934, and was previously called Rabbit Island. The island was selected by the New South Wales Government as the site for an asylum for inebriates in the late 1890s. It was an asylum from the turn of the 20th century and later became a facility for people with intellectual and mental disabilities, before finally being decommissioned in 2010.

The NSW Government on 27th October, 2022 confirmed a landmark agreement to transfer ownership of Peat Island and a portion of the mainland foreshore at Mooney Mooney to the Darkinjung Local Aboriginal Land Council (DLALC).

Next we cruised by Milson Island and closely inspected the wreck of the HMAS "Parramatta", a torpedo boat destroyer built by the Fairfield Shipbuilding and Engineering Company at Govan, Scotland. It was Australia's first warship. It lies below Cascade Gully. From 1914 until 1917 the "Parramatta", conducted patrols in the Pacific and South East Asia before she and her sister ships were transferred to the Mediterranean for anti-submarine operations. She returned to Australia in 1919 and was placed in reserve. Apart from a brief period of full commission during the visit of the Prince of Wales in 1920, "Parramatta" remained in reserve until 1928. She was fully decommissioned in 1928, stripped of parts, and sold for use as prisoner accommodation on the Hawkesbury River. After changing hands several times, the hull ran aground during a storm in 1933 and was left to rust. In 1973, the bow and stern sections were salvaged and converted into memorials.

2. Weathered sandstone boulder displaying well developed Liesegang rings.

3. "Pedestal rock". Note the bedding emphasized by brown deposits of iron minerals.

Next we cruised past the oyster leases and the off grid settlement on Bar Point where homes have many levels and lots of steps as they cling along the edge of the river below the 200 Ma sandstone escarpment.

The houses have their own jetties as water transport is the only means of travel. The residents rely on the Riverboat Postman to bring mail and supplies.

Settlement of Bar Point dates from the 1880's and today there are some 235 residential lots. There are about 90 permanent residents. Residents rely on rain water for their water needs. Refuse is removed by boat.

Bar Point is the head waters of interconnecting river tributaries, namely Berowra Creek, and Marramarra Creek fed from Hornsby Heights and Galston Gorge; also the main tributary flowing from Windsor/ Wisemans Ferry(fed from the Cox's River in the Blue Mountains) and the Nepean River.

A couple of prawn trawlers were passed at work in the river. Flocks of gulls and pelicans trailed behind them in the hope of a feed.

Marlow Creek entered the Hawkesbury River next and we travelled along it for a short distance to view the settlement along its shore.

We returned then past Fisherman's Point, Bar Island and Milson's Passage passed Milson Island Sport and Recreation Centre. It is a secluded place with sweeping views of the Hawkesbury River. Green, manicured lawns, towering palms and landscaped gardens are seen beyond the wharf area. A group of children were kayaking.

Milson Island was first settled over 100 years ago and has had many uses; as a bacteriological station, quarantine station, a hospital to treat soldiers from WWI with venereal disease, mental hospital, a rehab for alcoholics, a women's jail, and now a sports and recreation centre. It was also known as Mud Island on early charts.

Milson Island was sold by Aborigine Granny Lewis in 1865 to Robert Milson, who remained the owner till his death in 1901. The land was then purchased by the Government.

A Ploughman's lunch consisting of ham, cheese, salad leaves, carrot, cucumber, tomato, pickled onions, various chutneys and condiments and a freshly baked bread roll was served during the cruise.

We continued down river until we reached Juno Point where Lion Island Nature Reserve was observed in the distance in Broken Bay. Here the Hawkesbury River enters the Tasman Sea.

Eagle Rock where significant Aboriginal rock carvings are found was passed on the return trip back to Brooklyn.

Robert Coenraads took the opportunity to use the boat's microphone to give an off the cuff but very informed talk about the features of the Hawkesbury Sandstone and the river topography.

We returned to Brooklyn wharf at 1.15 pm having enjoyed a scenic and relaxing cruise. A few of our more energetic members walked around McKell Bushland Reserve to Parsley Bay before returning home. Many wildflowers were seen and further examples of the features of the Hawkesbury Sandstone were photographed.

Report by Barbara Dunn and Brian Dunn.
Photographs by Elaine Collier, Barbara Dunn & Ron Evans.

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Application of Photogrammetry and other Visualisation Techniques in STEM*

Presenter: Dr. Bill Landenberger.
Date: Thursday 2nd February, 2023.
Attendance: 23 members, 1 visitor.

This was another Summertime talk presented at Club Macquarie. This was a warm day and a great chance to enjoy the benefits of air conditioning while learning about Photogrammetry and its application in the local context and uses for teaching. The following is a very brief education and teaching background followed by a summary of his talk.

Background.

Dr Bill Landenberger *(photo 1)* has been a lecturer in Geology at The University of Newcastle for the past 30 years, specialising in igneous petrology with special interest in granites of the New England area. He completed his Honours Thesis in 1988 and went on to finish his PhD Thesis in 1996. His main reason for learning to use digital photos to turn them into 3D models and full spherical panoramas was to aid the development of virtual field trips and display virtual images of rock samples to assist in teaching his students. More recently, the scope of these panoramas has expanded into the fields of architecture, history and natural heritage.

Photogrammetry Talk Summary.

"Fieldwork is the cornerstone of geological education!"

Running student geology fieldtrips faces issues with time, cost, access and OHS considerations. Two years of Covid lockdowns, with no direct student contact, meant that new methods were required to augment field and lab-based education.

Virtual Excursions.

◊ Supplement field trips.
◊ One of the first projects was with White Island, NZ after travelling there some years ago for a family holiday where Bill took lots of photos while flying over it – uses Sketchfab website.
◊ Useful for teaching.
◊ Introduced to Photogrammetry by Michael Roach, Utas.

1. Dr. Bill Landenberger.

Geological Fieldwork and 3D Visualisation.

Interpretation of 3D features from ordinary photos is difficult for most people.

Geological Fieldwork often requires an understanding of the geometry of an outcrop or specimen.

A method is required to depict the geometry.

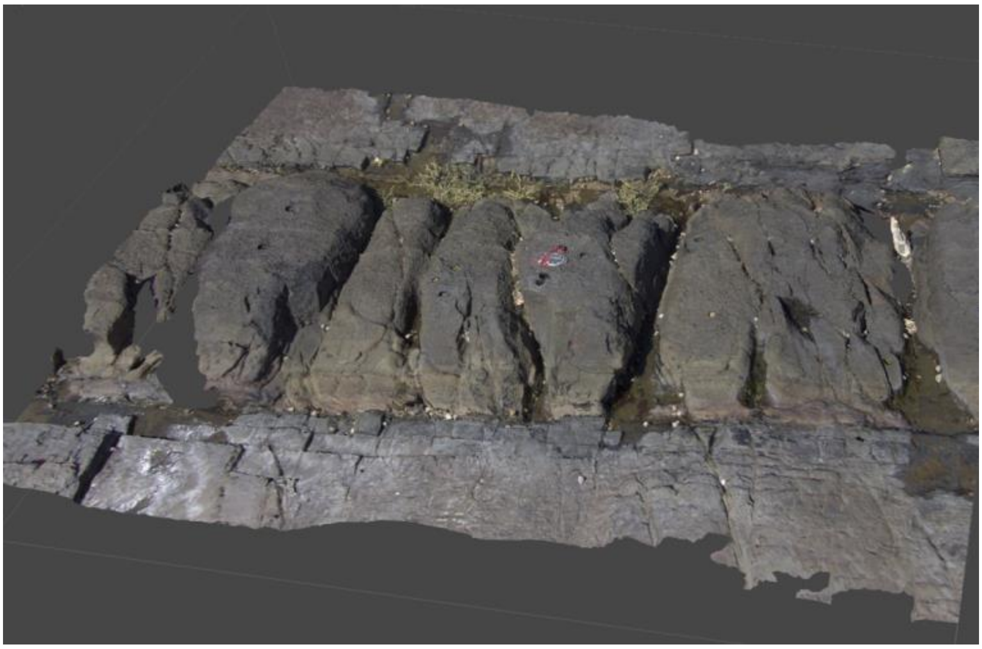
You can use:

◊ Laser scanning. A laser scanner can cost in the order of $40,000, or
◊ SLR camera or a drone camera, costing about $3000 plus a good computer is needed.

Photogrammetry Process.

◊ Take photos, more the better, from many orientations. Can take a few to hundreds.
◊ Software matches pixel patterns or features between photos.
◊ Makes a point cloud.
◊ Create a high resolution orthophoto or digital elevation model.
◊ Or you can go the other way with mesh generation
◊ Software goes back to photos – blends textures from original images and overlays the mesh *(photo 2).*
◊ Produces a photo-realistic model that can be rotated.

For accurate surveys, ground control points (GCPs) must be used (minimum of 3), measured down to mm accuracy by GPS. However, if positional accuracy is not critical, scale and orientation markers can give very high-precision images and models of an area.



2. Blended textures overlaying mesh on 3D model of a dyke on Fort Scratchley rock platform.

Taking Photos.

Photography is best done in diffuse lighting such as on a cloudy day.

◊ Use the same camera settings for all photos i.e. have the camera in manual mode.
◊ This allows the computer software to more easily match the photos.
◊ Bill generally takes 40 or 50 photos of a specimen or outcrop, but drone surveys require several hundred.
◊ Small specimen/hand specimen photos are taken in a light tent, rotating the specimen slightly between photos.

Using the Software (Bill uses AGIsoft).

First step:

◊ would be to align the photos – matches points between images.

Second step:

◊ For digital elevation models or orthophoto:
  * Create a dense point cloud. This can be in the order of millions of points.
◊ For 3D Model:
  * Generate a depth map.
  * Then a mesh surface is created. This can be in the order of millions of triangles.
  * Blended textures are then overlain on the mesh.

Photogrammetry Scales of 3D models.

◊ Outcrops are in the order of a metre in across.
◊ Small specimens can be one to several centimetres.
◊ Images made using a microscope can be < 1 cm.
◊ Images taken by drones can have a scale of >10 metres.

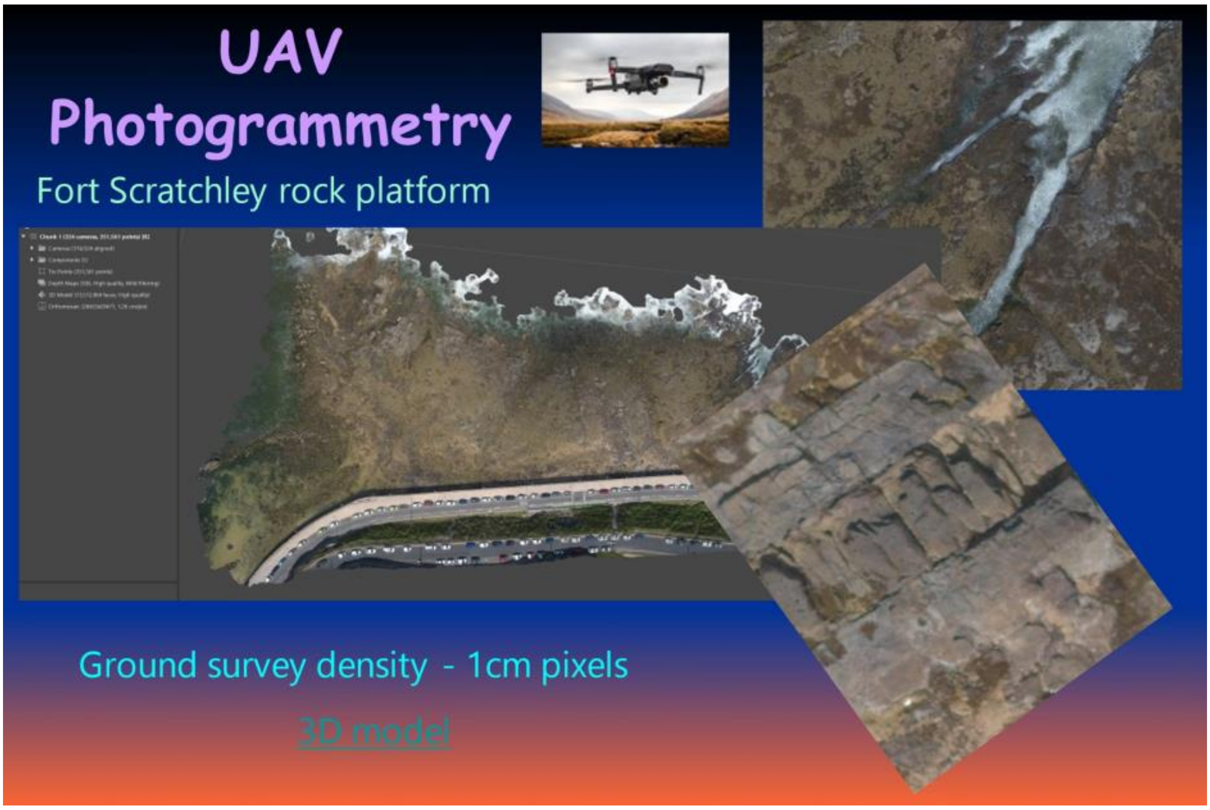
Bill Showed imagery of the Fort Scratchley rock platform dyke and the South Merewether Fault *(photo 3).*

Problems.

◊ Need to use all the same settings on the camera for each photo.
◊ Uses 'Raw Format' camera data rather than JPEG as it works better with the software.
◊ Has difficulties with intricate surfaces e.g. plants which require a lot more photos as they have a lot of hidden surfaces.
◊ Has problems with glossy, lustrous or transparent surfaces.
◊ Has problems with uniformly coloured or textured surfaces.

Photogrammetry applications in other areas.

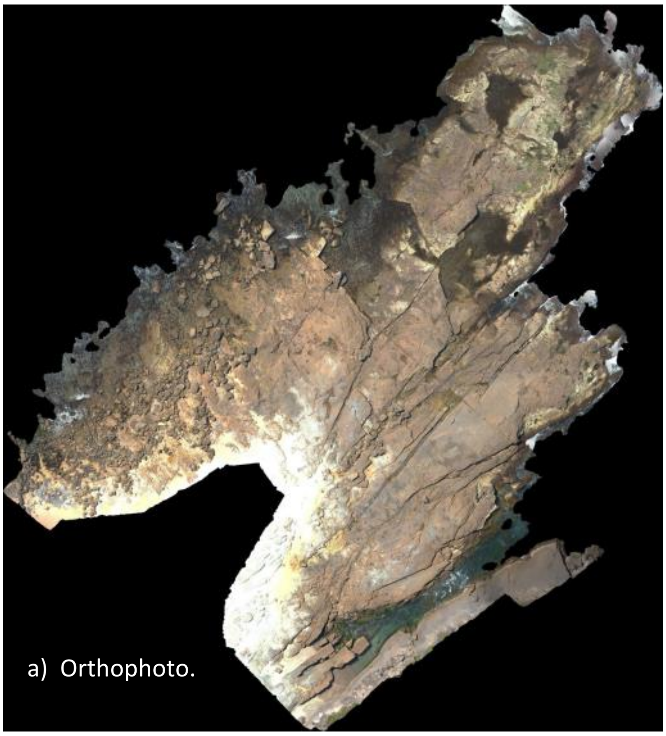
◊ Can be used in surveying for making topographic maps
◊ Architectural features e.g. buildings and rooms inside a building
◊ High resolution aerial photogrammetry
◊ Archaeological artefacts and artworks.



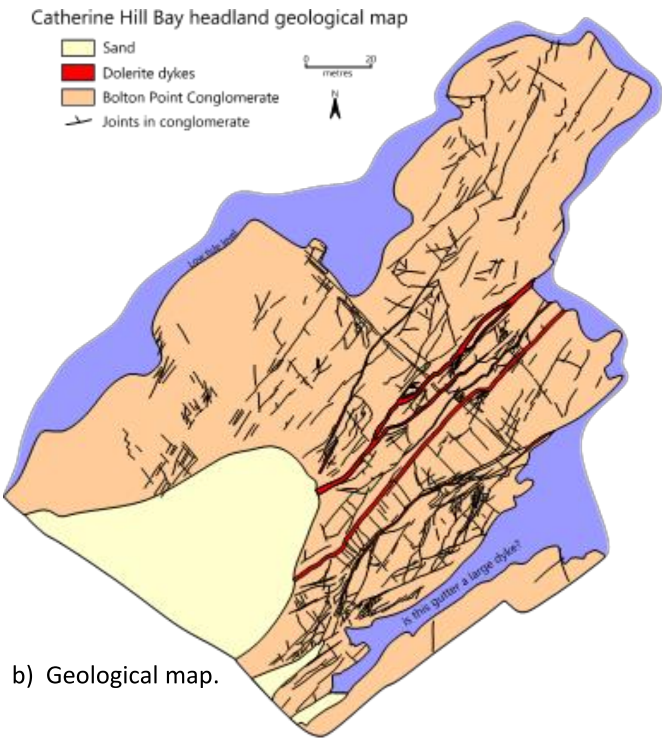
3. Power Point slide used in Bill Hardenbergers' presentation.

◊ Botanical applications e.g. making models of some specimens from the Don McNair Herbarium at the University of Newcastle such as seed pods or tree trunks.
  * Not good with plants or flowers - too many hidden surfaces.

Photogrammetry can produce more information in less time than other survey techniques e.g. geological surveying using tape measure and compass. A student project at Catherine Hill Bay rock platform took just 2 days to collect and process the data producing a digital elevation map, high resolution orthophoto, 3D model and geological map showing dykes and joint patterns *(photo 4)*.



a) Orthophoto.



b) Geological map.

4. Catherine Hill Bay rock platform.

Full spherical panoramas are generated by stitching together multiple photographs, from cameras using fisheye lenses or drone images, together to form a 3D mosaic. Bill showed examples from Caves Beach, Catherine Hill Bay and Merewether South *(photo 5)*.

Software Interpretation of Models.

There is software available that can collect orders of magnitude more data from the 3D virtual models than that collected by traditional fieldwork e.g. strike, dip, equal area stereo-net projections

Bill's Collections are available from:

- ◊ 360 cities (https://www.360cities.net/profile/landy42)
- ◊ Sketchfab site (https://sketchfab.com/Landy42/collections)

A larger virtual collection of Australian geology is available at AusGeol.org website (https://ausgeol.org/).

For those interested, the software used by Bill was AGIsoft, PTGui, Rhinoceros 3D or VRML

In summary, taking a series of pictures and using the right software can lead to the creation of orthophoto maps, a digital elevation models or a virtual 3D model of the object, which can be rotated on screen to view at all angles, and even some geological measurements can be determined. The subject can basically be any object, but Bill focussed on local headlands and some rock specimens. It is an amazing adjunct to teaching, though not a real substitute, with students being able to do virtual study of hand specimens and mapping areas, getting a grasp of what they should look for, before actually doing the fieldwork. Photogrammetry became exceptionally useful during the Covid lockdowns, when no students were on campus and all teaching was online.

** STEM.*

Means Science, Technology, Engineering and Maths.

Dr Bill Landenberger Acknowledgement.

On behalf of the AGSHV, we would like to thank Dr Landenberger for taking the time to give this informative and interesting talk on the uses of photogrammetry as well as access to images he has produced via the web links posted on the Society's Facebook page.

Also, many thanks to Bill for allowing me to make use of the power point slides he had prepared and their information as a guide in preparing this report, as well as taking the time to review this report.

Club Macquarie acknowledgement.

On behalf of the AGSHV, I would like to thank Club Macquarie and their staff for providing facilities that supported our presentation.

Report by Richard Bale and reviewed by Dr Bill Landenberger.
Photograph by Maree Bale & images by Dr Bill Landenberger.

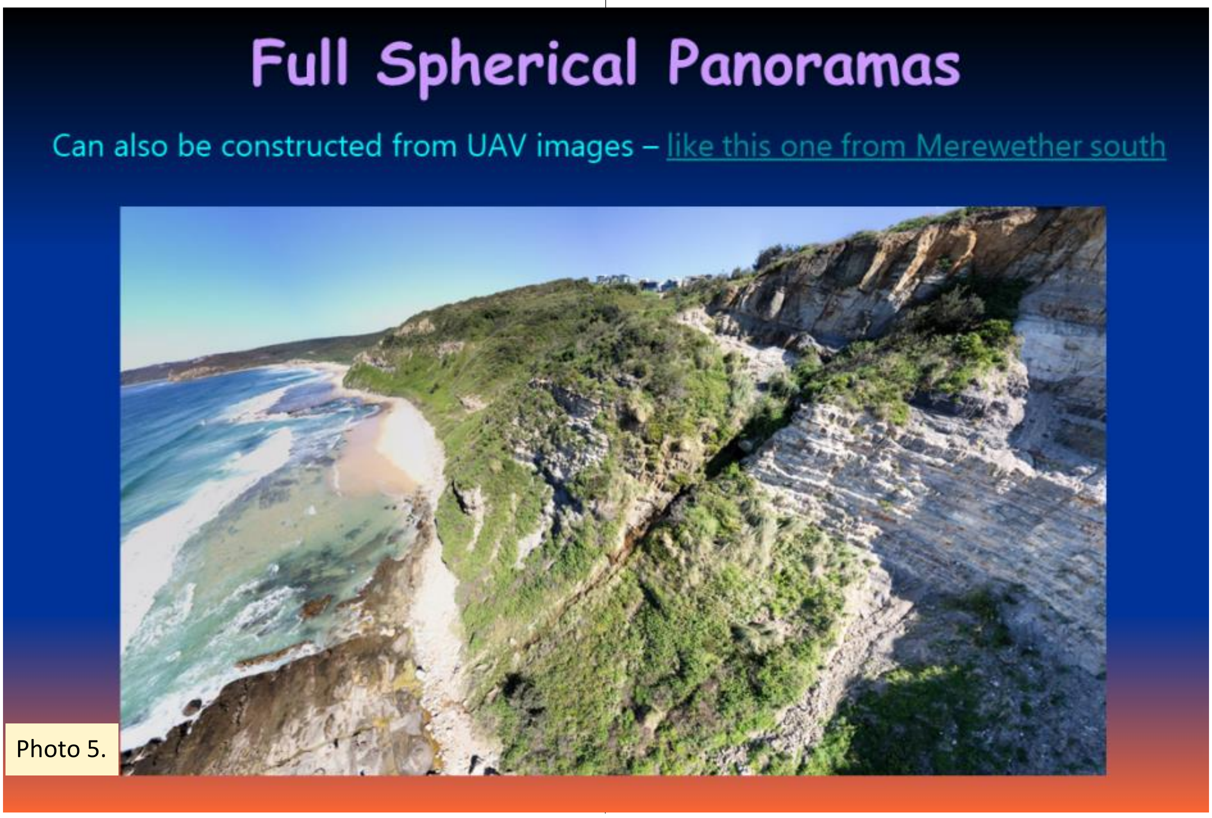


Photo 5.

Mass Movement Phenomena in Coastal Shore Platforms and Cliffs between Red Head and Treachery Head NSW

Leaders: Chris Morton and Brian England.
Date: Monday 3rd & Tuesday 4th April, 2023.
Attendance: 25 members, 1 guest.

This activity entailed observations of mass movement and slump-breccias exposed in inshore platforms and cliffs between Red Head north of Forster within the Southern Hastings Block (SHB) to Treachery Head in the south within the Myall Trough (MT). These localities are unusual in two respects *(Figure 1)*.

Firstly, the rocks at Red Head, Hallidays Point/ Black Head and Pebbly Beach SHB formed from submarine slumping of Late Devonian to Early Carboniferous marine sediments initially deposited by turbidity currents and pelagic sedimentation in a deep depositional basin. Slumping was initiated by minor tilting of the sea floor brought about by faulting or volcanic activity. Additionally, the coarse sandy layers proved the more unstable lithology, which failed by viscous fluid flow. The finer-grained interbedded layers in the slump mass fractured and remained as blocks and slabs, some large, in a matrix of coarser sediment (Leitch & Mayer, 1969) *(Figure 2a)*. The rocks at Red Head and Halliday's Point/Black Head were derived predominantly from a volcanic source. Measurements of slump folds suggest the emplacement of the breccias from a north-easterly direction (Leitch & Mayer, 1969).

Secondly, The Myall Trough region formed as an elongated trough between the magmatic arc to the west and an accretionary prism to the east. The trough is thought to be the result of basin subsidence, driven by the transposed strike-slip vector of oblique convergence (Maravelis et al. 2017) *(Figure 2b)*. The depositional environments range from fluvial to marginal-marine and shallow-marine at the base of the sequence (Booti Booti Sandstone), and pass upward into deeper marine (Yagon Siltstone) (Maravelis et al., 2017). Between the magmatic arc and the accretionary prism, sediment filling the Myall Trough comprises a thick succession of clastic strata with a maximum thickness exceeding 2000 m. The sequence contains five depositional systems in which environments range from non-marine to deep marine, representing the deepest water environments in the east.

Myall Trough sediments were derived from a south-westerly dacitic to rhyolitic magmatic arc (Nerong, Violet Hill and Alum Mountain Volcanics, 303 to 346 Ma). Overall, the sequence young towards the west (Skilbeck 1986). Subsequently, a complex development of folding, faulting and jointing has resulted in significant inclination of beds (Skilbeck & Cawood, 1994).

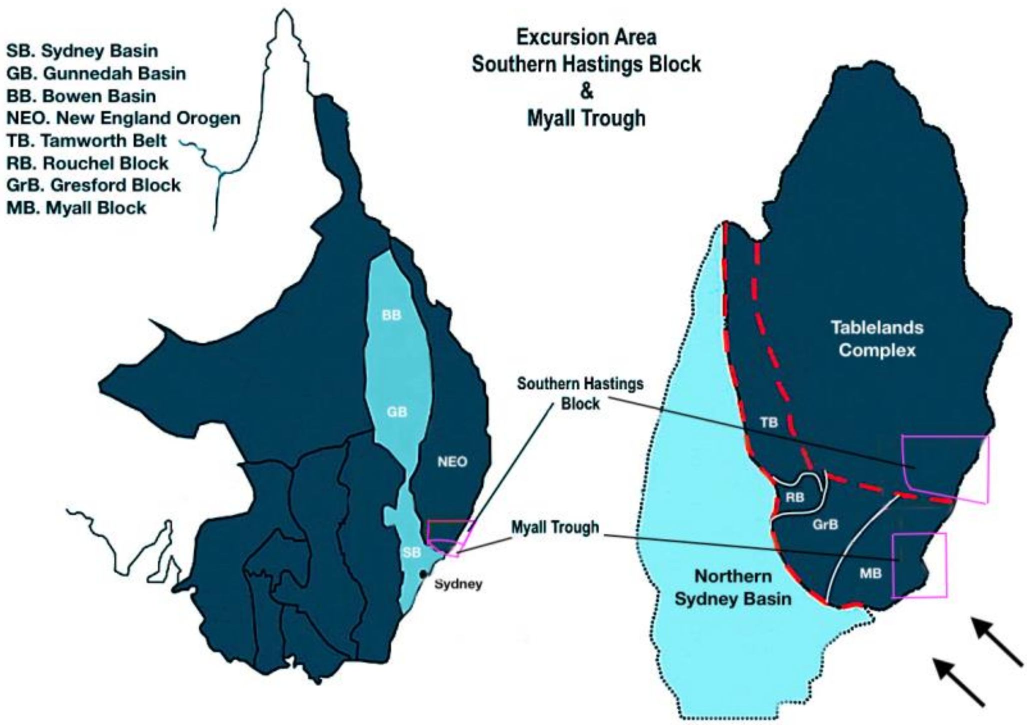


Figure 1. (After Palozzi et al., 2018) *Sketch map illustrating position of Southern Hastings Block (SHB) and Myall Troughs (MT). Arrows indicate oblique angle of plate convergence that resulted in basin subsidence, driven by a transported strike slip vector.*

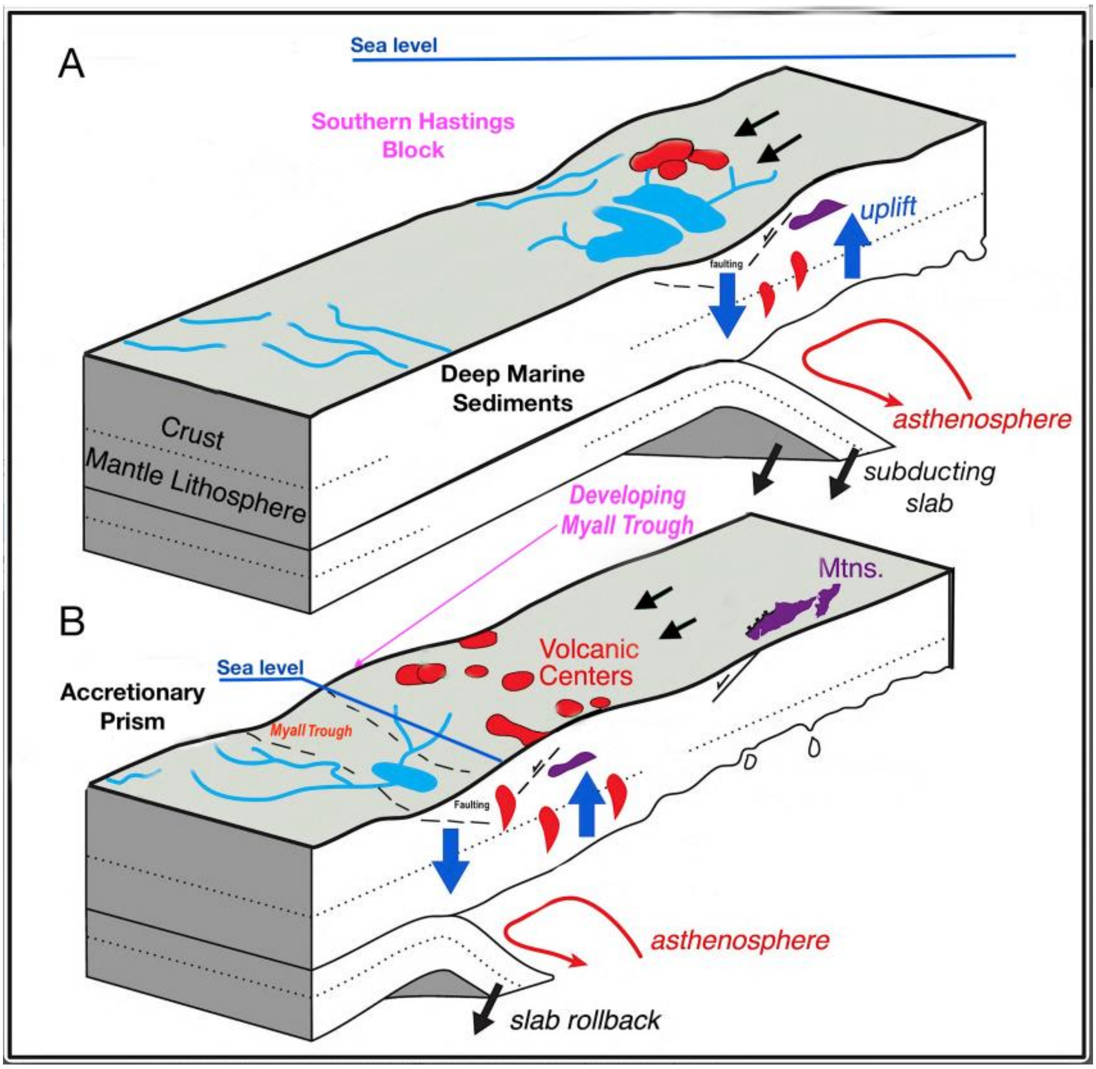


Figure 2. Schematic sketch illustrating tectonic processes in the evolution of SHB & MT within the Myall Block, that independently brought about consistent deformational processes in both areas.

Day 1: Monday 3rd April, 2023.

Red Head.

On a very wet and gloomy morning, we all gathered at the car park adjacent to the grassy reserve on Glenelg Circuit above Red Head Beach. Thankfully the liquid sunshine did not dampen our spirits (pardon the pun). There is a lot to admire about an eclectic bunch of extremophiles that turn up to a geology field excursion during an east coast low in what most would simply describe as atrocious conditions. Luckily the wind did not turn up to completely ruin our day. This goes to show our AGSHV members are not only resilient but tenacious as well. Of course, Chris copped a right royal pasting for not arranging better weather conditions.

Due to the inclement weather, the introductions had to be cut short. To help explain the complexities and aims of the field excursion, Chris had some interpretive panels made up which gave a visual sense in explaining how both regions to be visited on days one and two formed. Both areas looked similar despite the fact they show distinctly different evolutionary processes. The boards demonstrated the divergent circumstances and periods of time. Sediments making up the rocks at Red Head and Hallidays Point/Black Head occurred in a deep ocean environment beyond the continental shelf (Fig 2a). Mass slumping arose from the tectonic tilting of the sea floor (Leitch & Mayer, 1969). In contrast, the Myall Trough consists, in part, of a thrust-imbricated stack of ocean-floor igneous and sedimentary rocks that represent an accretionary prism assemblage in an elongated trough between a magmatic arc to the west (Fig 2b). The Myall Trough is understood to be the result of basin subsidence, driven by the transposed strike-slip vector of oblique convergence (Maravelis et al. 2017). Luckily the panels were covered in plastic, or else the rain would have made the ink run, rendering them completely useless.

From the meeting point, we sploshed along a well -maintained very wet grass track that leads to the stairs descending onto the beach and rock platform. Red Head rock platform offers easily accessible exposures of well-defined interbedded turbidites of greywackes and argillite with ample evidence of mass slumping initiated by tectonic tilting of the sea floor, brought about by faulting or volcanic activity. Evidence suggests the interbedded coarse sandy layers proved the more unstable lithology, causing failure by viscous fluid flow. The finer-grained interbedded layers in the slump mass fractured and remained as blocks and slabs, some larger than others, mixed in a matrix of coarser sediment that avalanched down the tilted slopes, coming to a jumbled rest towards the bottom of the inclines (Leitch & Mayer. 1969).

At the bottom of the steps, near the mid-point of the rock platform, you are immediately confronted with a mélange containing an assortment of debris that flowed down a palaeoslope, cutting through the turbidites. An image of Winston captured during a previous visit shows this. The photo shows Winston standing beside one of these flows that wreaked havoc on a turbidite outcrop. Notice the incised turbidites, where a mass flow event has occurred, leaving a slurry of sand and mud surrounding the outcrop. Also notice how differential weathering has eroded troughs between the beds *(photo 1)*. Throughout this confusing mess known as a mélange, it is easy to find many different examples of deformation. The units represent down-slope mass-movement deposits from the mobilisation of inter-bedded turbidite and pelagic sediments that constitute submarine slump breccias.

1. Winston standing beside deep-water turbidites disrupted by a slurry of sand and mud that flowed down a palaeoslope cutting through the turbidites. Note the differential weathering of the turbidite bedding resulting in troughs between the turbidite beds.

2. Turbidite beds unaffected by slumping and showing good examples of steep dip with some beds showing gentle folding.

3. Soggy but stoic AGSHV members eating lunch under limited cover at Hallidays Point Beach Reserve.

Towards the northern end of the platform, the rocks are relatively unaffected by slumping and show good examples of steeply dipping turbidites, with some of the turbidites showing gentle folding *(photo 2)*. A challenge for some members was to test their skills by determining the flow direction and depositional structures within the turbidites. At this point, we carefully negotiated our way around the southern headland and discussed the many different examples of the effects of slumping, folding and general chaos.

With the weather starting to weigh on some, we decided to make our way to Hallidays Point to try and find a dry lunch spot. We were somewhat successful in finding some covered picnic tables in the Hallidays Point Beach Reserve. That was OK, as long as you did not want to sit down on the wet seats, but the tables were covered, and it was alright if you stood up *(photo 3)*.

Hallidays Point.

After lunch, we proceeded south past the surf club and swimming pool onto the shore platform, revealing rocks and lithologies identical to those found at Wallabi Point (Pratt, 2016) and Red Head. Close similarity among these rocks also exists in their sedimentation and deformation history. Notwithstanding, the mass movement phenomena are much more in evidence at Halliday's Point and represent features indicative of large-scale movement of semi-

4. Swimming pool and uneven rocky section (foreground) onto the shore platform.

5. A random siliceous mudstone clast with a green halo surrounding it.
(Width approximately 10 cm).

6. Rock platform and cliff devoid of structure or bedding consisting of greenish-grey to dove-grey greywacke that contains random clasts encased by a green halo.

7. Green chloritic sandstone lying in a mélange of structureless slumped sediments.

consolidated sediments. (Leitch & Mayer, 1969).

The rocks at Hallidays Point dip steeply to the northeast, housing small-scale folds with two prominent joint sets dissecting the rocks at right angles. Faulting marked by a zone of intense crushing has displaced the sequence in the northern part section, but its attitude cannot be precisely defined. Well-bedded units of alternating greywackes and argillites, mainly the products of turbidity current and pelagic sedimentation, are present here.

Thick units of coarse greywackes show only indistinct internal stratification and contain large slabs and blocks of sedimentary material. These units represent second-cycle mass-movement deposits resulting from the remobilisation of inter-bedded turbidite and pelagic sediments and constitute submarine slump breccias (Leitch & Mayer, 1969).

Between the swimming pool and the rock platform, an uneven rocky section that needs a small amount of agility and balance to negotiate the path onto the rock platform *(photo 4)*. Arriving at the rock platform, you notice the cliff face consisting of massive greenish-grey to dove-grey greywacke containing random clasts with a green halo surrounding them *(photo 5)*. The cliff is devoid of structures or bedding planes *(photo 6)*. Some of this may be explained by the sedimentary structures being either partly, or wholly obliterated by convolution or homogenization during liquefaction. On the seaside of the platform, there is a massive block consisting of steeply dipping turbidite bedding. Between this and the platform, you encounter an assortment of structures that are too complex to describe effectively in this short report.

The platform consists of folded rocks, clasts of all shapes and sizes, green chloritic sandstone lying in a mélange of chaotic slumped sediments *(photo 7)* and slabs of turbidites *(photo 8)* from small to large, scattered in different orientations with some still retaining their sedimentary structures. One confusing section comprises very fine white sandstone exhibiting disrupted patterns of dark material.

8. A large slab of turbidite bedding that is randomly scattered still retaining its sedimentary structures, within structureless slumped sediments.

9. Small scale faulting caused by shear stress in a bed of fine sandstone.

10. Massive turbidite block, with a cave large enough for several people to enter, which many of our members could not resist exploring.

11. Members seeking relief from the rain by exploring the cave in the turbidite block.

12. Collapsed block of sandy matrix, surrounded by deformed paleochannel deposits.

The unusual patterns were caused by micro faulting resulting from shear stress between the enclosing more competent beds *(photo 9*). Similar structures are seen in turbidite beds at Wallabi Point to the north. Another unusual occurrence was embedded mudstone clasts within the matrix exhibiting a green halo *(see photo 5).* The reason for the halo has not received an adequate explanation and needs more investigation.

Towards the southern end of the rock platform, within the massive block of turbidite, there is a cave large enough for several people to enter, which many of our members could not resist exploring *(photos 10 & 11).*

Pebbly Beach.

With the rain persisting, we were off to our next and last stop for the day at Pebbly Beach. For most people, you wouldn't normally walk along a beautiful sandy beach in the rain. A sane person would wait for fine weather. However, curiosity about the geology, scenery and good company made it all worthwhile.

Our first stop was on the rocky headland, where we found a submarine palaeochannel with evidence of a channel wall had collapse into fine sediments at the bottom of the channel *(photo 12).*

With the weather marginally improving we moved on to where there was a cave in the cliff at the back of the beach. At the entrance to the opening of the cave there were several mudstone clasts with bedding still intact, with some clasts showing a green halo similar to those at Hallidays Point *(photos 13, 14 & 5).*

Further along, within an outlying rock outcrop, were two large bedded clasts lying at different angles. This unusual occurrence is a result of blocks juxtaposed in a slump melange. *(photo 15).*

We then continued to the north to the end of the beach, where we found spectacular beds of well-structured greywackes and argillite showing minor faults and slump folds *(photo 16)*. At this point, being wet and tied, we bid farewell to each other for the day and retired to our various places of rest to enjoy hot showers and a nice dinner.

<u>Day 2</u>: Tuesday 4th April, 2023.

Elizabeth Beach.

Given the weather was forecast to be somewhat worse than the day before, we set off with some trepidation. However, the weather gods must have pitied us because, at each stop, it miraculously remained clear and only rained whilst driving between each stopping point.

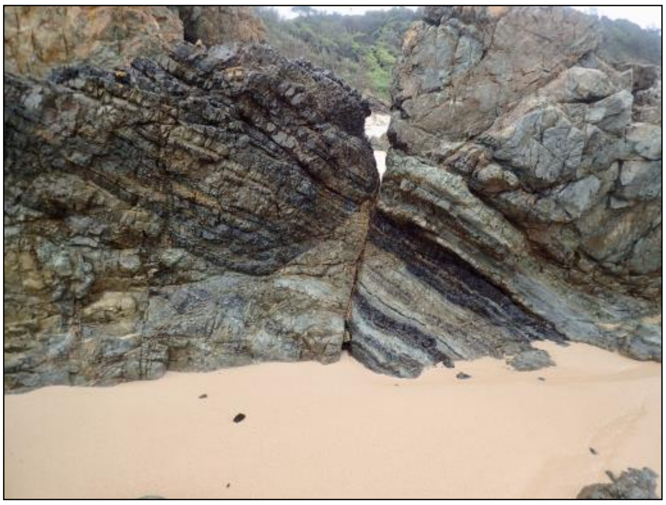
The first stop for the day was at the boat ramp beside Elizabeth Creek at the southern end of Elizabeth Beach, where the rocks on the eastern side of the boat ramp show some good examples of deformed folded rocks resulting from slumping.

We then walked along the NPWS access track to Shelly Beach (naturist beach). At the western end of Shelly Beach, the rocks consist of interstratified laterally-continuous sandstone and conglomerates. There are two associations here. The finer-grained rocks are considered to be levee and inter-channel deposits on a submarine fan, while the coarse-grained rocks are interpreted to be from channel deposits. The principal transport mechanism is most likely to be sediment-gravity flow (Skilbeck, 1979).

The weathered uneven surface of the sub-vertical bedding made it difficult for some to negotiate to a point where you can truly appreciate the spectacle of the tilted turbidite beds *(photo 17)*. Despite the obstacles and difficulties of the terrain, once gaining a good vantage point further around the point, you can see where a large block has collapsed in on itself. Beyond the collapse, adding to this dramatic scene, is a large section of the headland that has given away and slid down,

13. Several clasts with bedding still intact (some showing a green halo similar to at Hallidays Point - *photo 5*) beside the cave entrance.

14. Bedding obvious in some clasts next to the cave entrance.



15. Outlying rock outcrop, showing two slumped stratified slabs juxtaposed at different angles.

16. Spectacular beds of well-structured greywackes and argillite showing minor faults and slump folds.

17. Spectacular differentially weathered sandstones and conglomerates with sub-vertical bedding.

18. Arrows point to a collapsed section of turbidites in the foreground with a secondary collapse perpendicular to foreground event.

completely altering the orientation of the bedding planes *(photo 18)*.

Leaving Shelly Beach, we returned to our cars and drove to Cellito Beach car park near Bald Head. To reach Bald Head at the northern end of Celitto Beach, you traverse an elevated boardwalk through a magnificent littoral rainforest.

This hidden slice of paradise conceals a very different violent geological history. Getting to Bald Head which is out of sight behind the dunes to the north, requires a short but easy walk along the beach to where the dramatic geomorphology of Bald Head soon comes into view.

The rocks at Bald Head formed within the Myall Trough. Greg Skilbeck in his 1986 thesis described the Bald Head coastal area as comprising 'Blueys Beach Formation. But the so-named Blueys Beach Formation is recorded by Geoscience Australia, Australian Stratigraphy Unit Database (ASN. AUSD) as Yagon Siltstone, Violet Hill Volcanic Member, which applies to the sequence of chaotic beds, principally of sedimentary rocks, that are composed of alternations of volcanogenic conglomerate, sandstone and mudstone, with interstratified extrusive igneous and pyroclastic rocks (Roberts et al. 1991). The presence in the sequence of intercalated tuffs indicates that volcanism in the source area was contemporaneous with sedimentation in the Trough. Chert beds are laterally continuous for at least 200 m and up to 2 m thick, most commonly occurring near the base of the formation. These units have crude and often contorted internal bedding (Skilbeck, 1986).

Other than what is written by Greg Skilbeck in his 1986 thesis, there is scant information published on Bald Head. This is surprising because Bald Head offers a range of geological structures and features that would help to explain the evolutionary history.

The Bald Head peninsula has been dissected by a northeast-southwest trending fault that has either contemporaneously or subsequently infilled with magmatic material forming a rhyolite dyke *(see photo 20)*. The area between the headland and the mainland has eroded into a col, creating a cliff face on the eastern side, with a steeply dipping slope to the west on the headland *(photo 19)*.

The cliff face opposite Bald Head displays interbedded deep marine turbidite sediments, mainly volcanogenic material derived from a volcanic arc to the southwest. Exposed within the gently folded cliff face that has tilted to the west-south-west is a north/south trending prominent off-white 4 to 6 m thick band of ignimbrite 0.63 k in length *(photo 20)*, where at the northern end, has been truncated by faulting at sea level *(photo 21)*. This band outcropping within the cliff face was deposited as a submarine pyroclastic gravity flow showing deformation, such as crude overfolding and disrupted contorted bedding. Weathering from the harsh marine environment has removed softer material within the ignimbrite, effectively leaving them in a

19. Aerial view of Bald Head, northern end of Cellito Beach (**D**) *[Barrington Coast. Mid Coast Council].*
A - Ignimbrite, **B** - Dyke, **C** - Yagon Siltstone.

20. Section between Bald Head headland and mainland showing a rhyolite dyke (A) and cliff face with skeletonised ignimbrite band, along with location of vesicles (B) and pressure dome (C).

21. West-southwest white pyroclastic flow band that runs 0.63 km length of the cliff face, where it is truncated by a thrust fault at sea level.

22. Skeletonized ignimbrite band weathered by the harsh marine environment removing softer material within the ignimbrite, accentuating the visual effects of the folds and deformities within the band. Note pelagic sediment layers above the ignimbrite.

skeletonized state, accentuating the visual effects of the folds and deformities within the band *(photos 22)*.

The pyroclastic flow responsible for the ignimbrite bed is thought to be from a subaerial, large-volume eruption and associated pyroclastic flow (possibly from the Violet Hill volcano) that flowed into the sea. Within one section is an area dominated by vesicles and shrinkage joints with ash adhering to the walls of vesicles and shrinkage joints *(photo 23*). However, the ellipsoidal shape of some cavities, sigmoidal faults and the wavy structures in the upper part of the deposit suggest to me that deposit has been sheared, possible during deposition. Juxtaposed alongside the shrinkage joints and vesicles is a rare domed area. The circular dome (gas pressure dome) most likely formed from steam due to the interaction of hot ash with the wet mud beneath the pyroclastic flow at >580 °C *(photo 24 - see arrow)*.

Bald Head's geology is much the same as the mainland. However, an inaccessible band of ignimbrite outcropping within the north-eastern face of the island may or may not be related to the same pyroclastic depositional event as the ignimbrites on the mainland. Consequently, the proximity of the fault separating the two areas and whether the island has been offset downwards makes it unclear if the two outcrops are related *(see photo 19)*.

Although it was not raining at the time of our visit to Bald Head, the rocks were very wet and in some places surface runoff water was streaming across the surface. Therefore, in the interest of safety, we did not venture too far onto the rocks. So, for future reference and interest of AGSHV members and the general public who may visit this area or read this report, we will describe some of the geological structures found here.

Firstly, at the time when we first visited the area in the dry, within the thickly bedded mudstone (turbidites), several concretions had a white substance crusting the surface of the porous halo surrounding the dense nuclei of the concretion. The white substance is salt, where during the cool of the day, seawater is absorbed into the porous halo surrounding the concretions, only to be drawn back to the surface in the warmer parts of the day, where the water then evaporates into the atmosphere leaving the salt (sodium chloride) to crust on the surface *(photo 25)*. Additional features include thrust faults with associated back thrusting (antithetic faulting) and thin beds of siltstone showing conjugate jointing, indicating opposing stress fields. Bedding planes may be perfectly planar, but in many cases, the fractured faces show feather-like markings known as plumose or plume structures.

Treachery Head.

Our final stop for the day and this excursion was Treachery Head. The rocks exposed along the eastern flank of Treachery Head belong to the Pacific Palms Member of the Seal Rocks Formation. The main

23. Section of ignimbrite showing vesicles and shrinkage joints lined by an unidentified secondary mineral (perhaps clay) from gas streaming when super-heated ash reacted with sea water releasing steam.
(field of view 30 cm)

24. Rare example of gas pressure dome towards the base of the ignimbrite, a result of super-heated ash reacting with sea water releasing steam.

25. Pyritic concretions showing white sodium chloride coating the porous halo surrounding the dense nucleus of the concretion.

26. Good exposures of intricately folded olistoliths comprising sandstone and mudstones. The largest folded olistoliths can exceed 10 m in height. This outcrop comprises a mélange of a chaotically mixed rocks in a matrix of sand and mudstone.

Brian, Winston and Chris discussing geology of the area beside well bedded outcrop of Yagon Siltstone at Bald Head.
(photo Ron Evans)

sequence is a thick olistostrome in which the matrix, a mixture of poorly sorted sand and silt, contains blocks and slump-folds up to several metres long. The lithology is of thinly bedded outer shelf fine-grained sandstone and siltstone (Skilbeck, 1979).

From the car park at Lighthouse Beach it is a pleasant walk to the northern side of Treachery Head at the southern end of Light House Beach, where there are good exposures of intricately folded olistoliths comprising sandstone and mudstones. The largest folded olistoliths can exceed 10 m in height, and consists predominantly of interstratified bedding *(photo 26)*. Many of the folds are open and upright or almost so. In contrast, the smaller and thinner olistoliths are commonly affected by tight or isoclinal recumbent folds (Skilbeck. 1979).

Due to the lack of a sandbar, access to the best exposures of slump folding was out of the question, so we had to be content viewing the area from the beach. However, we could access the bottom parts of the rocks from the beach, where there was a mélange consisting of a chaotic body of mixed rocks in a matrix of sand and mudstone. This was enough to satisfy our curiosity. There are also at least three sheeted dolerite dykes dissecting the cliff rising from the rock platform and beach. The dykes would almost certainly be related to the opening of the Tasman Sea when New Zealand separated from Australia some 85 million years ago.

At this point, the Rain Gods decided to desert us, for just as we were about to finish, the skies opened up, drenching us, leaving everyone to make their way back along the beach to where our cars were a kilometre away in heavy rain. Though ending up saturated, we were happy that we completed 99% of the day, staying dry.

Acknowledgement.

I would like to show my appreciation to Winston Pratt for freely sharing and pointing out some of the geological sites we visited along with the insights and knowledge he has accumulated over the many years visiting the Red Head and Black Head areas.

Report by Chris Morton.
Edited by Brian England.
Photos: Chris Morton and Brian England (2, 5, 9, 23 & 26).

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Barrington Coast (Mid Coast Council) Aerial view of Bald Heads northern end of Celitto Beach. *https://barringtoncoast.com.au/directory/cellito-beach*

Geomorphology of the Northern Sydney Basin

Leader: Richard Miller.
Date: Wednesday 17th May, 2023.
Attendance: 12 members.

An outline of the geomorphology and its emergence.

340 Ma ago the Sydney Basin did not exist. Ferguson (2019) says that at approximately 330 Ma a large seamount congested the subduction zone off the coast and began to form an orocline (*diagram 1)*.

This produced a large extension in the crust on either side of the seamount. In the south the Sydney/ Gunnedah Basin opened and to the north it was the Bowen Basin *(diagram 2)*.

During the period of extension the basin began to fill with sediment eroded from the high land on the sides of the basin. The extension allowed some extrusive volcanism; for example the Alum Mountain Volcanics occurred at about 291 Ma. In the north deposition formed coal beds along the shallow coast. These became known as the Greta Coal Measures.

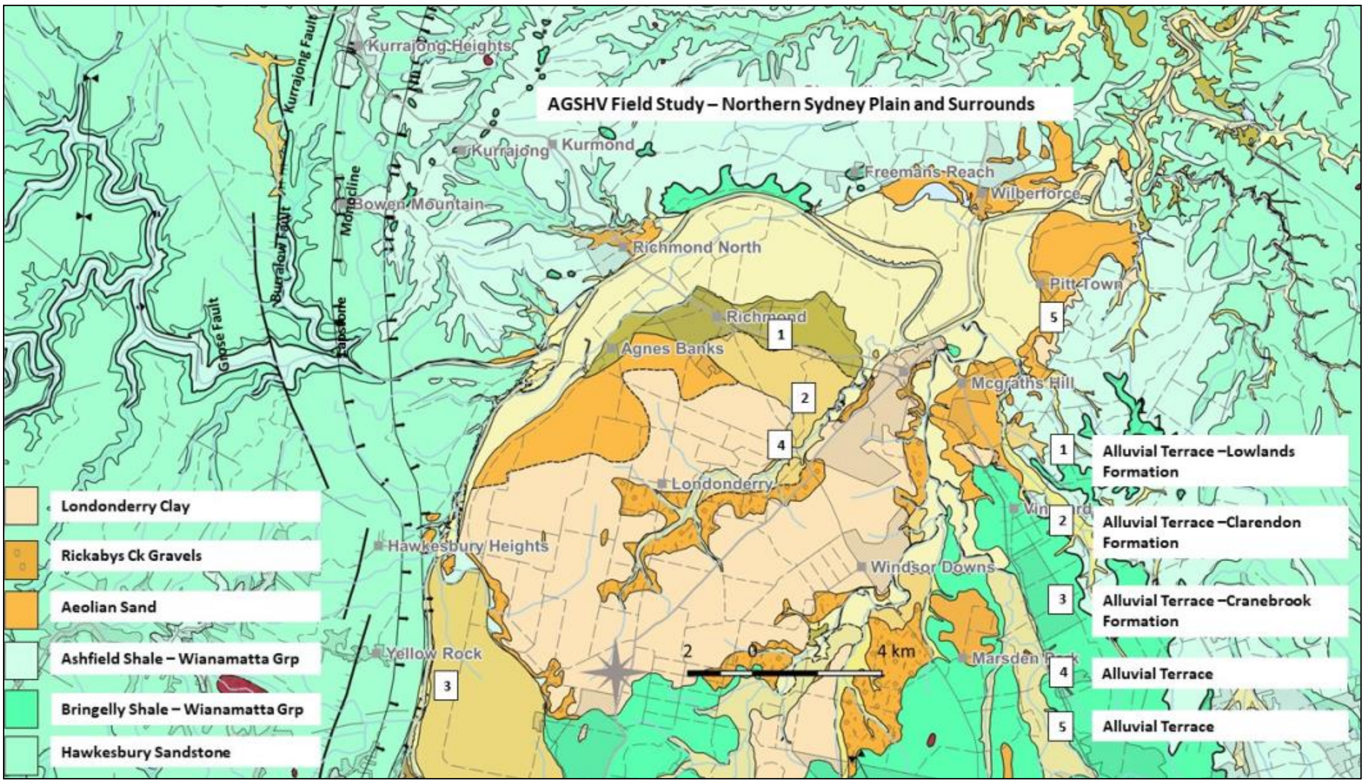
At approximately 260 Ma the orocline was complete and a subduction zone was re-established off shore *(see diagram 2)*. This produced a period of contraction. A number of anticlines were developed and these included the Coricudgy and Lochinvar Anticlines. The former separated the Gunnedah and Sydney Basins while the later and its southern extension, the Kulnura Anticline, separated what became the Newcastle and Western coal measures. The re-established subduction caused frequent periods of volcanism, with ash beds covering many of the coal layers.

The end of Permian extinction and an uplift in the Hunter Mooki Thrust System produced a period of erosion and deposition from the north. This covered the coal measures and produced the Narrabeen Series which has various rock types including sandstones, claystones, conglomerates and shales. They are up to 800 m thick.

Later in the Triassic, between 247 and 242 Ma., the source of material being deposited in the basin shifted to the south west and the Hawkesbury Sandstone was deposited in a massive formation. This ranged in thickness from 34 m in the lower Blue Mountains to 240 m in the Hawkesbury River district.

In the Late Triassic (235-201 Ma), after an initial marine transgression of the Hawkesbury alluvial plain, sediment was deposited into the Basin producing the Ashfield Shales. A barrier island system developed along the shoreline and this became the Minchinbury Sandstone. Later deposition on an alluvial plain resulted in the Bringelly Shales. Cumulatively these deposits have been named the Wianamatta Series; after the Aboriginal name for South Creek.

A period of volcanism followed during the Jurassic, with over 130 diatremes erupting in the Sydney Basin. In the places where they erupted through Wianamatta Shales they have been preserved as low hills e.g. Rooty Hill.



Map 1: Geology of the study area. (Source: Seamless Geology of NSW).

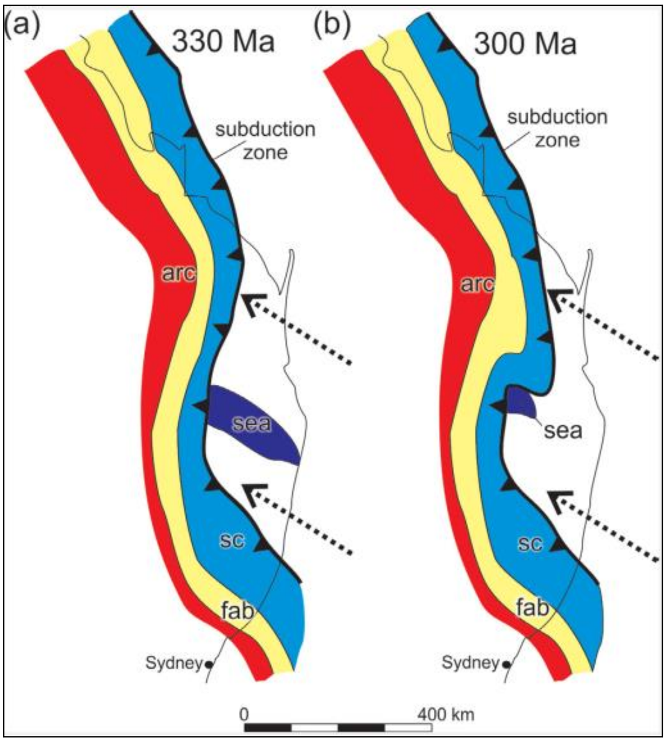


Diagram 1: Congested subduction. (Source: Ferguson 2019).

The Field Trip visited the lower Blue Mountains and Hawkesbury to study the following landforms that have developed in and on these rocks *(map 1)*. The Lapstone Structural Complex (LSC) which forms the Lower Blue Mountains rises between 200 and 600 m along its scarp and has been extensively studied by geologists. To the north is the Hornsby Plateau which extends from Belmont on Lake Macquarie down to North Sydney. The Hawkesbury River which flows through the area is associated with several river terraces and these house many settlements, including the five towns developed by Governor Lachlan Macquarie in 1810.

It is only since 2011 that the formation and timing of these landforms has been explained. Further research will no doubt add to the explanation.

In the Cretaceous, India began to split from Australia and Antarctica. This caused the latter two to move north and then east. Along the east of the Australian Continent, this produced the "Kosciusko Uplift" of 400 to 600 m. In the study area this equated to a rise of approximately 200 m in the west, with a gentle slope down to flat land in the east. In the Paleogene a large river flowed out of the uplifted area and towards the north east. It had a braided channel

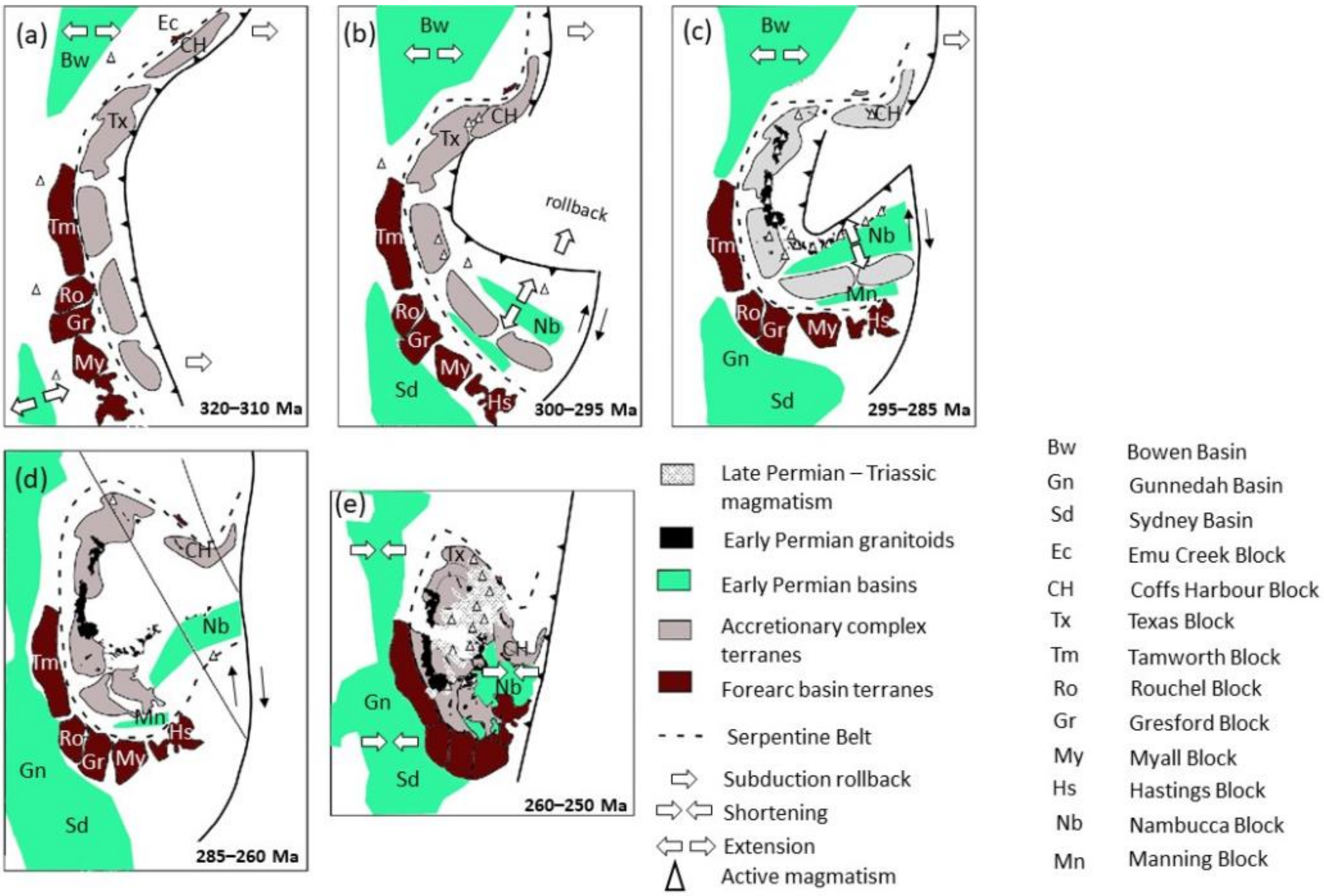


Diagram 2: Development of the Sydney Basin. (Rosenbaum et al 2012).

and deposited up to 17 m of gravel, sand and clay over an area between the LSC and the suburb of Blacktown. These deposits have been called the Rickabys Creek Gravels (RCG).

Geologists have known for many years that the RCG have been found on the LSC and therefore predate its rise. The present Hawkesbury River also flows in and out of the LSC in two areas and this suggests that it was in place as the LSC was uplifted (Langford Smith, 1976).

Above much of the RCG is a deposit of heavy clay termed the Londonderry Clay *(photo 1)*.

The location of this clay deposit was crucial for geologist Louis Carter in determining the timing of the land forming processes in the study area. The Hornsby Plateau is about 200 m ASL in the north and dips at about 20 to the south. It forms a semi-circle around the Richmond/Windsor area, reaching down to North Sydney. He suggests that the Hornsby Plateau was uplifted after 45 Ma and he based this on a basalt flow at Maroota which flowed in a northerly direction, consistent with a pre-uplift origin. The Barrington Tops were formed by basalt flows at approximately 50 Ma and Carter believes that under-plating produced the uplift in the Hornsby Plateau as the continent was moved north (Carter, 2011).

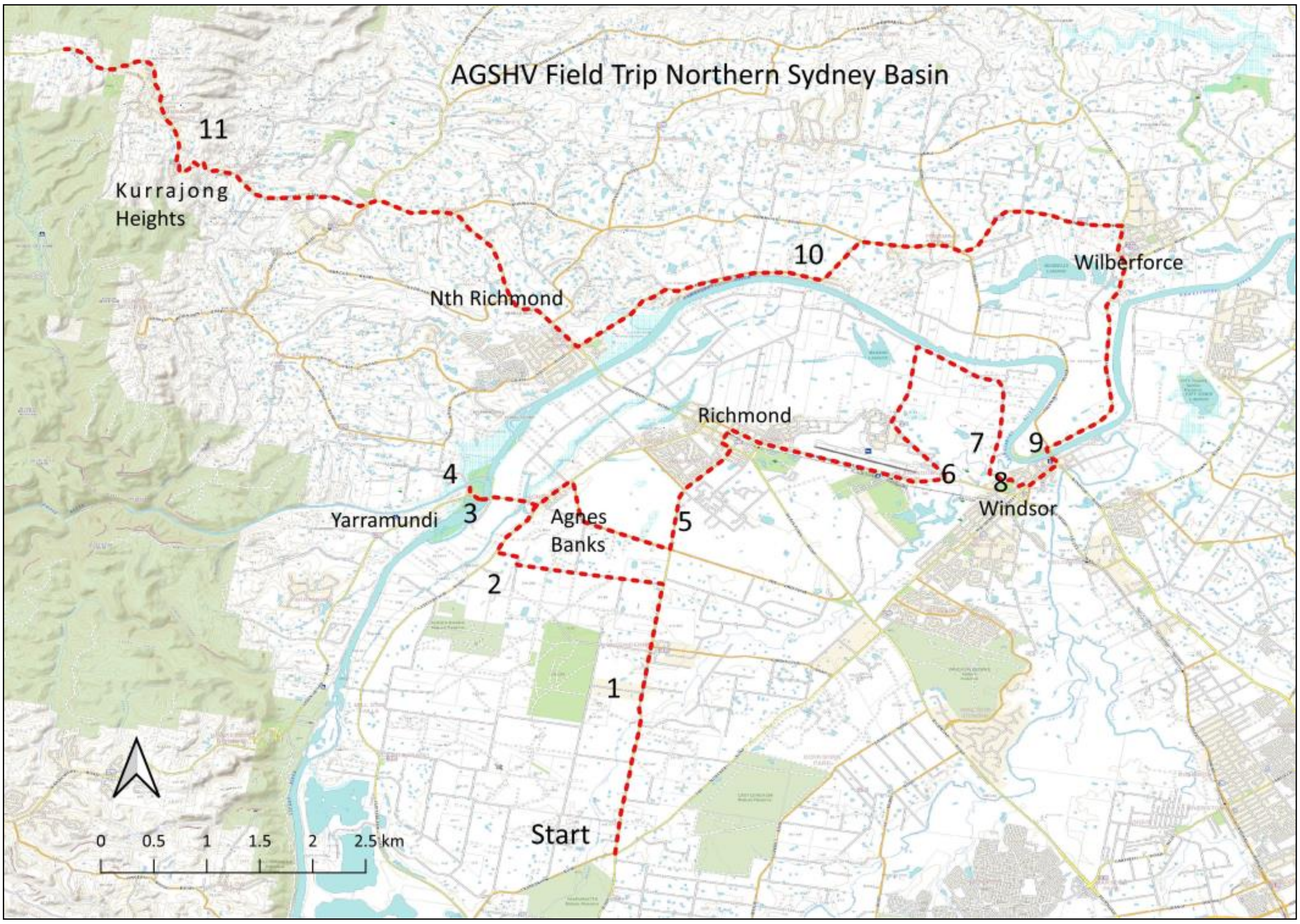
In his field survey he found deposits of Londonderry Clay on the LSC but none has been found

1. Londonderry Clay exposed in a road cutting at Windsor.

on the Hornsby Plateau. From borehole records he found that the Londonderry Clay was thickest near the edge of the Hornsby Plateau and that it was lacustrine in origin. Records showed that the RCG was thickest in the south, near Penrith and shallowed to the north.

His conclusion was that the Hornsby Plateau was uplifted first and dammed the river carrying the RCG. These could not be carried into the lake but the finer sediments could and these became the Londonderry Clay. This suggested that the LSC was uplifted last.

Eventually the Hawkesbury Nepean was able to overtop the Plateau and maintain its course to the sea.



Map 2: The field trip route. (Source: R Miller compiled with QGIS and NSW Base Map).

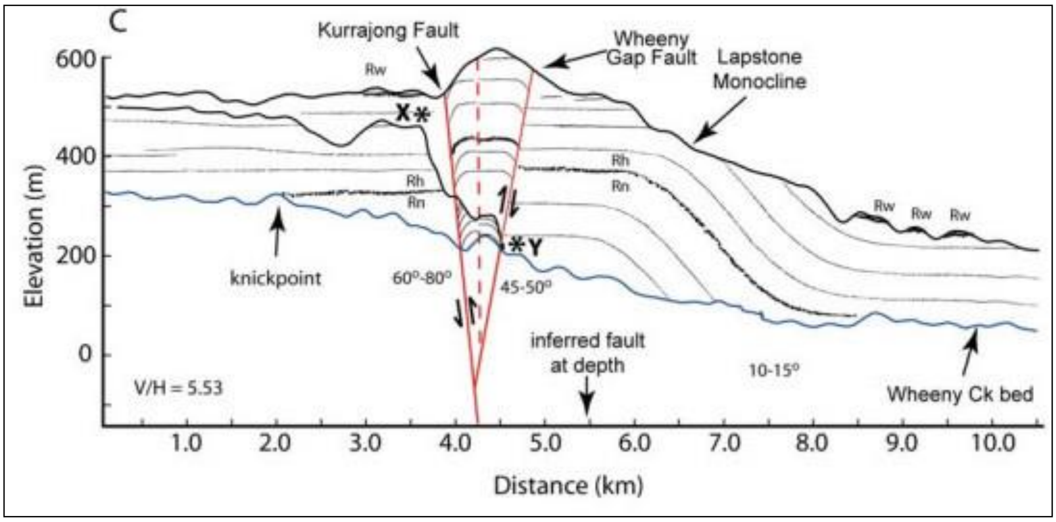


Diagram 3: Flower fault at Kurrajong Heights. (Source Clark and Rawson 2005).

The narrowness and height of the cliff surrounding the river as it enters the Plateau near Sackville has meant that overbank flooding is a regular feature of life for residents along the Hawkesbury Nepean.

From studies of streams flowing out of the LSC, Hatherly (2020) has determined that the LSC was uplifted between 10 and 5 Ma. These streams flowing out of an area of Cretaceous uplift have concave thalwegs in their headwaters consistent with being in equilibrium prior to uplift. They have knick points consistent with a subsequent uplift and these are tied to or closely tied to the base of the LSC. The timing of uplift on the LSC was then determined using calculated erosion rates.

Originally the LSC was termed the Lapstone Monocline but in the area of Bowen Mountain and Kurrajong Heights are an arrangement of en-echelon faults (Map 1). This suggests strike slip movement as well as the thrust fault system found near Lapstone in the south.

Clark and Rawson (2005) discovered a previously unknown fault in the scarp of Wheeny Creek and this suggests that the crest of the LSC at Kurrajong Heights is a flower fault *(diagram 3)*.

There is also evidence that at about 30,000 BP a further uplift of approximately 6-7 m dammed two creeks and produced extensive lacustrine deposits. They are at Burralow Creek and Mountain Lagoon *(map1)*. (Rawson and Clark, 2005)

The Trip.

The group met at the corner of the Northern and Londonderry Roads near Cranebrook and heard an introductory talk on the formation of the landforms and of the significance of these and the geology to both the Aboriginal inhabitants and the invading British. A route map was distributed *(map 2)*.

2. Rickabys Creek Gravel.

Stop 1. Rickabys Creek Gravel.

Here the RCG were examined *(photo 2)* and it was seen that the clasts were embedded in a mix of sand and clay. The deposit here was in the bank of Rickabys Creek which was named after Thomas Rickerby whose land grant was at the mouth of the creek where it joined the Hawkesbury River. The variety of spelling was a common feature of the period.

Stop 2. Agnes Banks Sand.

These extensive deposits *(map 1)* have been mined since the 1940s but areas of it have been preserved in the grounds of what is now the University of Western Sydney and in the Agnes Banks Nature Reserve, to the south. The sands are Aeolian and lie above the Londonderry Clay. They appear to have been blown onto this formation when the river reworked the RCG and formed a new and lower floodplain.

Agnes Banks was named by Andrew Thompson after his mother. He was granted the land by Governor King.

<u>Stop 3</u>. Yarramundi.

At this place the Grose River joins the Hawkesbury Nepean and the river bed is very shallow and full of gravel *(map 3, photo 3)*. In 1791 a party of British colonists including Governor Phillip and Lt Watkin Tench journeyed here and met Gomebeeree and his son Yarramundi. They were elders of the Boorooberongal Clan. Yarramundi and his children maintained a relatively positive relationship with the British over many years. (Tench, 1793)

The study group was informed that a second river crossing existed at about 1 km to the south at Blacks Falls. Aboriginals built and maintained fish traps in this area and there are extensive grooves in the sandstone nearby were rock tools were ground. The floodplains were heavily timbered. Stone axes were used to make notches and allow the trees to be climbed to gather possums and other tree dwelling animals and birds. Along the levee banks Aboriginal women cultivated native root vegetables.

As well as searching to see if the Hawkesbury and Nepean were one river Phillip and his party were also looking for fertile soils as the Hawkesbury Sandstone soils at Sydney Cove were relatively infertile. The diatremes and areas of Ashfield Shale were favoured but the riverbanks were especially sought because of their

3. Participants at Yarramundi Reserve. The Grose River is in the background.

sandy loam soils and high humus content. They had been kept open from the forest by the Aboriginal women.

By 1794 colonists were seizing the levees. They began in the area near present Windsor just west of the junction of South Creek and the Hawkesbury. Without a concept of private property the Boorooberongal then collected the crops grown by the settlers and this was met with resistance. Houses were burnt and Aboriginals shot and speared. This conflict continued to at least 1816 (Karskens, 2020).

<u>Map 3</u>: The Yarramundi Rapids at the junction of the Nepean and Grose Rivers. (Source: R Miller compiled with QGIS and Six Maps).

Stop 4: The Grose River Crossing.

The river is shallow here and both Aboriginal people and the Colonists used this as a crossing to travel to the north and west. The path took them up onto a low hill called Richmond Hill. The group heard that this place was the site of three punitive missions organised by the British against local Aboriginals. They were in 1795, 1805 and in 1816 (Karskens, 2020).

A land grant at Richmond Hill was given to Archibald Bell who was the Officer of the NSW Corps to whom Governor Bligh complained when his daughter was insulted in church. Bell was also in charge of the guard at Government House when Bligh was arrested on 26 January 1808. Macquarie later appointed him as the Magistrate for the Hawkesbury and he later developed a road to the north east called the Bells Line of Road. It is said that he was shown the way to Mt Tomah by an Aboriginal woman.

Sir Phillip Charley, one of the original founders of BHP, bought the land and expanded the house. It was left to the Catholic Church and became a mental hospital, St John of God. During the 1950s, on the Hills northern side, Professor Yeomans from Sydney University developed Key Line Farming, which gained world-wide attention.

Stop 5. The EucFACE Experiment.

Located on the Agnes Banks Sand and in the grounds of the University of Western Sydney (UWS), the EucFACE experiment involves exposing the canopy of eucalyptus trees in a patch of Cumberland Plain Woodland to levels of atmospheric CO_2 that will be associated with continuing global warming. It has a number of cranes and three steel ring towers *(photos 4 & 5).*

Early results show that Eucalypts cannot take up extra CO_2 to increase their growth rates and that this is limited by a lack of phosphorous in the soil. The extra CO_2 has, however, changed the composition of the grasses in the understorey.

4. EucFACE Experiment - cranes and steel ring towers as seen from Londonderry Road. (photo Ron Evans).

5. Aerial view of the EucFACE towers. (Source: R Miller compiled with QGIS and Six Maps).

Stop 6. Londonderry Clay.

On route to this location the group was shown where the highest historical flood reached the residential area in Richmond. The height of a probable maximum flood would be 7 m higher.

The group passed through Richmond which was one of the towns planned by Governor Macquarie and several historical sites were indicated. The Richmond Oval is situated between West and East Market Streets and this public square was a feature of his planning. With horses as a desirable mode of transport their breeding became and remains a feature of the land use in the Hawkesbury. Andrew Town was a prominent breeder and he used to organise horse races down the main street, finishing at the Black Horse Inn. His town house was pointed out to the group.

The gates to the Richmond Primary School have the name Kamilaroi. It was once the location for the home of Benjamin Richards who built the Riverstone Meat Works and along with Thomas Mort pioneered the sale of refrigerated meat to England.

The RAAF Base is on land that was set aside by Governor King in 1803 as a Common. This was land on which anyone could graze animals and conduct other agricultural activities. It was later called Ham Common. Being mostly Londonderry Clay it was regarded as unsuitable for cropping.

The UWS Hawkesbury Campus was part of the Common Land.

Set out at the eastern end of the Common is the village of Clarendon. This was built up by William Cox as a largely self-contained settlement to produce woollen cloth. Wool from sheep grazed on the Common was to be washed, carded, spun and woven by the villagers. He built his first home in Richmond and later, Fairfield House, on the opposite side of Rickabys Creek, with an outlook over the village.

The Londonderry Clay is exposed in a roadside at the corner of Hawkesbury Valley Way and Percival St and is at the eastern end of the RAAF runway. In this area it reaches its deepest at approximately 9 m *(photo 6).*

6. Profile of Londonderry Clay near Richmond RAAF Base. (photo Ron Evans).

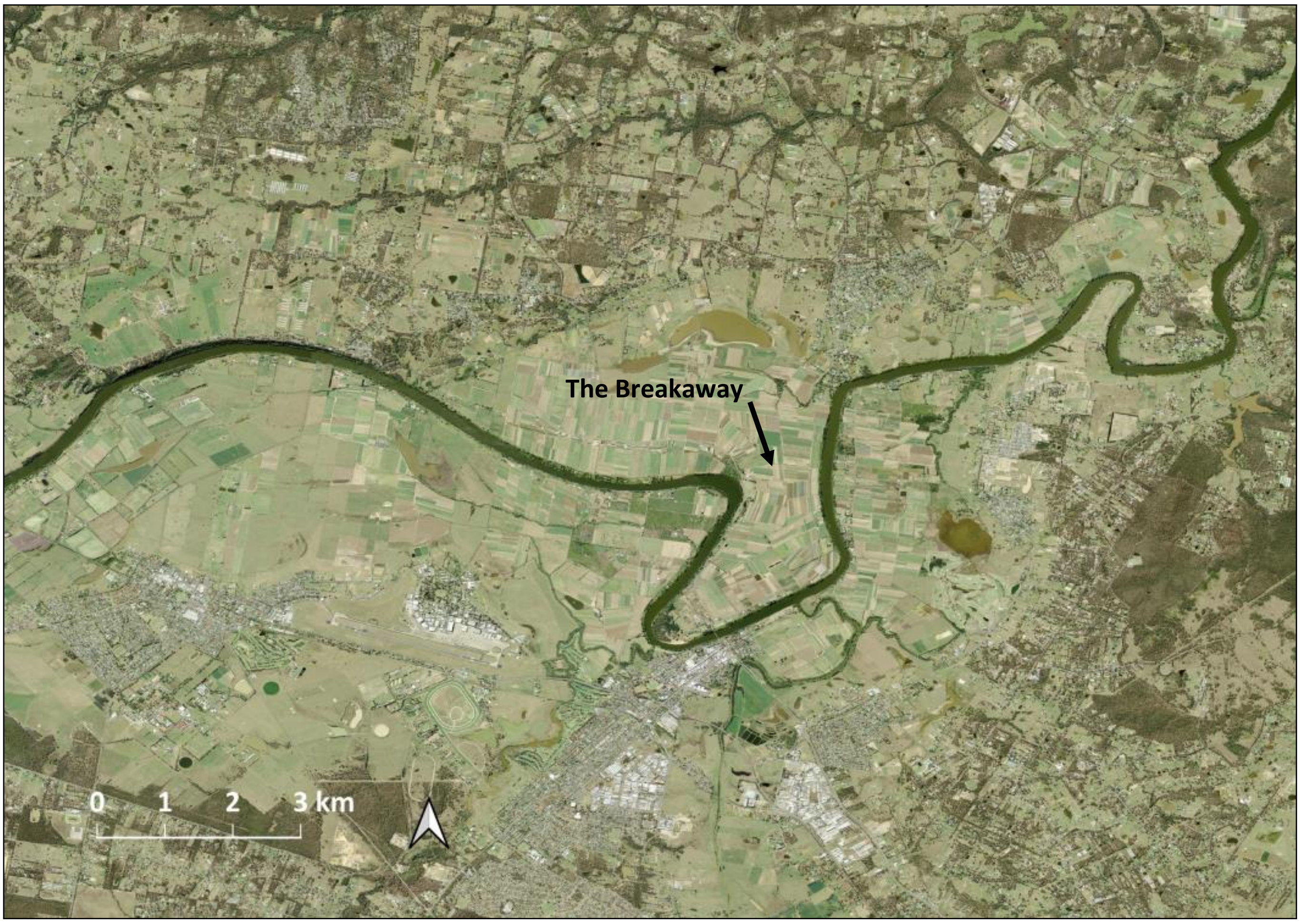
<u>Stop 7</u>. Deerubbin Reserve.

On the way the group drove along the present flood plain of the Hawkesbury and observed, on its northern bank, the scarp of the Hornsby Plateau. Some of the earliest European farms were located in this vicinity and spread along the river bank. The group was shown part of levee bank which was extensively cultivated by the Berooberongal people prior to European invasion. The floodplains and adjacent terraces were covered by temperate rainforest and wet sclerophyll forest. The Boorooberongal put conical traps in the shrub cover on the forest edge and frightened quail into these as they walked the bank. Fish and eel traps were used in the creeks.

The appropriation of the banks was responded to by aboriginal people collecting some of the wheat and corn that the Europeans planted.

Grace Karskens in her book People of the River says that by 1794 settlers were firing at Aboriginals seen near their farms. "And after firing 'wantonly' to drive the raiders away some of these settlers kidnapped some of the Aboriginal children, mostly babies and toddlers, claiming that their parents had abandoned them."

"In September of that first year, conflict and skirmishes tipped further into atrocity. Robert Forrester and his neighbours, Michael Doyle and Roger Twyfield, saw a large group of Aboriginal people gathered in the bush at the back of their farms on Argyle Reach, the lowlands known as Cornwallis. A boy from the group was coming down the path towards them. They grabbed him. Some accounts say they bound him hand and foot and dragged him repeatedly over a fire so that his back was dreadfully scorched. Then they threw him in the river still bound and shot him dead." An inquiry led by Lt John Macarthur took no action as the men claimed the boy was a spy for the group to plan an attack." (Karskens, 2020)



<u>Map 4</u>: Aerial photo of the potential meander cut-off at Windsor. (Source: R Miller compiled with QGIS and Six Maps).

This was quickly avenged with two settlers being attacked, speared and beaten and the process of attack and revenge occurred regularly.

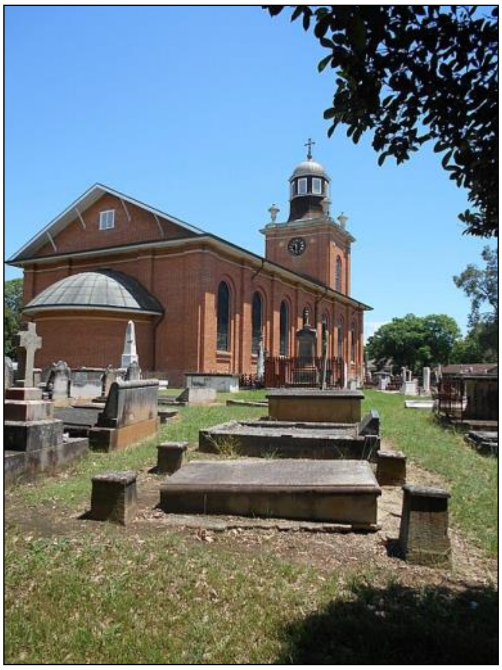
In late May 1795 Acting Governor Paterson sent a detachment of 62 soldiers to the Hawkesbury with orders to shoot as many natives as possible. The details are unclear but the soldiers were patrolling at night near a farm, probably near Yarramundi. They came upon a large group of Aboriginals which included many old people, women and children. This would suggest that they had gathered for a maize raid. The soldiers fired into the group and seven or eight people were killed. Five women and a crippled man were taken as hostages and transported to Sydney. Although there were no farms on Richmond Hill at that time the massacre became known as the Battle of Richmond Hill. (Karskens G, 2022, p135).

Another punitive raid was organised in 1805 and led by Andrew Thompson, who was then the Senior Constable for Green Hills.

Killings and pay back continued. In 1816 after a number of attacks on settlers near Appin and the retaliatory Appin Massacre, Governor Macquarie banned all Aboriginal people from the farms and settled areas. William Cox, the Magistrate at Windsor, organised five permanent parties of armed soldiers and settlers to patrol the northern bank from Richmond Hill and kill any aboriginals found. Late in 1816 many of the remaining Aboriginals surrendered and were invited to a great feast at Parramatta.

The settlers also ignored information about flooding provided by the Boorooberongal and many lives were lost during floods in 1805 and 1809.

The group was also informed of the potential for the river to cut off the meander on which Windsor is situated and turn it into and ox-bow lake *(map 4)*. Significant erosion occurred in 1948 and 1972 but it also does some damage in each flood.



7. St. Matthews Church Windsor. The grave of Andrew Thompson is in the foreground. (Source: Wikimedia Commons).

Stop 8. St Matthews Church Windsor.

When inspecting the Hawkesbury settlements in 1810 Governor Lachlan Macquarie planned to solve the human cost of floods by moving settlers into five towns which he sited above the observed flood levels. He planned that each town would have a market square, a church and a hotel with accommodation for visitors

Macquarie renamed "Green Hills" as the area was known and called it "Windsor" and ordered that a church, school-house, gaol and a "commodious inn" should be built. He chose the site for the Church and had Francis Greenway design it. This was initially constructed by Henry Kitchen. Work was slow and Greenway was sent to inspect the work. He blamed Kitchen and said the locally made bricks were inferior. The building was pulled down and the bricks were used to build a wall next to the Macquarie Arms hotel in Windsor. 178 years later these walls are still standing and survived the flood of 1867. When the clay was mined for the original bricks at what is now the Richmond Golf Club the quarry was made in the shape of a broad arrow, the symbol for Government property and pointing at the Church.

The Church *(photo 7)* was finally opened in 1821 and consecrated by the "flogging parson", the Reverend Samuel Marsden.

During WW11 Tokyo Rose revived the controversy of the bricks saying don't bother trying to camouflage the RAAF Base. We will just follow the arrow *(photo 8)*.

The group walked to view another road cutting at which the Londonderry Clay is exposed and saw, in the distance, the home of William Cox *(photo 9)*. He was famous as the builder of the first road across the Blue Mountains. In this he was guided by Colebee, the son of Yarramundi.

9. Fairfield, the home of William Cox at Windsor. (Source: Realestate.com.au).

8. Location of the quarry in Londonderry Clay used for the initial brick making for St. Matthews Church. (Source: R Miller. Compiled with QGIS and Six Maps).

Stop 8: Macquarie Park.

Macquarie Park has been a popular tourist site for most of its European history, variously a caravan park, camp ground and picnic area. The building of the latest bridge across the river has been vigorously opposed by members of the community since 2013 and they staged a 24 hour vigil of protest in Thompsons Square for 1000 days. Touted by local member Dominic Perrottet as a "flood free" bridge it was twice covered by flood waters soon after construction was completed *(photos 10 & 11)*

The group walked across the bridge to Thompson Square to look at the flood levels marked on a wall and have a discussion of some of the significant historical events associated with the area.

Windsor (originally Green Hills) is one of the five Macquarie Towns. All were situated to supply refuge to European farmers from the frequent floods. Thompsons Square was the centre of Windsor and very significant in early colonial history. These are a few of its stories:

Much of the colony's grain supply was stored in the Government granary situated to the east of the Square. A large number of Irish, convicted for participating in the uprising of 1798, were transported to NSW. The majority were housed at Castle Hill and they rebelled in 1804. Numbering about 400 they were defeated, partly by trickery and by soldiers commanded by Major George Johnson. Led by Phillip Cunningham the rebels were marching to take control of the granary at Windsor and scour the Hawkesbury for arms. Their leader was gibbeted and left to hang in the square until

10. The replacement "flood free" bridge at Windsor. (Source: Blue Mountains Gazette).

11. House at the northern end of Windsor Bridge partially submerged by floodwaters in 2022. (Sydney Morning Herald).

the smell became too great. Other leaders were given 250 to 500 lashes, some while tied to a cart and being walked to Parramatta.

Andrew Thompson, after whom the square was named, built four ships and used them for trade, mostly with Sydney. He was a significant entrepreneur, building among other things a salt pan initially at Mullet Island (Dangar) and then at Scotland Island.

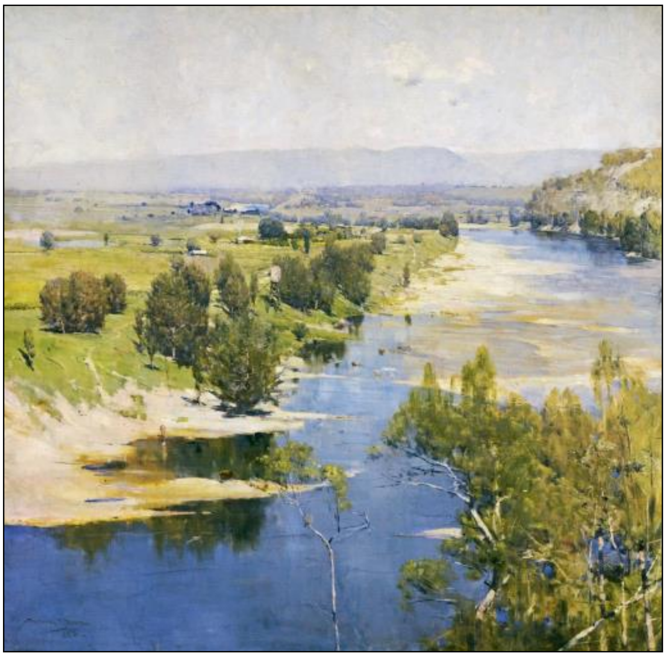
An extensive landowner himself he also managed the farm that Governor Bligh granted to his wife.

For the Government he built and ran the Toll House on the side of South Creek. This collected tolls for those using the Government road from Parramatta and crossing the bridge over the creek. The Toll House is still standing.

When Macquarie arrived in 1810 Thompson was in poor health. He had caught a respiratory infection while rescuing stranded farmers in the 1809 flood and as a supporter of Governor Bligh had been out of favour. Macquarie restored him to favour and appointed him magistrate at the "Green Hills", the first emancipist to be appointed to such a position. He also named the town square after him.

In the square the Doctor's House is closest to the river on the western side. Dr Thomas Fiaschi came to the Hawkesbury after eloping with a Nun from St Vincents Hospital in 1876. It is reported that as Catherine Reynolds ran to his waiting carriage the Mother Superior ran after her shouting "this woman is married to God". They were both ex-communicated by the Catholic Church but married the next day. He became a great asset to the community and he and his wife were highly valued.

<u>Stop 9</u>. Streeton Lookout (Corner of Cliff and Terrace Roads, Freemans Reach).



12. Sir Arthur Streeton's painting "The Purple Noon's Transparent Might (1896)".

The main structural land units are visible from the lookout and the group could also see them in Sir Arthur Streeton's painting "The Purple Noon's Transparent Might (1896)", *(photo 12)*.

The plain on the south side of the river is the Richmond Lowlands and it is the current floodplain of the river. The river meander below the lookout is currently removing part of the Hornsby Plateau on which the group is standing.

The group saw that the Hornsby Plateau forms a semi-circle, the edge of which is created by river erosion.

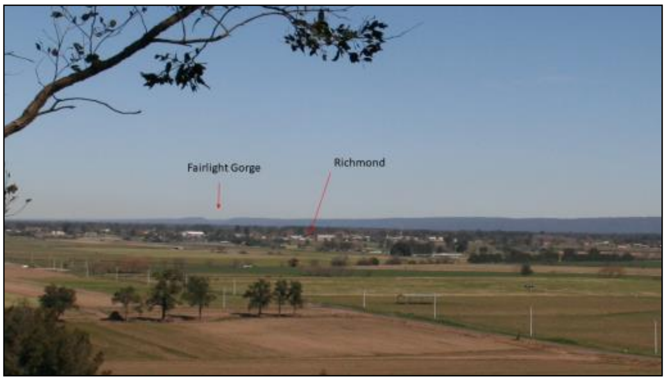
In the east the plateau extends to the Sydney CBD. The Lapstone Structural Complex (LSC) rises along the western skyline and looking along the river channel to the west the gorge seen is the Grose River. It is at the confluence of the Grose that the Nepean River becomes the Hawkesbury. The river is tidal up to the North Richmond Bridge and with sea level rise it will soon reach the Grose.

A second gorge, the Nepean (Fairlight) Gorge, was seen in the distance to the south west (2200 m). There the Hawkesbury/Nepean River flows into and out of the LSC. It also does this in another area just to the south of it near Bent's Basin. In the north the river flows back into higher ground near Sackville *(photos 13 & 14)*.

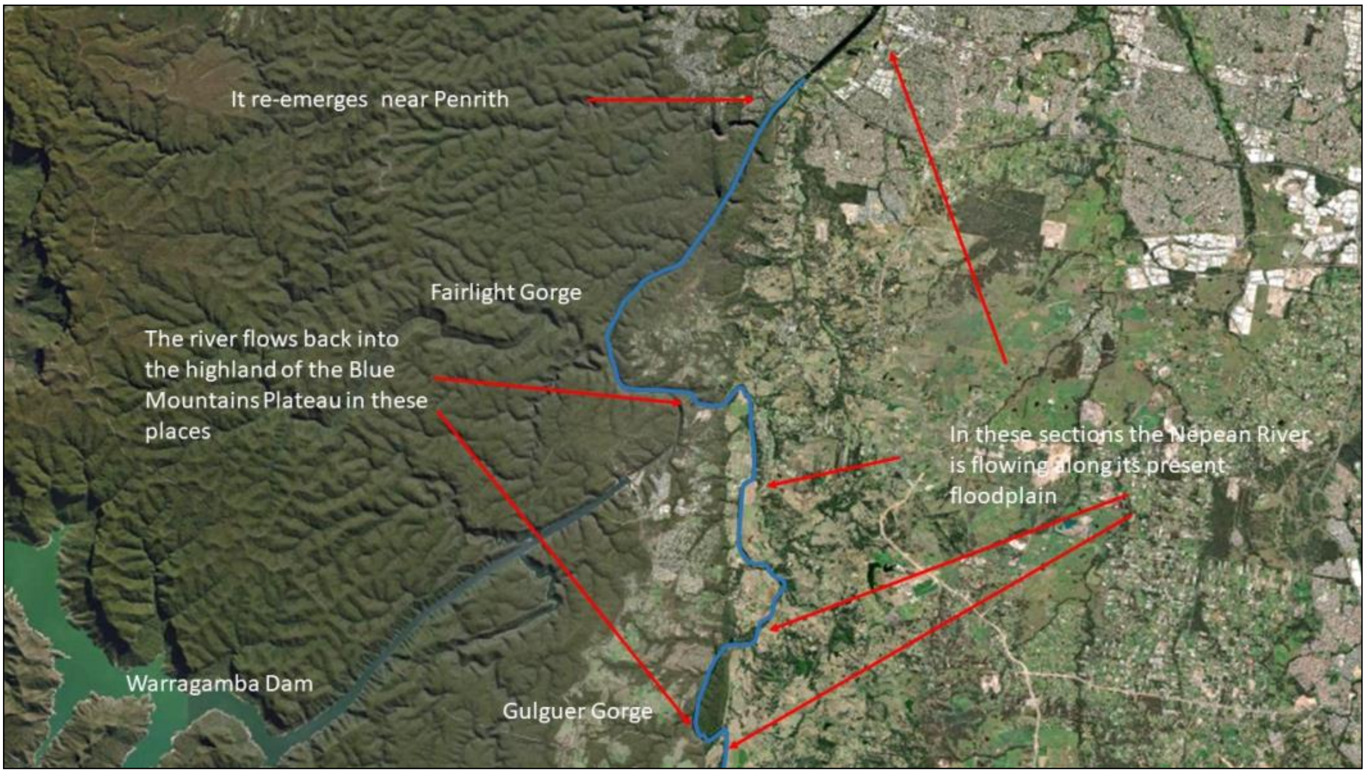
The view from the lookout gives perspective to the explanation of the timing of the uplift of the LSC relative to the surrounding alluvial terraces and the Hornsby Plateau. Flooding allows an understanding of the position of the floodplain *(photo 15)*.

<u>Stop 10</u>: Kurrajong Heights Lookout (photo 16).

At this stop the group could see over the Hawkesbury Plateau to Castle Hill and Sydney. The flower fault at Kurrajong Heights was discussed. Rawson studied the area and found that there had been recent movement on the Kurrajong Fault. An uplift of approximately 6-7 m had dammed two streams and this had resulted in a lacustrine deposit forming in the valleys at Burralow Creek and at Mountain Lagoon *(map 1)*.



13. View to the South from the Streeton Lookout.



14. Aerial view of the Fairlight and Gulguer Gorges. (Source: R Miller compiled using QGIS and Six Maps).

16. Kurrajong Heights and its flower fault are in the background. The land in the foreground was part of the Keyline demonstration farm.

15. 2009 Flood. The levee bank is out of the flood water in this photo from the Terrace. (Source: M Rose).

17. The drop associated with the Kurrajong Fault on the Bells Line of Road, Kurrajong Heights. (Source: R Miller modified from Google Earth).

The group then drove over the Kurrajong Fault to inspect the drop down on the western side *(photo 17).*

Report by Rick Miller.
Photographs, maps and diagrams Rick Miller.

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Field Trip leader Rick Miller pointing out structural features of the landscape at Streeton Lookout. (Ron Evans).

Hawkesbury City Council sign at Streeton Lookout acknowledging the artwork of Arthur Streeton and his famous painting “The Purple Noon’s Transparent Might (1896)” - photo 13. (Ron Evans).

Special Activity
Reid's Mistake & Wybung Head

Leader: Chris Morton, assisted by Ron Evans, Brian England, Brian Dunn, John Hyslop and Alison Cook.
Date: Sunday 28th May, 2023.
Attendance: 6 members and 6 guests.

This special excursion was mooted after Lyndal Morrow from the Central Coast sent an enquiry to the AGSHV web site in early May concerning a local Aboriginal legend about a recent volcano off the Newcastle coastline. Chris picked up on this and offered to take Lyndal and a small group of her friends (some of whom are geologists) to two of our coastline's most interesting sites. An invitation was sent out to all Society members interested in tagging along.

At 9:15am a small group of geology enthusiasts began to assemble at the Reid's Mistake Reserve car park on a perfectly clear and still morning, the cool early start necessary to make the most of the low tide *(photo 1).*

Several hours were spent exploring the fossil forest exposed along the rock platform south of the car park. The trees were felled in the Late Permian (253Ma) by a base surge volcanic ash flow similar to that caused by the 1980 Mount St. Helens eruption, but much larger (Morton and Evans, 2010; Morton and England, 2014). Most Society members had been to this site many times but, quite surprisingly, a number of new features were observed on this trip which at previous times had been covered by sand. These changes illustrate the dynamic nature of our ever-changing coastline. The volcanic blast had broken the trees off at their base, leaving only the stumps rooted in the underling Lower Pilot coal seam. A few of these clearly showed tilting towards the west *(photo 2)* suggesting that the volcanic blast came from the east/ northeast. The adjacent cliff line exposes a complete section through the Reid's Mistake Tuff beds as well as the overlying Upper Pilot coal seam and at the top the Belmont Conglomerate.

One common feature of this fossil forest not previously explained is the presence of a significantly tougher mound of volcanic ash (tuff) encasing most of the stumps

1. Visitors and AGSHV members at Reid's Mistake.

2. Fossilised tree stumps (*Dadoxylon*) in Reid's Mistake tuff point west (W) indicating a blast from the east. Note the raised hardened tuff band surrounding the fossil stump.

(photo 2), nearly all of which have been skeletonised by burning. It appears that the stumps were ignited by the super-hot volcanic ash and continued to burn at high temperature under the blanket of ash causing it to harden around the burning wood. In contrast the Dudley fossil forest to the north was not felled by a sudden surge of hot volcanic ash but by a major flood, with the felled trees totally replaced by siderite (iron carbonate). Here there are no such hardened mounds around the stumps.

Moving on to Frazer Beach in Munmorah State Recreation Area we paused for lunch before walking south along the coastal rock platform towards Wybung Head. Here our visitors and Society members alike were astonished at the spectacular exposures of in-situ *Vertebraria (photo 3)* in growth position in the grey mudstone bed underlying the Vales Point coal seam. These fossils are the vascular roots of *Glossopteris* flora seated in the coal seam above. And then, to be able to actually touch the rock sequence representing the Permian/ Triassic mass extinction event just blew our visitors away! *(see photo 6 on page 92).*

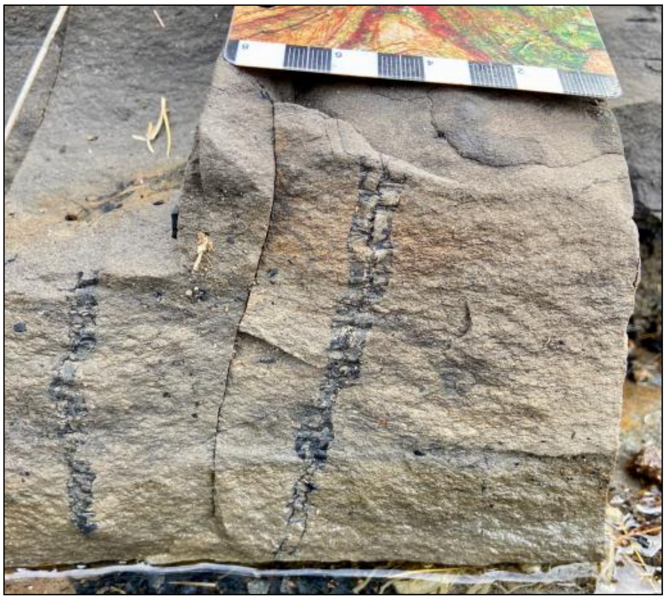
An added bonus here was the surprise discovery of a fossil radial tree root system *(photos 4 & 5)* exposed on the base of a large block of rock recently fallen from the Munmorah Conglomerate in the cliff above. What!!!

The activity ended at nearby Snapper Point where the huge sea cavern and another exposure of the Permian/ Triassic boundary was observed.

In all, a very successful and enjoyable excursion in perfect weather (what happened Chris?) for all those involved. With Universities and Colleges across Australia and overseas now abandoning Earth sciences courses, perhaps it is now down to groups like our Society to help ensure at least local interest in the rocks beneath our feet continues so this may not be the last of such special activities.

Report by Brian England.

Photographs by Ron Evans.



3. Vertebraria (roots of *Glossopteris* flora) in situ that grew up through sandy sediment.

4. "Hey! Look at that!

5. Surprise find of a radial root system on a block of sandstone/conglomerate that had fallen off the above cliff.

6. The walking stick on left points to the Permian/Triassic mass extinction event boundary at Wybung Head.

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Publication Acknowledgements.

Once again, due to Covid 19 restrictions, only some of the planned 2022 activities took place.

This again resulted in a Geo-Log of 2022 activities combined with those from the first half of 2003, thus Geo-Log 2022-2023.

As usual, the Geo-Log is a collaborative publication with reports from trip leaders who organise and conduct activities together with photographs from various members who attend activities.

Activities conducted during this period were conducted, when necessary, within Covid-19 protocols.

A special thanks to Geo-Log editor Brian England (Life Member) for the onerous job of checking the geological content and seeking out errors in the reports submitted for inclusion in Geo-Log 2022-2023.

He was ably assisted with some editing by Ron Evans.

Life Member Ron Evans compiled Geo-Log 2022 -2023 and organised its publication by Lakemac Print, Speers Point.

Ron Evans.

QR Code.

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