Newcastle Coastal Geotrail – our dynamic coast

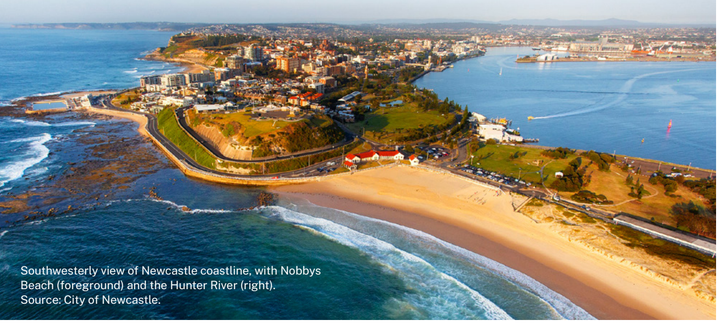
Around 255 million years ago, in the Permian Period, the climate and landscape around Newcastle were very different to those today. Wide rivers flowed across a cold and thickly forested landscape, depositing sediments over vast floodplains and swamps. From time to time, distant volcanic eruptions blanketed the region with ash. The layers of sediment and ash were later compacted and gently folded, to produce the undulating layers we now see in the cliffs around Newcastle. This sequence is called the Newcastle Coal Measures and coal seams can be traced between cliffs and headlands from Nobbys Head to Merewether Beach.

A changing geography

Back in the Permian, Australia was closer to the South Pole. Earth's tectonic plates were colliding along eastern Australia, resulting in volcanoes and high mountain ranges developing to the north of what is now Newcastle, and the broad Sydney Basin forming to the south and west. Between 84 and 52 million years ago, Australia separated from the continent of Zealandia (including New Zealand and Lord Howe Rise), creating the current coastline and injecting volcanic dykes that are still visible in cliffs and rock platforms. Over just the last 120,000 years the sea level has fluctuated more than 100 m, resulting in migration of the shoreline up to 25 km east and 30 km west of its current position!

The geotrail

Newcastle Coastal Geotrail largely follows scenic Bathers Way and is a walk of about 10 km one way. You can also drive to stops, which are mostly accessible from nearby car parks, although parking restrictions apply. Public buses service Nobbys Beach, Merewether Beach and coastal areas in between.



Southwesterly view of Newcastle coastline, with Nobbys Beach (foreground) and the Hunter River (right). Source: City of Newcastle.

Stop 1: Erupting volcanoes

Volcanoes were erupting around 255 million years ago in the New England area, to the north of Newcastle, and also possibly offshore to the east. Nobbys Head is formed from volcanic ash that fell from the air after these eruptions, and was also later transported here by rivers. Seen from the beach (Stop 1A), the brown-light grey rock near the base of Nobbys Head formed from this volcanic ash and is called a tuff. The Nobbys Tuff is made up of around 20 main layers, averaging around one metre thick. Above the tuff, and extending up to the lighthouse, is a darker shale and coal layer about 4 m thick called the Victoria Tunnel Seam. At the base of the headland, covered by scree and vegetation, is the Nobbys Coal Seam. Lastly, you can see a younger volcanic rock, around 90 million years old. Basaltic magma intruded through the coal and tuff, forming a near-vertical dyke about 3 m thick (see more details on dykes at stops 2 and 5).

The Awabakal people first arrived in the lower Hunter Valley at least 20,000 years ago. Whibayganba is their name for Nobbys Head and the Nobbys Tuff there was used to make stone tools.

Panorama of Nobbys Head.

Nobbys Head became an island around 8,000 years ago, as sea level rose after the last ice age. The first European sighting of the island was from Captain Cook's ship Endeavour on 10 May 1770. In 1797, Shortland noted several coal seams in the feature, which was first named Coal Island. To improve the harbour, Governor Macquarie commissioned Macquarie Pier to be built to the island from 1818 to 1846. The breakwater was constructed in 1880. Part of the southern side of Nobbys Head was quarried to complete the pier. Originally 43 m in height Nobbys Head was cut down to around 28 m in 1855, with 11 m of the Merewether Conglomerate removed. Nobbys Beach became famous as a shanty town in The Depression in the early 1930s, as an army camp in World War II and more recently due to the nearby grounding of the Pasha Bulker coal ship in 2007.

Aerial image of Nobbys Head showing location of Nobbys dyke. Imagery, map data: Google.

Stop 2: Hot magma from deep Earth

The dark stripe in the rock platform is a dyke – a near-vertical injection of molten basaltic (magnesium- and iron-rich) material from deep Earth.

This dyke is about 90 million years old – much younger than the 253 million year old sandstone of the rock platform. It is of similar age and composition to the Nobbys dyke (Stop 1) and the dyke at Newcastle Beach south (Stop 5). Hot magma intruded the sedimentary rocks and fractures to form the dykes. The edges of a dyke cool more quickly than the middle, so the crystals on its margins are smaller and form a feature known as a 'chilled margin'.

Rock platforms are a harsh environment to live in; the tides rise and fall, organisms are exposed to direct sunlight and also flooded by water. Despite this, 123 different species have been identified on this rock platform.

High-shore platforms are home to barnacles, limpets and chitons. Mid-shore platforms are characterised by a band of white, hard, limy Galeolaria worm tubes which form dense colonies providing a microhabitat for a large variety of intertidal animals. The low-shore platforms are home to anemones, sea stars, urchins and crabs.

These areas are extremely sensitive to human disturbance; please help protect them by leaving all creatures alone.

Dyke extending across the rock platform just north of the Cowrie Hole. Dyke is approximately one metre wide. Source: Phil Gilmore.

Stop 3: Ancient and modern life

Near the steps from Newcastle Ocean Baths down to the sandy beach at the Cowrie Hole, fossilised remains of the extinct tree Dadoxylon can be seen. Round stumps and long trunks of several trees can be seen in pebbly sandstone, suggesting they were buried by river sediments and may have been carried along by the river. Even though the trees lived over 250 million years ago, internal tree rings, roots, external linear bark-like features, and nodes where branches would have connected can still be seen. Many of the fossils are red-brown, as the mineral siderite (an iron carbonate) that replaced the wood has now rusted, forming the mineral limonite. The hardness of limonite has helped preserve the tree rings and other features. Look closely at a large fossil tree. How many tree rings can you count? Each ring represents one year of growth. Dadoxylon is believed to be an ancient relative of the genus Araucaria – evergreen conifer trees that include the modern Norfolk Island pine and monkey puzzle trees.

Fossil tree trunks seen from the ramp at the northern end of Newcastle Ocean Baths. Log is approximately 1.5 m long.

Pumice found on the beach at the Cowrie Hole. Source: Carson Cox.

Honeycomb weathering. Field of view approximately 1.5 m.

Stop 4: Rocks from faraway places

The rocks in this wall don't look anything like those in cliffs and platforms along the rest of the Newcastle coastline. Carried in ships as ballast, they could have come from any port in the world!

Wall constructed from rocks brought to Newcastle as ballast in ships.

Most of this wall contains metamorphic rocks called gneiss that are thought to have come from near Rio de Janeiro in Brazil, South America. Gneiss looks stripy as there are dark layers of the platy mineral biotite, and pale layers with elongated quartz and feldspar crystals. The rocks were subjected to great pressure and temperature, causing the original minerals to recrystallise, stretch and flatten to form the layers. Two dark rocks on either side of the plaque are basalt – their origin is unknown.

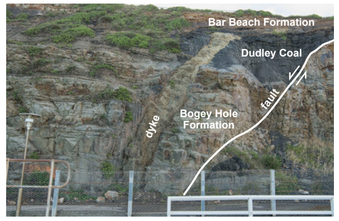
Stop 5: Splitting from Zealandia

Cliff exposures above the skate park show how rocks behave when put under stress. They don't form the continuous layers that are seen elsewhere along Bathers Way, but are heavily fractured. Some younger features (dyke and fault) crosscut older rocks (sandstone and coal layers).

The dyke looks different from the surrounding rocks as it is made of different minerals. This is because it was formed from molten rock deep in Earth's crust. When the crust stretched, as the continent of Zealandia moved away, molten rock was injected into the rocks above, where it cooled and hardened to become a dyke. The sandstone is relatively hard and brittle, so it broke along straight lines. The coal layers above are softer and more difficult to break, so the dyke couldn't push through them.

Faults are fractures where the rocks either side have moved past each other. Viewed from the skate park, the most obvious fault is to the right of the dyke and has cut off the coal layers on the left, pushing them down relative to the sandstone layers on the right.

The coal layers aren't visible in the right-hand block because they have been eroded away. This type of fault is called 'normal' since it was the first type identified by geologists in the 18th century. On a regional scale, normal faults let Earth's crust stretch by making it wider and thinner.



Dyke, fault and joints cross-cutting older sandstone and coal rocks at Newcastle Beach south.

Stop 6: Coal and convicts

The Bogey Hole is a window into Newcastle's early history. Here you can see a close-up view of the coal seams that shaped Newcastle's early economic development, together with a reminder of convict history. A prominent black layer can be seen in the small cliff above the retaining wall at the end of Shortland Esplanade. This layer is part of the Dudley Coal, the first coal mined in Newcastle. Close up, you can see thin bands of shiny and dull coal. These result from preservation of different plant parts – including some leaf and branch remains. The Bogey Hole is thought to be Australia's oldest convict-built ocean bath, dating from around 1820. It is heritage listed and probably Newcastle's oldest surviving construction by European settlement.

The Awabakal name for coal is 'nikkin'. The Awabakal people are the only documented tribe in Australia to use coal for warmth, cooking, opening shellfish and making coal tar. Coal was easily collected from fallen blocks along the coastline and around hills where coal seams are exposed – such as here. Middens (remains of domestic life) in Lake Macquarie and Swansea Heads contain pieces of coal, suggesting it was used routinely.

Joseph Lycett, ca. 1817. Aboriginal Australians spearing fish and diving for shellfish. Source: National Library of Australia, PIC MSR 12/1/4 #R5686. The Aboriginal name for Newcastle is Muloobinba (meaning place of edible sea ferns).

Rocks formed from sediments deposited on a river floodplain 253 million years ago can be seen as you walk down the stairway to the Bogey Hole. Field of view approximately 4 m.

Glossary

Anticline upward-curving fold with the oldest rocks in the centre.

Basalt a common, grey to black or dark green volcanic rock. It is commonly fine-grained due to rapid cooling of lava on Earth's surface and may contain large crystals. The weathered surface of basalt may be orange or even white.

Bedding rock layers of varying thickness and character that formed during deposition and compaction of sediments or volcanic debris.

Coal a sedimentary rock formed from peat by the pressure of overlying sediments or rocks.

Conglomerate a rock made up of large (greater than 2 mm in diameter) rounded rock fragments (clasts). The space between the clasts is generally filled with smaller particles and/or a calcite or quartz cement that binds the rock together.

Crevasse splay a deposit formed when a stream breaks its natural or artificial levees and deposits sediment on a floodplain.

Delta (river delta) a landform created at a river mouth by the deposition of sediment carried by the river as it enters slower-moving or stagnant water.

Dyke a commonly sheet-like near-vertical intrusion of magma or sediment that cross-cuts older rock layers.

Erosion the action of surface processes such as wind or water/ice flow that remove soil, sediment and rock fragments and transport them.

Estuary a partially enclosed coastal body of brackish water with one or more rivers or streams flowing into it, and a connection to the open sea.

Fault a fracture in Earth's crust along which rocks on either side have moved relative to each other.

Floodplain an area of land adjacent to a stream or river that stretches from the banks of its channel to the base of the enclosing valley walls, and is flooded during periods of high waterflow.

Fold a bend in rock layers caused by stresses in the Earth's crust.

Forb a herbaceous plant that is not a grass.

Igneous rocks formed by the solidification of molten rock material. There are 2 main types – intrusive rocks crystallise below Earth's surface and volcanic deposits erupt onto the surface then cool quickly to form rocks.

Magma molten rock formed beneath Earth's surface.

Metamorphic rocks that have been modified by heat, pressure, and chemical processes, commonly while buried deep below Earth's surface. Such extreme conditions change the mineralogy, texture and chemical composition of the rocks.

Mineral an inorganic, naturally occurring solid substance that has a definite chemical composition and characteristic atomic structure.

Peat partially decayed vegetation that accumulates in wetland bogs, mores, mire, and swamps.

Pumice a pale igneous rock that contains abundant, round bubble-shaped cavities known as vesicles, and forms during explosive volcanic eruptions.

Sandstone a sedimentary rock made up of sand-size grains (0.06–2.00 mm diameter) of mineral, rock or organic material.

Sedimentary rocks formed by the accumulation of sediments. There are 3 main types – clastic, chemical and organic. Examples are mudstone, sandstone, conglomerate, limestone and shale.

Sediments fragments of minerals and rock (silt, sand and gravel) that are moved by water, ice or wind.

Shale a fine-grained, sedimentary rock composed of mud that is a mix of flakes of clay minerals and tiny fragments of minerals such as quartz or calcite.

Tuff an igneous rock that forms from the ash, rock and magma ejected from volcanic vents during an explosive eruption.

Weathering the physical and chemical processes over time that lead to the decomposition of rocks.

Credits

Authors: Phil Gilmore, Ron Boyd, Kevin Ruming, Bronwyn Witham, Russell Rigby and Roslyn Kerr

Editing: Simone Meakin and Cait Stuart

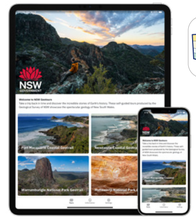
Figures and cartography: Kate Holdsworth

Graphic design: Carson Cox

Photos: Guy Fleming, unless otherwise credited

Cover photo: view south from Strzelecki Headland over Newcastle Memorial Walk

Learn more



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Newcastle Coastal Geotrail

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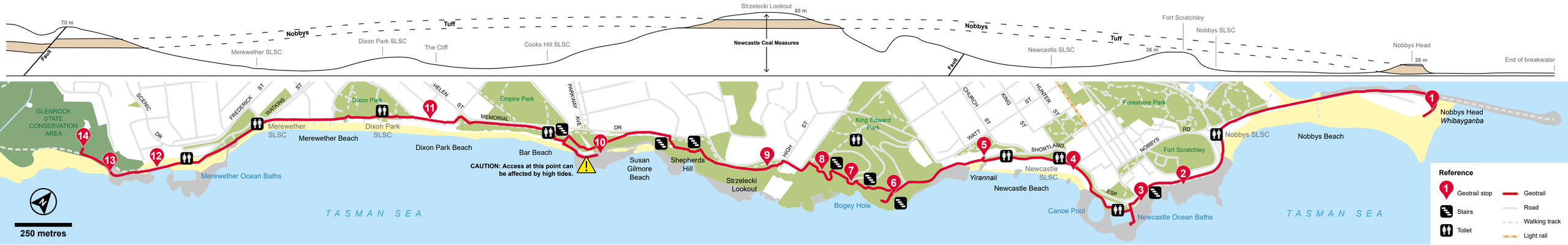
Newcastle coastline – generalised cross-section and geotrail map

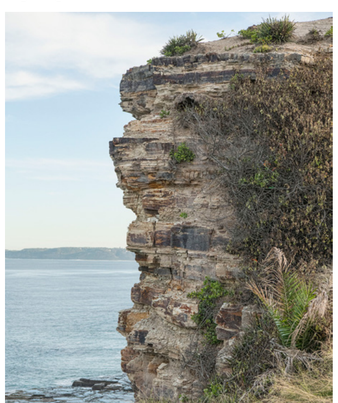


The ocean pool known as the Bogey Hole was originally dug out of sandstone by convicts in 1820.

Stop 7: A pioneer's view

A cliff exposure is visible behind a fence at the southern end of the car park on York Drive.

Sir Tannatt William Edgeworth David, a famous geologist and explorer, described the geology of the Newcastle coastline as 'probably the finest of its kind anywhere in the world'. He was well respected in the Hunter Valley, not just for his pioneering geological mapping of the area, but also his humility and community spirit. From this spot, you can see a magnificent view of the rocks exposed in the cliff, stretching southwards to Redhead. You are at the level of the Nobbys Tuff and Nobbys Coal, also seen at Stop 1. This is also a great place to spot dolphins and migrating whales in winter.



Looking south at the Nobbys Tuff, King Edward Park.

Stop 8: Rock...soil...plants

Weathered rocks of the Newcastle Coal Measures are topped by Themeda Grassland, a remnant of the original coastal vegetation. The NSW Scientific Committee has included Themeda Grassland on seacliffs and coastal headlands as an endangered ecological community, so work has been done to preserve the remnant in King Edward Park.

Themeda Grassland community.

They are dominated by Kangaroo grass (Themeda triandra) but also include a variety of other native grasses, forbs and shrubs. There are numerous remnants scattered along the trail but the section along this path contains the greatest diversity of plants with 15 species. Please keep to the tracks to help protect these important remnants.

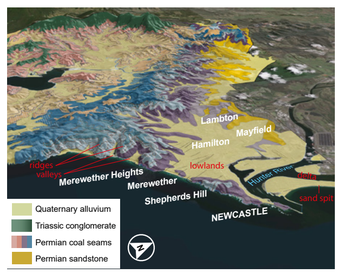
King Edward Park and many coastal areas contain examples of the Norfolk Island pine (Araucaria heterophylla). Native to Norfolk Island in the South Pacific Ocean, historically it was planted in coastal locations around Australia as a wayfinding tool for settlers due to its height and tolerance to salt and wind. These columnar trees are living fossils, dating back to the early Mesozoic Era. Fossil records show that the genus also formerly occurred in the northern hemisphere until the end of the Cretaceous Period.

It is believed that the long necks of sauropod dinosaurs may have evolved specifically to browse the foliage of the very tall Araucaria trees. The global distribution of vast forests of Araucaria during the Jurassic Period makes it likely that they were the main high energy food source for adult herbivorous dinosaurs.

Stop 9: The modern landscape

From Strzelecki Lookout on top of the Merewether Conglomerate, there are 360-degree views of the modern landscape of Newcastle. On a clear day, you can see over the city and suburbs northeast to Port Stephens, south along the beaches and coastal cliffs to Merewether and Redhead, north to Barrington Tops, northwest up the Hunter Valley and west to Mount Sugarloaf.

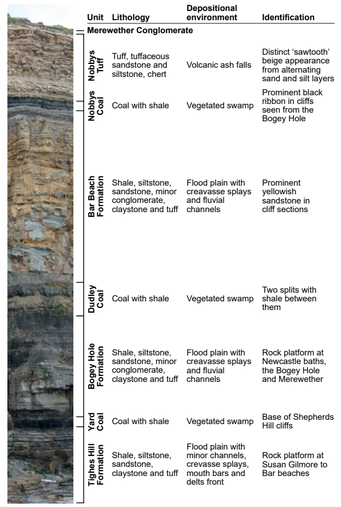
Geological processes and the resultant landscape have had a critical role in human settlement of the Newcastle area. Newcastle's landscape consists of a series of ridges and valleys, with the lowland of the Hunter River estuary and delta. Creek erosion of the Permian Newcastle Coal Measures has resulted in resistant conglomerate remaining on the tree-lined ridges extending north towards the Hunter River. These conglomerate-capped ridges include Shepherds Hill, Merewether Heights, Charlestown and New Lambton. In between, creeks have eroded valleys down into softer shale. Most of these creeks are now concrete drainage channels – e.g. Styx Creek in New Lambton and Ker-rai Creek in Lambton. Higher ridges to the north, in the Mayfield–Waratah–North Lambton area, are formed by the Waratah Sandstone (the bottom layer of the Newcastle Coal Measures). The lowland areas of central Newcastle, Hamilton and Newcastle Racecourse are where relatively young muddy sediments (<120,000 years old) have filled the Hunter River estuary. Further north is the modern Hunter River, its delta at Kooragang and the long sand spit of Stockton.



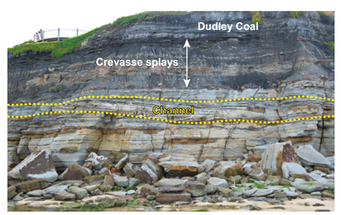
The landscape of Newcastle is determined by its underlying geology and has controlled human settlement in this area.

Stop 10: Layers of time

In the cliff at the northeastern end of Susan Gilmore Beach you can see the thickest sequence of rocks along the Newcastle coast. This is because it is in the highest part of a fold in the rocks, and also because the resistant Merewether Conglomerate at the crest of the hill slows erosion. Each rock unit represents a different layer of time. The geological law of superposition states that, in an undisturbed area, each layer of sedimentary rock is younger than the layer beneath it. So as you walked down from Stop 9 at Strzelecki Lookout to Susan Gilmore Beach, from younger rocks down to older rocks, you walked back in time!



Rocks of the Newcastle Coal Measures. Cliff height is approximately 55 m.

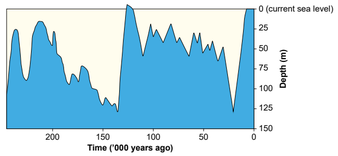


Southern Susan Gilmore Beach rocks formed from sediments deposited in channels, crevasse splays and peat swamps.

Stop 11: The changing seascape

The sea level has varied considerably here over the last 2.6 million years. When the sea level was low, the Newcastle area was a series of river valleys and ridges. When sea level rose, former valleys became coastal lowlands and were occupied by beaches such as Bar Beach and Merewether Beach. Former ridges eroded by the sea formed coastal cliffs (like those at Susan Gilmore and Merewether beaches).

Although we use mean sea level today as a reference elevation, over longer time spans sea level is constantly changing. The modern coastline has been here for about 7,000 years. Before then, climate change caused the growth and subsequent melting of continental-scale ice sheets. Because the ice sheets stored frozen ocean water on land, sea level fell during ice ages and rose when the ice melted. During the last ice age 18,000 years ago, sea level fell over 120 m and the shoreline at Newcastle migrated eastward around 20–30 km. During the last 2.6 million years, multiple ice ages have seen the shoreline continuously migrate back and forth over about 60 km and the sea level oscillate over 130 m.



The Australian sea level curve for the past 250,000 years. Source: Lewis et al., 2013.

Stop 12: Fallen rocks and fossils

Plant fossils from the vast Gondwanan forests are common along the Newcastle coast. The dark grey shale beds contain plant fossils here, including Glossopteris leaves and Phyllotheca stems. In a couple of places at the base of the cliffs, these beds are crumbling and fossils can be found in the rubble. Other displaced blocks have been dislodged from higher in the cliffs. Sparse Dadoxylon branch fossils are also found here.

The most common Permian forest fossils found in the Newcastle Coal Measures are the leaves of Glossopteris, a woody seed-bearing plant. Glossopteris fossils are also found in South Africa, India, South America and even Antarctica! The seeds of this plant were heavy and couldn't have been transported far by wind or water. This indicates that all these places must have formed a single landmass in the late Permian – joined together in the supercontinent Gondwana.

Glossopteris leaf fossils. Source: Phil Gilmore.

Aboriginal people used boulders of Nobbys Tuff at the base of these cliffs to make cutting and scraping tools.

Stop 13: Rocks and sediments under stress

At Merewether headland you can see evidence of movement by rocks and sediments due to Earth's forces.

Look upward to the cliff face and the small gully. The gully follows a normal fault preserved in the cliff face. A fault is a break in the rocks along which there has been movement. In this fault the southern side (the 'hanging wall' of the fault) has been displaced 5 m downwards relative to the rocks on the northern side (the 'footwall' of the fault).

Westward view of the fault, showing relative displacement.

Between Nobbys Head and Merewether Beach, the Newcastle Coal Measures were folded by tectonic forces millions of years after they were deposited. The Nobbys Tuff is located high in the cliff here. The change in elevation of this rock unit along the coastline highlights the gentle folding of the layers. If you join the elevation levels of the Nobbys Tuff along the coast, it makes a boomerang shape called a fold. This fold is named the Shepherds Hill Anticline.

Some layers in the Bogey Hole Formation on the rock platform and next to the storm water pipe show deformed bedding. Unlike the folds and faults, the deformed bedding does not affect the rock layers above and below. This tells us the deformation occurred at the time the sediments were deposited. When sediments are first deposited underwater they have lots of water trapped in the pores between the particles. If disturbed, the water can be expelled suddenly and the original beds are deformed while still soft. This commonly happens during gravitational movement downslope, but can also result from earthquakes.

Deformed sandstone south of Merewether headland. Field of view approximately 5 m.

Stop 14: Machines moving the Earth

European settlers used coal for producing energy for smelting and power, and were prepared to move the earth to mine it. The Burwood Colliery railway from Merewether to Glenrock Lagoon ran on top of this culvert. Remnants of the railway can be seen along the base of the cliffs – including embankments, tunnel portals, culverts, bridges and even old rail lines and wagon bogies along Burwood Beach.

Remains of the old Burwood Colliery railway culvert south of Merewether headland.

Timescale of major geological events recorded on the Newcastle coastline

Million years ago	Period	Geological event
0		
2.6	Quaternary	Multiple ice ages. Development of Hunter River floodplain.
23	Neogene	–
66	Palaeogene	–
145	Cretaceous	Dykes form when Australia separates from Zealandia.
201	Jurassic	–
252	Triassic	–
299	Permian	Coal measures form in swamps of Sydney Basin. Volcanic activity elsewhere.

Note: All ages are approximate. Not to scale.