

The Oaks lies upon a broad, lengthy belt of rocks which extend in outcrop from the Hunter Valley to near Warialda and are referred to as the *Tamworth Belt* (Figure 1). These rocks mainly range in age from Early Devonian to Late Carboniferous. They span an age range from about 400 million to 306 million years ago.

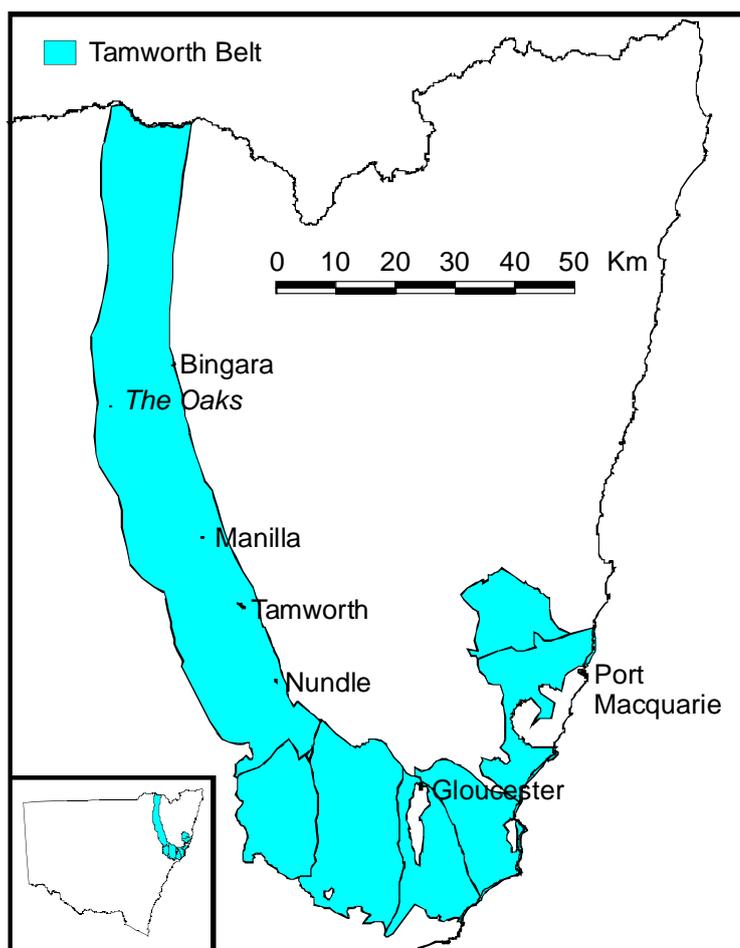


Figure 1. The distribution of the Tamworth Belt in NSW.

During the Devonian period the mass of land which was later to become the Australian continent was part of the supercontinent *Gondwana*. Eastern Australia in this region was largely submerged beneath a deep, tropical ocean (Figure 2), close to a subduction zone (Figure 3). The materials deposited in this deep ocean included sands and muds of mainly volcanic origin, formed from erosion of the ash and lavas erupting from the nearby elevated volcanoes. The volcanoes were fuelled from melting rock produced by the subduction process. Coral reefs forming along the margins of the volcanic islands were occasionally dislodged by cataclysmic earthquake activity, the reefs tumbling and sliding into much deeper water where they otherwise wouldn't have formed.

During the latter part of the Devonian there was a reversal of the subduction zone (Figure 3) and collision of the older Australian crust with the new volcanic and sedimentary crust which had formed above the subduction zone. This collision and subduction reversal resulted in a slow elevation of the region. The ocean within which the Tamworth Belt rocks were forming began shallowing. The Australian continent, which was still part of *Gondwana*, moved slowly southward toward polar latitudes (Figure 4). The rocks formed during this

Early Devonian 390 Ma

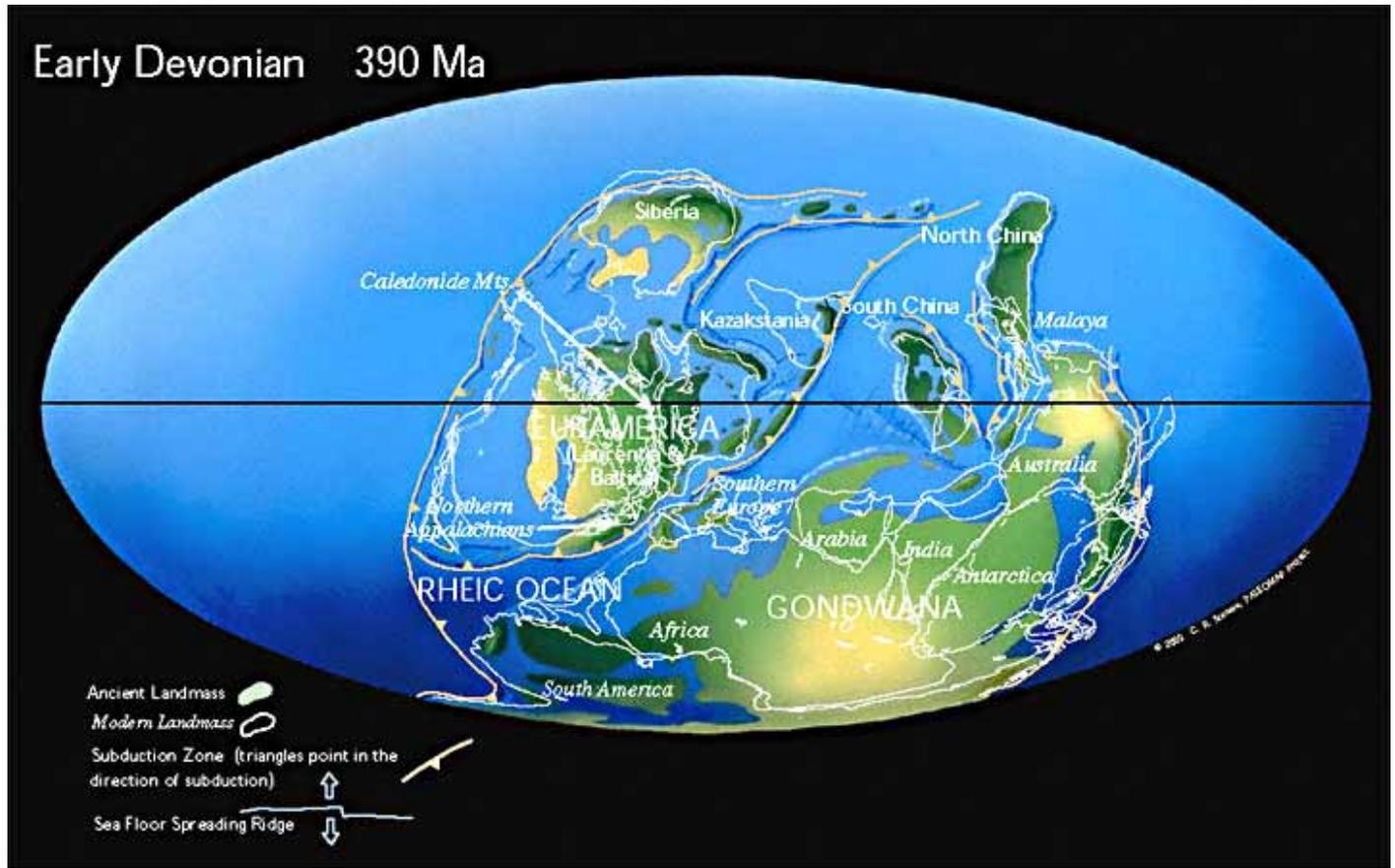


Figure 2. The location of the pre-Australian continent during the Devonian. Figure from www.scotese.com/earth.htm.

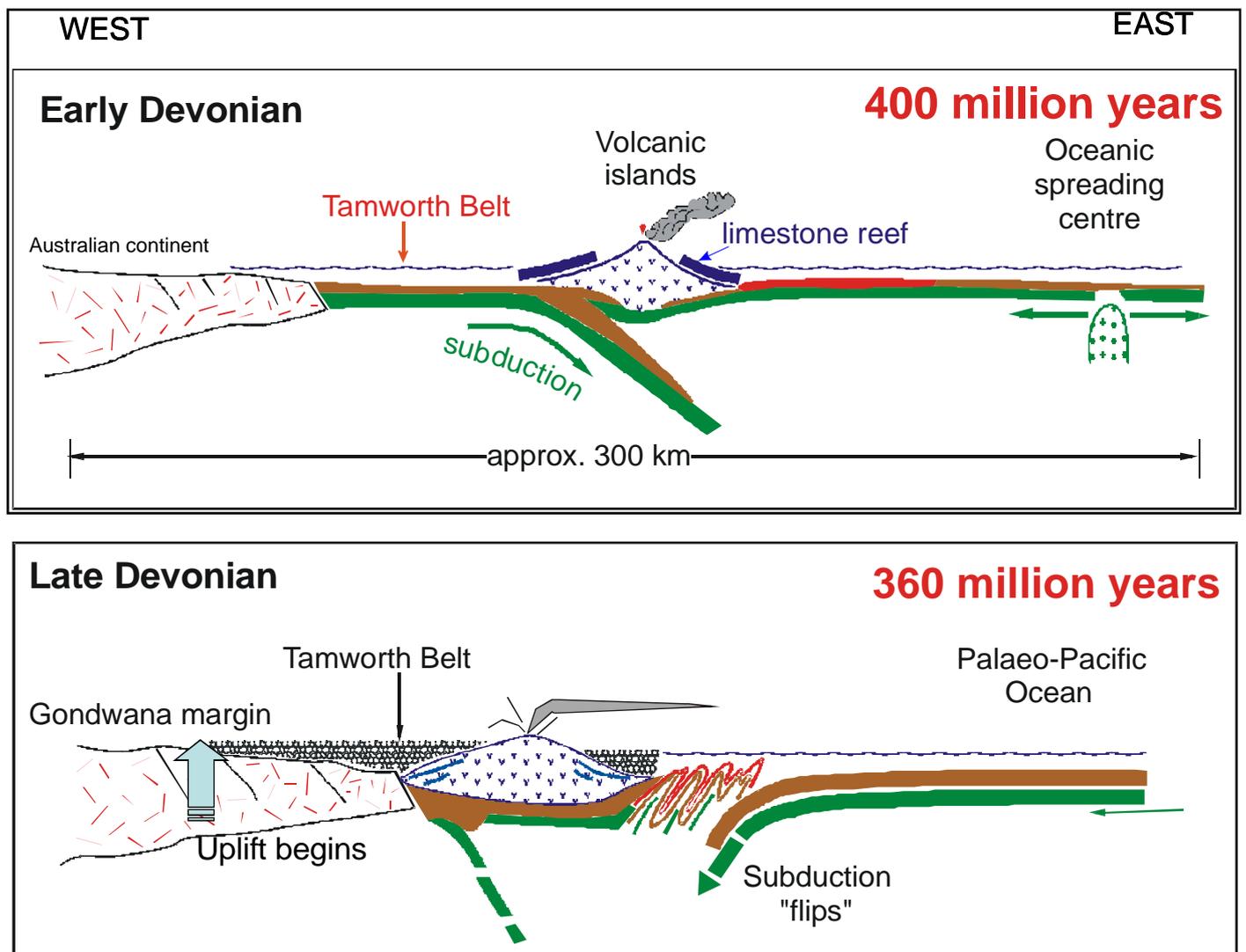


Figure 3. The tectonic setting of the Tamworth Belt during the Devonian. From Bob and Nancy's Geological Tour Site: <http://ozgeotours.110mb.com>

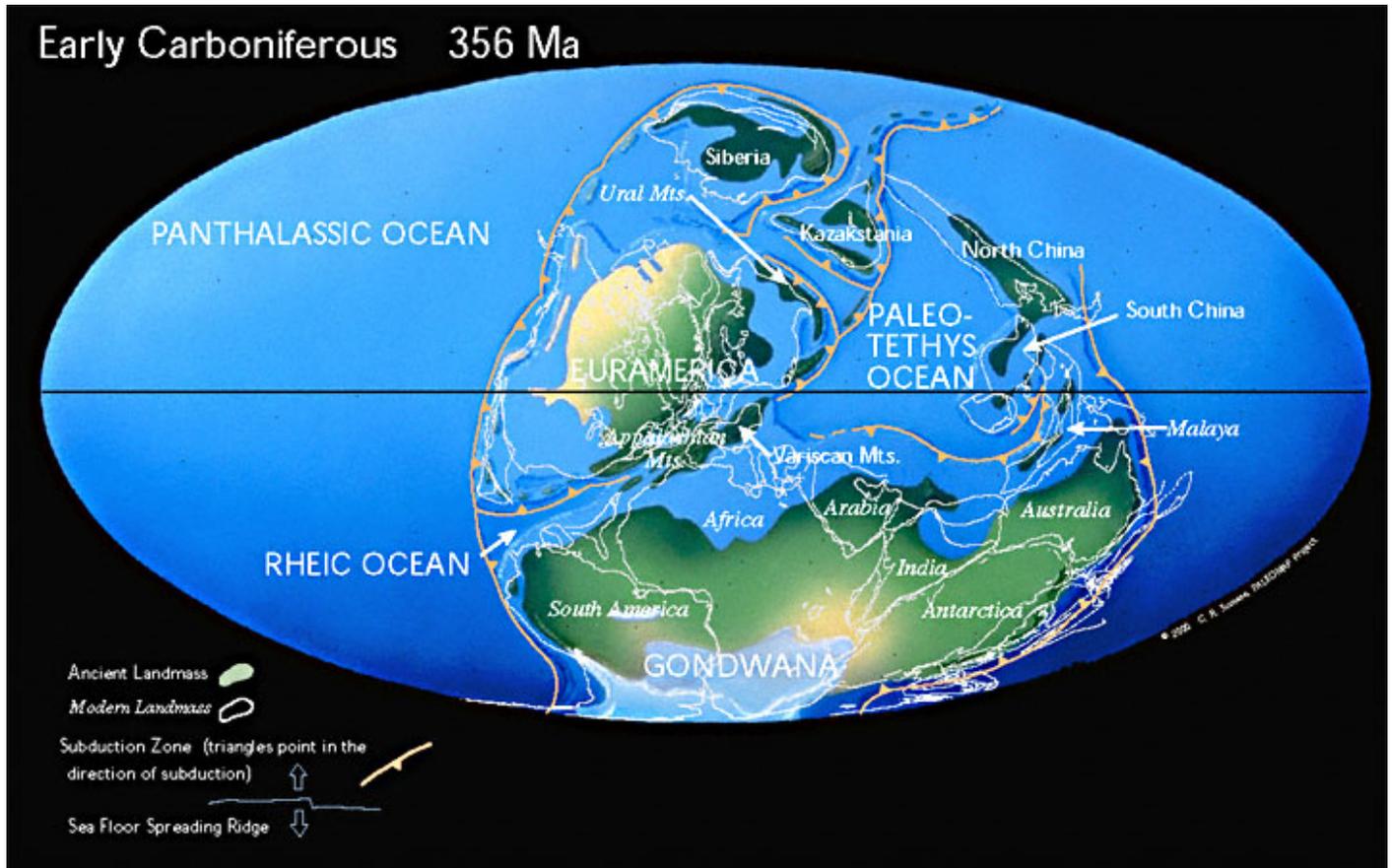


Figure 4. The location of the pre-Australian continent during the Early Carboniferous. Figure from www.scotese.com/earth.htm

In the latter part of the Early Carboniferous the sea was becoming very shallow, and the shoreline rapidly moved eastward. Rocks indicative of this shoreline outcrop near the Horton River bridge at Caroda. They include beach zone sandstones, and a thick heavy mineral sand bed.

As the ocean was finally infilled in the local region, a rapidly cooling non-marine environment prevailed. This was now the Late Carboniferous period, a time during which the subduction zone moved progressively away from the continent by repeatedly jamming, breaking up, and reforming further toward the mid ocean spreading centre (Figure 5).

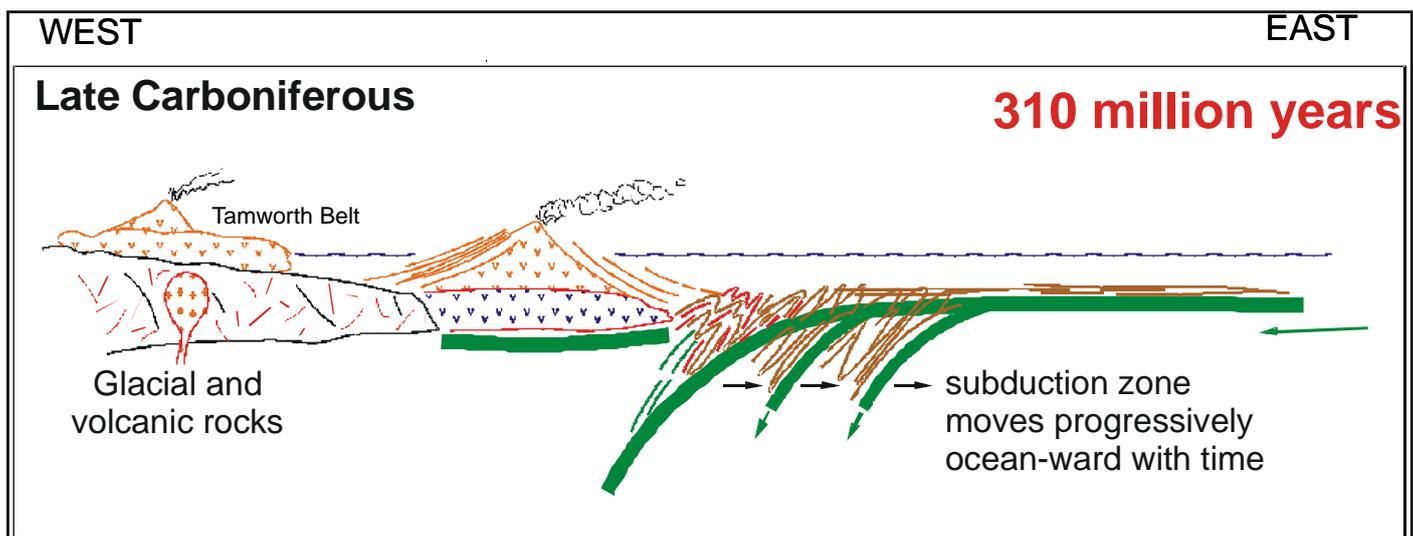


Figure 5. The tectonic setting of the Tamworth Belt during the Late Carboniferous.

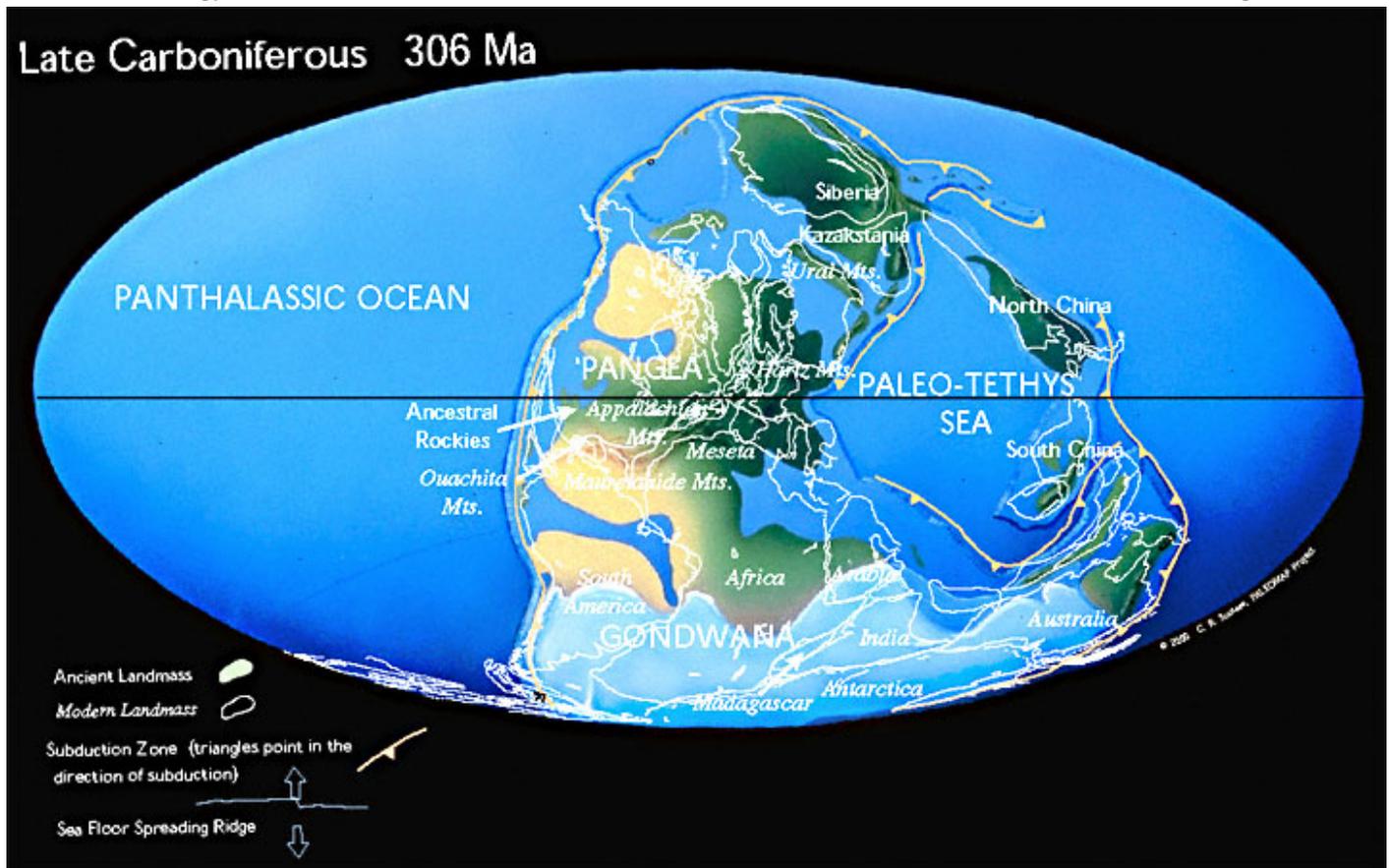


Figure 6. The location of the pre-Australian continent during the Late Carboniferous. Figure from www.scotese.com/earth.htm.

During the Late Carboniferous the Australian continent had drifted into polar regions (Figure 6) and ice covered much of the southern hemisphere. It was during this time that most of the rocks that outcrop on the surface of The Oaks were formed. Compression upon the local crust continued to elevate the older crustal rocks, pushing them up into high altitudes and forming high, long mountain ranges. Volcanic activity commenced in these rocks as a result of accompanying shallow crustal melting. Polar conditions formed ice sheets and glaciers (Figure 7). The volcanoes were of similar type to Mount St. Helens, producing limited extent lavas, and common explosive ash flows which covered large areas for distances up to 100 km from the volcano. The glaciers and surface ice created large amounts of sand and gravel which were dispersed from the mountains onto a coastal plain by fast flowing braided streams, building up great thicknesses of well rounded, gravelly to bouldery and sandy alluvium. Small swampy lakes formed in places between the rivers, and these marshy areas were subsequently converted into thin coal seams.

Material swept down from the mountains was mainly of volcanic origin. This formed by erosion of the ash and lava being produced in large volumes by the volcanoes in that area. The lavas were dominantly *rhyolitic*, a compositional term which indicates that the lava comprises quartz and feldspar. Rhyolitic lavas are relatively cool and viscous, so only travel short distances from the eruptive centre, typically only a few kilometres at most. No lavas are evident in the vicinity of The Oaks. The ash deposits formed from these volcanoes are typically *ignimbrites*, extensive layers of ash which formed when explosive eruptions blasted outwards large volumes of fragmented rock and congealed magma, together with trapped high temperature gases. As these fell back to ground, the trapped gases buoyed the ash upwards and supported individual fragments, resulting in a very hot mass of rapidly flowing ash. This ash traveled down slope at speeds exceeding 100 kmh, moving across the coastal plain until friction and lowering temperatures and gentle gradients eventually stopped the ash flow. Modern and ancient ignimbrites can cover distances up to about 120 km. Although no ignimbrites are present on The Oaks, there are a number of bodies within several kilometres.

The most abundant material deposited on the coastal plain was sand and fine to coarse gravel. The well

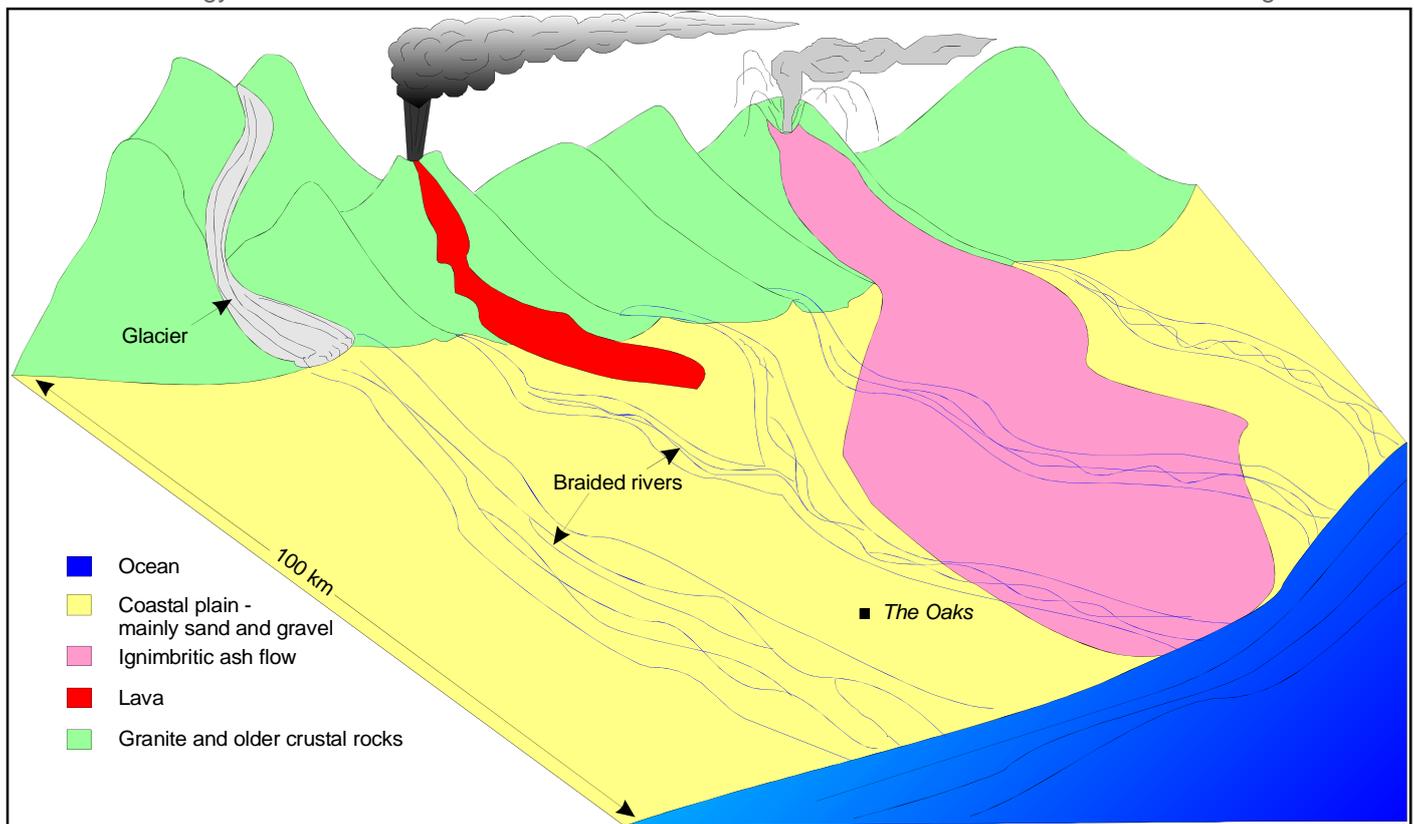


Figure 7. Interpreted geography of the region about The Oaks during the Late Carboniferous, about 305 million years ago.

developed rounding of the pebbles and boulders is indicative of the rapid flow of the streams which fed down from the mountains. The gravels are almost entirely made up of a mixture of volcanic rocks, although in places some granite pebbles may be found. The granite is derived from erosion of the older continental crust which made up the core of the mountains.

In places some of the rocks and structures formed by the glaciers and melting ice can be found. Although none have been observed on The Oaks, excellent examples are present up stream of the marked Glacial Area on the Bingara-Narrabri road (see Barraba-Bingara Tour for more details).

Major crustal upheaval at the end of the Carboniferous uplifted and folded the Tamworth Belt rocks. The gravels were converted to conglomerates, and the sands to sandstones. Groundwaters moving through these porous rocks cemented the grains together with dissolved quartz and *zeolite*, and some of the fine grained ash, muds and silts which formed in lakes were converted to zeolite-rich rocks. Zeolites are interesting minerals which have become an important material for a host of agricultural and industrial applications. The properties of some zeolites enable their use as molecular sieves and as selective retainers of nitrogen compounds - hence they are used as stock feed and fertiliser additives, and as deodorisers in feedlots and battery egg production. Zeolitic mudstones are exposed on The Oaks, and very colourful examples are present near the Glacial Area on the Bingara-Narrabri road.

After the Carboniferous, the region was inundated by shallow seas and large areas of gravels, sands and reefs were formed. None of these are preserved in the vicinity of The Oaks.

About 150 million years ago, during the Late Jurassic, Gondwana began to break apart. The Australian continent was attached to Antarctica, but began to separate and move northward after the Cretaceous, about 65 million years ago. By about 50 million years, Australia was moving rapidly northwards (Figure 8). The continent began moving across a stationary *mantle hotspot* (see Nandewar Volcano Tour), resulting in the formation of volcanoes in north Queensland. As the continent continued moving over the hotspot, those volcanoes which had moved away from the magma source became extinct, and a discontinuous trail of volcanoes developed from north Queensland towards the south. About 21 million years ago the region between Narrabri and Tweed Heads was above the hotspot, and a series of *shield volcanoes* (these are shaped like Roman shields - broad and gently curved) and smaller vents erupted. Eruptions continued locally until

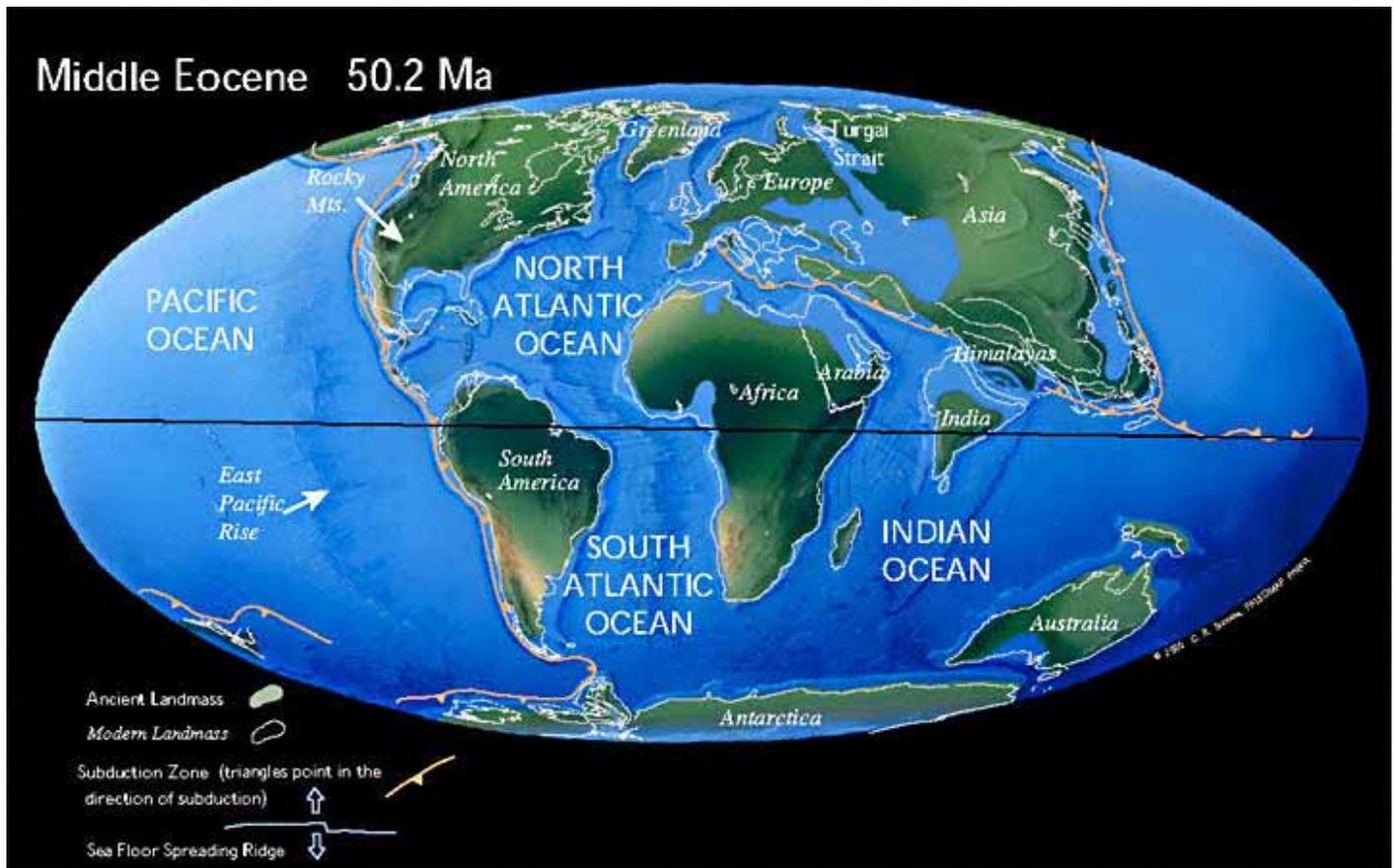


Figure 8. The location of the Australian continent during the Eocene. Figure from www.scotese.com/earth.htm.

about 17 million years ago, covering the region in a thick blanket of basalt, with some rhyolite closer to the volcano. Basaltic lava is preserved on the top of the ridge north of The Oaks. However, most basalt has been eroded over the past 17 million years, leaving the present incised terrain and the core of the Nandewar Volcano. Where the basalt has only recently been eroded the original relatively flat land surface is still visible, especially on the top of the main ridge immediately south of The Oaks.

The Geology of The Oaks

The Oaks comprises a ridge with large amounts of outcropping rocks, and alluvial flats with little or no outcrop (Figure 9). The rocks which make up the bulk of the ridge are Late Carboniferous conglomerate and sandstone. The locations of some particularly instructive outcrops of sandstone, conglomerate and zeolitic mudstone are illustrated on Figure 9, and are described below. The ridge is capped with basaltic lava originating from the Nandewar Volcano.

The Carboniferous sandstones have been folded and are now tilted downwards towards the southeast at about 20 degrees in the east of the area, and at about 10 degrees in the west (see cross section on Figure 9). Some southerly hillsides are formed by a single hard layer of sandstone or conglomerate which give the hillside a flat, planar appearance. These are known as *dip slopes*, and by walking up or down a dip slope you are essentially walking on a single rock bed. By contrast, westerly hillsides reveal a multitude of beds, and give us a section through many sedimentary layers.

The descriptions of selected outcrops below start in the southwest corner of the map (Figure 9) and pass along the marked track in a clockwise manner. Grid references are given for each site using WGS84 datum and GDA 1994 MGA Zone 56 projection.

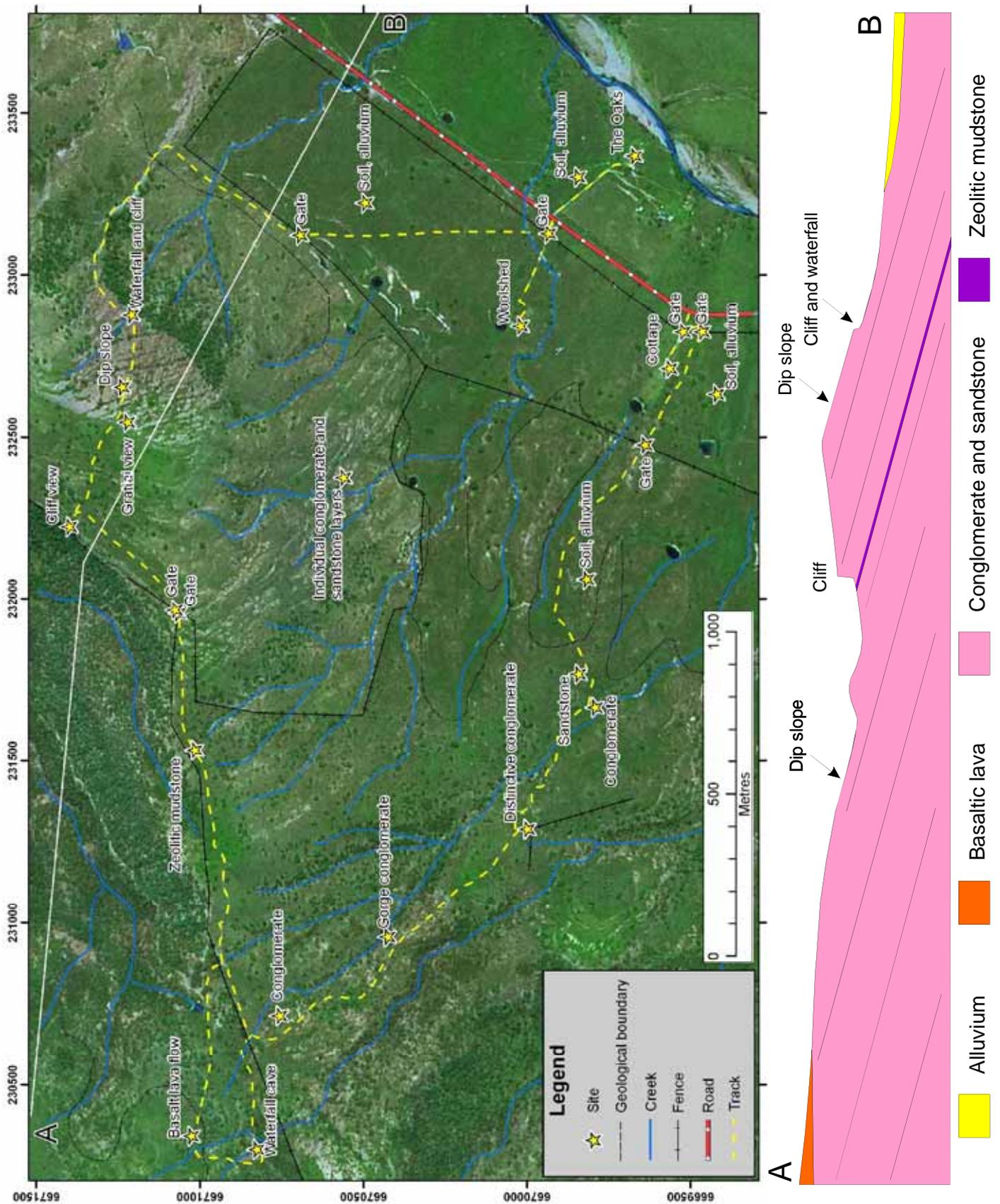


Figure 9. Map of The Oaks superimposed on a satellite image. Interpreted major geological boundaries and a geological cross section are illustrated.

Sandstone and conglomerate on low hill and in gully (Photos 1 & 2)
Grid reference 231765 6669841 to 231665 6669789

These are the first major outcrops of sandstone and conglomerate on the track. A prominent outcrop of fine sandstone occurs along the crest of a low hill. The sandstone is pale coloured and is composed mainly of quartz and feldspar. This sandstone is typical of those deposited during the Late Carboniferous, and was derived from the erosion of volcanic material which was erupting tens of kilometres away.



Photo 1. Interlayered sandstone and conglomerate.



Photo 2. Bedding planes in sandstone and conglomerate. The bedding here dips at a very low angle to the southeast.

Outcrops in the gully are instructive for showing the types of pebbles and their distribution within the sedimentary rock. Note how the pebbles are well rounded, demonstrating energetic stream activity and possibly the rounding influence of a glacier. The beds are discontinuous within the outcrop, which indicates that the alluvial environment was constantly changing with fluctuating depositional and erosional conditions. Gravel and sand similar to this would be found in perennial creek beds where most water flow is due to flood waters, or in the many watercourses of New Zealand which are fed by glacial melt water.

A Distinctive Conglomerate: Grid Reference 231288 6670001

On relatively flat ground, near the fence corner can be found some very distinctive cobbles originating from a non-outcropping conglomerate. The pebbles are made up of ignimbrite, with pale pink to orange feldspars and black quartz grains surrounded by a very fine grained mixture of quartz and feldspar. It is significant that no other pebble types are present, which is in contrast to all other conglomerates in the area. This suggests that this conglomerate was a gravel derived from a specific source area which was abruptly made available with little other sediment input. The source was shortly returned to its previous state. An explanation for this may be that the unique source area was associated with one particular ignimbrite which was temporarily subjected to increased erosion by flooding, or alternatively that other sources of gravel were temporarily shut off from this site by changes in the direction of the stream channel, thereby allowing gravel from one source area to dominate.

Gorge Conglomerate Exposures. Photos 3 & 4. Grid Reference 230955 6670429

From the track, walk carefully into the deep gully on the eastern side. This site reveals a large thickness of sandstone and conglomerate, and shows an unusual erosional landform. Note how the rocks are dominantly sandstone, with discontinuous beds of pebbly conglomerate (Photo 3). The types of pebbles can easily be examined here, and it is apparent that they are mostly ignimbrites of many grainsizes and colours. Rare rhyolitic lava pebbles can be found. Note how the conglomerate beds dip at a very low angle to the south. Contrast this with the somewhat steeper dips in the east of the area.



Photo 3. Thick sandstone with thin, discontinuous beds of conglomerate. Note the low angle dip.



Photo 4. Unusual sandstone and conglomerate erosional landform. This is very delicate, so please don't touch!

An unusual landform is present on the western edge of the gorge (Photo 4). This was once a boulder which has been eroded away at its base, forming a very sculpted feature. Undercutting of the base has left the block very unstable, and any contact may destroy it.

Waterfall Cave (Photos 5 & 6) Grid Reference 230298 6670826

Cross the fence and travel westward toward the gully. A low cave is developed beneath a sandstone ledge in the centre of the gully (Photo 5).



Photo 5. A cave has formed beneath a sandstone ledge in the centre of the gully.



Photo 6. The interior of the cave, showing relatively soft interlayered shale and sandstone.

The cave is quite deep and is populated with some bats. **Don't enter the cave, as the roof may be unstable, and by inhaling dust formed from bat droppings it is possible to contract the potentially fatal disease *Histoplasmosis*.**

From the cave entrance it is possible to view the thinly interlayered shale and sandstone which has selectively eroded to form the cave. Erosion has probably taken place by backwash from the gully when in flood. Fast moving storm water has been deflected back against the rock, sluicing away the relatively soft mudstone. Once again, note the relatively low angle dips of the rocks.

Continue around to the top of the rock ledge and walk northwards towards the low, virtually treeless hill.

Basalt Lava. Grid reference 230339 6671025

This low hill, and the top of the ridge to the north and northwest are remnants of the basaltic lavas derived from the Nandewar Volcano. The lavas are dark brown in outcrop, and when broken show a black interior

with glossy, elongate crystals of feldspar.

From near this site it is possible to view the ridge on the opposite side of the valley to the south (Photo 7). Note that the top of the ridge is relatively flat. It is also almost the same height as the ridge at this site. The flat surface on the opposite ridge represents the pre-eruptive land surface which existed before the Nandewar Volcano disgorged its basaltic lavas over this area. Erosion has stripped the lavas from the opposite ridge, eroded deeply into the valley floor, but left a thin veneer on the ridge beneath us. Also note the dip of the rocks on the opposite ridge, which are dipping at a low angle to the east.



Photo 7. Relatively flat surface on the ridge crest to the south of The Oaks. This surface is probably representative of the pre-eruptive land surface which existed before the Nandewar Volcano.

Proceed from here in an easterly direction, passing southward of the earthen dam and recrossing the fence and regaining the main track. Continue eastward, following the fence and track.

Zeolitic Mudstone. Grid Reference 231536 6671014

A relatively flat section of the ridge top with few, scattered trees corresponds with sparse, flat, slab-like blocks of fine grained, dark brown zeolitic mudstone. Freshly broken surfaces of the rock show curved fracture surfaces, a pale brown colour, and very sharp edges. Weathered exterior surfaces show thin banding which corresponds with bedding in the original mud.

This was originally a silt or fine ash which had settled in a lake between watercourses on the large Late Carboniferous coastal plain. The mud has been converted to zeolite during deep burial in the Earth's crust. Although relatively hard, this rock is brittle and breaks into blocks easily. Erosion of this mudstone to the northeast has been partially responsible for the formation of the large valley which will be examined at the next site.

Continue along the fence line, passing through several gates. The track passes over more conglomerates and sandstones. The mudstone has dipped beneath us and passes under the ridge but would have surfaced to the north of us prior to extensive erosion.

Cliff View. Photos 8, 9 & 10). Grid Reference 232224 6671399

A high cliff line presents a great view of the local area, and shows a very good example of a dip slope on the adjacent ridge to the north (Photo 8). **Extreme caution is advised at this site, as a fall from here would be fatal! Maintain a safe distance from the cliff.**

The rocks on the adjacent dip slope pass beneath the foot of this cliff. A relatively soft rock, probably the zeolitic mudstone, exists between the dip slope rock and the rock which makes up the cliff. Erosion of that softer rock over millions of years has resulted in the retreat of the cliff line. By looking along the cliff to the southwest it is likely that the soft rock which has caused this phenomenon lies within, or close to, the gully in the near distance (Photo 9).

Fractures in the conglomerate at the top of the cliff have carried groundwater over the millions of years of burial of this sandstone. The groundwater was locally enriched in dissolved minerals which have percolated into the adjacent rock where they precipitated, selectively strengthening the rock. After the rock was exposed to the atmosphere and erosion took place, the relatively hard rock on opposite sides of the



Photo 8. View from the cliff looking northeast. Note the dip slope on the adjacent ridge.



Photo 9. View from the cliff looking southwest.

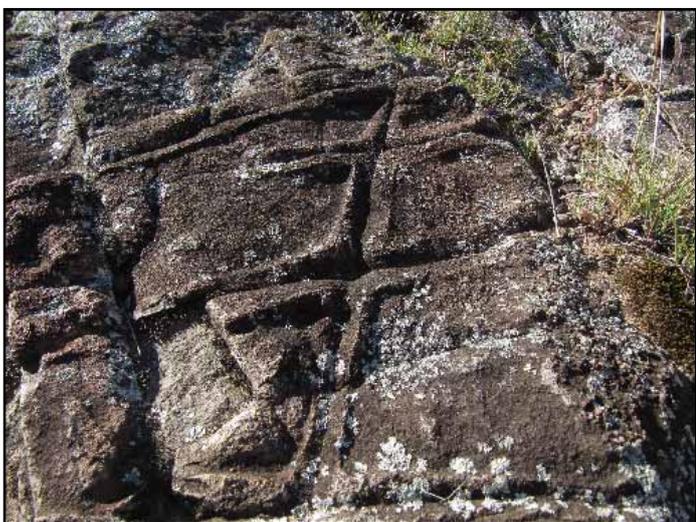


Photo 10. Alteration along fractures in sandstone.

fractures has been eroded at different rates, resulting in raised margins (Photo 10). This is a relatively common phenomenon in some rocks, and is particularly well exposed in places along the cliff top.

Continue to the top of the ridge in a southeasterly direction.

Dip Slope and Grattai View (Photos 11, 12) Grid Reference 232650 6671241

This site, at the top of the ridge, offers wonderful view of the valley. The distinctive peak of Grattai Mountain is visible to the west. The tilted top of this peak is a lava flow which has preserved the geometry of the slope of the Nandewar Volcano from which it erupted. By projecting a line across the top of this

peak, parallel to its surface, and curving it across the known position of the various vents which made up the Nandewar Volcano, it is possible to estimate the shape of the volcano when the lava on the peak of Grattai was erupted (Photo 11).

The ridge slopes to the southeast across a prominently outcropping sandstone and conglomerate bed which forms a dip slope. This feature is very visible on the satellite image (Figure 9). Fracturing of the conglomerate has formed a series of north-trending depressions and gullies which are very visible in Figure 9. Follow the dip slope downward, moving toward the gully on the north side of the dip slope. The slope is terminated by a cliff line which has formed by erosion related to water cascading over a waterfall.

Waterfall and Cliff (Photo 13) Grid Reference 232874 6671208

Be very careful at this site. A fall over the edge would be fatal!

For millions of years running water has eroded the base of the dip slope. As the base of the slope retreated up hill, a cliff line has been formed, and the resulting perennial waterfall has accelerated



Photo 12. View of the conglomerate and sandstone dip slope top.

the erosional process.



This is the conclusion of the guide to The Oaks geology. There are many outcrops visible on the satellite image, and a walk up any part of the ridge will reward you with new outcrops and slight variations on the rocks described in these pages.

Photo 13. Cliff and waterfall marking the lower edge of the dip slope.