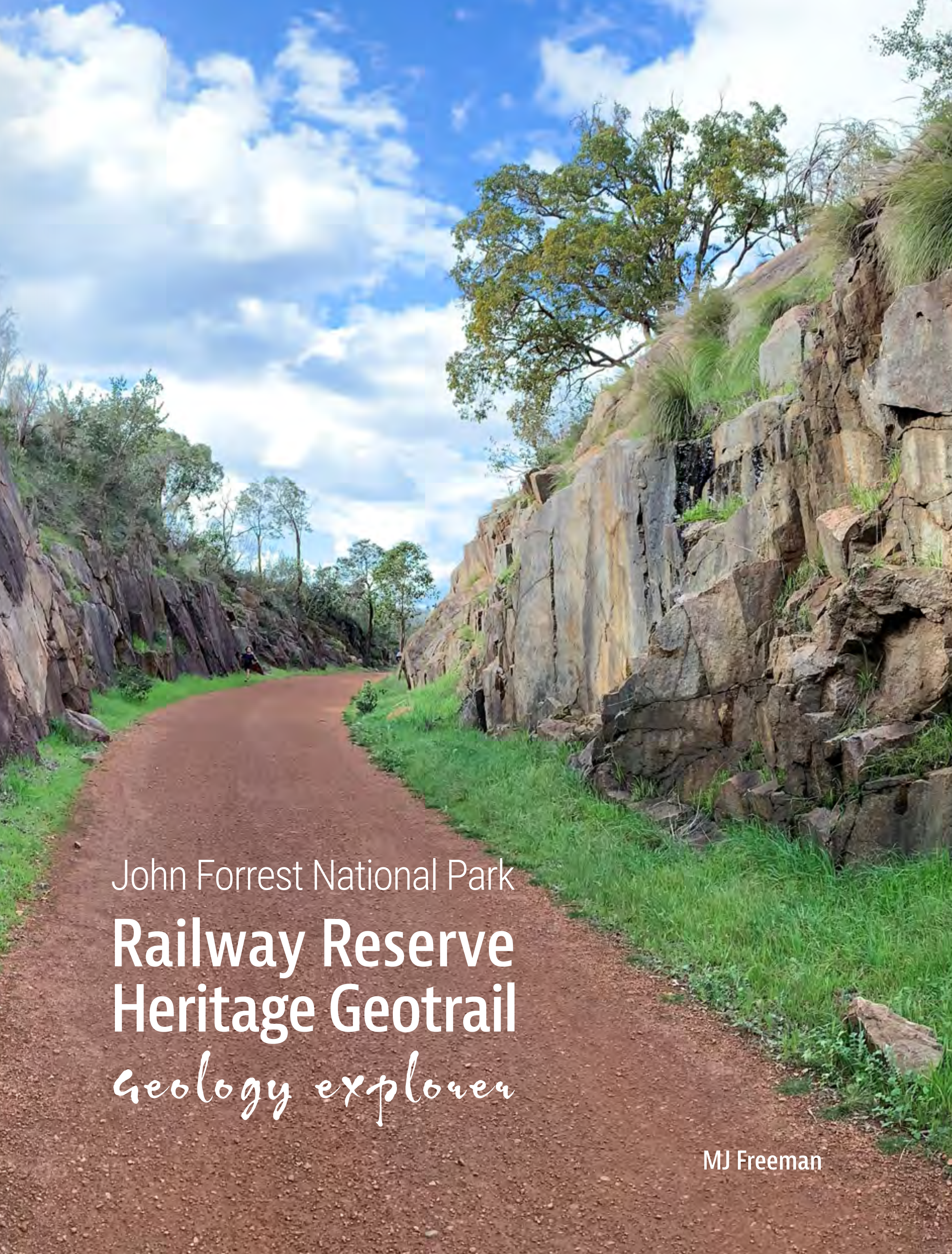

John Forrest National Park

Railway Reserve Heritage Geotrail

geology explorer

MJ Freeman

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The labour of many rough and calloused hands is preserved in the tunnel stonework where it blends organically into the natural rock from which it was cut

Geology and landscape

This guide describes the geology and landscape along the disused Railway Reserve Heritage Geotrail, in John Forrest National Park that is located on the Darling Scarp about 22 km east of Perth (Fig. 1). According to the Geological Society of Australia, a geotrail is a route through nature that 'delivers a geotourism experience through a journey linked by an area's geology and landscape as the basis for providing visitor engagement, learning and enjoyment.' The spelling of the name Forrest is after Lord Forrest, the first Premier of Western Australia and a member of the first Cabinet of the Commonwealth of Australia.

The walk starts from either end of the geotrail (see Fig. 2). At the western end are two Morrison Road car parks, entered off either Swan Road or Pechy Road. At the eastern end is a picnic area near the John Forrest National Park ranger's office adjacent to the John Forrest Tavern. Access to the picnic area is from the Great Eastern Highway, turning off at the signposted Park Road 7.0 km from the traffic lights where the Great Eastern Highway goes under Roe Highway (Fig. 1). There are many other walking tracks within the national park, and maps are available online from the Parks and Wildlife website showing these routes (parks.dpaw.wa.gov.au/park/John Forrest). The walk described in this book is now a heritage route, converted from the former main east–west train line, and is very popular with cyclists.

The walk follows the valley of Jane Brook and, being a former railway line, has very gentle gradients. The surface, though unsealed, is hard and is suitable for bikes, prams and strollers. At the western end, the former railway tunnel is an exciting experience for youngsters, although it can be a little scary for those without a good torch. Meanwhile, you can hear from down in the valley bottom Jane Brook babbling along its rocky path in winter and spring.

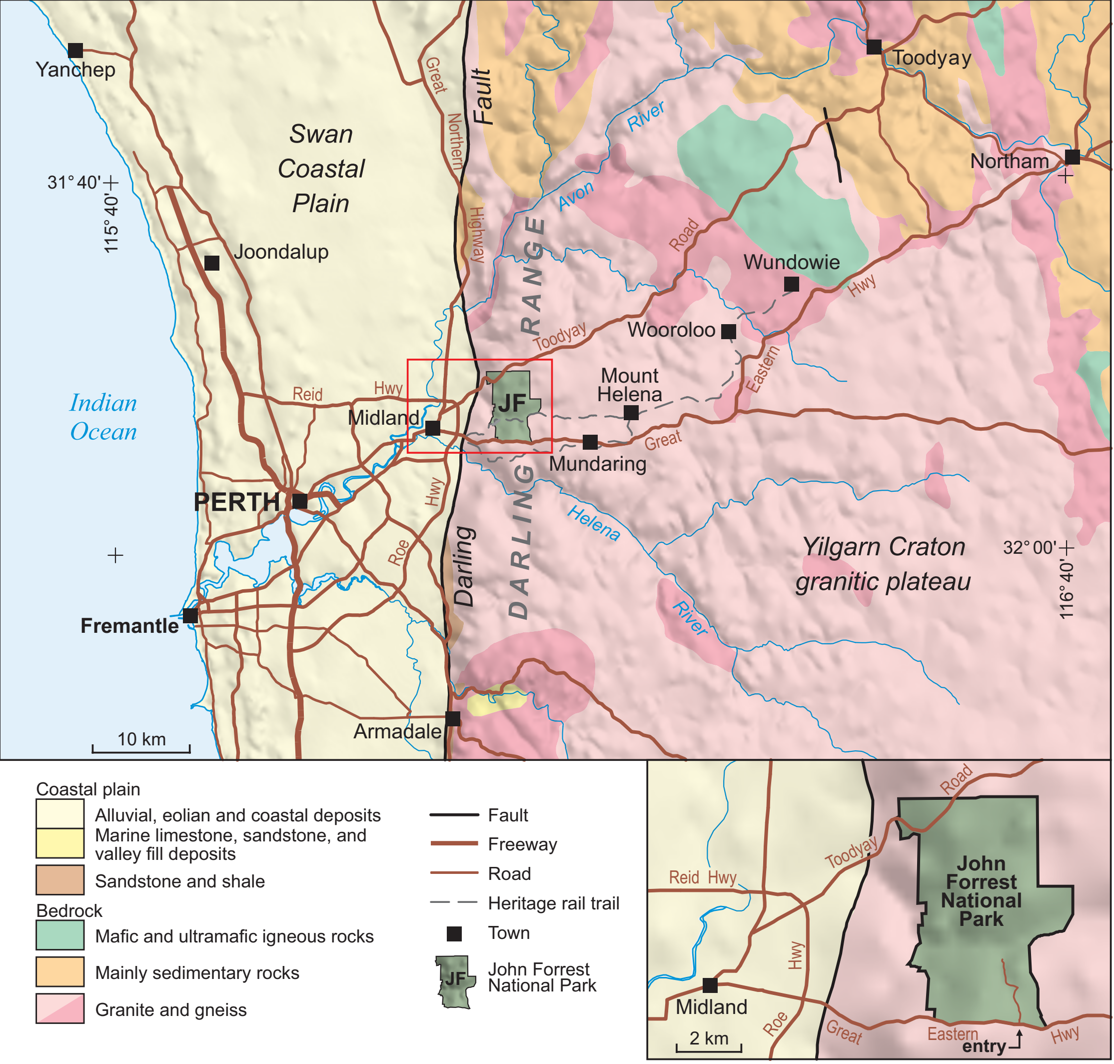


Figure 1. Locality map showing the geographical and regional geological setting of John Forrest National Park, and access to the Railway Reserve Heritage Geotrail

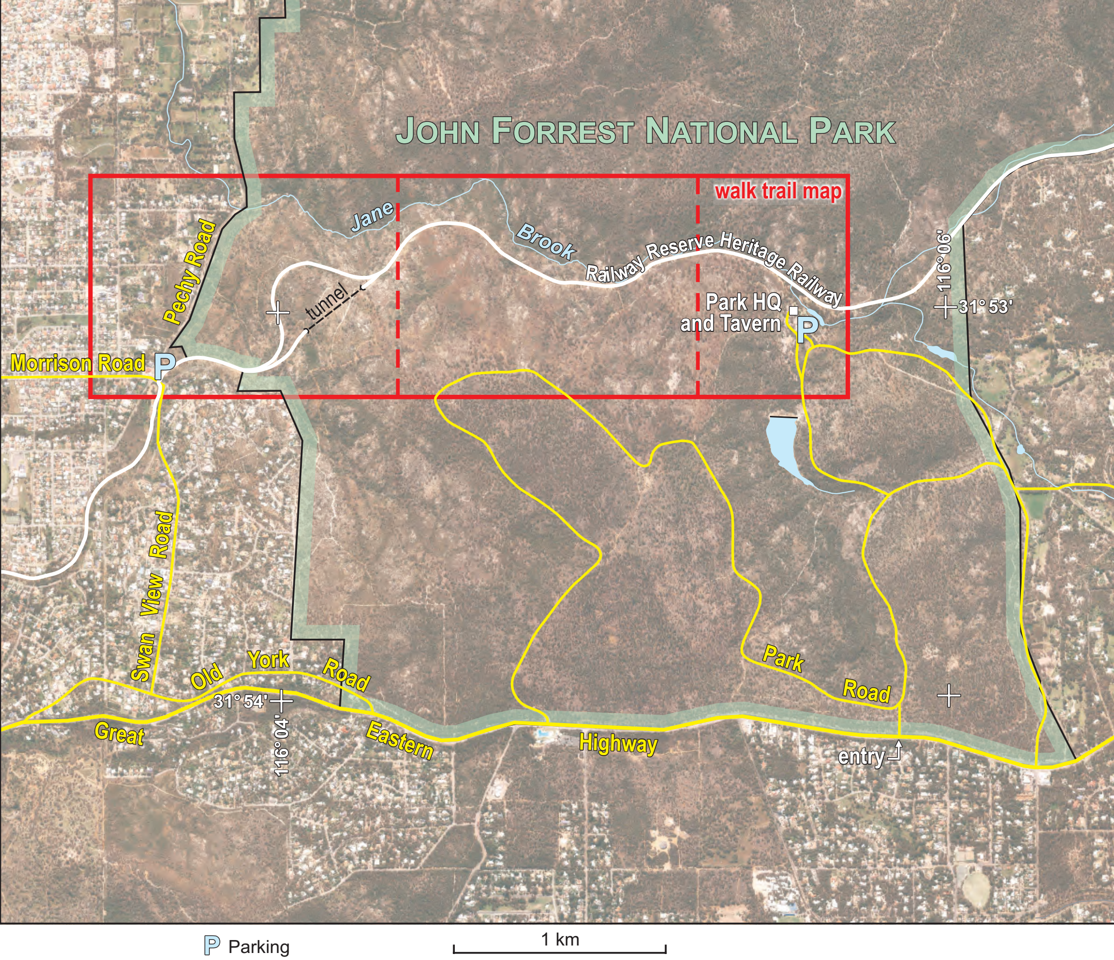


Figure 2. Southern part of John Forrest National Park with the route of the heritage geotrail and principal access roads from both the Morrison Road end and the National Park ranger's office end. The park headquarters, locations of parking areas and an outline of the geotrail maps bound in this book are marked. The background is a satellite image showing residential housing tightly clustered around three sides of the park

This guide includes a map (see p. 22). A slightly more detailed version is available online from the Department of Mines, Industry Regulation and Safety (DMIRS) eBookshop (www.dmirs.wa.gov.au/ebookshop). A number of the features are labelled on the map and referred to in this guide, such as the cuttings and dolerite dykes, to help relate them to the descriptions.

The order of recommended stops and geological features as described in this guide presumes the visitor is starting from the Morrison Road (western) end of the geotrail as most sites of geological interest are along that part in the former railway route (Fig. 3). However, there are additional features to be seen in the eastern half starting from the National Park ranger's office and, if walking from that end, visitors can follow the descriptions in reverse.

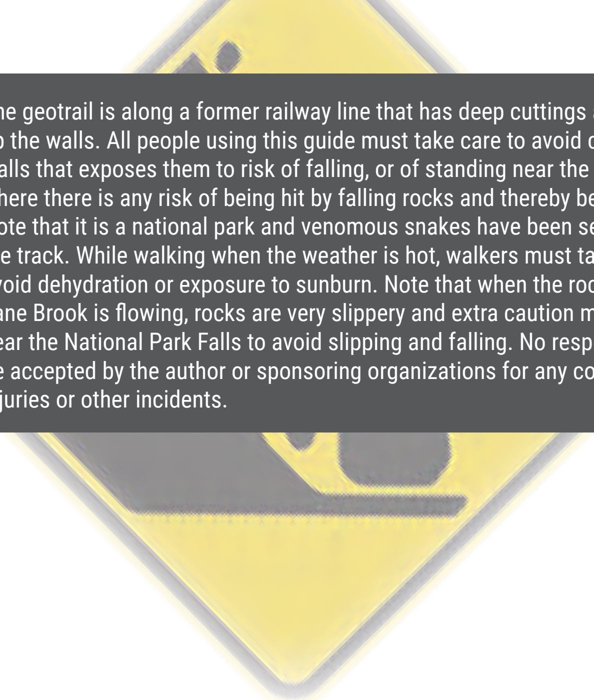
For additional reading, there are two books that describe a number of geological features and sites around Perth or along this geotrail.

- *A field guide to Perth and Surrounds* by JA Bunting that is accompanied by links to teachers' lesson guides
- *Geology and landforms of the Perth region* by JR Gozzard.

Figure 3. Typical activities in Cutting 3. Pale granite on the sunlit left wall and darker dolerite in the shadow on right-hand wall of the cutting. View is towards the west along the geotrail

Safety First

The geotrail is along a former railway line that has deep cuttings and high rocks up the walls. All people using this guide must take care to avoid climbing on the walls that exposes them to risk of falling, or of standing near the base of a wall where there is any risk of being hit by falling rocks and thereby being injured. Note that it is a national park and venomous snakes have been seen crossing the track. While walking when the weather is hot, walkers must take care to avoid dehydration or exposure to sunburn. Note that when the rocks are wet and Jane Brook is flowing, rocks are very slippery and extra caution must be used near the National Park Falls to avoid slipping and falling. No responsibility will be accepted by the author or sponsoring organizations for any consequences, injuries or other incidents.



Setting

The geotrail is located east of a major landscape feature, the Darling Scarp, which forms the boundary between the sand-covered Swan Coastal Plain that Perth sits upon and the Darling Range, which is underlain by old rocks of the western Yilgarn Craton (Fig. 1). The Yilgarn Craton is one of two original old parts of the Australian plate and consists mostly of rocks of Archean age, more than 2.5 billion years old. The Darling Scarp follows the Darling Fault which is a major geological structure that runs for nearly 1000 km from the south coast northwards to level with Shark Bay.

The scarp can be easily seen from space, and is evident in Figure 1 as a change in hill shading that reflects topography. The land rises from an altitude of about 50 m above sea level on the plain on the western side, to over 250 m nearby on top of the Darling Range. Jane Brook, that parallels the geotrail in this guide, crosses the scarp after flowing west from its headwaters about 15 km east of the national park. The brook depends on winter rains and carries water only between about July and the beginning of November.

Beneath the Swan Coastal Plain west of the Darling Range, up to 12 km of sediment was deposited between about 300 and 65 million years ago. To allow this thickness of deposition, older basement rocks under the plain were progressively downthrown by 12 km along the Darling Fault.

East of the fault along this geotrail, the rocks were formed in two main periods: granite formed about 2.6 billion years ago, whereas the dolerite formed at 1.2 billion years ago.

Therefore, the geotrail passes through rocks with some amazing differences in age. Geologists talk about the ages of rocks and the Earth in millions and billions of years but it can be difficult to really appreciate what these numbers mean. After all, who can appreciate what a period of a million years means, especially in contrast to the length of a human lifetime? Inside the back cover of this book is a table of the Geological Year where times and events from the formation of Earth to the present day are related to one full calendar year. This helps us to appreciate when things happened in relation to each other. Even though the granites along the geotrail are regarded as quite old, nearly half Earth's history had already passed when they formed, and complex life did not emerge on Earth until nearly 90% of geological time had passed!

The rocks, the land surface and the landscapes along the geotrail can be thought of at three scales from the smallest to the largest.

- On the **smallest scale** are the rocks with their different appearance due to the different minerals they are composed of, and how the rocks fracture and weather as seen along the walls of the railway cuttings.
- At an **intermediate scale** is the local terrain along the geotrail. It is dominated by granite tors (see the later description of this term) and broad, rounded sheets of granite, separated by areas of stony soil with trees, shrubs and grasses. The cuttings and embankments stand out as prominent features at this scale, along with the Swan View tunnel.
- At the **broadest scale** is the landscape with the valleys and hills, gullies and slopes. From the start of the geotrail, the landscape is dominated by how the geology has controlled the location, gradient and path of Jane Brook. This influences the shapes and heights of the hills and the spurs, although many of the controlling geological factors are inferred rather than seen directly. Human developments are commonly controlled by landscape. Along this geotrail, the valley became a good route for the former railway, allowing the trains to climb over the Darling Range following a relatively gentle incline.

The rocks

At the **smallest scale**, we can look at the rocks themselves. There are two main types along the geotrail — granite and dolerite — and they have very different appearances.

Granite

This is a pale-grey to cream rock with a coarse crystal size (Fig. 4). The crystals are mostly up to 5 mm across and rarely up to a centimetre or more. There are two main minerals: cream feldspar and grey quartz. These minerals are accompanied by small amounts of little flakes of black biotite mica.

Most of the granite you see is slightly to highly weathered. On some faces of the granite, the weathered surface results in the larger feldspar crystals clearly jutting out (Fig. 5). Much of the weathered surface has a coating of lichen and, where water seeps down the surfaces, the lichen can produce regular flow lines. Unweathered granite is rare but can be seen in some of the cuttings or in blocks taken out during construction of the rail line, now sitting at the edge of the geotrail.

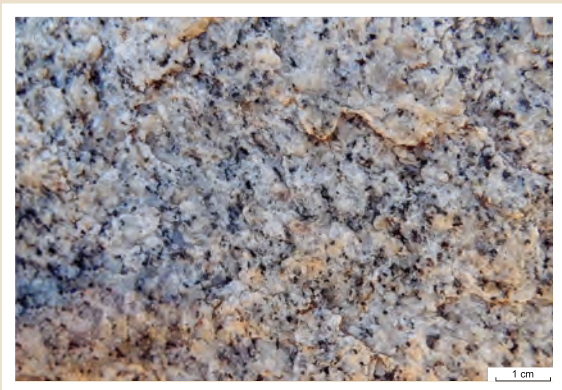


Figure 4. Fresh granite with pale feldspar and grey quartz crystals, and rarer black mica flakes

Figure 5. A partially weathered and etched surface of granite showing the larger, rectangular crystals of feldspar jutting out of an indistinct groundmass

In places, the granite is intensely weathered and has turned into a gravelly soil (Fig. 6). It is interesting to compare two nearby sites where, in one, the granite has a strong rocky appearance and, in the other, it is totally weathered and forms a gravelly soil, called grus. Why has the rock responded so differently in the two nearby places? Was the difference because of slight variation in the original mineral or chemical composition of the granite? Or was it through the amount of water that affected the rock during near-surface weathering?

The granite, which represents about 85% of the rocks along the geotrail, occupies the western edge of the Yilgarn Craton granitic plateau (Fig. 1). This extensive body of granitic rock underlies about 35 000 sq km, extending from Toodyay southwards to the Stirling Range, and from the Darling Fault easterly for up to 170 km. This huge area of granite started its journey as molten rock, referred to by geologists as *magma*, deep within the Earth, possibly 20 km below the land surface. Geologists are still trying to understand how such large amounts of rock can melt to produce such enormous volumes of granite.

Rocks can be dated using their natural radioactivity. Using a variety of methods on samples of granite, geologists have worked out that the original magma crystallized between 2650 and 2625 million years ago (about 3 June in the Geological Year).

Figure 6. Gravelly soil in the foreground formed from the destructive weathering of granite. Compare this with the very weathered but intact granite in the middle of the photo. Note the plants growing in the weathered rock show it is weak and not solid rock

Dolerite

Dolerite is a dark grey, slightly greenish to bluish rock, with much smaller crystals than in the granite (Fig. 7). Where the crystals are large enough, you will see scattered rectangular crystals of white feldspar in a matrix of dark green to black crystals (pyroxene and hornblende).

Why is the dolerite dark and the granite pale? Both the granite and dolerite consist mostly of silicon and aluminium with smaller amounts of sodium, potassium and calcium all combined with oxygen. However, it is the presence of iron in the minerals pyroxene and hornblende that dominate in the dolerite which makes the rock dark. Dolerite has between 5 and 20% iron whereas granite typically has less than 2% iron. The chemistry tells the story.

Many of the rock surfaces along the geotrail have a dark rusty brown coating of iron oxides a fraction of a millimetre thick. This can create the impression that even the granite is dark and can look confusingly like dolerite. It is important to look for freshly broken rock surfaces to see what the underlying rock is really like. Figure 8 is a photo of the dark staining that is coating a drillhole used when blasting the rocks for creating railway cuttings.

The dolerite is more resistant to weathering than the granite and does not form the rounded tors that granite does. However, where it has been affected by later faulting and other earth movements, it appears as slivers of rock where it has been fragmented and then weathers to a greater degree. Dolerite does not weather to form the grus like weathered granite does.

In contrast to the granite that covers a large area, the dolerite occurs in relatively narrow, vertical bodies called *dykes* that are up to 100 m wide and mostly run in a roughly north–south direction cutting through the granite.

Figure 7. Dolerite showing dark minerals that are a mixture of pyroxene and hornblende, and white patches of the mineral feldspar

Near the geotrail, several different dykes have been dated as having intruded 1200 million years ago (about 24 September in the Geological Year). That is, the dolerite dykes are only half the age of the granite they intrude.

Figure 8. Dark iron oxide coating on granite surface. Note the drillhole, used to hold the explosive to blast the rock apart, has the coating as well as the broken rock surface showing how quickly the surface stain can form. Fresher granite in the middle of the photo is slightly yellowish, and discoloured through the early stages of weathering

How do the granite and dolerite relate to each other? After the granite crystallized at depth, over the following 1400 million years, the land was gradually uplifted and the overlying rocks eroded. At about 1200 million years ago, the granite along the geotrail was probably at a depth of a few kilometres. As it was exhumed and cooled, a series of major north–south fractures developed, allowing magma from the Earth's mantle to flow up along them. The surrounding granite was much cooler than the dolerite magma so that the magma directly in contact with the granite crystallized faster and formed smaller crystals than in the middle of the dyke. Thus, geologists refer to these dykes as having *chilled margins*. Several of the dykes along the geotrail show this.

Wildflower count

How many of these wildflowers do you see on your geotrail?

Rocks break and move

At the **intermediate scale,** rocks in the walls of the cuttings are extensively cut by fractures with a wide range of orientations. Although most appear irregular, some form sets of parallel joints, spaced at a few tens of centimetres. A joint is a simple fracture that has split apart without further disruption.

Some of the fractures are *faults* — fractures along which rock on one side has moved relative to the other side. How can you tell if you are looking at a joint or a fault? There has to be some indication of offset or displacement. In granite where the rock on either side looks the same, there is little to show that movement has occurred. However, if there is some distinct feature that has been displaced, the direction and amount of movement can be seen. As an example of this, Figure 9 shows a small amount of movement where a quartz vein in the granite has been offset across a minor fault.

Figure 9. Weathered granite in Cutting 2 has a quartz vein that has been cut by a small fault. Offset of the vein on each side shows how much movement occurred (the pocket knife is 9 cm long)

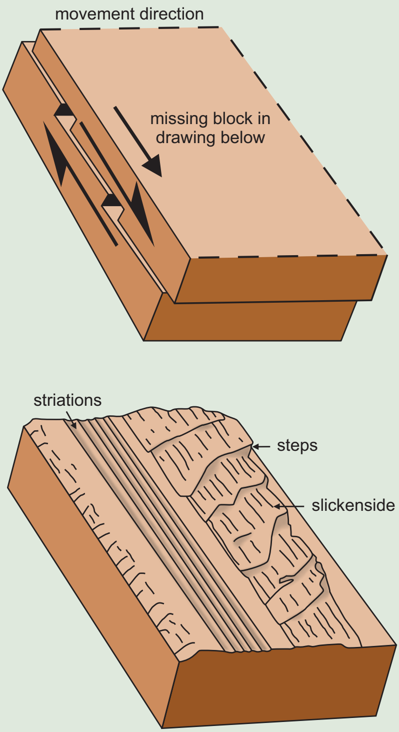


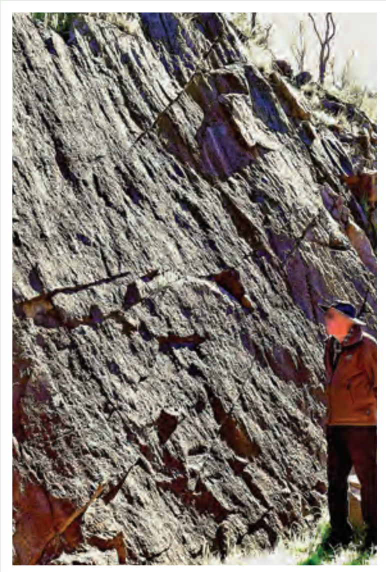
Figure 10. Block diagram showing how sliding on a fault creates a slickenside and its striations and other features

The Earth is constantly moving, but so slowly that to us it normally seems stable and immovable. However, when a fault suddenly moves we experience that as an earthquake.

Slickenside. When two sides of a fault move past each other, the movement can scratch, groove and pluck the rock surfaces (Fig. 10). The worn, polished or grooved surface is a *slickenside*. These marks show the relative direction of the last movement. Many rock faces in Cutting 2 have slickensided surfaces and one particularly large face (Fig. 11) is described further at Stop 2.

The direction of movement along the slickensided surfaces can be identified by feeling as well as looking at the surfaces. Sliding your fingers along some of the grooves and ridges, you might feel the small steps that result from this plucking process (Fig. 10). Conversely, running your fingers in the other direction the surface feels smoother. This is the direction in which the 'missing' block moved along the fault.

The slickenside would have developed through many sliding events of several centimetres, and each increment of movement probably would have generated a minor earthquake, although it's difficult to estimate how large these earthquakes might have been. On some faults, the direction of movement can change as the stresses on the rocks vary over geological periods. Hence, on some slickensided surfaces, in suitable light, you might be able to see two sets of slickensides with a later set overprinting an earlier set.



Joints and fractures can be important factors when road or railway cuttings are made or in mines. In the cuttings, the way the rock is broken shows differently in opposite walls. In places the fettlers (railway workers) utilized natural fractures, removing the rock between the joints. If the fractures sloped downwards into the cutting, they gave a nicely sloping and stable wall. If the fractures sloped downwards away from the cutting, they could create less stable walls that were liable to drop rocks onto the railway line, running the risk of derailment. Figure 12 shows a clear difference in the stability of the two faces of Cutting 2. In order to detect if rock falls had occurred and to protect trains from derailing, the Western Australian Government Railways installed a series of electrified wires along the base of the cutting to alert them to any rock falls.

Figure 11. Large, nearly flat surface in Cutting 2. This face has a series of fine ridges and grooves running vertically along the surface and with puckering running across. It is a slickenside with the grooves, ridges and puckering showing it was a fault surface

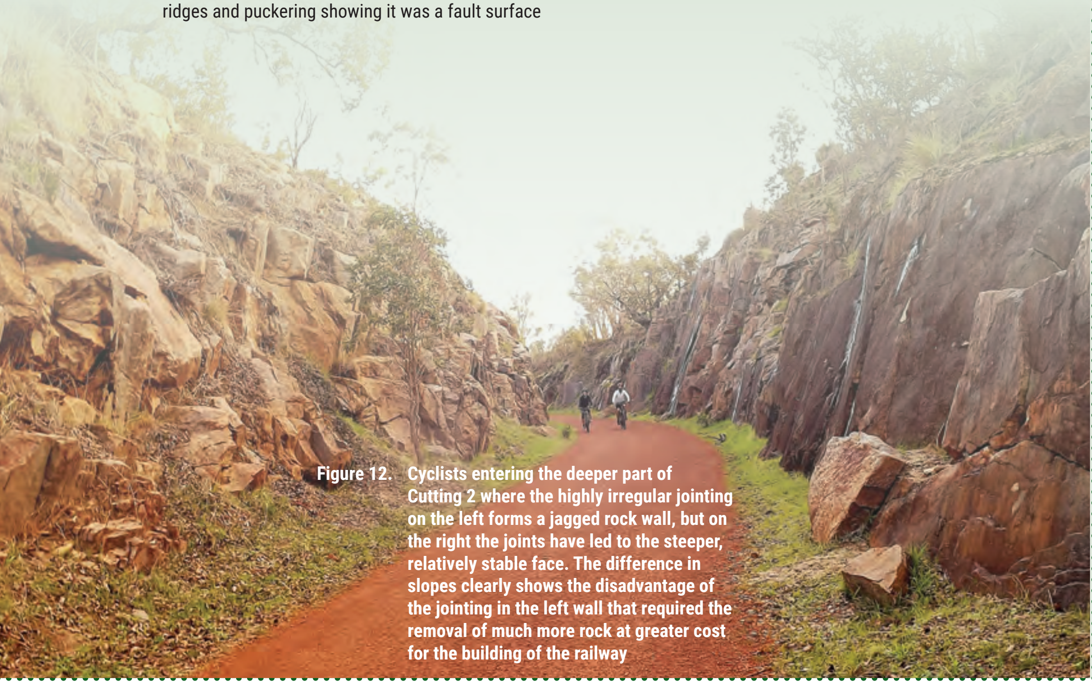


Figure 12. Cyclists entering the deeper part of Cutting 2 where the highly irregular jointing on the left forms a jagged rock wall, but on the right the joints have led to the steeper, relatively stable face. The difference in slopes clearly shows the disadvantage of the jointing in the left wall that required the removal of much more rock at greater cost for the building of the railway

Granite tors and their formation

At the **intermediate scale,** the granite hillslopes are dotted with conspicuously rounded rocks termed *tors*. In places these are isolated, single boulders; elsewhere, blocks are balanced on top of each other and resting on broad sheets of rock. These prominent, rounded granite boulders or stacks of boulders perched on hillslopes are a distinctive feature of the geotrail (Figs 13 and 14) and tors are a common landform of granite country worldwide.

As earth movements lifted the granite up from the depths at which it formed, kilometres of overlying rocks were eroded off, pressure was released, and the rock could expand. In contrast, as rock cools during uplift it tends to contract. The opposition of these stresses caused the rocks to fracture. Because granite is relatively uniform in its texture, these fractures are generally arranged to form rough cubes or rectangular blocks (Fig. 13).

Figure 13. Granite tors showing regular arrangement of rectangular joints

Figure 14. Once the rectangular blocks, as in Figure 13, become rounded through weathering at the corners, they will form tors. Here is a collection of granite blocks up to 4 m across showing a rectangular form that has partially formed into rounded tors

Near the surface, weathering takes advantage of these fractures and the blocks take on rounded shapes (Fig. 14). Figure 15 shows a sketch of how tors form. These rounded blocks or tors can form spectacular scenic features, like a naturally occurring castle, when piled upon each other such as at the famous Devils Marbles in the Northern Territory. Figure 16 shows a jumble of blocks where tors have partially collapsed. In Figure 17 is a hillside above the geotrail where the tors are partly concealed with trees, and showing the popularity of the route for weekend walkers in family groups.

The other conspicuous **intermediate scale** features are the cuttings and the embankments made from the rock removed from the cuttings and from the Swan View tunnel.

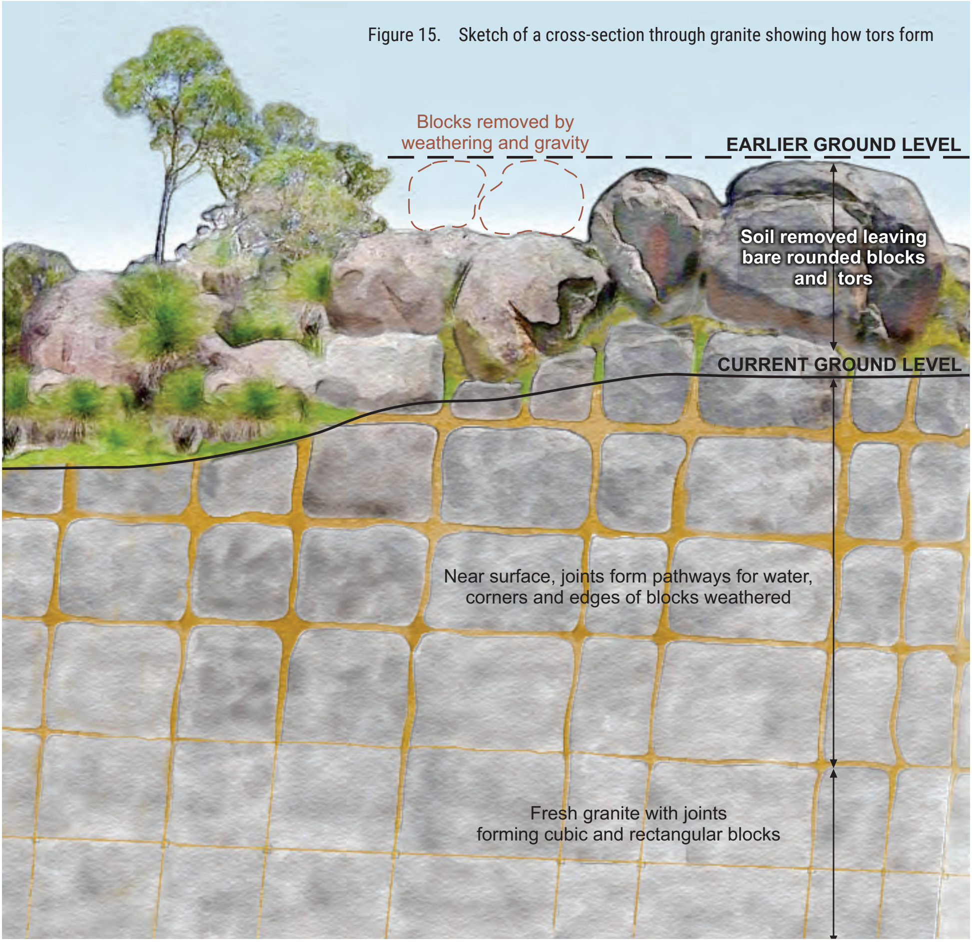


Figure 15. Sketch of a cross-section through granite showing how tors form

Blocks or tors can form spectacular scenic features, like a naturally occurring castle

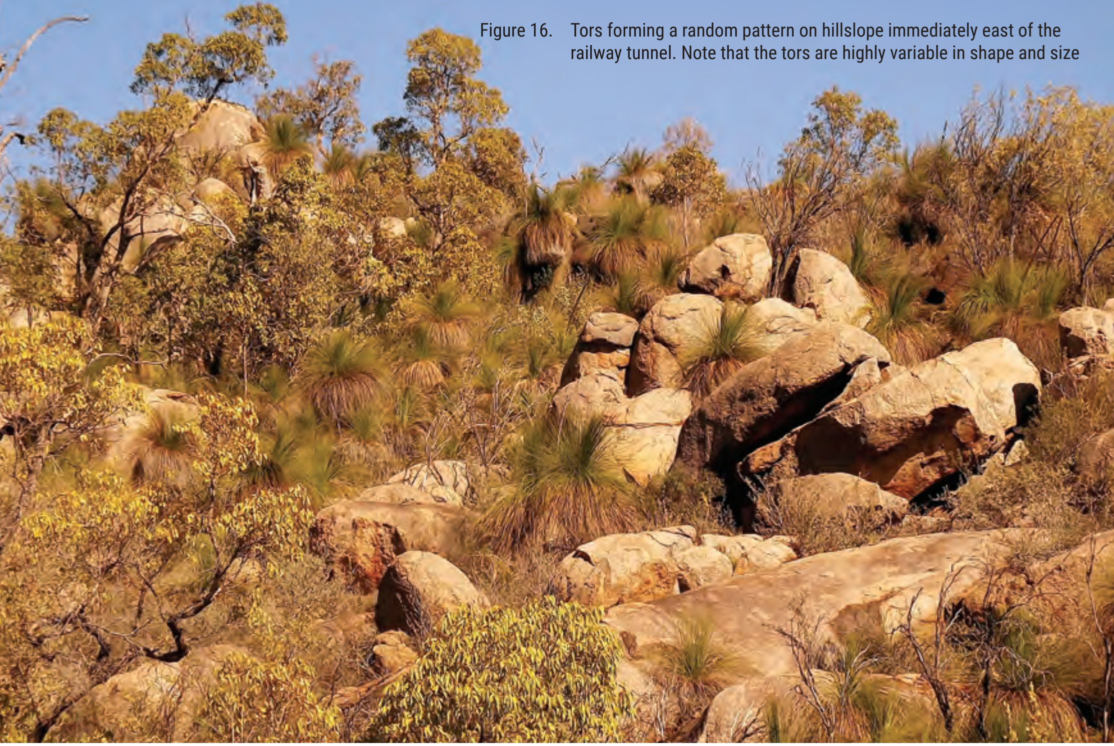


Figure 16. Tors forming a random pattern on hillslope immediately east of the railway tunnel. Note that the tors are highly variable in shape and size

Figure 17. Hillside east of the railway tunnel partly covered with gum trees, granite tors and sheets of granite. Note the popularity of the geotrail with many people taking advantage of a pleasant spring day. Immediately above the head of the cyclist is a granite block that some people will recognize looks like an elephant.
This is located across the geotrail from the location described in Stop 5

How the landscape evolves — National Park Falls

At the **broadest scale** of features are the hills and the valley of Jane Brook, and on this brook the National Park Falls (Fig. 18) forms the boundary between two different types of landscape.

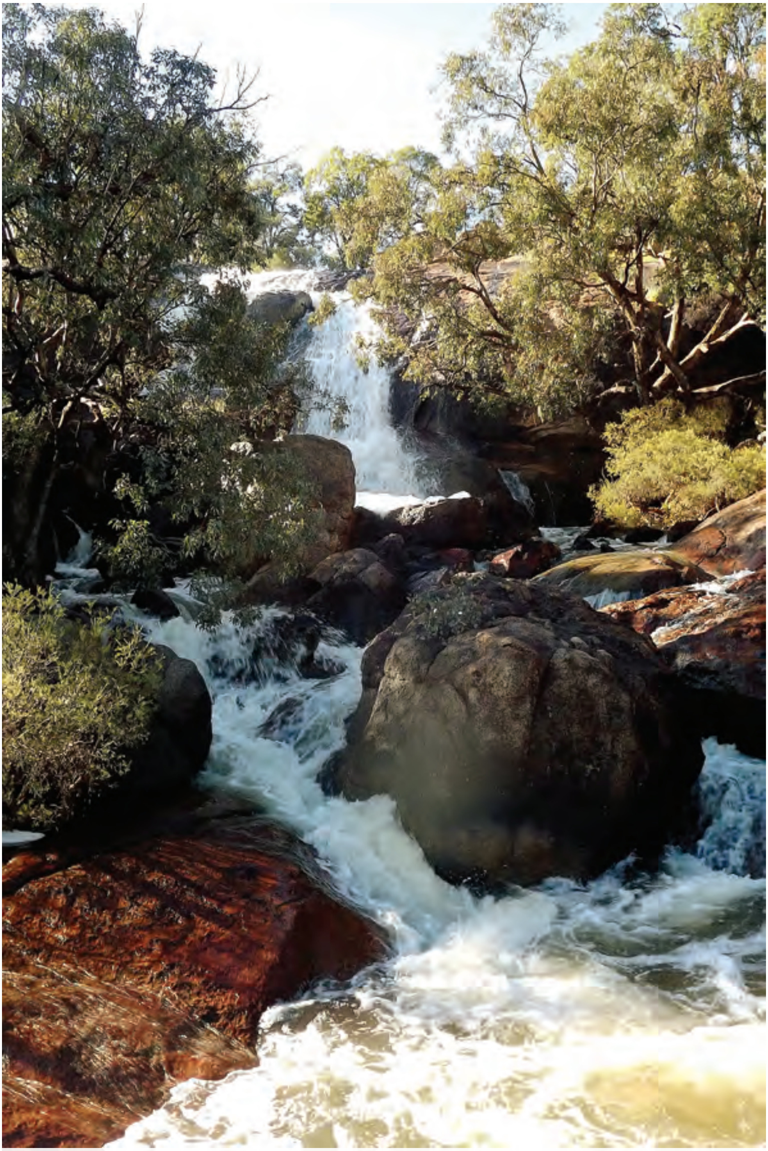


Figure 18. Looking up at National Park Falls when it has a strong water flow after heavy winter rains

The Darling Scarp separates the lowlands of the Swan Coastal Plain from the elevated Darling Range. The scarp formed as a result of relatively recent vertical displacement along the Darling Fault, which is located just to the west of this geotrail. We do not know precisely when this latest uplift along the Darling Fault occurred, but there are some regional geological interpretations that suggest it was during the Eocene geological period, possibly some 40 million years ago (about 28 December in the Geological Year). Before that uplift, Jane Brook probably had a gentle and even slope along its bed.

The effect of the uplift has been to renew erosion and downcutting of the bed of Jane Brook into the rocks of the Yilgarn Craton. Starting in the west near the Darling Scarp, erosion has proceeded upstream, eastwards, as far as the National Park Falls, which now form a nick point (Stop 6, p. 37). As you walk along the heritage railway downstream of the National Park Falls and look into the valley from the former railway embankments (Fig. 19), you will notice:

- a fairly deep valley with steep sides
- lots of bouldery rocks and sheets of granite along the bottom and sides of the valley
- when flowing, Jane Brook tumbles noisily along from pool to pool over rocky rapids
- trees lower in the valley are smaller and there are fewer compared with the growth higher up the valley sides.

Figure 19. Rocky part of Jane Brook downstream of the National Park Falls where rejuvenation started by uplift along the Darling Fault has created youthful river landforms. Note the large number of granite tors and the deep, V-shaped valley

However, when you walk along the heritage railway upstream of the falls (Fig. 20), you will see that:

- the valley is broader and has gentle sides
- thick soils support a dense growth of larger gum trees
- Jane Brook mostly flows sedately from pool to pool.

Below the National Park Falls, the active erosion along the brook has rejuvenated the valley exposing tors, blocks and sheets of rock with a thin soil along the valley sides. The slope of the brook falls at the rate of 35 metres per kilometre.

However, upstream of the falls, the bed has a shallower gradient of only 12 metres per kilometre, one-third of the slope below the falls and erosion is far less active. This saves the valley soils from erosion and allows them to remain thicker, supporting a more luxurious growth of trees.

Figure 20. View of the Jane Brook valley upstream of National Park Falls where there is a strong growth of large gum trees on the preserved thicker soils. Note the shallow depth of the valley

Major landscape features due to structures

As noted above, the 1000 km-long Darling Fault is a major geological structure that exerts a strong control on regional landforms (Fig. 1). Those landforms have, in turn, controlled the nature of human activities on both sides of, and along, the Darling Scarp.

Rivers and creeks will erode, picking out weaknesses in the underlying rocks. If there is a major fault or fracture system in the rocks, watercourses will tend to follow those weaknesses and, where the faults or fractures are relatively straight, the watercourses will also follow straight lines.

Some sections of Jane Brook are almost straight and alternate sections flow approximately west-southwest and northwest (see map). Along these sections, the brook is following faults or fractures where the rock is weaker and more easily exploited by erosion. In the air-photo image that underlies the accompanying maps, you may notice more linear features that pick out other faults and fractures.

GEOLOGICAL SKETCH MAP ALONG THE FORMER EASTERN RAILWAY

BETWEEN SWAN VIEW AND JOHN FORREST NATIONAL PARK HEADQUARTERS

Government of Western Australia
Department of Mines, Industry Regulation and Safety

Geological Survey of Western Australia

- Railway, abandoned
- Cutting
- Embankment
- Borrow pits for construction material, or fill areas
- Watercourse; major, minor
- Linear watercourse follows joint
- Geological boundary, between rock types commonly soil-concealed
- 1.5 km — Distance along railway route from start (note; distance measured bypassing tunnel. Through tunnel shortens distance by 500 m)
- × Geological feature described
- Viewing point, showing direction
- Joint; vertical, inclined
- Foliation in shear zone, vertical
- Shear
- P Carpark
- 60 Contour line, 20 metre interval
- 2 Point of interest mentioned in text

NOTE: Rock type is granite, granodiorite, or monzogranite with rare granite gneiss, except where...

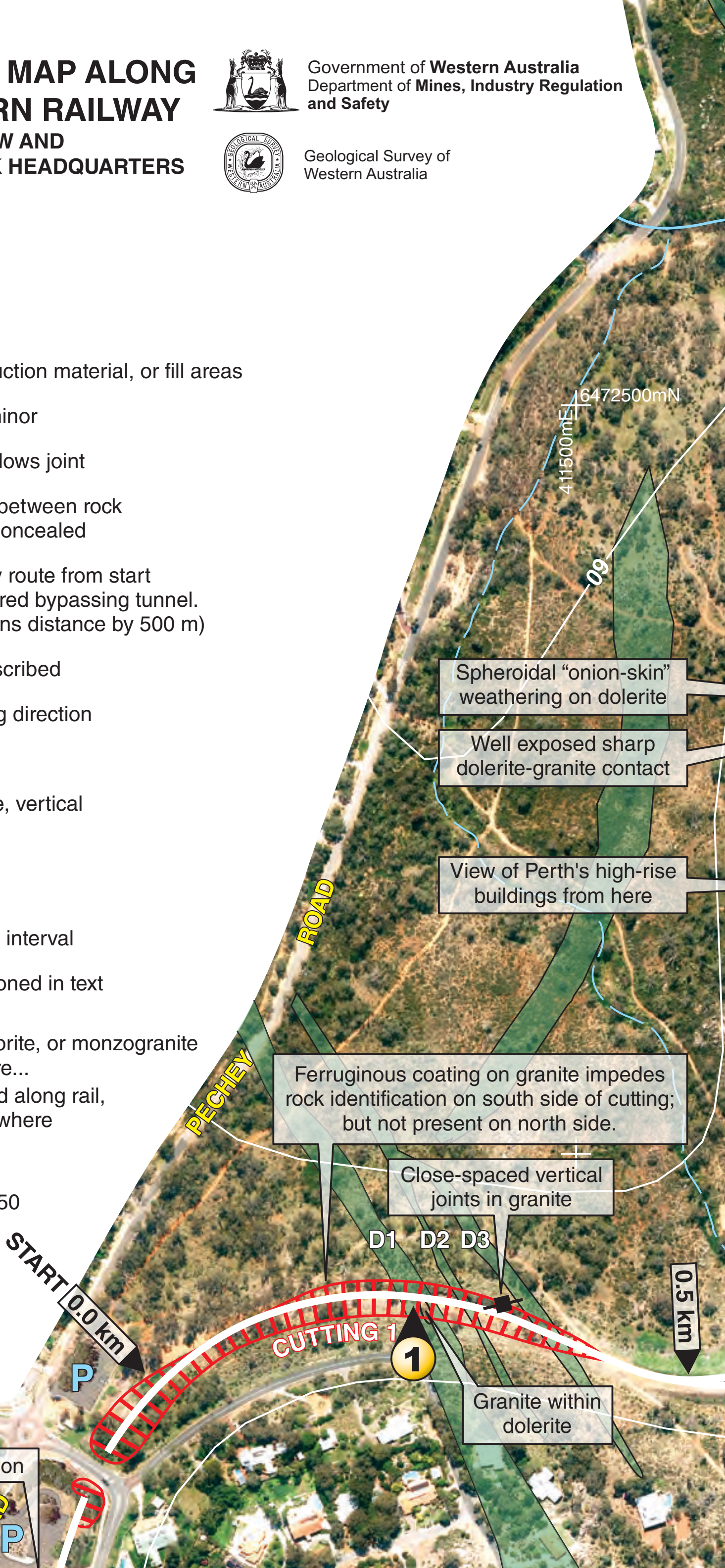
D1 Dolerite dykes mapped along rail, photo interpreted elsewhere

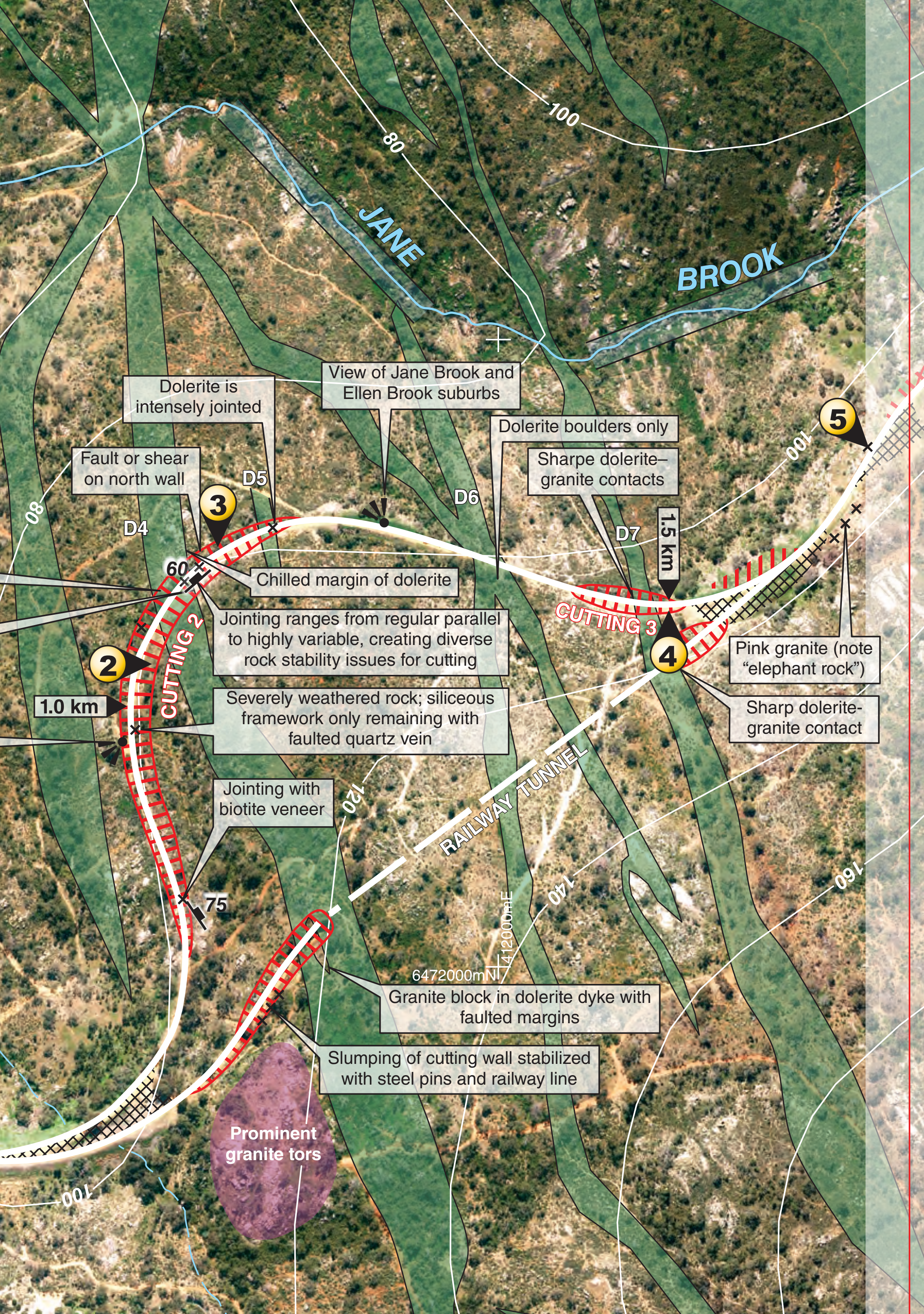
200 metres

Coordinates shown are MGA zone 50

Compiled by: MJ. Freeman, 2008, 2016, 2020

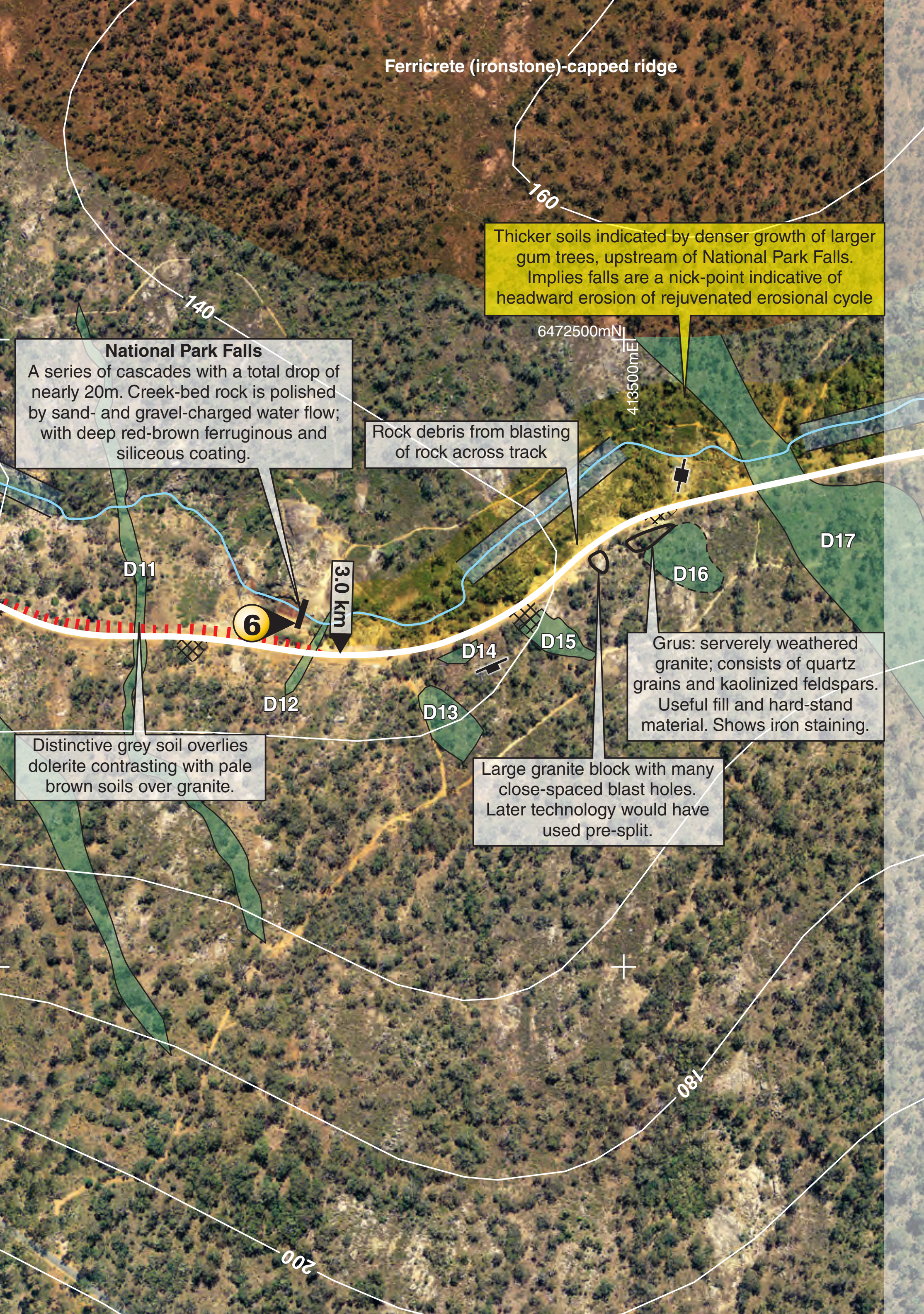
Aerial photography: Landgate, 2015





JANE
BROOK
100
80
08
View of Jane Brook and Ellen Brook suburbs
Dolerite is intensely jointed
Fault or shear on north wall
D5
D4
3
D6
Dolerite boulders only
Sharpe dolerite–granite contacts
5
001
D7
1.5 km
60
Chilled margin of dolerite
Jointing ranges from regular parallel to highly variable, creating diverse rock stability issues for cutting
CUTTING 2
CUTTING 3
2
4
Pink granite (note “elephant rock”)
1.0 km
Severely weathered rock; siliceous framework only remaining with faulted quartz vein
Sharp dolerite-granite contact
RAILWAY TUNNEL
Jointing with biotite veneer
120
75
140
160
412000mE
6472000mN
Granite block in dolerite dyke with faulted margins
Slumping of cutting wall stabilized with steel pins and railway line
Prominent granite tors
100

100
JANE
120
BROOK
2.0 km
Shear zone
Coarse-grained dolerite with chilled margin
D8
D9
CUTTING 4
Dolerite has ~ 2m wide chilled margin at contact.
CUTTING 5
Wall of granite was side of dolerite dyke
2.5 km
D10
Two blast holes exposed. Only western charged and blasted showing radiating fractures. Eastern hole intact
Pink granite (note “elephant rock”)
CUTTING 6
Distinctive red soil overlies dolerite contrasting with pale soil over granite
160
412500mE
6472000mN
180
200
220
220


Ferricrete (ironstone)-capped ridge
160
140
180
200
Thicker soils indicated by denser growth of larger gum trees, upstream of National Park Falls. Implies falls are a nick-point indicative of headward erosion of rejuvenated erosional cycle
6472500mN
413500mE
National Park Falls
A series of cascades with a total drop of nearly 20m. Creek-bed rock is polished by sand- and gravel-charged water flow; with deep red-brown ferruginous and siliceous coating.
Rock debris from blasting of rock across track
D17
D11
D16
3.0 km
6
D15
D14
Grus: serverely weathered granite; consists of quartz grains and kaolinized feldspars. Useful fill and hard-stand material. Shows iron staining.
D12
D13
Distinctive grey soil overlies dolerite contrasting with pale brown soils over granite.
Large granite block with many close-spaced blast holes. Later technology would have used pre-split.

160
200
180
6472500mN
414000mE
JANE
3.5 km
Former National Park
Railway Station
Altitude 155m
Railway bridge
"Jane Brook Bridge"
on Engineers Australia
heritage list
4.0 km
Blast holes in block. One
in corner shows two vertical
blast fractures at 90° to each
other. Second on face.
Note soil-infilled open joints
that are the focus of roots
D17
D18
7
Iron-stained brick-like wall is
the side of dyke 17
BROOK
National Park Pool
Ranger's Office
Toilets
John Forrest Tavern
P
P
P
P
160
6472000mN
to GREAT EASTERN HIGHWAY
180
200

Sites to visit

On the map, either the downloaded A3 or in this book, both the cuttings and the dolerite dykes are numbered from the Morrison Road end to the National Park ranger's office.

A walk along the line in the September–October period will coincide with peak wildflower season. Along the line, the diversity of plants is relatively poor due to the impacts of human activities in building and operating the railway line over many decades. However, short excursions along sidetracks will show the wonderful diversity of flowering shrubs and trees in the national park. A very nice circular walk in spring is to start from the ranger's office, follow the former train line downstream to the National Park Falls, cross Jane Brook, and return along the narrow and rougher walking track on the northern side of Jane Brook where the flowers tend to be far more diverse and prolific than along the first leg.

Stop 1 — Cutting 1

Weathered granite is the first rock that is well exposed along the geotrail when you get to Cutting 1. It is a grey, weakly *porphyritic* granite, although most of the rock faces have a coating of rusty iron oxide that conceals the true nature of the rock. Look for broken corners where the rock underneath the coating can be seen. The term porphyritic refers to the rock having scattered crystals that are much larger than most of the crystals (Fig. 5; see also Stop 2).

Dolerite dyke 1

Starting about 200 m from the carpark is dolerite dyke 1 (D1 on the map), the first exposed along the geotrail from the western end. This dyke is about 20 m wide and is accompanied by two more, thinner, parallel dykes a little farther along the geotrail. Figure 22 shows the view looking at the uphill (southern) side of the cutting. At the start of the dolerite (on the uphill side of the geotrail) the contact between the dolerite and the granite is clearly exposed (Fig. 23). Here the dolerite is strongly laminated for about 25 cm and the granite has parallel fracturing up to 5 cm from the contact. The layered or laminated fabric shows the margin of the dyke was sheared, possibly as it was intruded into the granite. This is a common feature where hot, ductile, relatively weak rock intrudes cooler, solid, stronger rock such as granite. However, the shearing could also have occurred during later faulting along the contact between the two rock types. Faulting commonly occurs along a single plane, although in some circumstances the movement occurs over a wider shear zone, within which the rocks have taken up this movement in a number of parallel and closely spaced faults.

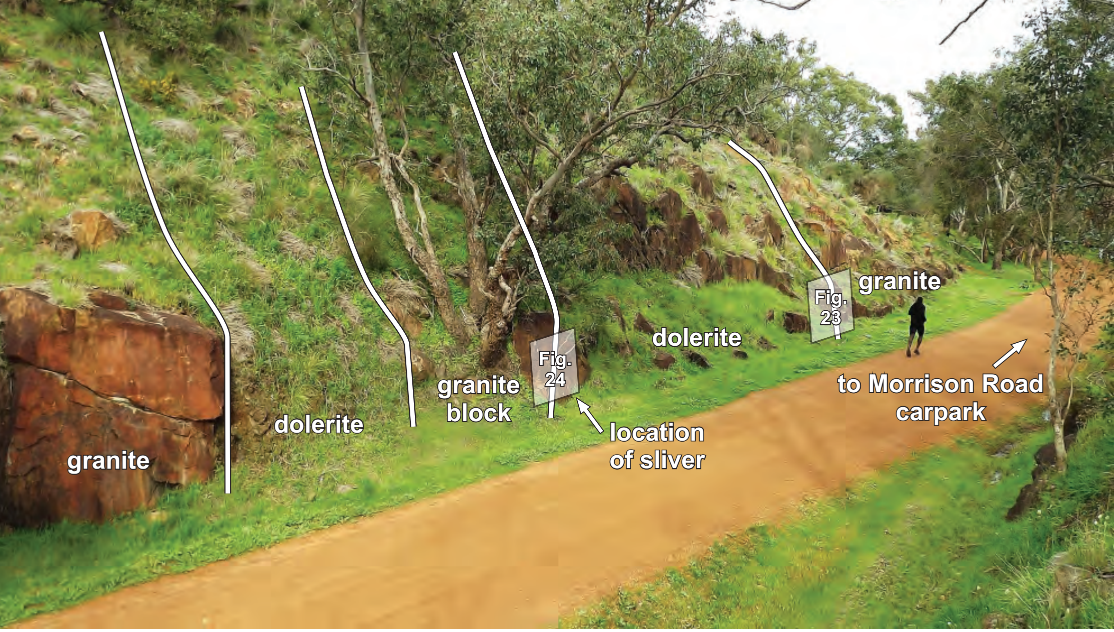


Figure 22. Annotated photo of granite and dolerite dyke 1 (D1 on map) in Cutting 1 on the geotrail looking towards the Morrison Road car park. The granite block in the middle of the photo is a xenolith, or block, within the dyke

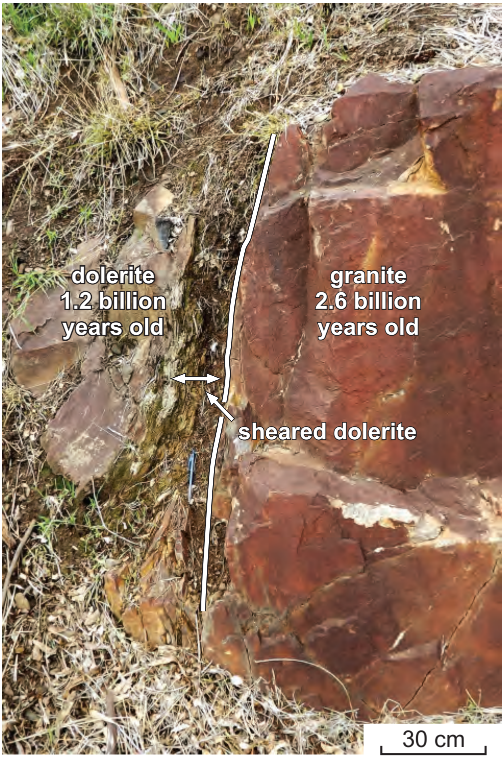


Figure 23. Granite–dolerite contact, western side of dolerite dyke 1. Massive granite on the right-hand side and dolerite on the left. The rocks are sheared into thin strips along the contact for 25 cm in the dolerite and 2 cm in the granite. Note the granite looks rusty with an iron staining on the rock

The granite is dated at about 2650 million years and the dolerite is dated at 1210 million years. Placing your thumb on the dolerite and your forefinger on the granite, there is an age difference of over 1400 million years across your hand-span!

Fifteen metres farther along the geotrail, at the large gum tree on the uphill (southern) side of the cutting is what seems to be the other side of the dolerite dyke in contact with the host granite. This contact is complicated because there are two alternating slivers of granite and dolerite in the contact and the dolerite is sheared over a 15 cm width (Fig. 24) before you get to the main granite mass. This shows that the intrusion of the dolerite into the granite can be a complex process.

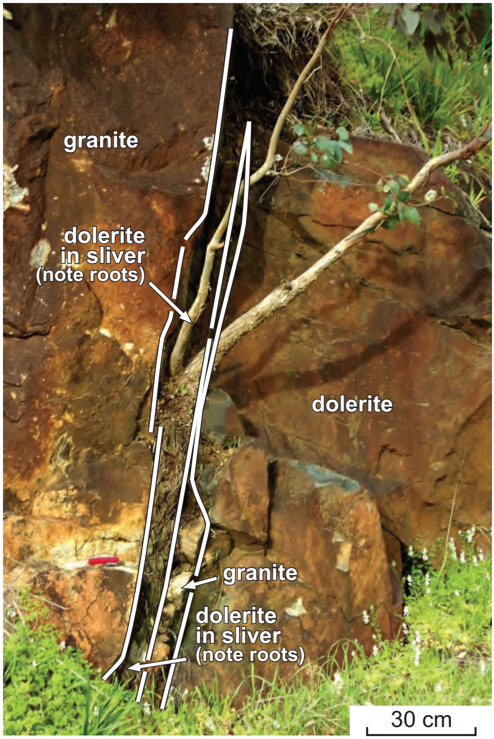


Figure 24. Detail of granite–dolerite contact showing slivers of both rock types along the contact. Note the rootlets taking advantage of the softer rocks at the sheared (fault affected) dolerite, showing a microcosm of how the geology can control living things. The rootlets have more easily penetrated along the multitude of shears and this has allowed easier entry and storage of water seeping through the rocks giving more water to the roots

Three metres along on this southern side of the cutting, we are back into dolerite. On the other, downhill side of the cutting, however, the dolerite is continuous and the granite is missing. This shows the granite is an isolated block of the older rock caught up in dolerite magma as the dyke was intruded. The term for this kind of inclusion of one rock in another is *xenolith* (pronounced *zeno*lith). At the eastern end of this granite xenolith, the contact is concealed by soil.

The ultimate eastern margin of this thick dolerite dyke is another 3 m farther along the track from the end of the granite (left side of Figure 22). Approaching the dolerite–granite contact, the dolerite is fractured in both walls of the cutting.

On the southern side of the track, the granite forms a large buttress but the dolerite is highly fractured and jointed for over a metre from the granite. On the opposite side of the cutting, the dolerite on the northern wall is also highly fractured for well over a metre, whereas joints in the granite are regularly spaced at 10–40 cm parallel to the margin of the dyke. This jointing probably preceded the injection of the dolerite magma; there are many places along this geotrail where such jointing had a major influence on the orientation of the dolerite dykes. These dykes (the Boyagin Dolerite Suite) are found all along the western edge of the Yilgarn Craton, and geologists note they reflect a very widespread stress event that affected the rocks over a distance of up to 750 km.

Continuing along Cutting 1 are dolerite dykes 2 and 3 (D2, D3; see map). Both of these are narrow (10–15 m) and are separated by about 30 m of granite. In both cases, the dolerite is poorly exposed and their contacts with granite are concealed by soil.

On the northern side of the cutting between the two dolerite dykes, note the presence of a series of parallel joints where the granite is broken into vertical sheets about 15 cm thick (Fig. 25). As you continue along the geotrail you will see several places where joint sets occur. Recognition of the presence of such joint sets is important to engineering geologists who study the nature of rocks and rock fracturing to facilitate efficient excavating.

The Earth's crust is constantly being stressed as it is flexed and uplifted over geological timeframes. For example, plate tectonics can transfer stresses a long way into a plate from the plate boundary. These stresses lead to the jointing and faulting in brittle rocks. The localization of vertical joints shown in Figure 25 suggests stresses were focused in this volume of rock, for reasons we can only guess.

Crossing the embankment beyond Cutting 1 you actually enter the John Forrest National Park. Ahead of you, note the hillside with a covering of well-formed tors (see **Granite tors and their formation**, p. 14).

Figure 25. A set of parallel vertical joints within granite on downhill side of Cutting 1. The stress on the granite, long ago, caused it to fracture along a series of close-spaced parallel planes

Building the railway

In building the railway, the fettlers had little mechanical equipment and most work in the 1890s was done manually with spades, picks and rock hammers, or using horses or bullocks. The walls in the cuttings show vertical, half-circular holes that were drilled by hand for placing explosives to break the rock (Fig. 8). Today, those drillholes would be made using high-powered rock drills. The fettlers drilled with teams of three men, two alternately swinging a sledge hammer to hit a steel rod, while the third used long tongs to hold the rod which he had to keep turning.

Dynamite had been invented in 1867 by Alfred Nobel and probably would have been the explosive used in this railway blasting, although before that invention, blasting was often done with the much weaker gunpowder. In a number of places you will see star fractures next to where the blast broke the rock open and an excellent example is at Stop 5 (see later in this guide).

As you walk along the geotrail, note the numerous hollows dug by the fettlers for soil and rock used to fill hollows and give an even gradient for the trains. At the time of the construction, the digging was done by workmen using picks and shovels, carrying material in wheelbarrows, and by horse-drawn scrapers — a far different situation contrasted with today's behemoth earth-moving machinery. The trains running along the heritage line were all pulled by steam locomotives and they were mostly powered by coal mined at Collie.

This is the second railway line built to cross the Darling Range and allow train access to the eastern parts of the State. The first was built about 5 km south of this route. However, at the time of its construction in the 1880s, there was little understanding of the geotechnical aspects of geology, and the materials underneath the line caused constant problems with creeping clays. The first route was abandoned and this route along Jane Brook was built and opened in 1895. Unfortunately, the tunnel along this route then caused problems as drivers and stokers collapsed in summer because of the heat from the firebox and smoke collecting with no air movement. In 1945, a side track was built that runs around the tunnelled hill to the north through the larger cuttings along this geotrail.

Along the route there are signboards, some showing where derailments and rail disasters occurred. Both of these train lines were narrow gauge (1067 mm) that went from Perth to Kalgoorlie, then south to Esperance and north to Leonora and beyond.

In 1965 the present dual-gauge railway was built following the Avon River that passes right through the Darling Range, saving the trains from having to climb up the Darling Scarp and over the range. This has both narrow and standard gauge (1435 mm) lines.

Figure 26. Passenger train leaving Swan View train station heading for the tunnel, 1910. State Library of Western Australia, reference BA1200/292

There is an interesting contrast in technologies along the geotrail. The route was used originally for locomotives to draw goods and passenger trains (Fig. 26) using one of the first major technological advances of the industrial revolution — steam power. But underneath the line, as shown by scattered markers, is an optic-fibre cable used to carry communications from Perth to the eastern states. It is interesting to think about the degree and pace of technological development represented by this contrast under your feet along this geotrail.

Stop 2 — Cutting 2

This was one of the deepest and longest railway cuttings in Western Australia from the time it was dug in 1945 until the new standard gauge train line was opened along the valley of the Avon River in 1966.

As you enter the cutting, look for the rock-filled drain and the low wall on the downhill (western) side of the geotrail. Across from the drain the granite is porphyritic, showing scattered larger white rectangular crystals of feldspar embedded in a finer crystalline groundmass (Fig. 5). As the granite starts to cool at depth, the first minerals to crystallize grow in the high-temperature magma. This allows them to reach sizes up to a few centimetres. If the crust is then uplifted and cooling accelerates, the remaining magma solidifies more quickly producing smaller mineral crystals enclosing the larger crystals. The result is this porphyritic texture with two distinct sizes of minerals.

Thirty metres farther along is an outcrop of highly weathered granite that has a 4 cm-wide quartz vein (Fig. 9) running up the hill. Note the vein is cut by a small fault with the uphill part offset to the right about 5 cm. Offset features like this clearly show the direction and amount of displacement on a fault (see **Rocks break and move**).

Another 25 m past the quartz vein is the remains of what was a small gum tree struggling to grow near the base of the uphill (eastern) face. Unfortunately, the gum tree died in early 2020 although it is likely to remain as a stump for a number of years. If you can locate it, you will find the rock face above the root shows a good example of slickenside. Note the block with the slickenside has moved outwards a few centimetres towards the former railway line. Did the tree root lift the block allowing it to move outwards?

Dolerite dyke 4

This 50 m-wide dyke in Cutting 2 is among the widest along the geotrail. The southwestern contact is soil covered, although note the series of joints in the granite that are parallel to the margin of the dyke. The northeastern granite–dolerite contact is very sharp and clear (Fig. 27).

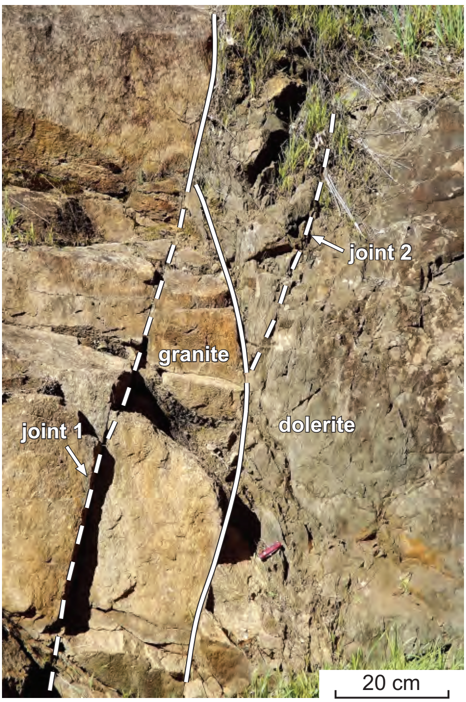


Figure 27. Northeastern margin of dolerite dyke 4. Note the two joints in the dolerite and granite (dashed lines) that continue along the granite–dolerite contacts (solid lines). The dolerite magma may have exploited the joints as a path of least resistance during intrusion

On the uphill (eastern) side of the track, look at how the joints in the granite have influenced the margin of the dolerite. The granite–dolerite contact jogs obliquely between joints that extend farther into the dolerite and granite. Does this show that the joints preceded the dolerite dyke being injected into the granite, or vice versa? On the other side of the cutting, the contact is straight. However, the dolerite within 30 cm of the granite is well fractured implying there was some stress that might have caused movement along the contact. There are a few rounded boulders of dolerite on the northern side of the cutting that have 'onion-skin' or spheroidal shapes. This is formed through a series of weathering steps that produce concentric layers of partly weathered rock which peel off the boulder. This is also shown in the dolerite at Stop 7.

If you look at the sizes of the crystals in the dolerite you will note those near the edge of the dyke are very small but increase in size as you move towards the centre of the dyke.

Stop 3 — fault exposed as large face

Thirty metres past the end of dolerite dyke 4 (D4), the downslope (northwestern) wall is a large, grooved and ridged surface that slopes steeply down towards the track. This is a slickensided fault surface as described in **Rocks break and move** (Figs 10 and 11). The fault is best viewed when the sun is glancing obliquely across the surface at a very low angle like in early to mid-mornings in April. The rock removed by the fettlers in digging out the cutting — the rock now 'missing' from the exposed surface of the fault — had moved down relative to the rock now forming the cutting wall. Other slickensided faults along the geotrail have evidence for different senses of movement. The directions of movement typically vary on different faults, so geologists must treat fault data statistically to work out the overall stress patterns.

This extensive sloping surface was ideal for the railway fettlers digging the cutting. This has left a stable surface that slopes back away from the cutting requiring minimal excavation of rock and reducing the costs of the railway work. Across the other side of the geotrail the joints dip away from the geotrail and are not so regular, meaning the fettlers had to take out more rock, in places still leaving overhangs and irregular blocks which can create a less stable slope.

Stop 4 — Cutting 3

Most of this cutting (see Fig. 3) displays blocky granite. Note the difference between the way the rock breaks between the two sides of the cutting. This is one of the best cuttings in which to clearly see the nature of the rocks. Dolerite dyke 7 (D7), at the eastern end of Cutting 3, is about 10 m wide and crosses the geotrail obliquely. Only the western margin of the dyke is exposed as the eastern side is at the soil-covered end of the cutting. This dyke has chilled margins with finer crystals near the edge of the dolerite and coarser crystals towards the middle. Rectangular crystals of white feldspar can be identified in the matrix of dark pyroxene and hornblende crystals. The sharp contact between the granite and the dolerite is beautifully exposed on both sides of the cutting (Fig. 28).

The contact on the northern side of the geotrail has a 4–5 cm-wide soil-filled sliver that has formed a root zone for plants. This is similar to the roots in the contact at Figure 24 and is a common feature where intensely fractured rock can form a micro-environment in which the rock is weak and is likely to stay moist for longer periods after rain. These sites show at a small scale how the geology can control the flora by providing a more favourable niche for plants to grow in. If you go around into the tunnel cutting, this same dyke (D7) is also well exposed at the eastern portal to the tunnel, confirming its northerly orientation.

Sixty metres past where the tracks merge just east of the tunnel, you may see a granite tor that looks like an elephant viewed from its rear left-hand side, if viewed from the correct angle (see Fig. 17) — can you find this 'elephant' in the rocks?

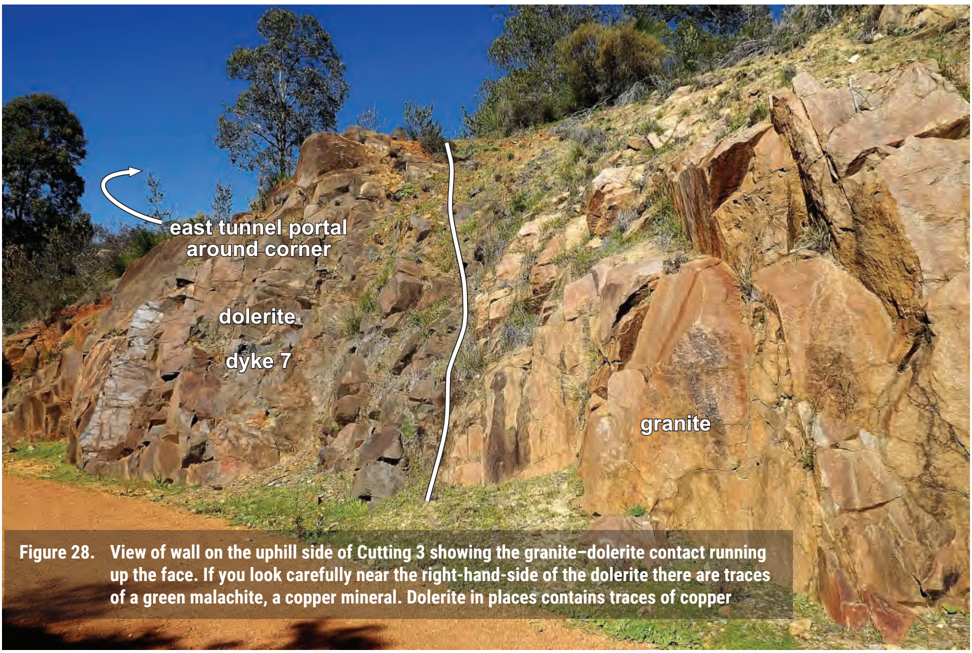


Figure 28. View of wall on the uphill side of Cutting 3 showing the granite–dolerite contact running up the face. If you look carefully near the right-hand-side of the dolerite there are traces of a green malachite, a copper mineral. Dolerite in places contains traces of copper

Stop 5 — Blast holes

About 200 metres east of the end of Cutting 3 and 100 metres from Cutting 4 on the northern side of the geotrail is a block of slightly weathered granite showing evidence of how the rock was blasted to create the path for the railway line. There are two semicircular grooves running down the face (Fig. 29). The left-hand groove has a number of fractures radiating from the bottom forming a star pattern (enlarged in the inset of Figure 29). The groove on the right is smooth without the star pattern. The grooves are the remains of holes drilled into the granite that would have been intended to be filled with explosives to blast the rock apart. It appears only the left-hand hole was charged and blasted.

One hundred metres to the northeast past this blasted rock, on the uphill side of the geotrail, is the margin of dolerite dyke 8 (D8). At this margin the granite stands proud of the dolerite and the wall of the dyke is shown as a one-metre high rockface. Note the shape of the margin — it is not straight but has steps and offsets along it showing how the erratic variation of properties and strength of the rocks results in irregular features.

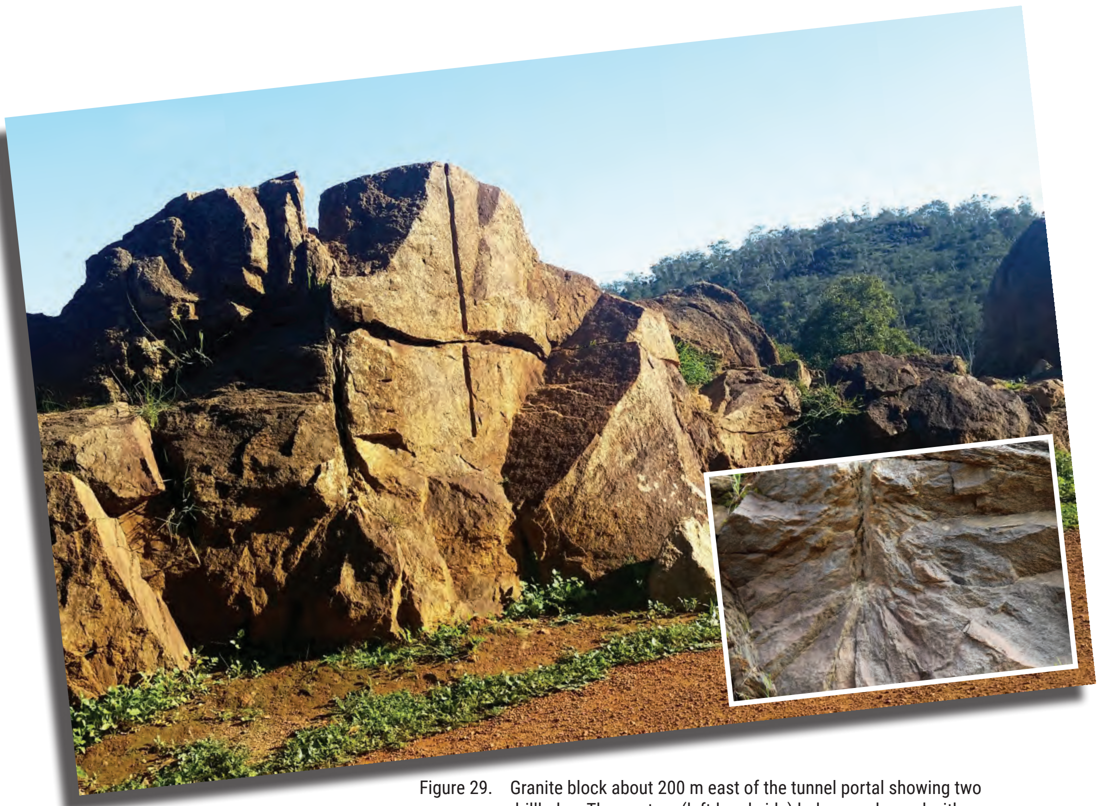


Figure 29. Granite block about 200 m east of the tunnel portal showing two drillholes. The western (left-hand side) hole was charged with explosive. The radial fractures at the bottom (inset) show where the blast occurred. The eastern hole has no star-shaped fractures and was not blasted

Stop 6 — National Park Falls

On reaching the falls you are confronted with a precipitous drop of about 20 m where Jane Brook plunges over the waterfall at your feet. This is a 'must see' along the geotrail when flowing (Fig. 18). Jane Brook is usually dry from about November to June. However, after good winter rains, it is a marvellous display of water cascading over the waterfall and through rockpools and past large granite blocks at the foot.

When the brook is dry, the rock face at the crest of the falls shows a number of interesting features. As the water flows, it produces flow lines with hollows and sharp ridges about a centimetre high parallel to the flow direction where sand and pebbles have worn away the rock. Looking at the surface, you will see a polished, reddish stain. Jane Brook water dissolves trace amounts of iron from seeping through soils into the watercourse. The red colour of the stain is typical of rusty deposits you see on walls around Perth where iron-charged bore water is used to irrigate gardens and shows the staining was precipitated on the rock surface from the flowing water.

Looking downstream, the valley is deeply incised with rocky, steep sides (Fig. 19). This is in contrast to the shallower, tree-clothed valley upstream of the falls (Fig. 20). National Park Falls marks a classic nick point — the upstream limit of rejuvenation of erosion in a watercourse where a waterfall at the nick point is migrating in an upstream direction. The valley downstream is classified as juvenile and upstream it is classified as mature. Nick points result when the upper part of a stream is uplifted relative to the downstream part. With Jane Brook, there is evidence that uplift of the Darling Range occurred during and possibly continued after Eocene times, some 40 million years ago.

The National Park Falls consists of a series of cascades. A nice view looking up at the falls can be obtained from a small viewing location at the foot, accessed by a track that descends from the northern side of the falls.

As you walk upstream from the falls, Jane Brook is a quiet stream with deepish pools between walls formed in deep soils and, where you can see them, the valley sides are relatively shallowly sloping but the vegetation is much denser.

Along the 500 m walk from the National Park Falls to Stop 7, there are no cuttings (reflecting the more gentle gradient of the route upstream of the nick point) but a few points of interest are noted on the map.

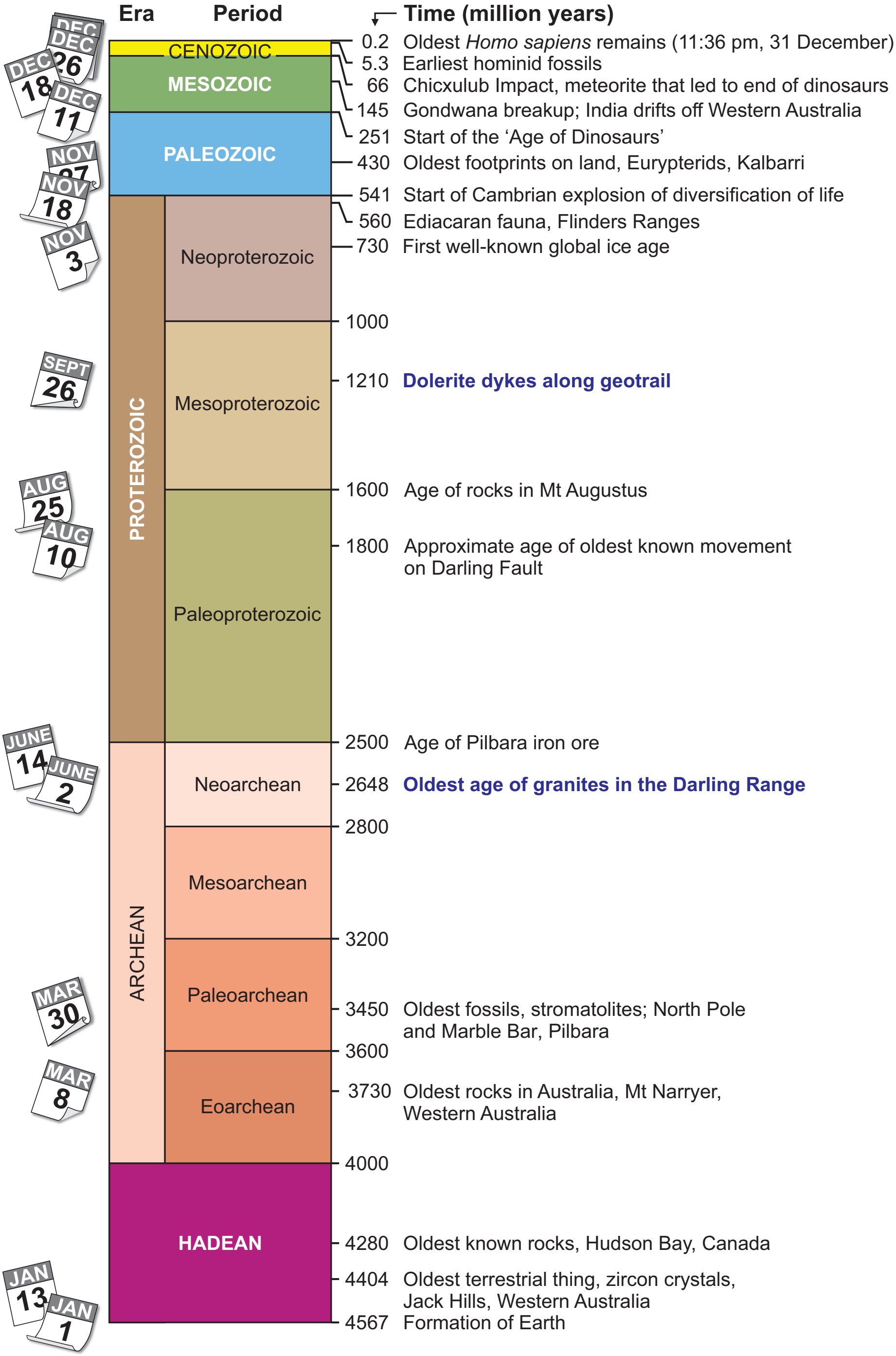
Stop 7 — Behind former National Park train station

Near the heritage-listed Jane Brook Bridge, the route descends and there is a wall of iron-stained rock on the southern side (Fig. 30). This is the weathered face along the side of dolerite dyke 17 (D17). The dolerite has been severely weathered, fractures have been enhanced through weathering, and the whole rock permeated by water that has leached the original iron-bearing pyroxene and amphibole minerals to generate the rusty staining. This is the only locality where the side of a dyke is visible in three dimensions so it is an unusual outcrop.

The hollow the geotrail has descended into is an original borrow pit where the railway fettlers were able to easily excavate the weathered rock and soil to use in the embankment leading to the Jane Brook Bridge. Note that, with the limitations of picks, shovels and horse-power, the fettlers stopped digging when they got to the harder rock under the more easily dug soils. The weathered dolerite dyke was too hard for them to dig out, as was the granite that is exposed in the bottom of the hollow.

Figure 30. Highly weathered dolerite forming the wall of dolerite dyke 17 (D17). The rusty colour is from iron deposited in the weathering rock. Note the rounded shape of many blocks, referred to as spheroidal, ‘onion-skin’ weathering, outlined by joints spaced at 10–40 cm

Notes


Era
Period
Time (million years)
CENOZOIC
MESOZOIC
PALEOZOIC
PROTEROZOIC
Neoproterozoic
Mesoproterozoic
Paleoproterozoic
ARCHEAN
Neoarchean
Mesoarchean
Paleoarchean
Eoarchean
HADEAN
0.2 Oldest *Homo sapiens* remains (11:36 pm, 31 December)
5.3 Earliest hominid fossils
66 Chicxulub Impact, meteorite that led to end of dinosaurs
145 Gondwana breakup; India drifts off Western Australia
251 Start of the 'Age of Dinosaurs'
430 Oldest footprints on land, Eurypterids, Kalbarri
541 Start of Cambrian explosion of diversification of life
560 Ediacaran fauna, Flinders Ranges
730 First well-known global ice age
1000
1210 **Dolerite dykes along geotrail**
1600 Age of rocks in Mt Augustus
1800 Approximate age of oldest known movement on Darling Fault
2500 Age of Pilbara iron ore
2648 **Oldest age of granites in the Darling Range**
2800
3200
3450 Oldest fossils, stromatolites; North Pole and Marble Bar, Pilbara
3600
3730 Oldest rocks in Australia, Mt Narryer, Western Australia
4000
4280 Oldest known rocks, Hudson Bay, Canada
4404 Oldest terrestrial thing, zircon crystals, Jack Hills, Western Australia
4567 Formation of Earth
DEC 26
DEC 18
DEC 11
NOV 18
NOV 3
SEPT 26
AUG 25
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JUNE 14
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