MAGPIE CREEK

Geological trail

STURT GORGE RECREATION PARK

A walk through time into the ancient glacial rocks of South Australia's Sturt Gorge

South Australian Division

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Compiled by Colin Conor (STEM, University of South Australia) and
Cynthia Pyle (Field Geology Club of South Australia)
for the Geological Field Guide Subcommittee.

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The walk is within the Sturt Gorge Geological Heritage Site M4.

Cover photo: *Westerly view from the head of the Sturt Gorge, along the base of the siltstone marker bed, at the top of the lower part of the Sturt Tillite. In the foreground, a pothole ground into solidified ancient glacial debris, i.e. tillite.*

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Introduction

If you want to learn about previous glaciations on Earth, you've come to the right place – South Australia's Sturt Gorge Recreation Park (Fig 1). Sturt Gorge's name has been introduced to the world as the 'Sturtian Glaciation', perhaps the greatest of several ancient glacial events.

Adelaide is fortunate in having spectacular gorges that dissect the steep scarp-face of the Mount Lofty Ranges. The Sturt River not only displays a fascinating landscape, but also erosion has created a window that allows an excursion into the depth of time. The gorge cuts deeply through the Mount Lofty Ranges, separating the suburbs of Bellevue Heights and Flagstaff Hill (Fig 2).

The 244-hectare Sturt Gorge Recreation Park protects the heritage-listed Sturt Gorge Glaciation Geological Site. The site is one of the first places in the world where rocks were found to show evidence of glaciation occurring about 665 million years ago (c. 665 Ma), prior to the existence of animal life.

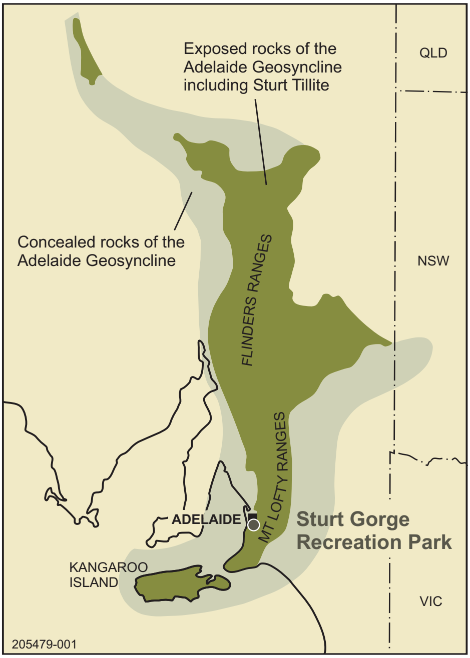
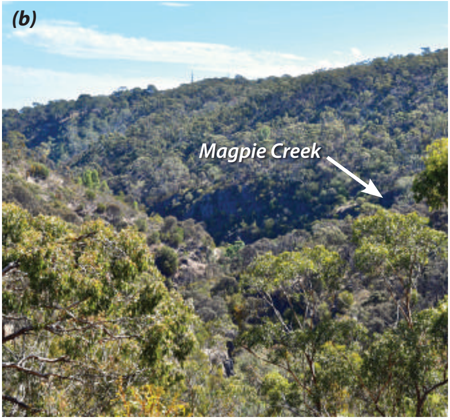


__Figure 1__ Location of the Sturt Gorge Recreation Park and extent of the Adelaide Geosyncline sedimentary basin, which includes the Mount Lofty and Flinders ranges.

__Figure 2__ Views of Sturt River. __(a)__ Oblique aerial view (Google Earth) looking west along the Sturt River and showing the location of the Magpie Creek geological trail..



(b) Northeasterly view of the eastern end of Sturt Gorge in the region of Magpie Creek

(c) Southwesterly view from Bellevue Heights of the flood mitigation dam in the Sturt River.

This guide explains why the landform exists and what the rocks tell us about the history of the Earth, including ancient changes in climate. Clues are given in the rocks that crop out along the steep banks of the Sturt River and its tributary, Magpie Creek. What we see now is a snapshot of the immensity of geological time represented by scraps of geological history written in those rocks. The rocks contain evidence for a lengthy period when the Earth was prone to cyclical freezing. At times glaciation was so extreme that the whole world is thought to have been enveloped extensively or entirely by ice (Fig 3). This period is known as the 'Cryogenian' [from cryogene: Greek kryos – cold; genes – born], popularly referred to as 'Snowball Earth'. Two components of the Cryogenian are represented in South Australia – the Sturtian (described herein) and Elatina (or Marinoan) glaciations.

The rocks exposed along Sturt River also provide glimpses into the tectonic setting – i.e. the process that controls the structure and properties of the Earth's crust and its evolution through time (source: Wikipedia).

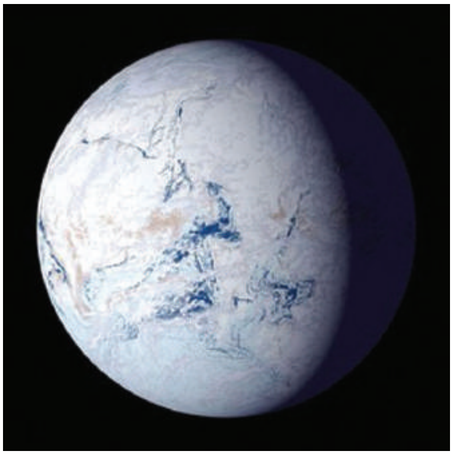
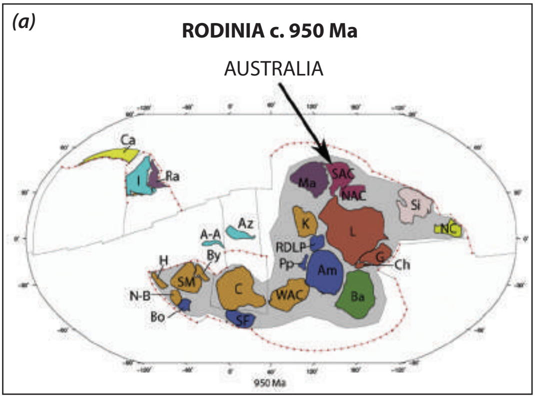


***Figure 3** An artistic impression of Earth from space during one of the more extreme cycles of the Cryogenian period. In this interpretation everywhere from the equator to the poles is covered with ice. At other times there was sufficient movement for the flow of glaciers to erode, transport and deposit rock debris. (Courtesy of NASA)*

Geological history

The Earth's crust is never motionless and the Australian continent is currently moving northward at about 6 to 7 cm each year. Australia was once part of 3 supercontinents – Gondwana, Pangea and the much older Rodinia (Fig 4a). Our story starts at c. 830 Ma when the continental crust of Rodinia first began to fracture – basalt erupted along faults and extruded into incipient rift valleys (Fig 4b). However, the glacial sedimentary rocks seen along the Sturt River were not laid down until about 170 million years later, a time interval during which a thickness of several kilometres of sediment had already accumulated in a sedimentary basin traditionally known as the Adelaide Geosyncline. Rodinia finally fully broke apart after the Sturtian Glaciation. The Adelaide Geosyncline is now represented by the rocks of the Mount Lofty and Flinders Ranges (Fig 4c).

Evolution of the Adelaide Geosyncline lasted for 315 million years between 830 and 510 Ma, and includes the Cryogenian period which lasted roughly 85 million years from 720 to 635 Ma (Fig 5).
The glacial deposits in the Sturt Gorge are estimated to be c. 665 Ma.



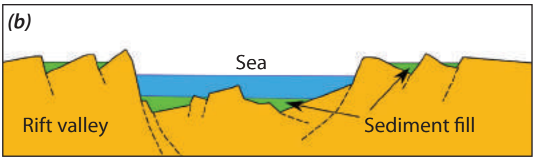


Figure 4 *Formation of the Adelaide Geosyncline.* ***(a)*** *One interpretation of how the continental masses were clumped together as the supercontinent of Rodinia c. 950 Ma. At the top right proto-Australia is depicted as two parts (NAC and SAC) alongside Antarctica (Ma). (Reprinted from Merdith et al. 2017, fig 6a, with permission from Elsevier).* ***(b)*** *A diagrammatic cross-section of a foundered and sea-flooded rift valley – basalt erupts along faults, and sediments are derived from the weathering and erosion of the high ground of the rift flanks.*

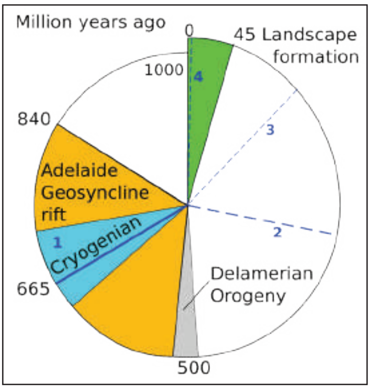


Figure 5 *The last 1,000 million years of Earth's history highlighting geological history recorded in in South Australia: 1 Cryogenian, c. 720–635 Ma, e.g. Sturt River. 2 Permian, c. 320–300 Ma, e.g. Hallett Cove, Adelaide. 3 Cretaceous, c. 125 Ma, e.g. Mount Painter, northern Flinders Ranges. 4 Pleistocene, c. 2.5–0.012 Ma, e.g. interglacial glacial deposits such as the Woakwine Range in the South East. [The age of dinosaurs (non-bird versions) is represented very approximately by the gap between 2 and 3, while that of humans is approximately from 4 to the present.]*

Towards the formation of today's scenery: 45 Ma to the present

Following the breakup of Rodinia, Australia and Antarctica continued to move as part of Gondwana which amalgamated with other elements to form the supercontinent of Pangea at c. 335 Ma. Tectonic forces within the Earth started to disrupt Pangea from c. 180 Ma and the smaller continental masses separated, dispersing at a rate of many centimetres per year.

Just like an eggshell the continental crust is rigid but also brittle, which means that it can crack. Cracks in the continental crust, across which there has been displacement, are called faults, and over the immensity of geological time many generations of faults form, intersect and reactivate.

The northwards drift of Australia from Antarctica accelerated at c. 45 Ma (Fig 6). Australia was undergoing west–east compression, which caused uplift and, moreover, the stresses activated new and ancient faults which promoted the formation of restricted marine basins and ranges of hills. In South Australia a series of step-like blocks evolved to form today's Mount Lofty Ranges, which are still on the rise due to episodic activity along the faults (Preiss 2019). The Sturt River owes its existence to the combination of tectonism and climate, that is the past and continuing uplift of the ranges together with ongoing weathering and erosion of the exposed rocks.

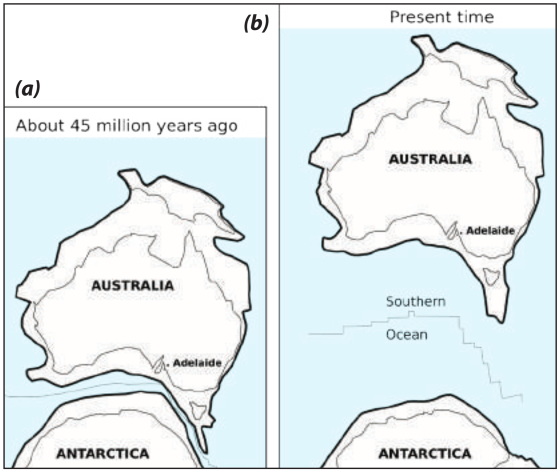


Figure 6 *The relationship of Australia and Antarctica.* ***(a)*** *Following the breakup of Pangea, c. 45 Ma.* ***(b)*** *Separation at present. (Adapted from Müller et al. 2000)*

Climate and tectonics are crucial geological forces, but no one place contains all of the evidence explaining the geological evolution of the Earth – everywhere the evidence is fragmentary, with most of geological time represented by great gaps in the record (Fig 5). While this is true for the Sturt River, there are 4 events that are preserved in rocks to show what has happened:

- **Formation of the Adelaide Geosyncline rift basin, initiated c. 830 Ma.** Evidence: the rocks of the Flinders and Mount Lofty ranges are the sediment fill of the basin and include early basalts and evaporite deposits (e.g. salt, gypsum), which are evidence for rifting.
- **Great freeze of the Sturtian Glaciation, c. 665 Ma.** Evidence: glacial sediments called tillite (described at site G2).
- **Formation of an extensive mountain chain, c. 515–490 Ma** – the Delamerian Orogeny and the uplifted and exhumed sedimentary fill of the Adelaide Geosyncline basin. Evidence: the Flinders and Mount Lofty ranges, deformation of the rocks including folds and faults, and metamorphic minerals and textures (also described at site G2).

- **Formation of current landscape, c. 45 Ma to present day** – renewed uplift along reactivated Delamerian faults continuing episodically to the present day. Evidence: the steep slopes of the Sturt River, including the Sturt Gorge and Magpie Creek, rock debris gravitating slowly down the valley sides, and boulders driven more rapidly down the river by floodwaters.

South Australia's great glacial controversy

From a world perspective Sturt Gorge first came to prominence in 1900 when the Reverend Walter Howchin, one of South Australia's early geologists, demonstrated that glaciation must have deposited the rocks that he and others, including the Government Geologist, HYL Brown, had studied along the Sturt River (Fig 7). In 1901 he gave the rocks the stratigraphic name Sturtian Tillite. However, not everyone agreed with Howchin's glacial interpretation and from 1905 to 1912 there was fierce debate amongst Adelaide geologists that gained substantial press coverage as the 'Great Glacial Controversy'. In 1906 the subject was highlighted at the International Geological Congress in Mexico and in 1907 the Australasian Association for the Advancement of Science conference held in Adelaide provided an opportunity for the nation's geologists to discuss the issue and visit Sturt Gorge. In 1914 Walter Howchin led a delegation from the British Association for the Advancement of Science to Sturt Gorge.

In 1950 the name Sturtian Tillite was modified to Sturt Tillite, the word Sturtian being reserved for the time period called the Sturtian Epoch (and the Sturtian Glaciation). Evidence for Sturtian Glaciation is now known from every continent except ice-blanketed Antarctica.

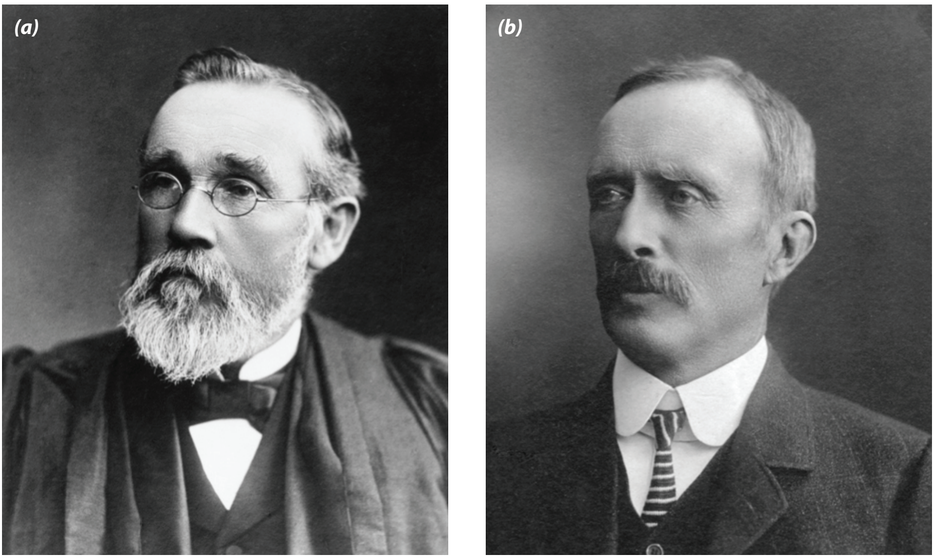


Figure 7 *Two of the several luminaries interested in the rocks of the Sturt Gorge – both supported the glacial hypothesis against considerable opposition.* ***(a)*** *Professor Walter Howchin, University of Adelaide, 1845–1937.* ***(b)*** *HYL Brown, Government Geologist, 1843–1928.*

The walk

Getting there

The Magpie Creek geological trail is in the Sturt Gorge Recreation Park and is accessed from the north via Shepherds Hill Road where it passes through Bellevue Heights (Fig 8). A choice of 3 side roads – Sargent Parade, Eden Avenue or Adam Avenue – lead southward to Eve Road. The walk starts at the southern end of the Gorge Road loop, a no-through road, which is accessed from Eve Road.

Access is available by public transport – currently bus routes 600, 601 and G30F which service Shepherds Hill Road between Blackwood Interchange and Marion Centre. Bus Stops 28, 28A and 29 are suitable. The walking distance from Shepherds Hill Road to the start of the geological trail off Gorge Road approximates 1.25 km. Please check Adelaide Metro route information as the services are irregular.

Many of the tracks are steep and rough underfoot, and require caution, a reasonable amount of fitness and appropriate footwear. Beware of snakes in spring and summer.

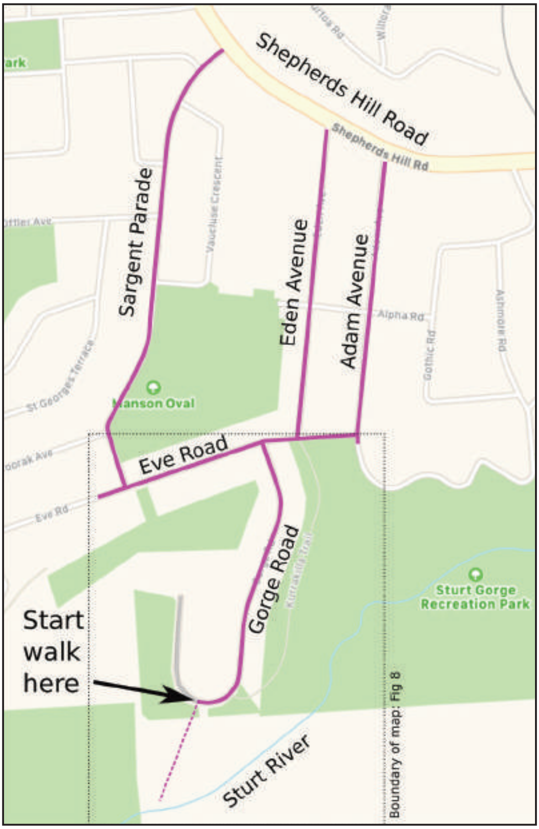


Figure 8 *Location map showing the start of the Magpie Creek geological trail from Gorge Road, Bellevue Heights.*

The trail commences at the southern end of the Gorge Road loop (Fig. 9). Trail markers (T1, T2 etc.) indicate reference points such as other intersecting tracks. The steepest parts of the walk are those dropping down to the Sturt River (T1–T5), ascending from the waterfall site (i.e. after G7), and finally climbing back up from Magpie Creek to Gorge Road (T10–T12). Ten sites of geological interest have been selected along the trail (G1–G10). The GPS locations (UTM WGS84 Zone 54) of trail markers and geological features are provided for each site. Directions are shown in italics.

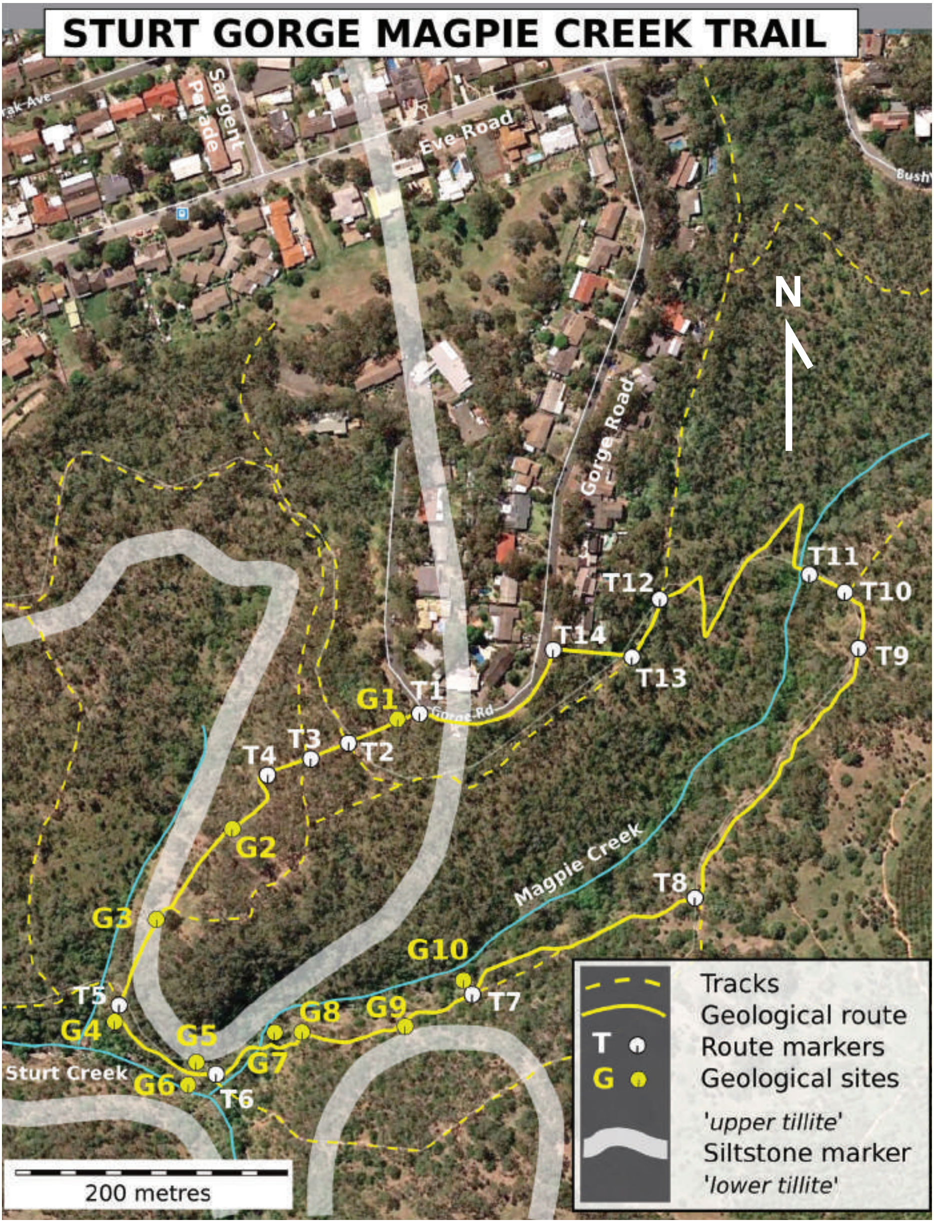


Figure 9 *Map of a portion of Sturt Gorge Recreation Park showing the Magpie Creek geological trail and the approximate position of a geological rock unit labelled the 'siltstone marker'. The siltstone marker separates the older 'lower tillite' in the east from the younger 'upper tillite' to the west.* ***Points labelled in white as T1, T2 etc. on the map refer to trail makers, or route locations along the track with guide instructions in the text shown in italics.*** *Points labelled in yellow i.e. G1, G2 etc. refer to the locations of geological interest that are described in this guidebook. Each G point has a brief description of the geology at that site.* ***The start of the walk from Gorge Road is shown as route marker T1.***

T1, G1: Southern end of Gorge Road, Bellevue Heights

279960 mE, 6120320 mN

The recommended start of the walk is at the south end of the Gorge Road loop (Fig 9). There is a flat area off the south side of Gorge Road which is a SA Water pumping station beside a power (Stobie) pole (Fig 10). If you have arrived by car, parking nearby is convenient for access to the start of the trail. The walk commences 20 m further west of the pumping station where there is an unsigned track heading downhill. Walk down the track for about 25 m until you come to the scene shown in Figure 11.

As you follow the track down off Gorge Road, you are at the top of Sturt Gorge ravine with the well-treed area falling away steeply to the south (Fig 11). It is steep because the Sturt River is actively eroding downwards as nature attempts to reduce the topography to sea level. Looking back in time, the present spectacular scenery of the Sturt Gorge originated c. 45 Ma following the breakup of the supercontinents Gondwana and Pangea and after Australia separated from Antarctica.

Continue the walk to site G2. Walk downhill for 25 m, cross over the marked Tapa Turrungha Trail (T2). A further 25 m takes you to another crossing track, cross over this and continue downhill past a post with a blue survey marker (T3).

Figure 10 *View looking southwest to the start of the walk (near the car). This is the southern end of the Gorge Road loop showing the power pole and the pavement of the SA Water pumping station. Location T1 is near the car.*

Figure 11 *The start of the walk a few metres from Gorge Road, looking downhill past the intersection of the Tapa Turrungha Trail to the blue survey post in the middle distance. A hint of what is to come – the track disappears from view, being replaced in the far distance by the steep southern flank of the Sturt River topped by the suburb of Flagstaff Hill.*

T3

279893 mE, 6120338 mN

Blue survey marker, continue downhill, leaving the survey maker on your right.

T4

279890 mE, 6120280 mN

The track bends around to the left turning away from an older track (Fig 12a). Continue walking for about 50 m to the left and downhill to G2, a bold outcrop of rock that juts across the track at a bend in the track (Fig 12b).

Figure 12 *(a) The former T4 track has been rerouted directly to the rock outcrop of G2.* ***(b)*** *Geological site G2.*

G2: Sturt Tillite

279850 mE, 6120261 mN

This site showcases tillite, a rock formed by the action of ice during glaciations. The name comes from the word 'till' as it was used in old Scotland meaning 'obstinate land', the English name being 'boulder clay'. As the latter name implies, till, or more correctly 'glacial till', is a mixture of various rocks of different types and sizes set in a similarly mixed-up gritty clayey matrix. Tillite is glacial till that has become solidified through time, generally because it has been turned into rock by burial pressures due to the loading during ongoing sedimentation within the sedimentary basin.

Tillite is the dominant type of rock present below the vegetation and soil along the Sturt River. Where freshly exposed it is a dark-grey rock made distinctive by obvious rock fragments – some rounded, some angular – set in a gritty matrix of finer grained clay, mica, feldspar and quartz, which are common minerals that together form much of the Earth's crust.

Look at the outcrop of tillite carefully (Fig 13). It contains fragments (called clasts) of many different rock types embedded in the fine-grained material that is the matrix. Some of the clasts are angular, while many others are rounded. Also, there is a wide range of clast sizes – geologists describe the rock as poorly sorted.

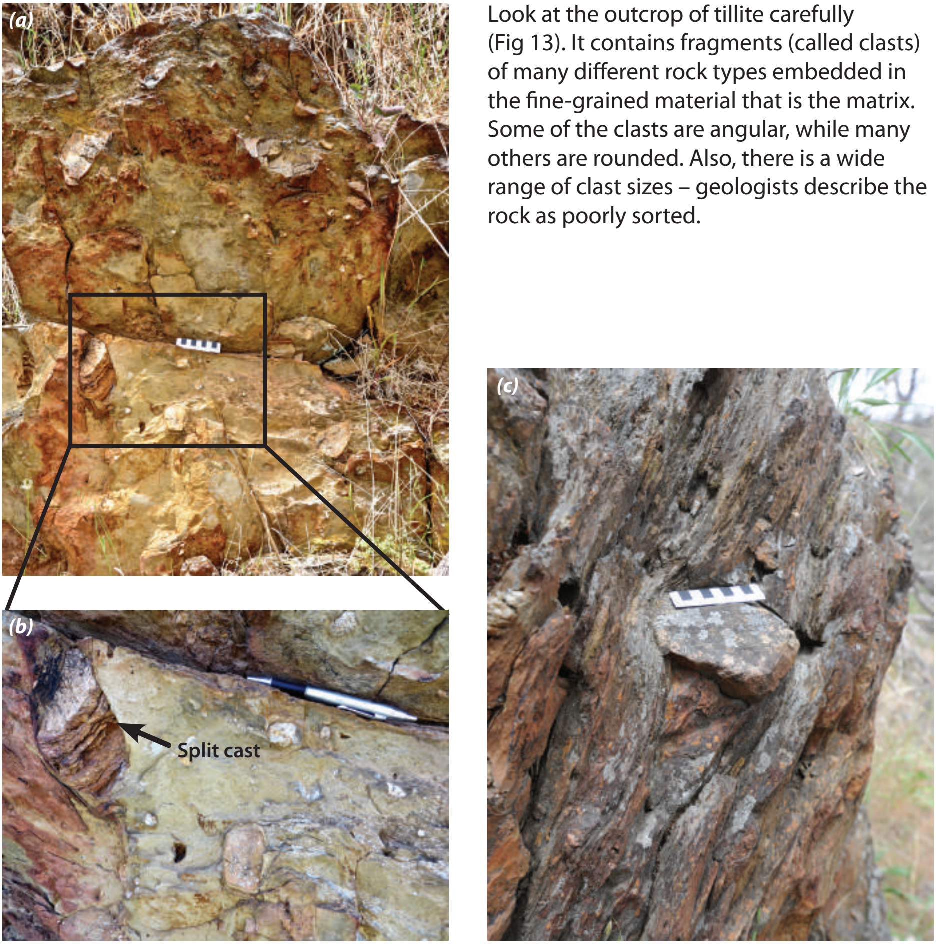


Figure 13 *Original form of till after it was deposited from a glacier at c. 665 Ma.* ***(a)*** *Note details of the outcrop face, especially the embedded rock fragments (clasts) in the tillite. The light brown to rusty red colouring is due to present-day weathering.* ***(b)*** *Clasts shown in detail.* ***(c)*** *The left-hand side of the outcrop, illustrating what happened to the tillite later when it was buried deep within the roots of a mountain chain (c. 510 Ma). A large rock fragment (clast) is wrapped by a streaky texture called 'cleavage', in this case 'slaty cleavage'. [Slaty cleavage is an approximately planar structure developed in a rock due to the preferred parallel orientation of platy minerals, such as fine grain-sized mica. It causes the development of a fabric or weakness throughout the rock along which the rock can be readily split or cleaved.]*

The clasts range in size from granules to boulders. They vary greatly in composition due to being plucked and transported by ice from distant and different source areas, and the different parent rocks in those areas – e.g. Eyre Peninsula and Antarctica (co-components of the supercontinent of Rodinia). This mixture of clast sizes and variation of clast rounding reflects their origin from different glacial environments before they were incorporated in a mass flow slurry of mixed materials. The angular clasts would have settled into the till quickly after leaving the thawing ice, but the rounded clasts, which are more common along the Sturt River, were tumbled in meltwater streams before they were deposited in the glacial till.

Tillite outcrops like those at G2 demonstrate that moving glacial ice has torn rock fragments from the distant lands over which it travelled. The ice carried these fragments along to form moraines (angular clasts) and outwash debris from glacial rivers (rounded clasts). The advance and retreat of glaciers to and from the ocean, which covered G2, resulted in immense quantities of unsorted rock fragments of all sizes – from fine clay sized particles up to large boulders – being released from floating ice to fall to the ocean floor to form glacial till, now visible as tillite at G2 (Fig 14).

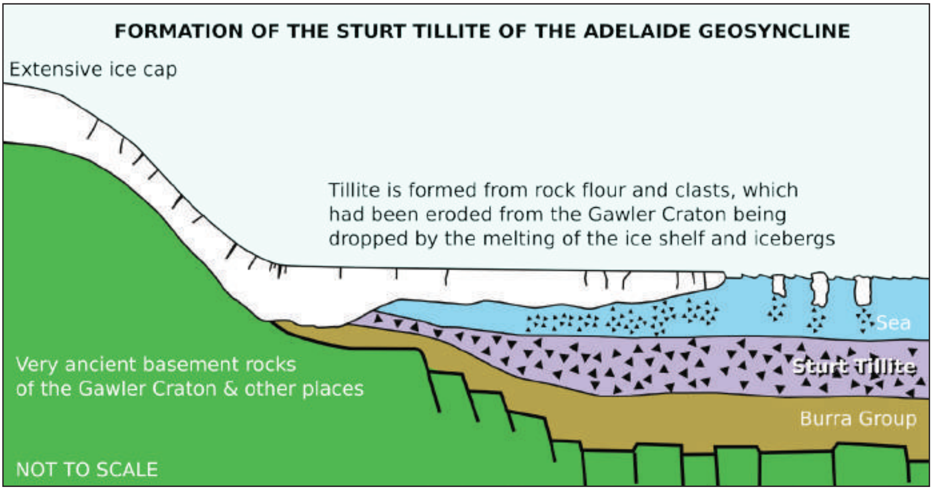


Figure 14 *Diagrammatic geological cross-section showing the environment of formation of the Sturt Tillite. Rock fragments and rock flour were carried into the sea by glaciers and floating ice to be deposited as the ice melted (after Rawolle 2011). (A craton [from Greek kratos – strength] is an old and stable part of a continent – in this case Eyre Peninsula).*

Thickness of the Sturt Tillite is hard to estimate as it is massive broadly homogeneous rock that has been complexly deformed by later tectonic forces. Fortunately, restricted lenticular (lens-like) sandstone beds and a siltstone marker bed, interleaved with the tillite, help with the structural puzzle (Fig 9; sites G3–G8).

There is more to this outcrop!

Building of an ancient mountain chain

The matrix of the tillite that surrounds the clasts possesses a streaky texture known as cleavage (Fig 13c). This texture was formed c. 500 Ma by extreme pressure during the Delamerian Orogeny mountain-building event. The tectonic pressure caused flakey minerals such as mica to grow in the matrix perpendicular to the pressure direction (Fig 15).

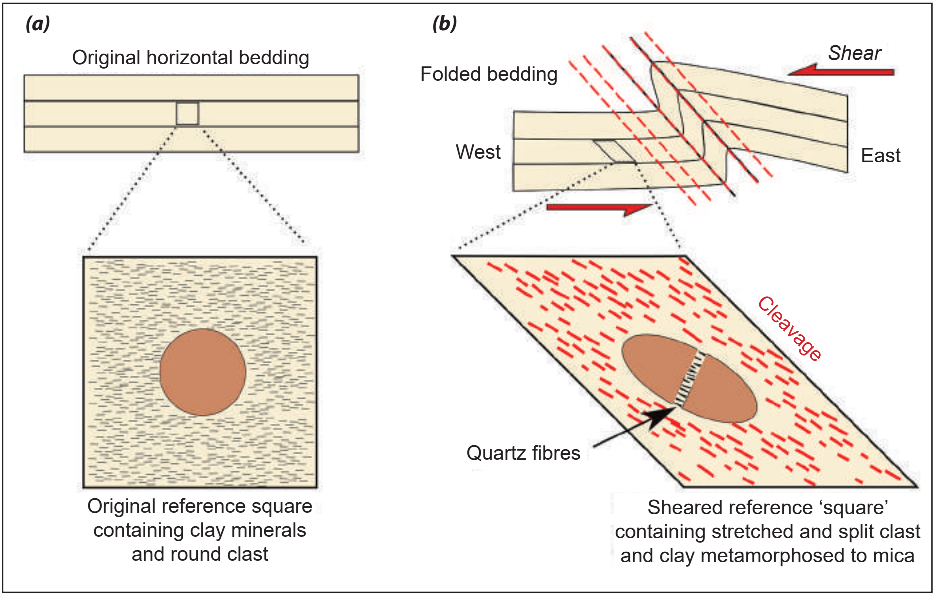


Figure 15 *Diagram showing what happened to the tillite during the Delamerian mountain-building orogeny.* ***(a)*** *Till, sandstone lenses and the siltstone were deposited to form horizontal beds in which there were clasts (brown circle) enclosed in a matrix containing much clay.* ***(b)*** *The rocks were buried to great depths and compressed to become tillite. Then tectonic pressures from the east caused them to be deformed by folding and faulting. Also, the original clay minerals were transformed (metamorphosed) into mica, so that the flakes, aligned at right angles to the direction of pressure, form the cleavage. Generally, the cleavage is distorted by wrapping around the large rigid clasts (displayed at site G2, and spectacularly so at G7). The clasts too have reacted in different ways, the most striking being that in stretching some quartzite clasts have split.*

Continue downhill to site G3 noting scattered rocks on the way – flattish pieces of tillite that have been displaced along weaknesses caused by the cleavage. Site G3 is marked by a subsidiary track joining from the left.

G3: Siltstone marker bed

279804 mE, 6120195 mN

The rubbly exposure of rock on the track is rather unimpressive and consists of grey-green to brown weathered siltstone, which is a fine-grained, thinly layered or laminated rock (Fig 16a). It is formed from fine silt sized quartz, and possibly feldspar particles, and a minor amount of clay that settled out of relatively calm water, but unlike the tillite it is generally well sorted. These layers mark the bedding planes that were formed by changes in the nature of the material that was being deposited at that time (Fig 16b). The presence of the siltstone bed, in contrast to tillite, indicates that environmental conditions briefly changed during the glacial period.

Figure 16 *Site G3, the siltstone marker bed.* ***(a)*** *The rock outcropping as rubble on the track is siltstone, which means that is made up of fine-grained particles, mainly of quartz.* ***(b)*** *Detail of a piece of siltstone on the right showing thin parallel bands – these are layers, which are called beds. The beds were formed by the settling of silt from relatively still water, such as a lake or below floating ice that was free of rock debris. Unlike the rock at locality G2, there are only infrequent clasts. A few are shown to the left of the scale bar, and are embedded in the siltstone having been dropped from floating ice, which on this occasion did contain glacial debris.*

Significantly, the rock unit is a geological marker bed – a marker bed being a layer of a distinctive rock that can be traced for long distances (Fig 9). Here at site G3 this fine-grained, thinly layered siltstone marker bed lies within the tillite mass dividing the tillite into two – a lower older tillite and upper younger tillite. In Figure 16a the upper tillite is to the left of the track and the lower one is to the right. The significance of the siltstone marker bed is discussed further at the next site.

Continue downhill following scrappy exposures of the marker bed in the track. At the top of the Sturt Gorge the track intersects with the River Trail (T5). When you arrive at site T5, G4 you will be standing on a tillite unit which is below the siltstone marker bed and from now on you will be walking in the older tillite unit.

T5, G4: View of the main Sturt Gorge

279779 mE, 6120131 mN

The track joins the River Trail, which follows Sturt Creek.

From this location, at the junction with River Trail, you can look down into the head of the Sturt Gorge which follows the westerly course of the Sturt River, i.e. to the right. The geological reason for the existence of the steep-sided gorge is that the Sturt River is cutting downwards in reaction to the past and continuing episodic uplift of the Mount Lofty Ranges (you will see spectacular evidence for this at site G10).

Looking across the gorge, the rocks of the lower tillite have a vertical pillar-like form due to the metamorphic cleavage which is more steeply inclined at this locality than it is elsewhere (Fig 17). The top of the 'pillars' marks the base of the siltstone marker bed.

Figure 17 *The view from site G4 is of the rocky start of the main part of the Sturt Gorge. The rocks forming the small cliffs on the other southern side of the gorge are made of the lower tillite. The sloping but relatively planar top to the tillite suggests that it is the contact of the base of the siltstone marker bed that we saw at site G3, and will see in sites G5 to G8. The column-like nature of the outcrop is due to the tillite being preferentially weathered and eroded along planes of weakness parallel to the near vertical cleavage.*

The cleavage in the tillite at site G4 indicates that the rocks along the Sturt River have been deformed and folded. Mapping of the siltstone marker bed (Fig 9) has shown that the rocks along the Sturt River (and the Mount Lofty Ranges in general) have been deformed into folded shapes, which in cross-section look like knees or elbows (Figs 15, 18). Both the folding and the formation of cleavage are due to pressure exerted from the east during the ancient Delamerian Orogeny. Figure 18 shows the geology of the Sturt Tillite as an east–west cross-section viewed looking south across the Sturt River.

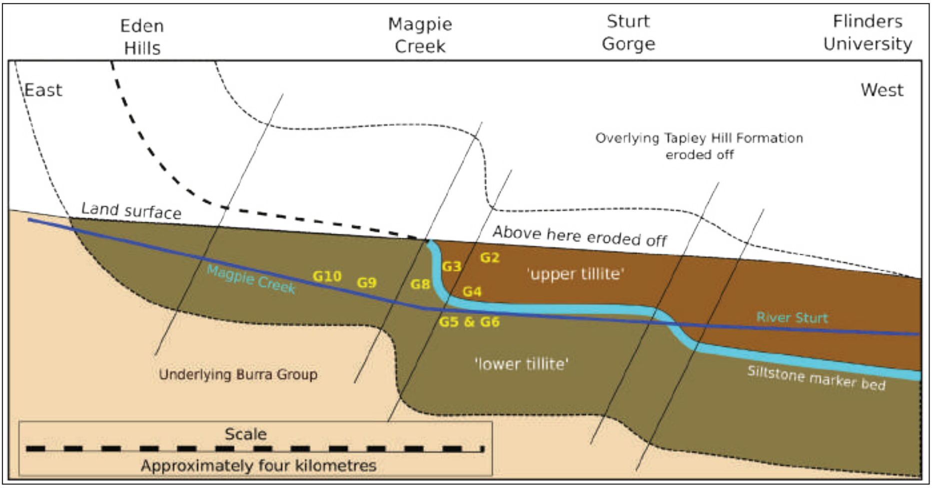


Figure 18 *Simplified schematic east–west cross-section showing how the marker bed defines the folded shape of the Sturt Tillite as it is between Eden Hills in the east and Flinders University in the west. View looking south. From site G5 to G8 the orientation of the siltstone changes from near horizontal to near vertical. This style of knee-shaped fold is typical for this part of the Mount Lofty Ranges. The white upper part of the diagram represents rock that has been lost to erosion, a process that continues today. The lowest part of the diagram shows the underlying pre-glacial sediments that are called the Burra Group.*

Before you leave this location look upstream towards the left to view the dam which has been built across the Sturt River to protect the downstream suburbs from flooding (Fig 2c).

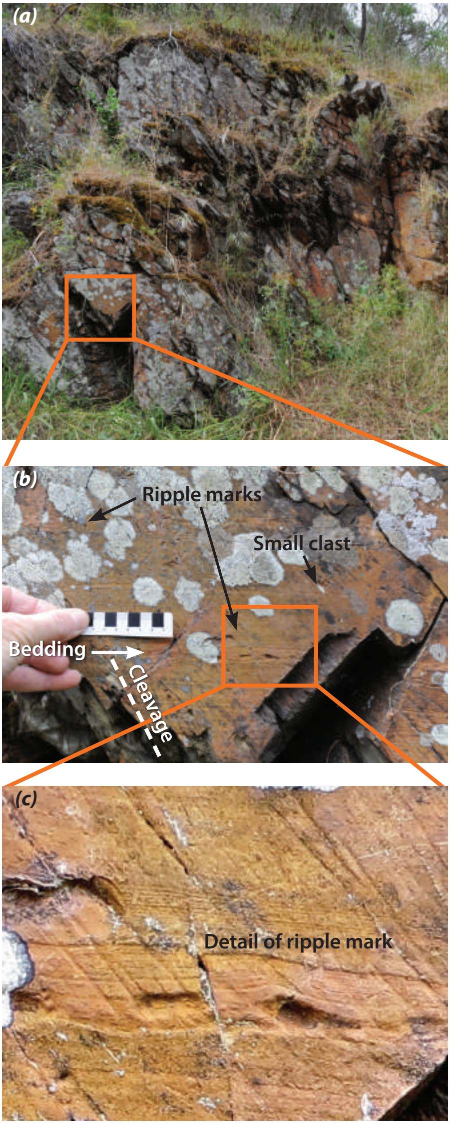
Turn left and follow the River Trail for about 50 m to G5.

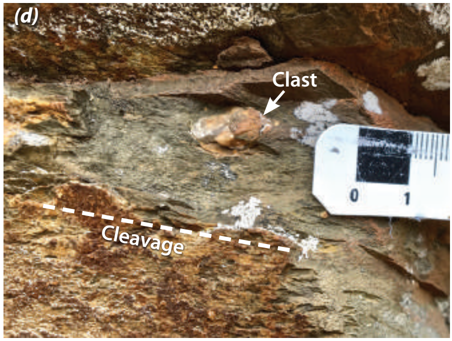
G5: Bedding and cleavage in the siltstone marker bed

279827 mE, 6120083 mN

You are now standing on the top of the lower tillite (Fig 19a). The rock outcrop on the left-hand side of the trail is the siltstone marker bed continued from site G3.

The surface facing you is a near-vertical joint surface (a natural planar crack in the rock; Fig 19b). By examining the joint surface closely you will see 2 different sets of parallel lines. The horizontal set is the bedding and the set inclined to the right is the cleavage (Figs 19b, c).





Bedding

Like the rock at site G3 here the bedding suggests deposition of sandy sediment in fairly quiet water, although ripple-like structures (c) do suggest some current activity. Originally this rock was not purely composed of silt-sized particles because it contains larger scattered quartz granules and occasional pebbles (d). These coarser fragments were likely to have been deposited from floating glacial ice. The sediments were deposited at about 665 million years ago, during the Sturtian Glaciation.

Cleavage

The set of lines that are inclined to the right (i.e. east) represent the intersection of irregular cleavage planes with the joint face, and are equivalent to the cleavage viewed in the tillite at site G2. The cleavage is the evidence at this site for the Delamerian Orogeny, the major mountain building event that was imposed about 150 million years after the Sturtian ice age. Also visible in this outcrop are irregular cracks in the rock that are partly filled with quartz, these represent later faulting.

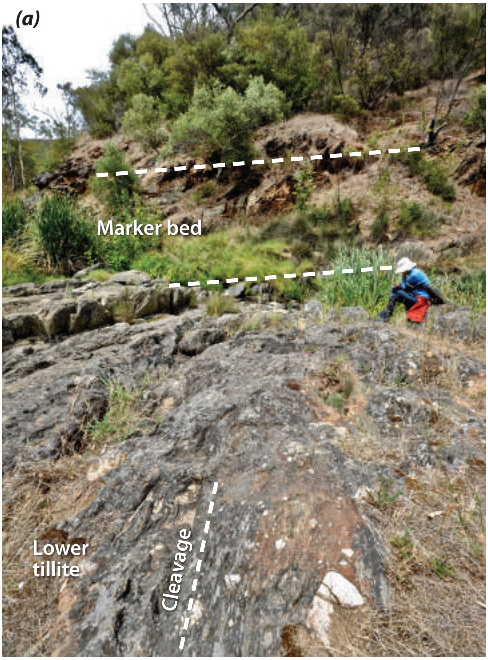
Follow the River Trail a few metres and turn right to a rock platform beside the Sturt River.

G6: Tillite platform displaying a variety of clasts

72980 mE, 6120098 mN

Here the lower tillite contains many fragments of different rock types that vary from rounded to angular in shape (Fig 20) like the upper tillite seen at site G2. Also repeated to the south across the Sturt River is the siltstone marker bed; it displays details that significantly show changes in the glacial setting (see the explanation of Fig 20 for more detail).

Crossing the river is not recommended as the rocks are slippery, additionally the long grass on the far side provides an ideal snake habitat.



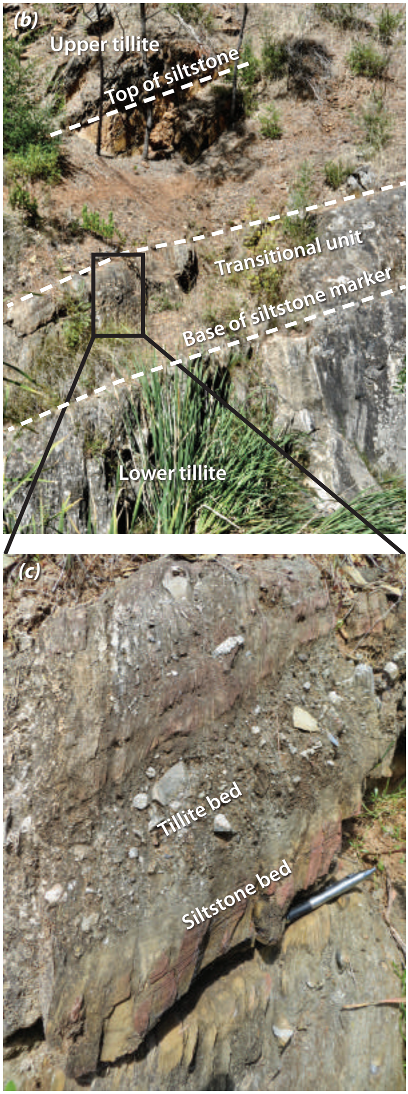


Figure 20 *(**a**) View looking south across the Sturt River to the siltstone marker bed forming the far bank. The pavement in the foreground is of the lower tillite and displays numerous clasts. The clasts are mostly rounded indicating that they were tumbled in water prior to being incorporated in the till, thus they indicate the influence of 'fluvioglacial' conditions. (**b**) The viewpoint of this photo is further to the left, showing not only the base and top of the siltstone marker unit, but also that it is comprised of two parts – a siltstone dominated upper part and a clast-rich lower part. (**c**) Detail of the lower part showing that it is composed of thinner siltstone and clast-bearing sub-beds. In contrast to (a), the clasts are angular suggesting that they were dropped from ice without being tumbled in water. Hence this regionally extensive siltstone marker bed does indicate that for a short time there was a significant variation in glacial conditions.*

T6: Magpie Creek track

279839 mE, 6120090 mN

To reach site G7, walk back and cross over the River Trail to follow the track labelled 'Magpie Creek Trail'. This track runs slightly uphill following Magpie Creek to the right with the Siltstone Marker Bed above to the left.

G7: The first waterfall

279883 mE, 6120128 mN

The first waterfall is a chute that has been eroded into the tillite to form a smooth pavement (a). There are many quartzite clasts (b), generally they are quite rounded indicating that they were incorporated into the till after being bowled about in an outflowing glacial river. Quartzite and granite (c) are very different rock types, thus illustrating that the rock debris was sourced from very different places. Additionally, note that the clasts were torn from parents that were much older than the tillite, their current host.

Most of the quartzite clasts are split (b), indicting that they were brittle when deformed during the Delamerian Orogeny. A close look will show that the cleavage is at right angles to the cracks, hence evidence for the E-W tectonic pressure direction. The granite clast (c) is composed of the minerals quartz and feldspar, it is not split like the quartzite clasts, so showing that the granite was more ductile than the quartzite.

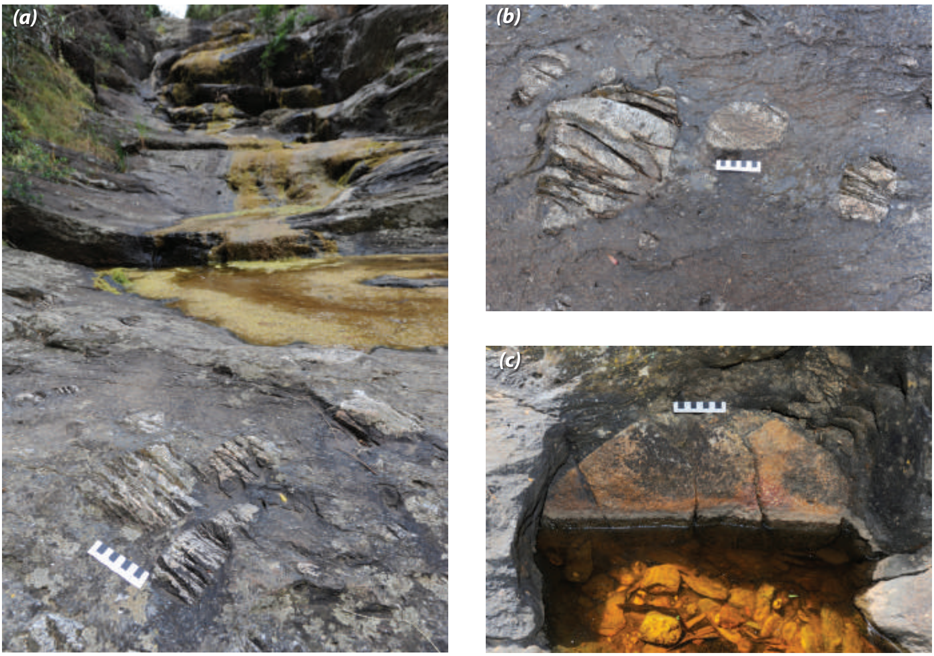


Figure 21 *(a) The first waterfall and a tillite pavement.* ***(b)*** *Tillite with split quartzite clasts.* ***(c)*** *A rounded granite clast.*

Leave the waterfall, and to the right climb up the steep stepped trail that traverses a rugged mass of the lower tillite. Nearing the top look to the left for the view displayed in Figure 22a.

G8: View from the top of the waterfall

279892 mE, 6120118 mN

You have reached the top of the cliff of rugged lower tillite. This site provides a good view across the waterfall to the other side of Magpie Creek where the upper tillite, the siltstone marker and the lower tillite track away up the steep bank (a). Here the siltstone marker bed is inclined steeply to the west – the evidence is displayed by the outcrop of siltstone in the centre of the picture (b). Compare this with site G5 where the bedding was near horizontal.

Continue on along Magpie Creek trail to G9.

G9: Vertical face of tillite

279919 mE, 6120018 mN

Intensely cleaved tillite is well expose along this joint face to the right of the trail (a). Numerous clasts are wrapped by the the cleavage (b), which as usual dips towards the east. The original till was deposited as an amorphous mass, thus unlike the siltstone marker no bedding is visible.

Continue on to site G10. After a short distance you will pass more deformed tillite to the right and then come to an alternative track that diverges to the left and down to the creek.

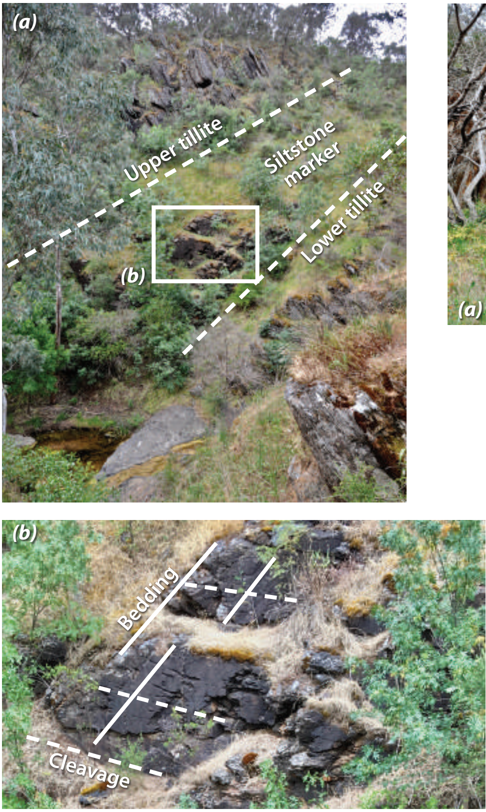


Figure 22 *(a) Northerly view of the siltstone marker bed sandwiched between the upper and lower tillites. (b) Small outcrop showing bedding and cleavage traces on joint planes.*

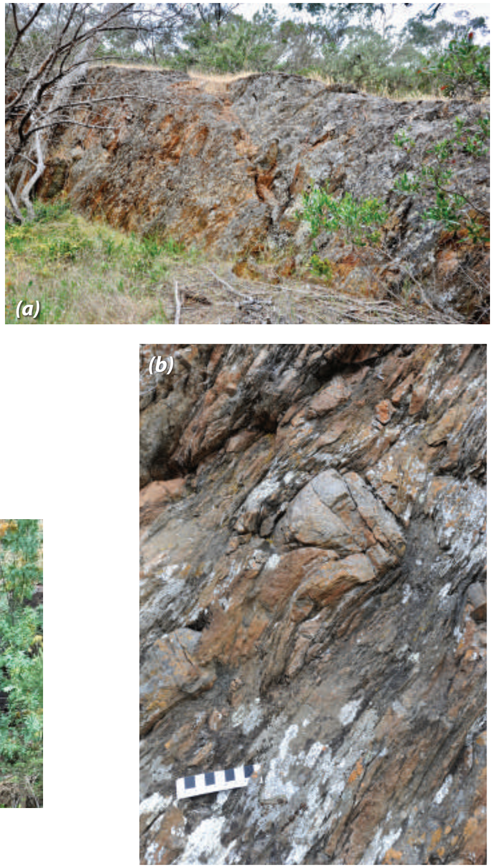


Figure 23 *Deformed tillite **(a)**, and a clast **(b)**.*

T7, G10:Tillite slabs and the second waterfall

279963 mE, 6120138 mN

Looking down into the small gorge of Magpie Creek you will see large displaced slabs of tillite (Fig 24). The slabs exemplify the forcefulness of continuing erosion, because undercutting by water has caused the tillite to fail along breaks in the rock that are a combination of mechanically weak cleavage and joint planes. The cleaved blocks are in the process of sliding downslope into the creek.

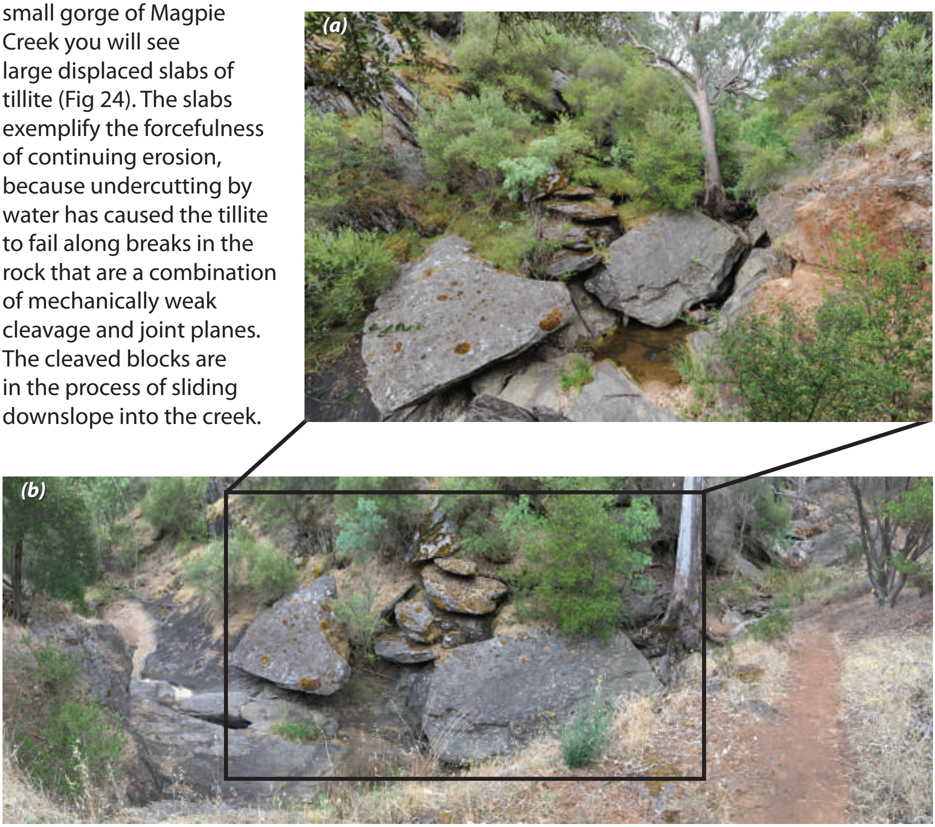


Figure 24 *Two views of the same fallen slabs of tillite.* ***(a)*** *Their shape is controlled by the cleavage, and the components of which they are made have started their journey to the sea.* ***(b)*** *Panoramic image of the second waterfall of Magpie Creek, showing clean outcropping tillite downstream in the chute (left) and the side-track continuing down to the top of the waterfall (right).*

Continue on down the left-hand track to the creek bank beside the eucalypt shown growing in the creek.

You will see smoothly eroded tillite forming the base of the creek (Fig 25a), and a jumble of tillite slabs both above the far bank of the creek and in the creek itself (Fig 25b). Some slabs are just starting to slide and some are rotated to lie horizontal. One horizontal slab in the creek is being temporarily held in place by the roots of the large eucalypt – at times roots stabilise the ground, but at others they contribute to erosion by breaking up the rocks.

Apart from being geologically interesting, this part of the creek is attractive after rain has filled the pools. It is a second chute-like waterfall that cleanly exposes the tillite to view. The variety of clasts once again demonstrates a range of different source regions. Some of the clasts are the size of boulders and some are distinctly split.

The Magpie Creek traverse is but a small part of the Sturtian Glacial succession which is exposed along the Sturt River. The rocks marking the start of the Sturtian Glaciation are exposed in a railway cutting 1.1 km to the northeast, and its termination can be seen in the Flinders University campus 1.95 km to the northwest.

G10 is the last geological site. To return to the starting point you can either reverse the walk or follow the directions below and on Figure 9.

T8: T-junction

280130 mE, 6120210 mN

There is a track junction at this location. The River Trail goes south, separating from the Magpie Creek track. Follow the Magpie Creek track to the northeast.

T9: Ruined building

280233 mE, 6120374 mN

There is a track junction uphill from the ruined building. Follow around to the left past the ruins.

Figure 25 ***(a)*** *Smoothly worn tillite at the top of the second waterfall.* ***(b)*** *Jumble of displaced slabs of tillite making their way into Magpie Creek. There is a large split clast at the lower right.*

T10: Magpie Creek crossing

280214 mE, 6120404 mN

Turn left off the main track, cross the now small Magpie Creek to join the zigzag track.

T11: Magpie Creek crossing

280190 mE, 6120400 mN

Follow the zigzag track (courtesy of the Friends of Sturt Gorge) uphill to the intersection with the Tapa Turrungha Trail.

T12: Tapa Turrungha Trail

28108 mE, 6120401 mN

Turn left and follow the trail to the southwest; there are houses above the trail.

T13: Turn right off the Tapa Turrungha Trail

280080 mE, 6120350 mN

Leave the reserve after the last house and go through gate 4 onto Gorge Road.

T14: Gorge Road

280043 mE, 6120364 mN

Turn left to the start of the walk and the end of the Magpie Creek geological trail.

Acknowledgements

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Be prepared when bushwalking

- wear sturdy shoes, hat and sunscreen
- carry sufficient food and drinking water
- keep to the defined walking trail
- beware of snakes.

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