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Newsletter No. 19

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Geology of the Mintaro Shale

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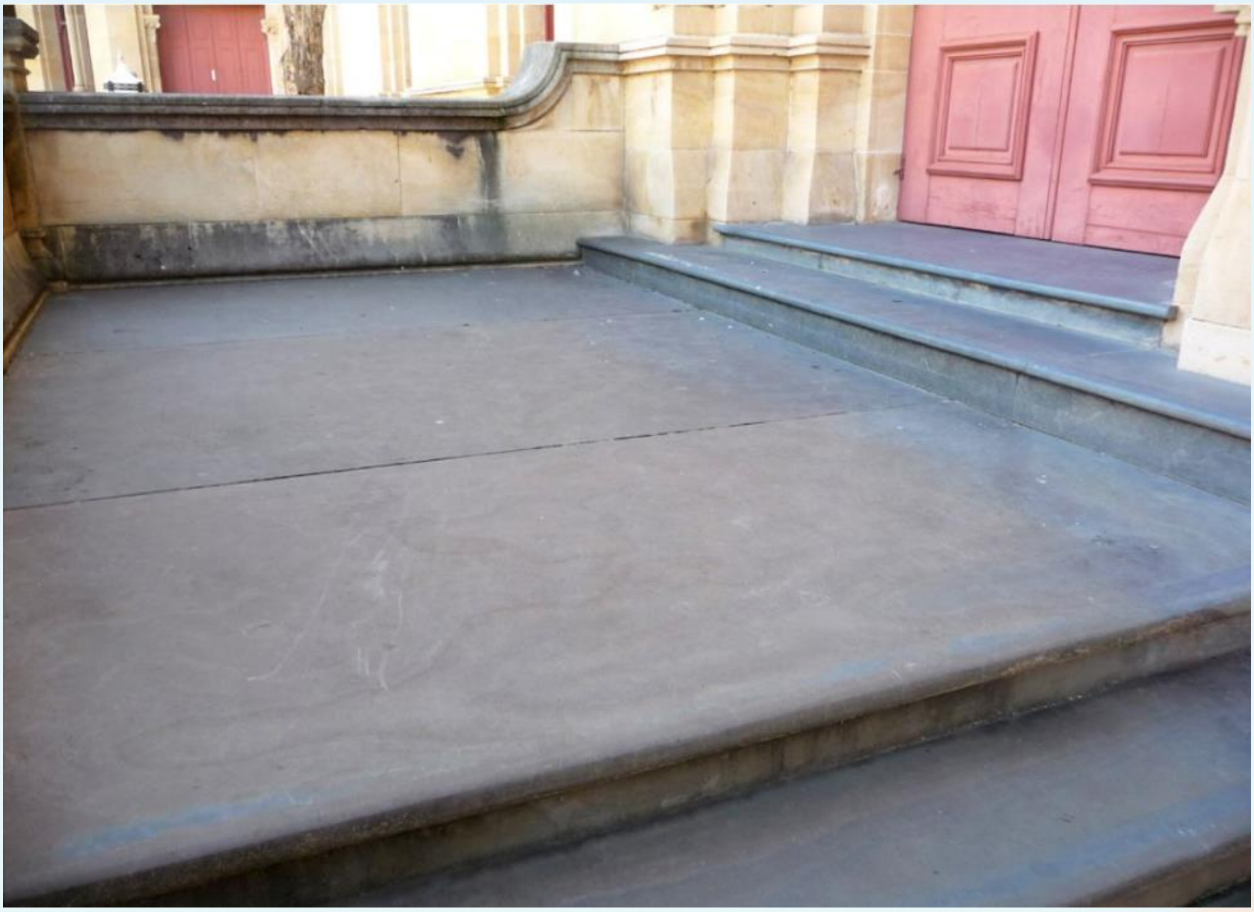
Geology of the Mintaro Shale

Wolfgang V. Preiss, Visiting Honorary Research Fellow, University of Adelaide and Geological Survey of South Australia

The beautiful and versatile stone known in the trade as Mintaro Slate has a long geological history and scientific significance well beyond the small Mid-North South Australian town after which it is named. The quarried rock is dark grey in colour, of fine grain size, tough and durable. It is composed of innumerable very thin parallel layers, or laminations, one millimetre or less in thickness.

Like all mappable geological rock units (known as formations), the stone has a formal name used in scientific publications. This name was first published as 'Mintaro Shales' by Wilson (1952) who mapped the geology of part of the Mid-North as a post-graduate project at Adelaide University. Later the 's' was dropped on the first published 1:63,360 scale geological map (Forbes, 1964) and today it is referred to as 'Mintaro Shale'. However, the rock quarried for many industrial uses at Mintaro is actually neither a shale nor a slate. The rock type is better described as a flaggy siltstone (or flagstone), because it is predominantly composed of silt-sized particles, and displays a flaggy parting. Secondly, the rock at Mintaro lacks a cleavage which characterises slates, instead parting along the original very smooth, parallel bedding planes, which makes it ideal for paving and billiard tables. The Mintaro Shale is widespread throughout the Mid-North from just south of Kapunda to north of Orroroo. In many other places within this region it does have a cleavage, making it unsuitable for use as flagstone as the cleavage and bedding planes intersect to produce only pencil-shaped fragments.



Steps and paving outside the South Australian Museum Eastern Wing constructed of slate slabs quarried at Mintaro. Photo courtesy South Australia's Department for Energy and Mining.

Mintaro Shale exposed in a disused quarry. Photo courtesy Wolfgang V. Preiss.

The Mintaro Shale is part of the very thick sedimentary succession deposited during the Neoproterozoic Era in a large sedimentary basin traditionally known as the Adelaide Geosyncline, which occupied the region of the present Mount Lofty Ranges, Mid-North and Flinders Ranges. The sedimentary rocks were laid down in a variety of marine and terrestrial environments. The Mintaro Shale was deposited as silt in a marine environment, probably in quiet, relatively deep water, perhaps at 100-200 m depth, near the outer limit of an ancient continental shelf. The sediment was derived from the weathering and erosion of older landmasses neighbouring the basin. After deposition, the sediment was compressed by the weight of overlying sediment, dewatered, and lithified to form a hard siltstone.

The most recent geological mapping of the Mintaro area can be accessed through SARIG on the South Australian Department for Energy and Mining's website: https://map.sarig.sa.gov.au.

The exact age of deposition cannot be specified at present, but can only be constrained by the ages of dated rocks above and below in the stratigraphic succession. About three kilometres below the Mintaro Shale lies the Skillogalee Dolomite (also named by Wilson, 1952) which, in the nearby Burra Copper Mine, contains volcaniclastic and intrusive rocks dated at about 790 Ma (Preiss et al., 2009). About one kilometre above the Mintaro Shale is the Appila Tillite (Thomson et al., 1964). The latter formation is part of glacial sediments that resulted from a widespread ancient glaciation and are found throughout the Flinders and Mount Lofty Ranges. The waning stage of this glaciation has been dated at 663 Ma on a thin volcanic ash bed in the northern Flinders Ranges (Cox et al., 2018).

Long after deposition, between about 510 and 500 Ma, the whole sedimentary succession was folded and faulted in a mountain-building event known as the Delamerian Orogeny. During this event, many of the finer grained sedimentary rocks were cleaved by the compressive stresses. Mintaro was, however, at the southern closure of an open, large-scale syncline in an area of little strain in the rocks, and so they have escaped being cleaved and folded on a small scale. This means that the beds have remained planar, with parallel partings, although they are inclined at a low to moderate angle to the northwest. These features can be clearly seen in the quarry.

The Mintaro Shale has geoscientific significance beside its many practical applications. Two additional features are of special interest, though they have not necessarily been welcomed by the quarry operators: sand dykes and pebbles.

Sand dykes varying in width from a few centimetres to nearly one metre have been observed in some of the quarry workings, as well in other outcrops of the Mintaro Shale in the Mid-North. These originated as deep, open fissures that developed once the siltstone was consolidated, though not necessarily as highly lithified as it is now. Sand probably flowed into these fissures from above when sand was carried out into the basin by marine currents after silt deposition finished and the fissures opened. Alternatively, fluidised sand could have been injected from below. Either way, the sand sources are enigmatic as the closest sandstone units occur hundreds of metres above and below the Mintaro Shale.

Over more than a century of mining, the quarry operators have occasionally found rare pebbles encased in the siltstone. These were first recorded by Government Geologist L.K. Ward, who suggested that they had been ice-borne (in Jack, 1923, p. 28). Pebbles range from one to ten centimetres in diameter, and are of various rock types, including sandstone, quartzite and limestone (Preiss, 1987). In much younger sediments, stones can be carried out to sea by floating logs but these rocks are hundreds of millions of years older than the earliest plants. It is difficult to envisage a mode of transport other than by floating ice for isolated ‘lonestones’ into such distal sedimentary environments, which are normally reached by only fine-grained sediments.

Mintaro Quarry, South Australia. Photo courtesy Wolfgang V. Preiss.

The Mintaro Shale is substantially older than the well-known glaciation represented by the Appila Tillite, being separated from it by two additional formations and a major unconformity, but it is not known just how much older. Interestingly, Mawson and Sprigg (1950) suggested that rocks of the Belair Subgroup in the Adelaide Hills, which includes equivalents of the Mintaro Shale, had glacial affinities. So far it has not been possible to date the Mintaro Shale directly. Some Neoproterozoic glacial deposits in other parts of the world have been dated as older than the South Australian tillites, for example 717 Ma in Canada (Macdonald et al., 2018). If it could be shown that the pebbles in the Mintaro Shale relate to one of these older glacial periods it would greatly enhance the international significance of these rocks.

References

Cox, G., Isakson, V., Hoffman, P., Gernon, T., Schmitz, M., Shahin, S., Collins, A., Preiss, W., Blades, M., Mitchell, R. and Nordsvan, A., 2018. South Australian U-Pb zircon (CA-ID-TIMS) age supports globally synchronous Sturtian deglaciation. *Precambrian Research*, 315:257-263.

Forbes, B.G., 1964. Clare, South Australia. *1:63,360 Geological Atlas Series Map*. Geological Survey of South Australia, Adelaide.

Jack, R.L., 1923. The building stones of South Australia. *Bulletin of the Geological Survey of South Australia*, 10.

Macdonald, F.A., Schmitz, M.D., Strauss, J.V., Halverson, G.P., Gibson, T.M., Eyster, A., Cox, G., Mamrol, P. and Crowley, J.L., 2018. Cryogenian of Yukon. *Precambrian Research*, 319:114-143.

Mawson, D. and Sprigg, R.C., 1950. Subdivision of the Adelaide System. *Australian Journal of Science*, 13, 69 –72

Preiss, W.V. (compiler), 1987. The Adelaide Geosyncline. Late Proterozoic stratigraphy, sedimentation, palaeontology and tectonics. *Bulletin of the Geological Survey of South Australia*, 53.

Preiss, W.V., Drexel, J.F. and Reid, A.J., 2009. Definition and age of the Kooringa Member of the Skillogalee Dolomite: host for Neoproterozoic (c. 790 Ma) porphyry- related copper mineralisation at Burra. *MESA Journal*, 55:19-33.

Thomson, B.P., Coats, R.P., Mirams, R.C., Forbes, B.G., Dalgarno, C.R. and Johnson, J.H., 1964. Precambrian rock units in the Adelaide Geosyncline: a new subdivision. *Quarterly Geological Notes, Geological Survey of South Australia*, 9:1-19.

Wilson, A.F., 1952. The Adelaide System as developed in the Riverton-Clare region, northern Mount Lofty Ranges, South Australia. *Transactions of the Royal Society of South Australia*, 75:131-149.

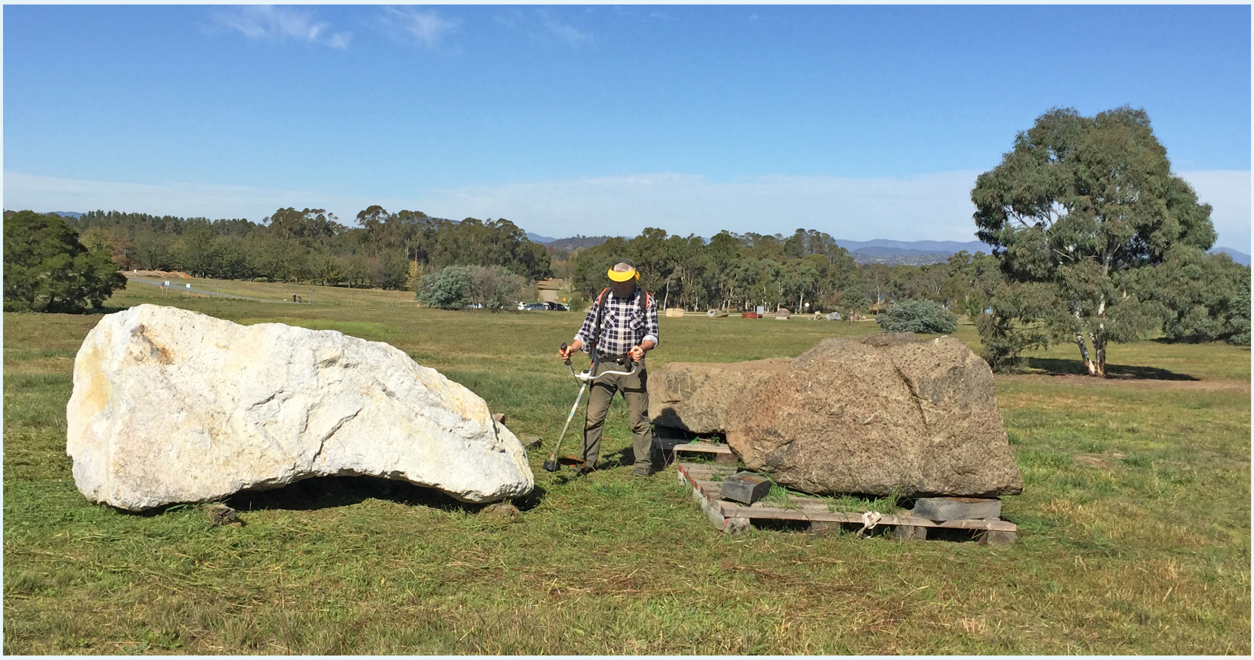
Glossary

Bedding	Primary layering in sedimentary rocks.
Claystone	A sedimentary rock composed predominantly of clay-sized particles (less than 0.0039 mm in diameter).
Cleavage	The tendency of a rock to split along aligned very fine-grained platy minerals, typical of slate.
Formation	A geological rock unit which can be traced and mapped over a certain area. It may contain one or several related rock types.
Lithification	The process of hardening of soft sediment into hard sedimentary rock by combinations of compaction, dewatering, cementation and recrystallisation.
Lonestone	Isolated pebble or cobble embedded within fine-grained sediment. Lonestones that can be demonstrated to have dropped into soft sediment from above are known as “dropstones”.
Ma	Million years before present.

Neoproterozoic Era	Geological era between 1000 Ma and 541 Ma.
Sand dykes	Fissures in sedimentary rock infilled with sand.
Shale	Fissile claystone parting on thinly spaced bedding planes.
Silt	Sedimentary particles between 0.0039 and 0.063 mm in diameter.
Siltstone	Sedimentary rock composed predominantly of silt-sized particles.
Slate	A low-grade metamorphic rock with strong cleavage.
Stratigraphy	The scientific study of sedimentary strata and their relationships.
Syncline	A U-shaped fold in layered rocks with the younger layers on the inside and older on the outside.
Tillite	A poorly bedded rock composed of a wide range of grain sizes from clay, silt, sand and pebbles to boulders interpreted to have been deposited by glaciers.
Unconformity	A gap in the sedimentary record during which the underlying strata were eroded before deposition of the overlying beds.
Volcaniclastic	Sediment composed of contemporaneous volcanic fragments.

NRG Steering Committee members in action

NRG Steering Committee members regularly tidy up around the Federation Rocks and the proposed site of the NRG. Below you can see NRG Steering Committee member, Matt Townsend, wielding his line trimmer to tidy up around of our stored rocks at the NRG site, with the Federation Rocks just visible in the background. These rocks will be among the next group of rocks to go on display at the NRG.



Matt Townsend tidies up around some of the NRG's stored rocks at the NRG site.
Photo courtesy of Brad Pillans.

An example of effective geology teaching to high school students

Colin Price, Marita Bradshaw and Mike Smith

About the Authors

Colin Price was an exploration geologist for 20 years before becoming an Earth and Environmental Science (EES) teacher at Daramalan College in Canberra. Colin has twice been a finalist in the teacher's category of BHP Foundation Science and Engineering Awards and received a Highly Commended award in the 2019 Prime Minister's Prizes for Science, for promoting open-ended learning and for his work in EES education. Marita and Mike make up the Education Committee of the Steering Committee of the National Rock Garden (NRG).

The NRG Education Committee is building relationships with geoscience educators to gain advice in regard to specific rocks which might be considered for inclusion in the display at the NRG. These specimens would be chosen based on their value as educational material. The Committee recently met with Colin Price to gain some appreciation of his teaching methods.

Daramalan College in Canberra provides Earth and Environmental Science (EES) students with direct exposure to the challenges of geological analysis by conducting practical field excursions. One excursion takes Year 11 students to a field northwest of Yass where there is a prominent exposure of a volcanic ash flow, a rock called an ignimbrite, which is overlain by a sequence of various sedimentary rocks. This field area was suggested by Garry Knight, a former EES teacher at Daramalan, who was shown the area back in the 1970's when he was a geology student at ANU. Incidentally, Garry was in the same geology class as NRG Chair, Brad Pillans (see our photo on the last page).

All of the units dip at about 20 degrees to the west, enabling students to walk across the rocks and so recognise and describe the layered sequence of sandstone, siltstone and limestone. The exposures are in creek beds and on gently undulating sheep pasture sparsely covered by grass and thistles, allowing convenient inspection of the various units (Figure 1). The youngest unit, in the southwestern corner of the area, is a shale unit and does not outcrop.

Figure 1: Google Earth image of the 400 x 300 metre field mapping area.

Before the excursion, the class is provided with a 1:50 000 scale regional geological map (Colquhoun & Cameron, 2013) and relevant sections of a report by NSW Government geologists (Thomas & Pogson, 2012). The students are given a notebook, clipboard, 1:2 000 scale Google Earth image, Suunto compass/clinometer and protractor for a day of practical field work. They also draw 5 metre spaced contour lines onto their image by using the elevation tool on Google Earth.

During the excursion, students are first taught how to locate themselves on the image, describe the rocks and fossils in each outcrop in their notebooks, and build up a fact map of the geology. This includes taking dip and strike readings and plotting these on the image (Figure 2). They are encouraged to describe at least two outcrops in each unit and then use the textures and trends on the image to turn their fact map into an interpreted geological map. The task that best shows their level of understanding is the conversion of the elevation contours, rock types, rock unit boundaries and dips and strikes into a cross-section sketch of the layers, from which they measure the true thickness of each unit and produce a stratigraphic column.

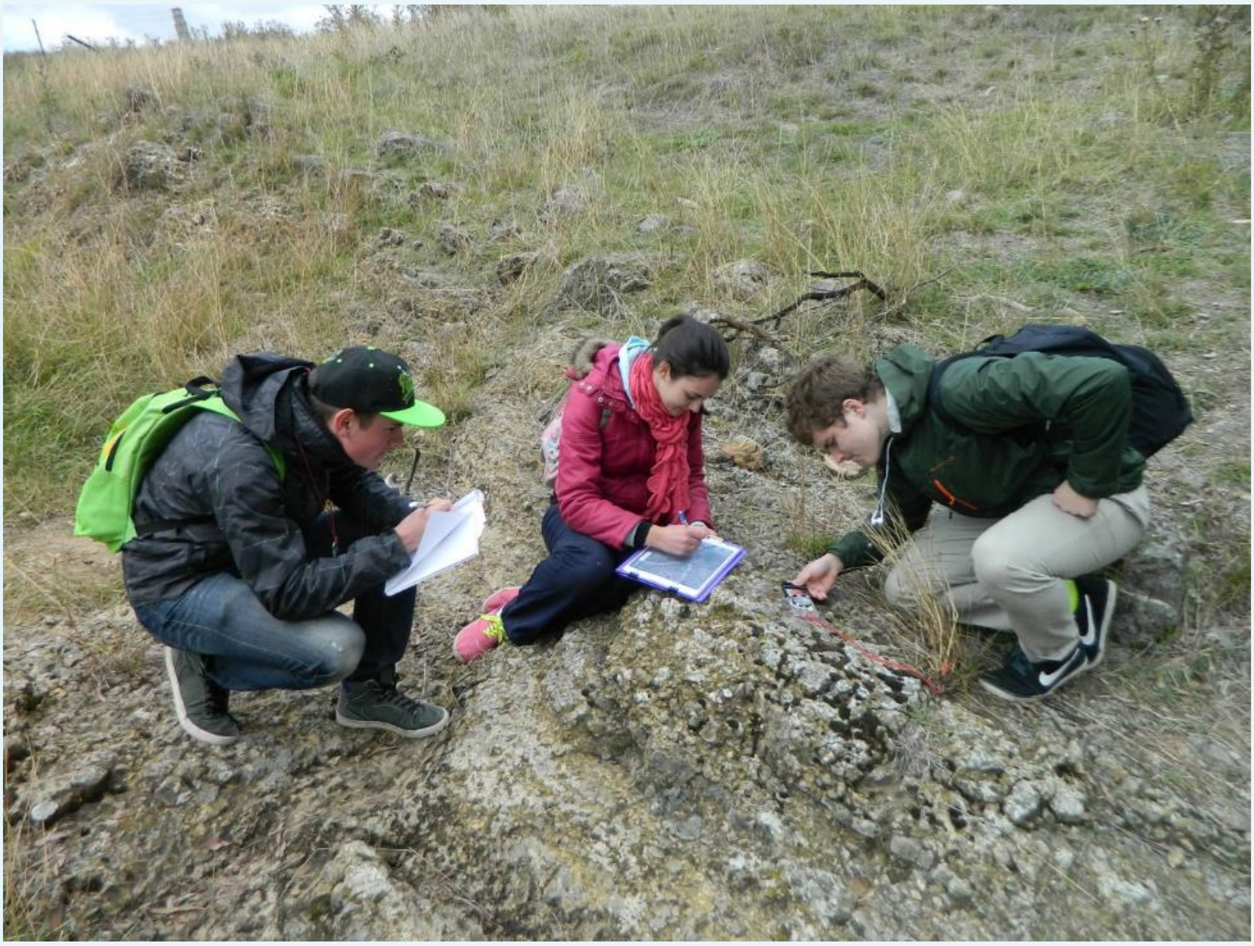


Figure 2: Year 11 students measuring the dip and strike of limestone beds. Photo courtesy Colin Price.

More importantly, the students interpret the depositional environment for each rock unit and the progressive changes in that environment from the older rocks to the younger rocks. The sequence records a rise in relative sea level (marine transgression), from volcanics on land to shallow water with coral patches, and then deep water as the shales were deposited by settling of fine particles.

The shallow marine sandstones are mostly massive in texture and the result of mass flows of weathered volcanic material eroded from the land, periodically swamping the coral reefs and shallow sea bottoms. Graded bedding can be found in just one outcrop of interbedded siltstone and sandstone, but these subtle changes in grain size enable the observer to decide that the dipping rocks are the right way up.

Students are most interested in the fossils in the limestone units. The most common fossils are tabulate and rugose corals, crinoid ossicles and stromatoporoids (Figure 3). A more careful search results in fossils of gastropods, brachiopods, bryozoans, fragments of trilobites and plates from the armoured skulls of placoderm fish (Figure 4). These fossils build up a picture of what life was like in the shallow tropical seas.

Figure 3: Stromatoporoid and Heliolites fossils in the Bowspring Limestone Member.
Photo courtesy Colin Price.

These rocks are Silurian in age and were deposited along the complex edge of the Australian continent which was then located much further west than the current coastline. In the Yass area an emergent volcanic terrain was drowned by a rising sea that supported corals and other marine organisms.

The Daramalan College students also use data from the NSW Geological Survey Explanatory Notes (Thomas & Pogson, 2012) to place time constraints on the evolution of depositional environment. The ignimbrite is the oldest rock and is part of the Laidlaw Volcanics, but there were no reliable radiometric ages for samples within the unit. However, a granodiorite intruding a stratigraphically lower volcanic unit has a SHRIMP U-Pb zircon isotopic age of 428.8 ± 1.9 Ma, so this represents a maximum possible age for the Laidlaw Volcanics. The wide error bars are a good introduction to the concept of uncertainty in scientific data!

The age of the youngest outcropping unit, the Bowspring Limestone Member, was better established because the upper half contains an important index fossil for correlation and age determination. This is a species of conodont called *Ancoradella ploeckensis* that is found throughout Silurian Australian and world sedimentary rocks in an age range of 423.7-425.0 Ma. Conodonts are tooth-like microfossils found in rocks that range from about 500 million to 200 million years old. The now long extinct marine creature that had these now preserved hard parts is thought to have been distantly related to living hagfish (Zhen, 2018).

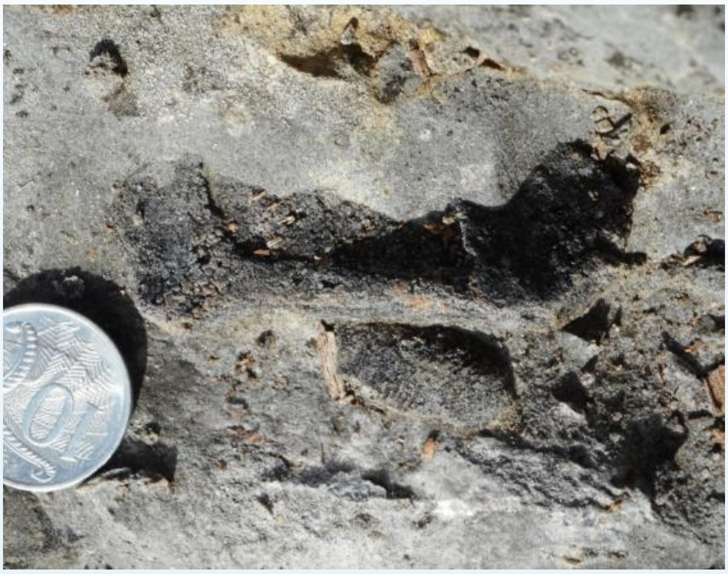


Figure 4: Placoderm fossil in the Gums Road Limestone Member. Photo courtesy Colin Price.

During a meeting at Geoscience Australia (GA) in December 2019, the authors had a series of stimulating discussions with Dr Simon Bodorkos in GA's SHRIMP Laboratory. A wide range of exciting geological concepts were discussed, including how it is possible to enable young people to understand difficult concepts (especially the sense of time for different groups of rocks).

Somewhat unexpectedly, Dr Bodorkos was able to provide the latest high-precision U-Pb date for the eruption of the Laidlaw Volcanics. The sample site was approximately 1 km east of the field mapping area and the Chemical Abrasion Thermal Ionisation Mass Spectrometry (CA-TIMS) analysis of carefully chosen zircon grains provided an age of 427.70 ± 0.12 Ma at 95% confidence. This new age means that the Laidlaw Volcanics ignimbrite and the roughly 110m thick sedimentary sequence disconformably overlying them, that the school students walked over and mapped, covered a time interval of 427.70 ± 0.12 Ma to 423.7-425.0 Ma; an approximately 3 million year slice of Earth history. Only those students who go on to university and a career as a field geologist will realise what an amazingly tight age constraint this is for an old sequence of rocks.

By examining the remains of a volcanic chain and an ancient ocean now found as rocks outcropping in the paddocks near Yass, the students have a rich educational experience and get a sense of the environmental changes that can occur over geological time. Science staff at Daramalan College are also enthusiastic about the capacity of the National Rock Garden to help teachers to engage with young people studying the rock cycle in Year 8, plate tectonics in Year 9 and those undertaking the Year 11/12 EES course.

References

Colquhoun, G P, & Cameron, R G, 2013. Yass Special 1:50 000 Geological Sheet (part 8628). Geological Survey of New South Wales, Maitland. Free download from https://search.geoscience.nsw.gov.au/product/1784

Laurie, J., 2009. Geological TimeWalk, Geoscience Australia, Canberra. Free download from http://www.ga.gov.au/education/classroom-resources.html

Talent, J A., Mawson, R. & Simpson, A., 2002. Silurian of Australia and New Guinea: Biostratigraphic Correlations and Palaeogeography. In book: Silurian Lands and Seas—Paleogeography outside of Laurentia., Edition: Bulletin 493, Publisher: New York State Museum, Editors: E Landing, M E Johnson, pp.181-220 https://www.researchgate.net/publication/255731389_Silurian_of_Australia_and_New_Guinea_Biostratigraphic_Correlations_and_Palaeogeography/link/5da1321c45851553ff88e795/download

Thomas O.D. & Pogson.J., 2012. 1:250 000 Geological Series, Explanatory Notes Goulburn sheet SI55-12. Geological Survey of New South Wales, Maitland

Zhen Y.Y., 2018. What are conodonts? Retrieved 13th April 2020 from https://australianmuseum.net.au/learn/australia-over-time/fossils/what-are-conodonts

A blast from the past—ANU class of 1974

A little bit off topic, but we thought you might get a smile out of this picture of a group of fresh-faced young geology students with their careers ahead of them. This photo was taken outside the old Geology Department building (now Engineering) at ANU. Do you see anyone you know?

Back row, left to right: Peter Nicholson, Jim Colwell, Terge Hansen, Dennis Fortowski, Richard Lesh, Jenny Clarke, Brian Gibson, Brad Pillans.
Front row, left to right: Greg Drake, John Kennard, Susie Gibbings, Ian levy, Garry Knight.
Photo courtesy Dennis Fortowski and Simon Beams

If you have an idea for a newsletter story, or there is a rock that you would like to see featured in a future NRG newsletter, please let us know via email or Facebook.

The Federation Rocks display at the National Rock Garden

National Rock Garden

Celebrating the Geological Heritage of Australia

Although work by committee members and friends of the National Rock Garden is voluntary, we nevertheless incur the regular costs of an incorporated entity. There are also costs for transport and delivery of rock specimens, preparation of specimens for display, creation of descriptive plaques for the rocks, and maintenance of the NRG site.

The acquisition and display of the Adelong Norite in November 2018 and the Mount Gibraltar Microsyenite in March 2018 was each agreat success, with good local, regional and national publicity. We are currently documenting proposed new rock garden display specimens and planning a major fund-raising campaign to construct an Interim Gallery Display.

While the committee pursues major funding from corporate and government sources, the ongoing costs must be met. We therefore seek donations from individual geoscientists who recognise the importance of geoscience and geoscience education to the future of Australia.

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Feedback and further information

We welcome feedback and suggestions on the development of the National Rock Garden. See the feedback boxes on the National Rock Garden website: www.nationalrockgarden.com.au

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Keep up with the latest NRG news, rock movements, rocks of the month and a whole lot more. Like us on Facebook: https://www.facebook.com/pages/National-Rock-Garden

Newsletter compiled and edited by Mike Smith, Brad Pillans and Michelle Cooper.