Bedrock, fills and cut surfaces: the story from Pungalina, Golden Valley and the Nullarbor

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Cave walls can be a feast of information for those interested in the geology because the exposures can be very good, clean of obscuring soil and vegetation and with enough length of exposure and etching effects to give an advantage over, say drill core sections. The story to do with bedrock geology is the most obvious one to follow and is illustrated by examples from Pungalina, NT and Golden Valley, Tas. But there is also another story to do with cave breccia fills, illustrated by examples from the Nullarbor SA and travertine deposits in the special case where they are affected by re-solution episodes illustrated by some examples from Pungalina. The story thus moves from caves merely as exposures to do with conventional geology more into something specifically speleological.

FIGURE 1. *Sample of* Conophyton *from Ballroom Cave*

At Pungalina

Commentary on the measured sections, and geological notes

Sections through the strata were measured in Balconies Cave and in Totem Pole Cave during the 2010 expedition. Both caves contain a "tuffaceous" section in the entrance zone of around 10 metres with stromatolites that include simple low dome and "pudding basin' types and do not include Conophyton above a section dominated by Conophyton, also of the order of 10 metre thickness. This has an upper portion in which the cones can be huge, divided by an interval most commonly including a green shale bed 1.5m thick, from more Conophytons in stacked columns on a smaller scale; these commonly weather brown in cave exposures. At the top of the Conophyton-dominated interval, smaller and deformed versions of the stromatolites develop which have dish forms between the stacked-cone columns. As the sediment associated with them becomes pinkish-brown tuffaceous mudstone rather than clean carbonate sediment, the cones become smaller overall and the dishes make up more of the colonies. Continuing input of this type of mud evidently killed off the Conophyton. The two sections correlate well down to the base of the Totem Pole Cave exposure which is thought to bottom at just below the first flourishing of Conophyton.

FIGURE 2. *Sample of "gargoyles" from Balconies cave (level with the head of the figure)*

The Balconies Cave section gets down considerably lower: its interval 24.1-24.35 is considered to correspond to 27.0-27.25 in Totem Pole Cave, at the very bottom of that measured section, and a marker just below the start of large scale Conophyton bioherm development. 8 metres lower comes the distinctive chert-replaced columnar stromatolites that make up the

gargoyles, and 2 metres lower still is the top of the interval with platy chert in which most of the cave is developed. This would appear to cover 6 metres of section with the base under water.

At the surface there is a cherty yellow dolomite unit present around Balconies cave and its approaches that is not present At Totem Pole Cave. The next bedrock unit up sequence is a sandstone mapped as Cambrian age Bukalara Sandstone but now thought to be part of the McArthur Group sequence, and therefore something else and as yet unnamed. The distribution of both these units hint at minor unconformities at the base of each. To illustrate this point the top tuffaceous section is present at Great Expectations Cave and its approaches and in the surrounds are the cherty yellow dolomite and further out, the "false" Bukalara Sandstone. At Bauhinia Sinkhole the sandstone is at surface presumably with dolomite below. At Totem Pole cave neither the sandstone nor the cherty yellow dolomite appear indicating non-resistant rock, most likely shale-dominant from a continuation upward of the tuffaceous section.

It is very likely that the gargoyles in Gargoyle Cave are the exact same horizon as the gargoyles in Balconies Cave; the brown-weathering Conophyton in Breccia and Ballroom Caves the same as the Lower Conophyton unit in Totem Pole Cave and the giant Conophyton in Conophyton Cave that of the upper Conophyton unit. It would seem that the caves of the area may be all in a dolomite interval barely 40 metres thick!

During the 2012 expedition another measured section was done in Conophyton Cave a few kilometres from Gargoyle Cave. A gargoyle type stromatolite bed was found low in the cave, of the same general nature as the one in Balconies and in the same position with respect to the major Conophyton development. In this cave the Conophyton zone is thinner, it stops at the entrance, there is no tuffaceous zone and just outside there is a form of flaky chert with small scale stromatolites in a kind of box cell construction with empty centres. This is also seen outside Balconies Cave so part of the sequence has been chopped out here. A nearby summit is capped with False Bukalara sandstone/conglomerate.

There is long standing uncertainty as to how the Karns Dolomite relates to the sequence seen at McArthur River to the west. Clearly the Karns Dolomite is a reduced and truncated

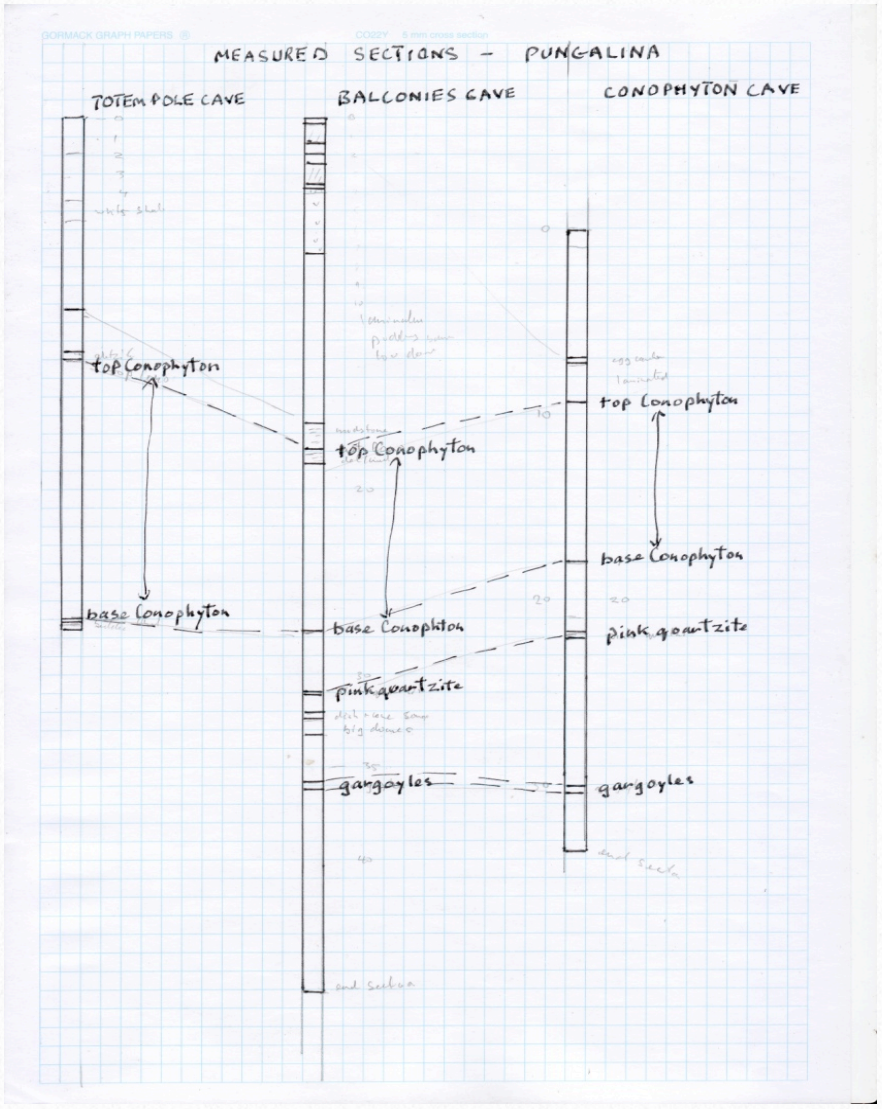

FIGURE 3. *Measured sections - Pungalina*

equivalent of the much thicker and complete sequence at MacArthur River, but is it equivalent to only to the Nathan group at MacArthur River, that is, the upper part as suggested by NT Mines Department staff or does it equate to the McArthur Group below? In the Pungalina area the rocks resembled bits out of the part of the Umbalooga sub-group of the McArthur Group that I used to work on at McArthur River: the Mara Dolomite (lots of Conophyton), the Barney Creek Formation (impure dolomite with tuffaceous material – a bit of shoehorning required) and Reward Dolomite as defined by Carpentaria Exploration (yellow cherty and no Conophyton). No rocks resembling those that are distinctive in the Batten sub-group sequence were seen but I am told (Maxwell Brown pers. comm.) there is an Upper Karns Dolomite outcropping along the N-S trending stretch of the Savannah Way West of Pungalina, which is stratigraphically above the "false Bukalara", in which Batten sub-group rock types are present.

For the moment I am inclined to think of the Karns Dolomite as seen at Pungalina as a reduced and truncated version of the Umbalooga sub-group of which I have seen only the upper portion. I suspect what has happened is that when

deeper water deposition took place in the McArthur area (Batten Trough) deposition could occur in the Karns Dolomite area (Wearyan Shelf) but not otherwise; so that where evaporite/mudcrack rocks were happening to the West, non-deposition or erosion happened instead on the shelf to the East. The "false Bakalara" would seem to be terrestrial sandstone represented in the Batten Trough by marine sandy dolomite in the Lynott Formation at the base of the Batten subgroup.

At Golden Valley

A cave in and around the basal unconformity of the Tasmania Basin, only partly in Gordon Limestone

The least aberrant of these new-to-us caves is Whatleys Hole which is at least partly in Gordon Limestone, in pretty much the very last exposure of a belt that goes to Mole Creek largely in subsurface. The rest of the cave is in the Stockers Tillite that is the basal unit of the Tasmania Basin sequence running from Late Carboniferous through Permian into the Triassic. As you stand in the cave passage from about waist down the rock looks like slate but is actually impure limestone with a lot of mica partings along a bedding plane cleavage, your head is in a ceiling channel what looks like conglomerate but the stones are faceted not rounded and so are essentially glacial, and the matrix is unsorted looking so it can be called reworked tillite. It is undercut where a weak layer about 30cm thick has been preferentially removed to make a shelf which is at and above the glacially cut surface on the Gordon Limestone. But there are surviving patches of the preferentially attacked rock remaining on the glaciated surface. It is a rock compositionally limestone judging by etched surface effects but also actually tillite. It is not uncommon for a till to derive almost entirely from close by and there would have been enough Gordon Limestone immediately to the south and west to provide a limestone-ground-to-rock-flour source for the original till. We have here a paradox in that the tillite is more of a cave-forming limestone than the Gordon itself at this point, and is preferentially dissolved out. The situation here matches that to be seen in Marakoopa Creek at the waterfall upstream of the track crossing going to Devils Pot, where there a thin basal deposit of more ordinary true tillite with very similar reworked tillite above it. At this locality it is possible to see glacial striations on a rock nubbin projecting on the unconformity surface. The cave does not appear to have any connection to modern drainage and in this respect is like the caves up the hill. Bear with me for going all geological but

FIGURE 4. *Stocker's Tillite resting on Gordon Limestone*

this is highly significant, geological monument level stuff and there is much more to caves than pretty stalactites and creepy-crawlies.

Some caves partly in a thin limestone at the top of the Glencoe Formation, but extending into Billop Formation

The next lot of caves are up the hill in a small escarpment below the Whatley's house. Going up the hill the rock sequence goes Quamby Mudstone, Glencoe Formation (fossiliferous with dropstones and minor limestone) Billop Formation (a fairly resistant silty/sandy matrix rock packed with fossils and glacial dropstones), Macrae Mudstone, Liffey Sandstone. The Billop Formation is resistant enough to cause the bench the house is on. The limestone of interest is just underneath it, so potentially following the Billop across the country and looking just below it is the way to spot any more caves. Note this limestone is not the same thing as the better known Permian limestone over on the East Coast of Tasmania, which has a few caves in it and hosts fauna 5. Caves have not been previously even been suspected to exist in Glencoe Formation limestone which has fauna 2. It was thought that there were only thin and sporadic beds of limestone present on the strength of a borehole section nearby but the limestone reaches nearly 7 metres a few km East along Quamby Brook.

The caves in the limestone at the top of the Glencoe Formation on the Whatley's property are at the base of minor cliffs in the Billop Formation and have ceilings of Billop Formation material. This is best seen in the Kids Cave which is widest at the formation boundary. The ceiling is studded with the drop-

FIGURE 5. *Upper half is in Billop Formation, and bottom half is in Glencoe Formation*

FIGURE 6. *A representative blowhole entrance shaft*

stones falling to the seabed from floating icebergs to the inconvenience of the shelly fauna of the time which makes up around 20% of the rock, limy enough to produce a patch of stalactites. The part of the wall underneath is limestone and it slopes evenly to a floor canyon; giving a typical cross section for a karstic cave. The other cave near the house is a flattener with a draught, recently dug enough to see to the next bit that has to be dug to see any further. A new cave found among the blackberries is bedrock floored with the limestone only about 30cm thick in the walls. It is wet belly crawl to what looks like an old mudbank. None of these caves amount to much at the present but they are clearly unrelated to modern drainage and make best sense as ancient features related to basin-wide artesian circulation. So if the entrance blockages are passable the caves might just keep going, but as belly crawls?

On the Nullarbor

Nullarbor fills story

The caves that have been turning up on the VSA expeditions have preserved features of some rather odd geology giving an idea of happenings later than deposition of the Nullarbor Limestone and prior to development of the powdery pinkish brown surface soil. There is more to the typical blowhole than the small vaguely vadose cave cut in Nullarbor Limestone, starting in a doline in the same rock, with a bit of dirt around it, assumed to be derived by weathering of the limestone which is what one might expect from a superficial account of Nullarbor blowholes.

FIGURE 7. *Grey clast limestone breccia at surface*

Figure 8. Calcrete horizon surrounds caprock entrance partly in grey clast breccia

Figure 9. Detail of grey clast breccia as caprock

FIGURE 10. Shaft entry of 5N4618. Partly developed in three generations of earlier fills

Pretty well all the caves are of phreatic character with the typical shaft being a stack of blobby ellipsoid forms and passing down into spongework in situations where a cave gets beyond the entrance blockage effect of a stream coming in from the entrance, which tends to just fill in the cave without doing anything to adjust wall sculpture. The dongas– big level flats at the local low points – typically lack cave entrances, and according to what the wombats show us have thicker earth cover.

The entrances can occur anywhere but mostly on the sort of steeper areas out from the dongas. Many entrances show evidence that they are formerly closed cupolas that have just broken the capping. Furthermore many are partly in breccias

FIGURE 11. *The pipe which contains dark grey clasts is inside a larger and older pipe with pseudofulgarites (bent rods formed along roots in sand dunes as a rule) from Footprints Cave 5N4745. So far the breccia type dominated by pseudofulgarite clasts has only been found in this cave. It is interpreted as sampling a vanished landscape with coastal foredunes which preceded the development of the commen black limestone often seen in pipe fills.*

which post-date the Nullarbor Limestone itself and which themselves are fills of former caves very like the ones that are there now. The implication is that cave development on the Nullarbor is essentially old and relates to a time when the water table and presumably some ground, was above the present surface. Also that the site of a blowhole tends to persist as a cave and be repeatedly re-established.

Where pipe fills of breccias of differing character have cross-cutting relations some kind of event sequence can be sorted out, as is the case in the photo on the right where there are 2 generations of grey clast breccia rimming a core of pink breccia, all filling a previous shaft, and exposed in the present open shaft. The strange rock types in the breccias show what once existed at the surface and has now gone. The fills give evidence of a vanished surface geology. The breccia clasts of black unfossiliferous limestone are sometimes coated with laminated buff limestone (probably developed in soil; that is the black is the core of a rudimentary pisolite; a concretion growing like a pearl in an oyster). This black limestone is intriguing stuff, it would seem to have formed in a toxic lagoon of some kind. There is a later breccia fill found only in Footprints Cave so far, where there is a pipe within a pipe. The outer breccia pipe has clasts with the black limestone; the in-

FIGURE 12. *Well developed pseudofulgarite bits and pieces etching out of breccia, note absence of black limestone clasts.*

FIGURE 13. *Peeling crust of cave coral exposes marine fossils*

FIGURE 14. *Older travertine with column engulfed by subaqueous layered travertine*

ner is packed with pseudofulgarites – calcareous concretions which encrust roots in coastal dunes. There is also some red-matrix breccia, not so consistently lithified which would seem to be later.

There is also travertine of more than one generation. Cave coral is abundant most commonly as a crust which is peeling off under present conditions though some is active. Travertine which is dark brown but otherwise of normal, humid climate forms is common and earlier generations have been redissolved as part of the wall in the present open caves though necessarily deposited in an earlier cave, at that time air-filled. Later on the former airspace has been filled with horizontally layered travertine deposited underwater. So the high water conditions have been interrupted by low stands occurring in a wet climate. The older travertine may even pre-date the earliest breccia pipe fills.

Later travertine looks just like ordinary cave formations but usually shows some breakage relating to floor subsidence and salt wedging. Washed in earth and stones are built up against these formations. The climate has changed away from something genuinely wet.

There are samples of a geology later than the lithification of the breccias. There is red sand found in some sinkholes and as reworked sand in a few caves. Is this the local expression of the Parilla Sand of the Murray Basin? The Parilla makes up dozens of beach ridges inland from Naracoorte. Later still comes the calcrete and pinkish dust which make sense as a

FIGURE 15. *An example of red sand*

wind-blown deposit somehow related to the Bridgewater Formation. The calcrete layer goes further than the Nullarbor and isotope studies match it to seawater implying that the calcium come down in the rain. The earth component does not resemble what could be expected as residue from dissolving the Nullarbor Limestone, but is possible for the dust of duststorms. It is within this deposit that the tektites are found so it was there 800,000 years ago. At some time previous it would seem the Nullarbor was largely stripped back to bare rock.

Pungalina again, dealing with travertine mainly.

Quite early on in the VSA Pungalina project Jacques Martini (a geologist from Switzerland who worked professionally in South Africa) identified 4 phases of travertine deposition in Ballroom Cave, which is a big one for the area, well decorated and easy. But I needed to work out for myself what he meant by the 4 phases, and this required some thinking time on the spot. So, the presumed phase 4 would be the various stalactites stalagmites and flowstone which have intact depositional surface, microgours and the like; and phase 1 would basically be the very old white flowstone which shows evidence of having been through a large scale re-solution event, in which the old flowstone mass shows the same style of scoop-out hollows as the bedrock dolostone next to it. In other words after being an open air-filled cave with travertine deposition on a large scale there has been a return to underwater conditions (phreatic) in which the travertine and original dolostone have been corroded out without distinction, to make a new cave in roughly the same place as the previous one. To work out the other phases, it could be seen that there was a sequence break in the older material, best seen in big severely corroded columns, cutting right into the formations to expose the growth lines in the travertine. Here the younger material included predominantly yellow to brown and thin bedded, variously coloured travertine, and because of the degree of corrosion the growth lines were conspicuous. All four stages are visible in Figure 14.

The implication is that return to phreatic solution occurred twice. And working back from the phase 4 stalagmites there were others which had been corroded but only to the point of being peeled back by a few centimetres and preserving the overall shape of the original formation. This may be just a

FIGURE 16. *The four Martini phases of travertine:*
1 white
2 multicoloured
3 small canopy boss corroded back
4 ordinary stalactites

FIGURE 17. *The Dragon in Ballroom Cave: a four phase travertine mass*

subaerial weathering effect but another but a shorter return to phreatic conditions is indicated.

The caves of the area occur in a restricted height range with respect to the water table so there is potential for correlation of the stages between caves, since what is being attempted is matching of corrosion events linked to regional water table rises and falls. Totem Pole Cave however does not have any of stage 1 or 2 probably because the extensive rockpile section relates to collapse that was later. There is plenty of stage 3

(notably the actual Totem Pole stalagmite). Balconies Cave entrance cavern has some stage 1 and probable stage 2.

Consider the underside of the travertine mass above the figures. The fringe of shawl/stalactites is stage 4 travertine built up on a base of stage 3 travertine which has been corroded back to expose growth lines inward from the fringe to the margin of the buff/creamy travertine. The red cemented breccia is stage 2 and includes a blocks of stage 1 travertine, one quite large and with only rudimentary banded travertine. The main white, massive travertine (some grey) is stage 1. The triangle of brown rock at the right hand edge is bedrock. Note that the cut of the cave wall runs smoothly from the white travertine on to the brown dolomite.

References

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