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Karst and Paleokarst Features involving Sandstones of the Judbarra / Gregory National Park, Northern Territory, Australia

Judbarra Gregory
Karst Research SIG

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Abstract

In addition to carbonate karsts, the Judbarra / Gregory National Park of tropical northern Australia has karst and paleokarst features associated with Proterozoic sandstone units.

On a sandstone plateau in the Newcastle Range, there are several large collapse dolines formed in the Proterozoic Jasper Gorge Sandstone. As there is a carbonate unit, the Proterozoic Campbell Springs Dolostone, lying about 110 m beneath the plateau surface, these sinkholes may be subjacent karst features resulting from the upward stoping of large cave chambers.

In the Far Northern area of the Judbarra Karst Region, areas of chert breccia are shown on the geological maps, and linear bodies of brecciated sandstone are inset into the carbonate beds of the Skull Creek Formation. The sandstone is derived from the Jasper Gorge Sandstone, which overlies the Skull Creek Formation in adjoining areas. The breccia is interpreted as paleokarst of uncertain age resulting from subsidence of the sandstone into karst trenches or collapsed cavities developed in the underlying carbonate beds.

Keywords: Karst; sandstone; subjacent karst; paleokarst; Australia.

Introduction

The Judbarra/Gregory National Park of the tropical Northern Territory of Australia is well known for its carbonate karsts, described elsewhere in this issue (Martini & Grimes, 2012; Grimes, 2012). However, the area also has paleokarst and modern karst-like features associated with sandstone beds. This short note draws attention to two such areas (marked on Figure 1). As field work has been limited, this is only a preliminary description. Suggestions are made for more ground work, which is needed in both areas and elsewhere in the region.

Regional geology

The geological units of relevance to this discussion are listed below, and their regional and local distributions shown in Figures 1, 2 and 5. The following information is based on Dunster et al. (2000) and Sweet et al. (1974). The main stratigraphic groups and their ages are: Limbunya Group, 1.66-1.63 Ga; Wattie group, 1.57-1.5 Ga; Bullita Group, 1.46 Ga; Auvergne Group, 840-750 Ma; and a Cainozoic duricrust and chert breccia. Note that the numeric ages are poorly constrained.

Campbell Springs Dolostone (Limbunya Group)

This unit is exposed in the valleys of the Newcastle Range. It is a shallow marine dolostone and dolomitic siltstone, about 50 m thick. It is thick bedded, and a photo in Dunster et al. (2000, p.8) shows some karren development, but no caves have been reported.

Fraynes Formation (Limbunya Group)

Conformably overlying the Campbell Springs Dolostone in the Newcastle Range area is a chert and

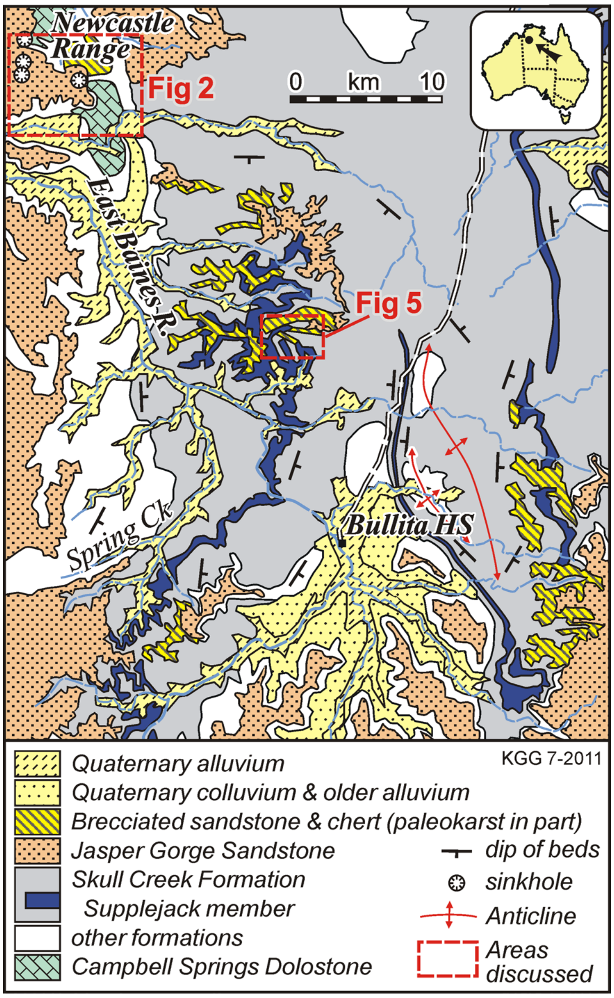


Figure 1: Regional location map (from Martini & Grimes, 2012), with rectangles showing the two areas described in this paper.

cross-bedded feldspathic sandstone unit up to 20 m thick. The chert is reported to be replacing carbonate, and has been locally brecciated, possibly during the Cainozoic (Dunster et al., 2000).

Wattie group

Unconformably above the Fraynes Formation is a poorly outcropping unit of micaceous siltstone, sandstone (a 5 m thick unit) and minor dolostone. The total thickness is not stated by Dunster et al. (2000), but where it forms part of the scarp in the Newcastle Range site it seems to be about 40-50 m (Figure 3).

Skull Creek Formation (Bullita Group)

This unit comprises silty and quartzic dolostone, dolomitic siltstone, dolostone and dolarenite. It is absent in the Newcastle Range as it was eroded away before deposition of the younger Jasper Gorge Sandstone. However, to the east it is the main karst-forming unit in the Judbarra / Gregory Karst Region (Figure 1) and includes the Supplejack Dolostone Member, which is described in more detail in the accompanying paper by Martini & Grimes (2012). This carbonate unit underlies the paleokarst breccia of the Far Northern area of that region (Figure 5).

Bynoe Formation (Bullita Group)

A slightly dolomitic siltstone and sandstone unit that conformably overlies the Skull Creek Formation elsewhere in the region.

The 'Bardia Chert member' or 'silcrete/duricrust' (uncertain age)

This problematic unit was first described by Sweet et al. (1974) as a chert breccia developed on dolomite at the top of the Skull Creek Formation, and was thought to be Proterozoic in age as it had been seen conformably overlain by the Bynoe Formation and in places it had been folded along with the Skull Creek Formation. However, Dunster et al. (2000, p.29) reinterpreted it as a younger weathering effect, and possibly a type of Cainozoic duricrust, that unconformably caps several different Proterozoic units.

Thus the brecciated cherts would seem to be of several types and ages, which have not been differentiated in the mapping. Possibly both authors are correct, as chert breccias associated with Proterozoic dolomite beds are fairly common across the Northern Territory and Western Australia and they can form in a variety of ways – several of which involve post-depositional solution that can produce paleokarst breccias (see later discussion).

The 'Bardia Chert' (pending a better name) is described as an internally brecciated chert, associated with and modifying dolomite beds, that is up to tens of metres thick but with significant variation over short distances (Sweet et al., 1974) . Sweet et al. (1974) report it developed on the carbonates of the Skull Creek Formation (Figure 1), but Dunster et al. (2000) also map it overlying other units, including the Campbell Springs Dolostone & Fraynes Formation in the Newcastle Range area (Figure 2).

The geological maps show discontinuous areas of the unit in both of the sandstone karst areas discussed in this paper (Figures 2 & 5). However, my field work found that at least some of the material mapped in the Far North karst area is actually a sandstone breccia.

Jasper Gorge Sandstone (Auvergne Group)

This is a resistant sandstone unit that caps flat-topped mesas and ranges throughout the region (Figure 1). It is unconformable on all the older units, with a major erosional time break, but only minor structural deformation. The unit is a near-shore marine, silica-cemented quartz sandstone and siltstone, with a basal conglomerate. Its maximum thickness is 130 m, but the upper part may have been removed by erosion in some parts of the area – especially in the paleokarst area described below.

THE NEWCASTLE RANGE SINKHOLES

This area is a dissected sandstone plateau in the Newcastle Range, to the northwest of the Judbarra / Gregory Karst Region (Figure 1). Three large collapse dolines and two smaller ones occur on the top of a plateau of Jasper Gorge Sandstone (Figure 2). Three

Doline	Latitude	Longitude	Width	Depth	Comments
AUB-1	15° 50' 30" S	130° 16' 05" E	70 m	~30 m	Steep conical form, partly cliffed. At edge of a major scarp.
AUB-2	15° 50' 08" S	130° 13' 44" E	70 m	~50 m	Deep, cliffed sinkhole. Visited by Bannink & others in 1993.
AUB-3	15° 49' 59" S	130° 13' 47" E	30 m	shallow	Partly degraded ?
AUB-4	15° 50' 00" S	130° 13' 18" E	30 x 10 m	shallow?	In a sandstone pavement with grikes. Grikes and sinkhole elongation both strike 160°.
AUB-5	15° 48' 42" S	130° 13' 58" E	40 m	deep?	Close to edge of valley. Steep cliffed edges. Floor hidden beneath trees with dense green canopy

Table 1: Collapse dolines (sinkholes) on the Newcastle Range. Location and widths measured from Google Earth. Depth of sinkhole AUB-2 estimated on site by Peter Bannink, others estimated from stereo air-photos.
'AUB' is the Australian Karst Index code for features in the Auvergne 1:100k map sheet.

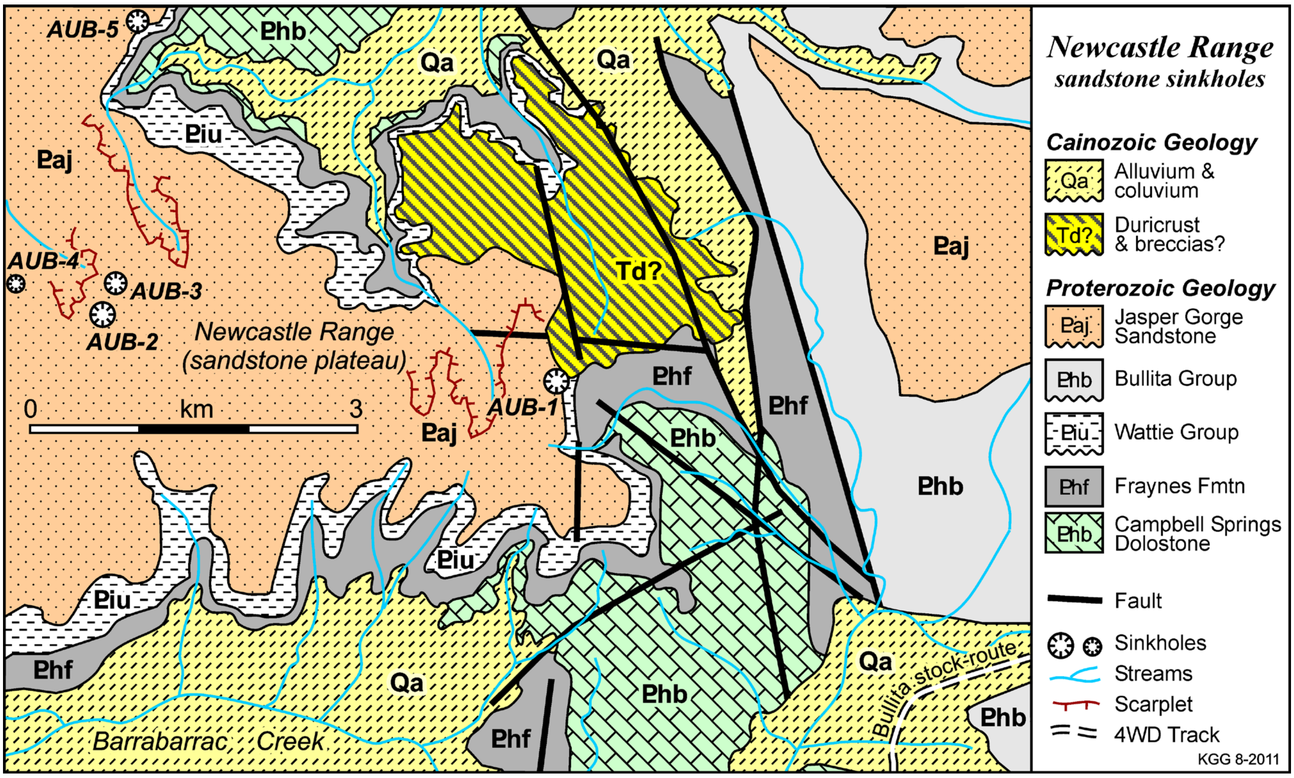


Figure 2: Newcastle Range geology (based on Dunster et al., 2000) and locations of the sinkholes.

of these are shown on the geological map (Dunster et al., 2000), and they were referred to briefly by Dunkley (1993). The geological map shows that the sandstone is underlain by several other Proterozoic units and eventually, about 110 m beneath the plateau surface, by Campbell Springs Dolostone (Figures 2 & 3, and see Geology section above for details). Table 1 summarises the information on the sinkholes.

Peter Bannink and members of the Top End Speleological Society visited sinkhole 'AUB-2' in 1993. The collapse doline is 70 m wide and about 50 m deep, with steep and locally overhung walls (Figures 3 & 4). Access to the bottom is from the NE via a small cliff then a steep rubble slope. It is developed mainly in sandstone, but Bannink (pers. comm., 2011) reports a thin-bedded mudstone at the bottom which might be the top of the Wattie Group. The upper part of the sandstone is thick-bedded, but towards the base the bedding is thinner (Figure 4).

Two of the sinkholes (AUB-1 & AUB-5) are very close to major scarps above deep valleys which have dolostone outcrops at their base. The dolostone beds have not been explored for cave entrances, but Keith Claymore reported springs in dolostone in 1992 (Susan White, pers. comm. 2011). The air-photos show an area of denser vegetation in the head of the valley beneath AUB-1, and similar vegetation areas are seen in valleys further to the south. These might indicate springs, although some of this vegetation may merely be a response to the sheltered environment in the narrow valleys.

Interpretation

A major dolomite bed, the Campbell Springs Dolostone, occurs about 110 m beneath the plateau

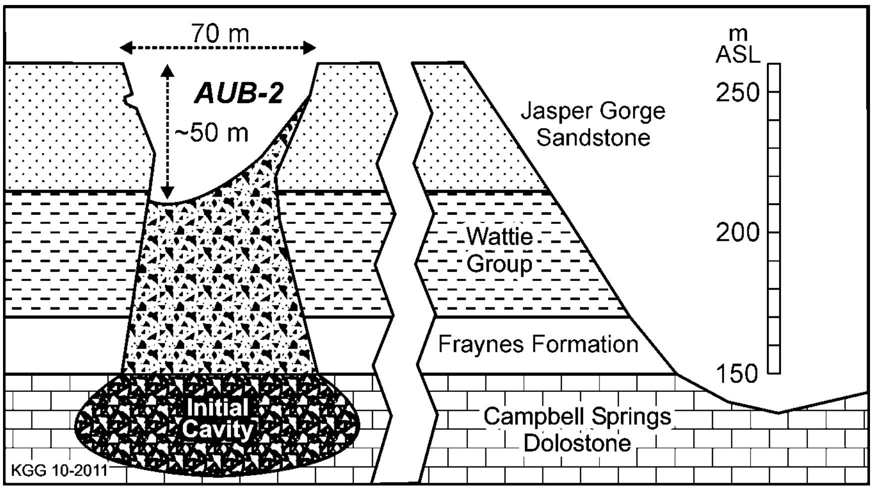


Figure 3: Profile of the AUB-2 sinkhole and scarp of the Newcastle Range, showing geological units and interpreted extent of the collapse breccia. The sinkhole is shown at real scale, but the slope of the scarp is exaggerated x3. Based on a sketch of the sinkhole provided by Peter Bannink, and air-photo interpretation guided by the geological map.


Figure 4: The southern wall of sinkhole AUB-2 on the Newcastle Range, taken from the surface. Photo by Peter Bannink, 1993

top, and lesser carbonate beds occur in the Fraynes Formation and Wattie Group. So the sinkholes may be subjacent karst features (*sensu* Jennings, 1985, p.112) resulting from breakdown which commenced above a large solutional cavity in the dolomite, and then stoped upwards through the overlying formations to reach the surface of the plateau (Figure 3).

Recommendations for further work:

- Explore the dolostone outcrops at the base of the scarps for possible springs and caves.
- Survey the dimensions of all sinkholes.
- Measure stratigraphic sections within AUB-2 and AUB-1, and up the scarp adjoining AUB-1, to verify the lithologies and unit boundaries.
- Visit the area to the north-east of the AUB-1 sinkhole that is mapped as duricrust / chert breccia by Dunster et al. (2000). What is the nature of this material?

Ground access to the eastern sinkhole, AUB-1, is possible by a rugged 4 km walk from the Bullita stock route (Figure 2). The western group are a further 4 km walk across the plateau.

Sandstone Breccias in the Far Northern Karst

In the Far Northern area of the Judbarra / Gregory Karst (Figure 1), linear bodies of brown sandstone rubble are inset into the carbonate beds of the Skull Creek Formation. The main drainage here is to the south (Figure 5), but some valleys at right angles to this are following bands of loose sandstone rubble.

The base of the sandstone unit is very irregular and unconformable on both the underlying Skull Creek Formation and the Supplejack Dolostone Member (Figure 6). The deepest parts of the unconformity surface are linear trenches, 50-100 m wide and up to 50 m deep, which seem to be following linear fault traces (south-east to east trends, Figure 5). These form valleys with normal, horizontal bedded, Skull Creek and Supplejack outcrops on the sides, but interrupted at intervals along their length by saddles of the brown sandstone. Where seen, the contact with the carbonate is sharp, linear and steep. Solid outcrops of flat-lying carbonate stop abruptly and are replaced by loose angular boulders and cobbles of brown quartz sandstone (Figure 7).

The sandstone forming the rubble is quartzose, brown to grey-brown, fine to medium and coarse-grained with scattered rounded pebbles of quartz. The sand grains are moderately to well-rounded and moderately to well-sorted. Bedding varies from thin (0.5 - 2cm) to thick and a set of small tabular cross-beds, 20 cm thick, was seen in one place. There are a few rippled surfaces and one set of climbing ripples. The rock is hard; a quartzite, but not a silcrete.

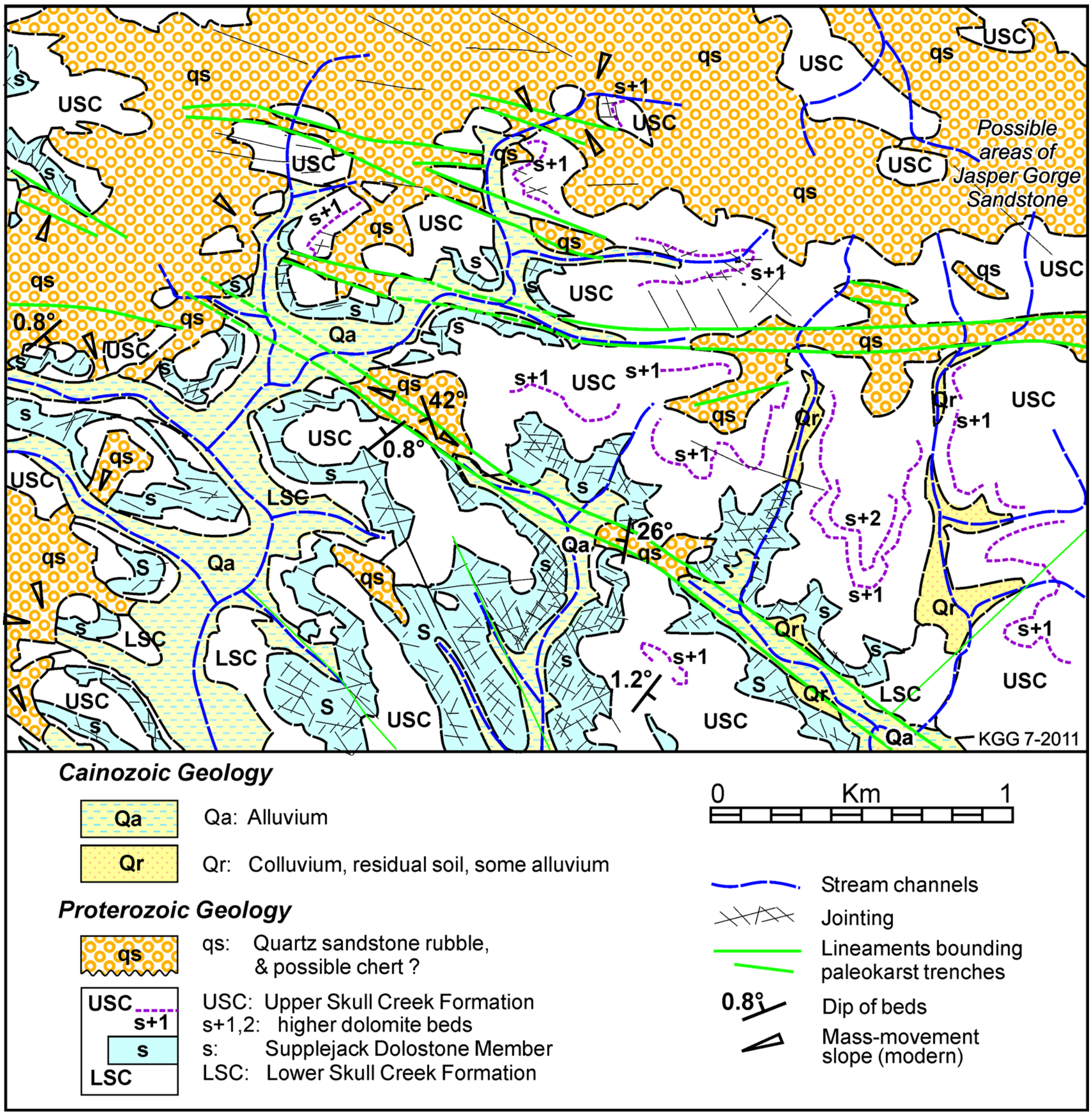
The lack of solid outcrop prevented reliable measurements of dip, but in two places large blocks and groups of boulders have apparently consistent dips, measured at 26° and 42°. These are much steeper than the limestone beds on either side, which average only 1 degree of dip (Figure 5).

Geological interpretations

The rubble is interpreted here as a post-depositional breccia, and possibly resulting from karstic subsidence (see next section).

Its full extent is uncertain. The unit has a distinctive brown colour on the air photos, and is a common capping on the ranges in the Far North area. This material was originally mapped as the 'Bardia Chert' but then revised to Cainozoic 'duricrust/silcrete' (see discussion of alternative interpretations in the Geological section of the Introduction). Both interpretations would have been based on similar appearing outcrops seen elsewhere. In this area the upper erosional surface of the brown unit is irregular – there is no flat mesa structure such as one might expect from a silcrete cap. Further ground work is needed to resolve the extent of the sandstone breccias and to determine the nature of the brown material on the ridge tops.

Figure 5: Geological map of part of the Far North Karst area. Based on air-photo interpretation and localised field inspections.



Although the inspected outcrops were sandstone breccia, it is quite possible that some of the brown material in the area is chert breccia, because elsewhere in the Northern Territory chert breccias are common at the tops of dolomite beds and have a variety of ages and modes of formation. For example, in the Mt Young sheet area of the McArthur Basin (Haines et al., 1993), five of the ten Proterozoic dolomite formations have associated chert breccias that appear to be at least partly paleokarst (solutional) in origin. Several of the dolomite units also have intraclast breccias reported, which are not karst related; so one needs to read the reports with some care. Some of the solutional breccias are thought to be syngenetic with deposition, forming during brief periods of emergence of the shallow sea floor; others are diagenetic, involving meteoric waters under Proterozoic land surfaces; and still others are much younger modifications involving vadose solution at unconformities of Paleozoic, Mesozoic or Cainozoic age.

A similar situation occurs in the East Pilbara region of Western Australia, where the Pinjian Chert Breccia is a multi-age unit developed on Proterozoic dolomites by weathering in several stages during the Proterozoic and Cainozoic (Williams, 1989; and see summary in Grimes, 2002).

Small areas of Proterozoic Jasper Gorge Sandstone are mapped on the ridge tops about 5 km further to the north-east by Dunster et al. (2000). That unit is a quartz sandstone which lies unconformably above the Skull Creek Formation (see Introduction) and is a likely source of the sandstone breccia.

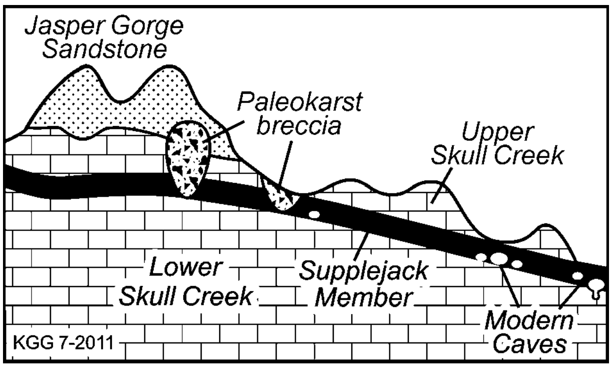


Figure 6: Schematic section of the paleokarst bodies in the Far North Karst area.

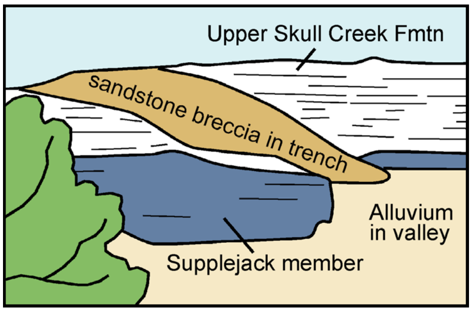


Figure 7: A body of brecciated sandstone inset between areas of flat-bedded Skull Creek Formation in the side of a modern valley. Photo by KGG.

Paleokarst interpretation

It seems likely that the sandstone in the valleys is part of the Jasper Gorge Sandstone, but the very irregular and steep contact with the older carbonates, the chaotic rubbly outcrop, and the two anomalous steep dips suggest that it was brecciated in a paleokarst situation – subsiding into an underlying cavity. The irregular basal contact might be partly a buried Proterozoic karst surface, but continuing solution in the carbonate after deposition of the sandstone would have caused subsidence and brecciation of the sandstone. Alternatively, it is possible that some of the breccia formed as scree falling into a narrow surface canyon cutting both the Jasper Gorge Sandstone and the underlying carbonates, but the extent and thickness of the material makes that unlikely.

The age of this brecciation is uncertain. It must postdate deposition and lithification of the Proterozoic Jasper Gorge Sandstone (about 800 Ma), and the loose nature of the brecciated material suggests that it is fairly young. However, it must predate the present erosion cycle as the modern drainage cuts across the belts of breccia, leaving remnants as saddles between adjoining valleys (Figure 5).

The simplest interpretation is that both the breccia and the linear trenches it fills are fairly recent (Tertiary?) features resulting from solutional development of large linear cavities within the Supplejack Dolostone Member. Upward stoping intersected the base of the sandstone and allowed brecciated material to fill the cavities.

An alternative, more complex, interpretation is that the Jasper Gorge Sandstone was deposited over a pre-existing irregular karst surface with linear trenches. In that case the linear structures are Proterozoic, but the post-depositional brecciation of the sandstone would be a younger event resulting from further solution of the carbonate beneath it.

In either case, the size and geometry of the breccia belts imply the existence of large straight cave conduits, following major lineaments (possibly faults?). This style is quite different to the present-day shallow maze-cave development described by Martini & Grimes (2012), examples of which occur in the Supplejack outcrops adjoining the trenches. Thus, the paleokarst must predate the present erosional cycle and could be a more deep-seated phreatic style, possibly even a result of hypogenic waters rising up the fault lines. Beier et al. (2002) report lead and barite mineralisation in the Skull Creek Formation, but that appears to be syngenetic or epigenetic, not hypogene in origin.

Recommendations

More ground data is needed in this area, especially concerning the ridge top deposits shown in the northern part of Figure 5. Are these sandstone or chert? Is the material brecciated or solid?

There is also a need to look at other areas that have been mapped as 'Bardia Chert' or 'Silcrete/duricrust' – how many variants are there of this unit? One such area lies immediately to the north-east of the eastern sinkhole (AUB-1) in the Newcastle Range (the 'Td' area on Figure 2). Another lies on the ridge to the southeast of the Spring Creek karst area (Figure 1).

A closer study of the trough-filling breccias and the adjacent dolomite outcrops is needed – looking for evidence of mineralisation or alteration that might support an older hypogene origin of the paleokarst.

Note that access to the area shown in Figure 5 is difficult, involving a 5-8 km hike from Limestone Creek over arduous terrain. The Traditional Owners have requested that visitation to parts of the area be restricted to males only.

Discussion

The two areas described above each have karst-like features associated with sandstones. In both cases the sandstones appear to have subsided and been brecciated in zones overlying karst cavities in the underlying carbonate strata and are therefore subjacent karst collapse features.

At the Newcastle Range the sinkholes are in a plateau surface, and the breccia zone is not seen, but is interpreted as extending beneath them (Figure 3). The steep and partly overhung walls of the bigger sinkholes suggest that the subsidence is continuing at present, so these features may be part of the present day erosion cycle.

In contrast, in the Far Northern area of the Judbarra / Gregory Karst the modern erosion has progressed further. It has exposed the breccia zones and removed much of the brecciated material to leave linear valleys at right angles to the modern drainage lines. If any of these breccia zones reached a prior land-surface to form sinkholes, all traces have since been removed.

The spaced and linear nature of the bands of breccia suggest that the originating cavities were in a different style to that of the modern maze caves. Thus the paleokarst breccias in this area predate the present erosional cycle and might be as old as the Proterozoic.

Acknowledgements

The management of the Judbarra / Gregory National Park (previously Gregory National Park), granted permission to perform the scientific investigation and to publish this article.

Peter Bannink provided photos and descriptions of the Newcastle Range sinkhole AUB-2, and identified two others that were not shown on the geological map. Nick White assisted in my field inspection of the Far Northern karst in 2005.

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