Non-Meteoric Speleogenesis: Evidence from Eastern Australia

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Abstract

Many caves in Palaeozoic limestones of eastern Australia have morphological, hydrological and mineralogical features indicating a non-meteoric, hydrothermal or artesian origin. Some caves decrease in volume with depth. Structurally guided cavities frequently terminate in blind ends. Cupolas, spongework, pockets and blades are common. Many caves intersect palaeokarst. Caves are often poorly related to the surrounding hydrology. Some caves and whole karsts lack streamsinks, springs or both. Cave streams postdate the main phase of excavation. Palaeokarst and less-soluble bedrock is altered, with pyrite and dolomite emplaced. These weather to form aragonite, huntite and gypsum. Etched walls, spar coatings and boxwork are common. Some caves contain remnants of iron-rich carbonate fills.

Introduction

Small impounded are common in the Palaeozoic fold belts of eastern Australia (Fig. 1).

The Palaeozoic limestones in which these karsts have developed have often undergone multiple periods of deformation and frequently have steep to vertical bedding. Despite their small size and impoundment by insoluble rocks, these karsts can be quite cavernous.

Many of the caves in the eastern Australian Palaeozoic karsts have morphological, hydrological and mineralogical features which suggest that they were either formed entirely or partly by water (most likely warm water) rising from below, rather than by sinking meteoric water. In addition many of the most cavernous bodies of limestone are closely associated with small hydrothermal ore deposits and some cavernous limestones have warm springs rising through them (OSBORNE, 1996). This paper reviews the features of the caves that are suggestive of speleogenesis by rising water.

Morphology

Eastern Australian caves have a distinctive morphology, while some of this can be accounted for by development in steeply-dipping limestone and by paragenesis (OSBORNE 1999a), conventional explanations have failed to account for many of their outstanding features.

Downward Narrowing Profiles

Many caves, such as the deep caves at Bungonia in New South Wales (Fig. 2) have a funnel-shaped profile, with cavities reducing in diameter with depth. It is very common for eastern Australian caves either to terminate blindly at depth, or to connect with small stream passages. The stream passages are usually smaller in cross-section the upper sections of the caves which they drain and have tortuous structurally-guided paths.

Downward narrowing of caves is observed in many eastern Australian karsts. It was previously explained as being due to higher water flows in the past. The enlarged midlevels of these caves, however consist of cupolas and blind halls (see below) and so could not result from fluvial action under wetter conditions in the past. Solution by upwelling water, rather than sinking meteoric water, could account for the upward enlargement of these caves.

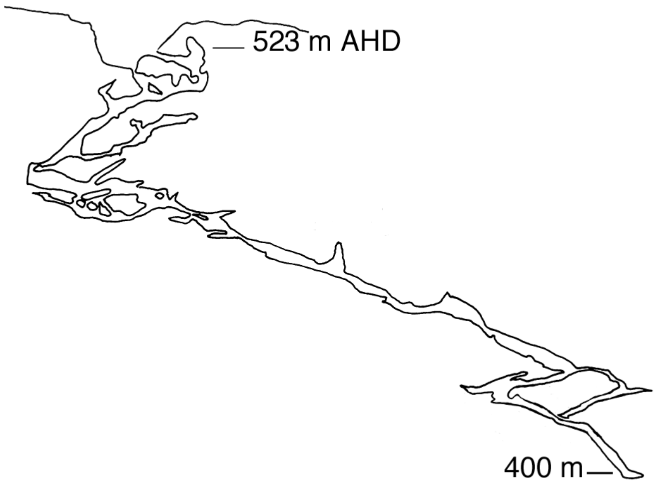

Fig. 1 *Fig. 2*

Fig 1. Karsts in Palaeozoic Limestones of Eastern Australia

Figure 2. Section of Grill Cave, Bungonia, A downward-narrowing cave after BAUER & BAUER (1998)

Hall and Narrows Caves

There are many relatively small network caves in eastern Australia. They generally consist of elongate north-south trending passages (halls) developed along the strike of the steeply dipping limestone, joined at right angles by short passages, which follow joints (narrows) (OSBORNE, 2001).

The key feature of these caves is that the halls terminate blindly in bedrock or mud plugs. Low velocity phreatic speleogens, such as roof pendants, wall and ceiling pockets and spongework are common, while scallops are rarely developed. Cupolas are often developed at the ends of halls (Fig. 3).

In some karst areas (eg. Bungonia) hall and narrows caves form groups aligned along strike. Adjacent caves often have halls developed at similar elevations in the rock. These have frequently been interpreted (OSBORNE, 1993) as representing sections of phreatic conduits along which water formerly flowed. This is not possible, since the halls have blind ends.

Downstream Narrowing Mazes

Exit Cave in Tasmania (Fig 1) is one of the most extensive caves in eastern Australia. It consists of over 40 km of network passages through which a major stream is captured underground. The captured stream flows through only some of the passages. And the trunk passage through which it flows becomes narrower downstream. There does not appear to be any lithological or structural impediment constricting this passage, rather it would appear that the passage width is unrelated to its situation in the course of the stream. This suggests that the stream was captured by the cave, rather than being responsible for its formation. BAKALOWICZ *et al*. (1978) noted that mazes of hydrothermal origin did not show a systematic increase in passage width downstream.

This particular observation is of limited application, since most network caves in eastern Australia, eg those at Cliefden (Fig. 1), do not contain active streams.

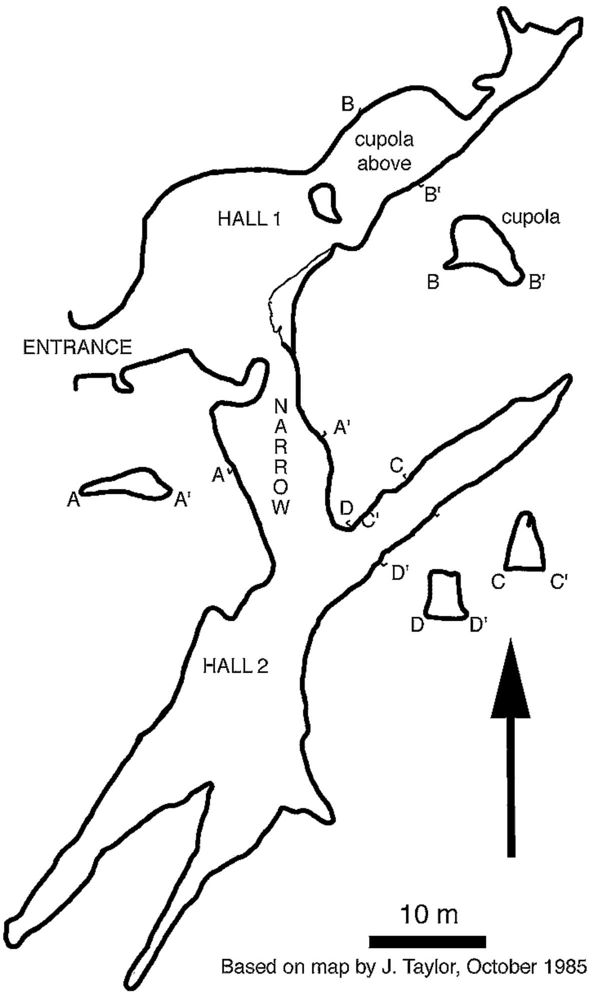

Figure 3. Map of Yessabah Bat Cave A Hall & Narrows Cave

Cupolas

Large cupolas are common in these caves. At Jenolan Caves (Fig 1) cupolas up to 80 m high and 20 m in diameter are key features of the show caves. Some of the larger chambers at Jenolan are sets of coalesced cupolas, while other groups of cupolas are grouped in rising sets.

The apices of these cupolas are flat to gently-domed and they show no sign of penetration upwards into a guiding joint or bedding plane. The apex of the cupola is often modified by the development of rounded pockets and bellholes, which also lack a specific structural orientation.

In many complex caves such as at Jenolan, cupolas are isolated from active streamways. Where stream passages and cupolas do intersect, the pattern of cave development suggests that the streams intersected the cupolas by chance, rather than being part of the same developmental process.

"Nothephreatic" Caves

The term "nothephreatic" has been used in Australia (see JENNINGS, 1985) to describe caves that were excavated by diffuse flow under phreatic conditions. These caves are characterised by speleogens such as spongework, rock pendants, wall and ceiling pockets. Jennings cited Octinska Aragonite Cave in Slovakia and Wellington Caves (Fig. 1) as examples of this type of development.

Many caves in eastern Australia that lacked evidence for dynamic phreatic or fluvial development were characterised as "nothephreatic" (OSBORNE & BRANAGAN, 1988). These caves exhibit many of the morphological characteristics described in this paper. As a consequence their origin is currently under review.

Intersection of Palaeokarst

It is not uncommon for eastern Australian caves to intersect, or be guided in their development by, palaeokarst deposits. Good examples have been documented at eleven major cavernous karsts. Internationally this is not a commonly reported phenomenon (OSBORNE, 2000).

Some intersection of palaeokarst can be expected to result as a consequence of development being guided by vertical inception horizons, and from paragenesis (OSBORNE, 1999a).

These mechanisms do not, however account for the exposure of palaeokarst deposits in the walls of large solution chambers and cupolas at Jenolan, Timor and Wellington.

FORD (1995) noted that palaeokarst was more likely to be interested and control the development of caves formed by ascending waters that in the case of caves formed by descending meteoric waters. If this is so then the frequency of exposed palaeokarst deposits in eastern Australian caves is a strong indicator that non-meteoric processes played a role in their development.

Hydrological Evidence

Many eastern Australian caves appear to have little relationship with the hydrology of their surrounding environment. Isolated caves on the top of hills are common (at Timor and Wombeyan, Fig. 1). At other localities (Bungonia, Fig. 1) the springs draining complex cave systems are perched, for no obvious reason, almost 200 m above the present base level.

There are a significant number of caves, and some whole karsts, that lack permanent streamsinks or springs or both. Where springs, but not streamsinks are present these springs are simply returning vadose seepage water to the surface, rather than acting as a resurgence for a regional karst aquifer. The underground streams that feed these springs are underfit and apparently unrelated to the initial excavation of the caves through which they flow. Some caves located directly adjacent to swiftly flowing streams show no sign that a stream has ever flowed through them.

This isolation from both present (and postulated past) hydrological systems would be expected if the caves were excavated by rising non-meteoric waters than by descending meteoric water.

Mineralogical Evidence

Palaeokarst deposits and less-soluble units within the limestone bedrock exposed in the caves are frequently altered with the emplacement of pyrite and dolomite. Under vadose conditions, these minerals weather, producing aragonite, huntite, hydromagnesite and gypsum speleothems. Gypsum and hydromagnesite, developing in veins, are responsible for the development of breakdown zones directly adjacent to cupolas.

At Jenolan and Wyanbene the caves contain remnants of weathered ore bodies, and there is good field evidence that many caves have been, and/or are now in the process of being, exhumed by weathering and stoping of the ores. The remnants suggest that the unweathered ores were composed of ferroan dolomite, calcite and pyrite. The remaining remnants consist of calcite pseudomorphs after dolomite, iron oxides/hydroxides and limonite pseudomorphs after pyrite. The remnants either take the form of gossans or of slimy yellow mud. In part of Jenolan Caves there has been secondary enrichment of the weathered ore forming haematite nodules.

Some caves are party lined by coarse euhedral spar; others intersect crystal-lined cavities and expose crackle breccias. Reconnaissance isotope studies have shown that some of the spar linings have $\delta^{18}O$ PDB ranging from to –20 to –6 and a $\delta^{13}C$ ranging from –2 to +2, placing them in the deep-seated hydrothermal range of DUBLYANSKY (2000).

Cave walls are frequently deeply etched and/or altered. In many places (eg. Ribbon Cave at Jenolan) the wall surface is not composed of dense limestone, but of powdery micritised limestone centimetres deep. This is an alteration process, rather than a coating, as outlines of fossils in the bedrock are preserved in the micritised zones. At Bungonia Caves some limestone cave walls are silcified and basaltic dykes intersected by the caves have been bodily replaced by calcite, preserving their igneous texture.

The evidence suggests that two associations of low temperature (in the mineralogical sense) mineralisation were involved in cave excavation and filling: - An iron-carbonate association which micritised the cave walls, altered resistant bedrock and filled the caves with ferroan dolomite, calcite, ferroan calcite and pyrite.

A silica-clay association, which silicified cave walls and filled caves with kaolinite and illite.

Discussion

Many of the characteristics of caves developed in the Palaeozoic limestones of eastern Australia are not easily attributed to excavation by sinking meteoric water. Recently, I (OSBORNE, 1999) used evidence of the type described here to propose that at least two of the ten phases of cave development recognised at Jenolan Caves were caused by rising hydrothermal waters.

There is no evidence in the caves for water temperatures higher than 80 degrees. Where warm springs occur in the karsts today, the water temperatures are just below 30 degrees. The hypothesis I am currently testing is that there were one or more phases of excavation by warm (approx 30 degree) mineralised water which excavated cavities, altered wall rock and filled the cavities. In some instances iron-rich carbonates, dolomite and pyrite were deposited and in others silica and clays were deposited.

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