THE NEW SCIENCE OF EASTERN AUSTRALIAN CAVES: IMPLICATIONS FOR MANAGEMENT AND INTERPRETATION

Dr. Armstrong Osborne

Introduction

Until the 1980s there was a dominant view of how and when limestone caves in the Palaeozoic limestones of eastern Australia (i.e. caves such as those at Mt Etna, Jenolan, Buchan, Mole Creek) were formed. Following European and north American geomorphic traditions this view rested on two firm foundations: -

1 Caves are very recent features of the landscape, and are certainly less than 10,000 years old.

2 Caves are dissolved by sinking meteoric water.

These two ideas are closely linked with what I call the "text-book" idea of speleogenesis (cave development). This idea, found in most introductory texts on caves and karst, generally assumes that: -

- the limestone in which caves develop has horizontal beds.
- caves form as a result of a single, recent process.
- there is a reasonable amount of topographic relief and surface water in the karst.
- it is reasonably easy to identify where water enters the karst system (the streamsink) and where it leaves (the spring).
- the water that enters the karst system today was responsible for its development.

It has only been in the last five years or so that I have realised that most of these conditions do not generally pertain in the impounded karsts developed on the Palaeozoic limestones of eastern Australia. They are, however, reasonable assumptions to make about *some* karsts found in the USA and southern Europe.

This "text-book" view has formed the basis for the conservation, management and interpretation of our caves. Kevin Keirnan's dictum that "Maintaining the hydrological system in a natural condition is the foundation stone of karst management" [Kiernan, 1988 p 43] for instance is grounded in the conception that surface water, flowing into the caves, is the most significant geomorphic and environmental agent in karst.

My research has been directed towards developing a new, locally relevant, concept of cave development that is able to explain the features of eastern Australian caves. While this is still a work in progress, it is possible now to: -

- show how the ideas developed,
- give an outline of this new science of eastern Australian caves,
- indicate the implications for cave conservation, management and interpretation.

Old Caves in an Old Land

From the mid 1970s to the 1990s, developments in the study of eastern Australian landscapes by workers such as Robert Young (Young, 1997), Paul Bishop (Bishop, 1985) and John Nott (Nott, 1995) demonstrated that geomorphic change in the highlands of eastern Australia was extremely slow. Landscapes such as the Blue Mountains and the coastal plain, once thought to have originated at most 2 million years ago, were now interpreted as being 40, 90, perhaps even 100, million years old.

In the 1980s my work on palaeokarst in New South Wales caves and John Webb's geomorphic studies at Buchan indicated that the caves were at least as old as the ancient landscapes in which they are located. It suggested that in some cases (e.g. Jenolan) they may be inherited or exhumed features that initially formed hundreds of millions of years ago.

By 1990 the idea of old caves had become fairly well established, no one (other than creationists) seriously suggested that caves were only a few thousand years old. Thus the first foundation of the old view had fallen.

Is everyone else blind, or are we different?

In 1995 I was asked to write a chapter on palaeokarst for an international text on speleogenesis (now published, Osborne 2000, in Klimchouk *et al.*, 2000). This forced me to delve deeply into the published literature on the subject. Almost immediately I ran into a major puzzle/problem.

Since 1982 I had been finding palaeokarst exposed in caves almost everywhere I looked in eastern Australia, from Ida Bay in Tasmania to Mt Etna in Queensland, but there were very few cases of palaeokarst reported in caves elsewhere in the world. The few cases that were reported came from "unusual" caves in the US and central Europe. Was everyone in the world except Pavel Bosak (Bosak, 1989), Derek Ford (Ford, 1995) and I blind to palaeokarst in caves, or were our caves somehow "unusual"?

The answer came in August-September 1997, and fortunately the publication of the speleogenesis book, like most multi-author book projects, was running late. For six weeks as guests of the Karst Research Institute at Postojna, Slovenia, Penney and I visited caves on almost a daily basis. While palaeokarst was found in road cuttings and in natural surface exposures, none was found exposed in the caves!
Palaeokarst was not exposed in the caves on which the "text book" model is (said to be) based. Our caves (e.g. Bungonia, Colong, Exit Cave, Jenolan, Timor, Wellington, Wombeyan, Wyanbene, Yarrangobilly) must be "unusual".

So What's Unusual about our Caves?

While the following characteristics are not found in all eastern Australian caves, the list gives an indication of the key features which occur, need to be taken into account or require explanation: -

<u>Exposure and intersection of palaeokarst by caves</u>
For example:

crystalline palaeokarst	Jenolan, Wombeyan, Yarrangobilly
laminated carbonate	Bungonia, Jenolan, Ida Bay
fluvio-glacial	Jenolan, Billys Creek, Ida Bay
volcanic/volcaniclastic	Borenore, Timor, Wombeyan
<u>Proximity of major karsts to unconformities</u>	Bungonia, Jenolan, Mole Creek, Wellington, Wyanbene, Ida Bay, Bendithera, Colong

<u>Proximity of major karsts to ore deposits</u>
For example:

sulfides	Abercrombie, Wyanbene,
Bendithera	
Mississippi valley	Cooleman Plain
copper	Yarrangobilly
low grade iron	Wombeyan, Jenolan
barite	Cliefden, Walli
<u>Major karsts with warm springs</u>	Cliefden, Hastings, Wee Jasper, Yarrangobilly

<u>Poor relationship between caves and surface geomorphology</u>
For example:

phreatic caves on top of hills	Rosebrook, Timor, Willi Willi, Comboyne, Wombeyan, Rosebrook
surface incision and caves out of step	Bungonia Gorge

<u>Unusual surface-underground relationships</u>
For example:

dry valleys paralleling underground drainage	Jenolan, Colong

<u>Poor relationship between karst and surface hydrology</u>
For example:

karsts without streamsinks	Church Creek, Comboyne, Wyanbene, Mt Sebstapol, Yessabah
karsts without sinks or springs	Ashford, Kunderang Brook, Rosebrook
caves adjacent to major Moparabah streams that do,	Cliefden, Wombeyan, not (and never have) capture/d them: Yarrangobilly
underfit streams in caves	Colong, Jenolan

<u>Pattern of cave development</u>
For example:

downward-narrowing caves	Bungonia
lack of "proper" stream caves	Bungonia, Colong, Jenolan
downwards narrowing "stream" passages	Exit Cave
complex route of cave streams	Bungonia, Colong, Jenolan
"passages" with blind ends	Ashford, Bungonia, Cliefden, [Hall & Narrows], Wee Jasper, Yessabah
Cupolas present	Ashford, Jenolan, Bungonia, Wellington, Wombeyan, Yessabah
Significant paragenetic development	Colong, Jenolan, Wombeyan
"Nothephreatic" speleogens	Cliefden, Timor, Wellington
symmetrical wall & ceiling pits	Jenolan, Timor, Wee Jasper
paucity of scallops in "stream" passages	Colong, Jenolan

<u>Mineral associations</u>

silicified cave walls	Bungonia
micritised cave walls	Jenolan
boxwork	Bungonia, Jenolan
crystal-lined caves	Wombeyan
crackle breccia	Bungonia, Jenolan, Wombeyan
aragonite, huntite, hydromagnesite	Bungonia, Jenolan Wyanbene

Which other Caves are something like ours?

Because many eastern Australian Caves have long and complex histories (e.g. Jenolan, Osborne, 1999), it is difficult to find exact analogues for them elsewhere. They do share characteristics with some caves, but not all, in thermal caves of Poland, the Czech Republic and Hungary, with some rather unusual caves in Slovenia and Slovakia and with caves associated with low temperature iron ore deposits in the Forest of Dean, UK.

Some thermal caves in the Czech Republic and Hungary intersect palaeokarst deposits, as do some of the Forest of Dean caves. Cupolas are developed in caves in Poland, the Czech Republic, Hungary and Slovakia, however only one cave in Slovakia (Bystrianska) compares with Jenolan (and may exceed) in complexity of cupola development.

Comparative study with these caves, and with the gypsum maze caves of the western Ukraine (Klimchouk, 2000) is an important component of ongoing research.

Elements of a New Synthesis

Since 1997, I have been working to bring together the elements of a new explanation for the development of karst caves in eastern Australia. Some of the pieces are now in place, while others require considerable further work. There are seven important elements, which now appear to be vital to a new synthesis.

1. Multiple Karstification

Many of the impounded karsts of eastern Australia have been karstified on more than one occasion (Osborne; 1984, 1986, 1991, 1993b, 1993c, 1995; Osborne & Branagan, 1988; Osborne & Cooper, 2001) Caves have developed as a result of both subaerial exposure, and also by solution from below (Osborne, 1999b).

These multiple periods of development result in filling, exhumation and overprinting of new forms over old ones. This makes the present underground landforms very complex, very interesting and extremely difficult to decipher.

2. Non-Meteoric Speleogenesis and Mineralisation

Many eastern Australian caves are closely related to ore bodies, and some are actually the spaces from which ore bodies have been weathered (Osborne, 1996). The structure of some caves (e.g. cupolas, "blind passages", downward narrowing profiles and "hall and narrows" development, Osborne, 2001b), the presence of crystal linings (Osborne, 1999b) and the inexplicable hydrological relationships and removal of sediments (Osborne, 2001a) all point to cave excavation from below.

The issues that need to be resolved are: -

- exactly what type of water did the excavation,
- where did it originate,
- when did the non-meteoric solution occur,
- at what temperature did it take place?

A significant amount of time consuming and expensive analysis and dating is required to resolve these issues. The preliminary work suggests that warm (20-40 degree) rather than hot water was involved.

3. Cave Development in Steeply Dipping Limestone

Almost all of the diagrams found in textbooks illustrating the profiles of cave passages assume that the host rock has horizontal beds. It struck me while in Europe in 1997 that many of the karsts of eastern Australia were developed in steeply-dipping limestone, and in some cases in limestone with vertical beds.

Caves developed here would differ in both plan and passage section from those in the textbooks. I tackled the passage cross-section issue first (Osborne, 1999a) and discovered that not only had the text book cross-sections resulted in serious misinterpretation of some passage shapes, but also that some other odd features of our karsts (e.g. parallel surface and underground drainage) made sense only if the effect of steep bedding was considered.

The effect of steep bedding on cave plans and gross cross-sections proved to be a much more difficult issue, and raised even more problems.

Much looking at maps and many field visits showed that "passages to nowhere" were a very common feature of our caves. Many of these had been interpreted by myself (Osborne, 1993a) and others as segments of ancient "stream" passages, but they really did end blind, go nowhere and did not connect (and never had connected to) to similar voids at the same level in the landscape.

These blind "halls" and the short lateral "narrows" that connected them laterally were to be found almost everywhere and provided the title for my paper (Osborne, 2001b) in which the plans and sections of caves in dipping limestones are discussed. The structural geology of the limestone is a critical factor in understanding the development of eastern Australian caves.

4. Varying degrees of invasion/intersection by present landscape

Unlike the thermal caves of Budapest, which are discovered only during building excavation and quarrying, our caves mostly have natural entrances and sometimes capture streams. There is thus significant interaction between the modern surface landscape and the more ancient underground landscapes.

Understanding the nature, degree and significance of this interaction is a very important part of understanding our caves. It is important to be able to tell how and when entrances opened, and what changes have occurred in the underground environment as a result of entrance opening. Little work has been done in this area, but it has considerable potential.

5. Stoping and Breakdown by vadose weathering

Weathering of unstable minerals in cave fill and veins has been important in driving the re-excavation of filled caves and the process of cave breakdown in many eastern Australian caves. Many of the open spaces we now walk in at Jenolan and Wyanbene, and the large breakdown chambers at Yarrangobilly are the product of minerals weathering when exposed to oxygen-rich vadose water (Osborne, 1996).

While this is clear from simple observations, there is much yet to be learnt about the chemistry, mineralogy and mechanics of these processes.

6. Paragenesis

Paragenesis is the process where sediment in caves pushes water up towards the ceiling, resulting in upward solution of the rock. In caves where there is a lot of sediment available e.g. Jenolan and Wombeyan, paragenesis can be a powerful process. A small depth of water will sit on a thick sediment mass and slowly excavate upwards. When the sediment is eroded out later, a very large tube remains (e.g. the Grand Archway). We may then mistakenly think that a large volume of water produced the tube.

Sediment blockages, resulting paragenesis and later reopening are important events in those eastern Australian caves, which have significant streams flowing into them. These events probably recur on numerous occasions, leaving behind sediment remnants and modified cave passages. Deciphering the history of paragenesis in any cave will be quite complex, and has yet to be attempted.

7. Cupolas

Cupolas are large dome-shaped chambers, or domes in cave ceilings. They are larger and much less common than bellholes. Cupolas are usually more than 2 m in diameter, but may reach 30 m in diameter and 50 m+ in height. Probably the most easily observed example of a cupola is the Commonwealth Dome in the Persian Chamber, Orient Cave, Jenolan.
Cupolas appear to be uncommon on a world scale and little has been written about their distribution and shape. It is generally thought that cupolas are formed by convecting water, in thermal or artesian situations. I know of their presence in 6 cave areas, but they are probably more widely spread.
Cupolas are next on my research agenda and I will be very happy to receive reports of cupolas from ACKMA members.

Implications for Conservation, Management and Interpretation

The new ideas concerning the history and mode of formation of eastern Australian caves have significant implications for the way in which the caves are managed and interpreted. The management implications are discussed below.

The main implication for interpretation is that it is no longer appropriate to seek out our cave stories in literature that describes other caves (most texts). There is a need for managers and interpreters to become aware of many new (and some not so new) ideas about cave formation. The chapters in Klimchouk *et al.* (2000) are a good start, and this is essential reading.

Locally specific interpretative material will need to be developed. The idea that the caves are complex and that understanding them is not a completed process, should form an important part of interpretation. Our caves may be much more special than we realise, and this could form the basis of new approaches to conservation, management and interpretation.

Catchment Management is Necessary, but not Sufficient

Since many of the important characteristics of our caves are not the product of the present hydrology. Managing the catchment, while important, will not of itself provide adequate protection for the significant features of the caves.

Inventory studies are essential

Our knowledge of even the most-studied caves in eastern Australia (arguably Wellington, Jenolan and Bungonia) is very poor and incomplete. While there has been lots of informal discussion about World Heritage Nominations, there is currently insufficient information available on which to base such nominations (except perhaps to add Wellington to the Riversleigh-Naracoorte vertebrate fossil listing).

Inventory studies of our major show caves (and "wild" caves) are urgently needed if their significance is to be recognised and they are to be appropriately managed and interpreted. These are not quick, cheap or easy to carry out, but the results can be illuminating. Trial studies at Jenolan by Ross Pogson, David Colchester and myself have identified unrecognised mineral deposits and many other significant features in caves that everyone thought they knew well.

Ignorance and inappropriate management actions are the greatest threat

Some of the most significant features of our caves are ancient mud deposits and weak crumbly minerals, not stalactites and stalagmites. These are very easily destroyed or damaged by pressure cleaning, trackwork and visitors (particularly in adventure and "wild" caves).

The greatest immediate threat to the most significant features is likely to be ignorance, rather than deliberate harm or overstocking with tourists. Some of these features will be susceptible to changes in atmospheric conditions or local seepage water chemistry, but we need to know what is there first, before thinking about what to monitor and manage.

Place by Place Significance -Based Management is Required

The type of management required by one feature may be quite different from that required by another a few metres away. Whole cave prescriptions are thus inappropriate, and feature by feature management will be required. This is a new and challenging approach, but given the complexity of our caves is the only one likely to be effective.

Acknowledgements

It is neither easy, nor popular; to seriously study caves in Australia. One is not overwhelmed by offers of jobs and funding. More often than not the housekeeping is the principal funding authority.

The support and assistance of my family, Penney and Michael over the years has thus been crucial. Penney endured and assisted greatly during two long overseas trips in 1997 & 2001.

The assistance and support of cave managers, property owners and ACKMA members particularly: - M. Chalker, the late B. Dunhill, E. Hamilton-Smith, D. Hearne, K. Henderson, E. Holland, A. Lawrence, S. Reilly, N. Scanlan, A. Spate and D. Stoneman is gratefully acknowledged.

The Faculty of Education at the University of Sydney has supported my research and overseas study programs. Recent work has been assisted by financial support from the Australian Museum Trust and by the hard work and enthusiasm of colleagues at the Museum; R. Pogson & D. Colchester.

I must particularly acknowledge the support and assistance of some overseas colleagues; D. Ford (Canada), D. Lowe (UK), P. Bosak & V. Cilek (Czech Republic), P. Bella (Slovakia), A. Tyc & M. Gradzinski (Poland), A. Klimchouk (Ukraine), R. Seeman (Austria), S. Leel-Ossey (Hungary) F. Sustersic, T.Slabe & Staff Karst Research Institute (Slovenia).

Finally it is important to acknowledge support over a very long time from Wellington Council. Their level of practical and financial support for pure and applied research puts to shame that from many much larger and better funded management authorities.

REFERENCES

Bishop P., 1985. Southeast Australian late Mesozoic and Cenozoic denudation rates: A test for late Tertiary increases in continental denudation. *Geology* .13:497-482

Bosák, P., 1989. Paleokarst of Czechoslovakia. *in* Bosák, P., Ford, D.C., Glazek, J., & Horácek, I., eds. 1989. *Paleokarst. A Systematic and Regional Review*. Elsevier and Academia. Amsterdam and Praha.

Dublyansky, V.N. 1980. Hydrothermal karst in the alpine folded belt of the southern parts of U.S.S.R. *Kras i Speleologia.* 3: 18-36. (in Polish)

Ford, D.C., 1995. Paleokarst as a target for modern karstification. *Carbonates and Evaporites*. 10 (2): 138-147.

Kiernan, K., 1988 *The Management of Soluble Rock Landscapes: An Australian Perspective*. Speleological Research Council, Sydney, 61 p

Klimchouk, A.B., 2000. Speleogenesis of The Great Gypsum Mazes in The Western Ukraine. in Klimchouk, A.B., Ford, D.C., Palmer, A.N., and Dreybrodt, W., eds., S*peleogenesis, Evolution of Karst Aquifers*: Huntsville, National Speleological Society: 261-273.

Klimchouk, A.B., Ford, D.C., Palmer, A.N., and Dreybrodt, W., eds., 2000. S*peleogenesis, Evolution of Karst Aquifers*: Huntsville, National Speleological Society.

Nott, J & Purvis, A.C., 1995. Geomorphic and tectonic significance of Early Cretaceous lavas on the coastal plain, southern New South Wales. *Australian Journal of Earth Sciences*. 42 (2): 145-149.

Osborne, R.A.L., 1984. Multiple karstification in the Lachlan Fold Belt in New South Wales: Reconnaissance Evidence. *Journal and Proceedings of the Royal Society of New South Wales*. 107: 15-34.

Osborne, R.A.L. and Branagan, D.F., 1985. ? Permian palaeokarst at Billys Creek, New South Wales. *Journal and Proceedings of the Royal Society of New South Wales*. 118: 105-111.

Osborne, R.A.L., 1986. Cave and landscape chronology at Timor Caves, New South Wales. *Journal and Proceedings of the Royal Society of New South Wales*. 119 (1/2): 55-76.

Osborne, R.A.L., 1991. Palaeokarst deposits at Jenolan Caves, N.S.W. *Journal and Proceedings of the Royal Society of New South Wales*. 123 (3/4) 59-73.

Osborne, R.A.L., 1993a. A new history of cave development at Bungonia, N.S.W. *Australian Geographer*. 24(1): 62-74.

Osborne, R.A.L., 1993b. The history of karstification at Wombeyan Caves, New South Wales, Australia, as revealed by palaeokarst deposits. *Cave Science*. 20 (1): 1-8.

Osborne, R.A.L., 1993c. Geological Note: Cave formation by exhumation of Palaeozoic palaeokarst deposits at Jenolan Caves, New South Wales. *Australian Journal of Earth Sciences*. 40 : 591-593.

Osborne, R.A.L., 1995. Evidence for two phases of Late Palaeozoic karstification, cave development and sediment filling in southeastern Australia. *Cave and Karst Science*. 22 (1): 39-44.

Osborne, R.A.L., 1996. Vadose weathering of sulfides and limestone cave development-Evidence from eastern Australia. *Helictite*. 34 (1): 5-15.

Osborne, R.A.L., 1999a. The inception horizon hypothesis in vertical to steeply-dipping limestone: applications in New South Wales, Australia. *Cave and Karst Science*. 26 (1), 5-12.

Osborne, R.A.L., 1999b. The origin of Jenolan Caves: Elements of a new synthesis and framework chronology. *Proceedings of the Linnean Society of New South Wales*. 121:1-26.

Osborne, R.A.L, 2000. Paleokarst and its Significance for Speleogenesis, in Klimchouk, A.B., Ford, D.C., Palmer, A.N., and Dreybrodt, W., eds., *Speleogenesis, Evolution of Karst Aquifers*: Huntsville, National Speleological Society, p. 113-123.

Osborne, R.A.L., 2001a. Karst geology of Wellington Caves, a review. *Helictite*. 37(1): 3-12.

Osborne, R.A.L., 2001b. Halls and narrows: Network caves in dipping limestone, examples from eastern Australia. *Cave and Karst Science*. 28 (1): 3-14.

Osborne, R.A.L. & Cooper, I. B., 2001. Sulfide-bearing palaeokarst deposits at Lune River Quarry, Ida Bay, Tasmania. *Australian Journal of Earth Sciences*. 48:401-416.

Young, R.W. 1977. Landscape development in the Shoalhaven catchment. *Z. Geomorphology. N.E.* 21, 262-283.