ANDYSEZ 34

(**Editor's Note**: ACKMA's Karst Science Officer, Andy Spate, currently in Antarctica, asked me to arrange a suitable "ANDYSEZ" in his absence. I am sure he will agree that the offering below by Dr. Armstrong Osborne, presented at the recent 5th Karst Studies Seminar at Wellington Caves, and reproduced here with permission, will more than adequately meet all expectations.)

GEOLOGY OF THE WELLINGTON KARST AREA

- Armstrong Osborne

How and when Wellington Caves formed and were then filled with bone-bearing sediments has puzzled researchers since the 1830s. I have only been investigating the problem on and off since the 1980s. During that time many of my ideas about cave geology at Wellington have changed, and work in progress will probably change them more.

Before relating how much we don't know about Wellington Caves I would like to record my thanks to the Councillors and staff of Wellington Council who have contributed resources, staff time and funds in support of fundamental and applied research at Wellington Caves over the past 20 years. I wish other, higher profile, cave management agencies were equally supportive.

I will raise nine significant issues related to cave geology at Wellington. I consider that none of these issues are reasonably well resolved.

1. THE CAVES AND THE BEDROCK

Caves at Wellington have formed almost exclusively in, or at the boundary of, massive lime mudstone facies of the middle Devonian Garra Formation. The exception is Anticline Cave which is developed along the hinge plane of an anticline in thinly-bedded limestone.

Two prominent ridges of massive limestone outcrop in the reserve. Bedding in the western ridge, which contains most of the caves dips generally to the east, while that in the eastern ridge dips to the west. This suggests that the caravan park is underlain by a plunging anticline (as seen in Anticline Cave and in the paddock to the south) and that the area between the two limestone ridges is a plunging syncline.

The main Chamber of Cathedral Cave is developed along an unconformable boundary between massive lime-mudstone and tightly-folded thinly-bedded limestone consisting of graded beds rich in faecal pellets. The stratigraphic significance of this boundary remains unclear and attempts at extracting conodonts from either of the facies have proved unsuccessful.

Plans of the caves indicate that their development has been strongly guided by a rectilinear system of vertical joints.

2. GENERATIONS OF CAVES

Observations in Cathedral Cave and the Phosphate Mine suggest that there have been <u>at least</u> three major periods of cave excavation (and filling) at Wellington Caves. The first period is represented by the block-filled structure behind the Altar. The second period is the initial cavity into which the older sediments (Phosphate Mine Beds) were deposited and may also be represented by parts of Cathedral Cave. The third most current event was the most recent excavation of Cathedral Cave and the other open caves and the cavity in which the Pleistocene bone-bearing sediments (Mitchell Cave Beds) were deposited.

As well as underground evidence for earlier periods of cave development, recent detailed mapping of the limestone outcrop has indicated the presence of a number of 'caves without roofs'. The most obvious of these is the open-cut section of the Phosphate Mine, but other examples are now known in the limestone to the south of the main caves areas.

The timing of these periods of cave development is as yet unclear. Late Devonian palaeokarst has been identified in the Garra Formation, this may be represented by breccia in Cathedral Cave. There is no indication of the age of the large block fill near the Altar. The two most recent major cave forming events are likely to be Miocene and earliest Pleistocene in age.

3. THE MECHANISM OF CAVE EXCAVATION

Since the work of Bud Frank in the1960s it has been recognised that the morphology of the caves at Wellington indicates excavation by slowly moving water below the water table. Conditions Joe Jennings described as *nothephreatic*.

The problem with the concept of nothephreatic as a term is that it described a set of characteristics of caves, but offered no real explanation as to how they were produced. While some of the speleogens in the Cathedral Cave provide evidence for mixing corrosion (eg penetration of solution cavities into joints and bedding planes, most do not.

Cupolas that are found in both Cathedral Cave and the Phosphate Mine (eg the Atrium) display many of the characteristics that have been attributed to solution by rising hydrothermal or artesian waters. Much of the bedrock morphology and speleothem in Gaden Cave is similar (although on a smaller scale) to that of the hydrothermal caves of Buda and remnants of crystalline wall coatings have been found in Cathedral Cave and Anticline Cave.

There is thus some evidence to suggest that the caves at Wellington were formed from the bottom up by rising, perhaps slightly warm water. This possibility is currently being investigated.

4. CAVE SEDIMENTATION AND STRATIGRAPHY

Thomas Mitchell, Bud Frank and I have all attempted to work out the stratigraphy of the bone-bearing sediments exposed in the caves and the Phosphate Mine. I can't speak for the previous workers but I continue to find this a challenge.

While it is clear that there are at least two major periods of deposition (one ?Miocene to Pliocene and the other Pleistocene to Recent) represented in the Phosphate Mine, separated by a major cave excavating event, in detail the sequence is clearly much more complex.

While much of the older sequence consists of turbidite facies deposited in irregularly flooded caves by slumping the younger sequence appears to consist largely of talus cone deposits with highly variable bedding.

Rehabilitation of the Phosphate Mine has better exposed the sediments, but this has shown that their relationships are really far more complex than has been previously thought. While the stratigraphy of the eastern part of the Phosphate Mine makes some sense (although there are at least two competing explanations) the relationship between the sequence in the east with the major phosphorite deposit in the west remains unclear and is probably unconformable. One major difficulty in working out the mine stratigraphy is that the miners excavated adits along the vertical unconformities, removing evidence of the relationships at them.

Both Paul Hesse (Macquarie University) and I are working on the stratigraphy as time permits, and I hope that by the end of this year there will be some progress to report.

5. SOURCE OF THE PHOSPHATE

It was popularly believed that the Phosphate Mine operators were simply grinding up fossil bones to make their product. While some fossil bones clearly did go into the mill, both the documentary and the physical evidence in the mine indicates that they were mining a variety of phosphatic deposits (not bones) the most important of which was a bedded grey phosphatic mudstone.

So where did the phosphate come from? One suggestion was from dissolution of fossil bones, but there is no evidence of leached bones in the deposits, in fact, bone-bearing sediments often contain a phosphatic cement.

When fossil *Macroderma* teeth were found in the Big Sink and more recently in the osseous sandstones of the Graded Bedded unit, bat guano became the obvious source. This however is not without problems. All of the phosphate in the main phosphorite deposit and in the various crystalline phosphate found in the mine occurs as hydroxyapatite. There is only one very tiny deposit in the Big Sink containing a typical guano mineral, crandallite. If the phosphate was derived from guano then it must have been redeposited.

It is quite easy to imagine guano slumping into pools of water rich in Ca^{2+} and apatite being deposited. If phosphate deposits in the region only occurred in cavernous limestone I would be quite pleased with this answer. There are however phosphate deposits nearby in limestone that aren't obviously related to caves and others which occur in basalt. Unfortunately there has not been any comparative study of the phosphate deposits in the region to the north of Orange, and without such a study I remain a reluctant, rather than enthusiastic, supporter of the hypothesis that the bats did it.

6. THE MECHANISM OF SEDIMENT REMOVAL

Whatever one believes about the origin of the caves, or the stratigraphy of the sediments, it is quite clear that large amounts of sediment have been removed from the caves at one or more times in the past. How did this occur and where did the sediment go?

There is no evidence of a major stream entering the caves, no obvious outflow point for a stream, and no evidence of sediment removal by scouring or down cutting. There are fallen blocks of old sediment incorporated into later deposits and rip up clasts incorporated in the higher energy parts of the turbidite sequence.

I have puzzled over this problem for some time. Wellington is not the only cave system where this situation occurs. Some of the possible answers are:-

i. There is an exit through which the sediment was removed by normal fluvial action, but it is obscured by valley-fill sediments.

ii. Sediment slumped down into progressively lower sections of the cave as solution at depth opened up new cavities. I describe this as the sediment shuffle hypothesis.

iii. The sediment was removed in a stopping process by water rising form below. There are few large insoluble clasts in the sediment; carbonate, phosphate fine silt and clay could be carried away by the groundwater. The geologists among you should think about granite emplacement.

I like option 3, but could be persuaded by some other explanation if supporting evidence is found. It would be nice to know the bedrock morphology below the sediment in Cathedral Cave and the Phosphate Mine.

7. CAVES AND THE SURROUNDING LANDSCAPE

There have been numerous attempts to relate the caves to the evolution of the surrounding landscape. Many workers have imagined the Bell River following a higher elevation, perhaps in the depression where the highway is located, or perhaps in the shallow depression between the two limestone ridges.

New development proposals have made it essential to know what is below the depression between the two limestone ridges. A drilling program, which has yet to be completed, has been undertaken to investigate the area.

The initial results suggest that the area below the shallow depression is underlain by a valley, perhaps as much as 50 m deep and some filled karst depressions. The valley is filled with silt, probably of Pleistocene age and similar to the red earth in the caves.

One can imagine during the height of the aridity the caves ridge, with deep-rooted trees reaching down into the limestone for water, forming a green oasis and standing above the dusty red landscape.

Many animals would be drawn to the lush vegetation, but would end their days at the bottom of a pit trap, lying dead and broken. There they would wait for excavation and the long journey to London, Edinburgh, Paris, Munich, California and perhaps, if we were lucky enough, to College Street or Kensington.

8. WATER IN THE CAVES

Until very recently the hydrology of Wellington Caves appeared to be pretty boring. There was no stream sink and no spring and, as first observed by Thomas Mitchell in 1930, the pools in the caves are at roughly the same level as the water in the Bell River. Since the water in the caves rises a day or so after the river floods it was obvious to us all that the water in the cavepools was in some sort of delayed equilibrium with the groundwater in the surrounding landscape.

The recent drilling program and other observations, have greatly complicated the picture. The deepest hole reached refusal in wet silt at a depth of 47 m. This is roughly **20 m below** the standing water level in the Cathedral Cave pool! A well in the limestone on the eastern ridge has a standing water level some **50 m above** the Cathedral Cave pool!

Things are not quite as had been imagined and much more work is required. Many of our more simple notions about environmental management of the area will need to be revised.

9. CO_2 IN THE CAVES

Myself and some of my more reckless associates recorded carbon dioxide concentrations of 13% at Wellington Caves during the late 1970s. The new entrance to Gaden Cave has improved the ventilation, and now new generations of crazies armed with SCUBA gear (not our more dodgy oxygen therapy equipment) are penetrating further into the CO_2 pit. The bottom of the pit and the mystery there remains as elusive as ever.

High levels of carbon dioxide have been reported at Wellington Caves since the 1870s, and may have contributed to the untimely death of Australia's first professor of geology. Whether the carbon dioxide is derived from the ground water, bacteria or has some more mysterious source remains a puzzle. There is lots of conjecture but not much good data. I have always thought that the carbon dioxide puzzle will play a key role in understanding the overall picture at Wellington Caves.

CONCLUSION

Wellington Caves present a complex 4(5,6,....) dimensional puzzle. There are interesting rocks, minerals, fossils (many now displayed at the Wellington Fossil Studies Centre), caves and sediments that need to be better explained. Both the water and the air behave strangely and we have along way to go to work out why this is. There are surely enough puzzles here to keep an army of workers busy for the next 170 years.