Natural History of the Belubula River Valley

& the adjacent area of central western NSW including the Cliefden Caves & Fossil Hill

A symposium to explain, interpret and review recent scientific research on geology, palaeontology, botany, zoology, and speleology of the caves and karst.

Monday 7th to Thursday 10th September 2015

Abstracts

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EXAMINING THE CONNECTION BETWEEN GEOLOGY, SOIL AND VEGETATION

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Geology has strong ties with biodiversity. The nature of the substrate, being soil and the underlying rock from which it derives, is a key factor in determining the composition, structure and distribution of vegetation communities. Species and habitats are influenced by many factors including soil, climate, topography - relief in particular, biota, and human influence, but the way these natural elements are expressed is primarily influenced by the nature of the parent material - the rock below. The Belubula Valley lies within a complexly folded and faulted section of the Paleozoic Lachlan Orogen. Geology of the region is dominated by granite, basalt, sandstone and limestone. Weathering of these rocks produces different soil types and plant species often prefer soils from one over another. Numerous studies in southeastern Australia have found that certain native plant species and communities favour particular soil types (see Keith 2011 for review) and that geology is a key controlling factor. Examples in the NSW Central Tablelands include Kurrajong trees (*Brachychiton populneus*) on outcrops of limestone and native pines *Callitris* sp. on sandstone or sandy granite soil. A number of exotic weed species also show a strong affiliation with particular soil and rock types. Across NSW, an inequality is recognized in the conservation of native species and communities preferring deep, fertile soil of a narrow range of geological substrates. These areas have been extensively cleared for agriculture and are underrepresented in the public reserve. This inequality heightens the value of remnant communities, weed control and revegetation programs. The geology of the Belubula Valley has been well documented through detailed geological mapping of students, exploration companies and government surveys. In comparison, little published data exists on the vegetation of the region. We ask can the geology of the area be used to predict what plant assemblages or in some cases, individual plant species are likely to be present? A better understanding of local geology may prove to be an advantage in conservation management in the region.

Keith D. A. 2011. Relationships between geodiversity and vegetation in south-eastern Australia. *Proceedings of the Linnean Society of New South Wales* **132**, 5-26.

FLORA AND VEGETATION COMMUNITIES OF THE CLIEFDEN KARST

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Areas of remnant woodland and degraded woodland in the Cliefden karst area of the Belubula River valley were identified from aerial imagery. Ground truthing of these areas was conducted using the random meander method described by Cropper (1993) to record flora species identified in each of the remnant patches. Condition of the vegetation community was assessed, along with the habitat use and potential for each patch.

Much of the valley has been cleared or partially cleared for grazing and cropping. Crops are grown on the fertile river flats, and the surrounding hillsides have a long history of grazing by sheep and cattle. Areas of contiguous canopy along the riparian zone of the Belubula River comprised a mixture of River She-oaks (*Casuarina cunninghamiana*) and River Red Gums (*Eucalyptus camaldulensis*), represented in varying proportions and with a range of age classes present. Elsewhere, scattered remnant White Box (*E. albens*) and Kurrajongs (*Brachychiton populneus*) were noted on open karst ridges and upper slopes. Lower slopes were home to Yellow Box (*E. melliodora*) and Blakely's Red Gum (*E. blakelyi*), with Apple Box (*E. bridgesiana*) also present along creeks and associated flats.

Steep areas of exposed limestone provide poor grazing opportunities and are difficult for stock to access, and they retain more of their original vegetation. Surveys of these areas revealed a distinct suite of flora species present, with some species noted only from one or two locations in the karst area. Many of these plant species were not recorded elsewhere in the study site, although this may be at least partially a legacy of ongoing perturbation due to differences in landuse.

When onground surveys for vegetation in the karst area were contrasted with mapped vegetation databases, a number of discrepancies were noted in the vegetation communities predicted for the area. Noteworthy omissions include large areas of the White Box – Yellow Box – Blakely's Red Gum Grassy Woodland, a Critically Endangered Ecological Community. This community persists in the valley in a number of forms and with varying degrees of disturbance and degradation, conditions which are included in current definitions for the community under the federal EP&BC Act and NSW TSC Act.

USE OF ULTRASONIC ECHOLOCATION CALLS TO IDENTIFY MICROBAT SPECIES IN THE CLIEFDEN KARST AREA OF THE BELUBULA RIVER VALLEY

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We used Anabat SD2 bat detectors to record ultrasonic echolocation calls for microbat species in the Cliefden karst area of the Belubula River in the Central Tablelands of NSW. A preliminary literature review indicated that this part of the country was on the cusp of known ranges for coastal and inland species of microbats, suggesting there was potential for the site to be a bat hotspot.

Based on local knowledge we selected five caves as possible bat roosting caves, and two sites on the Belubula River as survey locations. One of the caves is believed to be overwintering habitat for *Miniopterus schriebersii oceanensis* (Eastern Bentwing Bat), and another is believed to be a maternity cave for *Rhinolophus megaphyllus* (Common Horseshoe Bat). Surveys were conducted during spring and summer, with Anabat detectors positioned across each cave entrance for one night per survey. For river sites, bat detectors were located at a point one metre above the river surface, and at six metres above the water surface.

Numbers of calls recorded per night ranged from around 300 at Transmission Cave to more than 1300 at the Belubula River low site in spring, while summer surveys showed a slight increase in numbers of calls recorded (500-1800). Species were identified from calls using a combination of automated filtering and manual checking. A total of 15 species were identified from calls, including 3 listed threatened species. One group of calls was identified to genus, most of which are listed as vulnerable under NSW Threatened Species Conservation Act 1995. In addition, 3 species were possibly present, although the calls were of poor quality or insufficient duration to confirm the identification. These species are also listed as vulnerable, giving a possible total diversity of 18 species, 7 of which may be protected under current legislation.

The species richness observed and the abundance of calls strongly suggests that the Cliefden karst and possibly other areas of the Belubula River valley are microbat hotspots. Further research is necessary to confirm identification of species, and explore the spatial and temporal nature and extent of microbat use of the area.

GLOBAL GEOHERITAGE SIGNIFICANCE OF ORDOVICIAN SEQUENCES IN THE CLIEFDEN CAVES AREA, CENTRAL WESTERN NEW SOUTH WALES, USING THE GEOHERITAGE TOOL-KIT

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Ordovician rocks in the vicinity of Cliefden Caves, in central western New South Wales, include the Fossil Hill Limestone, Belubula Limestone and Vandon Limestone, the overlying Malongulli Formation and the underlying Walli Volcanics. Features of geoheritage significance in this area include (1) pillow structures in the andesite forming the majority of the Walli Volcanics, and its unconformable/disconformable relationship with the overlying limestone; (2) the sequence of bedded highly fossiliferous limestones spectacularly exposed on at Fossil Hill, contrasting with other less-fossiliferous limestones in the region; (3) the outstanding scientific significance of Ordovician fossils in the sequence; (4) the lithological sequence of limestones and their sedimentary record of quiet water muddy environments with shelly benthos that also formed small-scale substrates for encrusting skeletal organisms, interspersed with turbulent water conditions with cross-bedded lithoclastic grainstones overlying disconformities; (5) disconformities in the Fossil Hill Limestone reflected in features such as irregular solutional surfaces, lithoclast beds, and vugular limestone with infiltrated sediment into sub-disconformity beds, and (6) a rarely preserved deep-water sponge and microbrachiopod community found in allochthonous limestones in the Malongulli Formation. In contrast to cratonic successions of older Ordovician age in Tasmania, Queensland, Western Australia, and Northern Territory, limestones of the Cliefden area preserve a rare example of volcanic island biota, including some of the most scientifically valuable (and in several cases, unique) fossils in Australia. At least 191 genera and 263 species of fossils have been described from the Cliefden area with some 45 genera and 101 species unique to this region. These include the world's oldest known *in situ* brachiopod shell beds, some of the earliest rugose corals found anywhere on Earth, and one of the most diverse deep-water sponge faunas ever recorded, living on an oceanic slope environment that is very rarely preserved in the geological record. Several genera are of exceptional biogeographic significance for recognition of past continental distribution, including a trimerellid brachiopod genus recognized only in the Cliefden Caves area and in south China.

The geoheritage tool-kit is a method that systematically identifies geological features, and assesses their significance in a given area or region at all scales. Application of the geoheritage tool-kit to the Fossil Hill area in particular and the wider extent of Ordovician rocks in the vicinity of Cliefden Caves indicates that, on a comparative basis stratigraphically, lithologically, palaeo-pedologically, palaeogeographically, and palaeontologically, the various features of the limestones and the contact of the limestone with the underlying volcanics have nationally to international significance, with the key globally significant features being the fossil content, the lithological/sedimentological sequence, and the disconformities.

THE MICROBATS OF CLIEFDEN CAVES AND KARST – BIOLOGY AND CONSERVATION

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Microbats make up over a quarter of all Australian mammals, yet most people know little of their biology, requirements and the ecosystem services they provide.

We review the diets, breeding, habits, and habitats of the microbats found at Cliefden caves, and discuss the conservation implications of these. Most microbats are not cave dwellers but utilise tree hollows and vegetation. Some emigrate from Cliefden to breed, and others immigrate to bear and raise their live born pups. A number of the species recorded locally are at the limit of their previously documented geographic ranges, with at least one presence a possible range extension.

The reasons Cliefden caves may have become such a microbat hotspot and why we have only just discovered this is also explored. Preliminary surveys of the Cliefden caves area highlight the inadequacy of desktop surveys as a standalone tool for species detection. The results of this pilot field study have demonstrated that it is a microbat hotspot, with extremely high microbat activity levels with very high species richness. Such richness and abundance in such a small area from just a preliminary survey warrants further research.

MACROINVERTEBRATE DIVERSITY AND RIVERINE HEALTH IN THE CADIANGULLONG CREEK

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This Project was initiated in 1997 as an outcome of the Commission of Inquiry into the Environmental Impact Statement for the development of an open pit gold mine at Cadia Hill by Newcrest Mining Limited (Newcrest). The gold mine development also incorporated the construction of the 4200 megalitre (ML) Cadiangullong Dam in the upper reaches of Cadiangullong Creek, which runs through the centre of the mining lease. Cadiangullong Creek is a small upland Creek south of Orange and is a tributary of the Belubula River, part of the Lachlan River catchment. Several conditions relating to the release of water from Cadiangullong Dam and the maintenance of flows in Cadiangullong Creek were included in the Development Consent. In particular, the consent required Cadia Valley Operations to assess and model the effects of changing flow regimes (ie. drought, low, medium and flood) on instream and riparian environments and their associated organisms, and to use the results of the study to refine release timing and frequency of medium flows. The Environmental Studies Unit, Charles Sturt University (CSU), was contracted by Cadia Valley Operations to carry out this research in the period 1997-2002. The presentation will focus on the following aspects of this multi-faceted study:

- Changes in macroinvertebrate diversity under a range of flow conditions;
- The ecological resilience of this uplands river system; and
- The adequacy of environmental flows to maintain instream biodiversity.

This project assumed some significance in the late 1990s as it provided important baseline understanding of macroinvertebrate diversity in a tablelands stream.

PLATYPUSES AND DEEP WATER DON'T MIX – THE BELUBULA DAM PROPOSAL

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Much of the middle and lower sections of the 165 kilometre length of the Belubula River consists of pool-riffle sequences, with many boulder, cobble and gravel substrates and banks consolidated by riparian vegetation (particularly river sheoaks, *Casuarina cunninghamiana*). This combination of features represents suitable habitat for the platypus (*Ornithorhynchus anatinus*)[1], which is regularly reported in the river and some of its tributary streams[2]. With an aerobic dive capacity of only 40-60 seconds, and feeding predominantly on small benthic invertebrates, the platypus normally forages at depths of 1-5m and preferentially on coarse substrates[3]. As a result of these constraints, the species is seldom found in the waters of deep impoundments[4]. A number of potential impacts of large dams on the platypus have been identified, and will be discussed[5], although loss of habitat will certainly be the most marked effect of any deep impoundment constructed on the Belubula River. Except for South Australia, where it is now listed as 'endangered', the platypus is not currently on the threatened species schedules of Tasmania, Victoria, the ACT, NSW or Queensland and is listed as of 'least concern' by the IUCN. However, a recent reassessment of the current status of Australian mammals has recommended its elevation to the 'near threatened' category, predominantly due its decreased abundance and distribution in some local areas.

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1 Grant, T.R. and Bishop, K.1998. Instream flow requirements for the platypus (*Ornithorhynchus anatinus*) - A review. *Australian Mammalogy* **20**: 267-280.
Grant, T. 2007. *Platypus*. CSIRO Publishing, Collingwood.

2 http://www.bionet.nsw.gov.au/ and personal observation.

3 Grant, T.R. 2004. Depth and substrate selection by platypuses, *Ornithorhynchus anatinus*, in the lower Hastings River, New South Wales. *Proceedings of the Linnean Society of NSW* **125**, 235-242.

4 Grant, TR. 1991. The biology and management of the platypus (*Ornithorhynchus anatinus*) in New South Wales. Species Management Report # 5. NSW National Parks and Wildlife Service, Hurstville.

5 Grant, T.R. and Temple-Smith, P.D. 2003. Conservation of the platypus, *Ornithorhynchus anatinus*: Threats and challenges. *Aquatic Health and Management* **6**, 1-18.

KARST AND LANDSCAPE EVOLUTION AT CLIEFDEN CAVES

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Cliefden Caves have developed in a complex faulted block of Ordovician limestone, exposed following the incision of the Belubula Valley into two extensive erosion surfaces within the broader Western Slopes physiographic region. The karst is impounded upstream of a distinct strike ridge composed of tilted Devonian sediments, bounded by thrust faults of uncertain age, through which the river has carved a deep gorge at Needles Gap. Impoundment of the valley has meant that it now contains well preserved evidence for uplift and valley incision in both surface and underground landforms. This detailed geomorphic history is likely to provide a significant contribution to broader knowledge of Eastern Highlands landscape evolution.

Evidence for three major uplift processes may be tested and compared in the area:

(1) Dynamic uplift related to Tasman sea rifting (land surfaces and associated regional knickpoints);

(2) Uplift associated with dynamic topography, related to the northward passage of the Highlands over a static mantle plume (doming associated with Mt Canobolas volcanism); and

(3) Dynamic uplift associated with Neotectonics (thrust fault activity and knickpoint generation).

Evidence for subsequent valley incision and intermittent aggradation is found in a series of land surfaces and terraces preserved between 600m and 400m asl on “Boonderoo” and “Angullong” properties.

The caves are a combination of phreatic, epi-phreatic and vadose passages, which record the evolution of the area’s hydrogeology in relation to uplift and incision of the surface landscape. Many of the oldest passages in Main, Gable and Swansong Caves and Taplow Maze were originally phreatic, and exhibit evidence for slow, deep groundwater circulation with little water table control on elevation. They may either be pressure tubes related to low and upwards trending limbs of deep meteoric phreatic loops, whose points of emergence have been removed by surface erosion, or hypogene passages developed by warm, deep sourced groundwater systems. Stable isotope analysis of calcite wall linings will be used to deduce water sources. These passages have commonly been modified by epi-phreatic development (phreatic and paragenetic loops in mid – lower passages) and horizontal planation of dipping strata at previous water table levels. The flat ceilings appear to correlate with water tables associated with four lower terraces up to 30m above the river. Laminated sediments associated with both paragenesis and horizontal passage development also appear to relate to alluvial terrace deposits on the surface.

This paper describes current geomorphological work in the Cliefden Caves area to compare evidence for hypogene vs meteoric development of caves and ways in which both the caves and associated surface landforms may be used to understand the broader history of landscape evolution.

A SHORT HISTORY OF THE CLIEFDEN CAVES, MANDURAMA, NEW SOUTH WALES

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The Cliefden Caves are situated on the traditional lands of the Wiradjuri. There is little evidence to support their use of caves or karst features. A partial Aboriginal skeleton dated approx. 7000 yrs BP was found in a cave in the mid 1980s.

Cliefden’s European history began in May 1815, with Surveyor George W. Evans recording his discovery of the first ‘stratified’ limestone in the then colony of New South Wales. This was regarded as a significant discovery at the time. The area was subsequently visited by Surveyor General Oxley in April 1820; and by Surveyor James Byrne Richardson in the winter of 1828.

William and Frederick Rothery received grants of land on Limestone Creek in 1832; known respectively as ‘Cliefden’ and ‘Cliefden Springs’. Caves were first reported by Surveyor J. B. Richardson on his ‘Sketch of two grants measured at Limestone Creek, County of Bathurst, 1832’.

Caves first came to attention of the media following the brutal murder of an itinerant farm worker in the early 1870s.

The two best known of the caves, Main and Murder, were discovered by Christian Rittmeester, a small selector residing on the northern side of the Belubula River in the late 1870s. He also discovered several other caves including the Trapdoor Cave.

The caves became a popular regional recreational destination in the early 1900s. The anticipated breaking up of the ‘Cliefden’ estate resulted in a great deal of lobbying by the local communities in an effort to have the caves reserved as tourist caves. Associated with this agitation were visits by senior government ministers and the state’s leading speleologist, Oliver Trickett. The first proposals for the construction of a dam at The Needles on the Belubula River was made at the same time.

The ‘Cliefden’ estate was sold to a land speculator, named Edward Perrot in 1919. He subsequently subdivided the estate, retaining only the ‘Caves block’. In the 1930s Perrot gave permission to the Australian museum to remove speleothems from the caves, to be used in the construction of a replica limestone cave in that institutions mineral exhibit. Two collecting trips were undertaken, the first collection being deemed inadequate, over a thousand specimens being collected on each trip.

The first visit to the area by a Speleological Society was by the Sydney University Speleological Society in 1948. The Orange Speleological Society (OSS) was formed in 1955, beginning a long association with the caves. OSS's role in the management of the caves began in 1958, with the gating of the Main Cave. Following problems with some visiting groups, the property owner requested that OSS co-ordinate all visits to the caves. OSS continues to co-ordinate access to the caves; to advise property owners on the management and protection of the caves; and to promote the study of the caves. Management guidelines have evolved over the last 50 years to control access to the caves and to mitigate and reverse damage to the caves.

YOU CAN ESTABLISH A REGIONAL MANAGEMENT BASELINE FOR NATIVE AND INTRODUCED FLORA

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After land clearing and habitat loss, introduced species pose the second greatest threat to native biodiversity in New South Wales (Coutts-Smith and Downey 2006). Identifying and prioritising which plant species pose the greatest risks is possible and has previously been done across the state at Catchment Management Authority level. Subsequent to these groups being disbanded and reformed as Local Land Services regions in 2014, we decided to re-examine the methodology previously used to identify these weed threats to biodiversity, and in particular to collate a regional management baseline of native and introduced flora within a region. Our case-study area is the Upper Belubula River Valley, home of the internationally significant Cliefden Caves geoheritage sites.

Using publically accessible State government databases and spatial searches, we accessed 1243 recorded plant taxa (native and introduced). Within this dataset, 426 (34%) taxa belonged to three common plant families, the grasses (Poaceae with 170 taxa), the pea family (Fabaceae, with three tribes totally 135 taxa) and the daisies (Asteraceae with 121 taxa). The proportions were similar when both native and introduced species were considered separately, a finding common among many eastern Australian flora studies. This again confirms that many introduced plant species belong to relatively few plant families. Considering a range of (a) recently naturalised, (b) not yet naturalised, and (c) conflict (plants which have positive and negative impacts) species, within the area we recommend that the introduction and spread of such plants, particularly from these families, should be monitored closely.

The most common of the 503 genera examined were the native *Eucalyptus* and *Acacia* (with 47 and 43 taxa, respectively). There were 373 introduced taxa of which 41 were declared under the *Noxious Weeds Act 1993*: declared species generally have significant impacts but are less commonly widespread. The declared species identified were from a smaller range of families and genera such that the predictive value of using 'plant family' to predict the identity of future weed species was lessened.

Finally, it is possible to establish a regional management baseline for native and introduced flora using publically accessible State government databases and spatial searches. Having said this, the consistency of the same information between the different databases/information sources is variable and there is a need for thorough checking before management action which aims to remove weeds and protect biodiversity.

WHY A NEW DAM ON THE BELUBULA RIVER IS UNLIKELY TO BE AN OPTIMUM WATER SUPPLY STRATEGY

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Clearly there is an impending need to augment water supplies in a number of NSW Central West towns. A major El Nino event could rapidly exacerbate this need. However, the construction of the proposed dam is only one of many ways that water supplies could be better managed. As such, I think it is short-sighted to have a feasibility study that is essentially a Yes/No assessment for this one project. Instead, a study at this stage should be taking a much broader look at various available water management strategies and assessing them comparatively.

Reasons why the proposed Needles Gap Dam, or the alternative Cranky Rock Dam, is unlikely to be the optimum strategy in this case include: (a) the devastating impacts to the Cliefden Caves, which apply to both the Needles Gap site and the Cranky Rock site; (b) the Belubula River is an inland river and does not flow to the sea – hence any water captured from it is water that is taken from downstream users including irrigators and the inland riverine environment; (c) precious little water flows down the lower reaches of the Belubula River anyway, due to existing dams further upstream (Carcoar Lake and Lake Rowlands); (d) rainfall around Canowindra is about 700 mm/year, but evaporation is over 1000 mm/year. As such, storing water in shallow, high surface-area reservoirs will result in significant water losses, especially during the summer months; (e) water security problems are projected by CSIRO to intensify by 2030 in southern and eastern Australia as a result of reduced rainfall and higher evaporation; and (f) the proposed dam sites are just downstream from the Cadia Valley Operations open-pit gold mine and large mine tailings dam. These pose significant water quality risks for the proposed dams and would likely make them unsuitable storage locations for a drinking water supply.

There are a number of obvious alternative strategies that should be considered in parallel to the Needles Gap or Cranky Rock Dams. These include: (a) urban stormwater harvesting – the nearby city of Orange is an excellent example of what can be achieved; (b) non-potable water recycling: if carefully planned, treated municipal effluent (from sewage treatment plants) can be used for some important existing non-drinking water applications; (c) indirect potable reuse: there are many options to treat municipal effluents to a very high level suitable for recharging drinking water supplies. One only has to look at the proximity of the Orange sewage treatment plant to the city's main water supply of Suma Park Dam to see how simply this might be achieved; (d) direct potable reuse: There is a major emerging trend in the USA for inland cities (e.g. in Texas) to begin directly reusing advanced treated recycled water in their drinking water systems, without first storing it in an environmental buffer such as a reservoir; (e) Managed Aquifer Recharge (MAR): Instead of storing water in a surface water reservoir, water can be stored underground in an aquifer. There are a number of benefits in using an aquifer as a storage system including greatly reducing evaporation, delivering transportation and energy savings and lower construction costs compared to a large dam.

EXPERIENCES USING A ZEBEDEE SURVEYING DEVICE AT CLIEFDEN CAVES

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Several caves and the ruins of an old stone cottage of cultural heritage in the Cliefden Caves area of the Belubula Valley, have been surveyed with a Zebedee. A Zebedee is a hand-held surveying device developed by the CSIRO that scans a laser beam 40,000 times a second to build up a three dimensional "point cloud" representation of its environment. Data in this form can show us clues to the geomorphology of a cave which are often omitted in conventional flat "paper" maps. The Zebedee is the future of surveying methods in archeology, speleology, forensics and many other fields but there are still challenges in processing and visualising the large amountsof data and in integrating this data with conventional surveying methods.

THE VEGETATION OF THE BELUBULA RIVER CATCHMENT AND SURROUNDS

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A review of information relating to the vegetation of the Belubula River catchment in central western New South Wales was conducted. The catchment extends from Mount Canobolas in the north to the Newbridge and Neville areas, with the River joining the Lachlan River near Gooloogong. Published reports on the vegetation of the area include regional vegetation mapping surveys, reserve specific surveys and surveys of Crown land include travelling stock reserves.

Over 500 native plant species have been recorded from the area, based on the Atlas of NSW Wildlife and other records. The Atlas records only one threatened flora species, *Eucalyptus aggregata* from the catchment, while there are at least another two species , *Eucalyptus canobalensis* and *Bossiaea fragrans*, which have the potential to occur as they occur in nearby areas in similar habitats. *Eucalyptus aggregata* has been recorded from the Neville area on the eastern edge of the catchment. *Eucalyptus canobalensis* occurs outside the catchment in the Mount Canobolas State Conservation Area.. *Bossiaea fragrans* is known from Abercrombie Karst Conservation in an open White Box (*Eucalyptus albens*) Woodland on slate and volcanic substrates. A number of other plant species may be considered to be of regional conservation significance including Finger Flower, *Cheiranthera linearis*.

Over 14 vegetation communities have been mapped within the catchment. These include vegetation types which correspond to the Box-Gum Woodland endangered ecological community.

The area's high agricultural productivity has meant that intact vegetation remnants are rare and generally restricted to public lands such as State Forests and Crown land.

CAVE MAPPING AT CLIEFDEN CAVES

Kevin Moore and Philip Maynard

Sydney University Speleological Society, PO Box 3318, Redfern 2016

Cave surveys by speleologists were traditionally for the purposes of exploration and basic route finding. This talk will explore the mapping of Cliefden Caves by speleologists, dating back to the 1950s and extending to the current day. A historical perspective will be presented along with the development of techniques and equipment through the years. Recent improvements in the instruments used have enabled considerable improvements in the accuracy of cave surveys.

As speleology has developed into a broader and more scientific pursuit through time, the purpose and output of mapping projects has changed. Using case studies at Cliefden, this talk presents mapping projects as the basis for studies in structural geology, karst geomorphology, hydrology and cave biology - as well as exploration and route finding. In more recent times the traditional, paper-based map products have been replaced by digital, editable products, allowing the cave map to be a living document and providing the link to GIS products, LIDAR surveys and archived, open data repositories. As more sophisticated devices such as LIDAR are introduced to cave mapping, there is still a key role for the traditional survey carried out by volunteer speleologists.

FIRST STEPS IN THE GEOHERITAGE ASSESSMENT OF CLIEFDEN CAVES

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Assessing the geoheritage significance of cave systems is a difficult task as caves are small but complex features exhibiting and containing many different classes of features such as bedrock, structure, large-scale morphologies, small-scale morphologies (speleogens), speleothems, sediments, fossils, palaeokarst features etc. Within these classes there is a great range of features, which need to be assessed in terms of abundance, diversity, representativeness, rarity, fragility, and degree of development and then compared with similar features to establish their levels of significance.

In the case of Cliefden Caves, as with most caves in Australia, there has been very little scientific research and systematic documentation of the caves. This is in stark contrast with the fossil sites at Cliefden with research starting in the 1890s and continuing from the 1950s to the present with at least 62 papers being published.

Detailed inventory and assessment studies of caves and cave systems are rarely undertaken as the work is extremely time-consuming and practically difficult, even in large developed show caves.

Essential data for study, documentation and assessment of the caves is now being provided from high quality cave mapping by members of the Sydney University Speleological Society and others and from laser scanning by Dr Robert Zlot. This work is providing a completely new view of the caves and of their relationships with geological structure and topography. One new possibility emerging is that the northern section of Taplow Maze Cave may be the most extensive section of cave developed in thinly bedded limestone in NSW.

Ian Houshold is making the first ever study of the surface geomorphology of the Cliefden Caves area and is exploring possible links between the surface and the underground landscapes.

In the 39 years since I began my cave research at Cliefden there have been enormous changes in our understanding of caves and in the tools available for analysis. With assistance from Ian, I am applying these new ideas and analysis methods to Cliefden and reexamining both my old ideas and specimens. Analyses cost money and Save Cliefden Caves Association funding has helped to get the process started, but more funds and time are required. There is no doubt that Cliefden Caves are highly significant and some features, such as the blue stalactites, are rare and internationally significant. Establishing the geoheritage significance of Cliefden Caves is a substantial undertaking and important first steps are now being taken.

PALAEO-COMMUNITY SUCCESSION IN THE FOSSIL HILL LIMESTONE, CLIEFDEN CAVES AREA, CENTRAL NEW SOUTH WALES

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The Fossil Hill Limestone in its type locality of Fossil Hill and the adjacent Dunhill Bluff, near Cliefden Caves, preserves a unique record of the flooding of a newly emergent volcanic island and the development of a series of recurrent marine benthic communities, dominated by shelly faunas. On the eastern end of Fossil Hill, volcaniclastic conglomerates of the Walli Volcanics form the shoreline, unconformably overlain by mudstones and shales interpreted as a lagoonal bay fill. Appearance of the first carbonate rocks in the section coincides with the initial trimerellid brachiopod shell beds – the first of many on Fossil Hill – which include in-situ, disarticulated and hydrodynamically stacked shells in succeeding layers. These shell beds, consisting almost entirely of *Eodinobolus stevensi*, are assigned to Benthic Assemblage 1, inhabiting the intertidal zone and slightly deeper, where they were susceptible to storm disturbance. A wave barrier up to 2 metres high, dominated by the primitive tabulate coral *Tetradium cribriforme* associated with several genera of stromatoporoids, provided a degree of shelter from the surf zone. This micro-atoll-like feature most likely grew at or below normal wave base in water up to 5 m deep, and so is interpreted as representing Benthic Assemblage 2. Overlying strata are distinguished by their fossil content of orthide and atrypide brachiopods (*Dinorthis* and *Webbyspira*, respectively), together with rugose corals (*Hillophyllum*) and a variety of tabulate corals (*Coccoseris*, and heliolitids including *Propora*, *Nyctopora* and *Heliolites*) together with several genera of bryozoa. This increased diversity is taken to indicate deeper water communities (assigned to Benthic Assemblage 3) which lived on the narrow platform surrounding the volcanic island. A return to very shallow, quiet water conditions is reflected in a rock layer marked by vertical lingulide burrows, suggesting an intertidal mudflat environment. More agitated water of a similar depth was again dominated by the trimerellid *Eodinobolus*, while the most turbulent water Benthic Assemblage 1 environments were inhabited almost exclusively by the rhynchonellid brachiopod *Rhynchotrema*. These communities can be recognized as recurring in several transgressive-regressive cycles in sedimentation and fossil content across Fossil Hill, culminating in the development of another *Tetradium* barrier on the western end of the hill.

The section through the Fossil Hill Limestone continues on Dunhill Bluff on the east side of the Large Flat (a former meander of the Belubula River, now productive farming land). Proceeding up section from the *Tetradium* biostrome, water depth increased into the Dunhill Bluff Limestone Member, which is characterized by abundant plectambonitoid brachiopods (*Mabella*, *Sowerbyites*) and trilobites (*Pseudobasilicus*). From here the section shallows upwards again, through beds with a mass nautiloid stranding, to the poorly fossiliferous and massive bedded Belubula Limestone, interpreted as mud-rich carbonates derived from breakdown of algae, probably in an extensive atoll.

This section through the Fossil Hill Limestone is outstanding in its excellent preservation and relative continuity. Considering it represents carbonate deposits flanking a volcanic island, among the most ephemeral of geological settings, it is remarkable that it has survived since the Late Ordovician 450 million years ago, to be recently exhumed by the Belubula River. There can be no question about its scientific significance on an international scale.

A CLIEFDEN CAVE AT THE AUSTRALIAN MUSEUM

Ross Pogson

Geosciences, Australian Museum, 6 College St., Sydney NSW 2010

Dr Charles Anderson, later Director of the Australian Museum visited Cliefden (then Belubula) Caves with other museum staff in 1917 and collected some transparent, perfectly formed calcite crystals. He published a detailed crystallographic study of the calcite in 1920, and a fuller account of his visit in 1924. A spectacular calcite crystal group from the caves was presented in 1923 by Miss Judy Hosie, whose father owned the nearby property. This beautiful crystal group is still on display in the museum.

In August 1932 and April 1934 Australian Museum staff again entered the caves, but for a different purpose – to collect large numbers of cave formations for the construction of a limestone cave exhibit. This remarkable re-creation of decorated limestone cavern featured natural and simulated cave speleothems: a crystal basin, ‘broken’ column, helictites, shawls, stalactites and stalagmites, sparkling rim pools and an underground river, with an illusion of depth provided by mirrors. This display was opened in 1936 and lasted until 1984 when it was removed and replaced by the Gem Vault in a new mineral gallery. Some of the cave formations were reused in a much simpler limestone cave display in the new mineral gallery, but this cave was removed in April 2010. The museum collection contains many remarkable Cliefden speleothems, including large, transparent calcite crystals, flat trapezoidal stalactites, and stalactites with profuse calcite crystal overgrowths, in addition to other stalactites, stalagmites, shawls, helictites, straws and columns. Of special interest are small pale blue aragonite stalactites from Boonderoo Cave, acquired in 1921.

CANOWINDRA'S DEVONIAN BILLABONG – A BURIED TREASURE!

Alex Ritchie

Australian Museum, College St, Sydney. NSW.

An observant rural road-worker's chance find of a rock slab, with 144 well-preserved Devonian fossil fish impressions, near Canowindra in central-west NSW in 1955 led, nearly 40 years later, to the discovery of one of the world's great fossil sites. After I joined the Australian Museum in 1968 as its Palaeontologist, I spent twenty years, 1973-93, trying to locate the source layer of the Canowindra Fish Bed, without success. In early 1993, after I talked to Canowindra Rotary Club on my fossil fish finds in Antarctica and Australia, Cabonne Council offered the use of a 20 tonne bulldozer and driver (free of charge) to search for Canowindra's lost fossil layer. A trial dig found it in only three hours. In July 1993 I returned to Canowindra and excavated the site with the same machine and driver for 10 days. This time the project, with massive community support, recovered 70-80 tonnes of rock slabs with ca. 4000 well-preserved fish fossils, crammed together like sardines in a tin. Only the upper surface of the fossil fish layer was removed to display in Canowindra. The undersurface of the fossil layer, with fine belly impressions of the same fishes, was cleaned, protected and reburied until funding is available to reopen the site for research, and hopefully a unique, on-site, public display.

Canowindra's remarkable fossil site is a unique 'window in time', preserving what happened when a large lake or billabong dried up, trapping, concentrating and burying, in situ, many thousands of long-extinct fishes representing several different groups. This time, in the mid-late Devonian Period 360-370 million years ago, represents a crucial period in vertebrate evolution when our air-breathing fishy ancestors were beginning to emerge from the water to explore the land environment. The Canowindra fauna is dominated (ca. 97%) by three types of armoured fish (placoderms) found world-wide – *Bothriolepis*, *Remigolepis* and *Groenlandaspis*. Also present, but much rarer, are three types of air-breathing sarcopterygian fish, *Canowindra grossi*, *Gooloogongia loomesi* and *Mandageria fairfaxi*, and a small lungfish (or dipnoan) *Soederberghia simpsoni*, first discovered in East Greenland. Fossils of all these fish are on display in the Age of Fishes Museum in Canowindra.

The most exciting part of the Canowindra story is that only a small part of its world-class fossil deposit was uncovered in 1993 and then had to be reburied to protect it for posterity. I am convinced that many more thousands of well-preserved fossil fishes still lie buried at the site, and they probably include as-yet-undescribed taxa. Of particular scientific importance is the potential for discovery of articulated skeletons of early tetrapods in Canowindra's Devonian Billabong. We know (from fragmentary fossils and from footprints) that such early amphibians were already living in Australia at that time. In July 2013 when I took Sir David Attenborough to visit Canowindra, he agreed with me that Canowindra's mass-kill Devonian fossil fish deposit must be high on anyone's list of potential sites to search for articulated skeletal remains of early tetrapods which, if found, would be a first for the Southern Hemisphere.

SUBAERIAL DISCONFORMITIES IN THE ORDOVICIAN LIMESTONES AT FOSSIL HILL, CENTRAL WESTERN NEW SOUTH WALES, AND THEIR GLOBAL SIGNIFICANCE

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The Upper Ordovician Fossil Hill Limestone is a sequence of medium to dark grey to brown shelly limestones, comprising lithologies consisting of macro-skeletal and micro-skeletal packstones and wackestones, lime mudstones, skeletal and lithoclastic grainstones, and local skeletal boundstones (limestones formed by a framework of corals, stromatoporoids, bryozoans, or calcareous algae). The limestone sequence is richly fossiliferous and records mostly quiet shallow-water muddy environments that were periodically subaerially exposed, interspersed with occasional turbulent water deposits. Shelly fauna and algal flora inhabited these substrates as benthos and also formed small-scale encrustation points for frame-forming organisms.

Expression of subaerial depositional hiatuses in the Fossil Hill Limestone resulting from periodic exposure varies from low-angle bedding intersections to bedding-parallel disconformity surfaces. Some are solutional surfaces. The disconformities are directly underlain by bleached limestone and soil-filled fissures and, at deeper levels, by fossil-mould limestone and solution-enlarged vugular limestone. Disconformity surfaces are overlain by lithoclast beds, remanié fossils, and grainstones with varying amounts of calcrete ooids. Beneath disconformities, fossil skeletons generally provided the loci of solution, often with solutional-enlargening of the skeletal form to develop interconnected vugular structures. The fossils most susceptible to solution were trimerellid brachiopods and the possible tabulate coral *Tetradium*. Solution cavities are filled with sparry calcite, or partly to fully occupied with infiltrated fine-grained sediment (crystal silt) and sand-sized 'micro-breccia' that was collapsed and reworked from solution-sculptured walls into the cavities. Locally, the lithoclasts overlying a disconformity are reworked gravel beds of remanié fossils, such as *Tetradium*, that show evidence of solution-enlargening and filling with fine-grained infiltrate and 'micro-breccia' prior to their reworking.

The Fossil Hill Limestone with its suite of disconformity features stands in contrast to the subaerial disconformities recorded in the contemporaneous Daylesford Limestone at Bowan Park west of Orange in central NSW, in that the sequence at Fossil Hill contains more abundant shelly fossils and is more dominated by framework-building organisms. As such, subaerial disconformities at Fossil Hill have resulted in a suite of alteration features subtly different to those of the Daylesford Limestone. Subaerial disconformities, as recorded in both these formations, are not widely reported in the literature globally because generally, such features are not well represented in Ordovician limestones. Also, the occurrence of calcrete ooids (as a disconformity indicator) is a rare feature in limestone of this antiquity. Together, the Fossil Hill Limestone and the Daylesford Limestone present a suite of disconformity features derived from subaerial exposure that record the tropical zone climate regime when these limestones were deposited, and also reflect the tectonic setting of region immediately after lithification. Consequently, the story they present is unique and thus globally significant as examples of subaerial alteration in an ancient tropical climate volcanic island environment.

REVIEW OF DESCRIBED ORDOVICIAN FOSSILS FROM THE CLIEFDEN CAVES AREA OF CENTRAL NEW SOUTH WALES IN TERMS OF THEIR SCIENTIFIC, CULTURAL AND HERITAGE SIGNIFICANCE

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The cave-bearing Ordovician rocks of the Belubula valley near Boonderoo and adjacent properties show some of the most scientifically significant fossils in Australia, and a number are globally important in representing the earliest examples of their type in the geological record. Other fossil groups, like the deep-water siliceous sponges, are highly diverse in the limestone breccias that form a type of "Lagerstatten" because of their exceptional well preserved faunas. Also, Fossil Hill, Dunhill Bluff and Trilobite Hill are recognized as iconic examples of Australia's palaeontological heritage, given the diversity of well preserved shelly, coral, and trilobite-bearing strata. To date 62 scientific papers have been published in international journals, documenting 191 genera and 263 species of fossils from near Cliefden Caves, with 45 genera and 101 species unique to the area.

R. Etheridge described the first fossils (a stromatoporoid and a probable coral) from Fossil Hill in 1895 and 1909. B. Glenister, D. Hill and J. Phillips Ross documented additional forms (nautiloids, corals and bryozoans) between 1952 and 1961. N.C. Stevens only confirmed the Ordovician age of the limestone in 1952. Then, from 1968 to 2009, Webby (later with some 15 other co-workers) contributed 25 papers on fossils from the Cliefden Caves Limestone Group and Malongulli Formation, including stromatoporoids, sponges, corals, trilobites, nautiloids, conodonts, radiolarians and algae. Closely collaborative work by Percival added a further seven papers on the brachiopods and associated molluscs. Other authors undertook separate work on Ordovician faunas, such as ostracodes, graptolites, conodonts, and stromatoporoids, that added to knowledge of the rich biodiversity. The systematic descriptions of the fossils formed a firm foundation for recognizing a sequence of biostratigraphically-restricted faunas. This scheme has allowed precise correlations of other Ordovician limestones throughout Eastern Australia.

Late Ordovician fossils from the Cliefden area are also significant in defining biogeographic affinities in regions now remote from each other - the Macquarie volcanic arc of eastern Australia, and areas of China, Kazakhstan and the Russian Altai. Of particular importance are trilobites such as *Pliomerina*, and trimerellide brachiopods that colonised shallowest habitats of volcanic island settings at Cliefden during Late Ordovician time. The trimerellide *Belubula* is found only at Cliefden and Zhuhuia, south China, while the species, *B. spectacula* is restricted to Cliefden. The stromatoporoid species *Camptodictyon amzassensis* is known only from Cliefden and nearby N.S.W. sites, as well as in the Russian and Chinese Altai. This provides critical evidence that such taxa evolved and were dispersed to closely adjacent regions, but over time, with plate tectonic movements, became widely separated. In contrast, high numbers of endemic siliceous sponge taxa in the Malongulli fauna (84% of the 34 known genera; and 93% of the 45 sp.) indicate a record mainly of their diversification in an isolated volcanic island slope setting.

CONSERVATION ISSUES – CLIEFDEN AREA

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The spectacularly narrow gorge at The Needles has prompted many suggestions over the last century that this would be a good site for a dam. The unsuitable geology of the area has always caused engineers to reject the site outright. The adverse effects of a dam at this location have never been properly considered. These include the flooding of the Cliefden Caves, the fossil site, and the thermal spring. Also the adverse effect on the flora and fauna (including fish) has never been studied. Back in the 1960s and 1970s there was also an alternate proposal to dam the Belubula at a location called Cranky Rock and two different locations were surveyed. The construction costs at Cranky Rock were prohibitive and all proposals were dropped when the planned new city in the region did not go ahead.

It appears that the latest proposal for a dam at The Needles was first floated by the local federal member for Calare, John Cobb, at an on-site meeting with the chairman of Central Tablelands Water, Geoff Braddon, in March 2013. Mr Braddon reported this to the meeting of Central Tablelands Water on 10 April 2013. The matter was again in the press when the ABC reported that the General Manager of Central Tablelands Water, Tony Perry, would write to Calare’s election candidates calling for their support for a new dam on the Belubula River. Locals did not pick up on this media report. On 1 September 2013 the *Western Advocate* reported that some of the candidates for the forthcoming federal election supported a dam at The Needles. From that time onwards there were various reports in the local media and discussions by Central Tablelands Water, unfortunately these reports were missed or unreported by locals.

It wasn’t until an Illawarra caver, Robert Kershaw, posted a message on the Ozcavers mailing list on 13 June 2014 referring to an article that day in *The Australian,* that the general caving community realised what was going on. Immediately some speleologists commenced a vigorous campaign to stop any proposed damming of the Belubula River. They were assisted by the National Trust of Australia (NSW) who classified the Cliefden Area in August 2014.

On 3rd October 2014 the ABC 7.30 Report was broadcast which gave a very balanced analysis of the situation at Cliefden. It had a significant impact on the campaign.

In October 2014 the National Trust submitted their application to the NSW government for the Cliefden Area to be included as an item of NSW State Heritage. This application was considered at the February meeting of the State Heritage Register Committee of the Heritage Council of NSW and they resolved that Cliefden Caves are potentially of state significance. The National Trust published an article on Cliefden Caves in the

February edition of their magazine. A public meeting on 18th November 2014 called *Water & Wetlands – Needles Gap Dam* was held in Orange and was well attended.

As part of the campaign to save the caves, speleologists are resurveying all the caves to a much higher standard using state of the art laser devices and digital mapping techniques. This information will be used by geomorphologists for their research into the scientific importance of the caves and karst. The Australian Speleological Federation Karst Conservation Fund has funded a bat study, and the Save Cliefden Caves Association has funded research by Sydney University into the geomorphology and geoheritage of the Cliefden Karst.

In February 2015 WaterNSW released its report into possible dam sites on the Belubula. This report is nothing better than a stitch-up designed to obfuscate and confuse. The most striking error is that the map on page 134 is labelled "Cranky Rock Dam Site 1", however it is Cranky Rock Dam Site 2. There is no map of Cranky Rock Dam Site 1 and WaterNSW refuse to correct it. The best kept secret of the dam proposal is that it will be substantially funded by private enterprise. Who knows what will be in the contract, however based on the history of such contract in NSW you can be sure these are some fairly nasty clauses along the lines of "heads they win" and "tails we lose". You can certain that the water will no longer be publically owned – it will be privately owned; an outcome which will prove disastrous for residents and farmers alike.

HISTORY OF THE CLIEFDEN CAVES THERMAL SPRING

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The thermal spring on the banks of the Belubula River at Cliefden Caves NSW was described by Government Geologist C S Wilkinson in a report in the *Australian Town and Country Journal* in 1876. Wilkinson stated that the spring was first noted 30 years before – about 1846 – which was 14 years after the first land grants in the Cliefden area were taken up by brothers F J and W M Rothery in 1832. An official version of Wilkinson's report was published in the *Records of the Geological Survey of NSW* in 1892, the year after his death.

A more extensive description of the phenomenon was written by Oliver Trickett (Inspector of Caves) in his 'Report of the Cliefden Caves, Warm Spring, and Fossil Hill, Belubula River' printed in the *Annual Report of the Department of Mines* for 1908. Trickett measured the temperature of the spring as 84° F (29° C) and analysed a sample of the water. Wilkinson had reported a water temperature of 88° F (31° C) and a discharge of 40,000 gallons (190,000 litres) per hour, but this flow was considered excessive by Trickett who estimated the rate as about 10,000 gallons (45,500 litres) per hour. Trickett noted that while there was a main outlet, there were also several subsidiary ones and he stated that this caused difficulty in accurately estimating the flow rate. He also stated that the position of the main outlet changed, probably as a result of floods. This report is interesting as there have been no recent reports of the discharge point moving, and there seems to be only one point of discharge. It is not known what might have changed to cause this. One possibility is that the actual discharge point has been traced back further into the bank of the river by excavation. At some point in the past an effort was made to construct a bathing pool at the first point of discharge. This pool is approximately two metres in diameter and about the same deep. A wall was constructed to contain the water; however it is unclear how long ago this work was carried out.

Wilkinson's report also stated "That it [the spring] contains lime in solution is evident from the calcareous tufa deposited from it." As Wilkinson was the Government Geologist, we can be sure that he was able to correctly identify this deposit. Cursory examination of the site has not revealed any evidence of tufa, however it may have been carried away for rock gardens or incorporated into the bathing pool wall. There have never been any other reports of tufa at this site, although the tufa deposits nearby on Davys Creek have been extensively investigated by a number of scientists.

It is clear that much further work needs to be done on the thermal spring. As far as this author can ascertain, there have not been any scientific investigations done on the thermal spring since those of Trickett in 1908! This is a sad indictment of the state of science in Australia.

Recent temperature readings taken by the author (30° C, mid-way between the other two reported readings) seems to confirm that the temperature has not changed in the last 170 years. The most intriguing question is, of course, where does the water in the thermal spring come from? An annual flow of some 400 million litres per year at constant temperature seems to indicate that the water is welling up under pressure from some considerable depth.