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Published

2023

Conference Title

Asia Pacific Regional Conference on Underwater Cultural Heritage Proceedings

Version

Version of Record (VoR)

Funder(s)

ARC

Grant identifier(s)

LP210200704

Excavation, conservation, and preservation of the Mt Gambier underwater fossil deposits

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ABSTRACT
This paper will examine the history of underwater fossil research in the Mt Gambier region, Australia, focusing on ongoing efforts to study, conserve, and protect underwater resources found in the freshwater sinkholes and limestone caves of the region; as such, the topic of this abstract fits best within the session The Archaeology of Submerged Landscapes and Inland Waters because it is concerned with cave sites that have become flooded. I will describe the considerable past efforts that were undertaken to extract fossils from Green Waterhole, as well as recently successful efforts to have this site registered as a South Australian Heritage Listed site, ensuring legislated protection for the cave and its deposits into the future. In addition, a new research program funded by the Australian Research Council and in collaboration with the Cave Divers Association of Australia and the South Australian Museum will be presented. The new work includes efforts to successfully recover fossils with as much contextual information as possible, especially geochronological and environmental data. Using these data, we expect to determine the geological age of the extinct megafauna recovered from the sites and the environments they inhabited; data critical for determining the degree to which humans or environmental change contributed to their demise. We will also evaluate the impact of such research on the preservation of the caves, ongoing efforts to conserve the geoheritage potential of the sites, and means of educating the public on the unique underwater resources they represent.

Keywords: megafauna, Pleistocene, geoheritage, South Australia

LIST OF ABBREVIATIONS
ARC – Australian Research Council
CDAA – Cave Divers Association of Australia
ka – thousand years

INTRODUCTION

The topic of this paper fits best within the Session Archaeology of Submerged Landscapes and Inland Waters because the underwater caves of the Mt Gambier region are freshwater deposits in a young, terrestrial karstic landscape (Figure 1). The Mt Gambier caves are found in the latest Eocene to Miocene limestones of the Gambier Limestone within the Gambier Basin, although rarer younger caves are also formed in the Quaternary dune calcarenites (Grimes et al. 1999; Webb et al. 2010). The limestones are relatively soft and weakly consolidated, and both limestones and calcarenites show synergetic karst features such as development of solution pipes and calcreted caprocks (Grimes et al. 1999).

Collapse dolines are frequently recorded in the Mt Gambier region, and those that fall below the waterline form cenotes. These are up to 125 m deep, and generally circular, sheer-walled, and floored by large rubble cones (Webb et al. 2010). Cave and cenote dissolution is thought to be the result of volcanogenic CO_2 acidified groundwater resulting from Pleistocene–Holocene volcanic eruptions, in particular the 28 ka Mt Gambier eruption (Webb et al. 2010). The phreatic caverns formed by this dissolution collapsed possibly during the low sea levels of the Last Glacial Maximum (Webb et al. 2010), forming sites such as Hells Hole, Umpherstons, The Sisters, Little Blue Lake, One Tree, and Gouldens; The Shaft is a rare example of cave dissolution with a solution pipe entrance that has not yet collapsed (Grimes et al. 1999). Flooding of the cenotes is thought to have occurred approximately 8 ka based on radiocarbon dates associated with a stromatolite from Black Hole (Kelly 1998). There does not appear to be any hydrological or speleological connection between the cenotes and the phreatic caves of the region (Webb et al. 2010).

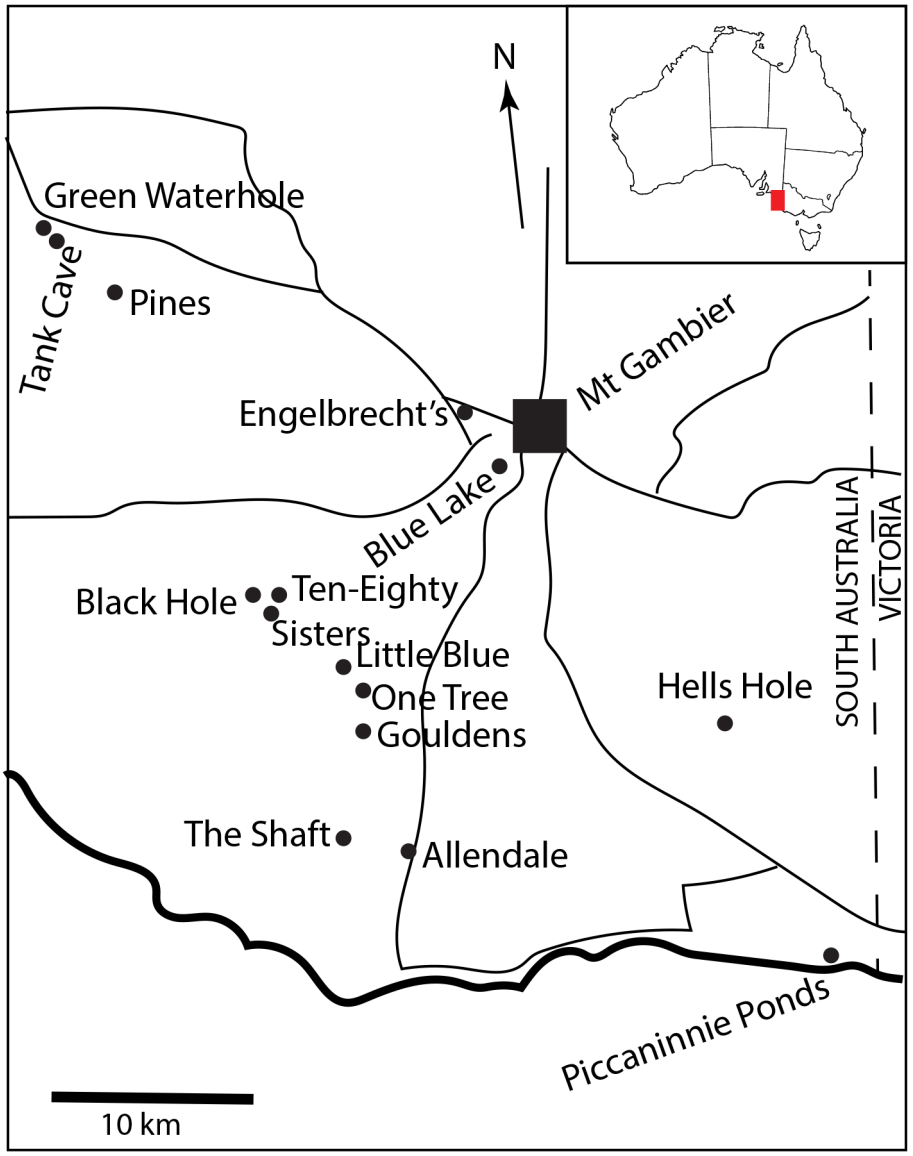

Figure 1. Location of some of the major cave diving locations in the Mt Gambier region. Adapted after Lewis and Stace 1982.

The phreatic caves of the Mt Gambier region are shallow, horizontal, joint and bedding-plane controlled systems (Grimes et al. 1999; Webb et al. 2010). Passages are primarily epiphreatic, fissure-style, and solution features associated with previous water table levels such as incuts and undercuts are frequently observed (Grimes et al. 1999; Webb et al. 2010). The bulk of the cave systems are underwater, and some have been heavily modified by breakdown, forming collapse domes and rubble filled passages (Grimes et al. 1999). These sometimes reach the surface, such as Green Waterhole (Fossil Cave). There are over 50 caves recorded around Mt Gambier (Webb et al. 2010), many of which have been mapped and/or discovered by the CDAA; the most extensive cave system in the region is Tank Cave with over 10 km of passages, one of which was recently (2018) connected to Green Waterhole.

Fossils from the underwater caves in Mt Gambier were first reported to palaeontologists in the 1960s. The following history is recounted from Pledge (1980) and Horne (1988). In 1964 G. McKenzie passed some possum and sthenurine (extinct short-faced kangaroos) fossils he found from Green Waterhole to amateur palaeontologist and caver F.W. Aslin, who subsequently passed them on to B.

Daily at the South Australian Museum. In 1965 Daily collected kangaroo and pig remains from near the entrance to the cave that probably represent more modern specimens. In 1968 divers B. Brawley and G. McKenzie recovered substantial sthenurine material including crania in 'excellent condition'. A second extraction occurred later that same year, with a third expedition in 1969 yielding considerable postcranial material. Fossil material had also been recovered at some point from the Pines Cave, but this material was only discovered in the Australian Museum in 1968, and it is not clear in Pledge (1980) or Horne (1988)'s accounts when or by whom this was collected. The fossil collecting exploits of some divers, however, was sensationalised in the 15 February 1969 issue of *Pix* magazine. In 1974 a further extraction took place from Green Waterhole after reports of 'unauthorised' divers in this cave who were planning on returning; presumably these divers were interfering with the fossil deposits.

Further dives in 1978 by cave divers from Flinders University recovered more bones, which were passed on to R. Wells, palaeontologist at Flinders. This resulted in the first systematic efforts to recover bones from Green Waterhole, as described by Horne (1988). At the end of 1978 a grid system was laid out across the southern exposures of fossils, and much material was again collected, this time however with more specific locality information preserved. In 1987 and 1988, through the South Australian Underwater Speleological Society (SAUSS) and Flinders University, further collection of fossil material in reference to the grid system was made. The results of these collections are described in Horne (1988) and Newton (1988).

Fossils representing extinct and extant Quaternary vertebrate faunas have also been reported from numerous other cenotes and caves from the Mt Gambier region (Figure 1); however, unlike those from Green Waterhole (Fossil Cave), none have been subject to systematic or extensive excavations. Underwater sites yielding fossils include Ewen's Ponds, Ten-Eighty Sinkhole, Goulden's Hole, Tank Cave, Engelbrecht Cave, Blue Lake, Kilsby's Sinkhole (Reed and Bourne 2000). Nevertheless, there has been little published in the scientific literature concerning the underwater fossils of Mt Gambier. Pledge (1980) provided descriptions of the initial finds from Green Waterhole, and the birds from the site were published by Baird (1985). Baird (1991) also discussed some aspects of the taphonomy of the site. Reed and Bourne (2000) summarised what was then known about the fossil taxa found in the Mt Gambier caves. Green Waterhole was listed as one of the most important Australian fossil sites in *Australia's Fossil Heritage* (The Australian Heritage Council 2012).

In late 2018, further megafauna fossils were discovered in pristine condition in the Bone Room chamber of Tank Cave (Green 2018). This represented one of the most significant finds of this kind in Mt Gambier since the excavations of Green Waterhole in the 1980s. Unfortunately, these finds coincided with reports of unauthorised fossil extractions in Green Waterhole. The history and potential of the fossil deposits in the Mt Gambier region, the dearth of published scientific studies, and the recent finds and incidences have highlighted the need to (1) conduct further scientific study of the underwater fossil deposits; and (2) ensure adequate protection and conservation of the cave systems and the fossils therein.

CASE STUDIES

The case studies under consideration are the following: (1) An Australian Research Council Linkage Project between Griffith University, CDAA, South Australian Museum, the University of Adelaide, and the University of Queensland, aimed at undertaking new scientific analyses and excavations of the fossil underwater deposits of the Mt Gambier Region. (2) The South Australian Fossil Heritage Working Group and their efforts to add Green Waterhole and Tank Cave fossil deposits to the state heritage list.

RESOURCES

The resources available to conduct the work include funding from the ARC, the CDAA, Griffith University, as well as the expertise and time from these organisations and those from University of Adelaide, University of Queensland, Flinders University, South Australian Museum, South Australia Department for Environment and Water (DEW). Griffith University and partners were awarded $268,529 in March 2022 by the ARC for a project entitled *Deep time extinctions and environments in Australian underwater caves*.

FRAMEWORK

ARC Linkage Project *Deep time extinctions and environments in Australian underwater caves*

The following summarises the goals of this project (from Australian Research Council, 2019):

> This project aims to investigate the unique submerged Mt Gambier fossil deposits to determine the role environmental change had on large Australian mammal extinctions. By using a combination of technical diving and scientific expertise to study untouched fossil deposits from underwater caves, this project expects to provide greater understanding of past ecosystems and animals, advancements in geochronological techniques, and data critical to prepare Australians for action in protecting our biological heritage. Expected outcomes include insights into cave conservation and protection of underwater cave systems, updated policies on cave management, and promotion of our understanding of Australian geo-heritage through education and displays.

This project consists of a partnership between Griffith University, CDAA, South Australian Museum, the University of Adelaide, and the University of Queensland to undertake new studies on the underwater fossil deposits of the Mt Gambier region, with results feeding back directly to the CDAA, the South Australian Museum, and other interested parties for education and conservation purposes, in addition to the scientific contributions. The focus of this project is on four caves and cenotes: Gouldens, Engelbrect's East, Green Waterhole, and Tank Cave. It will combine new excavations as well as novel (for the region and underwater setting) sampling, namely geochronological (uranium-series, optically stimulated luminescence, electron spin resonance dating) and palynological, alongside underwater palaeontological sampling and analyses. To prepare for this project, a thorough review of current underwater palaeontological techniques was published (Louys 2018), and pilot data were collected.

Since the award of ARC funding, the project has grown to include photogrammetry analyses in collaboration with the CDAA and Flinders University. The production of 3D models of the underwater systems will not only be of enormous benefit to the taphonomic and speleological analyses planned, but can also be fed directly into current cave conservation efforts, such those of the Project Baseline team monitoring Tank Cave (https://projectbaseline.org/), and displays and educational resources for the South Australian Museum. The project has also embraced new methodologies, such as environmental DNA studies, with recent efforts successful in securing additional funding for these analyses.

The South Australian Fossil Heritage Working Group

This group was set up in recognition of the need to establish a collaborative group of palaeontologists, conservationists, speleologists, and government members to further the protection of natural sites with significant fossil deposits in South Australia. South Australia has a strong and proud tradition of fossil conservation at the world and state level, exemplified by the World Heritage Listing of the Naracoorte cave system (alongside Riversleigh, as the Australian Fossil Mammal Sites; Bourne and Reed 2009), as well as State Heritage nominations of individual caves and multi-site areas in the Naracoorte Caves

National Park (Lewis 2019). Although the heritage importance of Green Waterhole had been recognised for some years (Australian Heritage Council 2012; Lewis 2019), the initiation of a new research program through the ARC Linkage Project and the new finds made in Tank Cave in 2018 provided the impetus for the formation of the group and the nomination of Green Waterhole – Tank Cave complex for State Heritage Listing. Members of the working group included representatives from Griffith University, CDAA, University of Adelaide, the South Australian Museum, Flinders University, and the South Australia Department for Environment and Water (see Acknowledgements for individuals involved).

The South Australian State Heritage Register is a list of areas protected under the Heritage Places Act 1993 from alteration, damage, or removal without formal prior consultation and permission (South Australian State Heritage, https://www.environment.sa.gov.au/topics/heritage/sa-heritage-register). State Heritage listing provides legal protection to fossil sites that would otherwise not be provided even if such sites are designated Geological Heritage Sites by the Geological Society of Australia (Lewis 2019). Current federal or state laws in Australia do not provide adequate or consistent protection for fossils (Percival 2014). Significant education and awareness training for cave divers has been in place for decades (e.g., Louys 2019), however, recognition of the State Heritage Register of the importance of the caves will, it is hoped, add impetus and focus on their preservation.

Like the nomination of the Naracoorte Caves National Parks to the State Heritage Register linked to the Natural (as opposed to Built) environment, the nomination of the Green Waterhole – Tank Cave Complex was orientated towards Geological, Archaeological, Palaeontological and Speleological heritage (GAPS heritage; Lewis 2019), and was a multi-site nomination. Specifically, it focused on the palaeontological, speleological, and geological significance of the caves and their deposits, as follows (South Australian Heritage Register 2022):

> The Green Waterhole - Tank Cave Fossil Complex contains the only known extensive underwater vertebrate fossil deposits in Australia. This unique freshwater depositional environment has ensured the preservation of extinct species not found anywhere else, with several additional species new to science recovered and awaiting description. The underwater deposits have also resulted in a completeness and preservation of fossil assemblies almost unique for Australia. This provides an important opportunity to investigate the evolution of South Australian mammals and birds. The impacts of this type of site on the age and nature of the fossil remains have yet to be fully studied. The complex represents unusual geological formations including the occurrence of a shallow fresh waterhole not usually found in sinkholes in the South East, and evidence of rare volcanogenic influences in the formation of the cave system. The cave complex also demonstrates rare speleological features, including length of cave passageways, clarity of water, underwater speleothems, and being a type locality for stygofauna. The complex also holds importance for the development of cave diving in the country and is closely associated with the Cave Divers Association of Australia. It is also acknowledged as a place of significance for the Boandik people.

The nomination was assessed under the following criteria under Section 16 of the *Heritage Places Act 1993*: (b) it has rare, uncommon or endangered qualities that are of cultural significance; (c) it may yield information that will contribute to an understanding of the State's history, including its natural history; and (g) it has a special association with the life or work of a person or organisation or an event of historical importance. These criteria recognise both the palaeontological (and associated geological and speleological) features of the caves, but also the history and connection with Indigenous groups as well as more recently, the cave divers.

RESULTS

The first field season from the project *Deep time extinctions and environments in Australian underwater caves* took place over 10 days in early April 2023. The season had three primary

objectives. First, collect surface samples and associated geochronological samples from the megafaunal deposits in Engelbrecht's East deposits. These are unique for the project in that they represent a fissure fill deposit actively eroding out in a dry section of the cave. It is included in this project because it requires diving through an underwater passage to access, but more importantly is actively eroding into a wet section of the cave. This provides significant contextual data for the taphonomic aspects of the project seeking to determine whether skeletal elements were deposited in wet settings pre or post fossilisation.

Second, three sample cores, one optically stimulated luminescence, one pollen, and one eDNA, were collected from each of the three sites of interest, Gouldens, Green Waterhole, and Engelbrecht's East from the underwater passage mentioned above; previous pilot data had suggested that sediments in this section could be as old as 95 ka (Arnold, pers comm., 2021). To preserve stratigraphic integrity within these cores, as well as any viable DNA, all cores collected during this season were frozen in the orientation in which they were taken. Sampling was made considerably more difficult in Green Waterhole and, to a lesser extent, Gouldens, due to the amount of fine particulates on the cave floor. Once disturbed, these sediments became suspended in the water column and reduced visibility to almost nothing, and most of the sampling and exit from the cave was done via tactile signalling.

Figure 2: The author examining a cow femur, Green Waterhole, Mt Gambier (image courtesy of Steve Trewavas).

Third, surface reference material, much of recent age (specifically, less than about 200 years old as represented by European domesticates) was collected from Gouldens and Green Waterhole (Figure 2). These were collected to provide modern baselines for faunal dating and taphonomic analyses. Species recovered thus far include sheep, cow, and murids. In addition to these objectives, the photogrammetry surveys were begun in all three caves. These will require numerous dives and trips to complete.

With regards to the protection of the sites, the Green Waterhole - Tank Cave Fossil Complex was officially confirmed as a State Heritage Place in the SA Heritage Register on 23 June 2022. The South

Australian Fossil Heritage Working Group continues their work listing other fossils sites on the registry; however, to date none of any additional sites relate to underwater fossil deposits.

ACKNOWLEDGEMENTS

The Cave Divers Association of Australia have been integral to this project and their immense contribution is acknowledged here. In particular, many thanks Peter Wolf who was instrumental in setting up the Linkage Project, and Joseph Monks who has since been intimately involved with the planning and execution of the project and fieldwork. The CDAA National Directors are thanked for their ongoing support. Dive field support was graciously provided by Joseph Monks, Damian Bishop, Ellyse Klein, Hiro Yoshida, Tim Featonby, Steve Trewavas, and Kelvin Ball, with surface support provided by Meg Walker, Gilbert Price, and Jody Kreuger. Scientific support was provided by Lee Arnold, Martina Demuro, and Liz Reed. The members of the South Australian Fossil Heritage Working Group involved in the listing of Green Waterhole – Tank Cave complex (Julien Louys, Peter Wolf, Peter Horne, Liz Reed, Diego Garcia-Bellido, Mary-Anne Binnie, Neville Pledge, Trevor Worthy, Rod Wells, Gavin Prideaux, Ian D. Lewis, Steve Bourne, and Anna Pope) are warmly thanked for their tremendous efforts in having the site entered in the State Heritage Register. Funding for this project is provided by ARC Linkage LP210200704 and The Australia Pacific Science Hermon Slade Research Fund HSF23047.

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