CONFERENCE
PAPERS

TASTROG 1993

LAUNCESTON, TASMANIA

Monday 4th January 1993

to

Friday 8th January, 1993

CONTENTS

HYPOTHERMIA

Hypothermia is a common and potentially serious problem amongst various groups in the community such as bush-walkers, water sports enthusiasts and the elderly. It may be encountered amongst cavers who should be alert to the early signs amongst members of their party.

There is no real consensus on the definition of hypothermia but a useful guide is:

Mild hypothermia	34 - 35°C
Moderate hypothermia	30 - 34°C
Severe hypothermia	< 30° C

The underlying cause and the duration of the hypothermia may influence treatment and the type of situation met by cavers will usually be a very acute immersion hypothermia or a slightly less acute exhaustion/exposure hypothermia so these are the only ones I will consider.

Body temperature is normally regulated by balancing metabolic heat production plus the more or less optional heat production from muscular activity against heat losses. Some of these losses are regulated automatically by the autonomic nervous system, eg sweating and vasoconstriction and some are regulated by voluntary behavioural changes, e.g. seeking shelter, wearing wet suit etc.
When the limits of heat production or insulation are exceeded, hypothermia may occur.

Hypothermia is often mistaken for fatigue when it is the result of exposure/exhaustion. Initially, there is shivering and tiredness combined with apathy, impaired judgement and slow progress. Then the victim repeatedly stumbles and falls and speech may be slurred and incoherent. Hallucinations are common.

Finally, there is complete collapse and they are noted to be cold and rigid with a slow heart rate.

If hypothermia is suspected, management should include:

- Assessment of <u>A</u>irway, <u>B</u>reathing, <u>C</u>irculation.
- Diagnosis.
- Gentle handing of victim.
- Prevention of Further Heat Loss
- Provision of additional heat.
- Evacuation.

<u>ABC</u> is always first priority in first aid but in hypothermia there is a trap; a detectable pulse is not necessarily present, heart rate may be only 6/min and respirations very shallow with fixed dilated pupils. Without an ECG, it may be very difficult to detect life and the victim is said to be in the "metabolic ice-box" and is more or less stable. At this stage, attempts at CPR may cause ventricular fibrillation (in-coordinate action of the heart without an output) which is resistant to treatment until the heart is warmed > 29°C.

This decision - whether or not to commence CPR - is very difficult and should not be made precipitately.

DIAGNOSIS

High index of suspicion in cold wet windy conditions, especially if the victim is exhausted, lost or poorly equipped.

The signs and symptoms of hypothermia have already been alluded to but confirmation comes with a thermometer reading. Temperatures can be taken in the mouth which is very unreliable, in the armpit (axilla) which is less unreliable and tends to read 1-1.5°C below core temperature or in the rectum or oesophagus. These last two are the most reliable but have their drawbacks in the practicalities of measuring at these sites.

Thermometers required are, in increasing order of sophistication (and expense!) - hands, low reading mercury/glass, digital electronic and thermistor.

GENTLE HANDLING

Cold hearts (<29°) are very irritable and any rough handling of the victim may cause ventricular fibrillation. Careful thought must be given even to the removal of wet clothes and particularly to rough transportation.

PREVENTION OF FURTHER HEAT LOSS

This is **essential**. It includes provision of shelter **immediately**, insulation from cold ground, replacement of wet with dry clothes, insulation of **head** and of body with sleeping bag and plastic bag. Attempt to reduce respiratory heat loss without suffocating the victim, e.g. a loose scarf around the face.

PROVIDE ADDITIONAL HEAT

The decision whether to rewarm on-site is complex. If evacuation can be rapid and smooth, it may be better to leave the victim in the "metabolic ice-box" until he reaches hospital. Otherwise the options range from warm (20°C) **not** hot shelter, warm drinks and food, all suitable options for the mildly hypothermic conscious victim. Body to body contact, heat packs in the armpits, groins and neck and airway rewarming may also be used in the more severely affected victim.

EVACUATION

As already mentioned, this should only be attempted if it can be achieved relatively smoothly and quickly. USA experience suggests 6 hours as a maximum. Remember that there must be frequent opportunity for reappraisal of the victim during the evacuation.

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Severely hypothermic victims should always be resuscitated unless there is an obviously lethal injury, rescuers are endangered or chest wall compression is impossible.

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No hypothermic victim should be considered dead until he is warm and dead!

AUSTRALIAN SPELEOLOGICAL FEDERATION
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8 December 1992

Dear Tastrog,

Here is the abstract for my update session at the conference.

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Abstract:

KARST INDEX UPDATE

The cave, map and reference lists in the book *Australian Karst Index 1985* were produced from databases running on a VAX minicomputer. These databases are being converted so that they can be run on PCs located with local clubs in accordance with a specification produced by ASF.

This will have the benefits of making the data more available to clubs, distributing the updating load, keeping the data more up-to-date, and facilitating the production of State volumes of the *Australian Karst Index* at intervals to suit the State's resources and needs at the time.

The databases are being built in a manner to comply with proposed International Union of Speleology (UIS) standards, whose aim is to facilitate the valid transfer and consolidation of karst data between independent databases around the world.

Distribution of the converted system to clubs is now imminent. This session will bring you up to date, demonstrate the system, and give you an opportunity to ask questions and offer suggestions.

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Yours sincerely

Peter Matthews
Convenor
ASF Documenation Commission

"What we have now is all there will ever be" —— **CONSERVE AUSTRALIA'S CAVES**

Cave Conservation at Mole Creek

Deborah Hunter and Michael Lichon
Mole Creek Caving Club

Humans and caves in the district have interacted since Aboriginal occupation. Restricted availability of karst waters dictated tribal movement, whereas firing regimes influenced some karst catchments.

The more detrimental effects of white man started in 1829. Pioneering activities removed the Aboriginals. Logging, farming, and cave visitation began to adversely change the integrity of the karst. Humans still rely on the karst systems for their water supply, yet today the impacts have only escalated, and now also include mining and pollution. While authorities now recognise the values of the karst heritage; Governments, rather than moving to encourage the appreciation and preservation of the karst, are still promoting the destructive attitudes of pioneering days.

In response to escalation of unsustainable logging (85% goes to woodchips) and the threat of "Resource Security" MCCC members have been involved with the mounting of the Great Western Tiers National Park proposal and the associated campaign. The maintenance of the integrity of the remaining karst heritage and forest cover of the catchments are core foci and reasons of the campaign. It remains that the 85% of Australians opposed to woodchip logging are being passed over by successive Governments for NBH-Peko. The Tasmanian Forestry Commission has responded to the Great Western Tiers National Park proposal with a draft management plan to log over 83% of the available public forests of the Great Western Tiers in the next 10 years, including the western karst areas of the Tiers.

The next greatest threat to the Mole Creek karst is the combination of detrimental effects of private landowners. Much of the lower catchments are privately owned. Logging of the remaining private forests is continuing unabatedly. Destructive "traditional" mechanised farming practices, fouling of waters, toxic chemical usage may soon be enshrined in "Right to Farm" legislation, which will usurp third party rights of common law regarding rights to clean air, water and soil. It will mean karst will have even less protection. All the benefits of recent LANDCARE initiatives will be undone.

The Mole Creek limeworks has a remaining life of 6-20 years at the existing site depending on various circumstances. This NBH-Peko owned company is looking to next mine the internationally significant Dogs Head Hill karst.

The Mole Creek municipal tip is still sited on polygonal karst, and being operated in contravention of the (outdated) licence conditions. Many landowners are still dumping rubbish, carcases etc into sinkholes. Stock are still being allowed free access to waterways by many landowners.

The Mole Creek Progress Association is publicising cave locations. Outdoor recreation and school groups are actively promoting caving as a sporting pursuit without addressing issues of ethics and conservation.

References:

D.Hunter 1992, A brief history of cave conservation at Mole Creek and the development of the Great Western Tiers National Park proposal, *Illuminations 1*, 9-14.

M.Lichon 1992, "Right to Farm", the latest new threat to the Mole Creek karst, *Illuminations 1*, 15-16.

M.Lichon 1992, Recent history & issues surrounding the saving of Exit Cave, and future options, *Illuminations 1*, 17-22.

EDM HEIGHT TRAVERSING ON THE NULLARBOR

by

Russell Q. Bridge

ABSTRACT

The use of electronic distance measuring equipment (EDM) for surface height traversing would appear ideal for use on the Nullarbor where distances are long and unobstructed and the weather dry and clear. However, it is these long distances and the climatic conditions that can produce apparent errors if corrections for both the earth's curvature and refraction are not correctly accounted for. The experience on a recent expedition indicates that refraction is a most significant phenomenon and care must be taken to include its effects on the height elevation of survey points.

INTRODUCTION

As part of the 1991 Australian Nullarbor Caving Expedition, it was decided to carry out an accurate detailed survey of the surface features of the area surrounding the entrance to Old Homestead Cave. This included establishing the surface positions (easting, northing and elevation) of RDF stations, other and additional survey reference points, entrances to blowholes and other surface features. In addition, a topographic map was to be established with accurate contours to determine the drainage patterns between the low ridges.

As a large area was to be surveyed, a total station incorporating electronic distance measurement (EDM) and an electronic data recorder was employed. The equipment used was a Sokkisha Set3 total station with an SDR2 Electronic Field Book, essentially a data logger/computer. This instrument has infra-red EDM and a resolution of 1mm for distances and 1 second of arc for angles. In terms of accuracy, the standard deviation was +/-(5mm+3ppm) for distance measurement and +/-4 seconds for angles. The target is a corner prism that reflects the light emitted from the theodolite back along the same path to the theodolite for processing. Depending on weather conditions, distances exceeding one kilometre can be measured.

Once a known reference point and an azimuth was determined, a traverse line was established using control stations. The SDR2 records the horizontal angle measurement θ, the vertical zenith angle measurement zd and the slope distance s at each target point. From the height of the theodolite h_{th}, the height of the target h_t, the known coordinates (easting, northing and elevation) at the theodolite station and the known azimuth (direction relative to North between control stations), the SDR2 calculates the coordinates at each target point. Back in the office, the data from the SDR2 can be downloaded to a computer for further processing. The contour plots for the Nullarbor survey were generated using SDRMAP software.

The EDM distances can be corrected for temperature and barometric pressure using the program in the SDR2. This requires regular monitoring over the day with a thermometer and a barometer. A small portable barometer was calibrated to measurements taken at the nearby weather station at Forrest.

Determining accurate eastings and northings is not generally problem. For example, over the initial closed traverse of approximately four kilometres with six intermediate stations from Station AZ at the entrance to Old Homestead Cave and back again, the closing error was only 11 mm in easting and 60 mm in northing.

However, the apparent initial closing error in elevation was over 1 metre, an apparent gross error considering the highest ridge was only 10.7 metres above the surface at the cave entrance. This apparent error is the result of two factors; the curvature of the earth's surface; and refraction, the latter being by far the more significant for the topography and climate of the Nullarbor. Corrections for curvature can be made simply, either directly with the SDR2 or with computer software in subsequent processing. Corrections for refraction are more difficult and require procedures and measurements to be made in the field from which coefficient of refraction k (a parameter which varies with time and the climatic conditions) can be deduced.

CURVATURE CORRECTION

In geodetic reference systems, a commonly used datum is an ellipsoid to approximate the shape of the earth. Mean sea level is conventionally adopted for the vertical component in an ellipsoidal reference system. In Fig. 1, the ellipsoid has a radius of curvature R at the location where the surveying measurements are being taken.

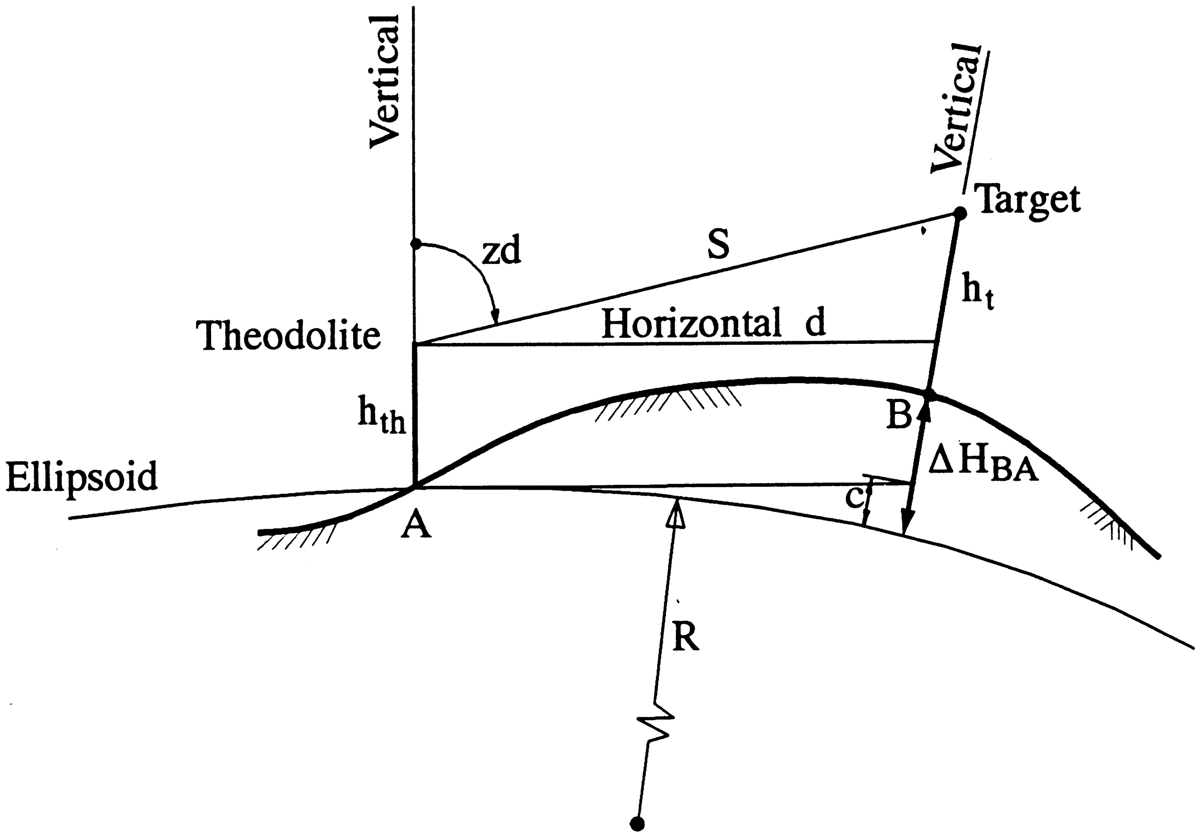


FIG.1

A theodolite of height h_{th} is set over point A on the earth's surface. A target of height h_t is set over point B. The theodolite measures the slope distance S and the zenith angle zd to the target. The horizontal distance d is given by

$$d = S \sin(zd) \qquad (1)$$

The orthometric height difference between stations A and B relative to the reference ellipsoid is given by

$$\Delta_{AB} = h_{th} + d \cot(zd) - h_t + c \qquad (2)$$

where c is the curvature correction and

$$c = \frac{1}{2R} d^2 \qquad (3)$$

Assuming a typical value of 6,370,000 m for the radius of curvature R, the correction c for a horizontal distance d of 1000 m (not uncommon for the SET3) would be 78 mm. If there were a number of such legs in a traverse (say 6), the accumulated error would be quite large (468 mm). However, if the horizontal distance d was only 100 m, the correction c would be only 0.78 mm. For an equivalent 60 legs, the accumulated error would be only 46.8 mm. It can be seen that the correction for curvature is very important for height traverse where EDM equipment is used to measure large distance between stations.

REFRACTION CORRECTION

This correction is similar to the correction for curvature. Refraction causes the light ray to bend (shown as a dotted line in Fig. 2) with a curvature of unknown radius taken as concave down. The theodolite therefore measures a zenith angle zd to an apparent point above the target.

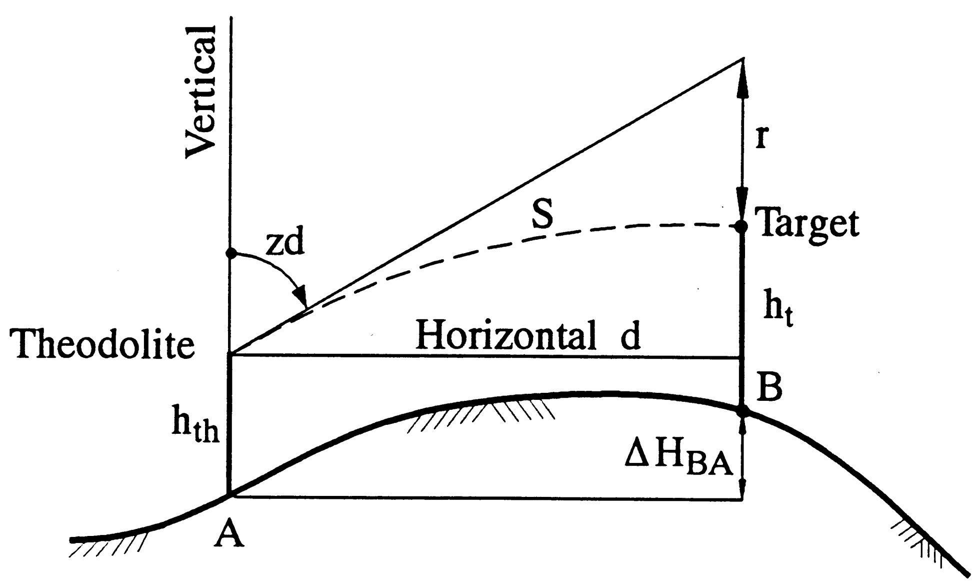


FIG.2

The apparent height difference measured by the theodolite between stations A and B relative to the horizontal is given by

$$\delta_{BA} = h_{th} + d\cot(zd) - h_t \qquad (4)$$

The actual orthometric height difference between stations A and B relative to the horizontal is given by

$$\Delta_{BA} = h_{th} + d\cot(zd) - h_t - r \qquad (5)$$

$$= \delta_{BA} - r$$

where r is the refraction correction and

$$r = \frac{k}{2R} d^2 \qquad (6)$$

and k is the coefficient of refraction and R is a reference curvature, usually taken as the radius of curvature of the reference ellipsoid at the location where the measurements are taken.

A typical value of k quoted in surveying texts is +0.13. For the Nullarbor survey, this is grossly in error!

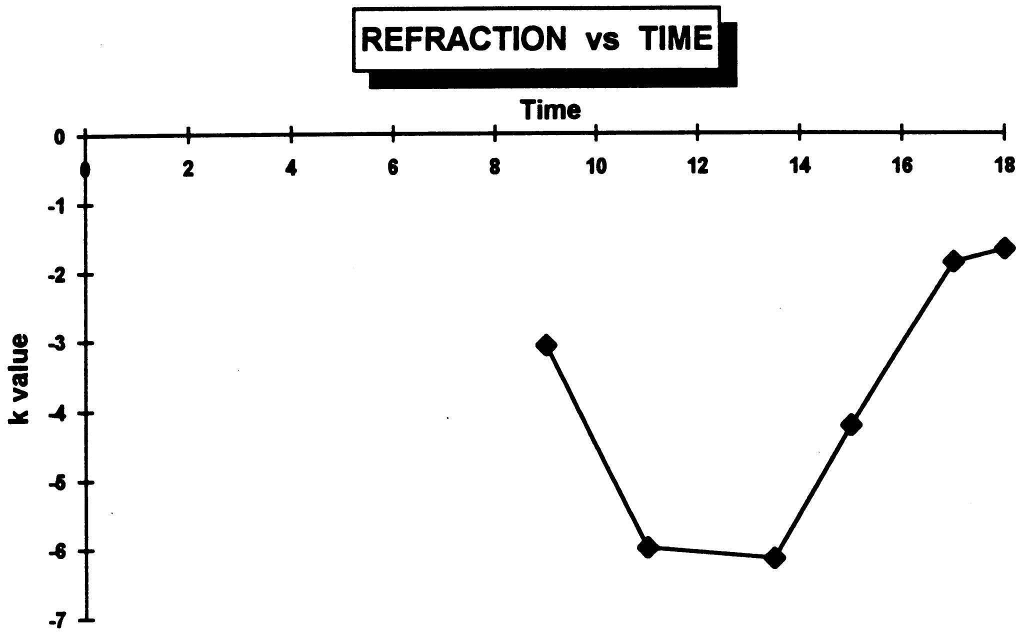
To determine a value for k, it is necessary to measure both the apparent height difference δ_{BA} between A and B with the theodolite at A and then to measure the apparent height difference δ_{AB} between B and A with the theodolite at B. The total orthometric height difference must be zero hence

$$\delta_{BA} + \delta_{AB} - 2r = 0 \qquad (7)$$

from which the value of k can be deduced. This must be done regularly during the day as the value of k is obviously temperature and hence time dependent. At each station, all intermediate points measured from that station must be corrected for refraction.

The results for a typical October day at Old Homestead are shown in the following graph. The absolute values of k increase to a maximum during the middle of the day and decrease in the cool of the evening or the morning.

Typical temperatures ranged from 15°C to 32°C. It can be seen that a value of k of -6 is not uncommon, a long way from the suggested value of +0.13, based on European experience. This also indicates that refraction can be up to six times more significant than curvature.



CONCLUSIONS

Surface surveying on the Nullarbor is difficult at the best of times; long distances, lack of features, heat, flies, no water, and staked tyres. Even when using EDM techniques to cover distances quickly, care has to be taken that corrections for curvature and, more importantly, refraction are not neglected. Where curvature is not accounted for directly, both curvature and refraction can be combined where

$$c\text{-}r = \frac{1-k}{2R} d^2 \qquad (8)$$

Values of k can be deduced directly from the total apparent forward and backward height differences between stations. Regular readings should be taken during the day as the value of k can have a wide range of values depending on the topography and the climatic conditions

KARST AND CAVE AREAS OF TASMANIA

Kevin Kiernan

Tasmania has some of Australias deepest, longest and most spectacularly decorated karst caves, and it has been common over the years to refer to Tasmania as having a karst estate that is abundant in comparison to much of Australia. Founded on the testimony from Junee-Florentine, Mt Anne, Ida Bay, Mole Creek and elsewhere, this reputation arose before the true extent of potentially karstic rocks elsewhere in Tasmania was fully realised, or in the rest of Australia for that matter (Jennings 1975, Smith 1988). It also pre-empted any assessment of the actual density of caves and other karst phenomena in some of these rock units, for in reality, while most limestones exhibit some sort of karst phenomena to at least some degree, far from all the limestone in Tasmania is significantly cavernous, including extensive areas of the limestone within some of our better known karsts such as Junee-Florentine. The limited number of researchers and cavers and the relatively reconaissance standard of geological mapping available for much of the island mean that it is still not fully possible to evaluate Tasmania's karst estate. However, the data base has improved immeasureably over the last couple of decades and this conference provides a useful opportunity to take stock.

If we take as our starting point Albert Goede's catalogue of Tasmania's caves spanning 28 areas in the ASF's *Speleo Handbook* (Goede 1968) and his review of Tasmanian karst prepared for the 1970 ASF Conference in Hobart (Goede 1971, the extent and nature of the changes revealed by two decades of exploration become pretty evident. First, far more caves are now known in the karsts recognised in 1968 than were known then. Differences in accessibility have played an important part in conditioning how rich in caves various karst areas appear to be. The list of known caves at Mole Creek, long a relatively accessible karst, has roughly doubled from 102 to over 200. In two less easily accessible karsts into which new logging roads or other routes have increasingly provided access the increase in the number of known caves has been more rapid - at Ida Bay the number has risen from 9 to around 250, at Junee-Florentine from 17 to well over 200. The data base remains more embyronic at Precipitous Bluff, which remains fairly remote. There the efforts reported in 1968 were totally eclipsed by a second visit in 1973, then those efforts in turn were totally overshadowed by discoveries during a third and subsequent visits since the mid 1980s. On the other hand, perception and how fashionable an area is has also played a role. The presence of caves in and around the gentle farmlands of Gunns Plains, less than half an hours drive from Ulverstone, has been known for over a century, yet by 1988 I was able to compile a list of only 13 caves - since the Savage River Caving Club has taken an interest reports in *Speleopod* indicate that number has more than doubled, with new discoveries approaching 1 km long and approaching 40 m depth.

Since 1968 we also seem to have become aware of more new limestone areas than we have cavers to look at them, a plus from a management perspective although no doubt only a temporary one. Whilke their advent is exciting, not all these additional limestone areas are necessarily ever going to be attractive as recreational caving venues, despite whatever other scientific, recreational or aesthetic qualities they may have. The most important of Tasmania's karsts were already recorded when *Speleo Handbook* was published. This is despite the number of areas found since - Kiernan (1988a) recorded well over 100 outcrops of the most promising carbonate rock types, with karst phenomena confirmed from at least 60 of these. The fact of the matter is that Tasmania has heaps of limestone that seems to contain nary a cave, a pity for cavers no doubt but also a point that makes current and proposed limestone quarrying operations in important cave areas all the more nonsensensical. But there are undoubtedly many important new caves awaiting exploration in some of these new areas nevertheless, once cavers start looking at them. It is important also to recognise that a particular limestone area is not necessarily an appropriate place for a limestone quarry if the only reason it appears devoid of caves is simply that cavers have never got around to investigating it, as the current Risby Basin quarry proposal has exemplified.

As my intention is to provide only a brief overview of Tasmanian caves and karst and I do not propose to exhaustively reference this paper. Instead I will simply refer readers who desire more details to the *Bibliography of Tasmanian Karst* produced by the ASF Bibliography Commission some years ago (Kiernan 1989a) and add a few more recent references of importance, especially those that contain useful bibliographies that facilitate access to the relevant preceding literature.

TASMANIAN CAVE AREAS

Present indications are that the most widespread of Tasmania's potentially karstic rocks crop out over about 4.4% of the island (~277 000 ha). Just over half this area comprises dolomite and limestone of Precambrian-Cambrian age, just under half comprises Ordovician (Gordon Group) limestone. In addition to this 277 000 ha, some karst phenomena are also known in limestones of Siluro-Devonian age, a rock very restricted in distribution; some very localised karst occurs in limestones of Permian age which are widespread particularly in eastern Tasmania, including the Hobart area where no caves are known; in Tertiary marine limestones; and in Pleistocene aeolianite, the latter two rock types being confined to areas within a few kilometres of the coast in northern Tasmania and on some islands in Bass Strait. Little known but of particular significance is karst developed in magnesite in that part of northwestern Tasmania popularly known as the Tarkine wilderness. No other magnesite karst appears to have been recorded in Australia and I am unaware of any other examples in the world literature.

In additon to the karst caves that are the focus of most attention from cavers, a variety of parakarst and pseudokarst phenomena is known, including caves. I will return to karst caves in more detail later, but will take the opportunity first to briefly record the nature of Tasmania's parakarst and pseudokarst caves. In part, I give them this prominence because I believe we tend to overlook them too often. Some of these caves are intrinsically interesting and are important for biological, geomorphological, archaeological, social or other reasons. The principal caves of this type have formed in sedimentary and igneous rocks in a variety of environmental contexts.

Parakarst and pseudokarst caves

Jurassic dolerite is widespread in the eastern half of Tasmania, and commonly exhibits a columnar structure. A large, well decorated solution chamber formed in dolerite was discovered during tunnelling near Wayatinah in the early 1960s but has since been sealed off (Hale and Spry 1964). A curious large enclosed depression with centripetal drainage occurs in the same rock type on the Du Cane Range (Kiernan 1988a). However, for the most part the caves in dolerite comprise either boulder mazes in blockstreams, in fossil rock glaciers or in talus heaps. A couple of hundred metres of passage have been surveyed at Mt Arthur near Hobart, while the most protracted cave rescue Tasmania has yet seen took place in another dolerite cave, Devils Den, on nearby Mt Faulkner. There are also some deep rifts formed down joints close to escarpments where sheets of columnar dolerite began to peel away from the hillside during the late Pleistocene but have largely halted movement during the present interglacial conditions. Some very large masses have detached and begun to move downslope, one that hangs above Mole Creek on the slopes of Nells Bluff measuring over 1 km long and several hundred metres broad. Large closed depresions have formed in some parts of the island where rubble has accumulated in the margins of the trough that forms upslope of the detached masses, and some of these have erroneously been labelled as sinkholes on topographic maps. Some dolerite caves have proven of interest in various scientific fields, such as the mineralogy of the cave at Wayatinah (Hale and Spry 1964) and the fauna of the caves at Mt Arthur.

There are extensive areas of Tertiary basalt in eastern, central and northwestern Tasmania but no lava caves to speak of. Such tubes as have been recorded have a diameter of only milllimetres, although a few low bubble-type chambers a few metres long were intersected by cuttings of the Mole Creek - Gowrie Park road and proved notable for their minerals, although sadly these have succumbed to collectors.

Caves formed in sandstones and mudstones of Carboniferous-Triassic age include inumerable small rock shelters, some of which are important as archaeological sites (McConnell 1990), and some caves formed at minor spring sites or behind waterfalls. Minor spelothems occur in some of these, occasionally comprising uncommon minerals. The invertebrate fauna of sandstone boulder caves at Francistown has also proven significant (Richards 1974).

Sea caves are common around various parts of the coastline, some of the largest having developed in sedimentary rocks of Carboniferous-Triassic age. These include some of the impressive sea caves of Tasman Peninsula where there may be up to 200 m of passage associated with Tasmans Arch. There are others formed in a variety of other rock types including dolerite. Some minor limestone lenses or carbonate-rich mudstones have given rise to some speleothem development in sea caves at Variety Bay on Bruny Island and reportedly elsewhere. The most richly decorated sea caves have formed in quartzite on King Island, where overlying calcareous dune sands have given rise to extensive, speleothem develoment including columns up to 2 m high, although considerable vandalism has occurred. Various sea caves have proven important for scientific studies, such as those on King Island where dating of the cave sediments has shed light on the antiquity of coastal evolution, and those at Rocky Cape and Prion Beach where important archeological studies have been undertaken (Jones 1968, Dunnett 1992).

A few small caves, generally only of crawling dimensions, have been examined in areas of severe tunnel erosion of soils. The only ones large enough to have warranted mapping, near Hamilton in south-central Tasmania, have since been infilled as part of a land rehabilitation project.

The other quite delightful form of cave deserving mention comprises those that form seasonally in snow banks on some higher mountains. Some are no more than bergshcrunds, others comprise mazes of snow-roofed large dolerite blocks, but in other cases stream caves regularly form over allogenic creeks or springs. These snow caves are invariably small but over time the stream caves increase in diameter to a couple of metres and can be memorable for aerogenically sculpted walls and ceilings, including large scale scallops, and sometimes for their natural lighting through the snow. They are also of some micrometeorological interest. These caves are relatively robust to all but deliberate vandalism, and at any rate regenerate themselves every year. They are but relics of a far more glorious past - we no longer have glaciers capable of hosting the numerous kilometres of cave passage recorded from some overseas sites, but in the Pleistocene an ice cap of over 7000 km^2 existed in the Central Highlands and other smaller glacier systems existed elsewhere (Kiernan 1990a). At these times many of Tasmania's largest rivers, including the Mersey, Derwent, Forth, Gordon and Franklin, originated from glacier caves that doubtless were far larger than any of our present karst caves. In a few cases fossil subglacial meltwater channels remain like life-size cave maps that were etched into land beneath the ice. Their former presence is of scientific import since such channels can provide insight into past glaciological conditions, ice thicknesses and glacier extents (Kiernan 1981). Where the land beneath of adjacent to the glaciers was limestone, there were important implications for the development of karst caves.

Karst caves

The cold glacial periods of the Tertiary and Pleistocene have contributed significantly to the character of some of Tasmania' karst. At least six glaciations are known to have occurred over this period, the earliest apparently contemporaneous with the onset of glaciation in Antarctica about 30 million years ago (Kiernan 1990a, Macphail, Colhoun, Kiernan and Hannan, in prep). Pre-existing karst depressions may have been favourable sites for glacial eroson, as has been sugested in the case of some of the lakes at Frenchmans Cap (Peterson 1966), at Lake Timk (Kiernan 1990b) and elsewhere. Some karst features may have been eroded away, in other cases they were simply buried by glacial deposits as at Nelson River. Seasonal meltwaters were delivered onto adjacent karst areas, and driven into limestone beneath glaciers, as was probably involved in the development of some caves in the Dante Rivulet karst. This offered the potential for considerable cave development in some cases but in others the possibility of caves becoming clogged by sediment, depending upon specific circumstances. Beyond the margins of the glaciers the cold conditions meant considerable snow-pack development, a much more restricted forest biomass than now, and a variety of periglacial processes such as frost wedging and solifluction. As a result, considerable volumes of sediment were delivered into streams, again offering the potential either for considerable elargement of developing caves by mechanical erosion, or their total blockage by sediment and a reversion to surface drainage. During times when water was locked up in glaciers sea level was more than 100 m lower than at present, while during the Last Interglacial when conditions were perhaps slightly warmer than now the sea was a few metres higher. Hence, the base level to which streams drained, and the zone of mixing corrosion at the interface between the marine and terrestrial environments has shifted dramatically, often over many kilometres where the coast is flanked by plains rather than mountains.

In order to gain some sort of overview of Tasmanian karst it is useful to consider its evolution and nature at several levels of analysis. The first comprises the **karst systems level**, or the context within which each karst has evolved. The systems can be characterised on the basis of different rock types and sub types; different structural contexts; different climatic regimes (both present and past); different solvent systems (including whether the solvent is juvenile water or rain water, and whether the solvent falls directly onto the karst as rain and sinks diffusely, or flows onto it as concentrated streams from neighbouring rock types that impart chemical differences); differences in topographic setting that have major implications for hydraulic gradients and other matters; and the relationship between the carbonate rocks and the direction in which overlying rocks have been or are being stripped away. All these attributes condition the way karst phenomena have evolved The second level of analysis is that of the **landforms and landform asemblages** present in each karst. Caves obviously comprise only one of the many landform families that may be present in any karst, alongside other families such as the closed depressions, surface solution sculpture and such like. Differences in systemic contexts mean there are genetic and morphological differences sufficient to recognise many different species of caves just as there are different species of plants and animals. Some are common and some uncommon, some very fragile, others more robust, some recreationally attractive, others not (Kiernan 1990c, 1992). The third level, **landform contents**, comprises the various sediment accumulations, including speleothems, clastic deposits, bone deposits, and archaeological materials, and the biological values contained in karsts both above and below ground. The fourth level is that of **human use and aesthetics**, comprising the whole range of scientific, educational, recreational, economic, social and other uses of karsts above and below ground, in the past, in the present or in the future. As caves are the karst landforms of most interest to cavers I will, for present purposes, focus largely on these rather than the the other values of our karsts. I will also focus on their recreational implications rather than the subtleties of different cave types, genetic attributes and speleogens.

For the purpose of the present exercise I will consider the Tasmanian karsts from the perspective of their topographic setting, focussing on four broad types: karsts of the coastline; low relief karsts on riverine plains and elsewhere; karsts on steep hill flanks; and mountain karsts. Obviously some karsts span more than one setting, but this sort of framework probably offers more useful insight than does differentiation on the basis of rock type, a framework commonly used in the past (eg. Kiernan 1988a). There is probably no such thing in Tasmania, if anywhere, as a "pure" karst - in each locality other, non-solutional, processes are at play besides simple solution. Mechanical erosion by stream-borne sediment in essentially fluvial environments, wave action and salt spray on the coast, the impact of snow and ice in the mountains; differences in the biological environment that condition water chemistry, all these and a host more interact with solution processes and, depending on specific circumstances, may overwhelm solution processes or be overwhelmed by them. As a result karst may not initially seem conspicuous. Moreover, an observor from the tropics, for instance, might be tempted to dismiss Tasmania as lacking much karren, although closer inspection would reveal that the karren species present here are simply less ostentatious than what he or she is used to - it is a question of differences in karren type rather than in karren abundance.

Coastal karsts

The coastal karsts comprise those outcrops of carbonate rock that occur at the interface between the marine and terrestrial environments. The impact of "non karstic" processes on the coast can be profound and those elements cavers think of as karstic may be obvious, muted or absent: such places nevertheless remain karsts. A number of coastal karsts are known to exist at present, including one in Pecambrian rocks, three in Ordovician limestones, one in Devonian limestone, at least one in Permian limestone, and four in Cainozoic limestone. These diferent rock types have imparted some distinctive characteristics to the karsts that have formed in them, the Tertiary marine limestones, for instance, having given rise to some interesting shore platforms, the Pleistocene aeolianites to very ruged karren and deep notching. Small caves occur in each of these rock types.

When the sea level was slightly higher than present during the Last Interglacial other karsts such as Lower Gordon and Precipitous Bluff were essentially coastal karsts. Additional complexity has been imparted by the fact that the land itself has been raised by tectonic uplift around parts of the coastline, in some cases by 20-30 m just since the Last Interglacial (Murray-Wallace, Goede and Picker 1990), hence relict coastal karst may now lie well above present sea level, and, in areas of generally low relief, my now lie well inland. In addition, when the sea level was lower during the glacial periods some karsts that are presently on the coastline themselves lay well inland and developed as terrestrial karsts that drained to a lower base level than now, deeper conduits probably becoming flooded as the sea rose again. Extensive areas of Tertiary marine limestone that presently lie drowned on the floor of Bass Strait and at various places off the northern coastline would have been exposed to terrestrial karstification at times of low glacial sea level when the Strait was dry and Tasmania was a peninsula rather than an island. In the case of one apparent sea cave at present sea level on Flinders Island it has been revealed by radiocarbon dating of a stalagmite that the cave was in existence during the Last Glaciation and was invaded when the sea level rose again and converted it to a sea cave (Kiernan 1992b).

From a recreational perspective none of the coastal karsts presently offer any serious caving, with probably only Tearflesh Chasm on Maria Island, one cave on Ile de Golfe, or the cave at Rocky Boat Harbour requiring a torch. Nevetherless, some of these karsts do offer some very fascinating sightseeing for the curious or the photographer, notable features being the fossils in and around the caves on Maria Island, the karren at Surprise Bay and on Flinders Island, the shore platforms at Point Hibbs, and the aboriginal rock engravings in the aeolian calcarenite near Mt Cameron West. At a scientific level these karsts are of geomorphological interest in terms of process studies, the landforms that have developed on the different rock types, and sea level histories. The Mt Cameron West engravings are of major archaeological importance, and at least one known cave on Ile de Golfe is likely to offer potential in this regard. The archaeological potential of caves that probably exist below present sea level in several of these coastal karsts remains untested, as does their significance from the perspectives of geomorphology, palaeoenvironmental studies, marine biology and various other disciplines.

Plains karsts

The low relief plains karsts are widespread, particularly in the valleys of western Tasmania and on coastal plains in northwestern Tasmania, there being at least 44 examples in Ordovician limestones, 25 in Precambrian carbonates, and a handful in Devonian, Permian and Tertiary limestones. These karsts are characterised by low hydraulic gradients, a high "water-table", and the carbonate rock has frequently been mantled by fluvial, glacial, marine or other sediments. The karstic nature of these terrains may be evident only from infrequent sinkholes as is the case in the Vale of Rasselass, or the plains may be dimpled by many cover-collapse sinkholes - occasionally fresh ones assert themselves by engulfing a road or a cow. Where rock outcrops protrude through the alluvial covers the outcrops may be attacked laterally by seasonal swampwaters, giving rise to destinctive landforms such as deeply undercut notches as have formed in Tertiary limestone near Redpa, and seasonally flooded caves, some of which are moderately extensive such as Main Cave, formed in Precambrian limestone south of Montagu. Other very distinctive elements are the riverine cliffs along such rivers as the Franklin, where in addition to the fluting of the limestone there are riverside springs, small tufa accumulations and a variety of caves (Middleton 1977).

In the Smithton area marine sediments of Last Interglacial age occur up to 20 m above present sea level on broad plains formed on Precambrian limestone and dolomite. During the periods of low glacial sea level these plains stood well over 100 m above sea level and offered far more potential for cave development than present appearances suggest. Collapse sinkholes that have formed through considerable thicknesses of non-carbonate rocks in the Christmas Hills indicate considerable cavity development in underlying carbonate rocks, perhaps most markedly at these times when underground water circulation had the potential to be most vigorous. Dismal Swamp is a large, semi-closed depression 2 km broad and 3 km long that appears to be a polje that has been partly filled by sediment facilitating seasonal overflow - indeed it may be the nearest thing to a classical polje to be found in Australia (Kiernan 1990d). Mound springs are another unusual feature of the karst in the far NW, some being warm springs. The largest are up to 10 m high, but virtually none have escaped damage during pasture improvement programs. In one case a milking shed has been built atop a mound spring and the warm waters are used to wash out the churns.

Some reasonably substantial caves occur in these low relief plains karsts, but generally speaking the caving potential of these karsts is fairly low. Nevertheless, swimming the cold winter waters of Main Cave at Montagu will provide a reasonable test of any caver's resilience, while any who have explored their way through the Franklin cliffs at Galleon Bluff to emerge in a decorated grotto set high above the rainforest and the river will not question the recreational value of such a place. In scientific terms these karsts are among our most valuable. The archaeological importance of caves such as Kutikina and Deena Reena in the Franklin Valley is well known (Kiernan, Jones and Ranson 1983), but there are other important prehistoric archaeological sites in the caves of the Maxwell Valley, the Andrew Valley, the Acheron Valley, the Weld Valley, and at Brougham Creek in the Pieman River catchment (Jones et al. 1988, Allen et al 1989, Cosgrove et al. 1990). Nunamira Cave, which lies in a small residual hillock on the floor of the Florentine Valley, provides the oldest archaeological evidence yet revealed for human occupation of Tasmania, ~31 000 years (Cosgrove 1989). A small cave at Jukes-Darwin contains evidence of early karst engineering by Europeans (Kiernan et al. 1989). Caves at Montagu and others on the floor of the Florentine Valley have revealed important subfossil bone deposits including extinct marsupial megafauna. Some of these karsts are also of geomorphological interest, while others have proven important for their invertebrate fauna (Eberhard, Richardson and Swain 1991).

Hill-flank karsts

The karsts are perhaps those best known to cavers, since they host many of our deepest and longest cave systems. There are at least 15 areas of karst of this type formed in Precambrian carbonates, 18 in Ordovician limestones, a handful in Permian limestones, and a knuckle or two in Cainozoic carbonates. These karsts include Tasmania's principal caving areas such as much of Mole Creek Kiernan and Junee-Florentine. They are characterised by good topographic relief of the carbonate rock, relatively steep hydrulic gradients, and, for the most part, allogenic streams that deliver chemically aggressive water to the margins of the limestone outcrops where steep cave systems have developed. Almost all these karsts have been subject to periglacial environmental conditions during the course of their evolution, and a few to glaciation (Kiernan 1992c).

The caves and other karst phenomena in these hill flank karsts are so varied as to preclude adequate description in a brief review such as this. The longest cave system yet recorded in Tasmania, Exit Cave Ida Bay, is developed in Ordovician limestone beneath Marble Hill, which is capped by non-carbonate sediments. Major discoveries made over the last couple of years in Little Grunt represent part of the Exit Cave system and when the two are connected underground by direct exploration the length of the system will probably approach ~ 25 km. However, the issue of the quarrying of the Exit Cave system is not yet fully resolved. In due course caves of similar length may well be explored in the Junee-Florentine karst, already the location of some of the deepest caves in Australia. The Mole Creek karst is particularly famed for the quality and profusion of the speleothems found in its caves. New exploration in areas like Mt Cripps and Gunns Plains, and in more remote areas such as Precipitous Bluff and the Cracroft Valley, will doubtless reveal many further exciting caves in years to come.

These hill-flank karsts are a major focus of recreational caving. The evolution of Exit Cave has been greatly influenced by environmental change and this karst complex is of great importance to several scientific disciplines (Houshold and Spate 1990, Eberhard 1990, Kiernan 1991). The caves of Junee-Florentine are already known to be of major importance in the fields of archaeology, hydrology, geomorphology and biology (Cosgrove 1989, Hume 1991). Similarly, the caves at Mole Creek are of major significance in many disciplines although curiously perhaps, archaeology has not yet proven to be one of them (Kiernan 1989b, 1990e, Eberhard et al. 1991). Also of geomorphological interest are the caves of Mt Cripps (Shannon et al., 1991). The biological significance of Pecipitous Bluff warrants particular mention (Eberhard et al. 1991). The hill flank karsts will doubtless occupy the attention of both cavers and scientists alike for many decades to come.

Mountain karsts

The division between hill-flank karsts and mountain karsts is again somewhat arbitrary, but in general I use the term mountin karsts with respect to karsts that are higher and often steeper than the hill-flank karsts, have been significantly over-run by glaciers during the course of their evolution, have also been strongly influenced by periglacial conditions, and which in many cases remain today generally susceptible to alpine climatic conditions to a significant degree. On this basis some plains karsts are also in a real sense mountain karsts, such as the high altitude Vale of Belvoir. About 6 areas of Precambrian carbonates warrant description as mountain karsts but only a couple of outcrops of Ordovician limestone (although about 19 have previously been glaciated to at least some degree) and a single area of Devonian limestone.

The mountain karst *par excellence* is Mt Anne (Bunton and Eberhard 1984). The deep vertical caves of this area are well known, as is the spectacular glacial scenery of the mountains. Other karsts in Precambrian rocks that probably warrant description as mountain karsts occur at Mt Weld, in the Gell-Alma area, and even at Frenchmans Cap were some karst phenomena have been recorded. Karst in the headwaters of Cook Creek in the Picton Range may be developed in Ordovician limestone. Also of interest is the karst in Devonian limestone further south near

Lake Sydney, which is a lake of glaciokarstic origin. The outlet cave system appears to have been clogged by sediment during the Last Glaciation, but tributary streamsinks downvalley offer at least some prospect of entry. Recent explorations recently undertaken in the Vanishing Falls karst, which borders on description as a mountain karst, have revealed a cave so far explored for 2.3 km (Eberhard, Eberhard and Wong, in prep).

The recreational significance of the mountain karsts varies considerably, with probably only Mt Anne being of major significance to cavers at the present time but many of the others being used by bushwalkers to enjy the surface scenery. In scientific terms, the karst at Mt Anne is of great geomorphological and hydrogeologcal interest (Kiernan 1990f) while the Lake Sydney area has also proven of interest (Kiernan 1989c). The karst at Vanishing Falls is now known to be of biological importance (Eberhard, Eberhard and Wong, in prep.). Further research will doubtless reveal still more of value in the mountain karsts.

The largest cave systems

The worth of any cave cannot be measured in terms of its size. Many highly important caves are relatively miniscule. However, cave size certainly impinges upon the perceptions of both cavers and political decision-makers, and it also offers some feel for the extent and intensity of karstification in different areas.

Given the incomplete state of exploration, the uncertainties of cave surveying and the perils of spelo-politics, only a fool would attempt to list the deepest and longest caves presently known, so I shall endeavour to do so. However, none of the three longest caves have been exhaustively surveyed and a little uncertainty also surrounds just which is Tasmania's deepest cave since only a few metres appear to separate a few systems, within the likely range of survey error. At present the longest caves known in Tasmania are Exit Cave at Ida Bay (perhaps 20 km of passages), Growling Swallet in the Florentine Valley (>12 km) and Herberts Pot at Mole Creek (>5.3 km). All three have formed in Ordovician limestones. The deepest known caves in this rock type are Niggly Cave (~371 m), the Ice Tube/Growling Swallet system (~354 m) and Khazad-Dum/Dwarrowdelf (~323 m) in the Junee area, all of which represent different sections of the same hydrological complex. The deepest cave in the Precambrian dolomites is Anne-a-Kananda (373 m), which at >3 km is also the longest dolomite cave, ahead of Newdegate Cave at Hastings. Deep vertical shafts are also worthy of note. Niggly Cave at Junee-Florentine contains a single continuous vertical pitch of 190 m, while Heartbeat in Anne-a-Kananda is 118 m and the entrance pitch in Kellar Cellar at Mt Anne is 115 m. More than 50 pitches have been explored in Anne-a-Kananda (Bunton and Eberhard 1984).

Where are the areas that offer greatest potential for the discovery of further large cave systems? We can be guided in our search by the fact that cave systems serve as subsurface drainage conduits, hence the relative position of streamsinks and springs therefore remains the best guide as to where we should look for large caves.

The longest underground hydrological system focusses on Junee Cave. Proven tributaries include Growling Swallet, a linear distance of 9.4 km from Junee Cave (Gleeson 1976). Direct exploration from Growling Swallet has penetrated scarcely 1 km of this linear distance. Other streamsinks up to 14 km from Junee Cave may also be part of the system (Hume 1991). The potential is immense although secrets are seldom revealed easily. The six longest underground drainage systems in the Mole Creek area span linear distances of 2.2-3.6 km. The most complex system at Mole Creek is that beneath the Mole Creek-Lobster Rivulet surface drainage divide, which includes Herberts Pot. Wargata Mina (Judds Cavern) in the Cracroft Valley lies 2.5 km from its most distant tributaries. The enigmatic Lake Timk at Mt Anne is 1 km long and 25 m deep. Water drains from the margins and bed into a cave system which can be followed in underneath the lake bed when the lake level is low, but this cave has seen no concerted attempt at exploration. This water is believed to be the source of a large spring 2.4 km away (Kiernan 1989c). It is vaguely conceivable that the drainage from Anne-a-Kananda forms part of the same system, which would increase the linear extent to ~4.8 km. While too much should not be made of the fact, it is thought provoking to contemplate that most of these drainage systems are longer that the 2.3 km between the Exit Cave outflow and its most distant streamsinks.

The greatest topographic relief of carbonate rock, and hence the greatest theoretical cave depth potential, is ~ 600 m in the Mt Anne/Weld Valley area, followed by ~ 450 m at Mt Ronald Cross, both Precambrian carbonate areas. The topographic relief of Ordovician limestone approaches 400 m at Junee-Florentine, and is also very considerable at Precipitous Bluff, in the Cracroft Valley and at Mole Creek. In the latter area the altitudinal diference between some streamsinks and their proven or probable springs approaches 300 m (Kiernan 1984).

LAND TENURE AND MANAGEMENT

Current estimates suggest that roughly 31% of Tasmania's carbonate rocks lie beneath State forest, 17% beneath parks and reserves, 33% beneath private land and 19% beneath other Crown lands. While ~24% of the Ordovician limestones lies in parks, only ~16% of the areas with sufficient topographic relief to offer much potential for significant caving are reserved. Most of the Siluro-Devonian limestone karst is reserved, but none of the magnestite karst, all of which occurs on Crown lands. If the exent of cave and karst resources in Tasmania represents a fairly happy story, the management of Tasmania's karst generally does not. Notwithstanding the fact that a number of areas have been formally reserved, the standard of karst management is generally very low, the legacy of past neglect considerable, the inertia huge. Political processes and issues that appear to have resolved some land-use and land allocation issues, for the present at least, have contained the seeds of some major management difficulties (Kiernan 1989d). The karst management problems involve surface land-use, groundwater quality, and in-cave management issues (Kiernan 1988b, 1989f)

The management of privately owned karsts varies from careful and considered to deliberately vandalistic, based in part on the political attitudes of particular property owners. No karst management expertise exists in the Tasmanian Department of Primary Industry to guide activity in agricultural areas, although logging of private forests on karst is subject to some influence by the Forestry Commission. About 5% of Tasmania's State forests are underlain by carbonate rocks. Karst management concerns in these areas include soil erosion; cave sedimentation; landslips in cave catchments; drainage and groundwater quality changes; and recreational pressures that stem from the construction of logging roads to within close prioximity of sensitive caves. District offices are responsible for land management on the ground. Forest Practices legislation prescribes some standards for logging operations in karst areas. To facilitate the implementation of these standards and other work, the Commission's Forest Practices Unit contains two karst specialists, Kevin Kiernan and Rolan Eberhard, both employed on temporary contract. The attitude of forestry companies varies. Two small forest reserves were established by the Commission in the 1970s to protect karst phenomena considered to be scenically attractive, but no progress has been made towards establishing the reserves recommended by the major karst management study of the Mole Creek area in 1983-84 undertaken within the Commission in 1984 (Kiernan 1989b). Some work has been undertaken towards management planning for the Croesus Cave area at Mole Creek (Spate and Holland 1990) and Welcome Stranger Cave in the Florentine Valley.

Carbonate bedrock underlies ~5% of Tasmania's parks and reserves, but until very recently the only karst management by the Department off Parks, Wildlife and Heritage (PW&H) has been focussed on the tourist caves at Hastings, Mole Creek and Gunns Plains. Nevertheless, at Mole Creek rangers Chester Shaw and Vic Fahey and their colleagues have undertaken excellent cave cleaning and restoration work in Marakoopa Cave with very little support or recognition. Steps have also recently been taken by Phil Bradley and his colleagues at Hastings to start to address the deplorable condition of the tourist cave there, initially through the construction of a new access walkway that will limit the carriage of material underground on the feet of visitors. Until very recently there has been virtually total neglect of the other karsts administered by PW&H, despite the fact that many lie within the World Heritage Area for which specific management funds are made available by the Australian Government (Kiernan and Eberhard in press). In some cases political influences have underlain the poor management standards, as in the quarrying and pollution of Exit Cave. Equally deplorable has been the situation in the Lower Gordon karst. After the Franklin dam was blocked by the Commonwealth government in line with its responsibilities as a signatory to the World Heritage Convention, and after the conservation movement had moved away to taller pastures, annoyed pro-dam state politicians were only too happy to foster the tourist operators at the expense of the environment. The Commonwealth Government that would tolerate no ground disturbance when the glare of publicity shone on the area now sat back and let 40 km of rainforested riverbanks be quarried into the river by the wakes of tourist vessels. But at least after years of lobbying, management plans for Kubla Khan and Exit Cave are now in preparation (Spate 1991), and Ian Houshold has been appointed on temporary contract as PW&H karst officer. Among his many dificult tasks is to repair the legacy of tensions that arose when concerned people within PW&H felt compelled to establish a holding operation by restricting access to some caves that were suffering damage until such time as their struggles to obtain adequate resources to plan and implement management responses could bear fruit. There was little communication between the parties or much attempt to understand the problems faced by the other.

Apart from such well publicised matters as the Exit Cave Quarry, karst resources are at present under considerable pressure from quarrying and other proposals and pressures. Investigations for possible new limestone quarries are underway in several areas, the past year has seen the partial inundation of the Nelson River karst beneath a new hydro-electric impoundment, controversy surounds a large tourist development at Lake Lea in the lovely Vale of Belvoir karst. There are incresing concerns about the implications of comercial adventure tours in caves. Meanwhile nature's processes continue, and the Gowrie Park road has in recent weeks collapsed into the same sinkhole as engulfed it with some publicity in 1974 - eighteen years on will we see it fixed properly this time? That the progressive impact of cavers feet continues to outpace the progressive impact of cave drps is only one of Tasmania's karst management issues.

TASMANIAN CAVE RESEARCH

It is worth recording here the research currently being conducted in Tasmanian karsts. The first group involved comprises the Tamanian Caverneering Club, Southern Caving Society, Northern Cavemeers,Savage River Caving Club and the Tasmanian Cave & Karst Research Group. The exploratory, surveying, collecting and documentation efforts of these groups have provided a vast amount of information over the years, much of it disseminated through their publications. Without their efforts many of the more detailed studies undertaken by universities and government agencies would have been much more difficult and sometimes impossible. From a management perspective the efforts of the Savage River Caving Club in the Mt Cripps karst warrant particular recognition (Shannon et al. 1992). It is instructive to compare the level of understanding that has developed between this group and the forestry company that manages the area and which fosters cave exploration as an aid to wise planning, and the very poor relations between cavers and the managers of the Junee-Florentine karst where cavers seem to have been regarded simply as a nuisance and a threat.

The government agency with the most longstanding involvement in karst research is the Forestry Commission, within which the geomorphology section of the Forest Practices Unit is involved in research focussed on the implications of karst for forest management, both in terms of nature conservation and karst hazards (Kiernan 1989e, 1990g,h). The Tasmanian Karst Atlas Project involves the progressive documention of karst, is funded by the forest industry through the Tasmanian Forest Research Council, and in some cases is involving work done on contract by caving clubs, individual cavers and geomorphologists. . Another project which focusses on the effects of logging on karst caves, has been funded initially by a grant from the Australian National Parks & Wildlife Service and has involved the establishment of a small underground laboratory in Little Trimmer Cave (Eberhard and Kiernan 1991). A major documentation and management study of the Junee River catchment is planned for 1993, funded by the Forestry Commission itself. The archaeology section of the FPU is also occasionally involved in karst work, primarily involving the Senior Geomorphologist, Anne McConnell. Within the Department of Parks, Wildlife & Heritage the archaeology section has also been involved in research in karst areas, generally involving external research grants and often undertaken in collaboration with mainland university researchers. Other karst area research has been undertaken by the earth science section, involving Mike Pemberton, Grant Dixon and others, mostly focussed on the Lower Gordon and on the Exit Cave Quarry (eg Houshold and Spate 1990, Eberhard 1990, Kiernan 1991, Clarke 1991) the latter studies generally undertaken by outside parties contracted to PW&H or in some cases to the Department of Mines. Andy Spate and Stefan Eberhard have been among those involved in management-related reserch in Kubla Khan, and since his appointment Ian Houshold has initiated further work.

University-based research has involved the ongoing sterling efforts of Albert Goede from the Department of Geography & Environmental Studies at the University of Tasmania, whose karst research is now focussed on speleothem dating and paleaeotemperature work (Goede 1988, 1990, Goede et al. 1990), but recently involved supervison of Nick Hume's honours thesis study of the hydrology of the Junee catchment (Hume 1991). A major study of Tasmanian cave fauna, funded by the Australian Heritage Commission, was recently completed by Stefan Eberhard from the Zoology Department, in conjunction with Alastair Richardson and Roy Swain (Eberhard et al. 1991). A current research project is focussed on cave ecology, and includes work in Little Trimmer Cave.

The outstanding contributor to archaeological study of Tasmania's caves over many years has been Rhys Jones of the Australian National University, who has layed the foundation for ongoing work in Tasmania's karst caves that will last for decades, and who has defined many issues that demand resolution (Jones 1984)). Such challenges have been taken up by others from the same institution, and more recently by workers from La Trobe University including Jim Allen and Richard Cosgrove. Archaeologists from the University of Western Australia have also undertaken work in the Nelson River karst for the Hydro Electric Commission.

CONCLUSIONS

The karst estate of Tasmania is extensive, varied and valuable. Just as caves are not the sole attribute of karst, neither are cavers the only group that competes to exploit our karst resources.- a fact that underscores many karst and cave management issues. Some of the karsts contain important cave systems of recreational significance, many of the karsts are of scientific importance, some are of economic significance. Ongoing research continues to provide insight into the karst resources and their management implications. Tasmania will remain the home of Australia's deepest caves and has the potential to remain the home of this country's longest caves. However, for the most part the response by land management agencies to the management implications of this karst estate remains very inadequate. Some caves have been heavily impacted by recreational use but many remain in relatively good condition in comparison to some caves elsewhere in Australia where the cave-using population is more numerous. Tasmanian cavers and land managers have the choice of responding to this situation either by seeing it as grounds for complacency or as an opportunity to ensure that Tasmanian caves remain in a better condition than is now possible over much of Australia. If the latter opportunity is to be seized it will necessitate the acquisition of good informtion, the adoption of high standards of protection of the cave environment, and a high degree of self discipline and genuine commitment by all involved.

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THE SANCTITY OF CAVES IN STOCKYARD GULLY NATURE RESERVE, WITH COMMENTS ON DEFINITIONS OF NATIONAL PARKS AND NATURE RESERVES.

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ABSTRACT

The Stockyard Gully Nature Reserve in Western Australia is a Class 'A' Reserve, which should give it the highest legal protection of all Nature Reserves in this State. Despite this, an exotic species of crayfish, *Cherax destructor*, now occurs in at least two caves on the Reserve, and an act of vandalism involving the felling of flora, blasting and clearing a cave entrance in 1984 went unpunished. Stockyard Gully Reserve has been referred to as National Park. Significance of this variation in reservation status and consequent security of important natural features, such as caves, is discussed at length here.

INTRODUCTION

Stockyard Gully Nature Reserve (Fig. 1) is an area of karst overgrown by native bushland lying approximately 20 km southwest of Eneabba, or 295 km in direct line north of Perth, Western Australia. In June, 1991, we visited Beekeepers and Aiyennu caves, both located within the Stockyard Gully Nature Reserve, to sample and study the amphipod *Austrochiltonia subtenuis*, a small (~2 mm long) freshwater crustacean. The issues discussed here (the sanctity of caves in nature reserves and the definitions of National Parks and Class 'A', 'B', and 'C' Reserves) are an unexpected development from that trip.

EXOTIC CRAYFISH IN CAVE WATERS

During our observations of the numerous small aquatic invertebrates in the waters of Beekeepers and Aiyennu caves we also noticed a number of crayfish in each cave. On closer examination these crayfish turned out to be yabbies, otherwise known as *Cherax destructor* - species native to the eastern states of Australia. This species of crayfish is now widely distributed throughout the wheatbelt and sheep-farming regions of the State, as well as in the hinterland of Carnarvon and it has been introduced into the Pilbara (Morrissy and Cassells 1992). Because this crayfish is not native to Western Australia it represents a threat both to the species of crayfish native to Western Australia and to other aquatic animals (Austin 1985, Horwitz 1989, 1991, Jasinska *et al.* in prep). During a literature search, not long after the trip, we found that crayfish were also observed in both caves in 1989. These crayfish were most likely also yabbies, but they were cited as marron (a species endemic to Western Australia) in the relevant trip report (Markey 1990): for a number of reasons discussed by Jasinska *et al.* (in prep), this classification is undoubtedly incorrect Our observations of yabbies of various sizes in each cave in conjunction with the report by Markey (1990) suggest that there is an established population of exotic crayfish in the two caves. Suffice to comment here that presence of an exotic species in a Reserve is contradictory to the purpose of a Nature Reserve.

Stockyard Gully Nature Reserve (# 36419), was proclaimed for the Conservation of Flora, Water and the Protection of Caves. We understand that, although Fauna is not specifically included in the proclamation, CALM views protection of fauna within the Reserve as falling under its aegis. However, we believe the word 'Fauna' should be included in the legal wording of the proclamation to remove any ambiguity regarding the purpose of the Reserve. Indeed, it is stated clearly in the "Report of the National Estate" (1974, p84) that:

> Strict nature reserves must always protect both flora and fauna, ...
> ..... This is clearly desirable, since flora and fauna are interdependent parts of the one ecosystem.

Prior to our observations, *Cherax destructor* has not been reported from caves in Western Australia. Therefore, we have prepared a paper reporting its presence in the Stockyard Gully caves.(Jasinska *et al.* in prep).

The surface terrain above Beekeepers and Aiyennu caves is free of water courses, lakes and swamps - how then did the yabbies invade the cave waters? East of the Stockyard Gully Nature Reserve there is a system of rivers and creeks draining private properties (Fig. 1) which include farms. From the topographic map of the area (Eneabba) it is evident these surface waters drain into the karst of Stockyard Gully Nature Reserve, presumably into a system of subterranean conduits. Furthermore, from the topographic information, it seems very likely that there is hydrological continuity between the caves of the area. Hence, it is possible that the yabbies entered the caves in waters draining the private properties east of Stockyard Gully Nature Reserve.

DESECRATION IN STOCKYARD GULLY NATURE RESERVE

In April 1984 Jimwa Pty Ltd, owners of the property called King Ranch which adjoined the eastern boundary of Stockyard Gully Nature Reserve, committed the following acts:

i drove bulldozers through the Reserve felling flora and displacing soil and rocks;

ii. using explosives and an excavator to remove two very large boulders from the entrance to Stockyard Gully Cave (Stockyard Tunnel thus increasing the flow of water, draining from King Ranch, into the cave.

It seems appropriate to reiterate here that the Stockyard Gully Nature Reserve was proclaimed for the purpose of conservation of flora and water, and protection of caves . Thus, Jimwa Pty Ltd in one sweep violated the threefold purpose of the Reserve. All these offences were carried out in about one week and despite strenuous efforts from the local ranger to prevent them.

Some 3 months later, on the 10th of August 1984, legal proceedings were initiated against Jimwa Pty Ltd by the then National Parks Authority of Western Australia (NPAWA). The penalty for the above offences under Section 107 of "Conservation and Land Management Act" (1984) was $4 000 plus imprisonment for 6 months according to point 106(c) and a further $10 000 plus imprisonment for one year for offences listed in points 107(d) and 107(h). Jimwa Pty Ltd pleaded not guilty, their defence being 'ignorance': the representative of the company claimed that they believed the Reserve boundary to be designated by old fencelines and not as shown on official maps and that the work was therefore thought to be carried out within the boundaries of King Ranch. It is worth noting here that the local ranger did point out that even according to the old fencelines, the mouth of Stockyard Gully Cave was within the Stockyard Gully Nature Reserve.

Unbelievably, the counsel for the Complainant (Mr Colin C. Sanders, the Director of the NPAWA) conceded that the owners of the King Ranch in fact believed that the entrance to the Stockyard Gully Cave was part of King Ranch and thus effectively helped Jimwa Pty Ltd to be aquitted. Furthermore, Mr Sanders was required to give important evidence at the Court Hearing but failed to attend. Such lack of concern shown by the Authority in whom the land is vested must have been frustrating to both the local ranger and to the public, especially the Speleological Community who lobbied the NPAWA to take out the summons. Unhappily, this lack of genuine concern for nature reserves by the relevant authorities is still displayed by the ways in which Nature Reserves are designated and classified.

STATUS OF THE STOCKYARD GULLY AREA

At the beginning of the Stockyard Gully Reserve, along the main vehicle track from the north, an old sign (in poor condition) states it to be the Stockyard Gully National Park. Working in a National Park requires permits and thus we applied to the Department of Conservation and Land Management (CALM) of the State government for a permit to do research in Stockyard Gully National Park. We obtained our permits without anyone in CALM querying the National Park status of the area.

While preparing the report on yabbies in Stockyard Gully caves (Jasinska *et al.* in prep.), we wished to verify the status of the Reserve as a National Park. The CALM officers who assisted in locating the relevant information from the files of their Department surprised themselves and us in discovering that the Stockyard Gully area is NOT a National Park. Instead, the area in question is classified as Stockyard Gully Nature Reserve (# 36419), an 'A' Class Reserve of 1 406 ha vested with the National Parks and Nature Conservation Authority (NPNCA) for the Conservation of Flora and Water, and Protection of Caves.

In 1985, the NPAWA also believed the Reserve to be a National Park: in the case discussed above before the Jurien Court of Petty Sessions between Colin Creeth Sanders, Director of National Parks, Complainant, and Jimwa Pty Ltd, Defendant, the Reserve is cited in all seven complaints as Stockyard Gully National Park!

DIFFERENCES BETWEEN CLASS 'A', CLASS 'B', CLASS 'C' RESERVES - AND NATIONAL PARKS.

Upon finding out the present status of the Stockyard Gully Nature Reserve (which seems to represent a shift from an earlier status, we then wished to know the differences between Class 'A', Class 'B' and Class 'C' Reserves - and National Parks (nearly all National Parks belong to the Class 'A' category of Reserve). In total naivety, we expected to find a government document which would define clearly, and distinguish between, the four types of Reserve, hopefully incorporating such objective criteria as:

i. local, state and regional importance of scenic, historical, geological, geomorphological, hydrological and biological components of the reserve.

ii. minimum proportion of species of plants (including fungi and bluegreen algae) and animals which naturally occur in the area;

iii. the minimum geographic area represented by the plants and animals in the reserve;

iv. the minimum number of ecotones the reserve should contain (i.e. the minimum diversity of habitats);

v. the minimum component of endangered habitats, plants and animals the reserve should contain;

vi. the minimum length and breadth of the reserve;

vii. the maximum disturbance caused by man to the geological, geomorphological, hydrological and biological components of the reserve;

viii. the minimum and maximum proportion of the reserve dedicated for public facilities such as roads, buildings and picnic areas;

ix. the level of legal and practical protection for the the reserve, especially for features, such as caves, which are particularly vulnerable to damage from human activities;

Afterall, without objective criteria, how can authorities choose the most appropriate areas to be set aside for reservation and, if the need arises, how can they decide, objectively, if the status of a reserve should be changed?

The appropriate CALM personnel were unable to give us a clear statement in document form on the distinction between Class 'A', Class 'B' and Class 'C' Reserves - and National Parks. However, the brochure entitled "Land Managed by CALM" did contain the following information.

> All reserves have to be classified as either Class A, Class B or Class C (irrespective of their purpose). The level of classification reflects the level of approval required to alter their area or their purpose:
>
> **Class A** - Approval of both Houses of Government (WA)
>
> **Class B** - Approval of the Governor, provided the Minister for Lands presents a report to Parliament
>
> **Class C** - Approval of the Governor
>
> Class A reserves are therefore more 'secure' than Class B or Class C reserves.

We then visited the Environmental Protection Authority Library, where the staff obtained for us copies of the relevant pages from the "Annual Report" of the Department of Conservation and Land Management (1990 to 1991) which, in addition to the above, also contained the following two definitions.

> **Nature Reserves** - Areas to be managed for wildlife conservation and scientific study. Have important conservation value, either as part of a reserve system, as a remnant or because of particular species. No historical commitments to inappropriate uses or activities.
>
> **National Parks** - Areas to be managed for wildlife conservation, scientific study and public enjoyment. Have important conservation, cultural and scenic values. Nationally or internationally unique, in terms of landscape and/or biota. Size must be sufficiently great to accommodate recreation or historical uses without significantly detracting from conservation values.

In short, National Parks differ from Nature Reserves by being nationally or internationally unique in their landscape and/or biota and they must contain areas dedicated to public access and recreation.

Still in pursuit of a more detailed classification system for nature reserves, we followed the advice given in the CALM brochure and purchased the Conservation and Land Management Act (1984). The Conservation and Land Management Act then directed us to the Land Act (1933 inc. amendments to date) for information on the classification of nature reserves. In this Act we found that it is up to the Governor (following advice from his government) to classify a reserve as either Class 'A', 'B', or 'C', or to proclaim a reserve a National Park. Once again, the criteria used for the classification were not given. Still in pursuit of such criteria, we purchased Conservation Reserves for Western Australia (1976) and Wildlife Conservation Act, 1950-1979 (1980 inc. amendments to date) and consulted the Environmental Protection Authority Library - all to no avail. Thus we were forced to accept that such elementary information is not easily accessible to the public or, worse still, it may not exist.

One of the recommendations of 'The Report of the National Estate' (1974, p130) states:

> that the selection of areas for reservation be based on objective scientific criteria, the need for representativeness of ecosystems and protection of threatened species, and the recreation needs of urban populations.

Sadly, 18 years later, at least in Western Australia, apparently little notice has been taken of this recommendation.

What is the point of the State Government creating National Parks or 'A' Class Nature Reserves if the agency with the function for managing those Reserves is unable to prevent deterioration in the ecosystems of the Reserves?

Whilst there are a number of Reserves and National Parks in the corridor of sandy plain heathlands between Geraldton and Perth, Western Australia, many adjoin land developed for agriculture - and herein lies a problem. Should the farmer of land adjoining a Reserve indulge in undesirable farming methods which impinge upon the Reserve, it is well-nigh impossible for CALM to stop them. The purpose of Conservation of Water introduces another problem which is not unique to Stockyard Gully. Perhaps the greatest volume of water in the Reserve enters from streams draining across farmlands immediately to the east of the Reserve. CALM has little direct control over activities on this farmland, and any which lead to a deterioration in water quality immediately translates into a deterioration in the quality of the water in the cave systems. Hence there is a need to monitor carefully the environments of caves and to draw attention to any undesirable lowering in the quality of the aquatic environment in caves as soon as it becomes evident.

Does it matter then, at the present time, whether an area is a National Park or simply a Class 'A' Reserve? Legally it does not, but it is likely that in the eye of the public, National Parks are to be held in greater reverence than 'A' Class Reserves. Importantly, we understand that in Western Australia at least, of all the different types of nature reserves, CALM rangers are based only in National Parks (even if not in every Park), although the rangers also periodically survey the other types of reserves. Therefore, in practice the status of a National Park , may render a nature reserve more secure.

Caves are: an integral component of the National Estate; the purpose for many Reserves; and important in the biology of this continent. Is the Stockyard Gully karst of national significance? - If so, [according to the "Australian Karst Index" (1985) the caves are important for biology, geomorphology, geology and hydrology] then it could be beneficial to the conservation of the area to proclaim it a National Park.

Nevertheless, we are fooling ourselves if we imagine an area or cave is safe from destruction simply because it lies within a Reserve of some kind. It seems that the real conservation work begins only after an area has been set aside for a nature reserve.

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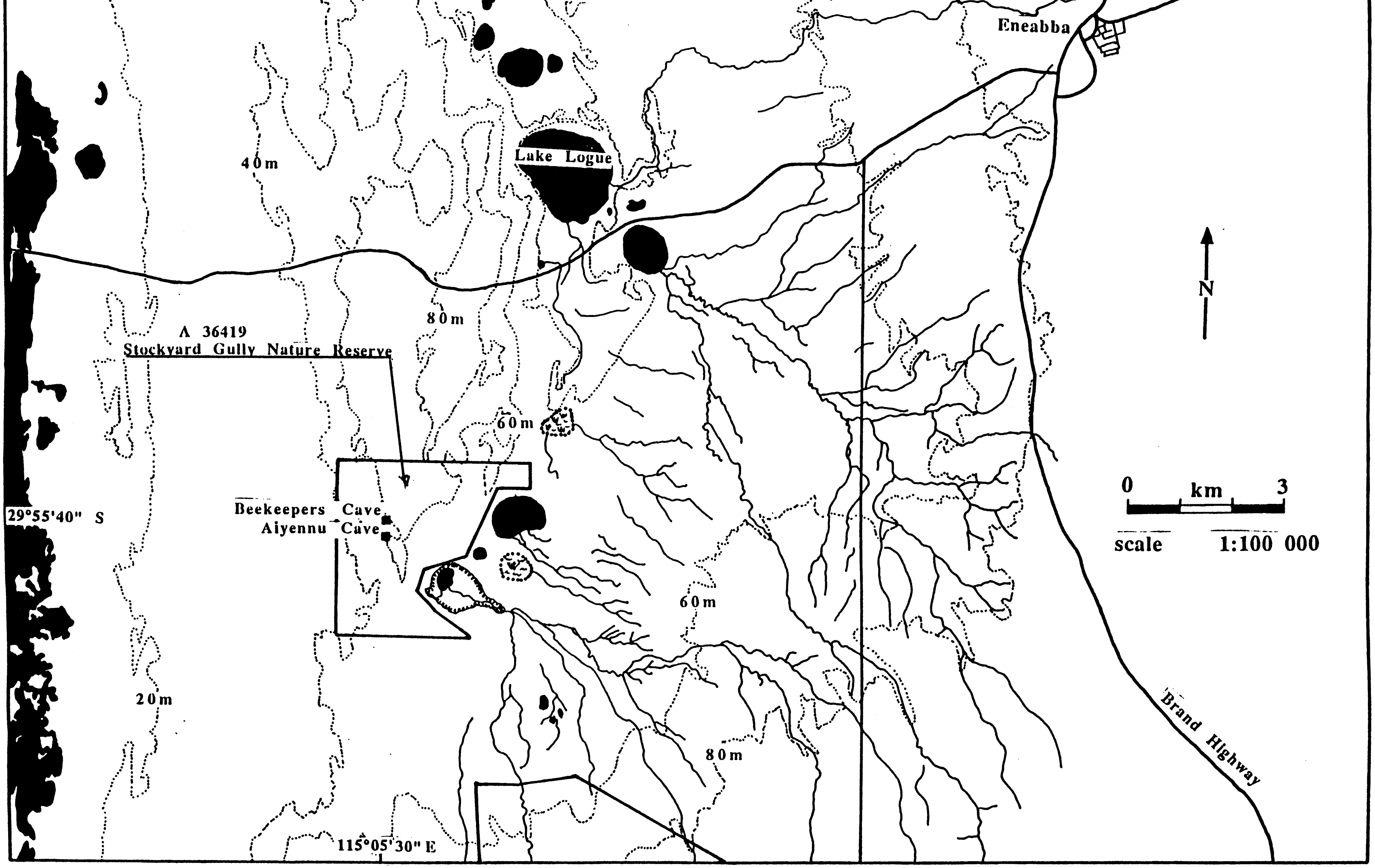

Fig. 1 Locality map of Aiyennu and Beekeeper caves showing: main roads, surface waters (lakes and streams) and land contours. All surface waters are intermittent.

Solutional Landforms on Silicates; largely ignored or largely unrecognised?

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Introduction.

The long held belief that the formation of karst, both the small-scale features superimposed upon a landscape, and the large scale landscapes themselves, can only develop upon relatively water soluble carbonate rocks has only recently been seriously questioned. Research into karst geomorphology has generally been restricted to the 'classic' forms developed on rocks of high carbonate content, even going as far as insisting that karst be strictly defined to carbonaceous rocks as this is where best developed karst forms are found; karst-like forms on non-carbonaceous rocks must, therefore, be "pseudo-karst" (cf. Otvos 1976). Others have discarded this circular reasoning and regard karst as a process, namely solution, the action of which is "thought to be critical (but not necessarily dominant) in the development of the landforms and drainage characteristics of karst" (Jennings 1983, p. 21).

It has further been argued that in a karst terrain not only do solutional features dominate surface landforms, but surface drainage gives way to underground water circulation (Dreybrodt 1988). However, sub-surface water flow is not definitive; a terrain may be karstic *sensu stricto* despite a lack of subsurface drainage if solution of bedrock matrix or cement has been critical in the development of the landscape (Twidale 1984; Young 1986a; Young and Young 1992). The implications of this are quite profound; if it meets this solution criterion a terrain may be karstic whatever the rock type, and even in the absence of significant subsurface flow.

Although karstic phenomena on silicate rocks have been reported for quite some time, little attention was given to their detailed study because, unlike limestone most silica rich rocks (notably quartzite and quartz sandstones) they were generally believed to be "virtually chemically inert" (Tricart and Cailleux 1972). However, the discovery of large scale solutional features, underground drainage networks, and large cave systems - possibly nowhere better displayed than on the Roraima quartzites of Southern Venezuela (White *et al.* 1966; Pouyllau and Seurin 1985; Briceño and Schubert 1990) - has shattered the classic view of karst formation being unconditionally restricted to 'soluble' rocks (Young and Young 1992).

Goldich's Scale of relative rates of chemical weathering suggest that quartz sandstone and granite are twice as resistant to chemical breakdown than volcanics and shales, nearly five times more resistant than most metamorphics, and over ten times more resistant to chemical attack than carbonates. However, if silicate karst is compared in detail with limestone karst, there is very little difference in landform morphology or in the genetic processes involved. The only significant difference between the two is that in silicates the removal of material by dissolution is restricted to about 10 to 20 percent of rock bulk, compared with the 80 percent or more generally found with carbonate rocks (Martini 1979).

Thus, silicate karst may be less common, and often less well developed than limestone karst, but given the appropriate environmental condition, almost any rock can be modelled to karst forms (Briceño and Schubert 1990).

Solubility of Silica.

Before examining the various forms and distribution of siliceous karst it is necessary to briefly examine the chemical processes, dominantly that of solution, responsible.

Whereas the chemical solution of calcium carbonate involves a multi-stage process (Bögli 1960), the solution of quartz in water can simply be written as (Henderson 1982);

$$SiO_2 + H_2O = H_4SiO_4$$

However, the breakdown of silicates is not as simple as it may at first seem. Dissolution of silicate minerals is more complex than for quartz and is often incongruent, that is, the solution process does not simply result in the formation a solute, but often leads to the formation/precipitation of new solid phases. For example, dissolution of felspar, a silicate mineral common in rocks and clays, often leads to the precipitation of aluminium hydroxide or kaolinite (Velbel 1985)

$$NaAlSi_3O_8(s) + H^+ + 7H_2O = Al(OH)_3(s) + Na^+ + 3H_4SiO_4(aq)$$

$$= 1/2Al_2Si_2O_5(OH)_4 + Na^+ + 2H_4SiO_4(aq)$$

These three processes result in uncharged monosilicic acid $Si(OH)_4$ being released into the natural environment, but this silica will not necessarily remain in solution. It may precipitate as one of the several naturally occurring forms of silica, generally either amorphous silica or opal-A, but almost never quartz. Silica in natural solutions may also be used in the neoformation of clays (Velbel 1985). These processes are themselves reversible; the clays may weather or the amorphous silica or opal-A redissolve.

The amorphous silica or opal-A thus formed may over time be transformed by diagenesis to more ordered forms of silica; to cristobalite-tridymite, thence chalcedony, and finally to the most stable form, quartz (Yariv and Cross 1979). Thus it is obvious that in any natural system, siliceous bed-rock, saprolite or soil, highly ordered quartz is not the only form of silica that can reasonably be expected to be present.

A further complicating factor in the geochemistry of silica is that the form taken by the silica greatly influences its solubility. Krauskopf (1956), Yariv and Cross (1979) and others have demonstrated significant differences in the solubility of silica. At 25°C amorphous silica is soluble in water to 100 - 140 mg/l whilst quartz is in equilibrium at 6 - 16 mg/l. At temperatures of 85-90° C, often attained on some exposed rock surfaces, the solubility of amorphous silica attains 300-380 mg/l - into the range of limestone solubility (Hedges 1969). The pH of the solvent solution has also been shown as having an influence on silica solubility. At pH below 9, silica solubilities are relatively uniform, however, above this point the solubility of amorphous silica increases very rapidly to 600-1000 mg/l (Yariv and Cross 1979), a six to ten fold increase over solutions with pH less than 9.

Although these rates of silica solubility have been widely modelled under laboratory conditions, concentrations of silica in rivers and streams suggest that similar rates may not always be found in nature. Recent studies indicate that the solubility of many silicates, especially that of quartz, may be reduced in the presence of some metallic ions, notably iron and aluminium (Yariv and Cross 1979). Conversely, rates of solution are greatly enhanced by some organic acids whilst the equilibrium solubility remains unchanged (Bennett 1991).

Thus, it is evident that the form of silica present and the environmental conditions under which the chemical attack occurs both have an important role in the breakdown of siliceous rocks. Silicate minerals and amorphous silica are potentially more than an order of magnitude more soluble than quartz. Nonetheless silica solution is an important process not only in granite, and felspathic or arkosic sandstones, but in highly quartzose sandstones and even very pure silica cemented quartzites.

Siliceous Karst.

Highly siliceous sedimentary rocks, notably sandstones and quartzites, often display karst features. Solutional forms on granite and related igneous rocks (granodiorite, syenite, etc), are common but generally at a lesser scale. Less familiar are solution features on metamorphics and even basaltic lavas.

The distribution of solution features on quartzose rocks spans an wide range of lithologic types and climatic regions. The most highly developed siliceous karst is generally found in the humid tropics (Wentworth 1944; Wall and Wilford 1966; White *et al.* 1966; Chalcraft and Pye 1984; Pouyllau and Seurin 1985; George 1989; Briceño and Schubert 1990), but excellent examples are reported from the seasonally dry tropics (Jennings 1979, 1983; Young 1986a,b), the hyper-arid tropics (Busche and Erbe 1987; Busche and Sponholz 1992), more temperate regions (Hayes 1900; Frye and Swineford 1947; Hedges 1969; Martini 1979, 1981; Battiau-Queney 1984; Cooks and Pretorious 1987; Whitlow and Shakesby 1988), continental Asia (Dzulynski and Kotarba 1979), and even sub-arctic environments (Dahl 1966).

Siliceous karst occurs over a similar range of scales and types to limestone, from towers, poljes and caves to the smaller *karren*. Indeed, almost every limestone form has been described on non-carbonaceous rocks with similar morphology and at a similar scale.

Tower Karst.

Probably the best examples of tower karst in quartz sandstone found anywhere in the world are in northern Australia. Jennings (1979,1983) describes large areas of the Arhnem Land Plateau, possibly best displayed at the 'Ruined City', the Proterozoic quartz sandstones of which have been "in parts chopped up by meshes of corridors and canyons, in parts reduced to towers jumping out of the plains" (1983, p.21). Percolation of water down and along joints during a long period of sub-aerial weathering removed much of the quartz cement which bound the rock. Later erosion of this weathered rock, dominantly along the major joints, has resulted in the formation of subsurface pipes and a general 'ruiniform' relief. Springs issuing from small tubes along bedding planes and numerous large closed depressions attest to underground drainage.

On a comparable scale, the Bungle Bungle Range in the Kimberley Region of Western Australia is also an extremely impressive example of tower karst. Solution of the quartz cement of these Devonian sandstones has been so intense that large blocks of the rock can be crushed in the hand. The interlocking network of grains has, however, resulted in the sandstone retaining a high compressive strength allowing it to stand in steep faces, turrets and sinuous arétes (Young 1986a,b, 1988).

Jennings (1983) insists the 'Ruined City', and presumably the similar landscapes in much of the Arhnem Land Plateau are attributable to solution, and thus true karst. Young (1986a) also demostrates conclusively that despite a lack of subsurface drainage, the intense etching and solution of silica that has occured in the Bungle Bungle Range has been critical in the formation of this landscape, which is thus also karstic.

Tower karst in many ways similar to those just described have also been found in the more humid Sydney Basin. In several localities south of Sydney the Permian Nowra Sandstone has been chopped up into numerous series of towers, aretes and cones, often closely resembling those of the 'Ruined City'. The best example of this 'ruiniform' relief is at Monolith Valley in the Budawang National Park. Here the sandstone is highly jointed and relatively thinly bedded. Springs often issue from small tubes along bedding planes high up on the cliffs. Preliminary analysis of the sandstone shows it has a low compression strength and is highly etched at the microscopic level

(Wray *in prep*). Other areas such as Bulee Gap exhibit a similar assemblage of rounded towers and coridors.

Tower karst and 'ruiniform' landscapes of this type are not unique to Australia and have also been reported from many parts of temperate Africa (Mainguet 1972) and the Roraima area of southern Venezuela (Pouyllau and Seurin 1985).

Caves.

Less well known but no less striking are the numerous caves and shafts formed in sandstones and quartzites around the world. Whilst none reach the sizes or lengths found in the largest limestone caves, they are in many cases comparable to limestone caves in size and length, and in themselves very impressive.

The most imposing sandstone karst landforms in the world must be those reported from Venezuela. Precipitous cliffs, often nearly a kilometre high and dense jungle surround large table mountains of Precambrian Roraima quartzites. For an excellent photographic essay on this area see George (1989). The mountain tops are areas of very high rainfall with the runoff draining through fissures, canyons, sinkholes and caves, or plunging directly over the rim to form the highest waterfalls in the world (Briceño and Schubert 1990). Angel Falls, the highest, has a single uninterrupted drop of over 986m (Pouyllau and Seurin 1985). This drainage pattern is controlled by the major fracture systems and by lithological contacts. The water that proceeds underground via the myriad of sinkholes finds its way by large and intricate cavern systems, a tiny number of which have yet been explored, to reemerge on the vertical walls of the table mountains, generally several hundred metres below the summits. An complex passage system over 400m long with tubes of up to 20m diameter has been reported within Cerro Autana, 650m up the 800m high mountain (Jennings 1983). Other cave systems are reported in this area, including active river passages over 2km long, all in quartz sandstone and quartzite (Chalcraft and Pye 1984; Pouyllau and Seurin 1985; George 1989; Briceño and Schubert 1990).

The wet tropics are not the only region with significant sandstone caves. Busch and Erbe (1987) report closed drainage depressions and phreatic caves in the hyper-arid (20 mm precipitation p.a) Sahara of northern Africa. The caves are relict and have been attributed to wetter periods during the mid-Tertiary, although the scarp-foot depressions are believed to have been active until the Pliocene. Both Mainguet (1972) and Martini (1979, 1981) also describe large and active cave systems many hundreds of metres long in South Africa, particularly in the Transvaal.

Jennings (1979, 1983) discussed several large sandstone caves in northern Australia. Yulirienji Cave excavated in the Upper Proterozoic quartzose Hodgson Sandstone south of Roper River, Arnhem Land, is a large rounded remnant of a former river cave 50m long by 8-10m wide and 1.5 to 4m high, whilst Whalemouth Cave near Turkey Creek in the East Kimberley is an active river passage about 220m long and 120m deep. The impressive exit of this cave is 60m high and 45m in width.

Many other sandstone caves are also known in the seasonally dry tropics of northern Australia. Joyce (1974) reports similar caves in Arnhem Land and southern Queensland, several of which have intermittently active streams. Galloway (1967), R.W.Young (*pers comm.*), A.R.M. Young (*pers comm.*), G. Nanson (*pers comm.*) and others, all describe dozens of caves in the Precambrian Kombolgie Sandstone of Arnhem Land, some of which exceed many tens of metres in length. This region also contains large doline fields formerly attributed to load casts (Needham 1978), but more recently reinterpreted as solutional (A. R. M. Young *pers comm.*).

Temperate Australia also has sandstone solutional caves. The Natural Tunnel at Hilltop, south of Sydney, is a large active through cave 85m long in the highly quartzose Hawkesbury Sandstone. Smaller caves are also found in this sandstone, one 60m long on Cowan Creek north of Sydney (Pavey 1975), whilst Endless Cave at Kincumber, near Gosford, is 35m long and intermittently fed from small solution tubes (Jennings 1983). The Yadbro Conglomerate below The Castle near Ulladulla is also riddled with hundreds of solution tubes many metres in length, some of which are accessible. Surface stains and drapes on the cliffs of the overlying Nowra Sandstone often originate from small solution tubes up to 30cm in diameter, also attesting to subsurface water flow.

Shafts.

Huge collapse shafts are also found, particularly in the tropics of South America. In the Roraima area (Gesner and Mehl 1977; George 1989) and in nearby Guyana (Urbani 1977) and Brazil (Brichta *et al.* 1980) huge vertically walled collapse dolines 150 to 400m wide and deep, all in sandstone and quartzite, have formed from collapse associated with chemical solution of quartzites and other siliceous rocks under the tropical climatic conditions.

Shafts of this magnitude are not unique to tropics however. Hayes (1900) describes two shafts or "solution sinks" (p.228), over 50m deep in quartzite in Alabama. Hayes proposed that the "beds in which they occur have been faulted over beds of limestone, and the material which originally occupied the depressions has fallen into underground channels through which it was carried off by flowing water" (p.229). There is, however, no evidence given for the presence of limestone below the quartzites.

This process of subjacent solution of limestone has been employed to account for many collapse features world-wide, even when no evidence for limestone has been found (Gesner and Mehl 1977; Brichta *et al.* 1980). The Big Hole near Braidwood, New South Wales, is a well known case in point. This 110m deep shaft in Devonian sandstones and conglomerates located on top of a hill has been attributed by Jennings (1967, 1983) to subjacent limestone solution and collapse into the resulting void. Although limestone is found in several locations close by, no evidence for limestone has been found in the vicinity of the shaft. Recent Scanning Electron Microscopy of the Big Hole sandstones indicates extensive etching and solution of the component detrital quartz grains and overgrowths (Wray *in prep*). In the light of this recent knowledge it is proposed that a quartz solution mechanism similar to those responsible for similar shafts worldwide may be in part responsible for the formation of this impressive and regionally uncharacteristic hole.

Small Scale Karst Features.

Notwithstanding their less impressive nature, smaller solution features are far more numerous than towers, caves or shafts. So ubiquitous are these small *karren* that they are normally passed by without a second glance or much thought as to how they originate in 'insoluble rocks'.

The study of small basins, rills and pits on siliceous rocks is one which has attracted the casual attention of numerous geographers and geologists around the world for over 130 years (Ormerod 1859; Cooks and Pretorius 1987), but during this period little detailed work has been done. German researchers have probably been the most productive in the field, and this language contains an extensive literature concerning these landforms, however, until recently few authors of other linguistic backgrounds were suitably impressed by these small solutional forms to have made more than superficial study of them.

Basins.

Solution basins, known variously as gnammas, opferkessel, rock tanks, etc., are the siliceous rock analogues of those on limestone (kamenitsa, tinajitas, etc). They are found on generally soil free, rocky outcrops of both inland and littoral areas. Their flat floors, undercut rims, and often well defined spillways are unmistakable testimony to the ability of rainwater initially impounded in small hollows to dissolve and carry away normally 'insoluble' minerals such as biotite, hornblende, feldspars, and even quartz (Hedges 1969).

These basins normally possess relatively flat to gently concave-up floors, interrupted only by occasional inclusions of material having a rate of solution different from that of the host rock. Their floors often terminate abruptly in vertical to slightly overhanging walls, and these exposed walls and floors are minutely irregular due to projecting crystals. They are often found in chains connected by shallow channels, and often coalesce to form larger, amoeboid hollows. Unlike kamenitsas, fretwork is not commonly found on the walls and rims of siliceous solution basins, possibly due to the coarse grained nature of the host rocks, but it is occasionally reported. Nested solution basins have not been found reported in the literature, but are common in the Sydney Basin sandstones (cf. Hedges 1969).

Sizes of these basins usually range from 1 or 2 cm up to a metre or two in width, and from less than 1 cm up to several tens of cm deep. They are usually much wider than they are deep. In most is retained a relatively thin regolith of fragments of the host rock, vegetation debris and organic scum. Many hold water for long periods after rain. Rarely, much larger basins are found, dimensions of which must be expressed in tens of metres (Dahl 1965; Howard and Kochell 1988; Netoff *pers comm.*).

Solution basins have been reported in numerous rock types, most commonly granite (Osmerod 1859; Hedges 1969; Dzulynski and Kotarba 1979), but also quartz sandstone containing less than 1% carbonate (Frye and Swineford 1947; Cooks and Pretorius 1987), granodiorite (Branner 1913), syenite (Branner 1913; Udden 1925), as well as certain schists, and basaltic lavas (Wentworth 1944).

Mostly described from relatively warm and humid climates, solution basins are distributed through as varied climates as those of much of the United States (Hedges 1966), western Greenland and Norway (Dahl 1966), Antarctica (Dahl 1966), Great Britain (Ormerod 1859), tropical Brazil and Venezuela (Wentworth 1944; Wall and Wilford 1966; White *et al.* 1966; Chalcraft and Pye 1984; Pouyllau and Seurin 1985; George 1989; Briceño and Schubert 1990), Hawai (Wentworth 1944), arid northern Africa (Busch and Erbe 1987), Mongolia (Dzulynski and Kotarba 1979), temperate South Africa (Mainguet 1972; Cooks and Pretorius 1987), and Southern Australia (Twidale 1984).

These basins are generally not relict forms, previously developed under more humid climatic regimes, although some exceptions to this general rule have been shown (Busch and Erbe 1987). They normally retain far too much fine surface detail to have survived been created under climatic conditions different to that of today. Smith and Albritton (1941) refused to place climatic limits on the development if limestone tinajitas in Texas because of climatic changes during the last few millenia, but in view of the wide variety of climates under which siliceous solution basins are presently found it would appear that climate *per se*, either past or present, is of little influence in their development (Hedges 1969).

Unlike solution basins on limestones which may develop beneath a soil mantle (Bögli 1980), siliceous solution basins are almost exclusively a sub-aerial form (Twidale 1984), but some currently inactive basins are found infilled with sediment. However, precursors of the basins are sometimes believed to develop at the weathering front beneath a soil layer (Twidale 1984).

Although Hedges (1966) believed that solution basins are only found in mountainous regions and other areas of high relief where weathering debris cannot accumulate to form a mantle over the parent rock, or on marine rock platforms (Wentworth 1944) this is clearly not always the case. Smith (1941) found that the largest basins were located where surfaces were flattest, finding none on slopes inclined more than 20 degrees.

Branner (1913), however, found basins developed on slopes as steep as about 45 degrees in Brazil, whilst Dahl (1965) reports large basins in Norway on slopes of over 20 degrees. Near Sydney solution basins are found on mountain tops, in valley bottoms, and at sea level. In favourable locations, basins tend to occur on level or gently sloping exposures of bare rock, such as the tops of rock bosses or boulders, the edges of clifflines, the beds of rivers and creeks incised into bed-rock, marine platforms and similar locations. The basins are most common on exposures inclined less than about 20 degrees, although in some rare instances basins on slopes as steep as about 50 degrees have been observed by the author.

Although basins are found in many different locations and a wide range of sizes, their morphology is not random. Morphometric studies, although rare, indicate there are definite relationships inherent in the gross characteristics of basins. Schipull (1978) studying 'waterpockets' in the quartz sandstone of Colorado discovered correlations between length and width ($r = 0.95$) and length and depth ($r = 0.81$) in the 80 basins examined. Similarly, Crooks and Pretorius (1987) found characteristic relationships of length, depth and width within basins in greywacke in two areas of similar lithology but markedly different climate in South Africa. Preliminary investigations of solution basins in the quartz sandstones of the Sydney Basin also suggest distinct relationships of similar correlation between basins in various locations, suggesting that "daß das Wachstum gleichzeitig in die Breite und in die Tiefe geht" (Schipull 1978, p.431) (*"that tincrease in width is simultaneous with tncrease in depth"* Translation R.Wray.)

Flutes.

Like solution basins, flutes, rilles or runnels resulting from the solvent action of flowing water are an almost ubiquitous feature of carbonate terrains. Solutional rilles have been classifed by size and supposed mode of origin (Bögli 1960), with numerous morphometric analysis conducted on these various forms (Dunkerley 1979, 1983). Solution runnels are also common on siliceous rocks, notably granite and sandstone, and are in many cases morphometrically similar to those on carbonates.

Twidale (1984) and Whitlow and Shakesby (1988) discuss various runnels and 'gutters' on granite outcrops in both Australia and Zimbabwe and demonstrate an evolution at the weathering front beneath a soil or regolith cover, with later stripping of this cover and sub-aerial exposure, in a similar manner to various limestone 'gutters'. These authors also demonstrate that these gutters are continuing to be modified by the solutional and corrosional action of running water.

Flutings that have developed sub-aerially have also been reported, but less commonly than the sub-surface 'etch' forms. Wall and Wilford (1966) report a comparison of small scale solutional features on microgranite in West Sarawak. Flutes of up to 6m length, with widths ranging from 2 to 100cm are common. These flutes are morphological similar to those on adjacent limestones. "The formation of these flutes appears to be mainly the result of solution by flowing rain water...corrasion by particles carried by the water.. is probably only of minor importance in flute formation" (Wall and Wilford 1966, p.466).

Excellent examples of flutes and runnels are also found on many sandstones. Whilst these are in general not as well defined as those on limestones, they are certainly well developed at several locations in the Sydney Basin.

Conclusions

All authors concede the influence of more or less chemical activity in the formation and enlargement of solutional forms on siliceous rocks. However, whilst chemical processes are critical, the physical processes of erosion of weathered material are paramount for continued development of siliceous karst features.

The actual focus of the chemical attack on siliceous rocks is also uncertain. Microscopic analysis suggests that alteration proceeds along mineral junctures, fractures and grain boundaries, with solution of alumino-silicates commonly leaving little residue. Klaer (1957) thought that by removal of the biotite in solution, the other mineral grains were freed and literally fell out. In similar fashion, Wilhelmy (1958) states that biotite and hornblende are the first minerals to be removed, followed by the feldspars, first oligoclase and then orthoclase, and then finally quartz.

However, in highly pure quartzites and sandstones this selective solution of silicate minerals cannot be shown. The slow chemical dissolution of quartz, 'arenisation' in the terms of Martini (1979), usually occurs along crystal boundaries with the freeing of individual grains, although it is often the case that the detrital grains are attacked more than the overgrowths which have lower surface free energies (Hurst and Bjorkum 1986). Faster rates of solution promote a general recession of surfaces and joint widening without rock disintergration (Martini 1979). This arenisation results in a rock that eventually becomes incoherent (Martini 1979; Young 1986a), and is thus highly suited to physical erosion. A plentiful supply of flowing water is then necessary for the removal of the material produced, preferably under vadose conditions (Martini 1979).

Unfortunately, the actual mechanisms of this arenisation are still unclear. White *et al* (1966) report that the spectacular Roraima orthoquartzite karst has formed from the hydration of quartz to amorphous silica under tropical weathering conditions. This conversion would enhance the solubility of the rock immensely. Chalcraft and Pye (1984) disagree, however, that this is the process responsible. They present SEM and XRD analyses and argue that this karst formed by the direct solution of quartz grains and silica cement, not involving any intermediate hydration phase. During weathering the minor feldspar and mica component is altered to kaolinite and, with other minor impurities, leached out concurrently with the removal of the quartz in solution.

The very high rainfall in this area is also important. Douglas (1969) demonstrated that the silica load of rivers is dependant on runoff, and thus rainfall. The amount of water moving through a rock will influence solution; for a given solubility regime, the higher the rate of flushing, the higher the silica loss. However, field measurements by Chalcraft and Pye (1984) showed dissolved silica to be very low, indicating that this dissected landscape must have formed by slow solution over a very long time period.

This factor of slow but very prolonged solution is one that has all too often been ignored. The slow rate of solution of the numerous forms of silica, especially quartz, was believed to preclude to formation of karstic lanforms on these 'inert' rocks. In the areas where most of the highly developed silicate karst is found, notably South America, Australia and southern Africa, slow rates of solution have been offset by long periods of sub-aerial weathering. In these areas moist temperate or tropical climatic reigimes have often been common since at least the Early Tertiary.

Thus it seems that given the right environmental conditions and the necessary geologic time periods landforms produced by silica weathering, and especially that of quartz, are not always as would be expected from that predicted from Goldich's Scale. Given a sufficiently long time period, the landforms produced by the slow dissolution of siliceous rocks can be in many respects similar to those produced by the much faster solution of carbonates. This notion challenges the classic view of karst formation being unconditionally restricted to 'soluble' rocks.

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HYDROGEOLOGY OF THE MT ANNE KARST, TASMANIA

Martin Scott

Abstract

Cave passages and streams in Annakananda, Potatoes, Deep Thought and Kellar Cellar indicate that underground drainage in the Annakananda area of the Mt Anne karst flows to the north and northwest. This is in the opposite direction to previous inferrences that underground drainage flowed directly southeast towards Lake Timk and Snake River. A sequence of conglomerate, sandstone and siltstone outcropping 150m southeast of Annakananda forms an insoluble barrier to underground drainage flowing to the southeast. Water tracing and further cave exploration and geological mapping are needed to understand the hydrology of the Mt Anne karst.

Introduction

Northeast of Mt Anne is a ridge of spectacular karst surrounded by deep glacially eroded valleys. The top of the ridge is a plateau 900-1080m asl (Davis 1988) composed of dolomite which strikes northwest to Sandfly Creek at an altitude of 400m, and southeast to Lake Timk at an altitude of 490m and beneath Lots Wife Ridge to the Snake River catchment below 400m (Calver 1991, Kiernan 1990a,b). The topographic relief of the Mt Anne karst is in excess of 600m, making it highly prospective for the discovery of deep caves in Australia.

Considerable cave exploration by numerous caving groups occurred at Mt Anne during the 1970's and 1980's. The most significant cave found is 3000m+ long Annakananda, which for some time was the deepest cave in Australia at 373m deep. Other caves over 100m deep in the karst include Kellar Cellar, Col-in-Cavern, Potatoes and Deep Thought. The largely vertical nature of the caves at Mt Anne, the lack of significant underground streamways, and no complete published plan map for Annakananda has made determining the hydrology of the karst difficult.

Recently Kiernan(1990a) has inferred that underground drainage from the Annakananda and Col-in-Cavern areas of the karst flow along strike southeastwards to the Lake Timk area and then further southeast to springs in the catchment of Snake River.

Cave maps published in the speleological literature, and cave and geological mapping conducted during the SUSS Mt Anne Expedition suggest the karst drainage is not as simple as inferred by Kiernan(1990a).

Cave Drainage

The hydrology of the karst can be investigated by following streamways within the caves. Maps of caves from the Annakananda area show drainage and passage development to the north and northwest, towards Sandfly Creek.

There is no complete plan map of Annakananda available, but maps of parts of the cave have been published. Early in the exploration of Annakananda, Eberhard(1982) published a map of the entrance passages showing drainage trending northwest from the doline. Maps of the Desiccator Series in Annakananda are shown in Webb(1985) and Carter(1985). Cave development trends and drains NNE from the Organ Grinder down the Dessicator Series to a depth of 345m below the top of the doline. The developed long section of Annakananda by Bunton & Eberhard(1984) is presumably drawn north-south, and shows the Heartbeat and Priority Paid Series heading further north of the Dessicator Series. The King Rat Series is also shown draining beneath the entrance doline. These maps and sections show Annakananda draining to the north towards Sandfly Creek.

Potatoes, Deep Thought and Kellar Cellar are another drainage system in the Annakananda area. Numerous streams in these caves drain north to northwest, approximately parallel to Annakananda, towards Sandfly Creek.

The karst to the east of the Annakananda area contains numerous caves although Col-in-Cavern is only significant cave with streams. Two small streams in Col-in-Cavern flows south following the general trend of the major passage (Anderson 1971). The streams and passage orientation suggest the drainage from the Col-in-Cavern area heads towards Lake Timk.

Geological Investigations

Rocks of the Weld River Group outcrop on the northeastern ridge of Mt Anne (Turner *et al* 1985, Calver 1989, 1991). The basal unit of the Weld River Group is the Annakananda Formation, a 30 thick sequence of thin-bedded sandstone and massive conglomerate. Karst is developed in the conformably overlying massive Gomorrah Dolomite and bedded oolitic Devils Eye Dolomite. The Weld River Group is overturned and dips moderately to the southwest.

Reconnaissance geological mapping conducted on the SUSS Mt Anne Expedition has recognised a reddish-coloured siliciclastic sequence of conglomerate (containing boulders of dolomite) and thinly interbedded sandstone and siltstone outcropping 150m southeast of the Annakananda doline. The siliciclastics strike NE and dip NW, and form a sequence at least 20m thick. The complete thickness and lateral extent of the sequence is unknown. Conglomerate, sandstone and siltstone of the siliciclastic sequence all abut the dolomite along an irregular NE striking contact. The geological nature of the contact is uncertain. The siliciclastic sequence is tentatively correlated with the Annakananda Formation on the basis of similar lithologies.

The siliciclastic sequence southeast of the Annakananda area has formed an insoluble barrier to underground drainage. The NW dip and NE strike of the siliciclastics has directed underground drainage in Annakananda and Potatoes, Deep Thought and Kellar Cellar to the north and northwest. A small resurgence emerging above the siliciclastics indicate these lithologies act as a base level controlling minor southeast-flowing drainage in dolomite bluffs immediately above the contact.

Discussion and Conclusions

A siliciclastic sequence outcropping southeast of the Annakananda area has prevented underground drainage from flowing directly southeast to the Lake Timk area as inferred by Kiernan(1990a). Drainage in the caves Annakananda, Potatoes, Deep Thought and Kellar Cellar is directed north and northwest towards Sandfly Creek. Although drainage in these caves is to the north and northwest, the eventual efflux for their drainage is uncertain. Drainage from the Annakananda area may flow north to springs in the upper tributaries of Sandfly Creek (S. Eberhard pers. comm. 1987) or resurge in swampy alluvium along Sandfly Creek. Otherwise the streams in these caves may eventually flow eastwards to the Col-in-Cavern area and southeast to Lake Timk and the springs in the Snake River catchment.

Water tracing and further exploration for springs and caves should give a better understanding of the hydrology of the Mt Anne karst. Cave exploration to date gives only an uppermost glimpse into the karst hydrology, as the main streamways are still to be discovered. More detailed geological mapping of the area is also needed to further understand the hydrology.

Acknowledgements

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SOFT ROCK CAVING IN VICTORIA

CAVES AND KARST IN THE LIMESTONES OF WESTERN VICTORIA

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Abstract

South western victoria has extensive areas of Pleistocene and Tertiary age limestones. Significant karst features and cave development occurs at a number of localities from the Otways to the South Australia border. The authors will present an outline of these areas and their caves, with the aid of slides, maps and diagrams.

Caves and karst in western Victoria is in two main limestones - the Pleistocene calcarenites (aeolianites) of the Bridgewater Formation and the Tertiary (Miocene) Port Campbell Limestone. The Tertiary limestones are extensive in Western Victoria but are of variable carbonate purity and only limited areas show major karst development despite the extensive area of carbonates. These are Glenelg River area, Kentbruck, Timboon, Warrnambool and Drik Drik as well as some coastal areas such as the coast between The Twelve Apostles and Peterborough along the Port Campbell coast.

More extensive karst development occurs in the Pleistocene aeolian calcarenite (aeolianite). These near coastal dune systems show karst development which is contemporaneous with lithification (syngenetic karst). One significant area is Bats Ridge which is a series of Pleistocene Bridgewater Formation dunes inland from Cape Bridgewater. Other areas of syngenetic karst are found at Cave Ridge, Portland area, Cave Hill (Heywood) Warrnambool, and Codrington. In some places, such as the Lower Glenelg, these Pleistocene dunes overlie the Tertiary carbonates and show karst development in the form of solution pipes into the Tertiary limestones where the main cave development occurs.

Marine influence is also shown in the sea caves along the western Victorian coast. Sea caves are found in the basalt cliffs around Cape Bridgewater. These have the interesting feature of secondary calcite formation and tufa associated with them as they are overlain by the Pleistocene calcarenites and the percolating water from the groundwater deposits calcite over the basalts. Further east along the Otway coast are joint enlarged caves modified by marine action in the Mesozoic sediments, e.g. Ramsdens Cave at Cape Patten. Although marine action is important along the Port Campbell coast as can be seen in the rock stacks offshore and other features, the area does show evidence of karst solution from ground water and underground streams . The two caves at Loch Ard Gorge are good examples of this as they show underground fresh water streams, and percolating groundwater and speleothem development. These features show the definite joint control exhibited in the karst in the Tertiary limestones which relates to other features in the area as well.

The caves are not notable for length or depth, or technical difficulty. They do however show a diversity of forms and speleological interest as well as being 'caver friendly'. Some of the caves are simple passages developed along a single major joint, others present a more complex network and often have multiple entrances. The distinctive features of phreatic development are widely in evidence. Collapse modification is also common. Vadose enlargement can be clearly seen in some of the caves in the tertiary rock.

The characteristically soft and lower density limestone and often sandy floors makes for generally easy caving. Cavers can concentrate on appreciation of the cave environment rather than be preoccupied with gear or demanding techniques. Never the less, hazards do exist in the form of sometimes unstable rockfall, loose sand, waves (sea caves) and occasional unwelcome accidental fauna like tiger snakes.

Many of the south western caves are used by bats as casual or regular roosting sites. One of Victoria's two known breeding caves for bent wing bats (Miniopterus schreibersii) is located near Warrnambool. Several caves along the Glenelg River are home for the comparatively rare (in Victoria) Myotis adversus or large footed bat. Wetas are common inhabitants of the entrance sections and various spiders and insect life can also be observed near entrances. Frogs, lizards and the odd snake are involuntary and doomed victims of straying too close to solution pipe entrances.

A number of caves with solution tube entrance shafts have acted as natural animal traps for thousands of years. As a result, extensive collections of bone material is found on the cave floor and in the soil fill. Palaeontological excavations have been carried out in several of these caves, yielding important information on past surface fauna.

Following is a brief outline of the main cave areas:

Lower Glenelg (G)

Located in the far south west corner of Victoria, the flat topography of the area is traversed by the gorge of the Glenelg River which has cut deeply through the Tertiary marine limestone. The river gorge is typically 100 m wide with sheer sided limestone cliffs rising up to 35m above the river level. The river and natural bushland to the south is within the Lower Glenelg National Park. State Forest, planted with pines, occupies much of the land immediately north of the river.

Some seventy caves and karst features have been recorded at date. Many caves have entrances in the river cliffs. Several permanently active outflow caves are located at the present river level. Other now abandoned dry caves are found higher in the cliffs. The one tourist cave, Princess Margaret Rose Cave, is part of a former underground bypass across a prominent bend in the river, now abandoned as a result of later down cutting of the river gorge.

A striking feature of all the major caves is their general 120 - 300 degree (magnetic) orientation. This corresponds to the uniform alignment of major joints in the horizontally bedded Miocene age limestone. Apart from horizontal entrances in the river cliffs, solution pipes are the surface connection for quite a few of the Lower Glenelg caves. Well formed solution pipes ranging up to two metres in diameter and 15 m deep, penetrate overlying consolidated calcareous dune deposits to connect with cave development in the Tertiary limestone.

Other karst features of the area include dolines with permanent standing water, springs and swallets.

Eight of the caves within the National Park have been classified as being of special significance (Category 2.2) in the Park's 1991 Management Plan. Visits to caves within the National Park are subject to prior arrangement and a permit is required for access to the designated special significance caves.

Warrnambool (W)

This area of coastal limestone has spectacular high cliffs, exposed solutional pavements and sinkhole features as well as caves. The twenty-five numbered karst features range from tight, joint controlled cave systems to the spacious Starlight cave. Starlight Cave (W5), which has been known since the 1850s, has two interconnected, 40 m high, bottle shaped dry 'cenotes', one of which has multiple short solution tube openings to the surface. Natural light entering through these openings gives rise to the cave's name. A spacious upwardly rising passage from the base of the cenotes leads to an impressive entrance in an overhanging sea cliff. The cave was mined for guano early this century and is an important bat cave, and a possible breeding site. For this reason, visits to the cave are normally confined to late summer.

Most of the Warrnambool Area caves are located on private land and permission is required from landholders for any visits.

Bat Ridges (BR)

Bat Ridges on Cape Bridgewater is an area of syngenetic karst in Pleistocene calcareous dune limestone. In a relatively small area of about 500 ha, some 90 cave numbers have been assigned by V S A. The caves are shallow but often quite extensive. The largest cave, BR4, has a surveyed extent of about 1.4 km.

A common feature of many of the Bat Ridges caves is the large areas of low flat ceilings at the lowest level. Collapse is a significant part of the development of most caves. Speleothems are not a prominent feature, but in places, substantial flowstone deposits, stals. and columns can be seen, albeit often dry. Moon milk and cave coral is common on cave walls. Delicate straw formations also occur in a few of the caves.

The cave entrances to the are typically horizontal from the sides of the dune ridges with characteristic caprock arches. Multiple entrances are common with the interlinking of caves in a single dune. A small selection of the caves have solution pipe entrances.

In line with the area's name, bats roost in a number of the caves. These are mainly bent wing bats (M schreibersii).

Many of the caves are located within the Bat Ridges State Faunal Reserve. Others are on adjoining private property. Most of the area is native bushland.

Codrington (CD)

Codrington is another area of cavernous calcarenite dune ridges similar to Bat Ridges. Located on private land between Port Fairy and Portland, some forty caves have been documented since V S A began systemmatic investigations in 1989. Like Bat Ridges, the density of cave entrances is high. Many caves interconnect and others probably could be connected with determined effort.

Although usually dry, the lower parts of these caves are liable to inundation from surrounding low lying ground after prolonged wet weather. Phreatic development is strongly in evidence in many of the caves in the form of solutional ceiling pockets, rounded pillars and distinctive rock pendants. Like Bat Ridges, decoration is limited, but some caves have sections of attractive speleothems.

Portland (P)

The Portland area includes Cape Nelson and Cape Bridgewater, both of which provide rugged coastal scenery with high cliffs and frequently rough seas. Features include 'blowholes' and 'petrified forest' formations as well as some splendid sea caves.

At Cape Bridgewater two large adjoining sea caves in basaltic tuff provide shelter for seal colonies. One of these caves has two seaward entrances and an internal beach. A branch passage is home to often large numbers of bats. Difficulty of physical access and the active presence of the sea provides both challenge and hazard.

On the inland side of Bridgewater Lakes, the prominent Bridgewater Lakes cave, formed in dune limestone, exhibits calcite draperies, stalactites and columns, all clearly visible to passing motorists.

Timboon (T)

The Timboon area designation covers caves and karst in the vicinity of Timboon and Cobden to the west of the Otways. To date only ten caves and karst features have been numbered, but opportunity exists for more discoveries. Although the known caves are not large, they include four active stream caves, two of which have prolific white flowstone deposits.

CONCLUSION

In all, the soft limestone cave areas of south-western Victoria offer a diverse range of caving experiences and are enjoyable to visit. Each area also has its own character ranging from pleasant native bushland and scenic river gorges to wild coastal environments. As well as the main areas listed above there are a number of isolated caves which have their own interesting aspects. Cavers do not need to be "gung ho", and while a single cave is unlikely to attain a length record, there are plenty of caves, each with their own features and surprises. There is also much to interest the more serious speleologist, whether it be in the fields of geology and geomorphology, cave development, paleontology, bats or other cave science.

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Tourism as Cave Conservation ?

- 90 Years of Photo-monitoring.

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INTRODUCTION

Cavers have often regarded the traditional show cave with some contempt, and seen the physical development of such a cave as damaging and counter to what conservation principles would demand. An opposite viewpoint has frequently been expressed, namely, that commercial development may be the most effective means of conservation, and this was enunciated formally over twenty years ago by Russ Gurnee (1971). There certainly are some occasions on which this has not been realised, and Gurnee (pers. comm.) now argues that the most damaged caves are often those which were developed as show caves, but then abandoned.

Another problem is that any one generation may well develop show caves according to the best understanding of the time, but that later knowledge, by which past actions are often judged, may well be very different. So, in Australia, most of our show caves were developed at about the turn of the century and according to a pattern established by the Wilsons of Jenolan. The aesthetic value of stalactites, stalagmites, columns and helictites was highly valued ; floors were not, even when covered in gours or pool crystal. Speleothems would be protected with wire netting which was tightly stretched over piping frames, and would be displayed to the public with appropriate lighting to maximise their attractiveness. Pathways would be concreted, and visitors only admitted under the supervision of a guide.

The result of this is that floor deposits were often damaged beyond reclamation ; where they were comprised of sediments, these were often removed with scant regard even for sub-fossil materials. Because there was virtually no recognition of the special character of cave climates, the extent to which karst systems were dependent upon hydrological integrity, or the significance of biota, these matters could not be considered. One fears that even to this day, many of these issues might not be properly dealt with ; the continued pouring of concrete into show caves is one example of continuing a tradition long after it has been widely recognised as dysfunctional.

Against this background, the purpose of this paper is to examine the extent to which the apparent aim of preserving the aesthetic quality of speleothems has been achieved in Australia.

THE BASELINE DATA

It has only recently been recognised that in most cases, we have excellent photographic data on the state of most Australian show caves either at the time of their discovery, or at least prior to their commercial development. The photographers concerned were not taking photographs for this purpose, but rather for various commercial motives - sale to the press for news purposes, printing and sale of postcards, or promotion of the new tourist facility. It is the photographic prints, often in the form of postcards, which provide the best access to most of these images today and a reference catalogue of postcards is currently being prepared by Trevor Shaw, Ross Ellis and myself. However, it is fair to say that some, like Charles Kerry of New South Wales also appeared to have been driven by both exploration recording and aesthetic considerations. Kerry's own writings and reported statements are quite explicit about the joys of caving and the aesthetic satisfaction of capturing a fine image (e.g., Anon., 1903).

In New South Wales, both Kerry and Trickett (Middleton 1991) were outstanding contributors to early photography. The two were close friends, with a number of common interests, and so Trickett, in his capacity as Superintendent of Caves, was able to ensure that Kerry photographed the new discoveries at Jenolan within days of the first (officially announced) discovery, and that these photographs were then made available to the press of the day for publicity. Thus, the first photographs of Mafeking, River, Skeleton (now Cerberus), Orient and Temple of Baal Caves at Jenolan show the caves in pristine condition, and are readily available. Kerry also entered the Yarrangobilly Caves at an early stage of their history and even claimed, wrongly, the discovery and first entry of the Jersey Cave. His 'false' claim may well be a result of being accompanied by the manager of Thomas Cook's Travel Agency and a Sydney journalist.

For the caves which were discovered earlier, the data is less reliable. Certainly a number of photographers were active at Jenolan, recording the arches and in particular, the Imperial and Lucas Caves. These include Paine (actually under commission from the N.S.W. Government), King, Rowe, Bayliss, Beavis and Cooke. However, in most cases there is no record of the dates of their visits to Jenolan and these visits generally occured long after the discovery of the caves concerned.

At Buchan, the first photographs by Harvey in 1889 were taken in Wilson's Cave and Dickson's Cave, when both were already well-known and far from pristine. The best data come from three later workers. Flynn ('of the Inland') photographed those caves which were known in 1906, but of these, only Kitson Cave was likely to be genuinely pristine, although most others had probably only been entered by a relatively small number of people. But Frank Moon's progressive exploration of the present show cave system was comprehensively recorded by Howard Bulmer within days of the first entry as Moon has a shrewd eye to publicity and each new discovery was widely reported, with photographs, in the Melbourne press. Moon actually tried to convince the then Lands and Survey Department that Bulmer should be granted a monopoly - but they wisely ignored his proposal. This meant that the ubiquitous George Rose photographed not only the present show cave system, but also Murrindal and Lilly Pilly Caves which Bulmer had not recorded (perhaps because their discovery and exploration was not by Moon !). Rose's work was in both monographic and stereographic forms, and is technically of a very high quality.

At Naracoorte, W.P. Francis (and a horde of others) photographed both Victoria and Alexandra Caves at the time of their discovery. Francis and others also photographed various stages of the development in Blanche Cave, while Rose and Davidge provide a record of the remarkable garden development surrounding the caves. In Western Australia, one of the first acts of the newly appointed Caves Board in 1901 was to have the South-western caves photographed by a Mr. Morison of the Lands Department. Although some time after first discovery, these images were at least contemporaneous with the commencement of commercial development and taken prior to extensive entry. Similarly in Tasmania, Stephen Spurling III photographed the Mole Creek Caves, particularly King Solomon, at a very early stage.

So, this provides a surprisingly extensive series of baseline data on the spelothems of Australian show caves. I have commenced a systematic review of the present status of the various scenes depicted, and can now provide a preliminary report on this work.

THE SHOW CAVES TODAY

The most important point to make is that overall, the spelothems of Australian show caves are in a remarkably good state of preservation. The Wilson strategy has served well and some remarkably beautiful and often fragile scenes remain to us as a result of their work.

However, although cave managers always express deep concern about damage being done by visitors, this rarely happens in caves developed soon after discovery and according to the Wilson model. One example can be depicted here : the destruction of a major shawl at Buchan. In this instance, the offender was successfully prosecuted. I am aware of other incidents e.g., at Wombeyan and Yallingup (Poulter 1987). There was also some damage at Naracoorte, although it appears that this was done during a period when visitors were allowed into the caves without a guide.

But, the major depredations are by managers or their agents. Some of this may well have involved a deliberate decision, e.g., in the Mafeking Cave or the Temple of Baal at Jenolan, where the compromise to improve access at the cost of some speleothem features was made. But the installation of electrical services using heavy piping at Buchan led to some accidental damage, but the fact that it was accidential does nothing to reduce either its disastrous impact upon the cave or the ultimate irresponsibility of the managers. Crassly planned and implemented redevelopment of the Victoria Cave, Naracoorte during the late 1960's destroyed whole scenes.

Another form of destruction of pristine caves was the enhancement of scenes by moving 'surplus' decoration to new locations. Examples occur in probably most show caves but I note as examples only the 'Twelve Apostles' at Buchan and the 'Shower' at Naracoorte. The latter scene has recently been restored to its original state by removal of the transplanted stalagmites and the artificial pool, but most other examples remain. This scene was also the location of the infamous 'fish in the pool', where toy celluloid had been fixed to the ceiling in such a position that their reflection would be seen in the pool but that was taken out many years ago.

There are numerous examples which show the much worse fate of caves which are not placed under the show cave management regime, but left to the good will of cavers. The Chevalier Cave at Jenolan, Honeycomb Cave at Murrindal are conspicuous failures, while even such glorious places as Mullamullang and Kubla Khan are well on the road to disaster.

DISCUSSION AND CONCLUSION

Although the focus of earlier managers upon the aesthetic quality of speleothems is, to us, a very constrained view of what good cave preservation might involve, there is no question that many managers have achieved excellent results in this. As Andy Spate and myself (1992) have argued elsewhere, cavers have (probably inevitably) been far less successful in their stewardship of caves.

At present, however, we face a very different set of challenges to those dealt with by the Wilsons and their followers. We know a great deal more about the cave environment, and at least some managers are successfully dealing with much more complex issues than the beauty of speleothems. But, managers are still using far too much concrete in caves ; cavers are still far from adopting even a skeletal low impact ethos ; commercial 'wild' tours are adding to the despoliation virtually unchecked. Worst of all, most cavers find the idea that a specific cave might be placed 'off limits', or that it might even be sealed up to make further entry impossible, to be totally unacceptable. Yet none offer effective alternatives which will prevent the gradual degradation of new discoveries. I sympathise with the position that people should not be excluded, but short of massive changes in the ethos of recreation or tough action by much better resourced management agencies than we currently have, I see no solution to the problem.

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Impacts of caver groups in Tasmania.

Deborah Hunter and Michael Lichon
Mole Creek Caving Club

The impact of traditional and recent caving club activities are familiar to most ASF cavers, yet many of the problems continue to evade universally acceptable solutions. As is appreciated there are various types of caving club in Australia with different aims and standards of ethics. The ASF is in the midst of further encouraging certain standards through accreditation of club leadership schemes.

Casual inexperienced visitation to caves has always been a problem at Mole Creek since settlement. There has been a small increase recently, largely due to unled revisiting members of "outdoor experience" groups (see next section). Thankfully most occur at readily accessible sites such as Wet, and do not venture very far into the darkness. It is common for MCCC members to retrieve rubbish (beer cans etc) from the first 100 m of this cave. Some more malicious visitors pilfer speleothems and/or engage in vandalism. The management response to this type of visitor has been to lock well-known decorated caves, suppress locations of other caves, and leave one or two "sacrifice" caves for unfettered use of the yobbos. The club response is to encourage anyone who wishes to go caving "into the fold".

The main purpose of this discussion is to draw attention to other high impact groups that have appeared in the last decade or so.

The most alarming type of group is the emergence of Outdoor Recreation, Youth Clubs, and School groups onto the caving scene. Most of these "outdoor experience" group organisers are actively promoting caving as a sporting pursuit for (often immature) novices without addressing issues of ethics and conservation. These groups are automatically insured for all outdoor activities undertaken. These groups are taken by "professional" guides (in that they are paid), often with little grounding in caving and safety, much less in ethics and conservation. Recent experiences at Mole Creek suggest these groups are of very high risk to the caves and to themselves. Increased occurrence of poorly controlled groups has been noted in both Honeycomb and Wet. Some of these groups have been known to penetrate deeper, take the wrong route, tracking mud into Georgies Hall and then emerge at the top entrance, then to trespass across the land of a hostile landowner to get back to their cars (and buses). Within the last two years similar groups have wreaked havoc in the highly decorated, previously intact My Cave; throwing and trampling mud, trampling and breaking decorations, and entering during times of high flood danger. It is small wonder that Tasmania's only caving disaster occurred with this type of group, vis Mystery Creek. Members of "outdoor experience" groups are well known to surrupticiously return to the caves with their friends and wreak even more damage to the caves and risk to themselves. The organisers (policy makers, headmasters, scout commissioners etc) of these activities need to be rigorously educated (by ASF in particular) as to why they should curb recreational activities in the non-renewable cave environment. It is clearly unethical to encourage the attentions of otherwise uninterested youths towards caves, particularly in large numbers. At present Tasmanian authorities are attempting to address issues of leadership of these groups through an accreditation scheme. This process has failed adequately deal with the need for ethics and conservation, rather it concentrates on the ability to safely process large numbers of novices through caves. It also assumes access. Such groups are presently allowed unfettered access to all but locked caves. Clearly, Tasmania urgently needs to see this situation reversed, to see stringent access and licence controls brought onto what is evidently the highest risk type of group entering caves.

Commercial operators, on the other hand are mostly under far greater scrutiny. There are two variants of two types of operations: the variables being whether they are licensed or not, and whether they provide clients with experiences based on adventure, or on education about karst and ecology. Unlicensed operators are (in essence) similar to those described above, with no restrictions on access, safety, ethics or conservation, they are also unlikely to have insurance, and therefore are unlikely to attract a large clientele. Adventure providers may suffer access and safety restrictions as a result of licence conditions or insurance constraints. They may attract large numbers of clients, while lacking ethics and conservation background. The licensed karst and ecology education provider is insured, restricted in access and safety, and operate accordingly with ethics and conservation (by virtue of the experiential aims), and is likely to present less impact than the average caving club group. While rejecting the accreditation approach that Tas authorities are attempting to impose, commercial operators develop operations manuals which are subject to licence renewal and insurer scrutiny. It can be seen that there are different types of commercial operators, with impacts likely to be inversely commensurate with their restrictions and experiential aims.

One significant, though less frequent, type of high-impact party worthy of comment in Tasmania is the helicopter-lifted/heavy-weight/Himalayan siege-style expedition to remote, pristine locations within the World Heritage wilderness. The stated reasons for such adventures include exploration and scientific study. The 1980s saw attention focussed on Mt Anne, culminating in the 1987 Australian Geographic - sponsored trip of enormous size and duration. The legacy of tonnes of equipment and extended base camping has been devastation of the fragile alpine ecosystem, minefields of toilet and other waste, littering of dolines with spent caving equipment and so on in what is one of the last few pristine corners of the world. Despite explicit contraindication by the World Heritage area's new draft management plan, Departmental approval was forthcoming to a similar expedition to the much more remote and untouched Vanishing Falls area in April 1992. It was only fortuitous for the environment the party number ended up much smaller than intended. While these parties are often based on highly experiences cavers, there are often included visitors of other disciplines. These parties are seldom motivated by environmental and ethical concerns, rather more by thirst for adventure and personal glory. If cavers find themselves unable to enter and leave such a pristine, precious part of the planet by their own personal endurance and present no discernible impact to the area; ethically they should look to other places for their egotistic fulfilment.

Not unrelated are the biological surveys performed in Tasmanian caves in the last 20 years. Caves are extremely low energy environments, and support rather tenuous ecologies with very small spatial distributions. While the principle of learning about cave ecology is sound, in practice the commonplace sampling (and preservation in alcohol) of up to 12 individuals of a given species from such restricted enclosed distributions is deplorable. This rate of removal often represents a significantly large proportion of the entire genetic population of such species, is totally unjustified and ethically unsound. Extinction may easily result from the remaining genetically unviable population.

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Geomorphology of the South-East Karst Province of South Australia.

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SUMMARY

The South-East Karst Province of South Australia is an extensive area of low relief with dolines, cenotes, uvalas and a variety of cave types developed partly in the soft, porous, flat-lying Tertiary (Miocene) Gambier Limestone, and partly as syngenetic karst in the overlying calcarenite dunes of the Pleistocene Bridgewater Formation. Shallow swampy dolines and subjacent and covered karst depressions occur in superficial Quaternary sediments.

Systematic variations within the province reflect differences in the parent rock types, the extent and nature of the cover and most importantly the hydrology - in particular the depth to the water table and its gradient.

INTRODUCTION

The South-East Karst Province of South Australia (Figure 1) includes the official ASF Lower and Upper South-east cave regions of South Australia (5L & 5U series cave numbers). It also extends a short distance into Victoria (ASF Area codes 3G, 3CR, 3DD, 3KB, 3BR & 3P). The bulk of the caves and karst features are limited to the area south from Naracoorte and east of Millicent.

There have been few comprehensive karst studies of the area - most notable is the regional study by Marker (1975) along with the early summary in Sexton (1965), and the later honours thesis study of the Lower South-east by Lewis (1984). Thurgate (1986, 1992) described some selected caves & cenotes in the Lower South-East. Peter Horne has privately published several reports on studies of caves and cenotes by the cave diving groups (eg. Horne 1988a,b). Geological and geomorphological studies of relevance to the karst include those of Cook & others (1977), Schwebel (1983), Sprigg (1952), Twidale & others (1983) and Wopfner & Douglas (1971). Wells & Pledge (1983) review the fossil deposits of the caves. The hydrology of the region is discussed by Holmes & Waterhouse (1983), and Waterhouse (1977).

The present study is being done by ACKMA for the South Australian National Parks & Wildlife Service and involves an inventory of karst features on Crown land in the south-east of the state. This paper is an abbreviated preliminary version of the geomorphological part of the report that will be presented to the SA NPWS.

GEOLOGY OF THE PROVINCE

The South-East Karst Province lies on the Gambier Embayment in the north-western part of the Cretaceous to Tertiary Otway Basin (Wopfner & Douglas, 1971). The karst is developed on the Tertiary marine Gambier Limestone, on the younger Pleistocene calcareous dune limestones (Bridgewater Formation) and also on calcareous marine and coastal plain sediments of the inter-dune flats

(Figure 1). Its development is locally influenced by the thin younger sediments that partly cover the limestones. The topography is mostly low and flat, with local relief provided by the dune ridges, the volcanic hills and the gorge of the Glenelg River in the extreme south-east.

The *Gambier Limestone* was deposited in a shallow sea that flooded the region in the Oligocene and early Miocene. It is mainly composed of soft, massive to well bedded (sub-horizontal), bryozoan limestones (Waterhouse, 1977; Wopfner & Douglas, 1971). The unit varies in thickness from 300 m at the coast to less than 100 m at Naracoorte, but is reduced to nothing in a few areas near Dismal Swamp where it has been uplifted and eroded above the Tarpeena-Dartmoor Upwarp (Figure 3). The limestone is poorly consolidated in the subsurface but develops case hardening and calcrete cappings on exposure. It is locally well jointed with a dominant north-west trend. The influence of both the jointing and the bedding are exhibited in the cave passage forms.

The *Bridgewater Formation* is a series of calcareous sand ridges that represent the coastal dunes of old shorelines that developed during an overall regression of the sea during the Quaternary (Schwebel, 1983). They form linear north-west trending ranges that rise up to 30 m above the adjoining plains. However there are higher piles of dune sands in the Mount Burr area where dunes have climbed up the sides of older volcanos, and to the south-east of Mount Gambier where several dune ridges have coalesced. Within the study area the innermost, and oldest, ridge is the East Naracoorte Range, where the dunes have piled up on a pre-existing coastal scarp (The Kanawinka Scarp) cut into the Gambier Limestone (Figure 1). This has been dated at about 700 000 years old, and the ridges, and associated karst features, become progressively younger towards the modern coast (Cook & others, 1977; Idnurm & Cook, 1980).

These ridges are now partly consolidated calcarenites and contain syngenetic karst features in which caves and solution pipes developed as the sands were being cemented into a limestone (Jennings, 1968). Subjacent karst occurs where the Bridgewater Formation overlies the Gambier Limestone and there are a number of caves that have their entrances in Bridgewater Formation but their main underground extent in Gambier Limestone. The Bridgewater Formation has well developed dune forset bedding in places, and shallow angle medium to thin bedding elsewhere. It shows only minor jointing.

Between the lines of dune ridges there are extensive swampy plains. These are old coastal flats and comprise estuarine to lacustrine marls and clays up to 13 m thick. Some shelly beds occur near the present coast. In the Bool Region the inter-dune flats have been covered in places by thin Pleistocene and Holocene alluvial deposits and aeolian sand sheets of several ages.

Quaternary volcanics in the area are the western end of the Newer Volcanics of Victoria (Sheard, 1983). The main area of volcanics is centred on Mount Burr and ranges from about 2 million years to 20 000 years old. The isolated volcanos at Mount Gambier and Mount Schank are younger (4 000 to 9 000 years old).

HYDROLOGY

Natural surface drainage is absent over much of the province. Exceptions are in the far south-east where the Glenelg River, a major stream rising outside the province, has cut a gorge through the limestones; and in the north where several creeks in the Naracoorte area have maintained their surface flow across the Naracoorte Plateau.

The Gambier Limestone forms the main aquifer in the area. This has been referred to as one of the best aquifers in Australia. The porous nature of the Gambier Limestone means that much of the groundwater flow is via the primary porosity rather than in channels or fractures, and there is a well defined watertable. The gradient on the water table shows two steep zones and one major divide within an overall slope towards the coast (Figure 2). The groundwater divide in the Dismal Swamp area is caused by thin and relatively less permeable aquifers in that area. The water from further north is diverted further to the west.

Much of the groundwater from the Mount Gambier area is discharged in major springs in the Piccaninnie Ponds and Eight Mile Creek areas on the southern coast, and to lesser springs in the Kongorong area. Clisby (1972) reports a total flow of 5.2 cumecs (5200 l/s) from the coastal springs south of Mount Gambier. Marker (1975) shows a line of springs in the Millicent area, but the resurgence points further west are not well documented.

Marker (1975) considered that the nature of the groundwater regime is the most important control on the character and extent of karst development in the province. She correlated areas of strong cave development with firstly the areas where the watertable was at greater than normal depth, and secondly with areas having steep water table gradients. The areas of deep watertables would have enhanced vertical infiltration and therefore surface percolation which would promote solution. These areas are the Naracoorte Plateau and the Gambier Region both of which have high densities of caves. The steep gradient zones would indicate rapid water flow through the rock which will enhance the solutional enlargement of cavities. In contrast the areas of low and reversed gradients will have relatively sluggish flows and solution will be less effective. The northern steep gradient zone corresponds to the line of the Kanawinka Fault and the edge of the Naracoorte Plateau. This is also a zone of major cave development (Figure 2). The southern steep gradient zone passes north-west through Mount Gambier and is partly the result of the steep rise in the base of the Gambier Limestone which thins over this area (Figure 3) and partly due to permeability changes within it (Waterhouse, 1977; Holmes & Waterhouse, 1983). This zone also has a significant concentration of caves (Figure 2).

During glacial periods the lowering of sea levels would have caused the coast to retreat across the continental shelf. This would have caused a significant drop in the groundwater levels in the Coastal and Schank Regions - as shown by submerged speleothems in some caves (Figure 3). The reduced water table and extension of the steep gradient zone in the northern Schank Region during glacial periods may have been responsible for the concentration of cenotes and underlying large cavities in that area (Lewis, 1984). Reduced sea levels would have had less effect in the Gambier Region and the regions further inland where the distance from the coast would have reduced the sea level effect. In the Gambier Region the local geology, in particular the high levels of the inpermiable bed at the base of the Gambier Limestone, would have been the main factor that determined the glacial water levels (Figure 3).

CLIMATE

The climate of the region is a Mediterranean one (**Csb** in the Koppen system) with wet winters and cool dry summers. The annual rainfall decreases from 800 mm in the south to 550 mm in the Naracoorte area (Penney, 1983). Mean annual temperatures range from 14.4°C at Naracoorte to 13.2°C at Mount Gambier.

During the Quaternary the present conditions would have alternated with colder, drier and windier climates during the peaks of the glacial stages (Colhoun, 1991). Much of the area would have been flooded by the sea during the interglacial periods of the early Quaternary.

KARST LANDFORMS

Karst landforms comprise the caves, and a suite of surface features that have resulted directly or indirectly from solution of the limestones. Marker (1975) recognised seven regions within the South-East Karst Province. I have adopted most of her subdivisions, but with some changes (Figure 1).

Syngenetic karst

Syngenetic karst (Jennings, 1968) is an important feature of the province. In the calcareous dunes of the Bridgewater Formation some karst features have developed at the same time as the sand was being consolidated into a calcarenite. The main characteristics of syngenetic karst are the development of a calcreted caprock, of vertical solution pipes, and of low, wide, horizontal cave systems at the level of the adjoining swampy plains. The poorly consolidated nature of the rock means that collapse plays a very important role from an early stage. Solutional, subsidence and collapse dolines can occur on the surface, but the former two can be difficult to distinguish from primary dune hollows.

Typical syngenetic **cave** forms are shallow horizontal systems developed beneath the caprock. They have multiple entrances (often via solution pipes or the collapse of the surface crust) and an irregular outline of chambers, pillars and short connecting passages, generally with a roof height less than one metre throughout. Horizontal systems also occur at the levels of the adjoining swamps and are controlled by a water table. These are also low irregular systems, but tend to have thicker roofs and may have multiple levels, tied to older water tables. Most syngenetic caves show extensive instability and collapse domes and rubble filled passages are common.

Solution pipes are vertical cylindrical tubes, typically 0.5 to 1 m in diameter, which can penetrate anything from less than a metre to 20 metres into the soft limestone. They occur as isolated features, or in clusters with spacings as close as a metre or so. They commonly have a cemented rim that is harder than the surrounding rock, and they may be empty, or filled with a reddish soil. In some, the soil fill has been cemented to form a solid plug. Jennings (1968) postulated that the pipes formed around tree roots penetrating the soft calcareous sand, and that they contributed to the consolidation of the dune.

Syngenetic karst development is typical of the Quaternary dune calcarenites; however, the Gambier Limestone is a relatively soft porous limestone, and consequently it also shows some of the features of syngenetic karst, in particular the development of solution pipes and calcreted caprocks.

Caves

The caves in the South-east Karst Province are dominantly phreatic in origin. The limited relief means that vadose features are extremely rare though some vadose streams occur in the caves of the Glenelg River gorge in Victoria. Both joint and bedding plane control can be seen, but solution at temporary water-table levels can make the latter hard to recognise in this area of flat bedded limestone. Many of the primary phreatic caverns and passages have been modified by breakdown to form collapse domes and rubble filled passages. Cave diving has demonstrated the existence of extensive underwater cave systems, and it appears that in the southern part of the province the bulk of the cave development may be below the present water table, though these passages would have been partly or wholly drained during the low sea levels of the last glacial period.

Speleothems comprise most of the common calcite types, including some black formations in the Naracoorte area. Soft deposits of moonmilk (lublinite) are a common feature in many of the caves.

Bone deposits of Quaternary age have been found in a number of caves (Wells & Pledge, 1983). The most important, and world famous, deposit is in the Victoria Fossil Cave (U-1) at Naracoorte, but other significant finds have been in Henschke Bone Cave (U-91, Pledge, 1990), Tantanoola Tourist Cave (L-12, Pledge, 1980) and underwater in Fossil Cave (L-81, Horne, 1988a; Pledge, 1980).

Dolines

The most spectacular surface karst features are the **collapse dolines**, especially those that extend below the water table to form **cenotes**. These have formed above large phreatic caverns.

The term **cenote** has been used fairly broadly in the south-east to include not only collapse dolines that extend below the water table, but also dry collapse dolines that have water in associated caves, or mainly submerged caves with entrances that are not strictly collapse dolines. Part of the nomenclature problem comes from the emphasis by the cave divers on the presence of deep water in any situation, and partly from Marker's (1975, 1976) use of 'cenote' as a synonym for any collapse doline with sheer walls, regardless of the presence of water. I will follow the usages of Monroe (1970) and Jennings (1985, p 111) who restrict the term cenote to collapse dolines which contain a watertable lake. Goulden Hole (Figure 4) is a typical cenote that has been mapped and described in detail (Horne, 1988b, Thurgate, 1990). An interesting feature of some of the cenotes is the existence of stromatolites: underwater calcareous growths formed by algae (Thurgate, 1990).

Many **small shallow hollows** occur throughout the province, but are particularly common in the Bool, Nangwarry and parts of the Naracoorte Regions. There are several types of these small hollows, and a range of gradations occurs between them.

The first type of hollow has a saucer to basin shape, and may even be funnel shaped in some extreme cases. These are typically much less than 100 m across, and from 1 to 3 m deep, though they can reach depths of 8 m and some extreme cases have widths up to 300 m. They appear to be mainly subsidence dolines in either soft soil or superficial sediments over buried karst cavities in limestone, though where the cover is thin some might be simple solutional dolines. They may be dry or contain small intermittent waterholes. In some a small 'runaway hole' is seen at the base where the surface runoff has been soaking into the porous soil. These were referred to as 'funnel dolines' by Marker (1975).

A second type consists of shallow flat-floored hollows which Marker called 'swamp dolines'. These are typically less than a metre or two deep and can be from 50 to over 500 m across. They are generally swampy and may have seasonal lakes. The shallow swampy form is probably due to a restriction on vertical development as a consequence of a shallow water table or the thin limestone beds in which they have formed. Where they occur in association with deeper basinal dolines this could indicate a local perched water table. Not all of these swamps are necessarily karst features, some may be primary hollows in alluvial or coastal deposits, or shallow deflation hollows.

A third type are the shallow lakes with lunettes seen in the Bool Region. These are a larger variant of the flat floored swampy hollows. They may not be karst features, but rather primary coastal lagoons that have been modified by waves and the wind since the sea withdrew from the flats.

Uvalas

Uvalas are composite hollows. They are most common in the Naracoorte Plateau, the Nangwarry Region and the Gambier Region. They have formed in part by the coalescence of simple solution or subsidence dolines, in part as chains of hollows along old dry valleys and in part by the karst modification of primary dune hollows.

Dry Valleys

In the Naracoorte Plateau, and in the south-eastern end of the Gambier region there are old surface drainage lines that have been abandoned as a result of underground capture of their flow. Most are just chains of dolines and uvalas, and are not immediately obvious; however there are two better examples. The first, in the Naracoorte Plateau, is a meandering valley that cuts through the East Naracoorte range near Jerboa, east of Struan. The second is Dry Creek near the Glenelg River, in the Gambier Region, which is a well preserved incised meandering valley which now has no surface drainage and a number of shallow closures along its floor.

Quasi-karst forms

Primary **dune hollows** occur in the high dunes - these are not true karst, but may have had some modification by karst processes. All sizes and depths occur up to a maximum length of several kilometres, and depths of 15 m or more. They are typically smoothly rounded basins or closed valleys, but where the base of the dunefield has been limited by a water table they may have flat swampy floors.

Areas of **'hummocky'** terrain occur in several places in the Mount Gambier Region. These areas consist of an irregular to elongated pattern of rounded hills separated by basin shaped hollows. The larger hummocks, in the immediate vicinity of Mount Gambier, have a vertical relief ranging from 10 to 25 m and a 'wavelength' of between 300 and 700 m. The hollows are nearly always dry - indicating a well developed underground drainage. This terrain seems to be a primary dune topography that has been modified by karst processes, as the bases of the hollows commonly extend well below the contact between the old calcareous dunes and the underlying limestones of the Gambier Formation. The hummocks are gradational to a true high dune topography, as in the Gambier Forest, and also into true karst dolines and uvalas, as in the Wandilo area north-west of Mount Gambier.

CONTROLS ON KARST DEVELOPMENT

Marker(1975) referred to the South East Karst Province as a doline and uvala karst region with dominantly covered karst. Marker (1975) discussed the possible controls on the overall distribution and nature of the karst features within the province. She considered the effects of variations in climate, vegetation, lithology, topography, overburden (thickness and character), and hydrology. She concluded that the main control on variations in karst character within the province was the hydrology: in particular the depth to the water table and the water table gradient. Other factors that have had local control are the topography, the nature and thickness of the cover, and the nature and structure of the parent rocks, in particular the degree of joint control. There is also a possible effect from carbon dioxide derived from the volcanic activity (Lewis, 1984).

The depth to the watertable controls the amount of free vertical drainage. The areas of best cave and surface karst development are all areas of relatively deep watertables: the Naracoorte, Gambier and Glencoe Regions at present, and the Schank and Coast Regions during the glacial stages. The two belts of steep watertable gradient may also be significant as they would have accentuated water movement and thus promoted solution; these belts also correlate with areas of high cave density (Figure 2). The southern steep gradient zone would have been more extensive during the reduced sea levels of the glacial periods, and may have been partly responsible for the high density of cenotes and associated caves in the Schank region.

The topography in the province is mostly low and flat, with local relief provided by the dune ridges and the volcanic hills. Only in the gorge of the Glenelg River in the extreme south-east is there sufficient relief to allow the development of vadose streams.

Most of the karst is covered, but some areas of bare karst occur in the Schank Region. The cover is of Quaternary age and consists of partly calcareous coastal swamp and lagoonal deposits, quartzose and calcareous sand dunes and aeolian sand sheets and minor alluvial flats. Thicknesses can be up to 30 m. Thick cover can have an inhibiting effect on surface karst and thick soil cover can clog any potential cave entrances.

The karst features of the province are typified by development on relatively soft and porous parent rocks. Most of the caves and large collapse dolines are developed in the Gambier Limestone but some are partly or wholly developed in the Bridgewater Formation and these are of syngenetic type. Joints in the Gambier Formation provide strong control on the orientation and character of many caves in the southern part of the province, but joint control is less obvious in the Gambier Limestone in the north and almost absent in caves in the dune calcarenites of the Bridgewater Formation. The Tartwarp fault has a line of elongated dolines and uvalas developed along it. Dolines in the flat parts of the Bool Region and in the Nangwarry Region may be developed on thin limestones equivalent to the Whalers Bluff Formation.

Lewis (1984) refers to the reserves of carbon dioxide gas found at depths between 2500 and 2800 m during oil exploration (Wopfner & Thornton, 1971) and suggests that there could be movement of this gas along fractures into the karst aquifer. Wopfner & Thornton (1971) attribute the carbon dioxide to the volcanic activity in the area and Lewis notes the proximity of the cluster of dolines and cenotes in the Barnoolut area to the Mount Schank volcano and points out that the existence of lineaments in the area might indicate geological fractures. He therefore suggests that the movement of the gas into the groundwater may have been responsible for the increased solution in the area. This is an interesting hypothesis but the argument is rather tenuous, and there are other explanations for this area of enhanced karst development such as the reduced and steeper watertables during the glacial periods.

There are some similarities with the Nullarbor Karst Region (also developed on extensive, soft, flat-lying, Tertiary limestone) but the climate is wetter (at present) and the watertable variations, the younger dune ridges and the surficial sediments provide additional complications not seen on the Nullarbor.

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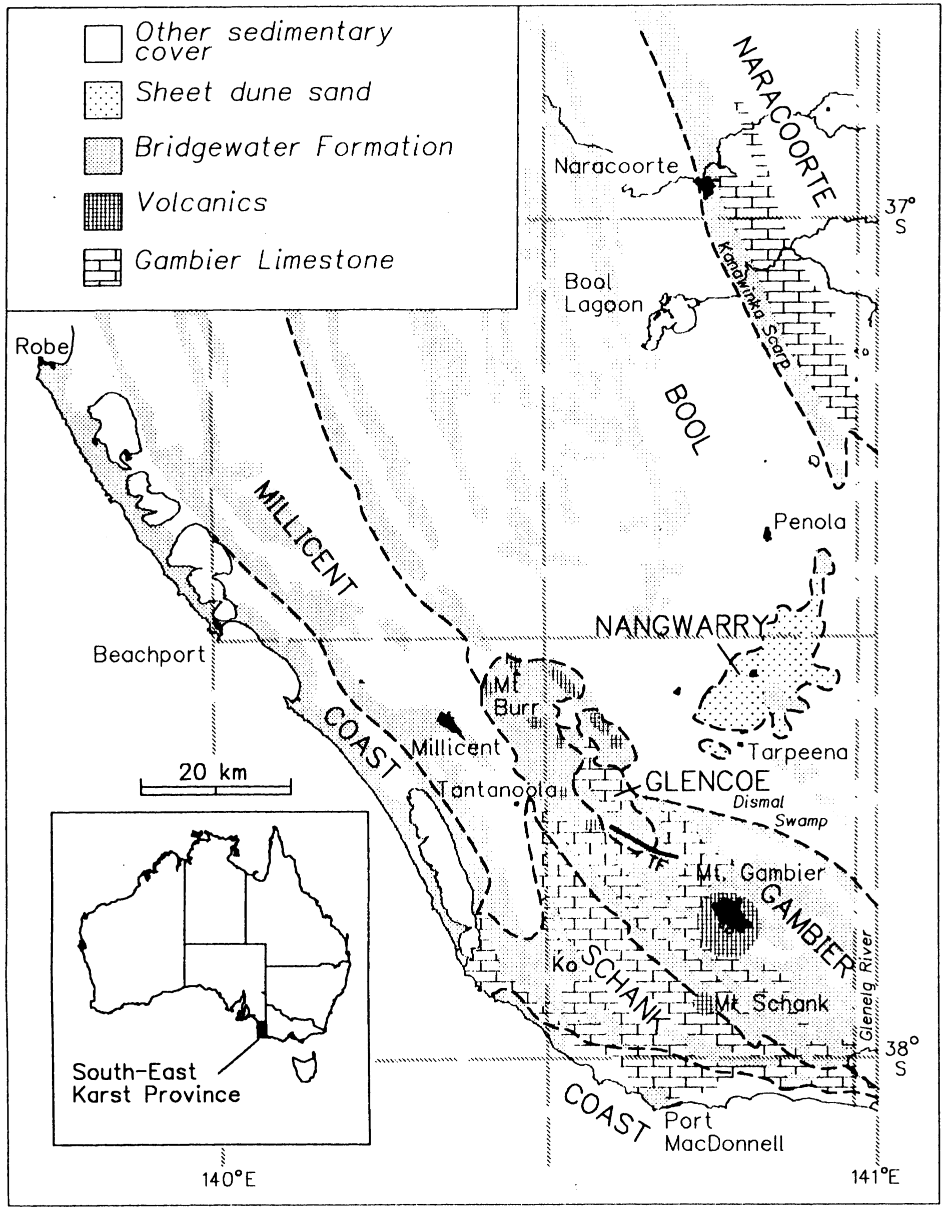

Figure 1: South-east Karst Province, Regions and Geology
TF = Tartwarp Fault. Ko = Kongerong.

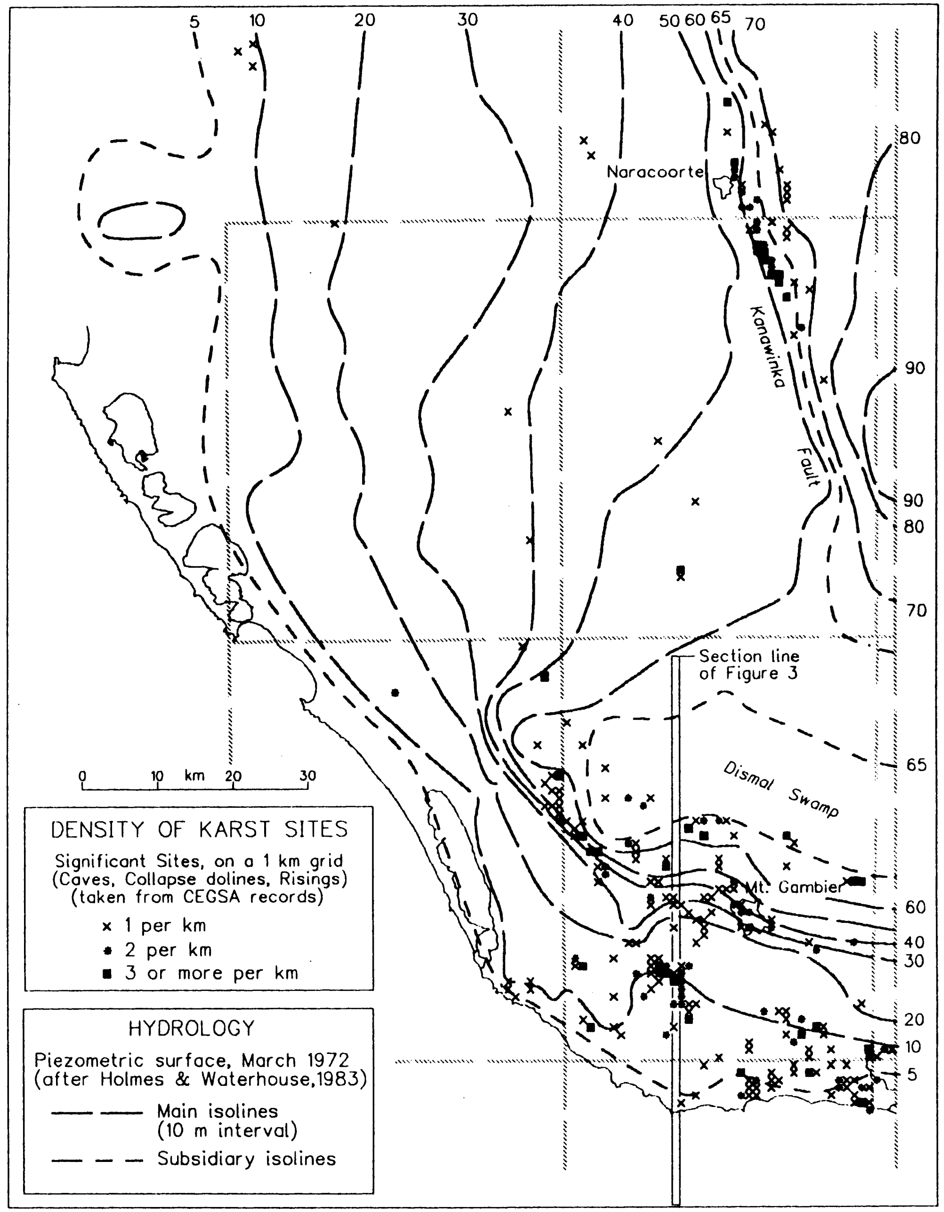

Figure 2: Hydrology and Distribution of significant karst sites

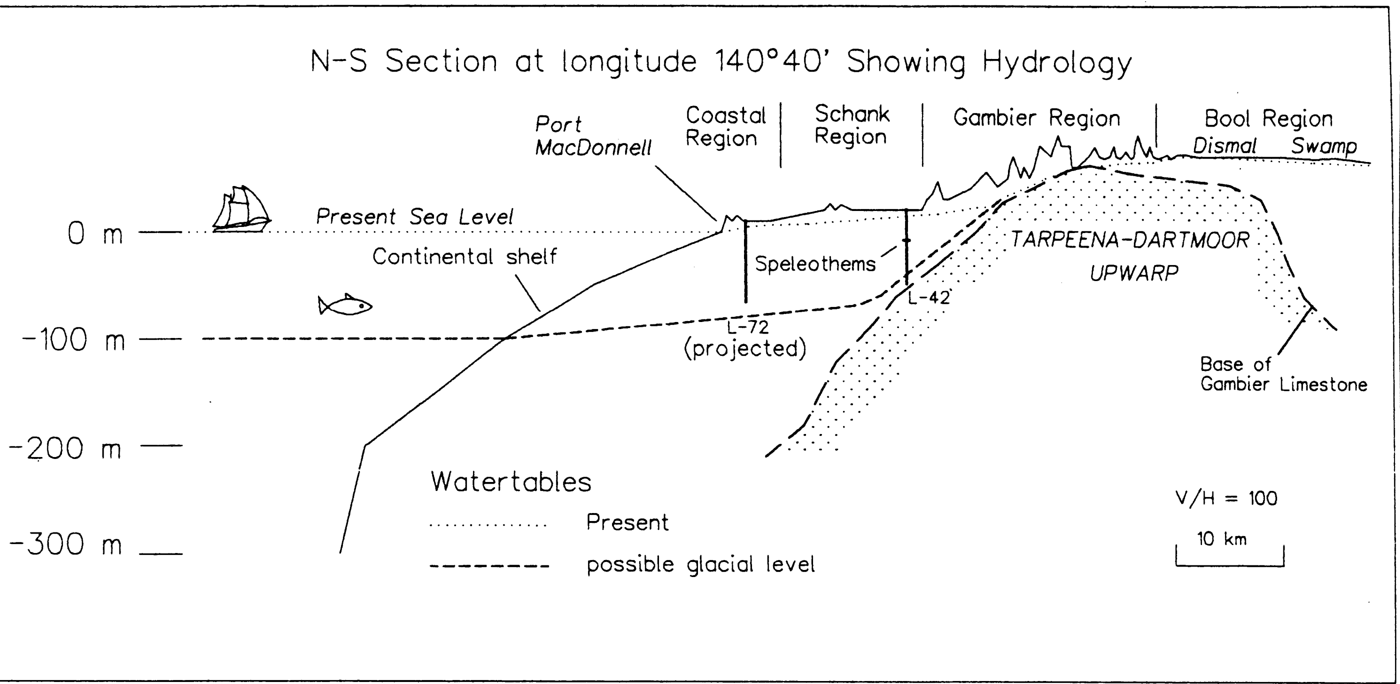

Figure 3: Cross section showing present water table, and possible glacial water table in the Mount Gambier area.

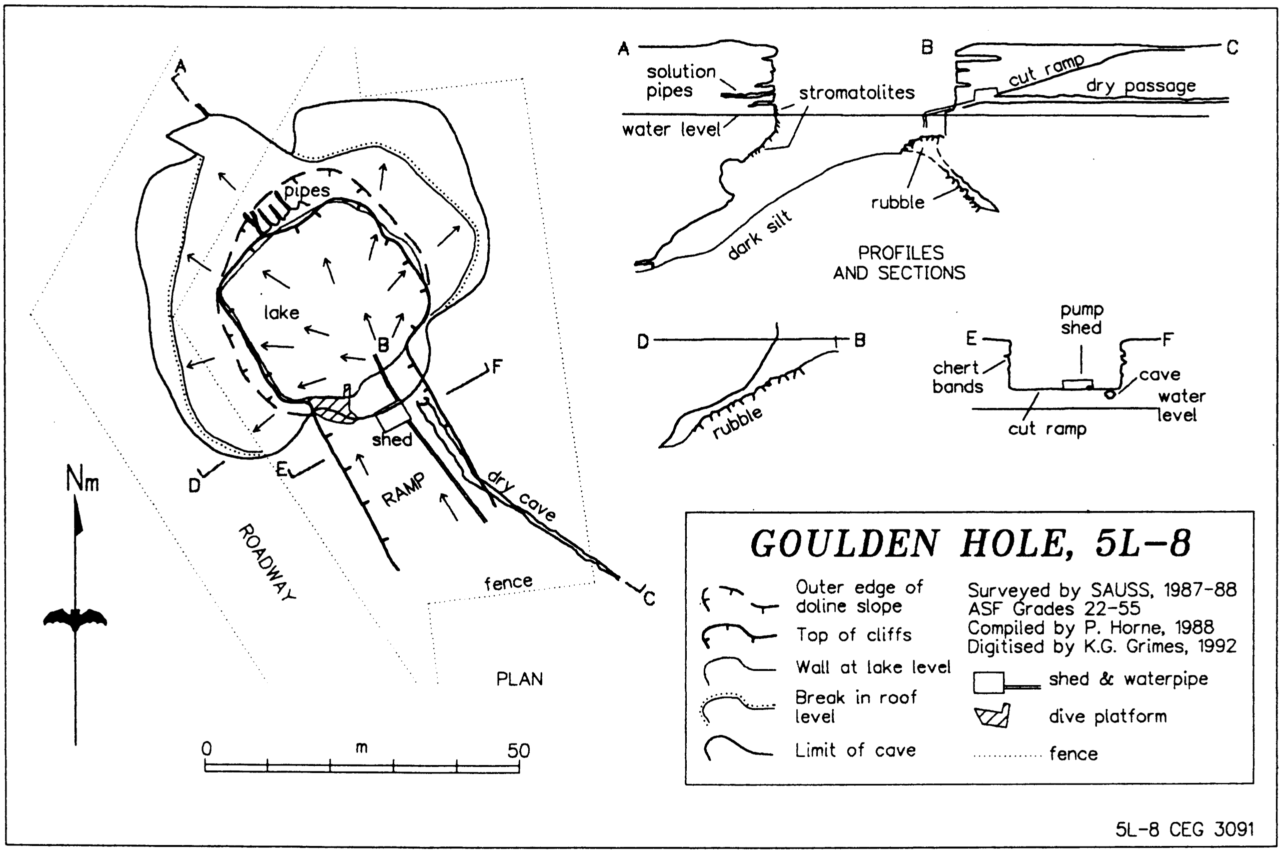

Figure 4: Goulden Hole (L-8), a typical cenote in the Schank Region.

The Benders Quarry saga, an update.

Michael Lichon
Mole Creek Caving Club

Pre-September 1992 chronology of the Exit Cave saga, and discussion of mining of Mole Creek karst is described in the reference.

Mid September saw the removal of loose and crushed material from the quarry floor despite Ros Kelly's closure on Aug 20. A Huon pro-mining lobby is set up at a public meeting including three State Cabinet ministers and the Tas president of the Liberal party. Later in the month Ros Kelly quietly gives Bender the nod to blast another 25000 tonnes. Through the night of the 28th a band of Wilderness Society volunteers filled the drill holes with rubble, thus foiling the blast. On the 30th Ros Kelly decides to stop blasting again, but allowed further active mining by "mechanical means". Thus continuing disturbances at the site resulted in further clay mobilisation into the cave system directly below. Both Governments still in the mindset of eventual relocation to a highly cavernous site near Maydena; the state Mines department spent huge sums proving up this deposit gratis and exclusively for Bender.

October 2, the mining resumed, creating more siltation problems. The next day a 70 year old sawmiller is assaulted by pro-mining blockaders, "protecting" the quarrying operations. Raising the profile of the main customer of the World Heritage limestone, a peaceful protest was held the following week at the EZ gates. The two infiltrator protesters were arrested at EZ for stopping the delivery of limestone by chaining themselves to the lime hopper. Thus the alternative sources of industrial limestone were publicised. The owner of the Glenorchy quarry was persuaded to speak to the 7:30 Report advertising that he could supply all of the agricultural lime requirements of the Huon. It was publicly shown that no market was dependent on Benders supply. 3000 tonnes of the Exit karst system was removed in this month. Federal/State talks broke down over funding and Ros Kelly again announced closure of the quarry on the 30th.

The start of December saw disgruntled quarry workers, still waiting for Bender to pay them out, reveal that Bender had for the last 20 years been using the lower parts of the quarry as a refuse site for industrial waste from his Hobart-based engineering workshops. In doing so he avoided paying municipal refuse charges by backloading lime trucks on the way back from EZ. The waste includes drums of sump oil, filters, rags, machinery etc, and has been hastily buried at the lower parts of the quarry. No strategy has yet been devised to effectively deal with the problem. The State minister washed his hands of it and says it is better not to disturb the waste. He is also reluctant to prosecute against the environmental breach.

The rehabilitation plan is still only in draft form, and Ros Kelly is not implementing it, on the grounds of funding wrangling with the state; rather, waiting for the next election.... Hewson? (shudder!)

In the meantime Mole Creek is under extra pressure, now supplying the EZ requirements as an additional market, and the prospect of cavers having to defend the internationally significant Dogs Head Hill karst against mining looms ever larger.

Reference:

M.Lichon 1992, Recent history & issues surrounding the saving of Exit Cave, and future options, *Illuminations 1*, 17-22.

THE UNTAMED RIVER EXPEDITION TO PAPUA NEW GUINEA

Paper presented at the 19th Biennial A.S.F. Conference "TASTROG 93" Launceston, 4th - 7th January, 1993

Steve Dickinson

Whilst some of the caves in the more accessible areas of Papua New Guinea have been explored since the 1930's, it is only comparatively recently that major expeditions have turned their attentions to the country. Papua New Guinea is a very difficult country to organise any expedition to; even the simplest caving trip can be a nightmare of logistics as there are very few areas in the country which are accessible due to the lack of a basic infrastructure of roads; the total lack of railways; and the generally limited development of the country.

It was in the 1970's and 80's that major International expeditions turned their attentions to the tremendous potential that exists in Papua New Guinea, with perhaps the most spectacular successes being achieved by Australian expeditions in the Southern Highlands with the discovery of Atea Kananda and Mamo Kananda. Certainly the Southern Highlands area still possesses a lot of potential for further major cave exploration. In addition there are several other areas of interest on the mainland, particularly the West Sepik Telefomin area explored by the British in 1975.

If one looks at the New Guinea islands of New Ireland, Bougainville and New Britain, the story is very different, with only limited caves being discovered up until the early 1970's. On New Ireland the Lelet Plateau exhibited quite a great deal of potential but was very disappointing when Australian expeditions spent some time exploring there.

On Bougainville there is a very noticeable Karst feature, The Sinkhole, and many smaller caves having been explored by expatriates working for Bougainville Copper and other companies on the island; however, again, no major development has yet been discovered and probably does not exist.

New Britain is the largest off-shore island of Papua New Guinea being 600 kilometres long and approximately 80 kilometres wide. The main mountain ranges are the Nakanai Mountains and the Whiteman Mountains, with some other small areas of Karst Limestone in addition to the major development in those two ranges. The Nakanai Mountains became known in the early 1970's when Mike Bourke and others discovered the huge, collapsed dolines of Nare, Minye, Kavakuna, Ora amongst others.

These shafts generally exhibit huge Karst features with major collapses into dolines usually in association with very large underground rivers. the Nare Cave is particularly spectacular, being a 340 metres shaft, 150 metres across, like a cylinder that has been punched down through the tropical jungle. In 1978 and 1980 two very successful French expeditions managed to explore the Kavakuna doline; partially explore the Nare, and descend the Minye shaft, but were repulsed by big rivers in each case. In particular a comment made by the French leader, that the river in the Nare was "untamable", led to the naming of *The Untamed River Expedition.*

The tremendous caving challenges of these huge holes was seen by Mike Boon, a well known British caver who now resides in Canada; who, along with Dave Gill, decided to mount an expedition to explore the Nare, the Untamed River. A team of twelve people was assembled in England consisting partly of experienced cavers to be involved in the exploration, and partly of less experienced persons to be involved in the surface support; these people actually finished up doing a lot of cave exploration themselves. The twelve expedition members were drawn from a variety of professions and included a doctor borrowed from the British Army.

It was a daunting task to establish such a major expedition with the intention of putting a twelve-man team into the jungle for a minimum of three or four months. Preparation took almost a year and involved the amassing of a tremendous amount of equipment, food and medical supplies. All possible contingencies had to be allowed for due to the remoteness of the area to be explored.

A major boost was given to the expedition when it was given Royal Geographical Society approval. This led to many doors being opened and, in addition, the nature of the expedition captured the public's eye and much sponsorship and publicity was received.

Our major sponsors included British Airways; Bank Line Shipping Company, who shipped all the equipment to Papua New Guinea for us; and many specialists in caving equipment including Beal (rope); Oldham (lamps) and Duracell (batteries). Over two tonnes of equipment was eventually assembled and shipped to Rabaul, the capital of East New Britain Province.

The principle intention of the expedition was to explore, survey and photograph the Nare cave; and then to look at any other caves in the area which could be discovered, since there were obviously many other caves to be found in that vicinity.

The Nakanai Mountains were reached by taking a day's journey on a small coastal freighter around the south coast of New Britain. Then a base was established at a logging camp, to which we were grateful for accommodation and storage. From that point it was approximately 45 kilometres into the jungle to the intended Base Camp. We were fortunate to have the services of a helicopter available to us, and this lifted in the majority of the equipment, and some of the personnel, to enable an early start to be made in the exploration of the Nare.

A camp site was established made out of polythene sheeting laid over saplings framed up by local villagers. We slung hammocks between poles under mosquito nets and set ourselves up approximately 400 metres from the huge shaft.

The nearest village, Ire, was about two or three hours walk away. Beyond that, going back down towards the coast, was a mission station called Nutuve, which was the nearest radio and medical post. It was often easier for the villagers from Ire to come to our camp and receive attention from our doctor than to go to the Nutuve mission.

The expedition began in earnest when the shaft itself was rigged. This was done in three ways. There was what was referred to as the Trade Route, which consisted of approximately 10 drops in varying sizes, some very short, with the final drop being 120 metres to the bottom of the hole. On the opposite side we rigged down through the trees, as we had done on the Trade Route, but reached an overhang which gave a free hanging pitch of 260 metres in a single drop. This was rigged using a rope especially brought for that purpose. In addition, above the upstream porch there was a hauling line established, again using a special long rope, to lower equipment, food and Carbide down the hole for the exploration.

At the base of the shaft a river was visible of approximately 15-20 cubic metres per second, running across the bottom between two large entrances. Upstream, it was a short distance to a sump where the river welled up from underground. Downstream was a huge porch and the river disappeared from view in a passage 70 metres high and 70 metres wide.

Initial exploration was made by going in and out of the cave every day. This very soon proved to be a major effort after a day's exploration and so a camp was established at the bottom of the shaft. It was a remarkable experience to look upwards, with blackness all around, and see an unexpected grey circle with stars in it, high above. Unfortunately, one night we experienced a major rockfall and spent the rest of the night sleeping in helmets! This prompted us to move the camp underneath the porch but there was nowhere suitable to camp without first crossing the river.

The fixing of a horizontal line across the river (Tyrolean line) was the crucial method of progressing the exploration of the cave. One proceeded along ledges, at or above water level, to which many safety lines and handlines were fixed in order to ensure that one didn't fall into the boiling white water leading who knew where. This carried on until the ledges ran out and the walls undercut, at which point it became necessary to cross to the other side of the river. This was usually accomplished by throwing a grappling iron across the river to lodge behind boulders or stalagmites.

We used a very carefully worked out technique, practised many times in white water rivers in Wales, whereby the grappling iron was used as a trail ferry (where a person holding onto the line is washed from one side of the river to the other while wearing double buoyancy jackets). It was necessary to have two lifelines on this person: one that was located upstream and one downstream.. If an upstream line only had been used, and had been required to hold a person in the event of the grappling iron coming loose, the water pressure would have forced the caver deep into the river incurring a serious risk of drowning. It was necessary for the person upstream to play the caver in the river like a fish; while the person on the lower end pulled in hand over hand as quickly as possible. Fortunately this didn't happen often. In some instances, where the river was too wide to throw the grappling irons across, we used a 50mm compressed air powered mortar to fire them, on permanent loan to the expedition from the S.A.S.

Progress in the cave was extremely slow. We would perhaps rig 100 metres of safety line along the side, and on some crumbling ledges, to reach a point where one could progress no further; spend several hours putting in a Tyrolean line; get over to the other side; progress another few hundred metres and then have to cross back over again! Thus a few hundred metres of cave could take a day or two to explore. Trips were normally taken as 12 or 13 hour working days and after three or four days underground a return trip was made to the surface to enjoy a bit of sunlight.

There were numerous places along the river where technical rock-climbing was involved to make progress, with some very challenging traverses and one climb across a rock bridge from one side of the underground river to the other.

Throughout all this, the noise was constant to the point where we had to wear earplugs to get any sleep at all. All movements such as river crossings had to be completely worked out beforehand because no form of verbal communication was possible should any unforeseen problems arise.

TheTyrolean lines themselves were fixed by the use of an ingenious tensioning (Pabsabloq) knot which we were very careful to de-tension at the end of each trip to reduce rope fatigue. This ensured that we were held as high above the water as possible because the river was liable to fluctuations due to the afternoon thunderstorms which were a regular occurrence even in this, the "dry" season. We did have two unavoidable low Tyroleans in the water and one very spectacular sloping one where it was necessary to prusik up; however sliding back down on a Petzl pulley was the best way to make the return journey, and considerably quicker too.

After some weeks of slow progress, one of the team jumped over a narrow chasm onto a ledge to which we were able to fix what proved to be the final Tyrolean. We rounded a corner and came to what we called Armageddon. The cave didn't end, there but was certainly impassable. The passage had come down dramatically in size to be approximately 5 metres wide and 1.5 metres high and completely filled with the raging river. There were no ledges available to us - they had run out - and every now and then a large wave sealed the passage completely. A spotlight shone down the passage indicated that this was happening for at least another 30 metres. There was a feeling of frustration at not actually reaching the end or a positive conclusion to the cave but it was not possible to make and further progress and remain alive.

A further week and a half was spent carrying out a survey, photographing and detackling the cave, in which everything was removed from the cave including a telephone line down to the first camp. The survey revealed that there were no side passages at all in the Nare.

At the same time that the Nare was being explored our support team was exploring numerous other small caves in the area. Unfortunately none of these revealed any major developments and certainly did not lead us into the Nare as we had hoped would happen. In addition a small team spent a week on a reconnaissance trip to the Ora cave but didn't succeed in getting any further than the Australian expedition had in 1973.

The last ropes were removed from Nare just before Christmas and we had a brief break down at the logging camp on the Coast to recuperate and to celebrate Christmas and the New Year. The local villagers were hired to keep an eye on our camp and they did a splendid job. Considering that there was no one else in the area who was likely to pinch anything, it was the best way to ensure that nothing went missing!

Upon our return to the jungle, we found the campsite a little more overrun, and the regrowth already starting. Of course the wildlife in the jungle has no regard for civilisation and we were often visited by such things as snakes, scorpions, spiders, bull ants, and leeches. The best near miss occurred when a scorpion was found in the seat of one man's trousers as he was about to put them on!

After Christmas the team was substantially reduced, initially to five, and then to four shortly afterwards. We had been shown the entrance to a cave called Pavie, just before Christmas, by the hunters from the village after we managed to make it known to them that we would be interested in exploring it.

Pavie was a large shaft, similar to Nare but not as deep, perhaps 120 metres in total. We set up a small base camp under an overhang at the entrance since it was several hours walk away from our Base Camp. After the entrance shaft we encountered a small series of passages (including a high dry ox-bow with nesting cave swiftlets) eventually leading to a pitch down into a large river. We were then involved in carrying out numerous Tyrolean crossings of the river for over one and a half kilometres until we reached the sump.

The survey showed that this was probably the upstream section of the Nare River Cave, but there were obviously other feeders since the river was small, perhaps only 10 cubic metres per second. Even though it was a smaller river, it was no less dangerous, and one of the team broke a rib on one of the river crossings here.

During the exploration of Pavie Cave there was a bit of light relief when the local villagers held a Sing Sing, which was partly an initiation ceremony for the young men of the village, and partly a gift exchange ceremony to another village who had helped out this one in the past. It was a fascinating insight into tribal cultures and we were possibly the only people from outside the area to have ever seen it.

When we had flown into the area by helicopter we had inadvertently gone further into the mountains than the Nare area and had spotted a large arch, taking a bearing on it from the helicopter. In order to find it we sent out our local guide, Camillus, to check other the villages in the area. He managed to locate the Gamvo arch, so after the exploration of Pavie was complete, two of the team went up to the site of the cave. This was approximately half a day's walk from our Base Camp and felt a long way into the bush. A very simple bivouac was set up with hammocks between trees, beginning the exploration of this cave.

Directly underneath the huge arch was a shaft approximately 170 metres deep and broken into several pitches by ledges. On many of the ledges there were large hairy spiders and Scutigera centipedes. The only similar life we had seen were large tailless whip scorpions, with 450mm antennae, in one cave, and 100mm leeches (which presumably fed off the bats) in another cave.

At the bottom of the shaft we encountered yet another river, smaller than the river in the Pavie Cave. The passage was low at first but then became wider and higher, eventually developing into a very well decorated river passage, 6 metres wide by 3 metres high; making exploration very easy and spectacular. A short pitch was encountered and a further few hundred metres led to another very intimidating-looking pitch. The whole passage went straight over the edge of the shaft, but unfortunately we had run out of rope and so surveyed out.

A couple of days later the Doctor and Camillus turned up with more rope, food and Carbide and so the exploration of Gamvo Cave continued.

The intimidating shaft turned out to be only 16 metres long but was exciting and spray lashed. This led to a short swimming section with a duck at the end of it exactly the size of a helmet! Very shortly afterwards the passage and the river went through a hole in the floor, a bit like a toilet, which proved tricky to negotiate.

Beyond this a series of very boisterous cascades led us again to a huge passage. After passing several inlets, all adding more and more water to the river, we arrived at the inevitable sump having just passed through a passage over 80 metres high and 60 metres wide. The inlets were explored on later trips when over one and a half kilometres of cave were explored. In total the cave was over 6 kilometres long and nearly 500 metres deep, which was a very respectable depth for Papua New Guinea and indeed the Southern Hemisphere.

Cave surveys were undertaken using a Suunto compass and clinometer and a fibreglass tape. The readings were then entered into a small programmable calculator which produced the co-ordinates. These were then drafted onto sheets of A4 graph paper so that even in the middle of the jungle we were able to draw up what we had explored that day.

Steve Dickinson

Ultimately we ran out of time and so the retreat was made back down to the Coast. This was no simple matter because of the logistics involved in moving all our equipment. In the end we hired an entire village as porters to make the long walk back. Once the equipment was organised we again took a very pleasant South Seas cruise back to Rabaul.

We consider that this was a very successful expedition with over 11 kilometres of new passage being discovered. We felt that we may have done some of the the best sporting caves in the world and were privileged to have participated in this expedition.

Further to our expedition a French team has been to the Nakanai Mountains but only found a few minor caves. The Whiteman Range of West New Britain was also explored by the French expedition but again nothing of major significance was found although it is also a major Karst area. It would seem that in future, expeditions to Papua New Guinea should concentrate back on the mainland again, particularly in the Highlands area. Only last month a Papua New Guinea helicopter pilot told how he had sheltered inside a doline, complete with a load on a sling below him, to wait out a storm squall that passed overhead. He later emerged and carried on about his business. That was in the Hindenburg Wall Region of the West Sepik Province and there must be many more dolines out there waiting to be found.

S.J.DICKINSON

Steve Dickinson is a member of the Eldon Pothole Club in the U.K. and has been caving since 1971. He has been on 11 International Expeditions including the Pierre St Martin and Gouffre Berger in France , Spluga Della Preta in Italy , Spain , Poland , Papua New Guinea , Sumatra and China.

Recent Advances in Reflective Track Markers, Barricades and Signs with a passing comment about cave number tags.

Norman Poulter
Speleological Research Group Western Australia

ABSTRACT

During the course of the 16th. ASF Conference (Sydney) in 1987 I presented a discussion paper entitled "Trail Marking and Area Designation" outlining the development and use of reflective discs made from recycled road signs. The intention was to 'float' several ideas with a view to establishing a standard approach to track marking throughout Australia.

The idea 'floated' at the Sydney Conference was fourfold;

1 - The use of reflective discs as track markers,
2 - as area designation utilising the various colours available,
3 - as information using a suggested numerical system, and
4 - protect the overall cave environment (from visitors).

The presentation, as well as some of the discussion was tongue-in-cheek, given not only the type of material used but how some of that prototype material was obtained. The subject matter itself though, was serious, given that I was advocating a method to minimise damage - a problem that should concern all members of the speleological community. A small committee was set up to further refine the ideas put forward but to the best of my memory, after some initial correspondence it was 'lost' to the passage of time.

Since that time the use of track markers have become (relatively) widespread with some new and interesting innovations. With the upsurge of recreational caving by individuals, social groups, commercial operators, often urged on by tourist-dollar driven governments, both state and local, steps must be taken to protect the cave environment from the descending hordes, which sometimes includes ourselves. This paper outlines methods evolved in Western Australia to protect cave environments from this invasion. While some of the methods are clearly aimed at 'public' recreational cavers, organised groups and individuals, the inference is raised that the speleological community should also take note.

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HISTORY

Track marking in caves in the first instance was employed purely as a means to find one's way into or out of a cave and usually consisted of string, piles of rock or candle/carbide soot on cave walls. Such methods ultimately led to confusion as these marks could only be understood by the people who made them and this led to a proliferation of marks as different parties made their own contributions, thus leading to further confusion and additional marks (in the case of arrows pointing in different directions the word "OUT" was often added).

During the 1960's, some attempt was made to protect sections of cave, usually areas of high decorative value, the most notable being the Chevelier Extn, part of the Jenolan System (NSW) where I believe, flagging tape, artificial carpet, carpet protector and other methods were trialed. Never having been to the section mentioned I am basing my comments on a couple of photographs seen long ago and anecdotal conversation.

Following the entry into the Christmas Star Extension of Crystal Cave (6Wi62) in 1968, a plastic pathway was laid on the flowstone floor throughout the extension and visitors required to remove outer garments on entering the section. However, by 1972, damage had been caused by sand contamination, break-up of parts of the pathway and visitor indifference. (Poulter 1979)

Track/route marking, mainly in the form of survey tape and some reflective material was employed in Tasmania's Kubla Khan Cave during the early 1970's to mark a path through muddy sections of the cave in order to keep visitors to one path and protect adjacent areas from despoilation - to my way of thinking it did not work very well due to the difficulty in seeing the small quantity of material in the prevailing low light conditions.

Track marking seemed to be all but forgotten during the late 1970's to early 1980's and was not resurrected to any great extent until the Northern Caverneers started to restore and track mark parts of Kubla Khan Cave in 1985 (Woolhouse 1985, 1988). This restoration work, before is was stopped by the land manager (Dept. of Parks, Wildlife & Heritage) resulted in the first major appearance of SRGWA's reflective discs manufactured from recycled road signs and led SRG to acquire many more damaged signs from the WA Main Roads Authority, planning to produce discs for 'sale' to all clubs (and cave managers) in Australia while attempting at the same time, to create a standardised system.

The paper presented at the 1987 Conference was a vehicle of ideas and announce to the caving fraternity that reflective markers were now 'readily' available at a modest cost. The idea of coloured 'area designation' and 'numbered keys' has been all but forgotten, probably due to its perceived complexity, in favour of route, track and survey markers. Sales were slow until news of the markers existence became more widely known due mainly to discussion and people encountering them in caves. Principal purchasers were initially confined to Western Australia where even the major government land manager, the Dept. of Conservation and Land Management (CALM) bought them from time to time. However, since 1990, sales have 'boomed' for specific areas. The Cave Exploration Group of South Australia Inc. (CEGSA) purchased 2500 markers for its 1991 Old Homestead Cave Expedition and the Top End Speleological Society (TESS) purchased 200 of the recently developed variation, the 50mm Cave Number Tag after coming across caves tagged by this method (by SRGWA) in the Kununurra region of Western Australia. Cave Number tags have also been used on the WA side of the Nullarbor Plain, sanctioned by CALM for use within the Nuytsland Nature reserve, and at Wanneroo - just north of Perth. (See <u>fig. 1</u> - more on this later.) Over the last couple of years the Western Australian Speleological Group Inc. (WASG), and individual members of, have purchased at least 1000 track markers.

There are numerous reasons to track mark in a cave but they generally fall within six broad headings; protection of fauna,

- decoration,
- bone deposits,
- special features <u>eg</u> mud pavement (Exit Cave, Tasmania),
- OR, maintain a cave or section of cave as near as possible, in its original pristine condition,
- OR, minimise further damage by restricting damage caused by human passage to one clearly defined area.

Perhaps I should pause here to relate my definition of route and track marking. I interpret route marking as plotting a basic navigable path through a cave (passage) but not necessarily intend visitors to follow precisely from point to point. An example of this would be the survey route marked through the main passage of Mullamullang Cave. If visitors to the cave have a copy of the 1966 map in their possession they can refer to the numbered survey markers along the way to pinpoint their current location. Track marking on the other hand, would indicate a clearly defined pathway that visitors must not deviate from, an example being the Christmas Star Extension mentioned above. This pathway includes a cement slab path (<u>Fig. 2</u>) through dense sand. On entering the main part of the extension, outer garments and footwear are removed in an area of extensive rock and cement construction that is a containment for a sandbank. Helmets are left in the previous (Helium) chamber. A plastic pathway, laid across an extensive flowstone floor is followed and plastic wash basins are located in the extension to further minimise sand contamination.

REFLECTIVE MARKERS

The use of reflective markers in caves to guide people is not new. In the past, the use of reflective markers has probably been restricted through not enough suitable material being readily available at the 'right price' (preferably free). SRGWA's access to damaged road signs (reflective material on 2mm marine grade aluminium) changed all that. Reflective material of a uniform colour and size is now readily available through SRG at a moderate cost. See Table 1.

Reflective variations have been developed by other societies. Track marking can be open to interpretation and the method employed is dictated by what is to be protected and the prevailing circumstances, plain rock, decorated areas with rock or earth floor or decorated areas with flowstone floor are but some examples, and the materials available. I believe that the Witchcliffe Area Speleological Sub Group (WASSG) has developed one method in areas of flowstone by suspending reflective material from the ceilings of cave using nylon fishing line. Another consideration is how WIDE a track should be. If Mullamullang Cave's "Coffee and Cream" section had been designated by a marked 300mm wide trail in the late 1960's, it might not be suffering the 1m+ wide 'highway' and peripheral damage that it is today.

Track markers initially manufactured by SRGWA were 25mm in diameter with a 4mm hole in the centre and left to the purchasers as to how they were to be employed within a cave. The most common method was to nail them to rock but this has the disadvantage of setting up an electrolytic action between the two dissimilar metals (a well documented problem) leading to the eventual breakdown of either the aluminium (into a jelly-like substance) or the steel nail rusting away (or both), leaving stains on the rock surfaces. However, in recent times, silicon based adhesives, such as Silastic 732 RTV have been used to glue markers (now increased in size to 30mm diameter with no central hole) onto dry rock and Monier M34 to wet rocks have been used with great success.

COLOURS

There are three basic colours to be gained from road signs, white - red - yellow, followed by blue (information & ring road) and green (freeway & traffic lights) with blue more numerous than green. A lot of the large green freeway signs are made from marine ply, not aluminium.

There are also two technologies of colour involved with the older type being preferable to cave work. The older style of signs consisted of the reflective material (glass beads) mixed into a coloured matrix (white or yellow) and information (red/black) then spray-painted onto the finished surface. The modern method is to have a standard white base background (as before) with the colour and information being screen printed onto a plastic film which is then glued to the signboard, the adhesive being in the form of hexagonal 'cells'. At the 1987 ASF Conference, experience of usage was not available to indicate the best technology that was suitable to the cave environment although by that time we were 'stuck' with the current number and type of signs from the Main Roads Dept. SO, which type of sign is best?

All signs, apart from having to withstand the ravages of the modern motorist, have to survive Australia's harsh environment. Some fare better than others, depending on their position and colour. KEEP LEFT, SPEED and STOP signs are favourite targets of motorists while STOP signs and the red circle of SPEED/NO TURN signs are the preferred target of the sun and its damaging UV rays. The red on the older type of painted sign ultimately fades to a much softer pink and sometimes even disappears altogether while the newer type not only fades but the plastic film becomes brittle with all colours but especially red. How does this effect their adaptation to the cave environment?

With the 30mm disc, we now perform two functions. They are produced as 30mm flat discs and the newer, curved variety (Fig. 3) to fit 25mm endcaps and to a lesser extent, 20mm conduit pipes, see below. Both types of flat disc perform well although it has been found that moisture ultimately works its way into both varieties. While the older variety 'bubbles' occasionally, in the case of the plastic film types, this may ultimately cause the film to fall off, only time will tell.

However, when it comes to curving the discs, the UV bombardment of the film style becomes apparent, especially the red, with cracking of the film often taking place. This is unfortunate as red STOP signs are not available in anything but the plastic film type, thus almost precluding their use as curved markers. As the number of red discs obtainable from the older style of SPEED/NO TURN signs is small, it may take some time to build up a workable stock of them for curving. Some minor 'crazing' occurs with the reflective material of the older signs when curved but this is hardly noticeable.

COLOUR ADOPTION

As mentioned previously, area designation by colour as speculated in my 1987 paper, has fallen by the wayside. The most commonly used colours at the moment are red, white and yellow in that order. 30mm red and white discs are widely used as track and route marking while yellow seems to be confined to 50mm discs used as survey points and cave number tags. A disadvantage with red is that it is relatively low on the visible spectrum and so may be difficult to see under low light conditions if used in isolation as a 'WAY OUT' disc. That is why SRG recently used yellow as a 'WAY OUT' indicator on route markers in Mullamullang and Thampanna Caves.

SRG has also used yellow 50mm discs as cave number tags (below) although for some rock types, blue would be a more appropriate colour to maintain suitable contrast, an example that springs to mind is the placement of the number tag at the entrance to Abrakurrie Cave.

ROUTE OR TRACK MARKING?

I am not sure what method of track marking CEGSA used during its Old Homestead Expedition of 1991 except that they purchased 1000 - 30mm red, 1000 - 30mm white and 500 - 50mm yellow discs. The yellow discs were to used as survey markers within the cave. I hazard the guess that some of the red and white discs were used as route markers while others defined the width of tracks. Anecdotal comments indicate that white may have been used to signify the way into the cave while red led the way out.

Members of WASG and WASSG have been active in the promotion of the 'highway technique' in defining track width and placement using closely spaced plastic price tags and discs adjacent to each other (Fig. 4) whereby you keep red on your left and white on your right. SRG on the other hand have pursued a similar although somewhat different idea under different circumstances using single posts whereby a visitor passes to the right of a red post but to the left of a white post, thus the width of the 'path' is defined with fewer markers Fig. 5. A disadvantage with both techniques is that they cannot define direction ie which way is out?

A route marker developed by SRGWA for CALM's use in an adventure cave in the Leeuwin-Naturaliste Ridge National Park utilised 50mm stormpipe, modified joining sleeve and a custom made, engraved cap which is glued to the sleeve (Fig. 6). A standard 50mm stormpipe joining sleeve is cut in half (making 2) and the cut ends bored out to a nominal diameter and faced in a lathe. A piece of PVC is machined to fit as a 'cap'. The 'cap' is then placed in a mill's dividing head and directional arrows engraved into the surface and then filled with suitable paint. The cap, sleeve and pipe are glued together and positioned in the cave. As the posts are intended to be placed some distance apart but in line-of-sight, it is desirable to put some reflective material in disc or self adhesive sheet form on it. The posts used by CALM had orange self-adhesive reflective sheet material afixed.

During December 1992 SRG replaced the route/survey markers in Mullamullang Cave using curved white and yellow reflective discs glued to free-standing 25mm PVC endcaps. A sign was placed near the Dune indicating that white led into the cave while yellow led out. So that the concept could be interpreted in low or yellow light conditions, a dot is placed over the white disc using a black felt pen. The method was repeated on markers originally placed in part of Thampanna Cave back in 1981. As the markers in Mullamullang are principally survey points, the new endcap markers have the survey point sign and number marked on the side of the endcap, again using a black felt pen.

POSTS

What happens when there is no convenient rock to attach discs to? The traditional method was to create a rock cairn and either leave it as is or place a marker on top of it, these can still be difficult to see. One method suggested in the 1987 paper was the use of plastic price tags but these are relatively small, fragile and not easy to obtain in anything but large quantities. Price tags would certainly not stand up to the rough conditions of 'public' indifference.

A track marking method being trialed under CALM's Leeuwin-Naturaliste Cave Permit System is the use of 25mm (Class 18) PVC pipe with curved reflective discs glued to the end caps placed on top. Fig. 5. The posts are 750mm long with about 300mm above soil level. A 20mm hole is drilled laterally near the base with a short section of PVC conduit passed through to 'lock' the post into the ground and stop it from being turned. The post can be kept in the ground either by 'tamping' the soil or cementing it into position, depending on circumstances. Using PVC means that the post does not deteriorate or react electrolytically with the aluminium disc. Anything that is to be installed in a cave for any length of time needs to be resistant to the cave environment and as inert as possible so that it in turn does not harm the cave environment or fauna. Another variation is to use endcaps only. As already mentioned, endcap route or trail markers have the advantage in that they are free-standing but can also be stuck to boulders, walls and rock cairns with Silastic. Endcap markers can be manufactured on site or, if the orientation is known, prefabricated - something to occupy armchair cavers at meetings or in front of the TV. The survey markers in Mullamullang Cave were recently replaced using the prefabricated method. Where a post cannot be sunk into an earth floor it can be placed or cemented inside a rock cairn or, as mentioned above, just the endcap glued or placed on a convenient rock or cairn.

Placing trail posts in a cave for the protection of the cave (principally) and the guidance/convenience of the public users of the cave is one thing, but what about guidance for speleologists, the so-called non-damaging experts? Many would and possibly have objected to such intrusions but sadly, some speleologists are just as thoughtless and uncaring as their public counterparts. However, it would be nice to think that in caves that the public does not have access to, less expensive or robust route/trail making materials could be employed. Price tag markers should be ideal under these circumstances.

A less expensive type of post can be manufactured from 20mm PVC conduit although these cannot have a similar size (conduit) crosspiece passed through it although a "T" can be glued to the end placed in the ground. Its smaller diameter would make it less obtrusive to puritan speleologists in wild caves. A forming die has been made allowing curved 30mm discs to be glued to the pipe but not the endcap although the tighter curvature causes greater cracking of the reflective material. So far, none have been made.

BARRICADES

Another method being trialed under CALM's Permit System in caves open to the public is the use of 50mm PVC storm pipe and PVC chain as passive barriers to cordon off sections of cave. (Poulter 1990) Fig. 7 & 8. The method, co-funded by CALM and SRGWA, stemmed from discussions within CALM's Cave Management Advisory Committee in an effort to arrest erosion damage to the soil cones in an extension of Calgardup Cave (6Wi49) caused by unrestricted and uninformed visitation. The exercise has met with limited success although it must be pointed out that unrestricted visitation to this extension would be countered in thousands per year and despite the damage caused by erosion, tramping on virgin sand/flowstone surfaces, decoration damage has been minimal. Periodic restoration trips help keep the sand shifting problem in check and it is speculated that the number of visitors complying with the spirit of the barricades is relatively high. The barricade method has since been used in two other "public access" caves to protect exposed bone deposits, a significant tree root and to prevent further soil/rock slope erosion.

Storm pipe, although expensive, is used due to its strong 5mm wall thickness, allowing it to be slotted to accept the 6mm PVC chain and resist vandalistic attack better than standard irrigation pipe of similar diameter. The cost of these materials are given in Table 2. It is open to speculation that if the barricades gain acceptance and compliance then less expensive pipe could be used in future works.

WHY USE PLASTIC?

Plastic is one of the few materials that can be used in a cave without being effected by the cave's environment, an environment that is very aggressive to the two most commonly used materials, wood and steel. Conversely, plastic, being inert, has no known adverse effects on a cave's environment or its faunal food chain. PVC posts and chain or track marking posts, may look "out of place" in that they stand out like the proverbial "sore thumb" in contrast to their surroundings, but then again that is why they would be in a particular place, to designate where to go, not to go, or stop. If a barrier or guide post looks neat and functional, then it stands a better chance of getting the message across, being adhered to and accepted by all concerned. Despite the fact that PVC post and chain is a relative expensive proposition, it is a method that is resistant to vandalism and decay, is lightweight and able to be fabricated in a (home) workshop prior to installation trips, it therefore presents a cost effective alternative to traditional materials.

SIGNS

Signs play an important role in everyday life - in that they give out information where it is impractical for someone to repeatedly do so verbally. A sign is on the job all day, every day. There are numerous occasions where signs can play an important role in protecting caves, sections of caves, their faunal inhabitants or other natural features. In the past, signs have been written on whatever material is available and, left unprotected, rapidly deteriorate. Such signs serve an important first step. However, those signs should be replaced by more permanent and better presented signs at the earliest opportunity.

Professional signs are expensive, take time to produce and more expense is incurred if the sign needs to be replaced or altered due to changed circumstances, vandalism or theft. They are also susceptible to a cave's environment.

SRGWA has produced several inexpensive signs over the last few years (either typed or computer generated) drawn on ordinary A4 paper and then laminated. On completion of a 'master' , copies made from it are trimmed prior to lamination to increase the laminated border area enhancing its resistance to a cave's humidity. After lamination, the sign is usually glued to a stiff backing board (PVC or Laminex) or used 'as is', depending on the circumstances. The completed signs can then be afixed to posts or rock walls using nylon sash cord.

The 'master' is kept in order to produce copies should they be required. If coloured signs are required, the new colour photocopiers produce excellent results.

The oldest SRG laminated sign is a multi-coloured one placed in Calgardup Cave during mid-1990. Despite one attempt to remove it from its backing board, it is still in A1 condition. The reprinted history of Mullamullang's Dome visitation, transcribed by WASG and laminated by SRG, was repositioned outside the Dome in July 1991 while the (laminated) history relating to Mullamullang's 1 Mile Cairn was put in place during December 1992.

Colour A4 photocopies cost $3 per sheet and laminating $1.50 at the University of WA's Media Services Unit. Single colour A4 photocopies cost about 10¢ a sheet. Many poster shops, education units and businesses throughout Australia possess laminating facilities.

CAVE NUMBER TAGS

What does cave number tags have to do with protecting caves from people? Absolutely nothing unless it stops you entering caves you didn't intend to because you didn't know which cave it was. It is mentioned here merely because SRG has become a major source of reflective material and that traditional brass or aluminium foil used with nails in some parts of Australia have proved inappropriate due to electrolysis. SRGWA first speculated the use of reflective cave number tags (Fig 1) in relation to the Nullarbor Plain due to the large entrances encountered although their first use occurred on caves of the Kununurra region in July 1989. The reason was simple - they were easy to see, one merely shone a light across the expanse of a cave entrance until a tag reflected, or, the contrast between the tag and the surrounding rock made them stand out. In areas infrequently visited by the same speleologists, it is important that caves receive only one identifying number. Since 1989 reflective cave number tags have also been used by SRG at Wanneroo, on the Western Australian side of the Nullarbor, being sanctioned for use by CALM in the Nullarbor's Nuytsland Nature Reserve and 200 were recently sold to TESS of the Northern Territory.

The 50mm yellow reflective discs have a 30mm plain aluminium disc glued to them using Silastic. The plain disc has the appropriate ASF cave number stamped on it. The disc is then attached to a prominent place in the cave entrance, suitably protected from the elements using a liberal amount of Silastic. Where there is no suitable site, SRG has glued it to a rock pavement and built a small rock cairn nearby.

Some cave entrances have a rock colour similar to the yellow disc making them difficult to see, despite the fact that they are reflective. In cases such as this, Abrakurrie's entrance for example where the rock is quite yellow, blue discs may be a more appropriate colour contrast. See <u>Table 1</u> for costs.

CONCLUSION

This then, is the state of play in Western Australia. We have caves, particularly in the Leeuwin-Naturaliste Ridge, south of Perth, where PVC posts with reflective route markers, PVC posts and chain, signs and track markers on price tags have popped up, seemingly overnight sometimes. Is it all necessary? Are we merely trying to lead Australia out of the recession we had to have with a PVC and recycled aluminium led recovery or, as some may argue, engaging in visual pollution? Is a bit of "neatly placed" visual pollution better than a "wrecked" cave? In my view, after other alternative solutions have been exhausted, yes, although I would hasten to add that what is deemed appropriate, neat and maintenance free for track, route marking or barricades in one cave may be considered totally inappropriate in another depending on what is to be protected.

In Western Australia, and no doubt elsewhere, speleologists are very much in the minority. Collectively, there are about 250 members of ASF affiliated speleological societies in Western Australia, ranged against casual cavers numbered in the tens of thousands of cave visits per year. Some of our very friable caves are suffering incredible damage. That damage is not confined to the L-N Ridge. The caves of the Nullarbor Plain are also suffering, Mullamullang in particular. Should we casually pass all that off as "normal wear and tear" as it has by some in the past?

The Leeuwin-Naturaliste National Park Cave Permit System (established in September 1992) is hoping to lower the casual and commercial cave user population through a user pay and visitor limit policy. During the public consultation process, casual and commercial caving may have increased due to publicity, it may still be increasing. A one year monitoring program is underway to find out what is happening and how the public is complying with the permit system. Some of the more dramatic PVC methods of "crowd control" mentioned above are being trialed in three caves available to the public. Other methods mentioned are used in caves (not available to the public) to control speleologists.

Most of the material costs for in-cave protection have been borne by the local speleological fraternity although CALM has helped with some funding. The costs have been high, PVC may be an easy material to work with but is not inexpensive to buy, even with discounts. Surface protection of caves in the L-N Ridge is a separate issue not discussed here that has been borne entirely by the land manager CALM with some voluntary help from speleological societies.

A 25mm endcap has a recommended retail price (RRP) of about 90¢, a 750 x 25mm post works out at about $4.85 without markers while 50mm post and chain is roughly $15/metre. Even though it is possible to buy the material for less than the RRP is it all worth it? If it assists in protecting a cave and all it contains, then I say YES. Otherwise, what are we doing in the speleological business? We need to educate everyone regularly, including ourselves, to have a greater appreciation of caves and their inhabitants. If this also means keeping to narrow trails and track marking whenever possible - so be it.

****

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TABLE 1

TRACK/ROUTE MARKERS - red, white, yellow, blue

30mm reflective disc - FLAT	2¢ each or $ 2/100
- 20mm curved	4¢ each or $ 4/100
- 25mm curved	4¢ each or $ 4/100
50mm Reflective disc	6¢ each or $ 6/100

CAVE NUMBER TAGS - yellow, white, blue

30mm plain aluminium disc	2¢ each or $ 2/100
30mm pre-numbered aluminium discs	22¢ each or $22/100
50mm reflective disc	6¢ each or $ 6/100
30mm plain + 50mm discs - glued	20¢ each or $20/100
30mm pre-numbered + 50mm discs - glued	40¢ each or $40/100

Prices effective 1992 (subject to change) but does not include postage costs.

TABLE 2

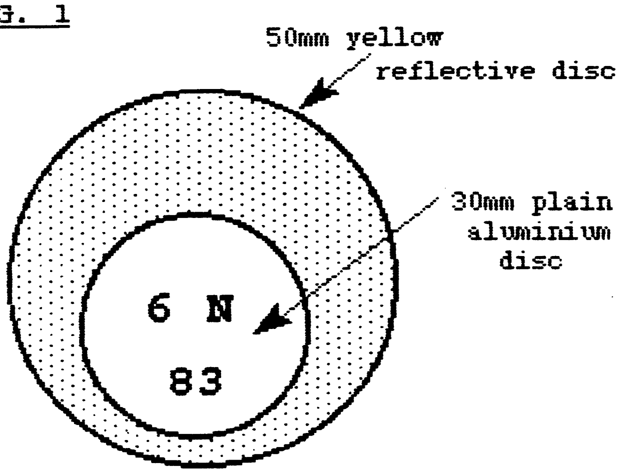
PVC MATERIALS AND COSTS

Material	RRP	Price to SRG
20mm orange conduit, 4m length		$ 7.25*°
20mm orange endcaps		$ .39
20mm grey conduit, 4m length		$ 5.75*°
20mm endcaps		$ .35
25mm, Class 18 pipe, 6m length	$31.56	$ 25.25°
25mm endcaps	$ .90	$ .45°
50mm stormpipe, 6m length	$ 79.80	$ 63.84°
50mm #6 endcaps	$ 1.70	$ 1.70°
6mm PVC chain, yellow or white	$140/40m	$112°
250gm tins of PVC glue		$ 4

* Orange conduit has a heavier wall thickness than grey conduit, hence is more resistant to damage and is thus slightly more expensive.

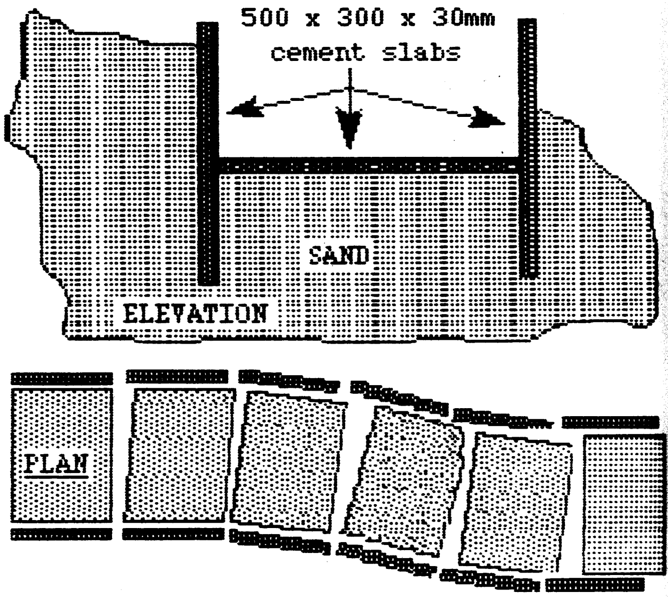
° When purchasing any quantity of PVC material, it pays to 'shop around' for the best price, or, seek sponsorship, donations or grants. It is possible that some materials can be purchased for even less than SRG has recently been paying.

FIG. 1



50mm reflective cave number tag labled for Old Homestead Cave W.A.

FIG. 2



Slab path through sand - Crystal Cave W.A.

FIG. 3

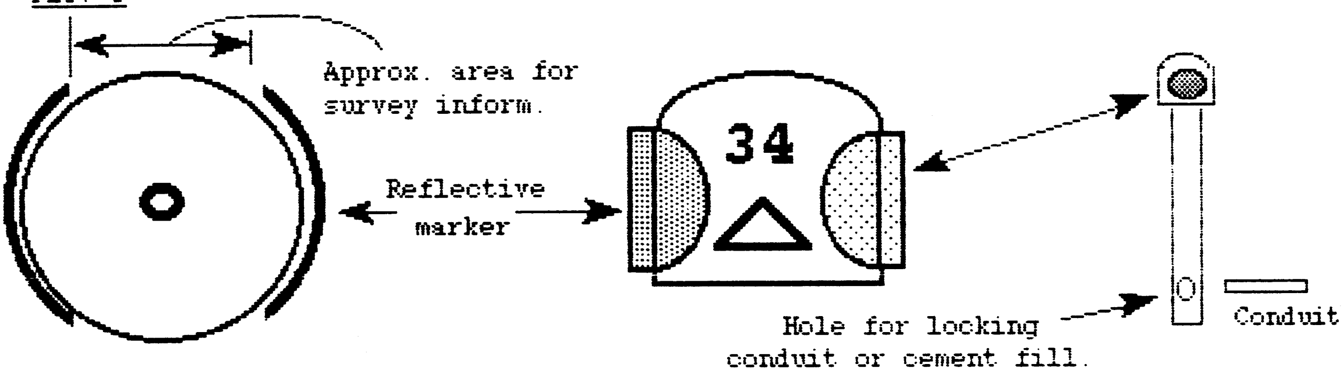
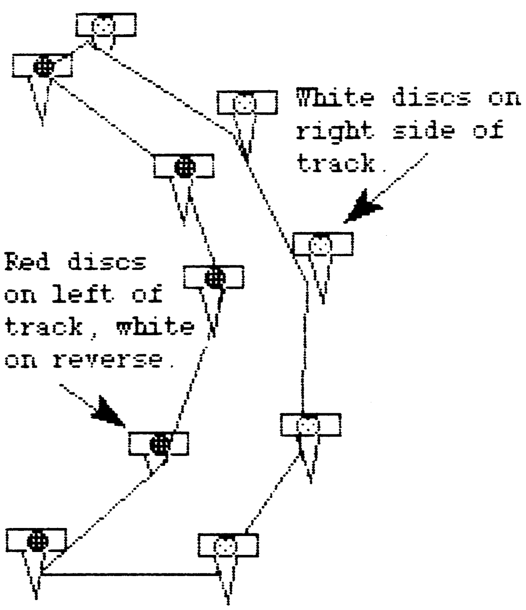
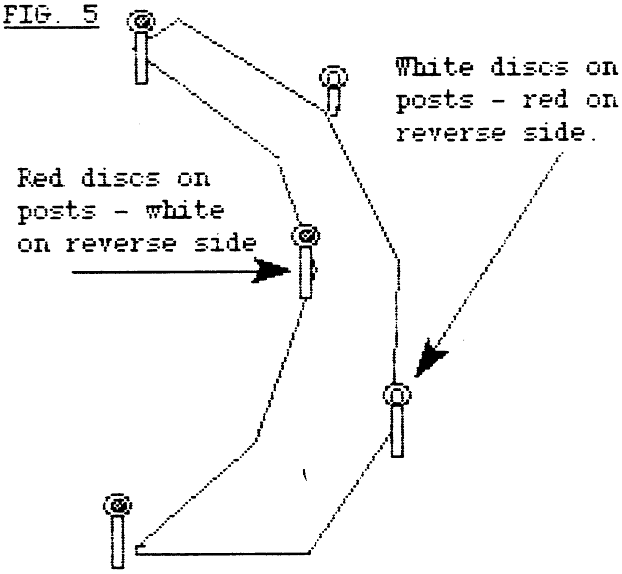


FIG. 4



"Highway Marking" Close spacing of price tags to clearly define track in high value areas. WASSG price tag method.

FIG. 5



Wider spaced definition of track in specific areas. Not necessarily of lower value.
SRGWA post & endcap method

HIGHWAY METHOD OF TRACK MARKING

FIG. 6

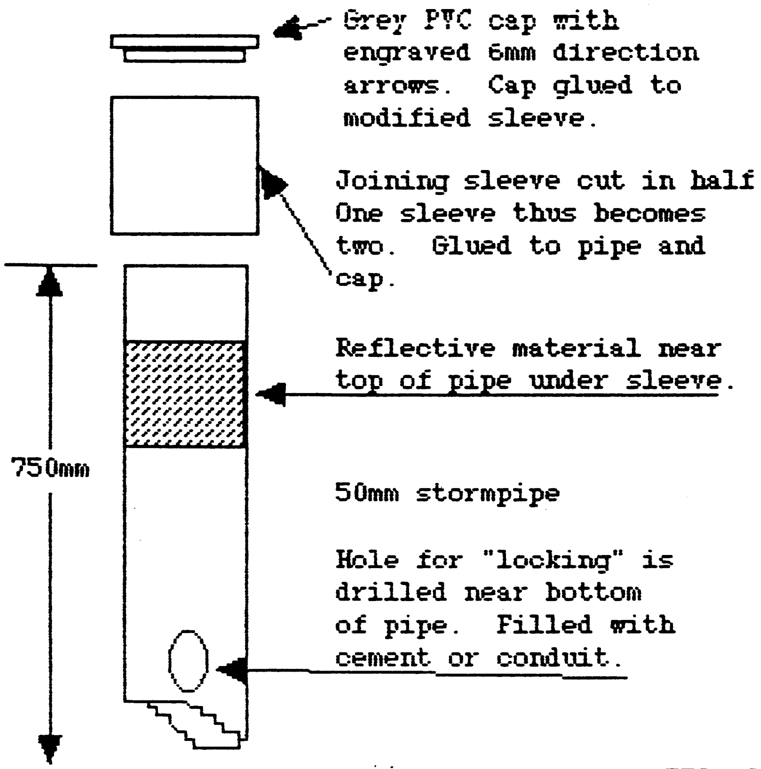
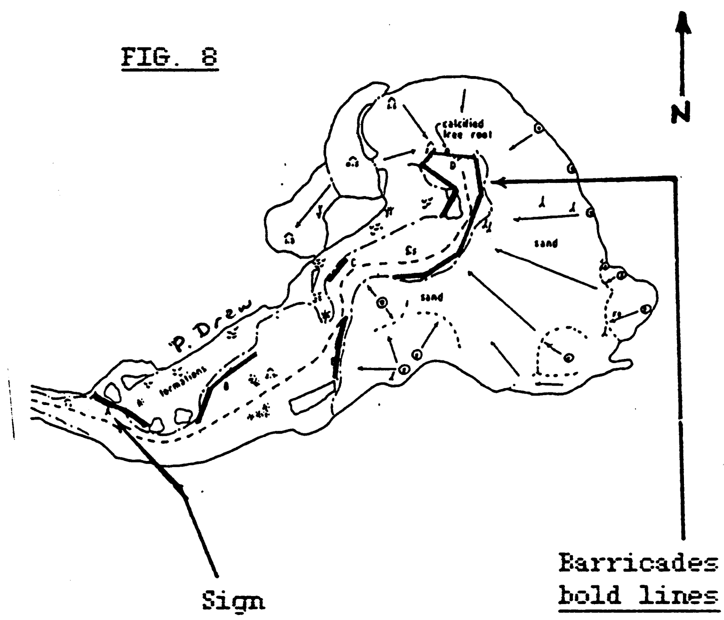


FIG. 8

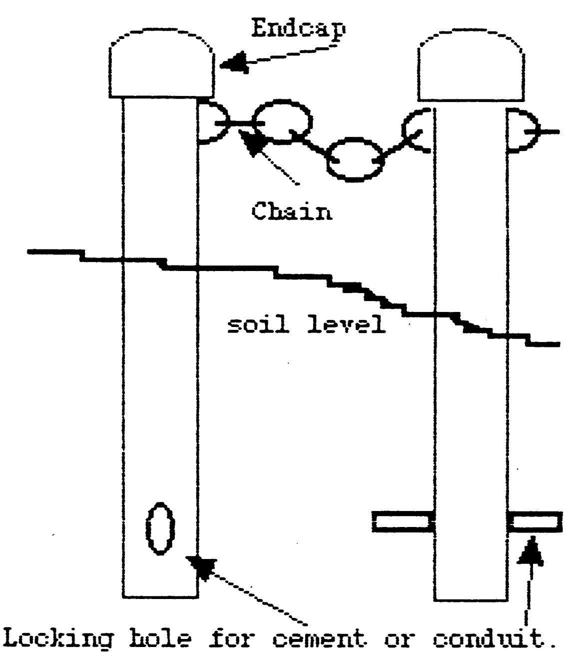


Calcified Tree Root Chamber
Calgardup Cave 6Wi49

Showing location of information sign and barricades

Scale 1:200

FIG. 7



50mm stormpipe & 6mm PVC chain barricade.

Some Historical Materials on Tasmanian Caves

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INTRODUCTION

It is commonly assumed that tourism in Tasmanian Caves commenced with the opening of the some caves at Mole Creek in the early years of this century. However, if we recognise that nineteenth century tourism was indeed somewhat different, in that travellers (usually from the gentry) penetrated into quite remote places, often with the assistance of local guides, then Tasmanian cave tourism has a long history indeed. This has already been pointed out by the Skinners (1978) in their *Mole Creek Caves*, summarising references from 1829 onwards, and including a delightful description of a visit to one of the caves (Honeycomb).

The purpose of the present paper is simply to note a number of further records of cave history in the state, which may otherwise escape notice.

TOURISM AT MOLE CREEK

Honeycomb Cave, then known as Oakden's Cave after the landowner, was depicted in a magnificent engraving in the *Illustrated Australian News* of 1877. This same engraving almost certainly would be found in the other associated journals of the day ; given the work involved in making a printing block, it is not surprising that they appeared in a number of locations. It appears that the lighting used was probably bark torches soaked in kerosene - a technique also used at Buchan, Victoria.

An important and long overlooked record is the first published account of the Tasmanian glow-worm. This reported their occurrence in the Chudleigh Caves (again Honeycomb) and was contained in an essay on caves by that astounding polymath, the Rev. Julian Tenison-Woods, writing in the Sydney Mail of 12th. April, 1879.

There is a brief account in the now rare *Tourists' Guide to Tasmania*, published in 1899 by the Union Steamship Company for the information of passengers. Like comments of that time upon most other cave areas around Australia, the author is strongly concerned about conservation :

> . . . the Chudleigh Caves, those natural wonders that will yet be recognised as a valuable national asset and cared for accordingly . . . The neglect of these caves, and their consequent mutilation by irresponsible persons who chip off bits of the many coloured and variously shaped stalagmites, is a matter for regret, and it is to be hoped will soon end.

At the same time, travellers were encouraged to visit the caves :

> At a cottage close by a fire and a hot cup of tea may be enjoyed before beginning the return journey. The road is quite good enough for cycling to within half a mile of the entrance, when walking would be easier for the remainder of the distance.

This sounds not unlike the 1870 description quoted by the Skinners ; one assumes things were slow to change, just as the neglect of cave resources has also been slow to change !

Thus, it is interesting to note from the Tourist Department's 1918 *Complete Guide to Tasmania*, that visits to the Wet Caves group at Caveside were still being encouraged, even though the development of the four more conventional show caves at Mole Creek had taken place by then. At that stage, the train to Mole Creek left Launceston in the later afternoon, returning in the morning, so night-time inspections were available to visitors. Various of the early references use the name 'Wet Caves', but it is clear that these generally refer to what is now known as Honeycomb Cave, not today's Wet Cave.

Another example of slow change is the information circular on Mole Creek Caves issued by Tasmanian Railways. I have copies dated 1916 and 1926, and the only change is that the provision of accommodation by the Scott family is deleted from the second. However, Scott's Cave is still listed among the attractions, even though it was apparently closed by then.

Tasmanian show caves appear to be the only ones in Australia which were lit by reticulated acetylene. This was the case at Scott's Caves and Baldock's Caves while hand-held acetylene lamps were used at Gunns Plains. Although there have been some statements about acetylene being used elsewhere (e.g., Naracoorte, South Australia), there is no evidence that this was so. However, it must be noted that hand-held lamps (drover's camp lights) were also used at Chillagoe.

CAVE PHOTOGRAPHY

Those interested in the history of Tasmanian show caves are fortunate, in that a number of excellent early photographs are readily available.

The famous John Watt Beattie - explorer, photographer, antiquarian, historian, tourism promoter - arrived in Tasmania (from Aberdeen) in 1878, and soon commenced his interest in photography. He is said to have been the first (in 1879) to use dry plates in Australia, and this took place on an excursion to Lake St. Clair. Then in 1882, he abandoned the family farm, and became a professional photographer, continuing work until the late 1920's. He photographed every part of Tasmania, including the West and the great river valleys, carrying a 15" x 12" plate camera which weighed 60 pounds ! His works include striking pictures of the sea caves of the Tasman Peninsula, as well as others of the Mole Creek Caves.

But Stephen Spurling III was probably more important to cave photography. Stephen Spurling I arrived in Hobart as a naval officer in 1837, settled there and worked as a surveyor, then established one of the earliest photographic studios. He was later assisted by his son, Stephen II, who then moved to Launceston and opened a studio there. He had a special carriage on the Western Railway which provided both studio and darkroom, and took some of the early photographs of the West Coast mines. Stephen III commenced his working life as a surveyor, but soon became a landscape photographer of distinction.

Using a 10" x 12" plate camera, he photographed the Western Tiers and Central Plateau country while cutting a track to Zeehan in 1898, and his second major project was then to photograph the Mole Creek Caves. He returned to the caves time and time again as new discoveries were made, and his negatives provide a great record of the caves there as they were. Some appeared in the press, generally the *Launceston Examiner*, many were used over the years in brochures, but probably the best series are to be found in his own high quality postcard prints. He also provides early views of Gunns Plains Caves, the cave of Goat Island, and a number of the pseudokarst caves.

His other exploits include the first winter ascent of Ben Lomond, exploration of the Cradle Mountain area, and the introduction of Gustav Weindorfer to that area, and what is claimed to be the first aerial photography in Australia (Cato 1979).

One of the additional benefits of the postcard copies is that they may have letters of interest on the back. Two cards from Gunns Plains, dated 19th. February 1909, in my own collection have together a letter which says, inter alia :

> '. . . they were officially opened by the Premier and party on Jan 5th., three days after our visit. Over 200 persons wnet through, you were taken in by the guide 10 at a time, being charged one shilling for admission . . . you have to have lights, each of our party had an acetylene gas lamp, we also had magnesium lights . . . about 60 persons entered into them the day we went through . . . we were in just one hour and a quarter.'

CAVES IN FICTION AND POETRY

Marie Bjelke-Peterson, who migrated with her family to Tasmania from Denmark, wrote a large number of 'romantic' novels all with a strong evangelical Christian flavour , between 1917 and 1937. The first of these, *The Captive Singer* (1917), tells of love in and about the Mole Creek Caves. Although she was highly regarded in her own time - a sort of Barbara Cartland of the Australian bush - and actually won the King's Silver Jubilee Medal for writing in 1935, her writing is so melodramatic that it is hard to read it today as other than humour :

> . . . I suppose I might as well let you know all - such scandal soon leaks out ; I tell you she has behaved most disgracefully, most shockingly ! They have spent afternoons together in dark caves, terribly wet places where you prowl about under hills and what not ; think of my daughter in that awful blackness for hours together with such a man ! However she comes to like these things is past my comprehension !

You will all be glad to know that, nevertheless, the heroine's story has a happy, economically successful and Christian ending.

But there is worse. Frederick Charles Meyer wrote and published at least three books of verse during the 1920's and 1930's. The last of these, *Bijoux of Mountains and Valleys of Tasmania* was copyrighted on 20th. December 1940, and one assumes it appeared at about that time. Meyer is without question a worthy rival to that famous Scot, William McGonagall, who is notorious for his doggerel commentary upon almost everything which was characterised by its forced rhyming and absence of rhythm, and is often described as the world's worst poet. Meyer took it upon himself to immortalise caves at Jenolan, Buchan, Hastings, and Mole Creek. I'll restrain myself and quote only one example :

NEWDEGATE CAVE

Stalagmites are forming figures,
    Hanging down in thousand forms,
Personalities of vigour,
    Frame the ceiling and the roof,
with silent whispers they confer.

Stalagmites are growing slowly,
    Drop by drop accumulating,
Men and women high and lowly,
    Seem together promenading,
Upturned faces sweet and holy.

Stalagmites are working wonders,
    Rising almost from a mound,
Others like the winged condors,
    Spontaneously flee from the ground,
And leave behind the wanderers.

CONCLUSION

I suspect many more historical materials relating to Tasmanian caves remain to be found. My own work in relation to other Australian caving areas has unncovered a remarkable amount of memorabilia, and this has often proved invaluable not only in understanding the past of our caves, but more importantly, in helping to guide management decisions today. I would encourage any of you to seek out any such materials and do what you can to ensure their proper preservation and recording.

SOME HISTORIC MATERIALS

1877 Oakden's Cave, Near Chudleigh, Tasmania. Wood engraving 22.8 cm. x 19.8 cm., from the *Illustrated Australian News*

1879 Tenison-Woods, Rev. J.E., The Wonders of Nature in Australia, *Sydney Mail*, 12th. April, 1879, p. 569.

1899 Morton, C.E. (Ed.), *Tourists' Guide to Tasmania*, Hobart : Union Steamship Company, 124 pp.

1904 and later
Beattie, John Watt, Numerous postcards, generally real photos.

1905 and later
Spurling & Son, Launceston, Numerous postcards, both Collotype and real photos. In particular, note the Collotype cards with the following numbers ;

135-139	Scott's Cave
400-423	King Solomon's Cave
424-435	Scott's Cave
464-466	Baldock's Cave
655-657	Marakupa (sic) Caves
439-443	Ulverstone (Gunns Plains) Cave

1916 *Tasmanian Railway Tours / Mole Creek District*, Hobart : Tasmanian Government Tourist Departmnent, 4 pp., 10 cm. x 17.5 cm. (also 1926 edition)

1917 Bjelke Peterson, Marie, *The Captive Singer*, London : Hodder & Stoughton, 307 pp.

1918 Tasmanian Government Tourist Department, *Complete Guide to Tasmania*, Hobart : John Vail, Government Printer.

n.d. but late 1920's or early 1930's.
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Observations in Mullamullang Cave in 1990- 1991

Sub-Title: The Big Breather Revisited.

Neville Michie.

Abstract

A method is described for observing air flow in a large cave by measuring the pressure drop across a constriction in the cave through which all the air flows. The relationship of air flow and consequent pressure drop for the Southerly Buster in Mullamullang Cave, Western Australia is given with the results of observations of barometric pressure and air flow measurements over a sixteen day period.

Introduction.

Mullamullang Cave, Western Australia, has been well known as a barometric breathing cave since the major expeditions in 1966 [1]. The author has made measurements in this cave to try to learn more of the structure of the cave and to find answers to questions of the interactions of barometrically induced air flow and the density motivated airflows that would be expected to operate in the cave. A suitable set of data would enable the testing of the application of the theory proposed by Wigley of barometric flow from porous rock [2].

In 1979, after travelling to Perth for an ASF conference, observations of the air flow and barometric pressure were made in Mullamullang Cave with an electronic recorder for air flow and temperatures and a precision aneroid barometer that was read every 10 to 20 minutes [3]. 54 hours of observations were made. Extensive analysis by Fourier transform showed only part of the response of the cave to the stimulus of changing barometric pressure, as much of the air movement was caused by changes in barometric pressure that had occurred before the observation started and a proportion of the effects of the barometric pressure that was observed would occur after measurement ceased. The attempt to extract more information from this data was abandoned.

Fourier analysis involves separating the component sine functions from which any function is composed. The barometric pressure and the resulting air flow were both analysed to give a list of amplitude of stimulus signal, which is the barometric pressure, and the amplitude and phase of the response, the air flow, for each frequency. The ratios of these gives the response spectrum of the cave. As a rule of thumb, it is good to have a data set at least 10 cycles long at the lowest frequency of interest, as this reduces the effects of truncating the record at the ends. The biggest problem with this approach is that it relies on all frequencies being present in the stimulus signal. In this case some signals a very strong, like the twice daily swing in barometric pressure, but other frequencies may only appear at low amplitude as components of the transient change when an event occurs such as a storm front moving over the cave entrance.

In 1990, on the way to another ASF conference in WA, a new attempt was made to measure the Mullamullang phenomenon. If a substantial improvement was to be made in the analysis of the cave then at least ten times the length of observation was needed and the equipment would have to be left running in the cave for some weeks. It was not practical to use one of the sensitive vane anemometers to measure the air flow as in 16 days of continuous running the possibility of violent wind gusts and the vulnerability of a neat brass anemometer sitting in the middle of a track frequented by hordes of itinerant souvenir hunters made its continuous operation and even eventual recovery doubtful. So another strategy was devised. The Southerly Buster would be used as an orifice - plate flow meter, that is the pressure drop across the constriction would be used as a measure of the flow rate. The Southerly Buster is a constriction of only about four square metres cross-section near the entrance of the cave and is renowned for the fierce wind that often blows through it.

Method

A sensitive electronic manometer had been constructed and calibrated to measure the pressure difference between the inside and outside of the Southerly Buster. The relationship between pressure difference and flow rate is approximately that pressure is proportional to the square of the flow rate, so that if flow changes by a factor of ten then the pressure drop changes by a factor of one hundred. This makes it difficult to measure for all rates so the instrument was made to deliver two outputs, one ten times larger than the other so that if the sensitive trace went beyond full scale deflection on the recorder then the less sensitive trace would be giving a significant reading.

The equipment was buried to avoid unwanted attention, and a pressure tube of 4mm. PVC tube was passed through the Southerly Buster to an area of little air velocity and was hidden, as far as possible, from view. In the instrument package there was a thermometer, a sensitive aneroid barometric transducer and the sensitive pressure transducer. The recorder logged a measurement every 16 seconds from one of the instruments in rotation.

We returned to the instruments on our return trip some two weeks later, and set about the calibration of the Southerly Buster. A section of the passage in the cave was located where the cross sectional area was measured as 35.5 square metres. This area was chosen because for at least 20 metres in either direction the walls were parallel and of uniform roughness. This would ensure that the air flow would be uniform across the area. This area was surveyed, see Figure 1, and the vane anemometer was set up with another recorder to record the velocity of the air flow. This gave a record of 37 hours with simultaneous measurements of pressure drop and air flow. The sampling point in the middle of the passage was assumed to have a velocity exactly 30% greater than the average in the passage. The data were fitted by a least squared error method with a function which is now taken as the calibration of the Southerly Buster.

RESULTS

Figure 2 shows a plot of the hourly averages of pressure drop and air flow and also the fitted function.

The relationship was found to be:

$$P = 0.5035\ F + 0.01609\ F^2$$

Where P is the pressure drop in Pascals and F is the airflow through the Southerly Buster in cubic metres per second.

During the course of the observations there had been a small shift in the zero of the manometer, but several methods exist to correct for this. When the chart was examined, values of air pressure and values of pressure drop were extracted for each hour. These were entered into a computer so that arithmetic and statistical operations could be applied to the data. The resultant data were plotted in the form of total air flow and barometric pressure, see Figure 3. Note the time delay between the variables and the time it takes for flow to catch up to the pressure after a

transient swing. By inspection of the data set, it is obvious that there may be components of the cave response with times of the order of ten days and that this data set still
may still not have adequately sampled the cave's response.

The task of pre-processing the data, transforming it, and analysing the system response will have to wait for available computing facilities and the time to perform the task.

Conclusions

The method of calibrating a natural constriction as an orifice plate in a flow meter has been shown to be useful. The data collected shows (by inspection) that long period transients have a larger response than shorter period transients, indicating that elements of the system response have long times of equilibration (ten days or more). The presence of one constriction with a significantly square law of pressure drop vs. flow rate raises the possibility of the cave not being a linear system, perhaps the system response could even have chaotic elements.

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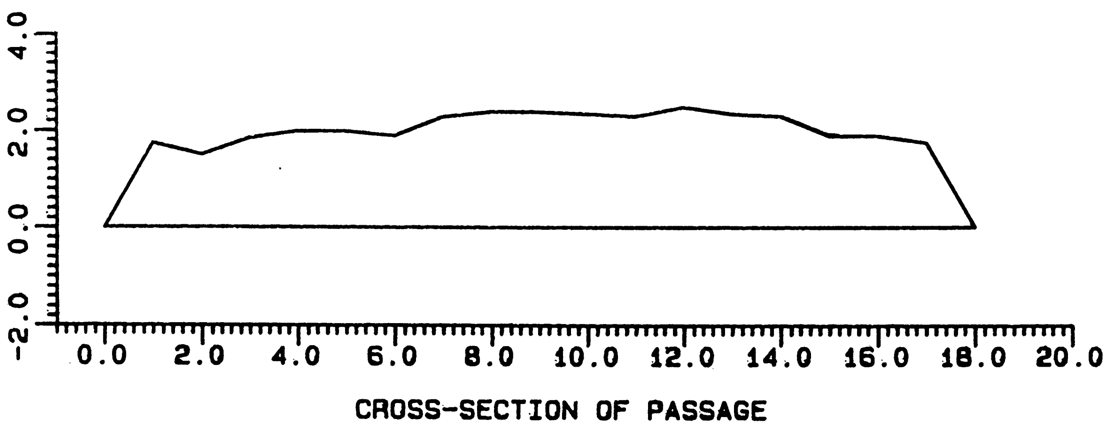

Figure 1. The cross section of the cave where the anemometer was located 1 metre from the ground in the middle of the passage.

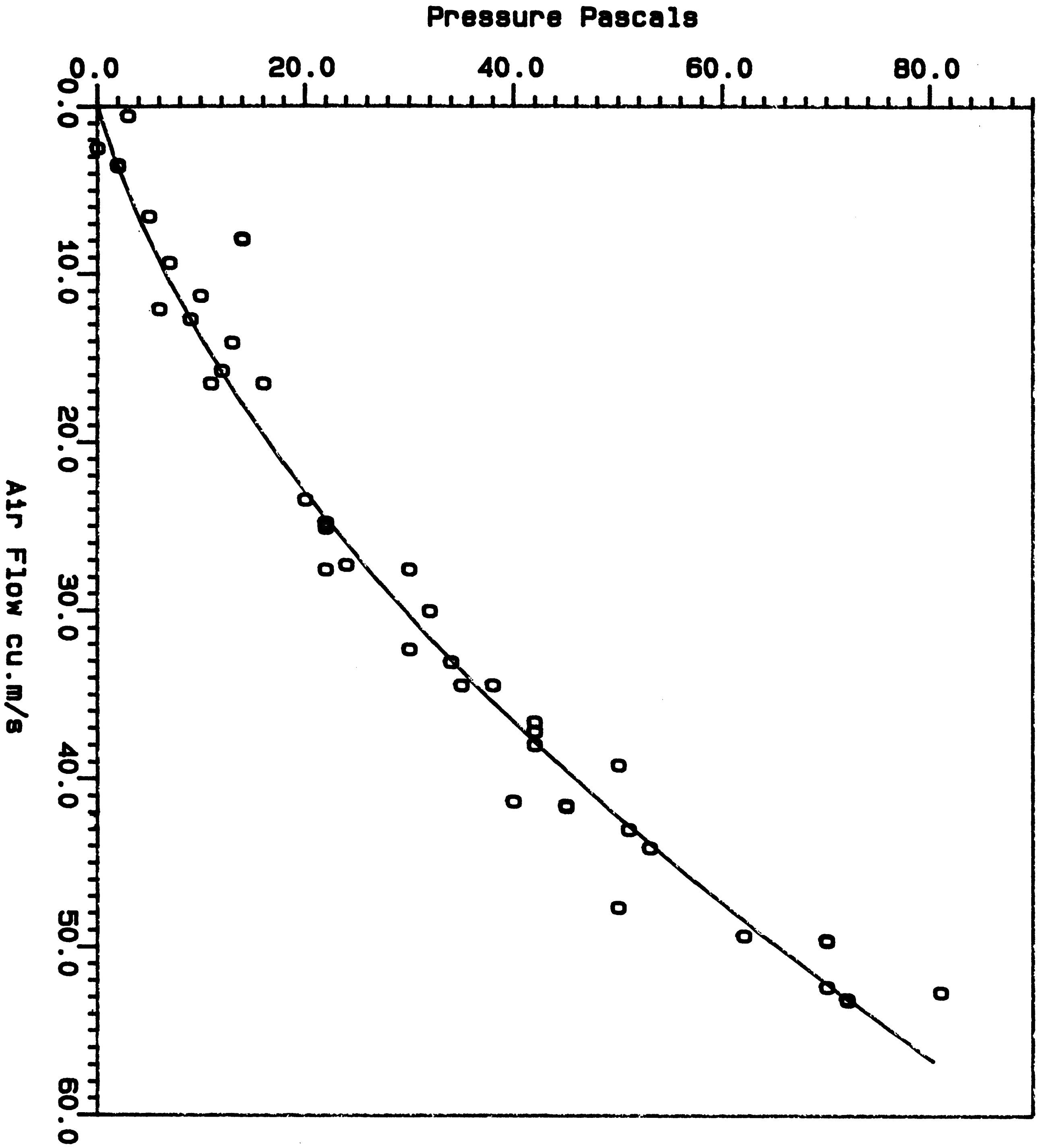

Figure 2. A scatter plot of <the total air flow for the hour> against <the hourly average of pressure drop across the Southerly Buster> with the least squares fitted function.

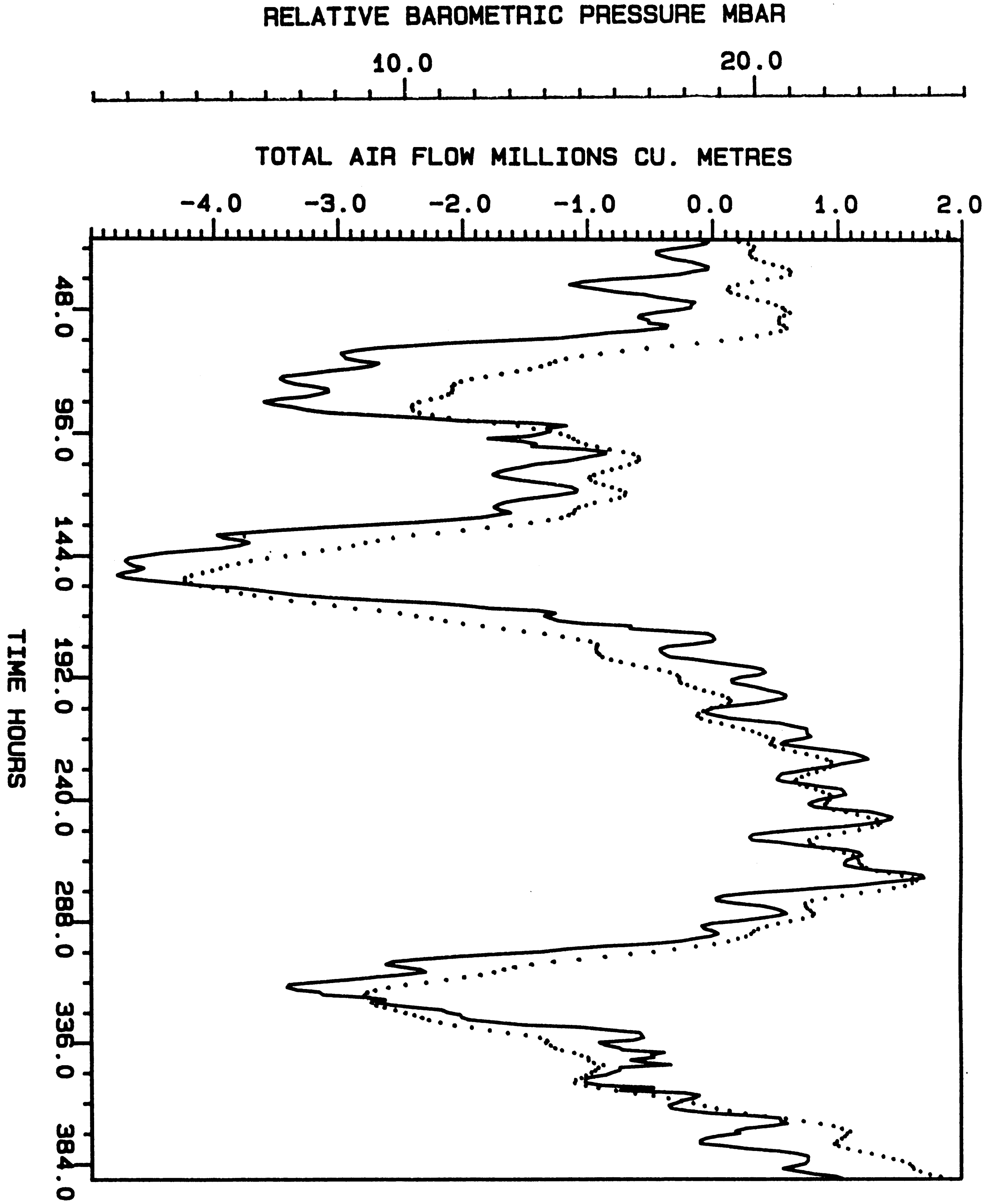

Figure 3. Plot of the barometric pressure (solid line) and the accumulated flow into the cave (dotted line). The time (0 hours) starts at midnight 28th Dec. 1990.

Paper 2 for Tasmanian Conference 1993

Recycling Mine Cap lamps.

Neville Michie.

Many of the lamps of the Oldham or MSA type cap lamp units have found their way into the hands (or at least on to the heads) of cavers. Because of the strength of their engineering design, they survive for many years, far outlasting the lead - acid accumulators that powered them.

The cost of the modern miner's lamp accumulators has become unreasonable, and their performance in caving situations has become unacceptably poor. For example, whereas the old hard rubber cased accumulators from 1960 that I have will still give about 6 hours high beam operation, batteries as little as 3 years old become open circuit, or short circuit, and are unusable. The old batteries used thick sponge - wood separators and tubular *Exide-Ironclad* type positive plates and so the batteries could survive being discharged and neglected. The modern batteries may be cheaper to manufacture but they are far less durable. So when it comes to a matter of replacing the accumulators for miner's cap lamps there are several options:

(1) replace the accumulator with a new one ($100+). If you do this be warned about a change to modern mine accumulators. They are now fitted with a fuse in the lid of the accumulator which is not accessible without special tools i.e. not likely to be able to be repaired in a cave. My advice is to open the lid of the accumulator when you get it and wire a link of two strands of 8 amp or one of 16 amp fuse wire across the fuse. This is easily available for repairing household fuses. This will ensure that the fuse in your lamp will not blow while you are underground. The original fuse was mainly used to satisfy mine safety demands that no spark should be generated by a lamp when in explosive atmospheres, even if a rail car ran over a lamp lead. I have not heard of any cavers having accidents with the old type of accumulator that had no fuse, but a short circuit in the cap lamp would blow a 16 amp fuse rather than melt the cable.

(2) The second option is to buy a "gel cell", a sealed no maintenance (except to keep it charged) lead - acid battery, about $30+. There are a large number of brands, sizes and voltages of these batteries so you can find one to suit your needs. They are not armoured for cave use, have no belt

fixtures and have no strain relief facilities for anchoring the cable of the cap lamp. So to use these batteries some alternatives exist:

(a) find a type that will fit inside the emptied casing of your old miners lamp accumulator. I have seen a battery that will fit inside a modern (plastic) accumulator case.

(b) make or find a strong case with belt fixtures and anchor point for the lamp cable.

(3) The third battery option is to find a nickel - cadmium

accumulator to run the system. This may need a case - belt - cable anchor job like (2) (b). The voltages that nickel - cadmium batteries come in are 1.2, 2.4, 3.6, 4.8 and 6 volts. There are reasons why the 2.5 volt system as is used by the Speleo Technics FX-2 is a good idea, the nickel cadmium cells run out very quickly, and, on a high voltage (e.g. 6 volts) system, as the battery runs down, one cell , the weakest, will run flat first and it will then charge in reverse polarity by the current of the other cells. This is bad for NiCds. With two cells, when one is flat the other does not have enough voltage on its own to seriously back charge the other, besides the light has gone out and the battery will be turned off. The nickel - cadmium batteries are rated as having a life of over 200 charge discharge cycles, but they should be deep cycled occasionally to avoid apparent loss of capacity, and there is no practical quick - top - up charging system that is as good as that for lead - acid batteries.

(4) the fourth battery option is to make up a system to use primary cells. These are the disposable torch batteries that are universally available. For caving the best type is the alkaline cell. A D size alkaline cell should have a capacity of over 10 Ampere/hours and a shelf life of about 4 years. Although they seem expensive, it is often found that in a four year period of caving, the cost of a miners lamp accumulator, gel-cell or nickel - cadmium system is greater that the cost of running a system with primary cells.

To use dry cells a battery holder is needed together with the attributes that a rechargeable battery needs. One solution is the Bonwick pattern dry-cell holders. The first of these was made by John Bonwick for his own use, and used 4 D size dry cells to run 6 Volt torch bulbs in a cap lamp. Figure 1 shows the version of this design that I made, slightly different to John Bonwick's. The batteries are open to the world, but are restrained by rubber bands. This can be made in two cell or four cell versions for 3 Volts or 6 Volts. Although it occasionally falters, a little push on the batteries clears any dirt on the contacts. The unit will fit in a pocket which may be more convenient than on a belt. The 3 volt version with a 300mA bulb should run for 30 hours on two alkaline D cells.

Another do-it-yourself battery holder is the Ackroyd type *sewer light* [1]. These are robust and can be made waterproof, and are made with a technology available to most cavers. I have made these for both NiCd and alkaline D cells. This introduces the topic of:

Interchangeable Systems.

My variation on the Ackroyd Sewer Light design (Figure 2) introduces a combined strain relief and connector (Figure 3). The internals are different from the original, a keyed bottom contact plate, and a heavily engineered top contact/cable entry section. With a lamp fitted with a connector, one can swap from a rechargeable system for every day caving to a dry cell system for expeditions that can be transported in aeroplanes and does not rely on recharging power sources. In between times a pack of dry cells can be a reserve for a rechargeable system on long trips. My systems have 4 Volt gel-cell packs, 3 cell NiCd Sewer Light packs and 3 cell alkaline Sewer Light packs.

The lead acid, NiCd or alkaline cell choice gives you the option of using other than the 4 Volt system used in the original miners lamps. Of the other systems 3 Volt and 6 Volt would seem to be the best idea because if you change voltage you have to find a source of lamps of the appropriate power and voltage.

Lamps (bulbs globes etc)

Quartz-Iodine (halogen) bulbs are only available for high current rating of about 0.8 Ampere or higher. Very white light, very high efficiency.

Gas filled bulbs use very low pressure gas in bulb to stop tungsten filament material depositing on the bulb, blackening it and reducing light output. The gas that works best is Krypton, but Xenon or Argon will work. These bubs can be run brighter without blackening the bulb and as efficiency increases with filament temperature these are more efficient than vacuum bulbs.

Vacuum filled (or emptied) bulbs blacken if run at maximum brightness thus shortening their efficient life. If they are run at a lower voltage they will last much longer but they will be much less efficient. Most bulbs are of this type unless marked otherwise.

Sources of bulbs. Good hardware stores have a range of bulbs in various base styles, mainly vacuum filled but some are Quartz- Iodine. Maglight sellers have some interesting pre-focus gas filled bulbs but they may not focus properly in a miners cap lamp. A 0.7 Ampere bulb will run for 60 - 70% longer on alkaline cells than a 1 Ampere Quartz - Iodine bulb because the batteries become more efficient at a lower drain rate. Petzl sellers have gas filled bubs of lower power rating as well as quartz. Some are pre-focus, some miniature edison screw,(the traditional torch bulb base).

Recharging storage batteries.

NiCd batteries should be recharged at the 10 hour rate or less at constant current for 140% of the charge used. Usually best to run them flat after a trip and charge them for 24 hours at about the 20 hour rate.

Lead acid, including gel-cells, are very easy and fast to recharge with constant voltage electronic regulators. There is no need to limit the maximum charging rate if the regulator has safe area operation limits unless the battery is very hot (do not leave batteries in the sun as the high temperature degrades their operation). Simply connect the battery to the charger and the battery will regulate its own charging rate to safe levels and stop drawing power when it is fully charged. Figure 4 shows the circuit of a good automatic charger for 4 volt batteries (the same regulator can regulate from 2 volts to 24 volts by changing the resistors.) Do not leave gel-cells in a discharged state; they sometimes get into a state where they will not accept charging, the only way to cure this is to charge them. This may mean leaving the battery on a charger for weeks until the minute current that leaks into them starts to build up to the normal charging rate.

Dry cells are unsafe to recharge. Although some recharging is possible, the gas that may evolve can pressurise them and cause them to leak or explode. The state that the cells would be in would be too unreliable for cave lighting.

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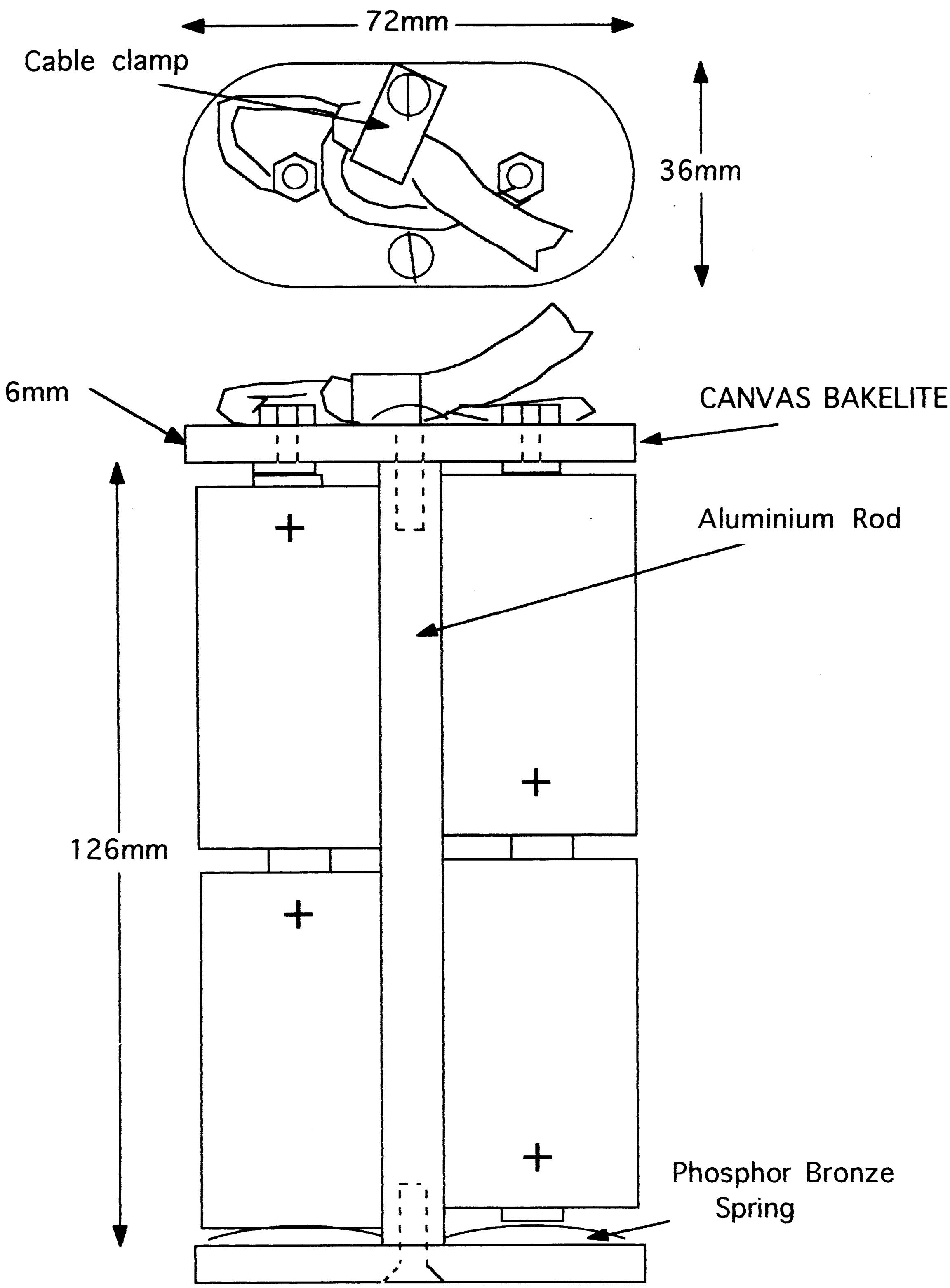

Figure 1. Four cell battery holder of the Bonwick type. The phosphor bronze contact spring is secured with two small screws to the insulating board.

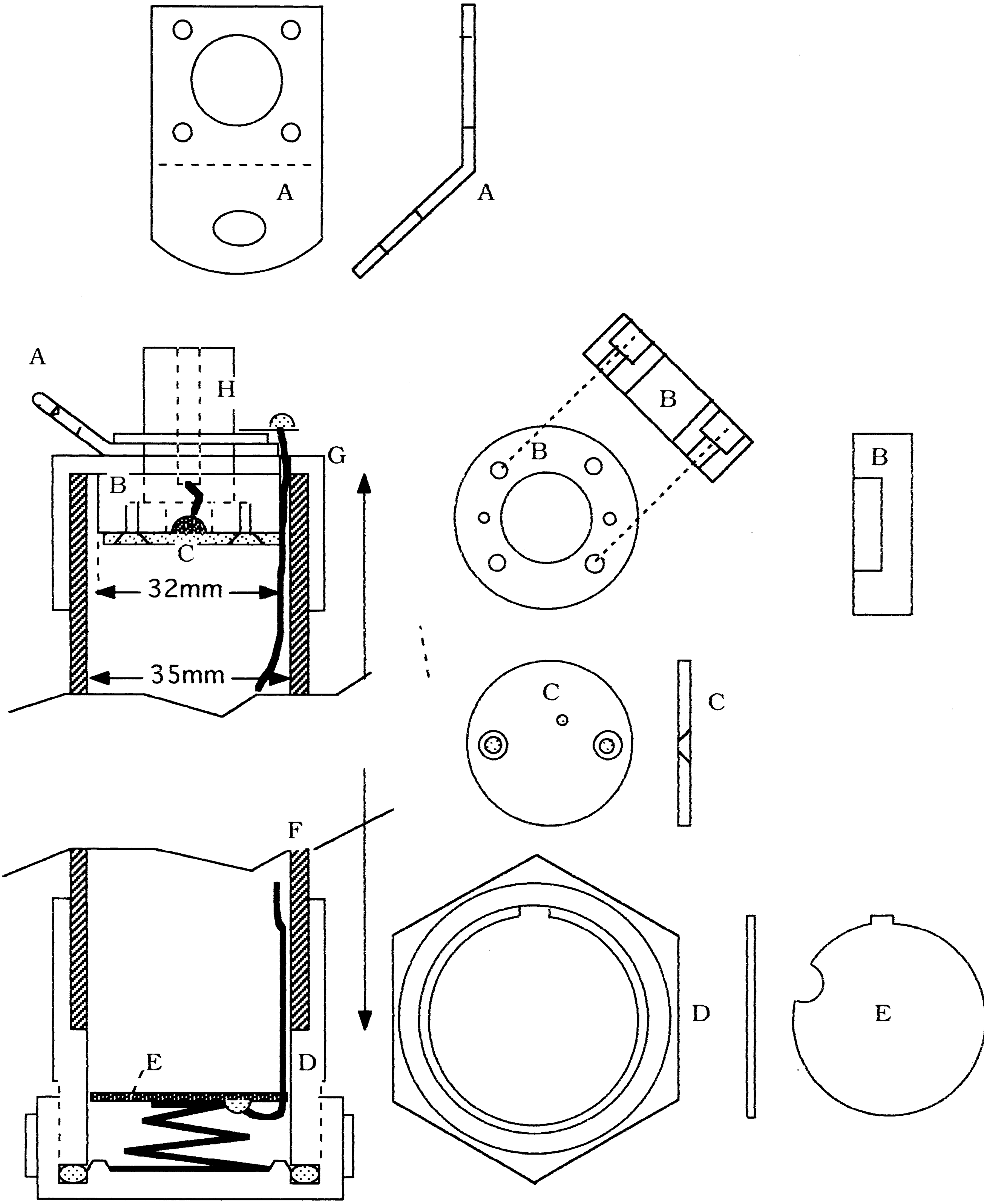

Figure 2. Sewer Light type battery holder. A is the lug to secure holder to a belt, B is made of PVC or wood, C is a brass disc 1.6mm thick, D is the screwed base fitting, E is a keyed disc of 1.6mm. brass, F is PVC 40 mm. tube, G is the cap fitting, H is a UHF co-axial cable connector. Four 3mm countersunk screws which must not contact C pass through B and secure the co-ax connector.

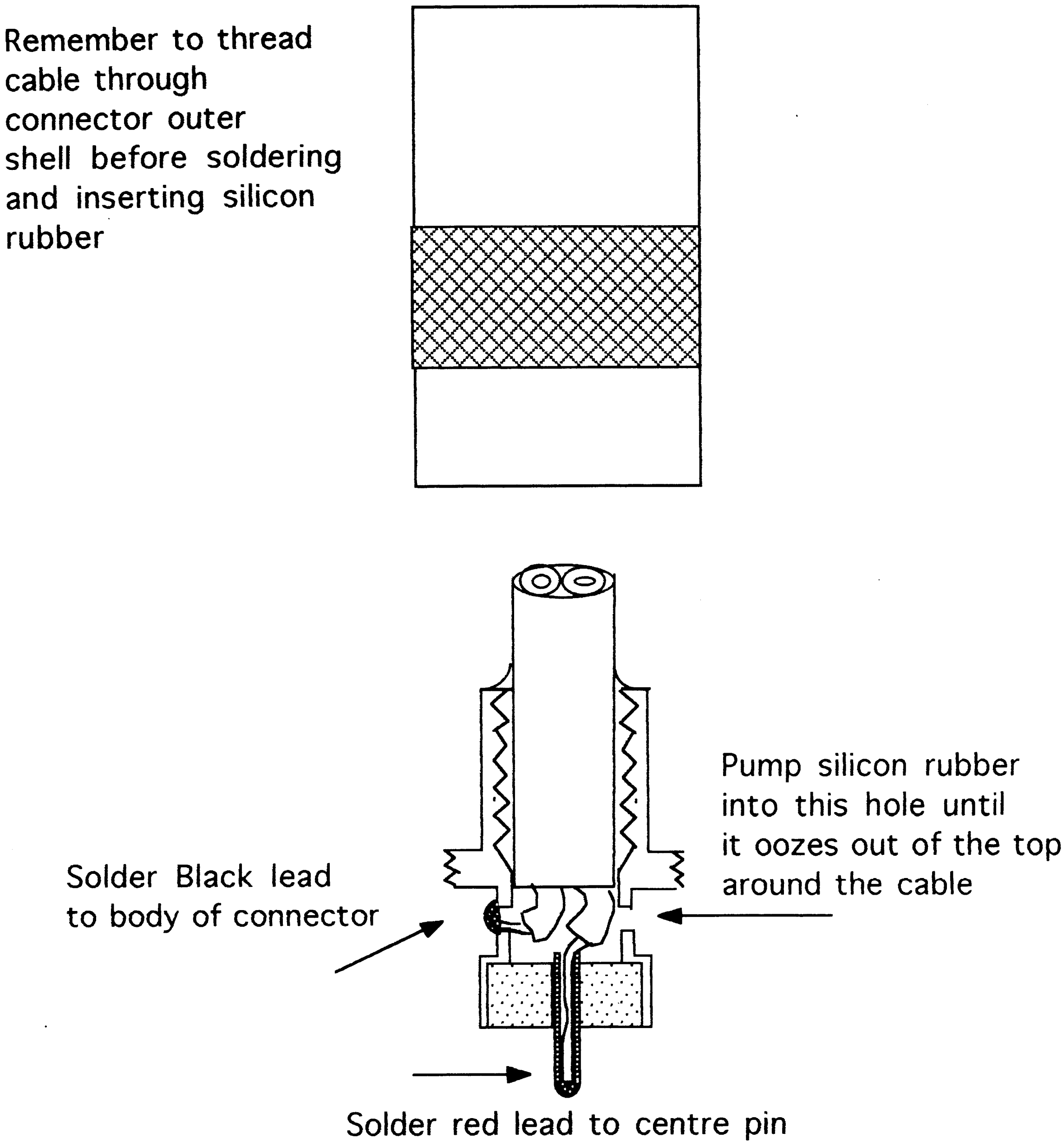

Figure 3. Detail of the fixing and sealing of the co-ax connector to the cap lamp cable. Use the roof and gutter silicone rubber, not the type that smells of vinegar.

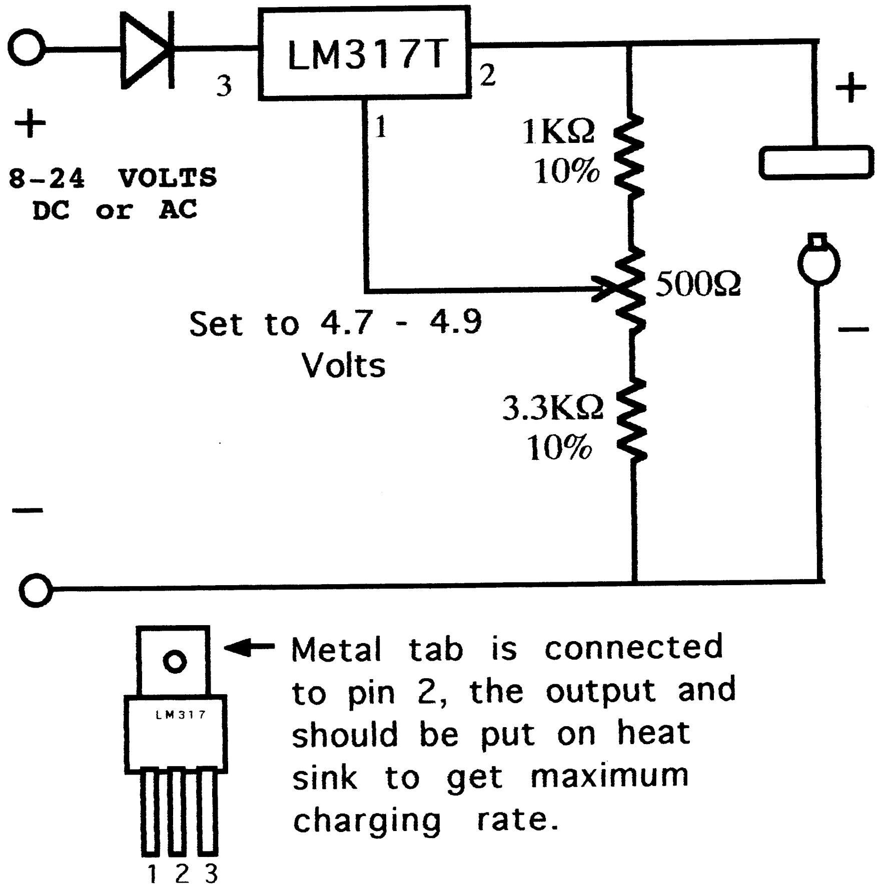

Figure 4. A circuit for a 4 Volt lead acid battery charger. To adjust, connect a 100 ohm resistor across the output terminals and adjust the output voltage measured with a digital voltmeter.