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Helictite

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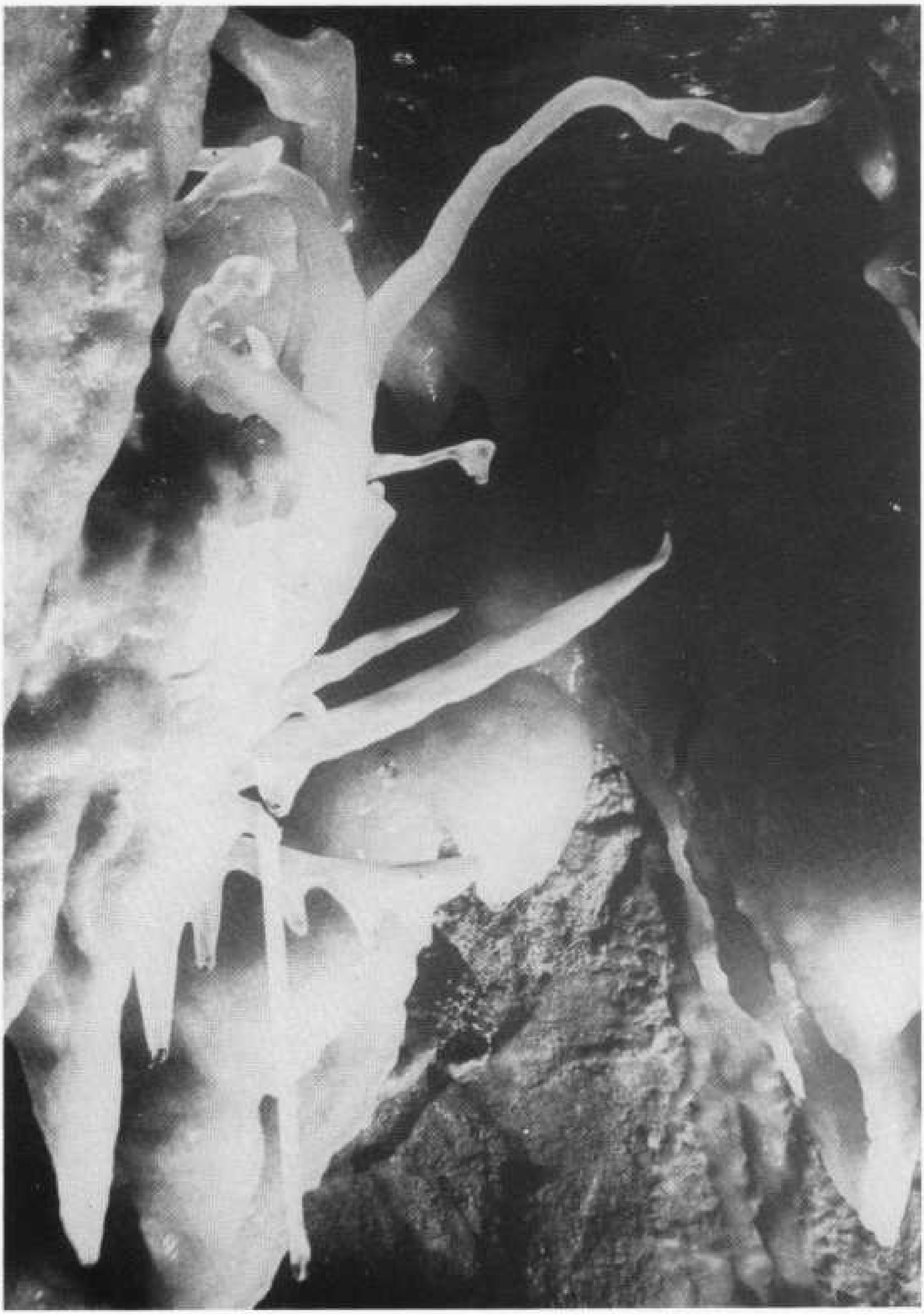

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LAND MANAGEMENT, WATER QUALITY AND SEDIMENTATION IN SUBSURFACE KARST CONDUITS

Kevin Kiernan, Rolan Eberhard & Bryan Campbell

ABSTRACT

Observations from several Tasmanian karsts suggest considerable changes have occurred underground following forest clearing for pasture and some commercial forestry practices. The changes include altered hydrological behaviour and water quality changes, together with the advent of sedimentation patterns that are (1) inconsistent with the stratigraphic record of cave sediment accumulation prior to human interference in the catchment, (2) at variance with what is happening beneath comparable undisturbed catchments, and (3) indicate the deposition of significantly greater volumes of sediment since catchment disturbance than was previously the case. Preliminary results from several Tasmanian caves suggest that the proportion of the anthropogenic isotope caesium-137 in cave sediments deposited during recent decades is inversely proportional to the broad degree to which the catchment overlying the caves has been disturbed. This is interpreted as being the result of the dilution of sediment eroded from the land surface by material derived from sub-surface sources. This seems most likely to be due to changed patterns of diffuse infiltration.

INTRODUCTION

The sensitivity of karst environments to land management practices is increasingly appreciated (Yuan 1988; Beck and Wilson 1987, Kiernan 1988). Disturbance of the natural vegetation cover in karst inevitably changes hydrological conditions due to modification of the relationships between rainfall, evapotranspiration, infiltration and surface runoff. Infiltration is likely to increase if transpiration is reduced through removal of forest and this is likely to increase the potential of cave waters to effect erosion and to transport sediment, resulting in changed patterns of sedimentation. A subsequent decrease in flow as a result of increased transpiration by vigorous regrowth forest is likely to inhibit both erosion and sediment entrainment. These changes are likely to favour the accumulation in caves of sediment eroded from the surface, from the epikarst, or from fossil cave deposits. This may diminish groundwater quality, sedimentation may derange groundwater

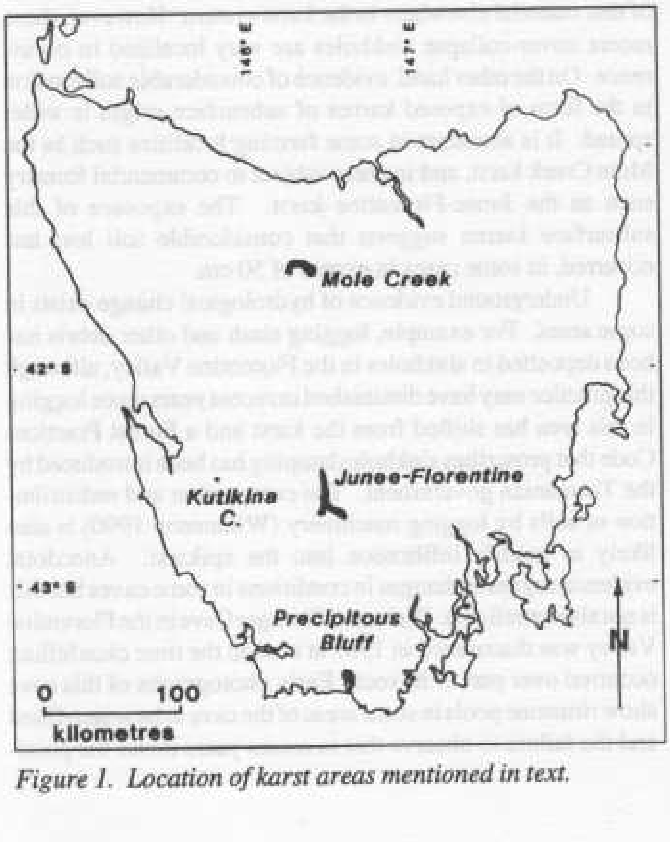

Figure 1. Location of karst areas mentioned in text.

systems, and nature conservation values may be compromised. Other components of a cave environment may also be put at risk, for example specialised cave biota that are highly adapted to stable conditions underground, palaeoenvironmental records contained in fossil clastic deposits or speleothems, the scenic attractiveness of caves, or the safety of caves as a recreational venue.

Gunn and Turnpenny (1988) demonstrated that forest clearing in the Waitomo karst, New Zealand, caused modification of cave stream discharge, apparently due to sinkholes becoming blocked by debris, leading to relatively greater overland stormflow at the expense of a subsurface stream. At a higher intensity of land-use, serious surface flooding problems have arisen in some parts of the world where urban development has resulted in an increase in the catchment of sinkholes due to the expansion of impermeable sealed surfaces, at the same time the capacity of the sinkholes to evacuate concentrated aquifer recharge has been diminished by sediment accumulation (Huppert *et al.* 1983). Contributors to Beck and Wilson (1987) present examples of increased land surface instability in karst due to land management practices, which imply accelerated removal of regolith material by infiltration waters.

Present understanding of the impacts of human-induced environmental change on underground karst conduits in the Australasian region remains based largely on anecdotal evidence, qualitative impressions and theoretical principles. Few attempts have been made to demonstrate the real impacts in quantitative terms. Land-use in Australasian karsts is seldom intensive and the consequences underground of surface disturbance are seldom conspicuous. Where no study has been undertaken an erroneous belief can arise that no real impact has been generated.

One likely means of demonstrating the extent of change underground lies in the study of cave sediments. While Tasmanian cave sediments have been the subject of some study this has generally focused on relatively ancient sediments that might shed light on Pleistocene climatic change rather than recent sediments. Previous studies have generally involved analysis of coarse gravel sequences or cyroclastic deposits interpreted as having been deposited under cold climatic conditions when the forest biomass was less than now and vigorous

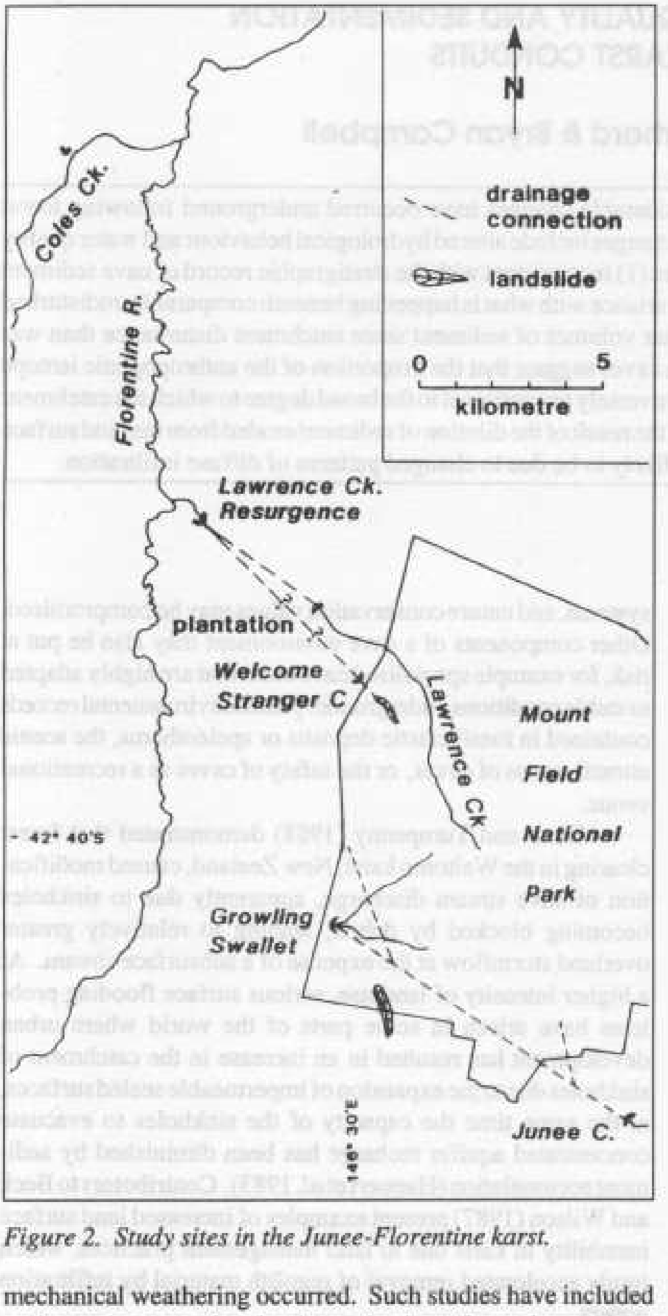

Figure 2. Study sites in the Junee-Florentine karst.

mechanical weathering occurred. Such studies have included radiometric assay of speleothems that have formed upon these sediments, predominantly under interglacial conditions. Cave sedimentation rates appear to have been very much higher during the Pleistocene than during the Holocene. The precise rates are poorly known other than in dated archaeological sites where the natural sediment contribution is masked by large volumes of anthropogenic stone and bone, as in Kutikina Cave where a mean accumulation rate of 0.26 mm/yr is evident for the period 20 000-15 000 years BP (Kiernan et *al* 1983). Some broad approximation of the maximum potential rate of natural alluvial sedimentation is offered by closed lake basins. These represent much more effective sediment sinks than do most stream caves where sediment may periodically be scoured by floods. Mean accumulation rates of c. 100 mm/yr are evident from 8 000-10 000 year records from alpine and subalpine lakes with undisturbed catchments (Macphail 1979).

Negligible research has been undertaken in Tasmanian caves into the most recent cave sediments which for the most part are much finer in calibre than those deposited during the Pleistocene. This paper reports a preliminary examination of evidence for recent changes in hydrological conditions, water chemistry and sedimentation that appear to have occurred in some karst conduits. The observations span a range of areas (figure 1) subject to a variety of land management practices from forest clearing to complete protection of the environment.

EVIDENCE OF HYDROLOGICAL CHANGE AND CAVE SEDIMENTATION RELATED TO LAND MANAGEMENT

Karstic rocks occur at the surface over about 4.4% of Tasmania. Fluviokarsts predominate, but some glaciokarsts and coastal karsts are also present. A variety of management concerns have been voiced (Kiernan, 1988). Tasmanian karsts include areas of undisturbed wilderness, forests that are utilised to varying degrees of intensity for commercial logging, areas cleared of natural vegetation to provide pasture or croplands, and areas where some small villages have been established. A variety of allogenic regolith materials overlie the carbonate bedrock in most of these karsts.

Although some evidence exists to suggest that fires lit by Tasmanian Aborigines may have facilitated erosion and the accumulation of sediment in caves in pre-European times (Kiernan et al. 1983) the evidence of impacts by Europeans is more obvious. The most conspicuous evidence of environmental change associated with the management of some of these karsts is the accelerated formation of cover collapse sinkholes in a few areas where the natural vegetation has been removed. Given the virtual complete absence of active sinkhole formation in areas of undisturbed forest, the recent sinkholes formed in farmland and forestry areas have been attributed to the removal of forest and a consequent dramatic increase in infiltration relative to transpiration. Drainage changes associated with road construction and with groundwater pumping have also been implicated in some Tasmanian sinkhole problems (Kiernan, 1989). These collapses all imply the removal of material from the regolith which in turn implies the deposition of that material elsewhere in the karst system. However, these recent cover-collapse sinkholes are very localised in occurrence. On the other hand, evidence of considerable soil erosion in the form of exposed karren of subsurface origin is widespread. It is abundant in some farming localities such as the Mole Creek karst, and in areas subject to commercial forestry such as the Junee-Florentine karst. The exposure of this subsurface karren suggests that considerable soil loss has occurred, in some cases in excess of 50 cm.

Underground evidence of hydrological change exists in some areas. For example, logging slash and other debris has been deposited in sinkholes in the Florentine Valley, although this practice may have diminished in recent years since logging in this area has shifted from the karst and a Forest Practices Code that proscribes sinkhole dumping has been introduced by the Tasmanian government. The compaction and redistribution of soils by logging machinery (Wiliamson 1990) is also likely to modify infiltration into the epikarst. Anecdotal evidence suggests changes in conditions in some caves but this is not always reliable. Welcome Stranger Cave in the Florentine Valley was discovered in 1969 at around the time clearfelling occurred over part of its roof. Early photographs of this cave show rimstone pools in some areas of the cave to be water-filled and the failure to observe this in recent years raises the possibility that logging was a factor in the change. While the observed conditions would be consistent with increased infiltration following removal of the forest, and/or subsequent diminished infiltration with the advent of vigorous regrowth scrub, the impact of logging is superimposed on the advent of generally drier conditions in Tasmania during the subsequent 15 years, and it is also possible that the rimstones have been full at times when no visitors have been present.

Sediment that is believed to have accumulated within the last few decades occurs in some caves in the Mole Creek area where forestry and farming enterprises have operated. The presence of sawn timbers in sediment at least 2 m thick that blocks the Sassafras Creek inflow cave at Mole Creek implies that this sediment postdate European settlement. Domestic and agricultural refuse forms part of the sediment in some caves. Accumulations of fine sediment of similar thickness and character have not been found in comparable situations where the forest cover is undisturbed. However, the most recent minerogenic sediments in Quarry Cave contain charcoal fragments that have been radiocarbon assayed at 1 801±310 BP (ARL 221) which implies that even in disturbed areas the most recent cave sediments have not necessarily all been deposited in response to disturbance by Europeans. Caution is required in the interpretation of the sedimentary record.

The Junee-Florentine karst has been subject to forestry activities since the 1930s, and evidence of changed patterns of erosion and sedimentation are widespread. For example, the accumulation of up to 1 m of sediment in one stream cave following clearfelling and sheet erosion in its catchment in the early 1970s precluded use of the cave as a recreational venue by cavers (Richards and Ollier 1972). Landslides that have resulted from forestry activities and which bare the regolith over extensive areas are another source of sediment. Some landslides have involved the failure of logging roads. More commonly they are the result of logging or the death of forest trees due to the escape of fires lit for forest management purposes. The loss of the trees leads to diminished drying of the regolith by transpiration which imposes increased stress on the slope, while the effective strength of the slope is reduced progressively by the rotting of tree roots that formerly served to reinforce the regolith. The largest of the landslides in the area exceed 1 km in length and in at least two cases they are known to have completely or partially blocked karst streamsinks. In some disturbed environments fresh sediment and vegetal debris have also fallen directly down holes in the roof of caves, one example being a cave near Cole Creek in the Florentine Valley that is located beneath a clearfelled ridge. This indicates that despite recent attempts to minimise the introduction of water-borne sediment into karst conduits via streams and sinkholes, material may enter more directly into caves by gravity fall into inconspicuous surface openings.

WATER QUALITY CHANGES

Unnatural changes in the quality of water are potentially of concern for several reasons. First, they may imply changes to geomorphic processes such as the corrosion of limestone or the deposition of speleothem carbonate. Second, increased turbidity levels imply the movement of sediment through the karst system. This in turn implies erosion in the catchment and raises the possibility of underground drainage being deranged due to subsurface conduits becoming blocked. Third, cave-dwelling organisms are generally highly adapted to stable conditions and have an extremely limited tolerance to changes in water chemistry, turbidity and nutrients. Fourth, unnatural changes in water quality may pose a broader risk to the potential human use of an aquifer.

Welcome Stranger Cave is an outflow stream cave in the Florentine Valley (Figure 2). On recent occasions the cave stream has been observed to have been strikingly turbid, in contrast to the previously crystal-clear water for which the cave was known (Eberhard 1992). Water tracing using fluorescein dye on 21 May 1991 has demonstrated that the principal tributary of the cave stream lies in the adjacent Mt Field National Park. However, the existence of the park has not protected the cave from gross disturbance, since the streamsink has been partially blocked by landslide debris from the adjacent steep slopes following the escape into the park of a fire lit to assist in management of the neighbouring commercial forest in the mid 1960s. This fire killed the trees at the head of the slope. Turbidity readings of up to 370 NTU (national turbidity units) recently obtained from the main stream in Welcome Stranger on 4 August 1991, a day of reasonably high flow following a period of rain, contrast dramatically with a figure of 4 NTU from an underground tributary stream in the cave and with results of no more than 5 NTU obtained from the undisturbed upper reaches of nearby Lawrence Rivulet on the same day (table 1). Turbidity levels of up to 602 NTU were recorded inside Welcome Stranger on 12 August 1991. These data from Welcome Stranger indicate the transport of sediment underground and its progressive deposition through the cave. Based on a discharge estimate of 0.1 cumec, these data imply that the main Welcome Stranger stream now transports as much as 180 kg /hr of allochthonous sediment under peak flow conditions. In contrast to Welcome Stranger, samples taken from upper Lawrence Rivulet on 12 August were again very low at 2 NTU. A second streamsink ~800 m southeast of Welcome Stranger also contributes water to the stream in that cave (Kiernan 1971) but whereas the throughflow time for the fluorescein used to originally prove the connection after rain in 1971 was only 30 minutes, the throughflow time exceeded 6 hours when the test was repeated in 1991 with a slightly lesser streamflow (Eberhard 1992).

Lawrence Rivulet itself disappears underground c. 2 km NW of Welcome Stranger Cave. Fluorescein tracing has shown that Lawrence Rivulet rises from a large spring several hundred metres from the Florentine River. The intervening terrain was extensively disturbed by quarrying and logging over a period of 30 years but large areas are now cloaked in regrowth forest. Nevertheless, abundant silt that is easily brought into suspension to produce extremely turbid conditions has significantly inhibited successful recreational cave diving at the spring and is probably the result of this surface disturbance. The extent to which sediment penetrates underground conduits depends in part on the nature of the aquifer, sediment is more likely to penetrate simple vadose or epiphreatic conduits with an open structure and strong flow and to settle out in more complex phreatic networks where flow velocities are low and there are long complexes of deep pools. The fluorescein testing was conducted under conditions of moderate flow on

Table 1. Turbidity of cave streams.

location	site/detail	turbidity (NTU)
2 August 1991		
Welcome Stranger Cave	mid cave	370
upper Lawrence Rivulet	pre-rain	2
upper Lawrence Rivulet	pre-rain	5
4 August 1991		
Welcome Stranger Cave	upstream sump	160
Welcome Stranger Cave	upstream sump	160
Welcome Stranger Cave	upstream sump	154
Welcome Stranger Cave	mid cave	150
Welcome Stranger Cave	outflow entrance	140
Welcome Stranger Cave	inner tributary	4
12 August 1991		
Welcome Stranger Cave	outflow entrance	602
Welcome Stranger Cave	outflow entrance	590
upper Lawrence Rivulet	at streamsink	2
Lawrence Rivulet	at spring	67
Junee River*	at Junee Cave	4

* mean of 15 samples taken between 24 June 1991 and 11 July 1992 was 3.9 NTU, maximum 7 NTU, minimum 1 NTU

11-12 April 1991 and involved a transit time of 13 hours for the linear distance of c. 3.5 km between the streamsink and the spring. Continuous flow fluorimetry revealed a single peak and consistent recession implying the existence of a single principal conduit but it is likely that additional tributary waters also rise from the spring. The Lawrence Rivulet spring tends to be significantly more turbid than other karst springs in the Junee-Florentine karst. For example, on 12 August 1991 the measured turbidity at the Lawrence Rivulet spring was 67 NTU, markedly higher than the 4 NTU recorded from the Junee River, a stream of comparable size that flows from a cave c. 16 km to the southeast of Welcome Stranger. Dye transit times suggest the Junee River also flows predominantly through an open conduit system.

One possible tributary to the Lawrence Rivulet spring is the Welcome Stranger stream which disappears underground again a short distance after emerging from Welcome Stranger Cave and also loses water into its bed a short distance inside the cave. Although this connection has not yet been proven by dye tracing, the much higher turbidity levels of 67 NTU at the spring on 12 August 1991 relative to those obtained from upstream Lawrence Creek (2 NTU) on the same day may be due to the contribution of water from Welcome Stranger Cave. Disturbance of low relief areas on the floor of the Florentine Valley south of the Lawrence Rivulet spring as part of forest plantation development at that time is an alternative but less likely source for the turbidity.

In some cases environmental change underground is not easy to interpret. Croesus Cave is an outflow cave c. 2 km long at the western end of the Mole Creek karst near Liena (Figure 3). This cave was originally formed by a large stream that at various times during the Pleistocene deposited coarse gravels and sands that in many instances were subsequently overlain by speleothem carbonate. However, the stream that now flows from Croesus Cave is very small, being fed by two small tributary streams and a number of smaller trickles. Croesus Cave is significant on a world scale for the presence within it of large rimstone pools that extend along almost 1 km of the streamway (Jennings, 1971). The scale and distribution of the rimstones is entirely consistent with their having been formed by the present stream, with ongoing carbonate deposition evident from a 14 mm thick crust of precipitate on a gate installed at the outflow entrance in 1961. Carbonate deposition and relatively consistent discharge of the Croesus stream suggests a predominance of autogenic diffuse infiltration over allogenic streamsink waters.

The catchment of Croesus Cave is now largely cloaked in regrowth forest but was previously subject to considerable robust forestry activity from the mid 1940s to the mid 1950s. Two lines of evidence in Croesus Cave suggest environmental change has occurred in recent decades. First, some of the rimstones in the upstream part of the cave have been largely buried by clastic sediment, some of which includes small calibre gravels. Second, minor solutional muting of some of the rimstone pools is now locally evident throughout the cave, which suggests that a change in water chemistry has occurred since the rimstones were formed. Near the upstream end of the cave corrosion and entrenchment of the rimstones is locally severe. Continuing deposition of rimstones along the length of the cave ought to be reflected in a progressive decrease in the Ca content of the cave stream towards the outflow but analyses have confirmed that the present-day chemistry is inconsistent with this demand. Some perturbations to the expected pattern are evident from unpublished water analysis performed in summer 1958 by J.N. Jennings (pers. comm.) which indicate a 33% increase in the Ca content of the cave stream in the upstream half of the cave, and then a 16% decrease in the Ca consistent with CO_2 degassing and rimstone deposition only in the downstream part of the cave. This seems to imply the advent of some downstream redistribution of Ca at that time, even by low summer flows. Analysis in June 1991 revealed a consistent downstream increase in Ca through the full length of the cave, totalling 20% between the upstream end of the accessible streamway and the downstream outflow entrance. An overall downstream increase was also recorded by Spate and Holland (1990) with a localised increase at one point which

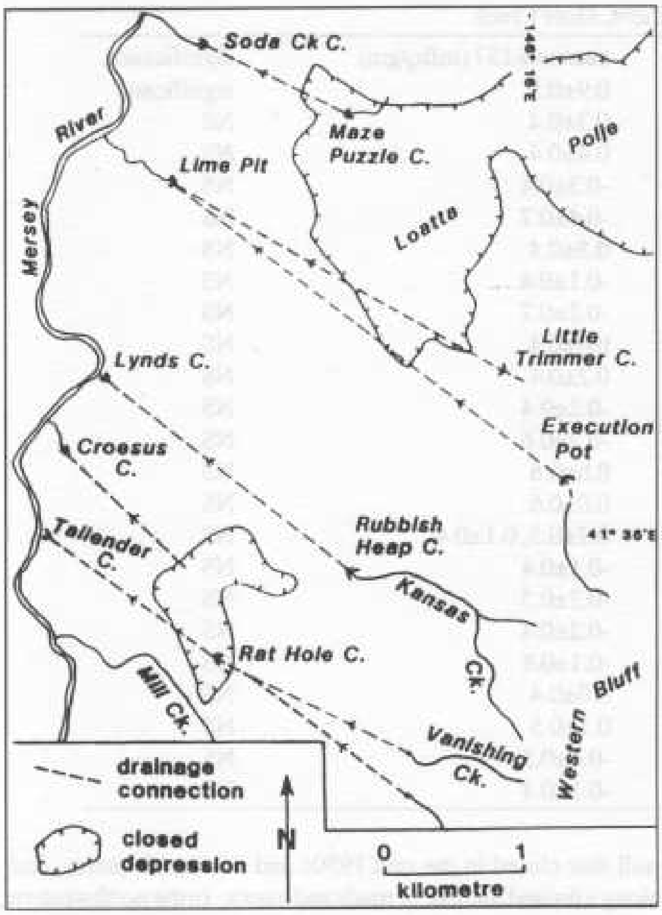

Figure 3. Study sites in the Mole Creek karst.

they attributed to a possible hidden tributary. Thus investigations to date suggest that while some rimstone deposition may be occurring in the downstream part of the cave calcium uptake, corrosion of rimstones now characterises a significant portion of the cave streamway.

The corrosion and burial of the rimstones in the upstream part of Croesus Cave bears comparison with similar speleothem degradation recorded from Tham Kaeng Khao in northern Thailand, where the cave catchment has been heavily disturbed by deforestation associated with hilltribe slash and burn agriculture (Kiernan, 1991). However, the possibility cannot be discounted that such changes in the chemical character of water in Croesus Cave are the result of natural processes. The lack of proven evidence that past surface land management has had an impact on Croesus Cave has been invoked to maintain current land tenures without the management changes that would ensure proper protection of this important cave.

CAESIUM-137 ACTIVITY IN CAVE SEDIMENTS

To aid in evaluation of possible sediment accumulation underground due to pasture clearing and management, sediments from several stream caves have been sampled for analysis of their caesium-137 content. Caesium-137 is a globally distributed by-product of atmospheric nuclear weapons testing since 1950. Fallout of this isotope is adsorbed onto soil grains, accumulating in the upper 20 cm of the soil profile but low levels of caesium-137 of slightly greater depth are possible due to bioturbation. However, the presence of significant levels of caesium-137 at depths of greater than c. 20-30 cm in sediments indicates that they include material that has accumulated in response to surface erosion that has occurred since the inception of fallout of the isotope (Campbell et *al* 1988). Thus demonstration of Cs-137 present in sediment accumulations should provide a means of confirming recent age and of assessing the rate of sediment accumulation relative to that prior to catchment disturbance.

The first site examined was Soda Creek Cave, an intermittent outflow cave at the western end of the Mole Creek karst. The principal catchment of this cave is a small karst margin polje, the Loatta polje, and its allogenic catchment. The floor of the polje (c. 390-420 m.) is formed in Ordovician limestone which also forms its western and eastern margins. Subterranean drainage northwards is cut off by the emergence of an anticlinal ridge of underlying siliceous rocks, while to the south the limestone is overlain by a sequence of marine and freshwater sediments of Permian to Triassic age, collectively known as the Parmeener Supergroup, that occur beneath a sheet of Jurassic dolerite that extends to the summit of Western Bluff (c. 1450 m). The polje floor has been converted to pasture while some forestry activity has occurred on the northern and southern slopes followed by regeneration of native forest. Pasture clearing in the Loatta polje dates from the 1950s, with the most recent intensive phase of pasture clearing and development occurring in the 1970s. Land degradation on the polje floor includes sheet and rill erosion and the formation of numerous cover collapse sinkholes none of which were associated with the infiltration of substantial concentrations of surface runoff. The observed accumulation of sediment in Maze Puzzle Cave, a streamsink on the polje floor, suggested that sheet and rill erosion was the source of a thick silt and clay accumulation in Soda Creek Cave, which has been shown by dye tracing to discharge the Maze Puzzle stream (Kiernan, 1984). It was hoped that the advent Cs-137 in the sediment profile would permit the extent of sediment accumulation since the early 1950s to be determined, and, by comparison of this site with caves in similar topographic and geological contexts that retained their forest cover, it was anticipated that a first approximation of the impact of land management could be obtained.

Sampling of the Soda Creek Cave sediments was undertaken in 2 cm increments to a depth of 24 cm. Due to decrease in the content of fine sediment relative to coarse that precluded retrieval of sufficient fine sediment at this sampling volume, sampling below 24 cm depth was continued at 5 cm increments to the cave floor at a depth of 76 cm. Unexpectedly, assay of the Soda Creek sediments revealed only extremely low levels of caesium, if indeed any was present at all, the maximum activity level being 0.9 mBq/g (table 2). This is despite the burial at the cave entrance of some undecomposed vegetable material which appears to demand a very recent age for at least some of the sediment.

Given the visible soil erosion at the upstream end of the system the most probable explanation for this low Cs-137 content of the sediments seemed to lie in dilution of material derived from the present ground surface by material derived from deeper in the soil profile or by the reworking of earlier fine cave sediments. The former option raised the possibility that erosion from the base of the soil profile into subsurface karren, a process evident from the active formation of cover-collapse sinkholes on the polje floor, may have been a much more

Table 2. Caesium-137 in cave sediments from Soda Creek Cave, Mole Creek.

sample no.	strata depth (cm)	caesium-137 (mBq/gm)	significance
1	0-2	0.9±0.5	significant
2	2-4	0.3±0.4	NS
3	4-6	0.4±0.4	NS
4	6-8	-0.3±0.4	NS
5	8-10	-0.4±0.7	NS
6	10-12	0.5±0.4	NS
7	12-14	-0.1±0.4	NS
8	14-16	-0.2±0.7	NS
9	16-18	0.0±0.4	NS
10	18-20	0.2±0.4	NS
11	20-22	-0.2±0.4	NS
12	22-24	-0.2±0.6	NS
13	24-29	0.6±0.6	NS
14	29-34	0.0±0.6	NS
15	34-39	0.7±0.5, 0.1±0.4	NS
16	39-44	-0.1±0.4	NS
17	44-49	-0.3±0.5	NS
18	49-54	-0.2±0.4	NS
19	54-59	-0.1±0.4	NS
20	59-64	0.0±0.4	NS
21	64-69	0.1±0.5	NS
22	69-74	-0.4±0.5	NS
23	74-76	-0.1±0.4	NS

significant source of land degradation than surface soil erosion even though it remained largely hidden from view unless collapse occurred. From this was generated the hypothesis that an acceleration of this process might more generally prove the most rapid form of land degradation in karst where the natural surface vegetation had been permanently or temporarily disturbed, resulted in diminished transpirational drying of the regolith and an increased throughput of diffuse infiltration seepage water from the surface to the epikarst and then to deeper conduits. If this was the case, then even though total recent sediment volume in caves beneath undisturbed forest might be expected to be less than in caves in more disturbed situations the latter should contain relatively less Cs-137 than sediments in caves beneath undisturbed forest.

In order to evaluate this hypothesis, samples were obtained from several sites subject to varying levels of surface disturbance in a similar geological and topographic context to Loatta (table 3). Three areas were selected. The first was Precipitous Bluff, a karst that is cloaked in rainforest and which ranges in elevation from sea level to c. 350 m. altitude at which point the limestone is again overlain by Parmeener sediments and then by dolerite that forms the summit at 1117 m. Second, sediments were obtained from a stream cave on the slopes of Western Bluff overlooking the Loatta polje in an area subject to forestry activity during the period 1945-55, with some activity possibly dating from the late 1930s. The area is now cloaked in regrowth wet sclerophyll scrub and forest. Finally, samples were also obtained from four caves in the Kansas Creek - Mill Creek area immediately south of Loatta where the principle streams again flow from Western Bluff. In this area extensive forestry activity that occurred in the period 1945-55 has been followed by the regeneration of native forest. Permanent forest clearance associated with forestry activity has been confined to only a couple of hectares around the site of a timber mill that closed in the mid 1950s and at a small quarry, and along a limited number of roads and tracks. In the northwestern corner of this area the presence of small grassy areas and of regrowth forest 60-70 years old suggests limited earlier localised clearing probably as a stock transit site for transhumance grazing practices (K. Eggins. pers. com.).

The Precipitous Bluff karst lies deep within the Tasmanian wilderness World Heritage area and has suffered negligible disturbance by humans. Archeological surveys of the Precipitous Bluff karst have consistently failed to locate any evidence of Aboriginal occupation, despite the presence of Pleistocene humans in the now heavily forested Cracroft karst 28 km to the north and numerous other now rainforested inland sites elsewhere in southwestern Tasmania. There exists abundant evidence for Holocene occupation of the adjacent coast. The situation contrasts with numerous other Tasmanian karsts where evidence of Pleistocene occupation, despite a present-day rainforest cover, has been attributed to a more open vegetation cover during the Late Last Glacial Stage (Kiernan et al 1983). The apparent absence of humans from Precipitous Bluff suggests that while fires lit by Aborigines appear to have greatly influenced the vegetation and possibly slope stability over wide areas of Tasmania, aboriginal firing is unlikely to have caused as significant disturbance at Precipitous Bluff even during the drier, colder and windier conditions experienced in Tasmania during the late Last Glacial Stage. This raises the possibility of this highly maritime karst and the adjacent continental shelf having served as a glacial refuge for rainforest species and for Precipitous Bluff being perhaps the environmentally most stable karst in Tasmania.

Radiocarbon assay of charcoal samples collected from 10 cm depth in debris deposited down a 50 cm long karren slot into the back of a small "swamp-notch" type cave (PB 201) at Precipitous Bluff gave a result of 750±80BP (Beta 41419).

Table 3. Caesium-137 activity in cave sediment samples, at 1 January 1990.

spectrum name	sample site	analysis date	Cs-137 (mBq/g)
4CC-1.TFC	Croesus Cave	8 Jan 1991	0.16
4EP-1.TFC	Execution Pot	7 Jan 1991	0.80
4LC-1.TFC	Lynds Cave #1	8 Jan 1991	0.92
4LC-2.TFC	Lynds Cave #2	10Jan 1991	0.76
4PB1-2.TFC	Damper Cave	9 Jan 1991	2.18
4RHC-1.TFC	Rubbish Heap Cave	10 Jan 1991	1.85
4TC-1.TFC	Tailender Cave	9 Jan 1991	0.39

Karren crevices provide a favourable site for the accumulation and preservation of sediment, and the charcoal collected appeared to represent the most recent fire event. This assay result is consistent with the botanical evidence that this area has not been burnt for at least 600 years and that some adjacent areas had not been burnt for at least 1 000 years prior to a fire earlier this century (M. Brown, pers. comm.). The limited sediment accumulation since deposition of the charcoal confirms that the landscape has remained stable with only limited erosion and sedimentation having occurred beneath this intact forest cover since this last major disturbance by fire. While sharp, subaerially-formed karren species are prominent in some localities, exposures of rounded sub-surface karren species are uncommon and in some cases demonstrably associated with fallen trees that have torn up root masses and soil.

However, despite the high level of landscape stability at present, sediment collected from the present streambed in Damper Cave at Precipitous Bluff, an outflow stream cave that discharges only a few metres above present sea level, proved relatively rich in Cs-137, revealing an activity level of 2.18 mBq/g. Hence, in comparison to Soda Creek Cave, a greater proportion of the recent cave sediments in Damper Cave comprises material that is caesium-bearing and which is therefore likely to have originated from the soil surface rather than from deep subsoil horizons. Such a result is consistent with the hypothesis that only a limited amount of sediment of subsurface origin is likely to be introduced into cave streams by diffuse infiltration where the natural vegetation cover remains intact.

Rubbish Heap Cave is the sinking point of Kansas Creek, an allogenic stream that gathers on Western Bluff immediately south of Loatta. This cave is the source of most of the water that emerges from Lynds Cave, an outflow stream cave 2.2 km further west. Sediment sampling has therefore been possible from both the recharge and discharge ends of this karst drainage system. Clays and silts that block human access into Rubbish Heap Cave a short distance inside the entrance locally overlie or are intercalated with actively forming flowstone that has in some cases incorporated vegetal matter. Together with the presence of sawn surfaces on some buried wood fragments within the sediment, this suggests that this large scale sedimentation is very recent and is related to the forestry activity previously widespread in this catchment. The relatively high Cs-137 level of 1.85 mBq/g is consistent with the sediment having been derived from the ground surface. The presence of Cs-137 in the sediments confirms that this sediment has been deposited since 1950, and compounds the evidence for the considerable damage caused to this cave as a result of past logging practices. However, despite the high level of caesium in Rubbish Heap Cave, analysis of two samples from just inside the outflow entrance to Lynds Cave revealed relatively low activity levels of 0.92 mBq/g and 0.76 mBq/g. This suggests that in this more disturbed karst, in contrast to the situation at Precipitous Bluff, there is considerable dilution of the sediments from the surface by material that is not Cs-137 -bearing. It might also imply some filtering of post 1950 sediment through Rubbish Heap Cave due to its having become blocked by debris at an earlier date.

Silty-clay sediments were also sampled from the upstream end of periodically-flooded upper levels of the stream passage at the bottom of Execution Pot, a vertical shaft system 90 m deep also located in regrowth forest on the slopes of Western Bluff overlooking Loatta. The principal source of the stream is a streamsink that is also sediment-choked and inaccessible. Whether this was naturally blocked or whether the streamsink became blocked by debris as a result of logging is unknown. The presence in the sediment of undecomposed vegetable debris, including green leaves, confirms its relatively recent age, and the incorporation of twigs in actively-forming flowstone and clastic sediment shows that material from the surface is not filtered by other inwashed debris. In these circumstances the low level of Cs-137 of 0.80 mBq/g is difficult to explain other than by considerable dilution of surface sediment by subsurface material that is not caesium-bearing.

Silty-clay sediment is presently being deposited by the stream in the most upstream accessible part of Croesus Cave. No streamsink is known that contributes to the present cave stream. The level of caesium-137 in these sediments is extremely low at 0.16 mBq/g which is consistent with their being of subsurface origin. Nevertheless, their active deposition includes their swamping of rimstones in the upstream part of the cave, and mechanical damage to rimstones by coarse sediment in transport. This implies a change in hydrological conditions since the rimstones were formed. The deposition of carbonate encrusting an old hobnail boot outside the cave mouth confirms that rimstone formation is a relatively recent phenomenon and the changes occurring further upstream are apparently anomalous in nature. The possibility exists that previous forestry operations in the Croesus Cave catchment may have caused or contributed to the speleothem damage in Croesus Cave, due to consequent hydrological changes that have facilitated the flushing into the cave of material from within the regolith, or reworking of fossil clastic cave sediments. If so, damage was not restricted to the period of logging or initial regeneration but may have involved the crossing of a geomorphic threshold that has triggered evolution towards a new equilibrium in the system.

Tailender Cave is another outflow cave 1 km south of Croesus Cave and it also drains part of the area previously subject to logging. The accessible cave stream is intermittent but a permanent spring occurs in the bed of the Mersey River just outside the cave entrance. This suggests that the cave itself is a conduit formerly utilised by the water that emerges from the spring but now functions only during peak flow conditions. The sediment-choked streamsink of Vanishing Creek is known to contribute to the stream that discharges from Tailender Cave, but the Tailender stream is considerably larger than can be accounted for solely from this source. One other streamsink is known but as yet this has not been proven to contribute to the Tailender Cave stream. It is likely that autogenic diffuse infiltration waters make a substantial contribution. Sediment collected from just inside the cave entrance revealed a Cs-137 activity level of 0.39 mBq/g suggesting that in this case too any sediment of surface origin is heavily diluted by subsurface material.

DISCUSSION

There is considerable evidence to suggest that recent changes in some Tasmanian caves are the result of land management practices, notably the impact of the clearing of forests for the development of pasture and by the forest industry. Gravity inputs through small roof-holes of sediment that contain fresh vegetable debris indicative of a very recent age have been observed in some caves beneath forests recently logged in the Florentine Valley. Stratigraphic relationships between various sediments and comparison of sediment volumes suggests cave sedimentation has been much more rapid in some disturbed karsts than was the case prior to disturbance or is the case in caves in areas not subject to forest disturbance. The high turbidity levels encountered in some of the cave systems in the Florentine Valley are a matter of serious concern and highlight the vulnerability of caves, cave biota and karst aquifers to activities in the catchment of streams that flow to karst areas. While there is evidence that the damage done in Welcome Stranger and in caves at Cole Creek is the result of forestry activities, it is seldom that the specific origin of a sediment input can be demonstrated unequivocally and it is seldom as easy to ascertain whether sedimentation has resulted from land management or is the result of natural processes.

Any unnatural disturbance to the natural system is unacceptable where an area has been reserved for the purpose of nature conservation or is important for that purpose. However, interest groups who wish to persist with activities potentially detrimental to a karst aquifer or an important cave system commonly focus on special attributes of a cave such as its speleothem assemblage or biota and argue that their activities are acceptable because they imply no greater change to that specific feature than nature might produce. When the discussion is structured in this manner the likely impact of an unnatural disturbance on the cave environment relative to what may have the capacity to occur naturally can seldom be easily assessed to the satisfaction of vested interests. For example, the possible changes in recent decades in the chemistry of the stream in Croesus Cave may be related to land management. However, variation in chemistry is commonly evident among different water inputs even in the same cave chamber, and sections cut through stalagmites occasionally reveal episodes of redissolution during their growth. Hence, it is not possible to be certain that current changes in Croesus Cave are not natural. This is despite the fact that redissolution of speleothems due to water chemistry changes is a demonstrated consequence of vegetation disturbance through its impact on the soil biota that conditions soil carbon dioxide levels and hence seepage aggressivity (Barany-Kevei 1987). Nevertheless, while some natural variation undoubtedly occurs, where changes are widespread and of considerable magnitude, they warrant scrutiny to evaluate the possible impact of surface activities. Where important natural values are potentially at stake the most conservative management is warranted.

Despite these uncertainties, evidence presented in this paper provides a strong *prima facie* case for further moderating or precluding surface disturbance where cave systems of significance for nature conservation are involved or where the maintenance of the groundwater system and groundwater quality ought to be an objective of management. Acceptance of these goals has been reflected in Tasmania by the inclusion in the Forest Practices Code of special provisions for forest operations in karst areas. These provisions focus in particular upon protection of soil values and the safeguarding of streams that flow into caves and other areas of concentrated infiltration such as sinkholes. However, these guidelines would not have been sufficient to prevent the damage that has occurred to Welcome Stranger Cave since the landslide there is likely to have occurred even if a streamside reserve had been established and protected during a logging operation within the surface catchment. The situation at Welcome Stranger simply reveals the hazards inherent in the application of some forest management practices in environments such as this, even where virtually the entire surface catchment of a cave stream is nominally protected within a national park.

Moreover, it appears that riparian protection along allogenic streams that flow into caves may be insufficient. Analysis of the caesium-137 content of sediments from several Tasmanian caves has shown that the highest caesium levels occur in caves in the least disturbed environments, and that caesium levels are lowest where disturbance has been most severe. It is also evident that even where the sediment entering streamsinks is rich in caesium-137 there is a relative paucity of the isotope further downstream in the system in cases where the intervening surface terrain has been disturbed. The relationship between the level of vegetation disturbance in the catchment to the caesium-137 level in sediments is the opposite to that encountered in fluvial environments on the surface where erosion of the surface horizons that contain caesium-137 results in the accumulation of caesium-rich sediments. In a karst environment, however, much of the precipitation infiltrates directly into the ground rather than forming a runoff that erodes surface horizons. In this case, an increase in the amount of free water in the regolith due to diminished transpiration, or a derangement of an infiltration route, is likely to result in grain by grain removal of regolith material from deeper in the profile and its being washed down subsurface karren and other solution channels. Hence, erosion may proceed unseen, often on very moderate slopes where a soil erosion hazard might otherwise seem unlikely. Unless there is a conspicuous acceleration in the formation of cover-collapse sinkholes this form of land degradation may remain undetected as the soil surface is gradually lowered, until such a time as bedrock outcrops sculpted by karren species of subsurface origin emerge through the soil surface. The low level of caesium-137 evident in cave sediments in disturbed environments is consistent with the dilution of any surface material by large volumes of regolith derived from subsurface horizons.

There are two alternative explanations for the low caesium levels in disturbed situations. The first is that sedimentation there predates 1950. However, where green or undecomposed leaves and other vegetable debris occur within and on the surface of wet sediments this interpretation is generally untenable, although it is acknowledged such debris can survive for very long periods under some special conditions. A second alternative is that active sediment accumulation is the result of the reworking of earlier sediments from further upstream in the cave system, a situation not dissimilar to that proposed by Bishop et al (1991) to explain the absence of caesium-137 from alluvial cutoff infill sediments of the Hunter River, NSW. Even were this is the case, however, an explanation would still be required where sediment deposition implies an increase in the capacity of water flows to mobilise sediment or indeed where diminished stream energy facilitates sediment accumulation rather than throughput. In the Hunter River case, it was argued that deposition occurred in response to high magnitude events that saw rapid erosion, deposition and burial of the sediments, but the situation is likely to be more complicated in a subsurface karstic context. The most likely cause for a widespread increase in streamflow of this kind, and for its apparent correlation with higher levels of catchment disturbance, is that management of the surface environment is the cause of the change and of any damage that may have occurred to the cave or groundwater system. This might involve destabilisation of a sediment accumulation due to increased subsurface water volumes as a result of decreased transpiration, or a loss of capacity to maintain sediment transport due to unnaturally high transpiration rates associated with vigorous young regrowth.

The analysis by Gunn and Turnpenny (1986) of cave streams beneath a single autogenic catchment subject to pasture clearing and beneath a comparable forested catchment at Waitomo found reduced stormflow yields and peak flow magnitudes together with increased delayed flow and antecedent baseflow in the disturbed catchment, presumably due to the blocking of sinkholes. However, it is important to recognise that their study is the only one of its kind undertaken to date and the situation they recorded may not necessarily be representative of all karsts. The timing of the main phase of sedimentation relative to forest removal is also unclear. In the case of forestry operations it would seem probable that infiltration would be greatest between initial clearing and the establishment of regrowth forest. The nature of the epikarst is obviously critical, together with the character of the regolith, while the clearing practices involved and their impact on the regolith are also likely to exert a major influence upon the extent to which infiltration is modified after forest removal. The duration of the period of enhanced infiltration will also be relevant. From a management perspective it is pertinent to note that silvicultural difficulties may arise due to accentuated drought effects in karst areas (Duncan and Kiernan 1988) and that some areas of regeneration in the Florentine Valley have failed, possibly due to a failure to adequately protect the trees against browsing by invertebrates. Addressing browsing problems may itself involve the application of substances that pose risks of another kind for very easily polluted karst aquifers and highly sensitive cave-dwelling invertebrates.

Nevertheless, this study has provided some further evidence for surface management having the capacity to cause major degradation of the subsurface environment. More significantly perhaps, it suggests that the greatest source of sediment may not be points of concentrated water input such a streamsinks, but broader areas of more diffuse infiltration. Hence, the present focus by concerned managers on protecting surface streams and sinkholes, as exemplified in the Tasmanian Forest Practices Code, may not provide for effective protection of karst systems. It may be the case that areas distant from streams where pasture development or forestry activity occurs are of far greater overall significance due to the importance of enhanced infiltration after forest removal. These issues are yet to be addressed by land managers. It has been argued that observed damage to caves in the Kansas Creek - Mill Creek area has resulted from forest practices that no longer occur and can be disregarded. However, some forms of damage may be the result of practices akin to those that continue to occur. The evidence from upstream Croesus Cave suggests that some changes may include the crossing of process system thresholds and the initiation of ongoing problems that persist long after logging and forest regeneration have occurred as the systems evolve towards a new equilibrium. The establishment of guidelines that proscribe clearfelling on most areas of karst and which set standards with respect to the relative density that must be retained in the vegetation during selective logging may be of much greater consequence to protection of the underground environment than those safeguards hitherto enacted.

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Address for correspondence:

Kevin Kiernan and Rolan Eberhard: Forestry Commission, 30 Patrick St., Hobart, Tasmania;

Bryan Campbell: Geosphere Applications Group, Australian Nuclear Science and Technology Organisation, Lucas Heights, NSW.

KARSTING AROUND FOR BONES ABORIGINES AND KARST CAVES IN SOUTH EASTERN AUSTRALIA*

Andy Spate

ABSTRACT

Whilst there appears to be a popular belief that Australian Aborigines viewed caves with some trepidation there is much anecdotal and physical evidence that karst caves were used for occupation, art and funerary practices.

This paper reviews the past and modern literature on Aboriginal use of karst caves on the Tablelands and immediate surrounds. About ten occupation and a lesser number of disposition sites are known as are hand stencils and "abstract" engraved art. More representational art has been reported in the past and skeletal material of "accidental" or unknown origin reported widely. Dated sites are few ranging from about 1500 years BP to as old as 23000 years BP. Much physical evidence has been lost and a number of sites are well known to have been used but have not been more than cursorily examined or results have not been published.

The paper also discusses karst caves that appear to have been suitable occupation sites; these may well repay examination.

INTRODUCTION

Curiously, very little can be gleaned from these sources [the ethnohistoric literature] *pertaining to man's use of Australian caves. It would seem that caves figure very rarely in the day-to-day life of the average hunter-gatherer. We are left, then, with a paradox: the type of site most sought after by the archaeologist was probably of least importance to the people who, sporadically, occupied it.* (Bowdler 1975:219)

However that may be, the present day natives can give no coherent account of the origin or of the use of the cave and other paintings scattered throughout the Kimberley and Central areas. (Daisy Bates in White 1985)

Although conventional wisdom has it that the Australian Aborigine was frightened by, and avoided caves, there are many examples of the use of karst caves. Most of the examples are of use in the entrance or twilight zones but there are occasions where evidence of use extends well into the dark zone. The best examples of this penetration into the dark zone are in the caves of the Nullarbor Plain where artistic activities, flint mining and perhaps pure exploration took place half a kilometre or more from the entrance - well into the dark zone. There are a number of examples in the Eastern Highlands of deliberate or accidental forays into the dark zone.

It is perhaps necessary to be careful here and define a few terms. This paper, and speleologists generally, use the word "cave" more narrowly than many archaeologists do. A karst cave is a cavity of solutional origin that has a dark zone needing artificial light for exploration. Between daylight and dark there is a zone of increasing twilight. We are here interested in discussing the deeper twilight and dark zones although a number of sites are virtually in full daylight. Thus rock shelters of the sandstone and granite "types" are excluded. Following the example of Meehan (1971) the term "disposition" is used rather than "burial" as the skeletal material found in caves may have been buried before placement in the cave when complex funerary practices were adopted and in most cases material in caves was not buried but prominently exposed.

Many authors have pointed out the fears that Aborigines had of caves. Bennett (1834:229) states that *"aborigines will not venture into the dark recesses of the caverns for fear of the "dibbil-dibbil" as they express it."* George Augustus Robinson (cited in Plomley 1966) could not induce his native companions to enter a cave. Etheridge (1893) cites a number of authors and personal observations in support of the dread of caves. More recently Massola (1962:128) says that:

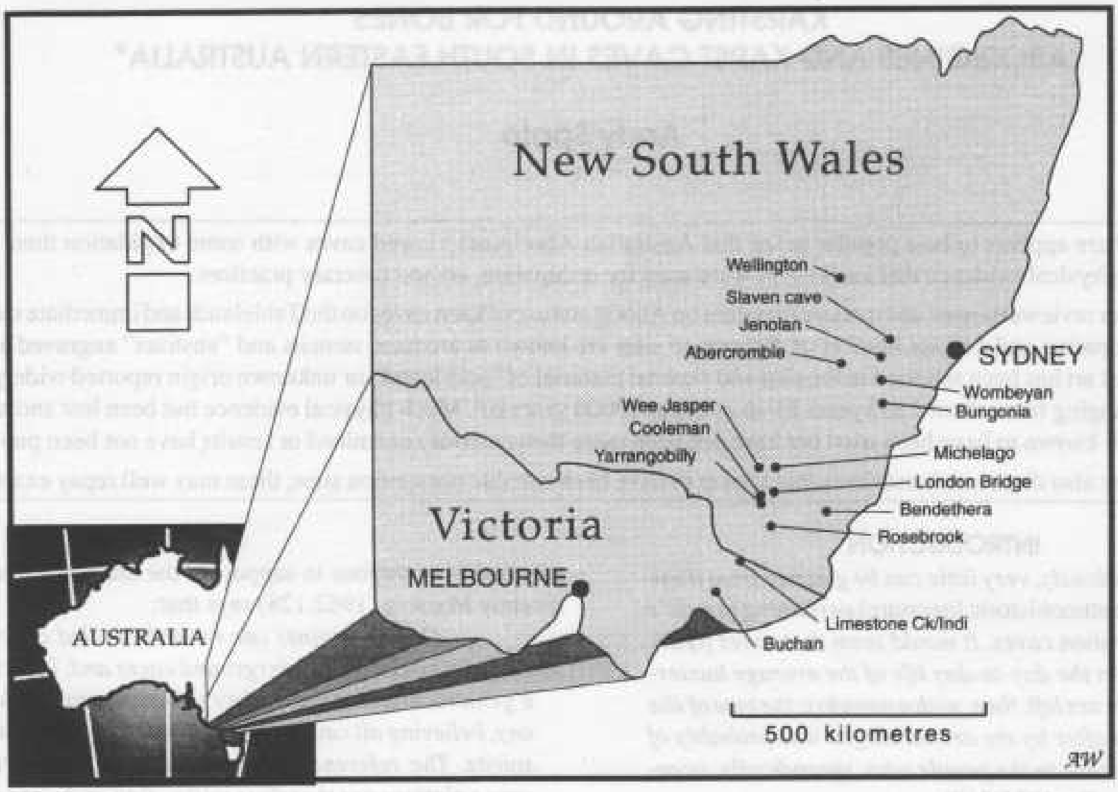
Our aborigines can never be called cave-men. They did not inhabit underground caves and, in fact, had a genuine dread of them; they seldom ventured close to any, believing all caves to be the homes of ghosts and evil spirits. The references commonly made to aboriginal cave paintings are therefore misleading and wrong. The term "rock art" or "paintings in rock shelters" should be substituted. These shelters, like those used as camping places, are shallow holes or overhangs in the sides of rocky outcrops. They are open to daylight and have no nooks or crannies in which malignant spirits might lurk.

Massola then goes on to discuss the various types of malignant spirit. However, the cave (Nargun's Cave) discussed in the paper introduced by the passage quoted above is not far from Cloggs Cave and from New Guinea Number Two, the former occupied as long ago as 17,700 BP and the latter 23,000 BP; both contain art (Flood 1980, Paul Ossa pers. comm.). Narguns Cave (not the Den of Nargun nor the cave known to cavers as Narguns Cave) is said to be of significance to the local people. In Tasmania we have much evidence of dark zone occupation (Kiernan pers. comm.) and on the Nullarbor there is some evidence that the Aborigines may have penetrated a kilometre or more underground.

Bednarik (1986) has discussed the significance of Australian cave art and whilst we have little evidence of art in caves (not shelters) in New South Wales it is probably due to lack of suitable wall conditions, the length of time since Aboriginal populations were sharply reduced following European contact and the taphonomy of the various sites.

In recent years more sites have become apparent from karst caves (eg Pardoe and Webb 1986, Cooke 1988, James and McIntyre 1989) and dated sites and skeletal material are now available. Parietal art has been identified from at least two sites. These data, coupled with the anecdotal accounts of earlier workers (eg Bennett 1834, Leigh 1892, Etheridge 1893, Brennan 1907), and the association of grave goods or other artifacts with skeletal material lead to the conclusion that Aborigines did use caves in south eastern Australia in spite of the ethnohistoric evidence to the contrary. Some ideas about the patterns of this use will be introduced below.

* An earlier version of this paper was first presented at the First Symposium on the Archaeology of the Southern Tablelands in 1989.



Study area

In spite of the known values of karst caves for the preservation of bone material and for occupation sites there has been no systematic attempt to evaluate the karst resources of New South Wales in terms of their archaeological context. Jennings (1979) reviewed man's use of Australian caves and Spate (1984) and Spate and Houshold (1989) attempted to assess the significance of New South Wales karst areas including their archaeological values. Jennings (1979) examined 275 likely literary sources in his review. Only 116 mentioned caves or shelters. His sources do not include some pre-1979 references cited in this paper.

This paper, then, discusses what we know and, perhaps more importantly what we don't know or have lost, about karst cave sites in south eastern Australia. That is, we examine Bowdler's paradox cited at the head of this paper. The most important conclusion drawn is that there is much scope for further research including physical investigation and examination of the ethnohistorical records and local folk sources. A hypothesis, unsupported by much evidence, suggests that deep twilight/dark zone occupation relates to more adverse climates in the late Pleistocene-early Holocene.

THE SITES

The major sites known are shown on map 1 and their characteristics are summarised in Table 1. There are obvious shortcomings in the data which result from the lack of systematic survey, from imprecise or too abbreviated observations from the early workers and from the passage of both time and grave robbers.

Most of the sites are on the Tablelands or in the escarpments beneath them; rock shelters and boulder caves (of the sandstone and granite "types') have not usually been included. This distribution reflects the distribution of karst caves and does not include the important boulder cave sites in Namadgi and the many rock shelters found in the sandstones of the Sydney Basin and hinterland or along the coast. Two caves, Slaven Cave near Lithgow and Caddigat Cave near Adaminaby, are not strictly karst caves but are more cave than rock overhang although the status of the latter is debatable.

I make no apologies for my extension of the Southern Tablelands to Buchan or to Cliefden and Canodomine on the Central Western Slopes. Pigeonholes such as "Southern Tablelands" are very much Eurocentric, and are nineteenth century, conceptual areas and whilst they have some relevance they do not have iron-clad boundaries. [Can one have an iron-clad line?]

The discussion below considers sites that are known to contain evidence of Aboriginal use and, in addition, discusses the various karst cave sites which are not reported as having Aboriginal affinities but which have characteristics that archaeologists might consider to be potential occupation sites.

Buchan

The Buchan area and its immediate limestone outliers are a diverse sequence of Devonian limestones containing some 400 caves. Many of these appear suitable for Aboriginal occupation and use. Only Cloggs Cave, discussed comprehensively by Flood (1973, 1980, 1983), appears to have been utilised by Aborigines although a small karst rock shelter (EB-6) nearby was excavated by Gallus and yielded evidence of the Small Tool Phase *"with hints of Pleistocene occupation"* (Flood 1980:254). Susan White (pers. comm.) considers that other small rock shelters such as EB-7 and EB-8 show some evidence of occupation; there may be others in the Aboriginal Affairs, Victoria, register. The use of Cloggs Cave extends over a 9,000 year period and was an occupation site between 17,000 and 8,000 years BP. Early artifacts were in the Core-tool and Scraper Tradition but later the Small Tool Phase became apparent. Immediately beneath the Aboriginal material is megafaunal material including *Stenurus orientalis* and the cave was apparently a carnivore den as both *Thylacinus* and *Sarcophilus* were present.

The rock shelter outside the dark interior of Cloggs Cave was utilised sporadically subsequent to 8,000 BP. Interestingly Flood (1980:255) mentions a "*small abstract Aboriginal rock-painting on the overhang.*" Apparently there are now doubts about the authenticity of this art as Aboriginal Affairs, Victoria (formerly the Victorian Archaeological Survey) has both validated and repudiated the painting (Flood pers. comm.).

Other caves such as Wilsons, Dicksons, Moons and Slocombes caves may have been suitable for use. European use and catchment changes consequent on clearing and grazing may have destroyed evidence of Aboriginal use in these and many other caves around the country.

New Guinea Ridge

New Guinea Number Two Cave (NG-2 = Snowy River Cave, Flood 1983) and Cloggs Cave are the most significant karst cave sites in south eastern Australia from an archaeological viewpoint. NG-2 dates back to around 23,000 years BP as an occupation site and contains significant art in the Koonalda and Mount Gambier tradition (Bednarik 1986). Most unfortunately an account of the excavation has not been published in spite of opportunities to do so. Paul Ossa presented an interesting paper at the first Fenner Conference on the Significance of the Australian Alps in 1988 but unfortunately no written paper was submitted.

Limestone Creek

An excavation in Ichmo Cave (LC-16) on Stony Creek, a tributary of Limestone Creek, and an Aboriginal skeleton are reported by Frank (1984). Flood (1980) citing Gallus (pers. comm.) says that a disposition was investigated on Limestone Creek. Houshold (pers. comm.) tells me that Gallus found an Aboriginal skeleton in or associated with a possum skin rug. However, the site (Aboriginal Affairs, Victoria site number 8524-0007) whilst indexed under "*Burial/human remains*" is now said to have contained "*non-human bones*" as well as flakes and a ground stone axe. Clearly there is a problem to be resolved.

Indi

The Indi area, just within New South Wales, on the Upper Murray or Indi River, has an anecdotal history of association with Aborigines. In 1872, the Town and Country Journal (April 6 p 434) reported in an article by "*a special correspondent*" entitled "*Tour to the South. The Billabong and the Murray*":

> *......up there I was told of walls of rock as high as Govett's Leap, through which escapes the head of the Murray, called there the Indi, and near which are found petrified blackfellows......*

The Victorian Speleological Association and its precursors report that local anecdotal evidence describes a cave (I-3) as containing the bones of "*an escaped convict*". There seems no physical evidence of either convict or Aboriginal remains. The vertical form of the cave suggests that the unfortunate individual fell in and was trapped - assuming that this is the correct cave.

The entrance of the main cave at Indi (I-1) has been modified to improve its value as a shelter. Whether this was of European or Aboriginal origin remains speculation.

Quidong

Little is known of the Quidong (Delegate River) caves. Local folklore has it that Aborigines did use the caves.

Yarrangobilly

Yarrangobilly was visited by TA Murray and SM Mowle as early as 1839 and they apparently explored the caves and removed two skulls, probably from the Glory Hole or North Glory Caves. Where are these today? Murray kept his "*beside his desk for many years*" (Wilson 1968:110). Mowle (quoted in Flood 1980:180) said "*In one of them [the caves] I found many human bones, and I brought away a skull.*" However, I have been unable to relocate Flood's (1980) source (Mowle *Sydney Evening News* 30 March 1891) in either the National or Mitchell Libraries and Wilson provides no further details. There is, however, some corroborative evidence (Gary Bilton pers. comm.). In the mid-1980s a diviner visiting Yarrangobilly Caves entered the North Glory and identified by means unknown the point at which a dead Aboriginal girl had once been! Certain members of NPWS staff refuse to enter North Glory Cave as they consider it haunted!

Flood (1980) investigated a number of caves in the 1970s and found little or no evidence of occupation. There are, however, literally thousands of possible disposition sites and many surface sites are known as well as the burial sites reported near Yarrangobilly Village. Many of the obvious cave entrances appear to be highly suitable occupation sites but the majority are characterised by strong, and usually cold, draughts. Late Pleistocene conditions would have been untenable as even today semi-permanent winter ice and frost-wedging occurs in a number of these caves.

In 1981 Marjorie Sullivan and I located a site in a karst cave at the northern end of the Yarrangobilly limestone belt (Geering 1983). This, possibly stratified, site has yet to be investigated.

Clive or Cave Creek

A number of small caves are found in very inaccessible terrain along Clive (or Cave) Creek near Black Perry Mountain between Talbingo and Yarrangobilly. One of these caves (JC-12) appears to be suitable for occupation (DS Gillieson pers. comm.). The site is well watered, of good aspect and in an ecologically rich area. The fact that European goods and graffiti are found in this highly inaccessible cave lend weight to the presumption the site has occupation values. An examination has shown no evidence other than that of Europeans.

Cooleman

Why should Cooleman Plains caves have the richest record of Aboriginal use in the Southern Tablelands? The climate is harsh for much of the year. There are better caves suitable for occupation sites almost everywhere else, there are two, perhaps, four separate disposition sites (Cooke 1988), more artifacts in caves than previously reported (NPWS records cf Flood 1980), reported art (Brennan 1907) and bora grounds (Flood 1980:146). "Gunyahs" were marked on cadastral maps late in the post-contact period.

Taking these in turn, Brennan (1907:208) states:

> *In the same year,* [1874] *while on duty at Coolamon* [sic], *sixty miles from Queanbeyan, I visited the famous limestone caves of the place, where I discov-*

Table1. **KARST CAVE AREAS IN SOUTH EASTERN AUSTRALIA ASSOCIATED WITH ABORIGINAL USE**

Site	Type of site	Dates[1]	Reference
Buchan	occupation site	17,000	Flood 1980
New Guinea Ridge	occupation/ art site	~23,000	Ossa1989pc[2]
Limestone Creek	occupation site?/ skeletal material?/ disposition?	no date	Gallus pc
Indi	skeletal material?/ burial?	no date	anecdotal
Quidong	?		anecdotal
Yarrangobilly	skeletal material/ disposition?/ occupation site/	no date	Mowle 1891 Sullivan/Spate
Clive Creek	occupation site?	no date	Gillieson pc
Cooleman	disposition sites/art sites?	1,300	Cooke 1988 Brennan 1907
Caddigat	occupation site/ art site	1,600	Flood 1980
Rosebrook	disposition	no date	Leigh 1892
Kybean	?	no date	anecdotal
Bendethera	?	no date	anecdotal
Wyanbene	art site/site	no date	Richards pc
Cleatmore	"sacred nativewell"?	no date	Shannon 1977
Marble Arch	stone arrangement?	no date	Spate
London Bridge	disposition/ occupation site	700-900	Brennan 1907 Boot & Cooke1990
Michelago	disposition	no date	see text
Paddys River	?	no date	Davey et al. 1992
Wee Jasper	?	no date	see text
Talmo	hiding place?	no date	Glover pc
Cave Flat	disposition	no date	Bennett 1834
Narrangullen	disposition?	no date	Cooke 1988 cf Bennett 1834
Bungonia	disposition	no date	Etheridge1893
Wombeyan	mythology/art?	no date	Dyson et al. 1982
Abercrombie	minor occupation	<15,000	Johnson 1977
Tuglow	?	no date	
Colong	?	no date	
Jenolan	skeletal material/ art site?/site/ mythology	no date	Etheridge & Trickett 1904 Hotchin & Houshold 1988 Mathews 1908
Slaven Cave	occupation site	1,600	James & McIntyre 1989
Cliefden	skeletal material	6,250	Pardoe & Webb 1986
Wellington	anecdotal/skeletal material	no date	Anderson nd Osborne pc

[1] Years before present, rounded off and with the author's quoted error terms ommitted

[2] pc = personal communication

ered on the smooth surface of one side wall traces of many paintings, representing kangaroos, dingoes, spears, boomerangs and womerahs. These were partly covered with fantastic-shaped stalactites hanging in lustrous profusion from the high roof.

Brennan was involved in a number of Aboriginal sites in the Queanbeyan district; perusal of his journals indicate that he is a relatively accurate observer and reporter (although later research indicates that this may be rather too charitable an assessment). Flood, Cooke and I have separately examined the caves for evidence of art. Unfortunately, and perhaps not unsurprisingly, nothing has been revealed. The wall conditions mitigate against engraved art of the "macaroni" form and the early post-contact destruction of Aboriginal society on the Monaro (Hancock 1972) has meant that "painted" art could not have been retouched for well over a century.

Several kilometres below Cooleman Plains proper, on the Goodradigbee River, are a number of caves near Blackfellows Creek. The cave known today as Blackfellows Cave (CP-42 & 43) cuts off a meander in the Goodradigbee and is an impossible site for occupation and an unlikely disposition site for the discoveries described hereunder.

The Geehi Club (1962:101) reported as follows, unfortunately without acknowledging their primary source:

Another parcel of bones was discovered in the Blackfellows Cave. They were found by surveyor Davidson in 1910, and although it is not known if they were positively identified it is presumed that they were Aboriginal as they had been cut off at the joints, neatly stacked, and surrounded by a border of stones.

The Queanbeyan Age (21 May 1915:2) reported that a party of surveyors found a disposition in a cave northeast of Blue Waterholes:

In one of these [caves] *recumbent on a ledge of stalagmite, they discovered a perfect human skeleton, bleached to almost whiteness, and which appeared to have lain where it was found for centuries past.*

Bluett (1954:13, cited in Cooke 1988) tells of a primary disposition in a cave on Blackfellows Creek (there are none!) which was apparently well known in the 1890s:

The white bones lay stretched in their correct anatomical position, with the exception of the arms, which were crossed over the chest. Close around the skeleton a fence had been made of stones the size of one's head. The bones were those of a man fully 6ft. or more in height.

This type of disposition was, according to Bluett (*op cit*:12), *"a high honour, reserved for kings and great warriors."*

Be that as it may, the question remains are these three the same disposition and which cave was it found in? Certainly Bluett and the Queanbeyan Age appear to be similar descriptions. However, the fact that two parties of surveyors were in the same area only five years apart appears surprising and it is hardly likely that the Queanbeyan Age would consider a gap of five years "recent'. Lynette Russell-Cook (pers. comm.) feels that these references are to one **surface** site. More fieldwork needs to be done in this relatively inaccessible area.

Flood (1973) investigated the caves, environment and ethno-historical literature of the Cooleman Plains. Further investigation of the caves has revealed some use in the entrances of Cooleman Cave CP-1, Right Cooleman Cave CP-2, Murray Cave CP-3, Blue Waterhole Cave CP-8 and Murderers Cave CP-57. Marjorie Sullivan and I found worked stone in all of these caves - albeit only a few pieces in each. Just above Blue Waterholes is an outcrop of chert intensively worked for tool material. Open campsites have become apparent near Coolamine Homestead and elsewhere, especially on the creek flats - an intense drought certainly helps.

In 1980 a bushwalker "discovered" a disposition site although it had apparently been known to locals for some time (Cooke 1988). Cooke's thorough examination of the material removed by the Police Department at the direction of the Coroner revealed that the tiny cave (CP-75) contained material now held in the Australian Museum (E 10527) dates to 1330 +/ - 80 years BP. Some minor grave goods were associated with the deposit which had been contaminated by other, modern, skeletal material in the bureaucratic process.

The material represents an adult and an infant, which may have been deposited in CP-75 at a later time than the adult. The cave is hardly a cave - the niche in which the remains were deposited is in full light but dry, alkaline and relatively inaccessible. The age of the adult was not easily determinable but she appears to have been of age 20-45 years; the infant less than six months old.

We have a number of problems to be resolved or considered at Cooleman. Is there further ethnohistorical material? The Campbell papers are in the National Library but are not available until early next century. The De Salis papers? Is there any art? Have we assessed the existing evidence adequately? Is Cooleman different - I would suspect not. What might be termed "lower Cooleman" - Blackfellows Cave and Blackfellows Creek are relatively inaccessible to speleologists and archaeologists - and a few days sensible fieldwork may well display dividends.

Caddigat

Caddigat Cave, near Adaminaby, is not a karst cave but appears to be more than a simple rock shelter. The cave, which is less than six metres long, probably developed by salt wedging enhanced by free water movement in the highly jointed Ordovician shales. Frost wedging has played a marked role in enlargement of the cave.

Flood (1980) reports that an excavation in the cave yielded a shallow deposit (to 30 cm) containing artifacts dated at 1600 +/- 60 years BP. The cave also contains seven red ochre hand prints - the only rock art known on the Southern Tablelands other than that claimed for Wyanbene and, of course, the art in a number of rock shelters in Namadgi National Park. These latter are discussed by Officer (1989). Aborigines apparently used the Caddigat Cave post-contact.

Rosebrook

The caves at Rosebrook, north of Cooma, are unlikely disposition or occupation sites. However, Leigh (1892) found skeletal material *"in close proximity to the Caves"*. The skeleton was *"more or less complete"* and was very friable. Leigh (1902:79) goes on to say:

Considering the small size of the cavity and the position in which the skeleton lay, it is evident that the body at burial had been tightly wedged between the lower limestone bed and the upper sheltering rock, thus follow-

ing the universal practice of the aboriginals of disposing of their dead in the smallest possible space.

These remains, now in the Australian Museum (E 12782), have been examined by Cooke (1988) who considers them to have been of a male Aboriginal. There are numerous artifact scatters in the vicinity of the caves as well as a burial site of two individuals with associated grave goods, dated to 7,000 years BP (Feary pers. comm.).

Kybean

The Kybean caves have been the subject of palaeontological investigations (Etheridge 1891) but do not appear to be suitable for occupation in spite of local anecdotes that they were used.

Bendethera

The Bendethera Main Cave (BD-1) entrance appears a suitable occupation site but no examination has been made although NPWS has a site on the register with no other details. Gin Cave (BD-35) was known for many years as *"The Gin's Cave"*. The Moruya Examiner of 3 April 1889 contains the following passage:

The high & almost perpendicular mountain known as the Gins Mountain exactly faces the entrance to the cave, and it well can be imagined how the Aboriginals mind pictured the spot with awe thinking of Her the "Live Forever" who sat & watched for some reason this enchanted place. Those of my readers who have read the thrilling story Ridar Haggard entitled "She" will better understand what I am stating. That for some reason or another this mountain & Cave had for the Aboriginal a certain dreadful charm which we cannot now discover. [sic, not seen in the original but from a typescript supplied to the NPWS by Ron Lampert]

Whether anything can be deduced from this passage is open to discussion.

Wyanbene

Local folklore has it that Clarkes Cave (WY-7) was utilised by Aborigines and the NPWS has a recorded site with no details on the site form. Careful examination has revealed little or no evidence. However, Kelvin Officer (pers. comm.) suggests that there is evidence of art. Several mounded sites thought to be graves are known within a few hundred metres although these may not be Aboriginal (S Dovey pers. comm.).

Cleatmore

There is little in the way of possible occupation sites at Cleatmore although there are plenty of opportunities for disposition niches. Shannon (1977) mentions a feature *"said to be a sacred native well"* and provides a physical description. However, the evidence for a sacred well remains unknown and Shannon (pers. comm.) is unable to recall his source. The NPWS Site Register has a site recorded here, again with no details.

Marble Arch

The upper levels of the Marble Arch itself provide a possible occupation site albeit somewhat exposed (in a rockclimbing sense). There is a probable stone arrangement on the ridge to the east of the Arch.

London Bridge

London Bridge is a very scenic, small arch over Burra Creek with many values (Jennings et al. 1976). Associated with the arch are a number of small caves. Brennan (1907:208) reported

In January, 1874, I discovered on London Bridge estate, the property of Mr. John McNamara, a veritable catacomb on a small scale. It was a limestone cave, wherein were found many hundreds of human bones, including skulls, centuries old. I had several bags of them conveyed to Queanbeyan, where they were carefully inspected by three surgeons, including Coroner Morton, who pronounced them to be skeletons of Aborigines of former times. London Bridge is a natural limestone formation spanning Burra Creek. Beside it is a very spacious cave, which bore traces of having been used in early times by aborigines.

John Gale, whom I do not regard as a particularly reliable observer or raconteur, states:

it is said .... that it has been used in bygone times as a burial-place by the aboriginals and was found to contain some crumbling remains of the native blacks, with their belongings, which had, according to custom been interred with them. (Gale 1927 p 60)

He goes on to quote Brennan *op cit.*

It is believed that the bones were re-buried in a portion of the Queanbeyan cemetery that was washed away by floods in the 1970s.

Phil Boot and Helen Cooke have recently conducted surveys around the London Bridge Caves and carried out an excavation in Douglas Cave and in a shelter immediately outside Burra Cave. The two excavations produced different but complimentary data (Boot and Cooke 1990). A rich faunal assemblage was revealed in Douglas Cave but the *"deposit contained little evidence of Aboriginal occupation and no evidence of Aboriginal or European burials."*

The Burra shelter had a similarly rich fauna, but of lesser abundance, and some quartz flaking debris. Two hearths were revealed dating to 700 to 900 BP with some charred bone material.

Given the enthusiasm of Brennan and Gale the research at London Bridge is disappointing - all the more so because it throws doubt on all their other sites and observations. Cooke (pers. comm.) suggests that the human remains may have come from either of two very small and inaccessible caves (LB-4, LB-5) above the apex of the Bridge itself. These have been examined, without excavation, and do not seem to contain artifactual material. There are a number of small caves a kilometre or so to the south which have not been examined.

Michelago

A probable disposition in a cave was reported in both the Goulburn Evening Penny Post and the Cooma Express in 1896 (13 and 14 February respectively). The remains were sewn up in an animal skin rug and the cave entrance was reportedly blocked up with rocks. The skull and other bones were reported to be of immense size:

...it would appear in life that the deceased must have been a proper Hercules (Goulburn Evening Penny Post).

The fineness of the sewing was commented upon at length (contemptuously). Constables Bradshaw and Brennan (again) were sent to retrieve the bones which were to be sent to Sydney. It is not known where this material is today.

Paddys River

The Paddys River or Cotter Caves do not appear to be particularly suitable for occupation but like all the other karst areas there are niches aplenty for disposition sites. There are open sites in the immediate vicinity of the caves. Excavations by Brian Egloff and Phil Boot did not reveal any Aboriginal artifactual material in two excavations in Cotter Cave (PR-1) or in Powder Store Cave (PR-2). There was very little bone material and at that unidentifiable (Davey et al. 1992).

Namadgi

There are many boulder and shelter caves in the Australian Capital Territory which do not fall within the scope of this paper. Some have revealed much interesting material dating back as far as 21,000 BP (Flood 1980 1983).

Wee Jasper

There does not appear to be any Aboriginal association with the Wee Jasper caves which is surprising in view of the number of relatively suitable sites (eg Punchbowl WJ-8, Signature WJ-7, Pylon 58 WJ-99), an ecologically diverse area, many surface artifactual scatters, the long European occupation and nearby associations with caves (Cooleman, Talmo, Cave Flat). Punchbowl, Signature and Pylon 58 may well repay detailed investigation.

Talmo

Talmo Cave, near Burrinjuck Dam, is reported by John Glover of Binalong, to have been utilised as a meeting and/or hiding place for relatively large numbers of Aboriginals. The cave described as Talmo Cave in the speleological literature does not sound a very suitable site. The area should be investigated further.

Cave Flat

A large cave at Cave Flat, now Cave Island, is revealed at times of very low water in Burrinjuck Dam. The cave was visited by Bennett in the early 1830s (Bennett 1834) and palaeontological material was removed in the 1880s by Charles Jenkins who had some expertise as a grave robber (NSW Legislative Council 1883). Jenkins does not mention Aboriginal material but Bennett (1834:229) following the "*dibbil-dibbil*" passage quoted above goes on to say:

> *In a small cave attached to this cavern a number of human bones had recently been found, which it was afterwards ascertained were those of a native female, and had been deposited there, (in accordance with a custom among the aborigines of placing the bodies of deceased friends and relations in caverns, hollow trunks of trees, &c.) about twenty years before.*

If this material survived until the advent of Jenkins or the flooding of the cave subsequent to 1915 is not known. The next prolonged drought is awaited.

Narrangullen

Cooke (1988) suggests that Bennett's 1834 mention of bones and their recent placement refers to Narrangullen Cave. However, it is thought that this is an erroneous supposition. Bennett says the cave is sixty yards from and not far above the Murrumbidgee River whereas Narrangullen is well above the River and is a kilometre away on a tributary; he does not mention the virtually permanent stream which flows through the Narrangullen Cave and its location does not fit well with Bennett's route. The size of the cave and his map [the first Australian cave map] also fits Cave Flat better than Narrangullen.

However, Narrangullen Cave, in both its upstream and downstream entrances, seems to have many advantages as an occupation site. It is dry, but with convenient water, of favourable aspect in both summer and winter and close to rich ecological resources.

Bungonia

In 1892 the "*Keeper of the Caves*", Louis Guymer, discovered a skull in a cave near Cardinal Point, below the Lookdown (Etheridge 1893). The cave, now know as Skull Cave B-46, is a small cave reminiscent of, but on a larger scale, CP-75 at Cooleman Plain. It is relatively inaccessible, overlooks a splendid view and there are nearby caves ideally suited for shelter from the elements. Several of the nearby caves appear to have smoke-blackened ceilings.

Etheridge (1893:129) describes the site as follows:

> *About twenty feet within the mouth of the cave, says Mr. Guymer, there is a drop of ten feet, then a small chamber, with the floor dust covered. Twelve feet within this chamber in a westerly direction was observed a large overhanging rock, and under this the skull was found. It rested on a skin of some kind, then rotten with age, face downwards, and was immediately covered with a net. This was overlain by some stringy-bark, and above the whole some stones were piled. No other human bones were discovered, but a number of smaller ones, probably wallaby. The position of the skull was at least forty feet under ground in a direct line. [horizontal or vertical?] The cave is said to have been years ago, the haunt of bushrangers.*

This description does not match very well the cave now known as Skull Cave (Ellis et al. 1972 There is some confusion of cave numbers and names at this site.). Etheridge goes on to say that the skull is of a child aged about eight, of "*doubtful sex*" and that the net is of undoubted Aboriginal origin being similar to nets he had previously seen illustrated from East Gippsland. He then discusses the fears that Aboriginals had of caves, with examples from all over the continent; he discounts the bushrangers (cf the account of the sewing at Michelago):

> *....it is exceedingly unlikely that they [the bushrangers] would have exercised the same care and attention to detail as that shown by those who placed the skull in the cave. (p 130)*

He concludes by saying:

> *It would seem, therefore, definite evidence to the contrary being absent, that this is a genuine case of the deposition of aboriginal remains sufficiently far within a cave to be an exception to the general rule previously referred to.* (p 132)

There are many surface sites nearby but no other records of use of the caves.

Wombeyan

Wombeyan has a number of caves which would make fine occupation sites but none have been properly investigated. Nurse (1982), citing Mathews (1908), tells of a legend of a mythical being, part fish and part reptile, which hid from *Mir'-ra-gan* in Wombeyan Caves before escaping to Jenolan. The being, *Gu-rang'-atch*, and its pursuer, created many of the holes and other landforms. Mathews apparently feels that the presence of these two beings discourages Aboriginal use of caves.

Ellis et al. (1982:184) state that Glass Cave W-9 contains:

> *...a series of drawings executed in pencil or charcoal which appear to represent fish. Popular legend has it that these are aboriginal in origin, but there is little evidence for this.*

These drawings should be examined. If they are executed in charcoal radio-carbon dating may be possible.

Abercrombie

The Grand Arch, and the nearby Bushrangers Cave and Stable Arch, appear highly suitable sites for use by Aboriginals. Europeans, in the form of bushrangers and goldminers certainly used the caves and it may be that their heavy tread has disturbed any evidence. Barry Cubitt (pers. comm.) attributes the lack of use by Aboriginals to the legend of *Gu-rang'-atch* discussed above in the section on Wombeyan.

Johnson (1977) excavated a small karst shelter above the Grand Arch. The shelter's contents are apparently not much older than 15,000 years. The site revealed a wealth of stone of which a small amount had been worked and appeared to fit "broadly within the eastern variant of the Small Tool Tradition'. A large range of animals were also represented. Johnson's students apparently found worked material in many of the cave entrances.

Near Abercrombie there is a non-limestone cave in the Coperhania Nature Reserve. This reputedly contains finger markings (Osborne pers. comm.).

Borenore

Borenore, near Orange, has the potential for many sites and the NPWS Site Register does record a variety of sites nearby. Frank (1972), in the course of a sedimentological study in the Arch Cave, had 2.2 metres of entrance facies material sieved in 15 cm spits. "*....only a few flakes of possible human origin were found and none of these were classifiable chronologically.*" A fireplace at 40 cm depth was thought to be of historic origin.

Tuglow

Pleistocene or Plasticene Cave (T-3) may be a suitable occupation site.

Colong

The main entrance to Colong Caves (CG-5) appears to be a suitable occupation site although only a cursory examination has been made of this spacious and dry area close to water and diverse ecosystems.

Jenolan

Jenolan is one of the most significant cave areas in Australia both from the point of view of the natural and European cultural resource viewpoints. There is some evidence of Aboriginal use of the caves. Hotchin and Houshold (1988) located a small number of surface sites during a survey for the recent management planning exercise as well as a possible quartz flake in cave sediments in one cave and an apparently painted anthropomorphic figure in a small karst rock shelter.

The legend of Gu-ra*ng'-atch* pertaining to Wombeyan and Jenolan has been referred to above (Nurse 1982).

Etheridge and Trickett (1904) describe the discovery and possible origins of a skeleton from the Cerberus (formerly Skeleton) Cave. This skeleton was formerly shown to tourists but at the request of the Gandangara Local Aboriginal Lands Council it is no longer mentioned or illuminated. Etheridge and Trickett consider the skeleton, which is about one hundred metres vertically below the surface, to have fallen from caverns above. There is some evidence that the material may have been washed in along with several marsupials found in the general vicinity. The origin will remain speculative as will the age. An age of 18,000 years BP is frequently cited without any evidence whatsoever.

Slaven Cave

Slaven Cave is a non-karst cave near Lithgow. It is however much more than a rock shelter and is a dark zone cave of somewhat problematic origins (James and McIntyre 1989). Investigations by McIntyre have revealed two separate hearths dated at 360 and 450 years BP (both +/- 50 years). She also reports an artifact dated at 1,440 +/- 50 years BP. As well as the cave's enigmatic origins, the archaeological material, whilst not ambiguous, is not entirely without question.

Cliefden

Skeletal material was discovered in a cave at Cliefden (Pardoe and Webb 1986) who identify it as CL-96. The Australian Speleological Federation (ASF 1985) lists CL-96 as an impenetrable stream sink. The correct code is CL-93. The material is without cultural context and currently the cave has only a very small entrance. Pardoe and Webb (*op cit*) date the material at 6,250 +/- 430 years BP and suggest that the adult male fell into the cave through an entrance now blocked.

Their analysis of the skeletal material is the most detailed of all on the cave sites we currently know. Although the site cannot be interpreted archaeologically Pardoe and Webb describe the individual as follows:

> *The rigours of life in this environment are recorded in the metabolic insults of this man of middle years: his susceptibility to repeated privation in childhood as measured by Harris lines; by his adaptation to a difficult terrain as evidenced by the enlargement of muscle insertions; by his arthritic deterioration with advancing years, no doubt exacerbated by the wet chill of winter and finally by his probably violent death.* (p 22)

Carved trees were to be found near the cave (Louise Coleburn pers. comm.) and a "nardoo stone" was recently found in a shallow karst cave at Canomidine (Bruce Howlett pers. comm.).

Wellington

Anderson (nd) in a comprehensive survey of the resources of the Wellington Caves area discusses the very limited evidence for Aboriginal use of the caves. Armstrong Osborne discovered a human mandible in Triplett Cave but its provenance is unknown. There were carved trees on the site and there are surface artifactual scatters. Interestingly Augustus Earle, the colonial painter, shows a group of Aboriginals around a campfire near a major cave entrance in one of his works. This may be merely artistic licence.

Wellington was also the site of the Krefft tooth controversy. This supposedly human tooth fragment, found in 1869 in association with megafaunal remains, generated much interest as it was the oldest evidence of human occupation in Australia (as well as the association with megafauna, Krefft 1870). Even Krefft himself was not completely convinced and the fragment was eventually proved to have been part of a macropod tooth (Campbell 1949, Finlayson 1949).

East of the Wellington are the Burran Burran Caves. These are now partly filled in but are reputed to contain paintings (Osborne pers. comm.)

DISCUSSION

The various reports and citations raised above indicate that the Aboriginal people have used caves in the tablelands and surrounds for twenty millenia or more. Earlier discussions by Bowdler (1975), Jennings (1979) and Flood (1980, 1983) recognised the value of karst cave sites but there have been further investigations from that time and increased knowledge of the climates of the late Pleistocene and Holocene add to our understanding of when and why caves might have been used. The very substantial discoveries of "ice-age" sites in Tasmania should prompt us to re-examine more closely our karst cave sites on the Northern Island.

Meehan's (1971) very complete and indexed thesis on Aboriginal mortuary practices surprisingly does not discuss a number of the references herein cited on disposition sites. It is clear that south eastern Australia has far more occurrences of skeletal material in caves (and rock shelters) than she records. Many of these are the results of accidents as at Jenolan, Cleifden and Indi. Others are clearly primary or secondary disposition sites as at Cooleman, Cave Flat and Bungonia. However the bulk of the material from reported "burials" has been misplaced.

Occupation sites are either Pleistocene or more recent sites and these latter are much more ephemeral than the ice-age occupations. In the words of Flood (1980:275):

> *The history of Cloggs Cave may reflect a change in the concept of the use of caves between the glacial and post- glacial periods. In the Ice Age such deep caves, although lacking light, would have provided welcome shelter and warmth, but later they were vacated, and in the Protohistoric Period were apparently regarded with awe and fear, and only used as burial places.*

The reasons are, of course, fairly obvious. Cloggs Cave was below the treeline in the late glacial period but a nearby site which contains an owl-deposit of small mammal bones contains above-treeline species. Clearly Cloggs would have been near an acceptable climatic limit for habitation. New Guinea Number Two is a similar environment. All other karst sites in south eastern Australia are much higher and presumably completely inhospitable. Possible exceptions are Bendethera and other Deua National Park caves and those further to the north as at Jenolan and Cleifden. Undated periglacial slope deposits are found at Jenolan. Gillieson et al. (1985) report periglacial slope deposits in Basin Cave (W-4, 660 m asl) at Wombeyan dated at 27,850 +/- 1,100 years BP. Jennings et al. (1982) discussed a similar deposit on the surface nearby dated at 19,700 +/- 1,500 years BP. These deposits indicate that conditions at this altitude and latitude would mitigate against occupation in the late Pleistocene.

Whether or not there was a change in attitude towards caves by Aboriginal people following climatic amelioration after the glacial period, will always be open to speculation but it appears likely that funerary practices only took place in the outer twilight zone although sites such as at Bungonia lend an element of doubt. How interesting it would be to know more about the skeletal material removed from Yarrangobilly, Cooleman, Michelago and London Bridge.

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Address for correspondence:
Southern Region
New South Wales National Parks and Wildlife Service
P O Box 733 Queanbeyan NSW 2620

Book Review

TITLE: THE INVERTEBRATE CAVE FAUNA OF TASMANIAN CAVES

Authors: Eberhard, Richardson and Swain
Publisher: Zoology Department, University of Tasmania. 1991
Reviewer: M. Gray, Australian Museum

This report on the cave invertebrates of Tasmania was published in 1991 and so will probably be familiar to many readers. However, its utility as a comprehensive source of faunal documentation for Tasmanian caves remains unsurpassed. Tasmania's significant zoogeographical position and climatic history makes the recording of its relict faunas of particular importance.

The data presented is based upon an ambitious sampling program of more than 130 caves covering at least half the Tasmanian karst areas. Some 50 species were collected and 34 of the genera represented contained troglobitic representatives. Many species remain undescribed but much of the material has been distributed to specialist taxonomists for further work.

The text is set out in four parts, the last comprising an extensive bibliography. A succinct introductory section deals with previous investigations (fittingly, the giant Tasmanian cave Spider, *Hickmania troglodytes*, was the first cavernicole to be discovered and described in 1883), a brief background on scientific cave biology, the aims of the study and its methodology. A map of the Tasmanian karst regions is also provided here. It would be helpful to refer the reader here to the listings for the actual sites sampled, eventually found in Appendix 1. A noteworthy outcome of this project has been the creation of a detailed Tasmanian cave fauna database. This should prove to be a useful ongoing and updateable research source. Sampling methods are rather briefly dealt with and it would have been interesting to learn more about the trapping techniques mentioned, including the target groups. This section ends with a useful summary of the terminology used in describing the fauna of the hypogean domain, from caves to the hypotelminorheic medium (miniature sub-humus/soil streams in montane areas!).

The main part of this work reviews the Tasmanian cave fauna, terrestrial, aquatic and interstitial, under the major invertebrate groups sampled (Appendix 4 lists fauna under karst areas). These comprise representatives of the phyla Platyhelminthes, Nemertini, Aschelminthes, Annelida and Arthropoda. Identification was aided by the distribution of sorted collections to many specialists. The arthropods, especially arachnids, crustaceans and insects, dominated the fauna (113 genera in 95 families). For each group a summary of faunal composition, relationships, behaviour and ecology is given, followed by a listing of distribution records. Distribution maps are given for a number of taxa. This section brings out clearly the need for taxonomic work to place the many undescribed species into a classificatory framework that will allow a fuller view of distribution and relationship patterns. Type localities for described taxa are listed in Appendix 2.

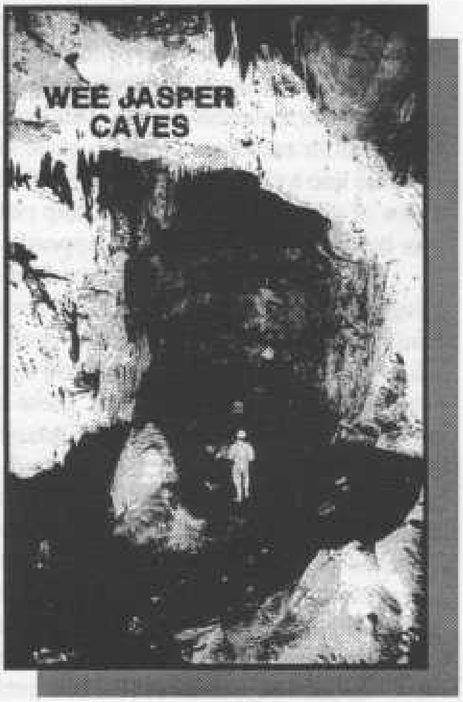
The third section discusses these results in terms of troglobitic evolution, diversity and conservation. At present only two groups are sufficiently well known in terms of distribution and relationships to allow hypothesis regarding the evolution of the troglibitic fauna. These are the carabid beetles and the Opiliones (harvestmen), though reviews of several mollusc and spider taxa should soon augment them. The conclusion is drawn that Tasmania has the richest cave faunal assemblage in temperate Australia and will be of great importance in elucidating the evolutionary history of the Australian cave biota. Conservation issues are addressed by identifying karst areas of high conservation value and those under threat from impacts as diverse as quarrying to recreational use.

In summary, this is an excellent publication. Comprehensive regional overviews of our cave biotas are rare and this work sets a high standard for future publications. It should promote a wider and more informed interest in cave biology among both researchers and cavers.

WEE JASPER CAVES

by J.N. Jennings

Reprints from HELICTITE, The Journal of Australian Cave Research, with additional material by Julia M. James and Andy P. Spate, edited by Julia M. James, D.J. Martin and B.R. Welch.



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