Cave and Karst Science

The Transactions of the British Cave Research Association

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Volume 29 **Number 1** **2002**

Shaft development: Slovak Republic
Madagascar karst and caves
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Cave and Karst Science

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Manuscripts may be sent to either of the Editors: Dr D J Lowe, c/o British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK, and Professor J Gunn, Limestone Research Group, University of Huddersfield, Queensgate, Huddersfield, HDI 3DH. UK. Intending authors are welcome to contact the Editors, who will be pleased to advise on manuscript preparation. Enquiries by E-mail are welcomed, to: djlo@bgs.ac.uk or j.gunn@hud.ac.uk.

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Abstract: All material should be accompanied by an abstract, stating the essential results of the investigation or the significance of the contribution, for use by abstracting, library and other services. Occasionally such abstracts may also be published in *Caves and Caving*.

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Speleological expeditions have a moral obligation to produce reports (contractual in the case of recipients of awards from the Ghar Parau Foundation). These should be concise and cover the results of the expedition as soon as possible after the return from overseas, so that later expeditions are informed for their planning. Personal anecdotes should be kept to a minimum, but useful advice such as location of food supplies, medical services, etc, may be included. preferably as a series of appendices.

Authors will be provided with 20 reprints of their own contribution, free of charge, for their own use.

If any problems are perceived regarding the nature, content or format of the material, please consult either of the Editors before submitting the manuscript.

Cave and Karst Science

TRANSACTIONS OF THE BRITISH CAVE RESEARCH ASSOCIATION

Volume 29, Number 1, 2002

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Cover photo:

Dissolution notches and small foot caves beneath a limestone wall fluted with razor-sharp karren, within the Tsingy de Namoroka of western Madagascar.

Photo by John Middleton

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EDITORIAL

David Lowe and John Gunn

In the last Issue of *Cave and Karst Science* we raised the question of whether or not to continue the practice of providing editorial comment. Encouragingly no one has said, *"Don't bother"*. We did not receive a deluge of messages, but those who did take the trouble to respond broadly said *"Go ahead, but only if you have something worthwhile to say"*, i.e. cut out the 'waffle'. On that basis we will continue to provide an Editorial. Several seemingly major issues are currently developing, but are not quite well enough developed to ensure considered comment. Thus, in this Issue we will take another opportunity to strengthen a message to potential contributors.

Obvious advantages are presented by modern methods whereby all materials for publishing reach the printing company ready formatted and digitized. Nevertheless, our own policy currently remains one of using digital techniques to produce our own camera-ready hard copy, which is supplied, lacking only its photographic illustrations, to the printer. This policy dates from when our layout and formatting were carried out using PC-based desktop publishing (DTP) software. Problems inherent in moving from PC-generated word processor and graphics files, through PC-based DTP software and on into the Mac-based technology that is preferred by most printing companies threatened significant scope for error introduction and major overheads in terms of checking and double checking proof material. Our "new" DTP operator, Becky Talbot, favours Mac-based computing, but still finds problems with some aspects of migrating specific aspects of PC-based originals into her Mac DTP package without corruption. As she finds ways to deal with these problems, and her output becomes more routine and less labour intensive, we will re-examine the potential advantages offered by omitting a camera-ready copy stage. However, in the meantime, we remain faced with one major difficulty in attaining high quality output via camera-ready copy – and that is the question of illustrations, especially photographic illustrations.

Line illustrations (figures), such as area maps and cave surveys, are inserted directly to the DTP files and printed as part of the camera-ready copy. In some cases authors provide figures as digital files, in a surprising variety of graphics formats. With varying degrees of ease (or difficulty) such material can usually be "edited" and, if necessary, cropped or re-sized for import into the appropriate DTP file. Some illustrations are provided as (usually high quality) hard copy, and these are scanned into a suitable graphics format at high resolution and imported directly to the appropriate DTP file. Putting aside the sometimes overlooked problem of actually moving huge graphics files around, and the occasional troubles that we have with "odd" graphics formats, all of the above is moderately straightforward and works reasonably well. Problems are only caused if authors provide low-resolution digital or analogue graphics or if quality is unavoidably lost during any enforced format conversions. The message to authors is straightforward. If you must send graphics files of line illustrations, ensure that they are in a common (industry standard) or easily-migrated format, and that their resolution will enable a print quality that you will find acceptable. If you can meet these criteria your files will be welcomed. However, if you can't meet these requirements, for whatever reason, simply send good quality hard copy.

In contrast, photographic illustrations (plates) are "dropped into" the camera-ready copy by the printing company. Originally this was because they could scan original photographs (whether colour or black and white, positives or negatives) at very high resolution and use dedicated software to produce an image of appropriate quality to give the best possible results when printed on their machines. Nowadays, of course, some contributors produce digital photograph files themselves, either directly or indirectly, as processing companies offer digital options and as more and more people gain access to digital cameras or reasonably high quality scanners and software that supports image "manipulation". In fact, we welcome such digital files, assuming they are in a usable/accessible format, as being very useful in helping to format a finished publication. Even then, however, we will eventually pass the file to the printing company, so that they will ensure that the image printed is the best that can be achieved from the available digital information. Though the printers do their best with what is supplied, for various reasons some of the digital photo files provided by authors are of relatively low resolution or poor balance, and this shows in the finished product.

Our first plea therefore must be, only provide photographic illustrations (in whatever format) if they are of sufficiently high quality to remain interesting and informative after printing. Whereas we will sometimes include less than ideal material if it adds to the impact or understanding of the related article, this does attract adverse comment, which is doubly galling if the criticism emanates from the originating author(s)! Some "archival" photographs or second generation copies of ancient pictures inevitably fall short of modern quality standards, but we will generally include these, because their eventual appearance will be judged sensibly and, hopefully, in an appropriate context. This isn't always the case with "modern masterpieces".

Our second plea is that if authors wish to provide photographic images digitally they should ensure that these are properly balanced and of sufficiently high resolution, as well as in an industry standard format that can readily be handled and "tweaked" by the printing company. As pointed out, even lower quality digital files will help us in developing the publication layout. However, especially in the case of potential cover photos, unless high quality, high-resolution photo-files are available, we still prefer to receive good hard copies (print or transparency). These can then be digitized to the highest possible standard using the professional skills and state of the art equipment available at the printing company.

Other than that, the various guidelines that we have included on the inside front cover continue to apply, though for most contributors the emphasis has moved over the years, as facilities for producing high quality illustrations have become more widely available. Recommendations regarding making text on proposed illustrations large enough to allow reduction before publication remain particularly important, and ignoring them commonly causes major problems during compilation. We recommend all authors to examine a few *Cave and Karst Science* back issues, and try to gain a feel for our most commonly used formats, before drafting and submitting line illustrations. In particular, note that, wherever possible, we try to avoid including large "landscape" figures that need rotating through 90 degrees and presenting sideways on a "portrait" shaped page. We will inevitably try to reduce these to fit across the page and be part of the flow of the article, but we cannot do so if vital text or other detail will thus become too small to read.

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Speleognesis along sub-vertical joints: A model of plateau karst shaft development: A case study: the Dolný Vrch Plateau (Slovak Republic)

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Abstract: Speleogenesis of narrow and relatively deep karst shafts (avens) was studied in the Slovak part of the Dolný Vrch Plateau (the Slovak Karst Biosphere Reserve, SE Slovakia). Most of the 211 shafts and shaft-related depressions located on the plateau have similar characteristics and no shaft has a known accessible connection to an active horizontal cave system. Dominant tectonic fractures are sub-vertical (sloping 70 – 90°) in most of the shafts. Several microforms, e.g. scallop-like forms, wall troughs or networks of protruding veins, evidence the main speleogenetic processes.

Water film dissolution extends the fractures, usually at the base of the epikarstic zone (Klimchouk, 1995), while the scallop-like forms develop. Then corrosive and erosive action of dripping water takes place and the wall troughs develop downwards – the shaft develops progressively now. Increased carbon dioxide concentration makes the solutions more aggressive and enables the processes working on the shaft bottoms. Water film action and selective condensation corrosion are responsible for upward shaft development. Later, shafts open to the surface, interacting with the effects of surface denudation.

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INTRODUCTION

Relatively narrow and deep vertical caverns, which developed in the epikarst and vadose zones of karst plateaus with no known accessible connection to active horizontal caves, are considered here to be *plateau karst* shafts. Until now, the origin of such caverns has not been well understood and has been the subject of conflicting opinions (Baroň, 1998, 2001, 2002; Baroň & Fiala, 1999; Hradecký *et al.*, 1974; Kósa, 1971; Lešinský, 1998; Lysenko *et al.*, 1974; Muller & Sárváry, 1971; Skřivánek, 1958, 1965).

This paper attempts to explain the more important factors of their speleogenesis and outlines the main stages of shaft evolution, adding the author's observations to older information. This research took place at the Dolný Vrch Plateau, in the Slovak Karst Protected Area in southeastern Slovakia (Fig.1), as part of a systematic 35-year speleological study of the plateau by Czech and Slovak cavers and karstologists.

GEOLOGICAL AND GEOMORPHIC SETTING

The Dolný Vrch Plateau is about 17km long and 1 to 7km wide, elongated from east to west. It is crossed by the east-west border between Slovakia and Hungary (the Slovak part is only 2km wide). In Hungary it is called the "Alsó Hégyi" Plateau. The plateau surface slopes southward from an altitude of 611m asl (the Pavlovský Vrch Hill) to 500m asl at the southern edge. The plateau surface extends up to 400m above the local fluvial base level (the bottom of the Turnianska Basin). The surface of the plateau is slightly irregular with isolated hills and dissolution dolines with diameters of typically 50 to 150m and ranging up to 300m. The Slovak part of the plateau consists of very pure lagoonal Wetterstein Limestone, 800-1200m thick, grading southward into bodies of Riff Wetterstein Limestone, both of Triassic (Ladinian-Cordevolian) age (Mello *et al.*, 1996, 1997). The large Vcelare Quarry is located at the eastern edge of the plateau.

HYDROGEOLOGICAL SETTING

There is a probable karst water table at the level of the plateau base, approximately at base level at the altitude of about 230m asl, where most of the karst springs are located. There are 11 karst springs at the base of the plateau on the Slovak side. The pH of the spring water ranges between 7.3 and 8.5 (Lysenko *et al.*, 1974). Above this general level is a vadose zone perhaps 350m thick, in which shafts have developed in the upper part.

At present the shafts do not contribute much to the groundwater system, as most of the recharge enters through joint networks below the dolines. The amount of water descending the shafts varies irregularly with depth and does not always reach the maximum intensity at the shaft bottoms. In some shafts much of the water is lost through openings in steps in the shaft walls, so that the lowest accessible parts of the shaft could contain almost no water flow. In general, the pH

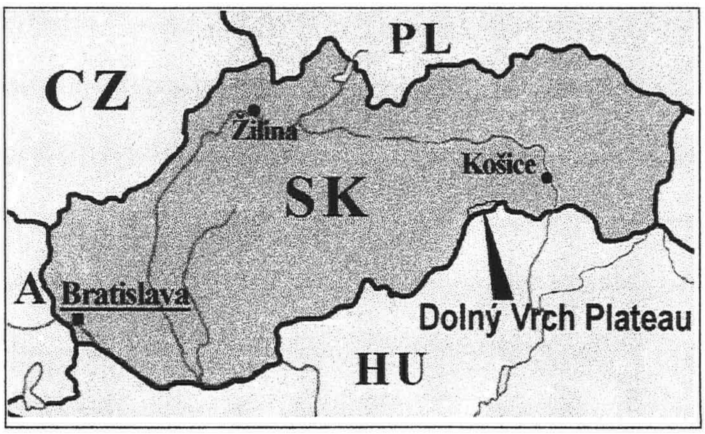


Figure 1: Location of the Dolný Vrch Plateau within the Slovak Republic.

Plate 1: Scallop-like forms have developed most probably due to water-film action (the Hlinos shaft).

diminishes with depth to values as low as 5.3 near some shaft bottoms (Lysenko, 1974). An epikarst (Klimchouk, 1995) has developed in the upper part of the bedrock (the subcutaneous zone of Williams, 1983). The epikarst is several metres thick and consists of highly fissured bedrock. Water becomes perched in the epikarst above the rest of the vadose zone because the jointing diminishes downward. The perched water leaks downward only along major tectonic fractures. Shafts form only along these fractures, predominantly below the base of the epikarst (Klimchouk, 1995; Klimchouk *et al.*, 1996).

SHAFT CHARACTERISTICS

The Dolný Vrch - Alsó Hégyi Plateau contains 211 known shafts or shaft-related depressions. The deepest is the Vecsembükki Shaft (-260m) located on the Hungarian side; the Natrhnutá Shaft (-123m) is the deepest on the Slovak side (Vlk *et al.*, 2002).

Most of the shafts have similar characteristics. They are relatively narrow and deep, and in general contain vertical steps with profiles

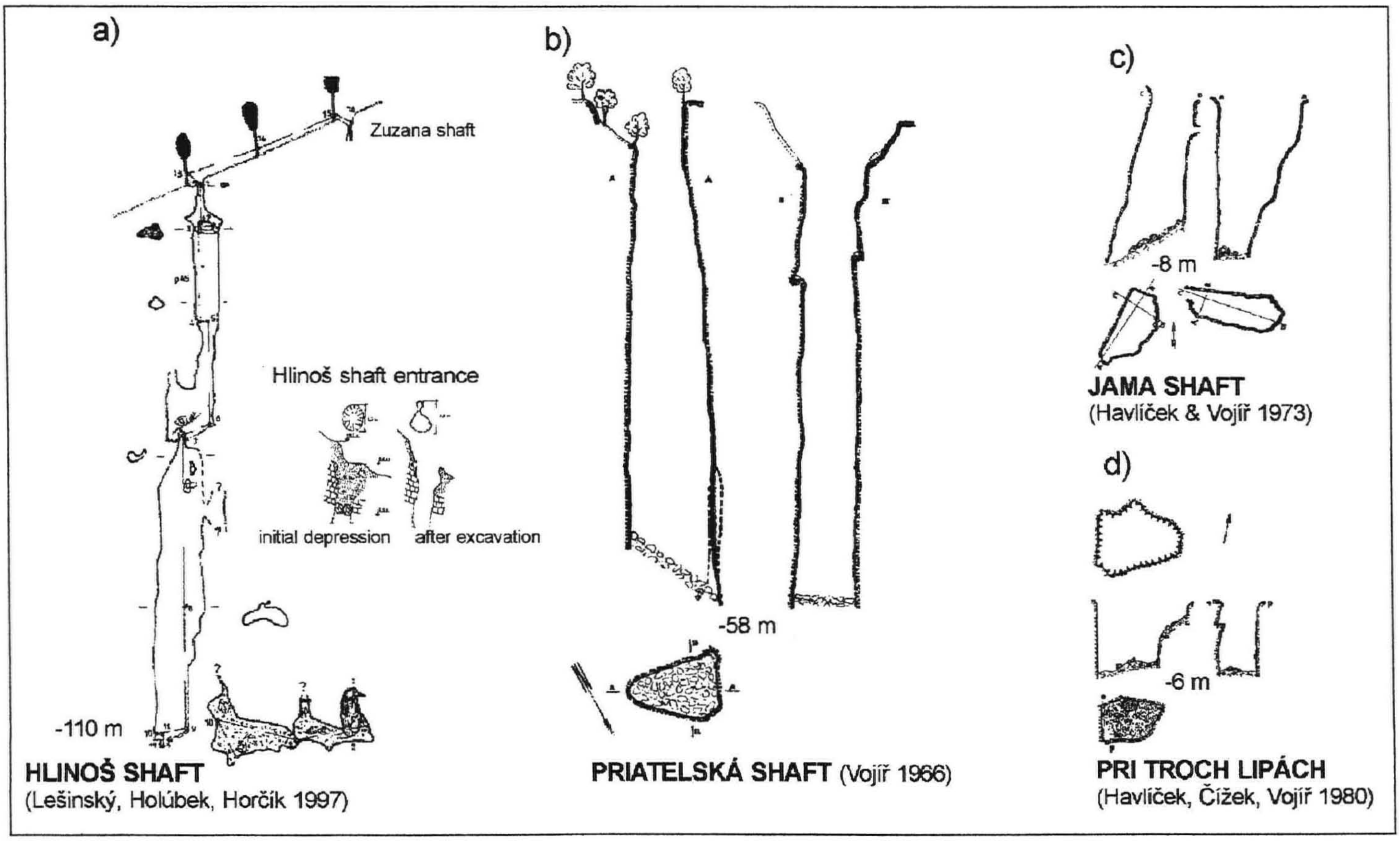
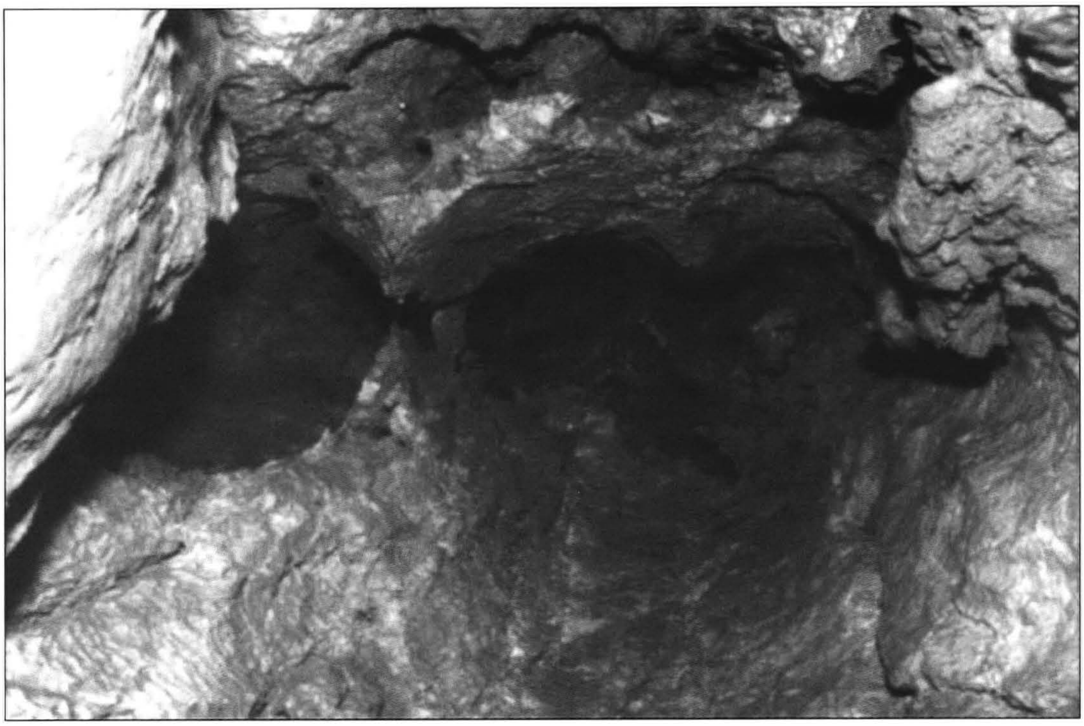


Figure 2: Speleological maps of some "typical" shafts at the Dolný Vrch Plateau: a = presently dug out shaft; b, c = old shafts with large entrances; d = relict shaft.

Plate 2: Top of the shaft modelled mostly by film water action and condensation corrosion (the Dubova shaft - upward view).



resembling right-triangles. The entrances are relatively narrow and their widths are related to the age of the shafts. The first shafts to be discovered generally have wide entrances, but those that have only recently been dug open have very narrow ones (Fig.2). Shaft-related depressions can be divided into two types: incipient depressions and relict shafts. The incipient depressions (Lešinský, 1997, 1999) are shallow doline-like depressions several decimetres in diameter in soil material. The soil creeps into young shafts below. In contrast, relict shafts (prepadlisko) are rock-walled depressions several decimetres or metres in diameter, which have filled with debris such as sinter fragments, soil, and recent organic detritus (Fig.2d).

Most of the shaft entrances are located on flat surfaces between large dolines (40%), in the slopes of doline walls (30%), at the foot of the slopes inside dolines (20%), and around doline edges (10%). No shaft entrances were found right in the centres of dolines.

CHARACTER OF DOMINANT FRACTURES

Dominant tectonic fractures were measured in some shafts. Their dip angles are very important in controlling the shaft shapes. In deep vertical passages – typical pits – all of the main fractures are sub-vertical, dipping 70-90° (Fig.3). Very narrow fissures develop along nearly vertical fractures. Where the dip of the main fracture is less than 45°, the passage is a narrow, sinuous stream canyon. The long axis of the passage cross-section is perpendicular to the fracture direction (e.g. in the middle part of the Kostnica Shaft). Most of the joints observed in the shafts are simple tectonic fractures with no brecciation (tensile joints or slip joints, according to Lysenko *et al.*, 1974). Along the plateau margins they may also have enlarged by gravity sliding (e.g. the Čertova Diera Chasm in the Horný Vrch Plateau). For shaft development, simple tectonic fractures seem to be more important than breccia zones, which have a greater effect on doline development and crumbling of debris from shaft walls. (Baroň, 2001).

CORROSIVE AND EROSIVE FORMS THE KEY TO DETERMINING SHAFT GENESIS

Features produced by corrosion and erosion have been studied in a few young and undecorated shafts. For example, small scallop-like forms occur on vertical or overhanging walls in the deeper parts of shafts (Plate 1). They probably were developed by the corrosional and erosional effect of undersaturated water flowing as thin films. In the upper parts of shafts, networks of protruding veins suggest a selective corrosion of the rock by condensation corrosion (Plate 2). Huge "wall troughs" occur on vertical shaft walls (Plates 3, 4, 5, 6). They are essentially large flutes that terminate downward in bedrock ledges. They are formed by the corrosional and erosional action of dripping

Plate 3: Wall troughs have developed due to drop-water corrosion - erosional effect on sub-vertical rock surface (the Slnecna shaft, downward view).

Plate 4: Shaft modelled by drip-water (the Drozdia shaft, downward view).

water along the walls of sub-vertical fractures. The troughs are tens of centimetres in diameter, tens of metres long, and include a large proportion of the shaft volume. Their bases, as well as the shaft bottoms, are usually covered with debris such as loamy sediment and recent organic detritus (Plate 7). Only active shafts are free of this sediment.

MORPHOLOGY OF THE LOWER PARTS OF SHAFTS

A profile of the lower part of a shaft was found in the Vcelare Quarry (Plate 8). This preserved remnant is about 8m high and 2m in diameter. Clearly developed wall troughs can be observed, as well as the drainage channels below. These channels form a complex network along sub-vertical joints as the result of corrosion and erosion by water flows or films (depending on the amount of water). Scallop-like forms in the channels give evidence for at least occasional turbulent flow. The channels are several decimetres to several metres wide. They occur not only below the shaft, but also parallel to it. Probably they are precursors of future shafts.

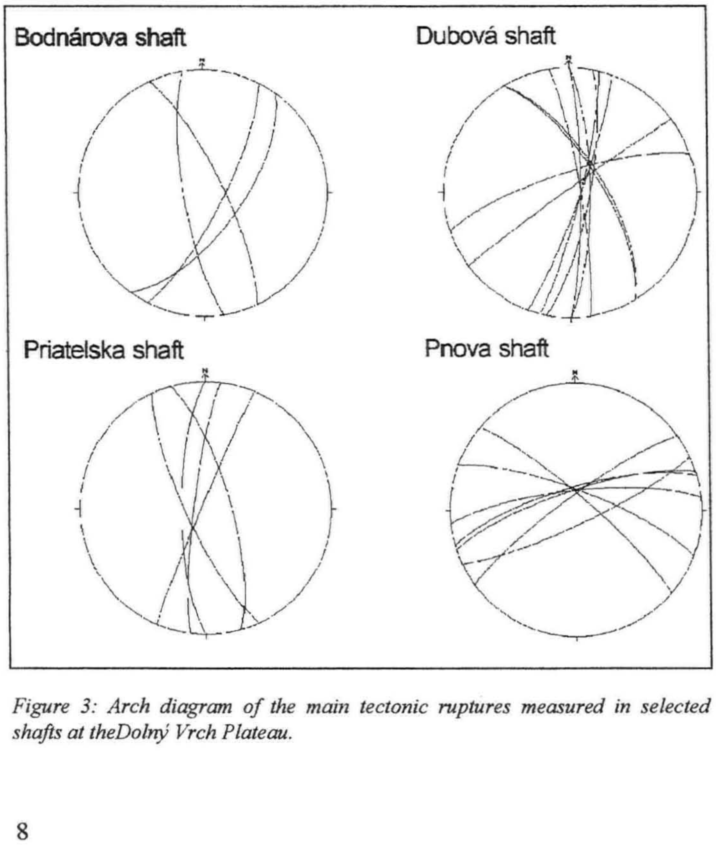


Figure 3: Arch diagram of the main tectonic ruptures measured in selected shafts at theDolný Vrch Plateau.

CO_2 CONCENTRATIONS: ORIGIN AND CONSEQUENCES

Carbon dioxide concentrations were measured for 10 years, systematically, in four shafts and occasionally in other shafts. To obtain these measurements, members of the Barrandien caving club were provided with an Airwatch PM1500 electronic CO_2 detector with glass-tube indicators (Vlk *et al.*, 2002). Carbon dioxide concentrations are greatest near the bottoms of poorly ventilated shafts (Table 1). No consistent maximum value of CO_2 accumulation was observed in the shafts. A carbon-isotope analysis was made to determine the origin of the CO_2. Carbon dioxide in the shafts comes from present biological processes, probably mostly from the soil (Žák, in Vlk & Novotná, 2000). High CO_2 concentrations can acidify water and aid in the dissolution of carbonate rocks.

DISCUSSION – MODEL OF SHAFT DEVELOPMENT

1. Embryonic cave stage (Fig.4)

Precipitation water dispersed in the epikarst is focused along major joints and faults, which act as leakage paths to the vadose zone below. This focused flow widens the fractures mainly at the base of the epikarst (Williams, 1983; Klimchouk, 1995). Closed *embryonic caves* and *drainage channels,* both of lenticular cross section, are developed as a result. They are usually very narrow and have no accessible connection to the surface. *Corrosion by thin water films* is probably the main speleogenetic agent in widening them (see Frumkin, 1996). Several caverns can occur at different locations along the same fracture, each fed by different water sources, and all showing different stages of development according to the amount of water available.

2. Young-shaft stage (Fig.4b)

Later, shaft enlargement becomes most rapid when trickles and drops of water are able to fall vertically through the high-CO_2 atmosphere and achieve great dissolutional capacity. They attack the bedrock intensively. Depressions develop where drips land. As the shafts

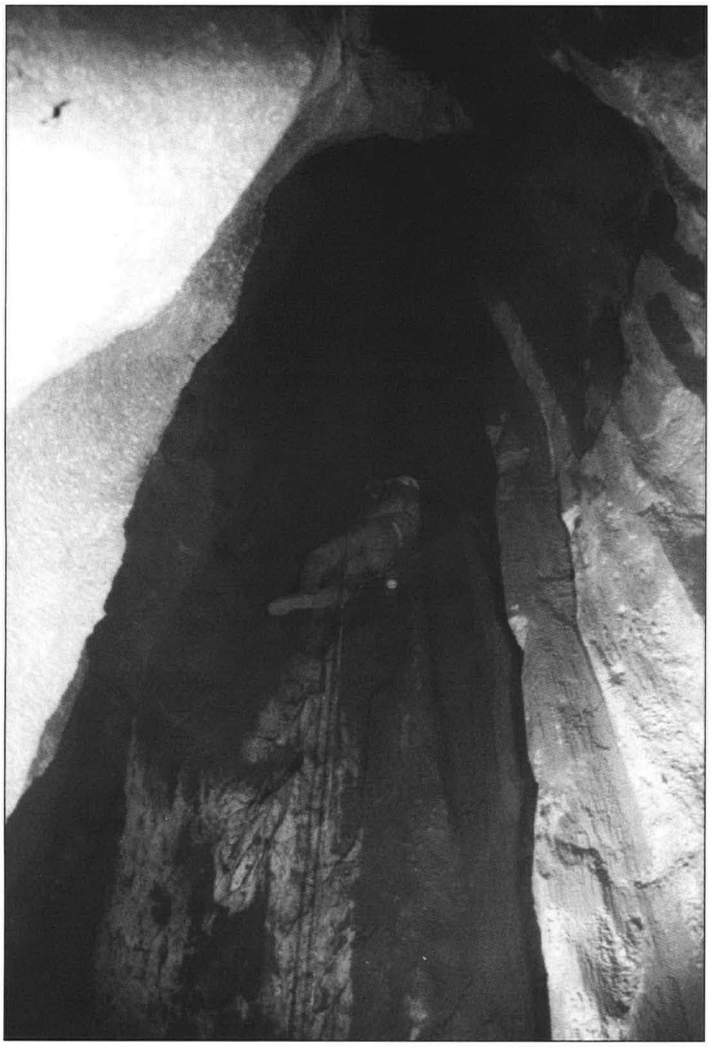


Plate 5: Wall troughs occur on vertical walls of the shafts (the Hlinos shaft, upward view).

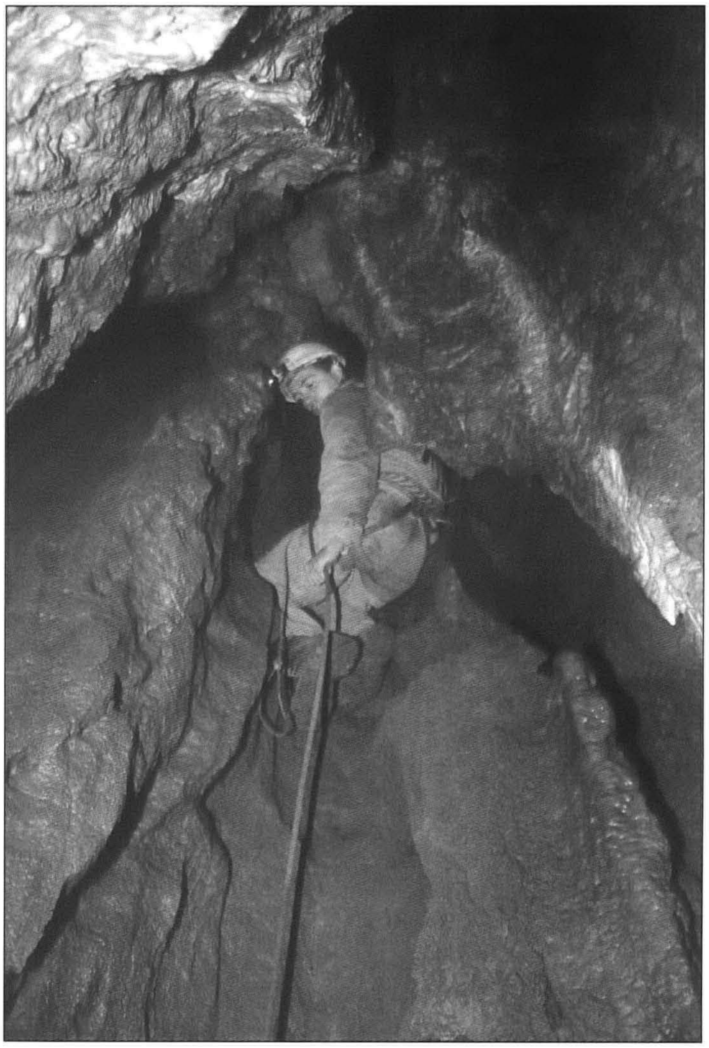


Plate 6: Wall troughs are essential parts of the shaft volume (the Drozdia shaft).

deepen, these depressions elongate into wall troughs along the upward-sloping walls of sub-vertical fractures (with slopes of 70 to 90°). The rate of shaft enlargement is greatest at this time. The troughs are the dominant parts of the shaft volume and reach lengths of tens of metres and diameters of several decimetres. The resulting shaft profile resembles a series of steps shaped like right-triangles, with the vertical walls formed by dripping water, the diagonal walls formed by the fracture surface. Drainage takes place downward along the fracture, which is still an inaccessible embryonic channel.

Expansion of the shaft width is minimal if the fracture is vertical. This is also the case along sub-horizontal fractures, where ponding of water in depressions inhibits further deepening by dripping water. The drip-water action was also noticed in cave pits by Merrill (1960).

The action of water films and rock-fall add to the drip-water effect, but they have relatively small influence on shaft enlargement. All of the shaft-forming processes are accentuated at intersections between fractures.

3. Stage of shaft opening (Fig.4c)
Shafts develop upward, too, by the action of water films and condensation corrosion. Condensation corrosion is the most intense at the top of the shaft, at the base of the epikarst, especially during the winter (Klimchouk, 1995). Surface denudation, subsoil corrosion, and the chemical and mechanical effects of tree roots combine in opening shafts to the surface. First, the incipient depression appears in the soil material at the surface. The shaft then opens spontaneously or by human excavation.

4. Notes on further shaft development (Figs 4c, d)
As they widen, parallel shafts and channels draw more perched water from the epikarst. Shaft deepening gradually diminishes as less water becomes available to any single opening. Sinter decoration begins, and these deposits tend to conceal the earlier dissolutional forms.

The diameter of an open shaft increases as the result of frost weathering (especially in late autumn and early spring), by rockfall, and by biological activity (e.g. by moss, lichens, and tree roots). Debris, including soil and organic detritus accumulate below the entrance and partly fill the shaft. Rotting organic material enhances the CO_2 concentration in the cave air, especially near shaft floors. The high-CO_2 atmosphere can increase drip-water aggressiveness and help deepen the shafts.

As the falling material accumulates in the shaft, and surface denudation reduces the terrain, only relict shafts eventually remain. These can be considered the equivalents of unroofed caves of Mihevc (1996), Geršl *et al.* (1999) or Šušteršič (2000).

The relationship between shafts and dissolution dolines remains unexplained. Although there is great hydraulic conductivity beneath the dissolution dolines, surprisingly, no plateau shafts have been found in their floors. Also, no shafts were found below the centres of dissolution dolines in the Vcelare Quarry.

CONCLUSIONS

Shafts in the Dolný Vrch Plateau develop mostly along sub-vertical tectonic fractures, and predominantly at the base of the epikarstic zone.

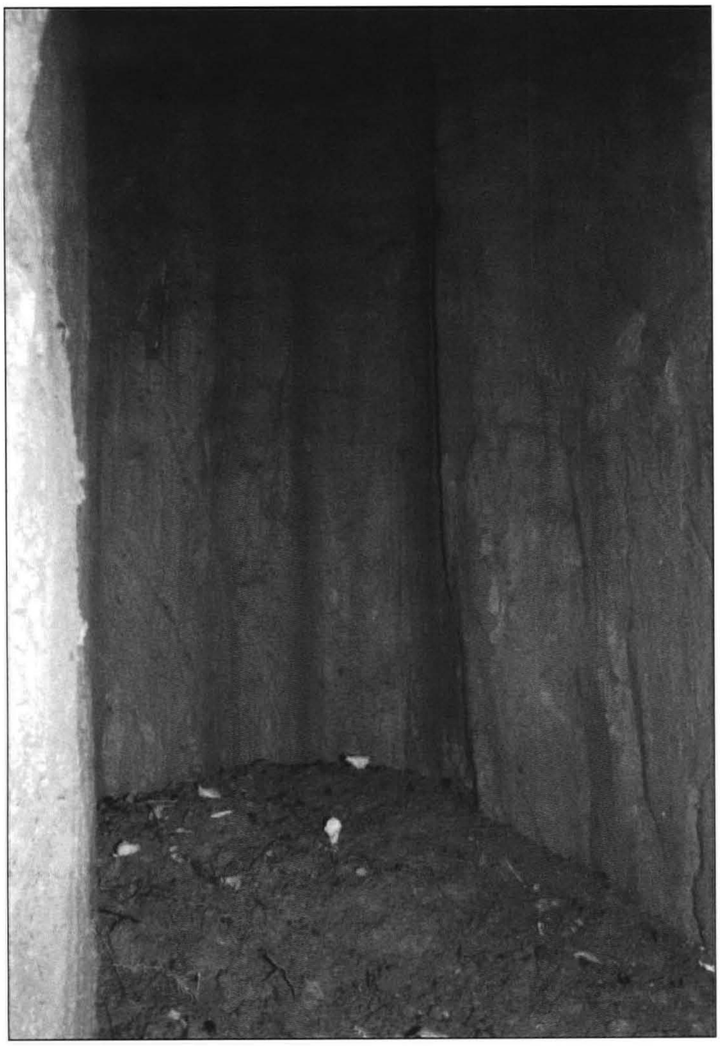


Plate 7: Foot of the trough covered with modern organic detritus, soil and debris (the Hlinos shaft)

The corrosive and erosive effects of drip-waters are the most important factor in shaft deepening. Water-film action and rockfalls are less important. In addition to surface denudation, subsoil corrosion, and tree-root action, the water-film widening and condensation corrosion are responsible for the natural opening of shafts to the surface. Shaft development is strongly controlled by the high concentration of CO_2 in their atmospheres.

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I thank Gabriel Lešinský, Rostislav Melichar, Václav Cílek and Pavel Bosák for helpful discussion of the problems and Arthur N Palmer for reviewing the English version of the text. The work could not have been done without help from friends in the Barrandien, Orcus, Badizer and Drienka caving clubs.

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Shaft Number	Shaft name	Sample location	Concentration of CO_2 (%) on sampling date shown										
			Aug 1991	Aug 1992	Aug 1993	Aug 1994	Aug 1995	July 1996	Aug 1997	July 1998	Aug 1999	Aug 2000	Aug 2001
29	Dubová	bottom of Entrance	3.50	2.80	1.70	0.50	2.50	0.95	0.40	2.45	1.20	1.10	2.50
		Entrance and main passage junction	4.00	3.20	2.40	1.80	3.00	1.30	4.00	3.15	3.36	3.50	3.20
		at -50m	4.20	5.00	2.80	3.20	3.60	4.00	5.00	3.48	3.99	3.85	3.50
		bottom	5.00	—	4.00	3.20	3.50	4.30	5.20	3.55	4.04	3.90	4.20
6	Kettős (Dvojitá)	bottom of Entrance	3.00	1.80	3.00	2.60	3.00	2.25	1.60	3.20	3.16	3.20	—
		foot of 2nd shaft	5.00	2.80	2.30	3.00	3.00	2.00	1.80	4.00	3.64	3.42	—
		at -42m	—	4.00	3.60	3.00	3.50	3.00	2.40	—	3.56	3.58	—
		bottom	—	—	2.60	3.00	—	3.00	2.60	—	3.71	3.68	—
76	Bodnárova	-5m	0.40	0.20	—	—	—	0.50	0.40	—	0.33	1.05	0.23
		-8m	—	—	2.00	1.25	1.20	—	—	1.16	1.37	—	1.17
		the "Floor"	2.50	1.00	1.80	2.00	2.00	1.30	2.00	2.01	2.01	2.20	2.17
		bottom	3.00	1.30	1.80	2.10	2.30	1.90	1.60	2.31	2.49	—	—
90	Geodetov	-5m	3.00	2.00	2.20	2.50	2.50	2.10	2.40	1.40	0.92	1.10	1.80
		the "Floor"	3.00	2.00	2.20	2.75	3.00	3.90	3.00	3.30	2.77	2.30	—
		bottom	4.00	2.00	3.50	2.50	3.00	3.90	3.00	3.50	3.01	3.00	—
137	Pňová (Pařezová)	top of main part	—	—	—	—	—	2.50	1.80	2.30	—	1.25	0.70
		bottom	—	—	—	—	—	3.00	2.00	3.40	—	2.00	2.50
141	Hlinoš	foot of first shaft	—	—	—	—	—	—	—	1.85	—	1.70	—
		bottom	—	—	—	—	—	—	—	—	—	2.20	—
27	Barát	bottom	1.10	1.00	0.80	0.80	0.80	0.80	—	0.80	0.70	—	—
23	Oriás	bottom	1.60	—	1.15	—	—	1.00	—	—	1.40	—	—

Table 1. Variation of carbon dioxide concentrations over time within selected shafts on the Dolný Vrch Plateau.

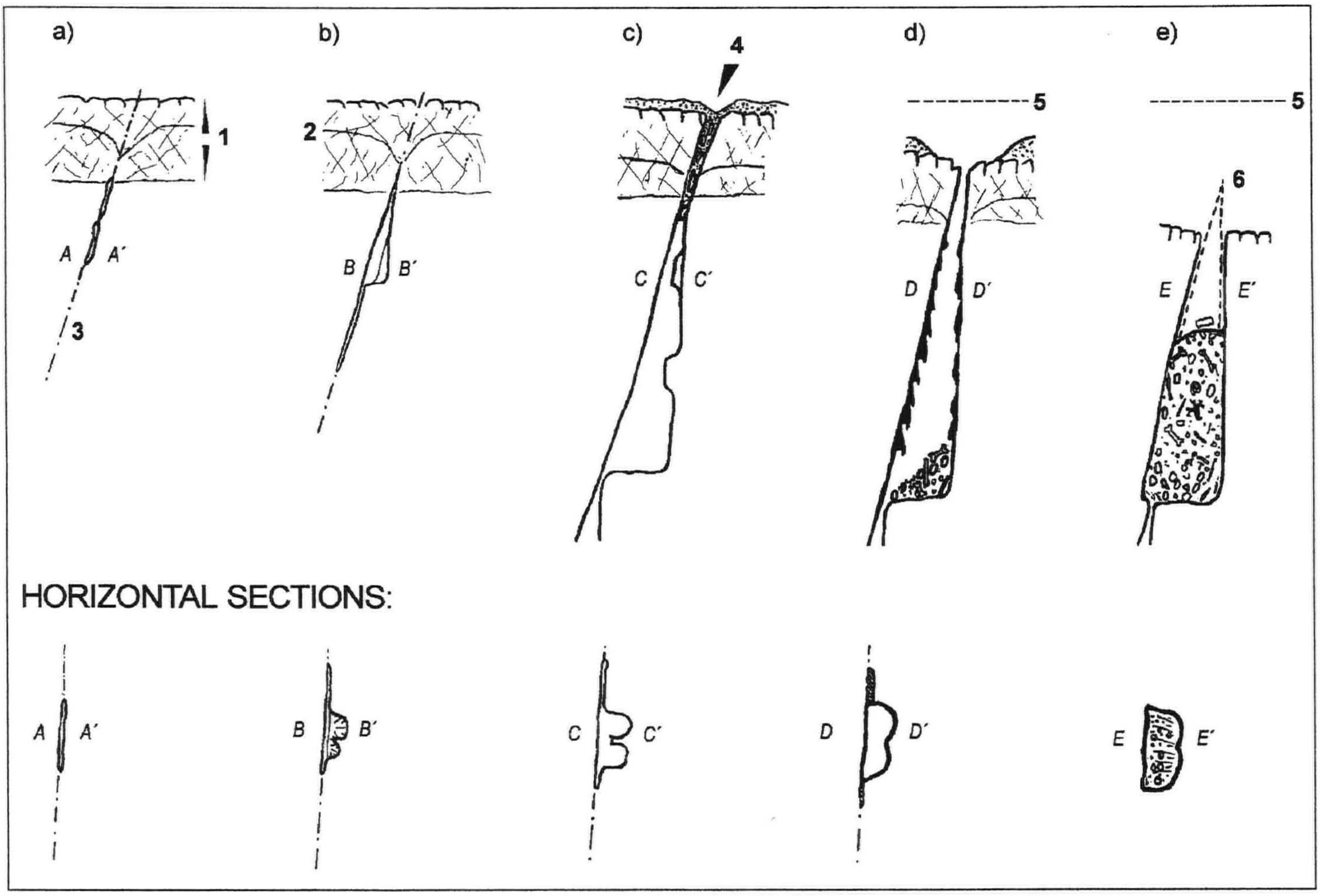

Figure 4: Generalised sketch of the plateau shaft development: a = embryonic cavern stage; b, c = young shaft stage (drip-water modelled); d = fully developed shaft; e = relict shaft. 1 = epikarst zone; 2 = perched aquifer "level"; 3 = tectonic rupture; 4 = incipient depression; 5 = former surface; 6 = former top of the relict shaft.

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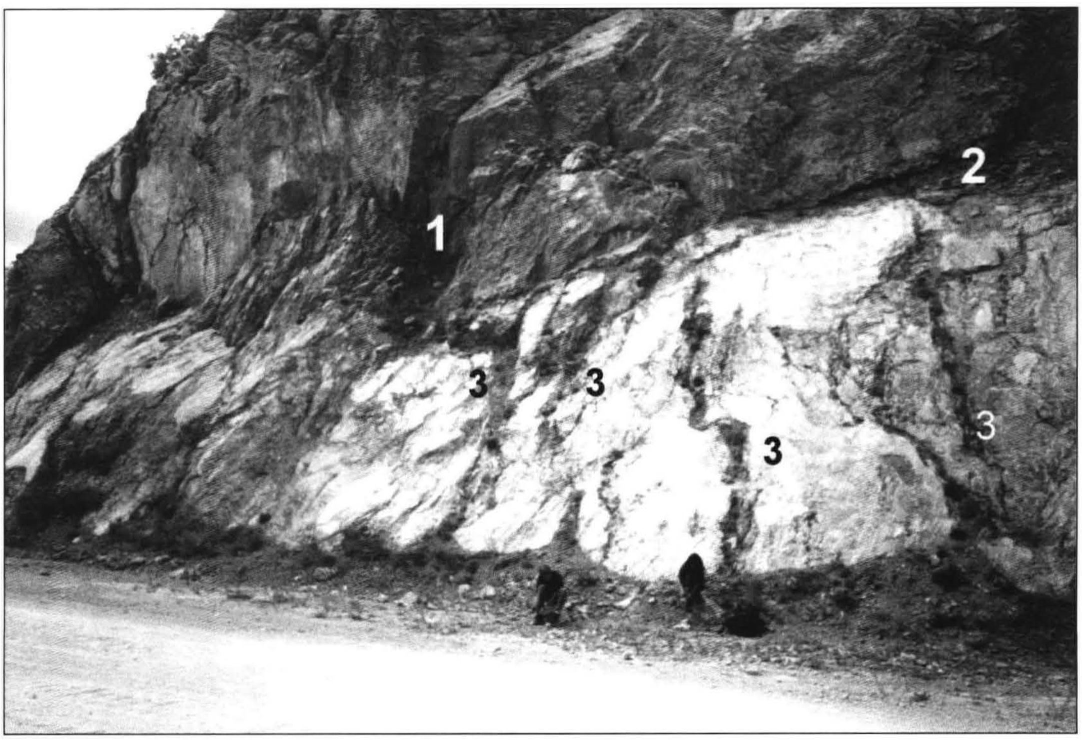
Plate 8: Cross-section of the lower part of a shaft in the Vcelare quarry: 1 = remnant of the shaft; 2 = embryonic cavern; 3 = drainage channels.



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Karst and caves of Madagascar

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Abstract: Madagascar contains some major areas of cavernous karst close to its west coast. Ankarana has the largest and longest caves. Bemaraha and Namoroka have the best of the dramatic and almost impenetrable tsingy landscapes - small-scale versions of pinnacle karst. The karst areas are reviewed from north to south, and new data are included on caves and landforms in the smaller karst blocks around Majunga.

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INTRODUCTION

Madagascar is the fourth largest island in the world, measuring about 1580km from north to south and 570km at its widest point. The total land area is around 594,000km^2 – more than twice the size of Great Britain. Limestone covers an estimated 33,000km^2, and most of it lies in two discontinuous outcrops extending along the drier western side of the country.

The inner outcrop of Mesozoic limestones commonly exceeds 50km in width, and is home to the famed tsingy karst. This landform is essentially a mixture of jagged spitzkarren and pinnacles, all surfaced with long, deep rillenkarren and razor-sharp ridges. Some pinnacles are up to 30m high, though local relief is typically no more than about 5m. It still creates a seriously inhospitable terrain that can extend unbroken across tens of hectares. The local people consider all limestone with sharp edges to be tsingy, but the term is used by karst geomorphologists to describe a particular type of small-scale pinnacle karst. Confusion arises over comparisons between tsingy and pinnacle karst, as only a few areas of the Madagascan tsingy have pinnacles as large as those that typify the pinnacle karsts in southeast Asia or the stone forests (shilin) in China. Caves are numerous beneath the tsingy, and have so far been discovered up to 18,100m long, with many passages of very impressive dimensions.

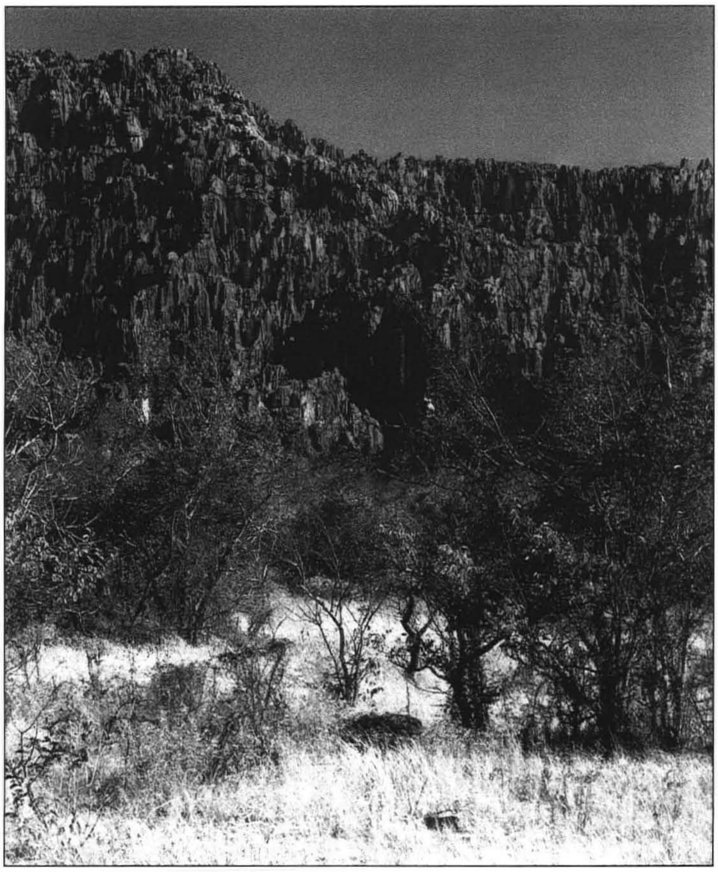

Plate 1. The Ankarana Wall, seen from the savannah near Ansatrabonko cave.

Limestones of Tertiary age form the outcrop that is generally narrower and closer to the coast. Its northern sections have been eroded into some superb cones and mogotes, some of which are steep enough and high enough to be described as towers. Within these hills are found

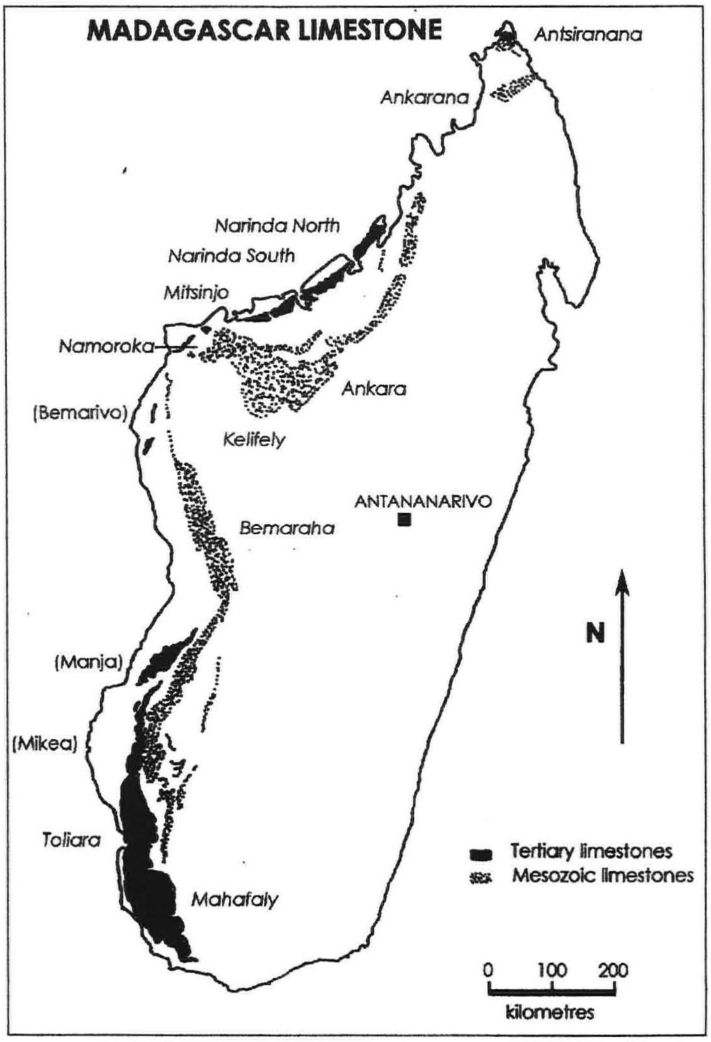

Figure 1. The major karst regions in Madagascar.

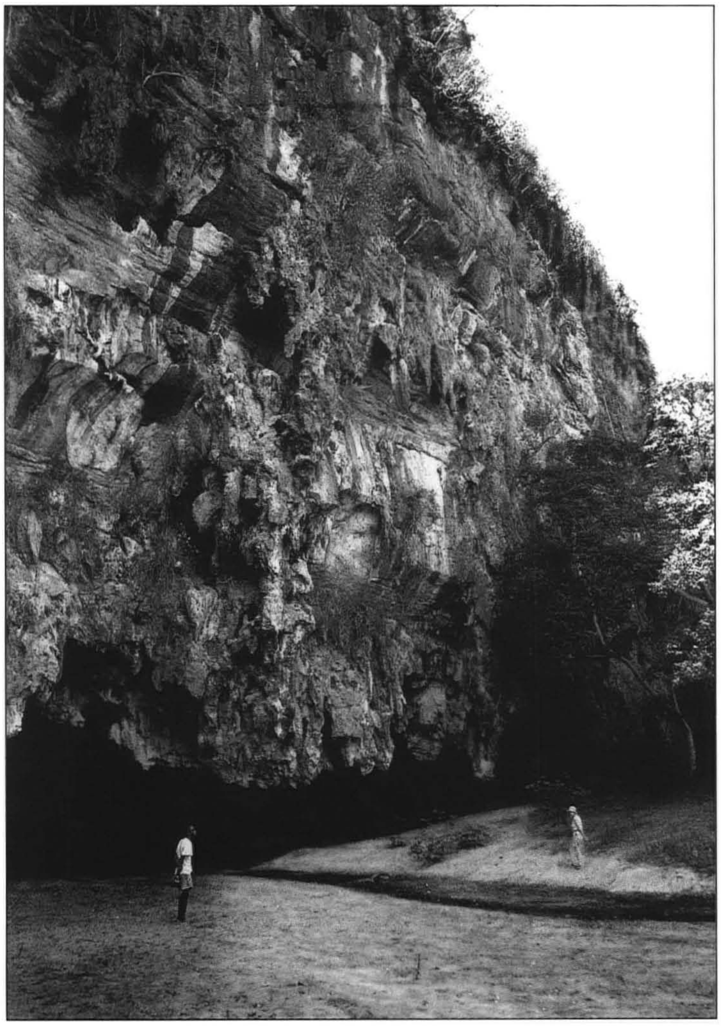

Plate 2. The exit of the main crocodile cave, Ambatoharanana, with the resurgent river at low flow.

many large, well-decorated cave chambers, while others have some massive cave passages; the longest yet known reaches 5330m in length. On the southern outcrops, gentle hills and undulating plateaux predominate. Few caves are known, but shafts up to 200m deep have been explored.

Exploration of the Madagascar karst was first undertaken by French cavers in the early 1930s, but it was not until a visit by a British team in 1981, that the infamous crocodile caves were widely reported, and Madagascar was really put on the international cavers' map. Since then, French exploration has continued apace, though numerous expeditions have been made from a variety of nations, resulting in some very fine discoveries. Potential for new cave exploration is considerable, although any newly discovered caves are likely to prove to be of significant beauty, notable volume, and modest extent, rather than of any great depth or extreme length. The maximum thickness of limestone is estimated to be around 400m, and the maximum depth potential is not much more than this as the karst is of generally low relief.

The inaccessibility of most of the karst regions has created oases of exceptional, and commonly endemic, fauna and flora, surrounded by landscapes that have been reduced to an arid savannah due to deforestation by the local people for their stock animals. The flora in particular shows many extreme adaptations to the environment, and protective care needs to be exercised in any exploration, above or below ground.

This review is based upon a number of visits to Madagascar by the authors, covering all the karst areas except the inland region of Ankara and Kelifely. Further notes on these visits and comment on the logistics are published elsewhere (Middleton, J & V, 2002). There is an extensive but not very comprehensive literature on the caves of Madagascar; papers by Decary & Kiener (1970a,b) and Saint-Ours (1959) provide access to the key early material. Study of the surface karst is best initiated with the papers by Rossi (1973a, 1983b). The main areas of karst and caves in Madagascar are reviewed below in sequence from north to south (Fig.1). Elsewhere on the island, smaller areas of quartzite, granite and sandstone have minor but interesting karst features and caves.

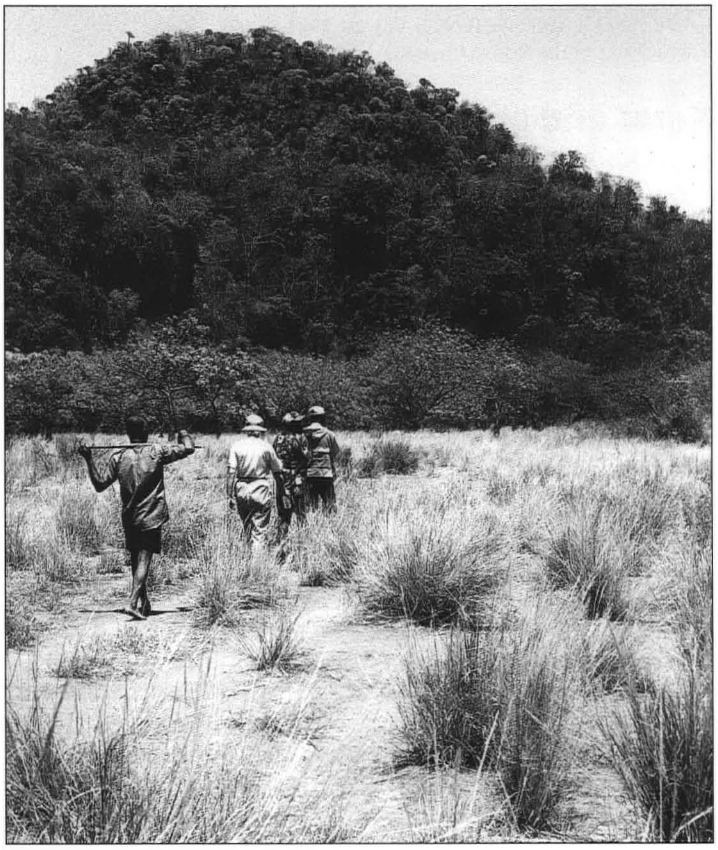

Plate 3. Hemispherical hills in the cone karst of Narinda North.

ANTSIRANANA

Within the complex geological structure of the far north, there are about 140km^2 of limestone outcrop. Tertiary limestone is to be found just south of Tanjou'ny Bobaomby and then again to the north of Antsiranana Bay. Small caves have been noted only in the difficult and eroded landscape of the former. Mesozoic limestone occurs to the south and west of the bay, most notably in the Montagnes des Français and around Windsor Castle. Classic tsingy, some on a spectacular scale, is common, while small canyons and dolines also occur, but it is only in the Montagnes des Français that many short caves have been reported, albeit with large entrances. Near the coast at Cap Mine, Grotte aux Pintades has 490m of decorated passage containing a stream and many skylights (Middleton, G, 2002). Some caves are of archaeological significance, and the area also includes several artificial passageways (probably left from World War Two).

ANKARANA

The relatively small Ankarana massif is known across the world for its spectacular tsingy and large cave passages. The karst covers an area of about 180km^2, in a block almost 30km long and up to 8km wide (Fig.2). It contains over 100km of mapped cave passages, including six systems each over 5000m long (Table 1). French cavers have made most of the explorations in Ankarana, with serious expeditions dating back to the early 1960s. Particular mention must be made of Jean Radofilao, who was party to virtually all the explorations, often as a solo explorer, during Ankarana's "golden" period between 1970 and 1990, when around 50km of new cave passages were found (Radofilao, 1977).

There is a considerable available literature on Ankarana, covering both the geology and the caves (Rossi, 1973a, 1973b; Peyre, 1982; Decary & Kiener, 1970; Wilson, 1987). These notes have therefore been restricted to the karst highlights and some of the writers' own observations.

The Ankarana Wall is the long line of boundary cliffs facing northwest, that reach up to 200m above the surrounding savannah, with a skyline, and locally the entire face, made jagged by the tsingy pinnacles (Plate 1). Great canyons, varying in width upwards from a few metres, are lined by walls up to 200m high, and some slice through the full breadth of the limestone massif. They are fault guided, and their most recent displacements are believed to date to as late as the Pliocene. A deciduous forest, locally dense and not easily traversed, surrounds the base of the cliffs and makes exploration difficult. Any excursion onto the Ankarana plateau becomes even harder if not impossible across a terrain that is almost continuous tsingy. Furthermore, the plateau is broken by great collapse dolines (Mangily, at the southern end of the karst, is an amazing 800m x 600m x 100m deep), and the canyons cannot be crossed where their cliffs offer drops of anything up to 200m. On top of much of the tsingy there sits a unique xerophytic flora of highly specialised plants that are able to cope with the arid conditions.

Caves abound in Ankarana, with large entrances in the boundary walls and also within the canyons, though some are not easily reached through the forests. Many passages are of massive proportions; galleries in Andrafiabe are up to 50m wide (see Radofilao's map in Wilson, 1985, also Middleton, 1995). Some systems are complex, notably Ambatoharanana (Plate 2). Most caves contain at least small streams in the rainy season, and there are many sumps and deep pools – the River Styx in Ambatomanjahana offers an underground boat ride 4km long. Smaller dry caves do occur at base level, but most are found higher up the cliff faces. Exploration at the southern end of the massif, within the caves that drain into the Ankarana and Mananjoba rivers, is made more challenging due to a small population of Nile crocodiles that inhabit them during the dry season of May to October. These have been recorded up to six metres in length! Nine species of fruit eating and insectivorous bats roost in the caves, and there is an abundant and complex permanent cave fauna that lives on the large amounts of bat guano and on other organic matter washed in by the annual floods. An unusual inhabitant of the karst is the humble snail, *Tropidophora cuvierana*, whose habit of eating the algae on the limestone is considered to have had an appreciable effect on rock erosion (a phenomenon also recorded in Israel).

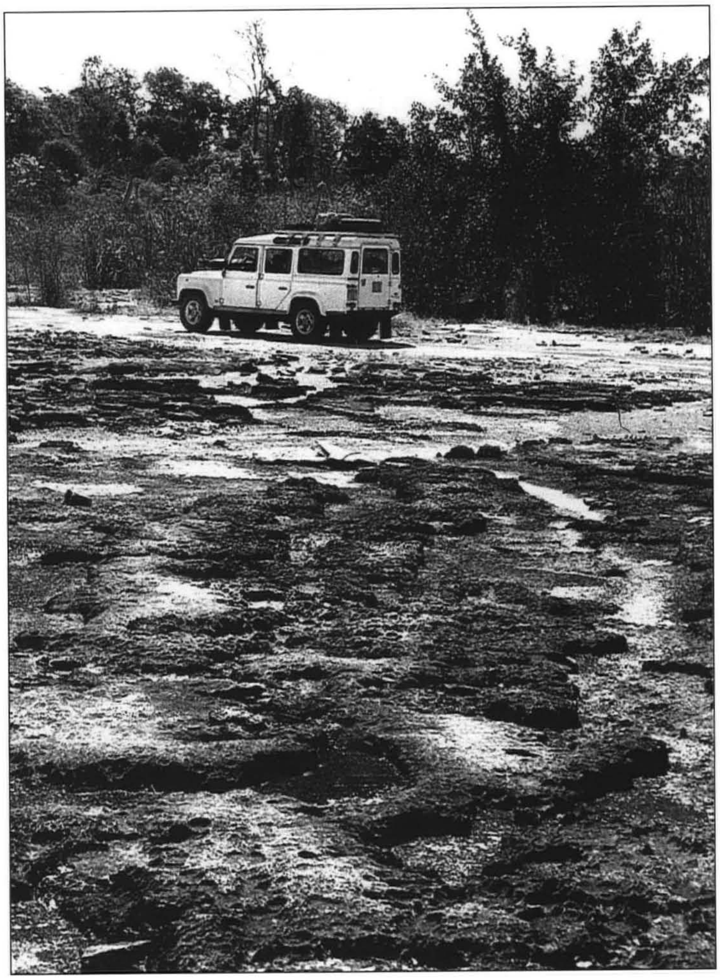

Plate 4. The flat limestone bed fretted with kamenitzas at Anjohibe, in the Mitsinjo karst.

NARINDA NORTH

This inaccessible cone karst to the west and southwest of Narinda Bay extends to about 200km^2 (Fig.3). Clusters of cones and isolated steeper-sided mogotes are set among rice fields, small cassava plantations and a savannah grazed by zebu (a cross between an ox and a cow). Individual hills are up to 70m high (Plate 3); some have vertical cliffs on one side, and they all bristle with sharp-edged karren upon which the familiar xerophytic flora proliferates. Nearly all the hills appear to contain at

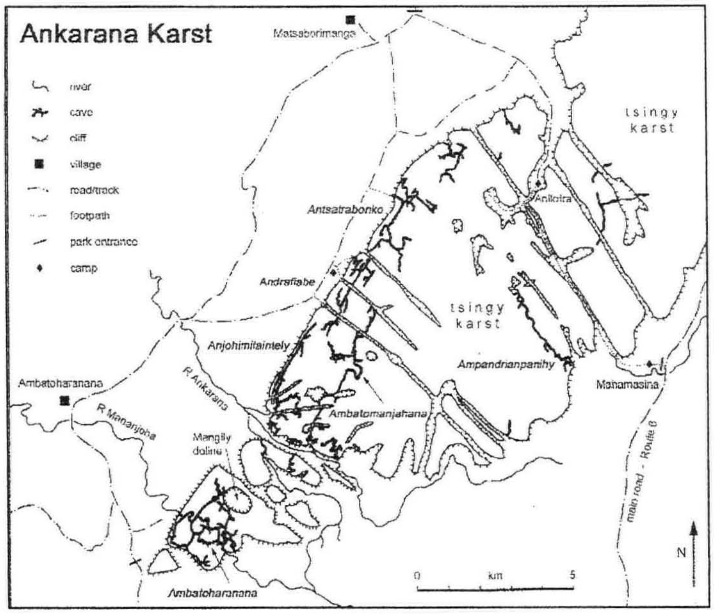

Figure 2. The southern end of the Ankarana massif.

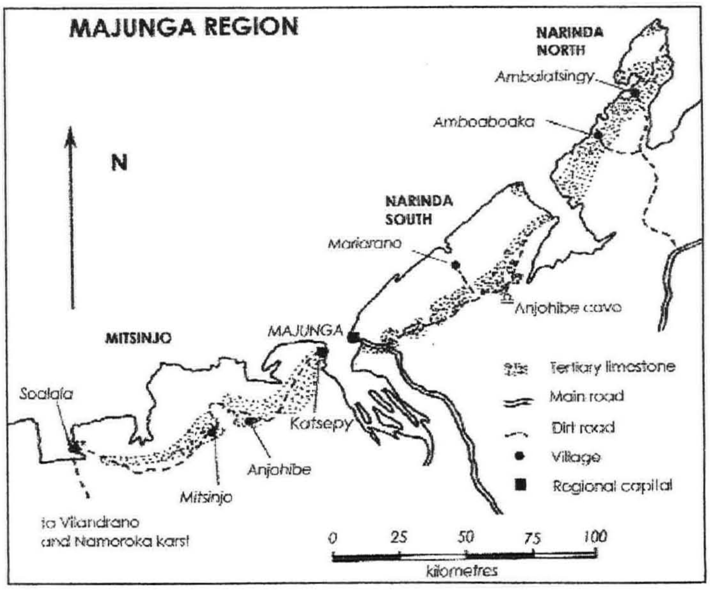

Figure 3. The karst areas of Narinda and Mitsinjo.

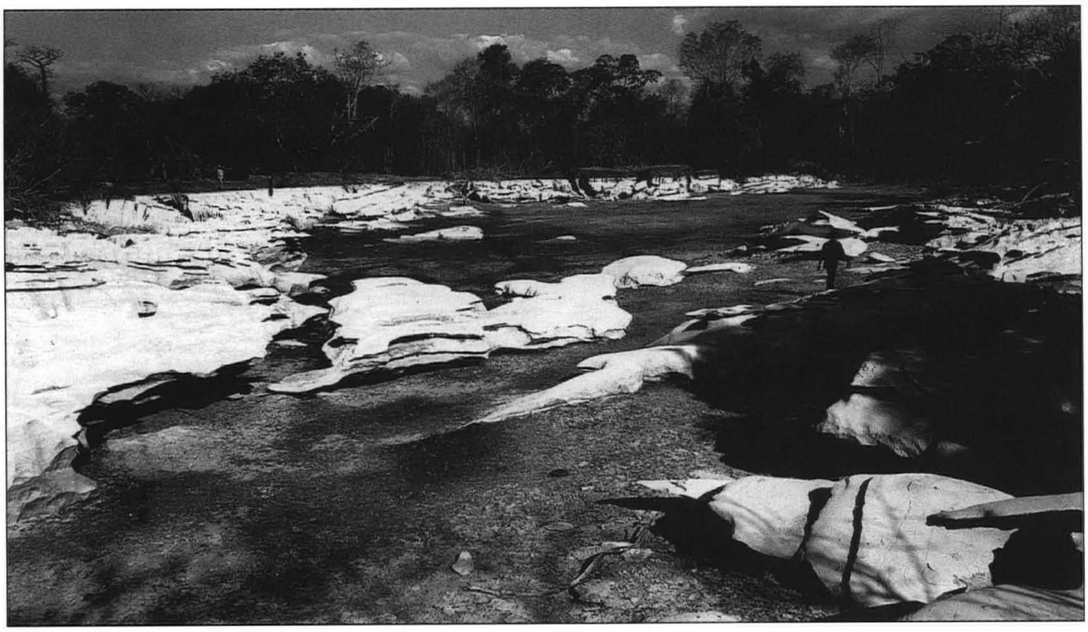

Plate 5. The depression of Ankitsakitsa, on the margin of the Namoroka karst.

least one large cave entrance, which leads into a very well decorated chamber. Some have further passages, extending to 600m in Ampanito Valakely. Most caves are host to several species of insectivorous bats. Close to Ambalatsingy village, the karst not only reaches the sea but extends into the Bay of Moramba where many stunningly beautiful and highly eroded islands are all that remain of a drowned cone karst. Early writers (Saint-Ours, 1959; Decary & Kiener, 1970) refer to this region as "Komaraja" and state that it is *"truffe de cavites"* (peppered with caves), but little further work seems to have been done here.

Our visit started in the small village of Amboaboaka, where the villagers were keen to show us their caves, even though they themselves rarely ventured into the darkness. Ampanito Valakely looked promising with its 15m-wide by 6m-high entrance passage to a major junction and 600m of passages (Fig.4). Superb formations abound, and include some straws and small helictites. A chamber 20m above the main passage is notably beautiful. At Ambalatsingy we found a similar karst and equally friendly villagers greeted us. The nearby cave of Ambalatsingy Lavabatu (lavabatu means village cave) was mapped for 220m (Middleton, 2002), and there are numerous other caves in the surrounding hills – which suffer from a distinct lack of reference points. Each hill looks the same, there are no rivers or roads, zebu tracks criss-cross everywhere, and there are no large-scale maps.

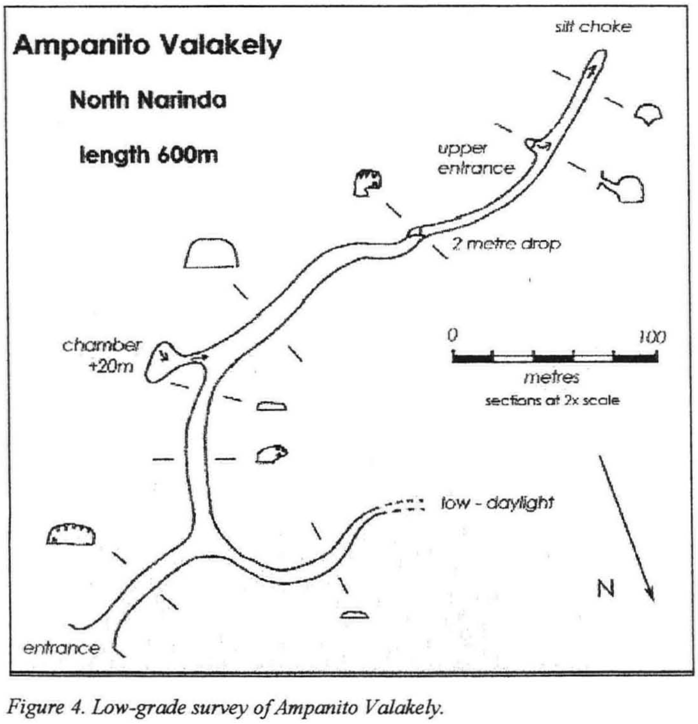

Figure 4. Low-grade survey of Ampanito Valakely.

NARINDA SOUTH

Northeast of Madagascar's second city, Majunga, there is a fascinating range of limestone outcrops extending to about 300km². In the centre, south and east of Mariarono village, the morphology is one of cones 40m high, covered in karren and scrub vegetation, rising from a palm-studded savannah. Farther east, beyond the small village of Mitsinjo (not to be confused with the larger village of the same name west of Majunga), the karst has developed into mogotes and broad towers up to 60m high. Dolines, generally formed by cave collapse, are numerous, and there are seasonally flooded poljes between the mogotes. The region has reasonably easy access, and some of its caves have been known since the 1940s. Each cave extends as a complex of passages through the base of a single hill, the size of which limits the scope for long caves. Anjohibe (also known as Anjohiandranoboka) has 5330m of mapped passage and 13 entrances. It was partly commercialised with electric lighting in the 1940s (probably the only lit show cave in Madagascar); it is no longer lit, but appears to be popular with adventure-tour operators (Laumanns *et al.*, 1991; Middleton, 1998). Close by, Anjohikely has 2100m of passage (Laumanns & Gebauer, 1993). The cave passages in this area are typically large, and are huge in Angoragabe (750m long). They also contain a multitude of formations, which were originally compared to some of the best in France (Decary & Kiener, 1970b), but are now much damaged. Bats of several species are numerous.

MITSINJO

A narrow outcrop of Tertiary limestone extends to nearly 150km², east and west of the small town of Mitsinjo (Fig.3). There are few obvious karst features other than very small raised plateaux that are topped with diminutive karren and a few shallow depressions. Several minor caves have been noted south of Katsepy. About 15km east of Mitsinjo, the tiny village of Anjohibe sits on a flat bed of bare limestone that covers many hectares (Plate 4). This is punctuated by a number of collapse dolines about 4m deep, from which walking-size phreatic dissolution

Cave	Length, (m)
Ambatoharanana	18,100
Androfiabe	12,030
Ambatomanjahana	10,810
Antsatrabonko	10,475
Anjohimilaintely	9,005
Anjohikibojeniy	4,970
Ampandrianpanihy	4,480

Table 1. The longest caves of Ankarana

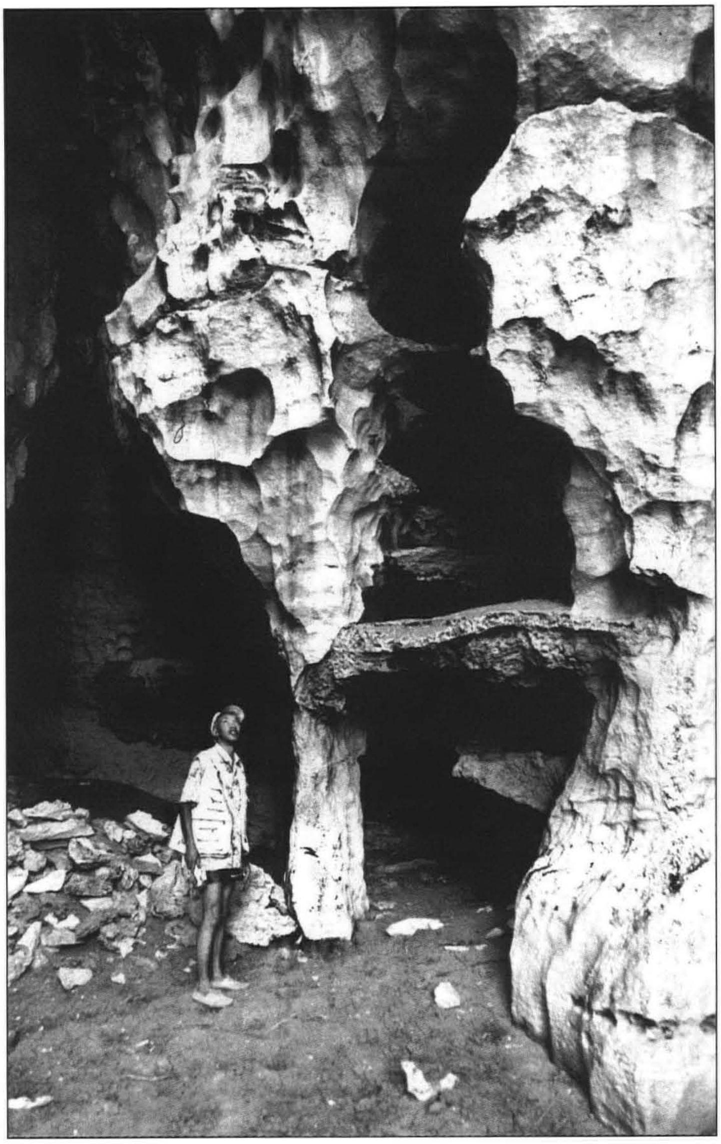

Plate 6. One of the entrances to Anjohiambovonomby, in the Namoroka karst, with five false floors left by successive stages of development.

tubes extend at shallow depth. Anjohibe Lavabatu is about 110m long, and another cave contains a perennial water source for the villagers. Extending north and east from this rock platform, more dissected karren fields have infills of broken rock and red earth, and also contain remnant cave passages. The two caves of Atsinana Madiromasina are less than 100m long but are notably well decorated.

NAMOROKA

With 160km^2 of karst, Namoroka is probably the most beautiful reserve in the whole of Madagascar, and is only just becoming accessible again after having had many years of problems with the Dakalos bandits. It is an area very similar in its landscape to Bemaraha, a terraine of fantasy, of extravagant rock sculptures, pinnacles, balanced rocks and fallen slabs. Hills of Mesozoic limestone up to 80m high (Fig.5) have been incised by deep canyons with vertical or overhanging walls developed along faults and joints. The karst is a classic impenetrable tsingy, on which grows thin forests of xerophytic plants. Many of these are local endemics such as the highly succulent *Cyphostemma sakalavense, Pachypodium ambongensis* and *Euphorbia viguieri* var. *vilanandrensis*, while the baobob tree, Adansonia fony, squeezes its giant form spectacularly into the karst. Exploration of the outer canyons can be difficult due to the dense forest on limestone that is fretted by low karren. Complex phreatic maze caves have developed around the margins of the limestone hills. These occur mostly where shallow depressions on the surrounding alluvial plain are seasonally flooded and funnel the surface

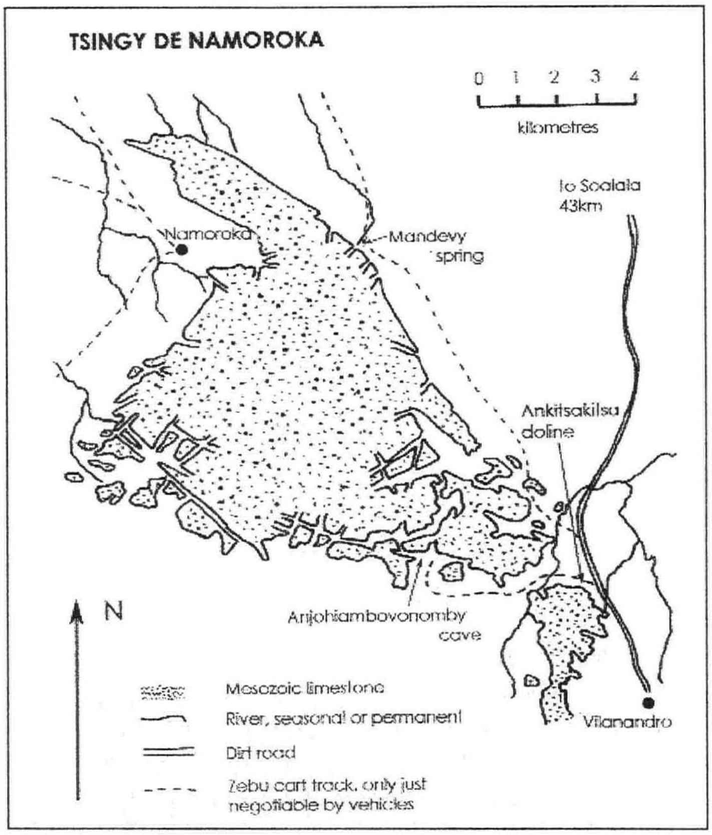

Figure 5. The Namoroka karst.

drainage into the limestone. The rock is bleached to a dazzling white where water stands against it, in stark contrast to the darker outcrops of algae-coated limestone above (Plate 5). Anjohiambovonomby is an unusually large foot cave with a maze of 4630m of fissure passages (Laumanns & Gebauer, 1992, 1993; Middleton, 1998). Some of these contain successions of false floors that appear to indicate a cyclic evolution of the cave (Plate 6). The Mandevy spring is the largest perennial drainage outlet from the karst, but there is no accessible cave behind it.

ANKARA AND KELIFELY

These two great limestone massifs, separated only by the beautiful Mahavey River and totalling about 8000km^2 of karst, have a potential that remains an enigma. This is due to both the region's inaccessibility and also the hostility of the nomadic Dakolos tribesmen (violent robbery was reported in 2000, and there were murders not long before). The karst is spectacular, and is complicated by recent volcanism (Rossi, 1983b). The little known about caves is summarised in early French reports (Decary & Kiener, 1970b; Peyre, 1983), and an aerial recce by British cavers offered little prospect (in Wilson, 1987). The southern and western edges of the Kelifely escarpment rise dramatically to between 700m and 847m before gradually dipping to around 200m in the northeast. Many deep, seasonally-active river canyons and valleys are cut into the southern section, but few show any obvious karst features. North of the Tsimarahodiavolana River, there are extensive areas of doline karst and smaller outcrops of tsingy, at altitudes of 200-400m. The much-described Tondraka River sinks and emerges several times on its journey to its resurgence in the bed of the Mahavey River. A French expedition in 1983 visited this region, but left many questions unanswered (Peyre, 1983). The Ankara escarpment is similar to Kelifely, in that it also dips from a crest at 500-720m in the southwest to around 100m in the northeast. The many rivers across it have not cut down so steeply, but there are numerous dry and blind valleys between areas of doline karst in the northern half. To date, no caves have been recorded.

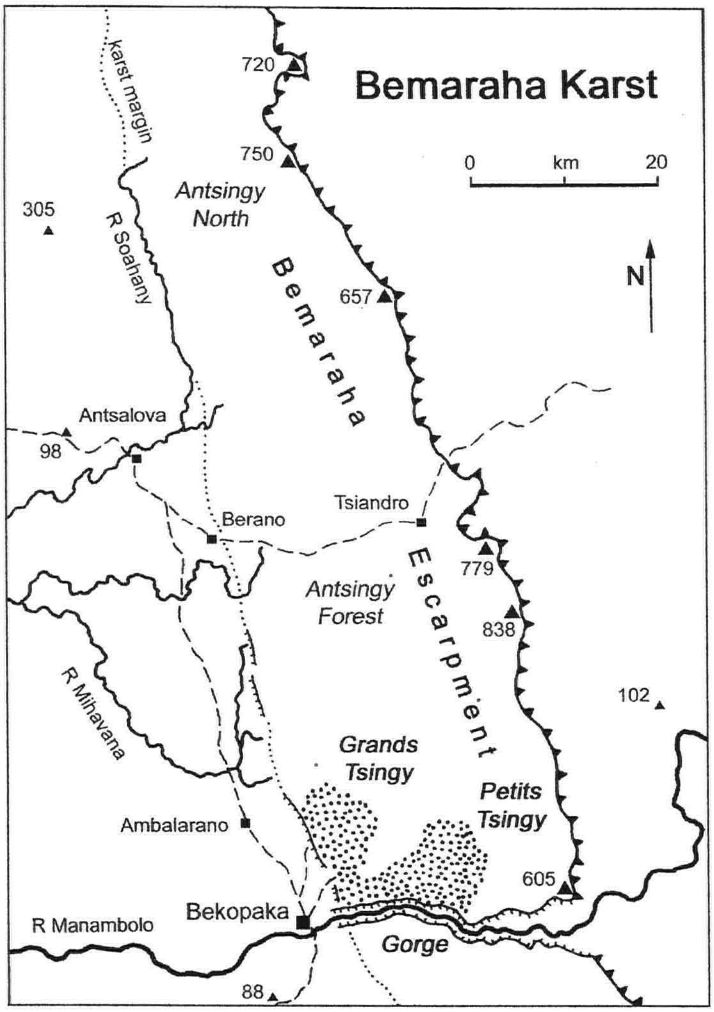

Figure 6. The central part of the Bemaraha karst. Nearly all the escarpment area on this map is within the Tsingy de Bemaraha National Park.

BEMARAHA

The chain of limestone hills and plateaux that make up the Lembalemban Bemaraha extend 180km across a limestone outcrop of 4000km². They culminate in the spectacular Tsingy de Bemaraha National Park (Fig.6). Due to its inaccessibility little is known of the karst outside the reserve and few caves appear to have been recorded. The Park itself encompasses 152,000ha of plateau, roughly 80km long and up to 20km wide (Rossi, 1983a; Bousquet & Rabetaliana, 1992). It is bounded in the south by the impressive gorge of the Manambolo River (Plate 7), and dies out in the north where the main outcrop of limestone becomes more broken. In the east the altitude exceeds 800m along the edge of an escarpment, while levels fall away to less than 100m in the southeast. No deep cave systems have yet been found, but there is depth potential of 400m in the region. Most of the area is surfaced by superb tsingy (Plate 8), some of which has very tall pinnacles, thereby warranting description as a true pinnacle karst.

The tsingy blocks are dissected by canyons up to 80m deep, carved along a multitude of cross fractures and faults. It is normally only possible to gain access to the karst interior through these canyons, but even this is difficult due to the dense forest within them. The most notable canyons yet explored are probably Ankizo d'Ankazoambo and Tsy Hita, both east of the village of Ambalarano. The protected canyon environment holds a great diversity of both flora and fauna, much of which is unique. As at Ankarana, the canyons are home to an otherwise lost fauna. Above the canyons, the tsingy surface is almost impossible to traverse, but it is home to many strange succulent and other xerophytic plants, several of which are also endemic to the region; these include the flamboyant "flame tree" *Delonix regia*. In 1996, several tourist circuits were developed within the Petits Tsingy, through co-operation between ANGAP and UNESCO, instigated by the French ex-patriot Jean-Claude Dobrilla. These remarkable routes take in canyons, stunning views over the Manambolo Gorge and traverses/boardwalks round, over and through the tsingy karst. Two years later, the process was repeated in the Grands Tsingy – to produce an ultimate tsingy experience with trails through caves and arches, along canyons, and up onto the plateau surface 80m above for spectacular views of the tsingy karst (Plate 9).

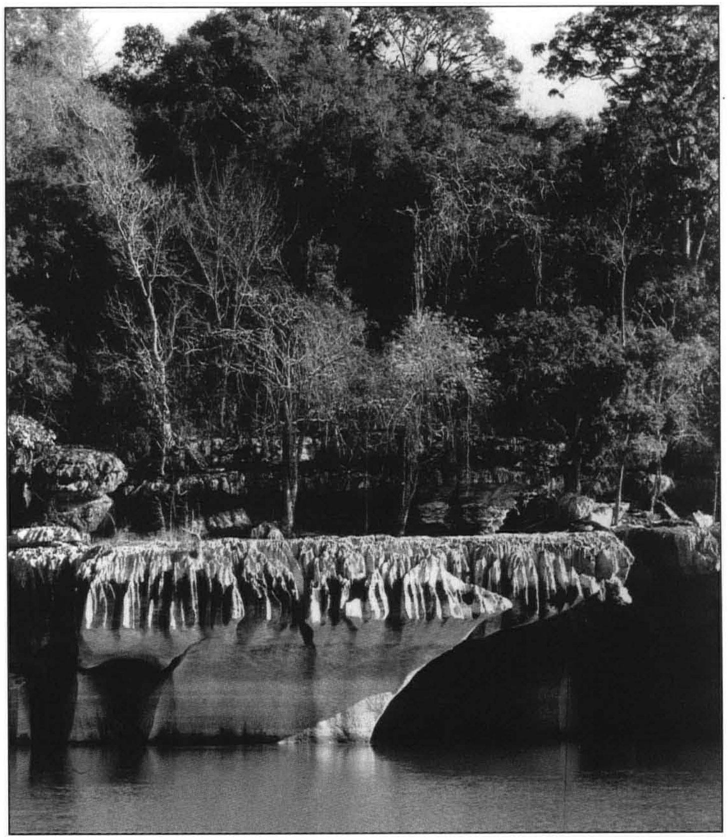

Plate 7. Large karren runnels score the limestone face above a deep river-cut notch in the Manambolo Gorge, at Bemeraha.

Bemaraha is, without doubt, the jewel within Madagascar's landscapes, and it seems incredible that it was not until Jean-Claude Dobrilla visited in 1992 that any serious cave exploration began. Since then, 53km of passages have been surveyed in 81 caves, including 12 that are each over a kilometre long (Dobrilla & Wolozan, 1994; Delaty, 1997, 1999, 2000; Wolozan, 1993, 1999; Dobrilla, 1994, 1995, 1996;). Whereas forays have been made into many parts of the karst, the most explored area is the most accessible, in and around the Grands Tsingy. Among many resurgence caves, and also dry caves, there are long and complex mazes, including Anjohy Kibojenjy, 9780m long (Wolozan & Delaty, 1997). Anjohy Ambalarano is 4055m long, with one of its entrances in a deep doline 50m across. The caves of the Petits Tsingy and in the Manambolo Gorge are much shorter and less well developed; the longest is the Reseau Ming, with 1050m of passage. South of the gorge, the limestone continues unbroken for many kilometres, and it is only close to the river that caves have been explored with some difficulty; Zohy Siramany is 1950m long. Crocodiles can create problems on the Manambolo River and in some of the caves, notably Miharana, and a few of the caves have restricted access where ancient burial sites remain sacred to the local people.

Close to the Tsiribihini River at the southern end of the karst, limestone is thinly bedded and much fractured. There are small patches of tsingy, between scattered dolines and dry valleys. Of the few recorded caves, Lakata Zafera is 710m long in limestone, and Lakata Ampasimaraha is 350m long in sandstone. Not far from these caves, in the first big gorge of the river, an unprepossessing subsidiary gorge houses a very beautiful series of tufa cascades (Plate 10). It is clear that only a very small part of the karst has been investigated to date, and the potential for cave exploration is still considerable.

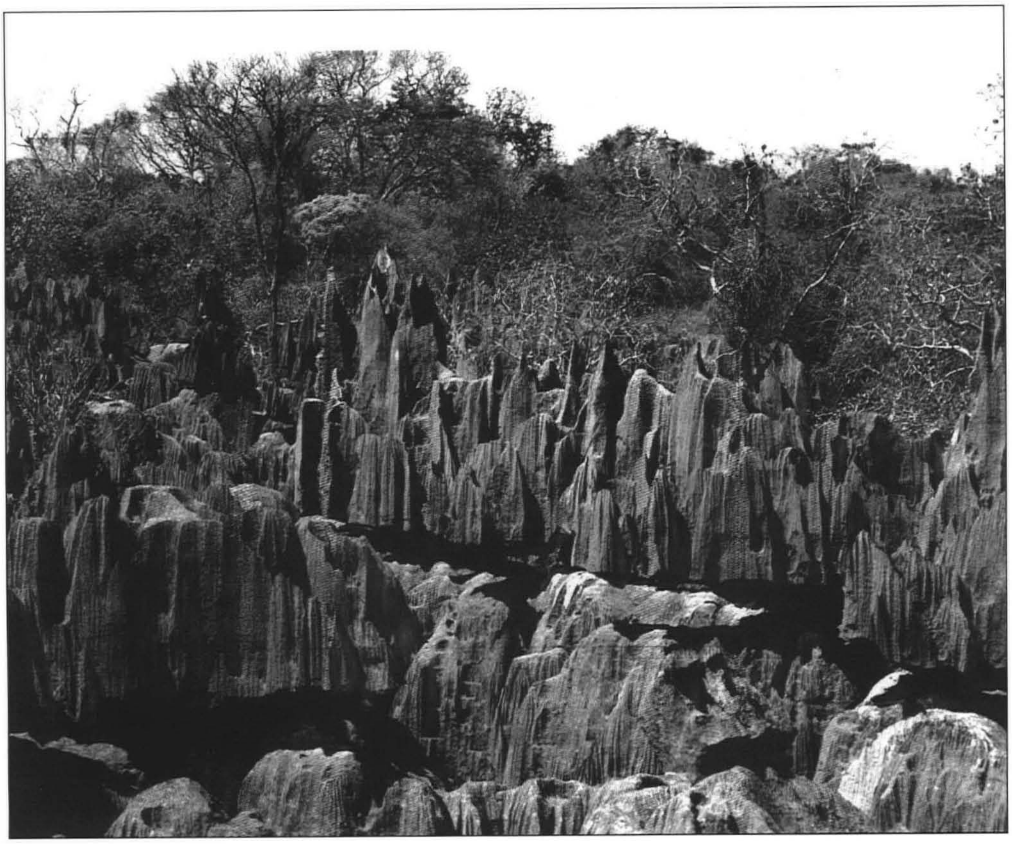

Plate 8. Typical karst on the Grands Tsingy of Bemaraha. The pinnacles rise about 3m above the conspicuous bedding plane.

TOLIARA

Inland from the dusty coastal town of Toliara (Tulear) there are the two important karsts of Mikoboka and Belomotra-Vineta, each with around 2000km^2 of Tertiary limestone outcrop (Bonardin, 1988; Salomon, 1978, 1983; Durand, 1995). The adjacent plateaux of Mikoboka and Manamby, 100km northeast of Toliara, have a depth potential of 400m to small resurgences in the valleys of the Manombo and Fiherenana Rivers. Unfortunately, the plateau environment is significantly hostile to exploration; it is hot and arid, difficult of access, and awkward to traverse across its rough karren, dry valleys and many dolines. More than 50 deep shafts have been recorded on the plateaux. Some are single drops, while others are in rifts with minor horizontal development, and many have loose rock. The deeper shafts include Aven du Perroquets (-200m), Aven de Manamby (-105m), Aven des Mousqueton (-94m) and Aven du Gros Caillou (-88m).

East of Toliara and north of the Onilahy River, the large, dry Belomotra-Vineta karst is a barren causse covered in prickly scrub, with some areas of open savannah. This karst contains many more shafts, and the Gouffre de Tokilisy is 160m deep, but few have any horizontal development; Lakata Bejoro is little over 150m long. One particularly impressive site, situated about 2 hours walk from the village of Tokilisy, is the Aven Ankiky, a circular shaft 60m across with vertical walls 80m deep (Salomon, 1983). There are several minor resurgences close to the Onihaly River. Just south of Toliara, the Grotte de Sarodondrano is a locally well-known cave with four coastal resurgences all within 200m of each other; behind the largest, a collapse doline drops into a tidal underground lake over 50m long, noted for its rich aquatic and terrestrial fauna (Middleton, 1999).

Near to Andalambezo on the edge of the Helodrano Fanemotra (Bay of Assassins) several small caves are reported with lakes in which blind fish are to be found – possibly of the same species as those known in the Mahafaly region.

MAHAFALY

Whereas limestone extends southwards from the Onilahy River there is little of interest to cavers until south of the road inland from Beheloka. From there to the Menarandra River, almost 200km away, a limestone outcrop of about 7000km^2 presents a diverse karst landscape of low plateaux pitted with dolines and broken by dry valleys and a few poljes (Middleton, 1999; Delaty, 2000). There are numerous shafts on the plateaux, and many short caves are known, particularly along the western margin. Many of the caves contain pools that are a valuable water source for the local people, and several are home to an endemic blindfish, *Typhleotris madagascariensis*. Around the Lake Tsimanampetsotsa reserve at least nine small caves have been recorded including the Grottes Mitaho and Jaqueline, both notable for their beautiful calcite formations. Farther south, the Lavaboro hills are broken by at least fifty shafts, including Lava Boro (-125m), Lavaka Etsivavae (-84m) and Lavaka Emoky (-83m). Farther to the east, near Antsahasarotra, the region's longest cave is Zohin Andavaka with about 1000m of passage. Inland from Itampolo and just north of Bevoalavo more shafts are known, but they have not been visited recently.

OTHER AREAS

There are many smaller areas of limestone lying outside these main karst regions, which could also repay attention by searchers for new caves. Perhaps the most significant are the Mikea, Manja and Bemarivo karsts, each extending to over 300 km^2 (Fig.1). Outside the limestone, the quartzite rocks of Mount Ibity, 140km south of Antananarivo, exhibit many karst features including dolines, karren, shafts, springs and caves; Grotte Albert is 43m deep and 152m long. The basalt slopes west of the forested Montagne D'Ambre National Park, in the far north, contain a number of caves up to 280m long (Middleton, 2000), while a basalt plateau close to Ambohitralana, in the east, is reported to be riddled with holes. Various sandstone areas, notably around Isalo, are claimed to have caves, but few are more than extended rock shelters.

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The authors are grateful to Michel Rakotonirini whose knowledge, friendship and assistance as principle guide made all things possible, to Madagascar Airtours whose excellent organisation always got us to remote destinations, to the Malagasy people whose welcome and enthusiasm added greatly to our experience, and to Tony Waltham for help in preparing this paper.

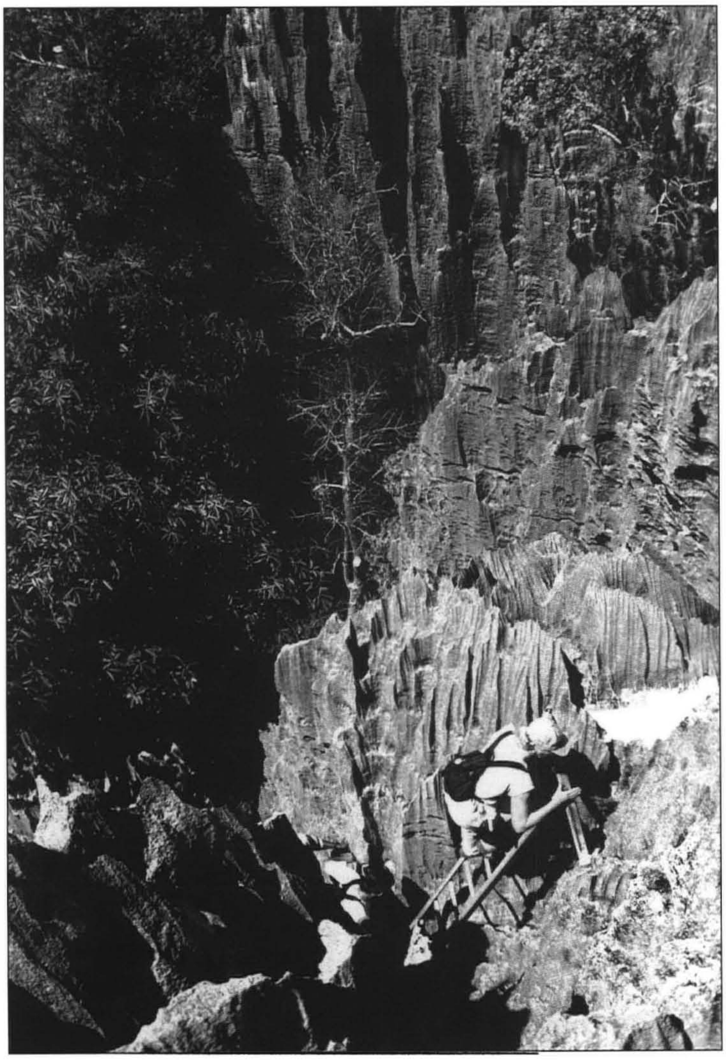

Plate 9. *On a trail through the tsingy of Bemaraha.*

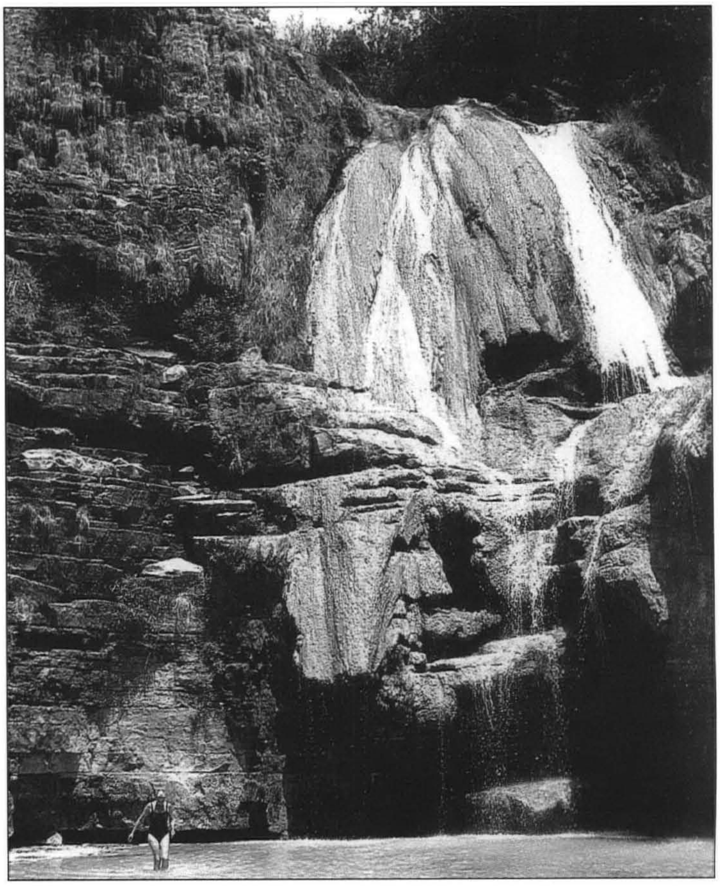

Plate 10. One of the tufa waterfalls in a gorge that is tributary to the Tsiribihini River.

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A history of cave exploration in the Northern Pennines, United Kingdom, from 1838 until 1895.

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Abstract: The trends of cave exploration in the northern Pennines during the second half of the Nineteenth century responded to the arrival of the railway at the western periphery of the limestone country. This ease of travel for the working classes encouraged access to the show caves. It also enabled the more affluent residents of the Lancashire and Yorkshire conurbations to explore the caves, whereas the relative contribution of the local landowners became less.

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INTRODUCTION

In a previous paper it was shown that poor communications, superstition and ignorance inhibited early cave exploration in the north of England. The construction of the Keighley – Kendal Turnpike in the 1750s improved access to the caves, and was responsible for a thriving tourist industry based at Ingleton[1]. All the caves that were explored were of easy access, and required no equipment other than lights, a short primitive ladder and suitable clothing.

Subsequently, access was improved by the coming of the railways from the Yorkshire and Lancashire conurbations. For nearly a century the railway companies enabled the inhabitants of the industrial towns and cities to visit the countryside with ease and with economy. Up to 5,000 day trippers would come to Ingleton on a Bank Holiday[2]. In 1849 the railway reached Ingleton from the south, with stations at Giggleswick and Clapham, and in 1861 from the north via Lowgill. In the following year trains began to run between Skipton and Lancaster, with stations at Giggleswick and Clapham[3]. In 1862 the railway was opened to Pateley Bridge, facilitating access to upper Nidderdale[4]. In 1876 the Midland Railway opened its Settle – Carlisle main line with stations at Settle, Horton-in-Ribblesdale, Ribblehead and Dent[5]. Initially it was only the middle, business and landowning classes who had the time and money to indulge in the unfashionable pastime of cave exploration, as opposed to visiting show caves.

JOHN BIRKBECK II AND WILLIAM METCALFE, 1838 – 1870

The common factor in all the explorations performed up to the middle of the nineteenth century is their progression in a horizontal direction. It is true that wooden ladders were kept by some of the guides to facilitate access to the short pitches in Long Churn Cave and into Great Douk Cave; but the conspicuous great shafts such as Rowten Pot and Gaping Gill were left severely alone. Even the more modest 12m-deep Dolly Tubs Pitch in Lower Long Churn Cave had to wait until 1847 before it was first descended.

The first people to turn their attention to the technical problems of descending pitches were John Birkbeck II and William Metcalfe. Birkbeck was born on 6 July 1817, son of John Birkbeck I, the Settle banker (Fig.1). He lived at Anley House, immediately south of Settle, and died on 31 July 1890[6]. His most famous relative was George Birkbeck (1776 – 1841), who gave his name to a college of London University, and who founded the Mechanics' Institutes. Metcalfe's family originated from Nappa Hall in Wensleydale, and had migrated over the watershed and settled at Weathercote House in Chapel-le-Dale. Metcalfe was interested in caving because he owned Weathercote show cave. He died on 27 April 1888 aged 73 years (Fig.2)[7].

On 6 November 1847 Messrs Birkbeck and Metcalfe approached the Dolly Tubs Pitch in Lower Long Churn Cave, equipped with lights, planks, ropes, a windlass, a pulley and a *"fire escape belt"* with attached rope. They were accompanied by William Howson (the schoolmaster at Horton-in-Ribblesdale), Mr Watson (the engineer of the *"little"* North-Western Railway then being built between Skipton and Lancaster), Christopher Jackson Jr, Messrs William and Thomas Wilcock of North Cote Farm (on whose land Alum Pot was situated) and Messrs W and T Carr[8]. They descended this 12m shaft without difficulty, and on looking up from the Bridge saw a crowd of locals staring at them from the top of the main shaft. Having crossed the Bridge, five men were lowered in the

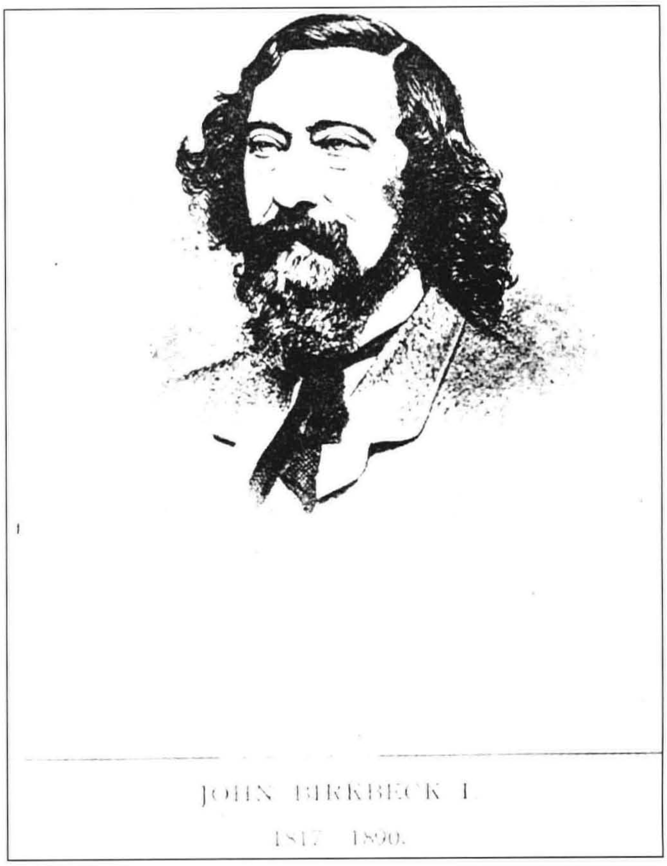

Figure 1: John Birkbeck II, taken from the Alpine Journal (1918), 32(217), opp. 20. The Journal erroneously attributes this portrait to John Birkbeck I.

Figure 2: Grave of William Metcalfe in the Chapel-le-Dale churchyard. Photo by S A Craven.

fire escape belt to the bottom of the following 18m shaft. William Metcalfe was the first man to stand at the bottom of the main shaft of Alum Pot. He made little further progress because his candle was wet and could not be lit; but he did hear a waterfall beyond.

The ascent of the 18m shaft proved to be difficult. William Howson was put in the fire escape belt, from which the attached rope passed through the pulley at the Bridge down to his four companions – who were not strong enough to raise Howson. The five men on the Bridge could not raise him either, and curiously alleged that the Bridge would not bear the weight. Metcalfe solved the problem by tying a second rope to the belt; half the weight was taken by the Bridge party, and half by the party below. After seven hours underground everyone emerged safely, to the disappointment of those old residents of nearby Selside who were confident that they would never return alive!

The following year Messrs Birkbeck, Metcalfe, Watson, Thornton and two others descended in style. Mr Watson had borrowed a gang of labourers from the contractor for the Lancaster railway. They placed two enormous timber beams across the top of the shaft (Fig.3), planks were laid across them and a pulley fixed above. The labourers lowered the explorers in a bucket, two at a time, to the bottom. Having good lights, it was then a simple matter to follow the stream past the Diccan Pot waterfall to the sump. They correctly guessed that the water reappeared either at Footnaws Hole or across the River Ribble at Turn Dub.

The second descent of Alum Pot was organised in similar fashion on Monday 2 May 1870. On this occasion John Birkbeck borrowed the labourers from J Ashwell, the contractor for the Settle Junction – Dent Head section of the Midland Railway's direct line to Carlisle. A wooden cabin was erected near the pot. Birkbeck, at his own expense, provided a picnic for most of the Ribble Valley gentry and clergy, who had come to watch. Ten men and three women were lowered, including Birkbeck, William Metcalfe, Professor William Boyd Dawkins of Owen's College, Manchester, Sir Leslie Stephen (Fig.4), the Secretary of the Alpine Club (of which Birkbeck was a member), and Mrs Leslie Stephen, the daughter of the novelist William Makepeace Thackeray. After commencing descent at 1300 hours the last explorer arrived back on the surface at 1630 hours. Two guide ropes were provided to prevent the bucket spinning, and two rigid 2m ladders were taken to facilitate descent to the sump. Leslie Stephen was first into the lower reaches, and he was so keen to proceed that he fell into a deep pool and lost his light[9]. In 1893 the timber beams were declared rotten, and thrown down the shaft.

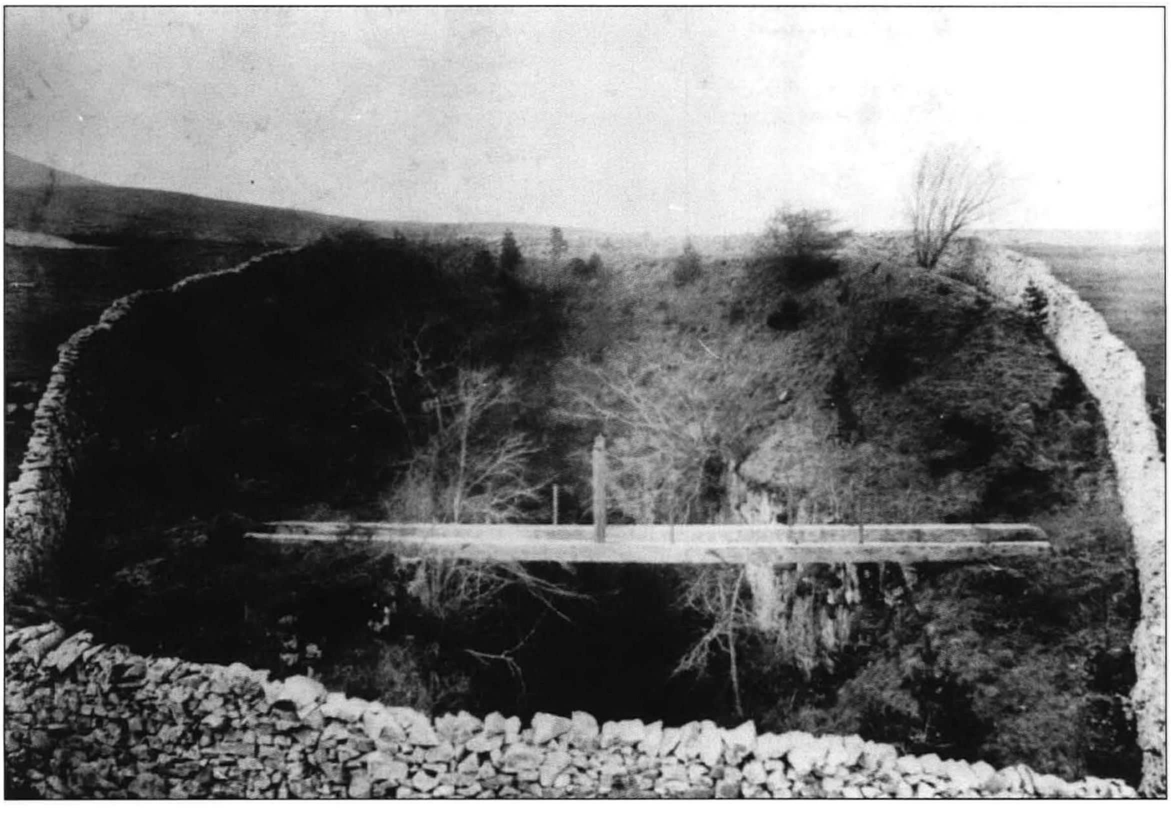

Figure 3: The wooden beams across Alum Pot between 1874 and 1893. The trees were planted in about 1874 by Robert Wilcock of North Cote Farm. His lifeline was held by Thomas Ayrton of Goldielands, Settle[71]. Photo by Charles H Wood of Bradford. Another photograph of the beams was taken in 1892 by W H Chitty, a Giggleswick schoolmaster[72].

As an aside, it is interesting to note that, while working on the railway, the contractors lost a tip wagon in an 18m-deep pothole on the alignment near Selside. The hole was filled to prevent the embankment from subsiding[10].

It appears that Birkbeck and Metcalfe caved elsewhere during these three decades, but very few records have survived. Some time during the 1840s, they made at least one, and possibly two, attempts to descend Gaping Gill, where the problem of overcoming the big 112m shaft is aggravated by the sinking water. This water was diverted along a 1000m-long trench dug from a point just below Sware Gill Sike in a southerly direction along the contour towards Grange Rigg Pot (Fig.5). This earthwork required the excavation of an estimated 51 tonnes of soil and 64 man-weeks of effort. An earth dam just below the origin of the trench would have sufficed to divert Fell Beck. The water in the lower, western, tributaries of Fell Beck was diverted into Know Gap Sike (Fig.6) – a watercourse that had previously been dug to supply water to Flatts and Clapdale farms[11]. By these means the Main Shaft was made dry, but Birkbeck descended no further than the ledge at -60m. His rope frayed; and therefore he had to retreat.

In 1868, during a period of drought, William Metcalfe, and Thomas Richard Clapham of Austwick Hall, failed to force their way beyond the Mere in Meregill[12].

THE NINETEENTH CENTURY TOURISTS AND THEIR GUIDEBOOKS, 1844 *et seq*

The railways generated an increase in the number of tourists, and this encouraged guidebook writers. Jonathan Otley's "*Guide to the Lakes*" ran to eight editions. The seventh (1844) and eighth (1849) carried an appendix entitled, *"An Excursion from Lancaster, up the Vale of Lune and from Kirkby Lonsdale to the Caves of Yorkshire"* by Henry Harrison Davis. The 1849 *"Excursion"* was also published separately, and was reprinted in 185113. Davis' only original observation was that Yordas Cave was kept locked and that the key was with the guide, W L Whittingdale of Gale Green. He had been guide since 1838, and possibly earlier.

Figure 4: Leslie Stephen taken from the Alpine Journal (1918), 32(218), opp. 220.

The same William Howson who attempted to descend Alum Pot in 1847 wrote the first comprehensive guide to the Craven district in 1850[14]. In it he published the most complete list of the caves and potholes then known (Table 1). It is clear that he had explored many of the caves, in particular Dowkabottom Cave (whose guide was Mr Trueman of the Tennants Arms at Kilnsey), Douk Cave, Dangerous and Staircase caves on Giggleswick Scar, Douk Gill rising, Hull Pot

Figure 5: The Birkbeck Trench in May 1896. Photo by S W Cuttriss.

Figure 6: Know Gap Sike in 1973. Photo by S A Craven.

(descended at the east end using a pole and rope), Ringle Pot Green off the Horton – Selside road, Browgill Cave as far as the waterfall, and Alum Pot, where he states that he turned back at the top of the Dolly Tubs pitch.

Howson mentioned that someone had descended Gaping Gill to -60m, obviously referring to John Birkbeck or William Metcalfe. Other anonymous descents recorded are Hunt Pot (to a depth of -28m, using rope) and Sell Gill Hole, which had been attempted but not bottomed three times, with exploration stopping at -31m. It is not unreasonable to assume that these explorations had been done by Birkbeck and Metcalfe.

Howson also recorded the fees charged by the guides at the show caves. Josiah Harrison charged one shilling per head for the privilege of seeing Ingleborough Cave. W L Whittingdale, who seems to have moved to Masongill or Westhouse, demanded two shillings each for the first two visitors to Yordas Cave, and thereafter one shilling each. Howson's subsequent career took him to a school at Alston, whence he was appointed Headmaster of Penrith Grammar School. He died in 1866.

BONE CAVE HUNTING, 1838 – 1894

The 1850s saw the development of the occupation that became known as *"bone cave hunting"*. This was the beginning of the era of popular science, especially of geology and archaeology, when those citizens with educated and enquiring minds began to wonder about their distant ancestors. In this research they were encouraged and supported by the regional literary and scientific societies that were found in most of the cities and manufacturing towns. Since caves provide a suitable environment for habitation and the preservation of artifacts, it was logical to look in the cave entrances for such evidence. These early amateur archaeologists were more concerned with what they found, rather than with where they found it. Therefore, with the benefit of hindsight, their discoveries may have had limited scientific value.

The first Craven cave to be so excavated was Dowkabottom in Littondale. Work commenced in the summer of 1856 on the instructions of James Farrer of Ingleborough Hall, with Lawrence Hodgson, a Settle stonemason, as site foreman. On 9 May 1857 he unearthed 3 human skulls and other bones[15].

Unofficial bone cave hunting had been going on for at least thirty years previously, when *"Bone cave hunting"* came officially to Settle in 1869, with the formation of the Settle Cave Exploration Committee, which seems to have died a natural death nine years later. For the whole of that time the Secretary and Treasurer was John Birkbeck III, son of John Birkbeck II who had been caving under Ingleborough in the 1830s and 1840s. Members of the Birkbeck family were staunch supporters of the Committee, contributing both time and money.

The cave that attracted most of their attention was Victoria Cave, in Attermire Scar above Settle. Michael Horner of Langcliffe and John Jennings of Settle had discovered this in May 1838. Jennings had put his dog into a foxhole, and was somewhat surprised when the dog reappeared from another hole. A week later they removed a large stone from one of the foxholes; and Horner was the first man to enter the cave, which was named in recognition of the recent coronation of Queen Victoria. Three weeks later Horner told his employer, Joseph Jackson (a Settle plumber and glazier), after which they paid many secret nocturnal visits to the cave. The speleothems disappeared almost at once. The proprietor, Anthony Stackhouse, later reprimanded Horner for not telling him immediately so that he could have preserved the formations.

Jackson excavated the cave, and sold the first specimens to the British Museum for £20. By 1840 he had collected many further specimens, which he sent to Charles Roach Smith, a London antiquary. Despite Smith's favourable opinion on the finds, the site remained of purely local interest until 1869, when Professor Thomas McKenny Hughes of Cambridge saw Jackson's collection and recognised its importance. It was through Hughes' influence that the Settle Cave Exploration Committee was formed with an impressive list of patrons including Sir James Kay-Shuttleworth (Chairman); Professor William Boyd Dawkins of Manchester; Louis C Miall of the Yorkshire College (Leeds), and Richard H Tiddeman of the Geological Survey. Joseph Jackson was appointed Site Foreman. Work commenced on 21 March 1870 by driving a level into the cave a few metres south of the original entrance[16]. This is not the place to discuss the scientific importance of the excavation of Victoria Cave. Suffice it to say that as the earthworks progressed, the floor was lowered and the entrance enlarged. The prolific number of finds stimulated other digs in the Attermire area.

Work continued at Victoria Cave. The British Association for the Advancement of Science (BAAS) contributed £1000 towards the expenses; but money was always short, and appeals for cash appeared regularly in the newspapers. Organised parties from the urban natural history and scientific societies came to inspect the site, and scientists filled the journals with their opinions on the significance of the finds. By 1878 the money and enthusiasm were exhausted, and little more was heard of Victoria Cave until 1998[17].

'Bone cave hunting' returned to Littondale in the early 1880s. In August and September 1881 Dowkabottom Cave was re-excavated by Professor E B Poulton assisted by a dozen Oxford undergraduates and two Grassington lead miners[18]. Then in 1888 *'bone cave hunting'* also came to Thorpe in the Wharfe valley. On 29 August 1888 members of the Craven Naturalists' and Scientific Association (CNSA.) and of the Yorkshire Geological and Polytechnic Society (YGPS) met at Elbolton

Figure 7: Grave of John Kidd in the Chapel-le-Dale churchyard. Photo by S A Craven.

Cave. The CNSA had previously visited the cave at least twice that year. The owner, N H Kelsall of Cracoe House, had fitted a door and lock. The CNSA members were impressed with the archaeological potential of the place, and commenced excavations under the supervision of the Reverend Edward Jones of Embsay. On 19 November 1889 Jones was the victim of the first recorded northern Pennine cave accident. He slipped 6.2m from the end of the cave and sustained a minor head injury, from which he had recovered a week later[19]. With financial assistance from the BAAS, work continued until, in 1894, operations were transferred to the newly discovered Calf Hole beyond Skythornes, owned by Sir Matthew Wilson of Eshton Hall.

STUMP CROSS CAVERNS – 1860

In January 1860 two lead miners were prospecting on Greenhow Hill. At a depth of 17m they broke into a series of well-decorated cave passages, said to be 930m long. Most miners did not enthuse about caves if they contained no payable ore; their only useful function was to serve as dumping sites for dead rock. William Newbould thought differently. He leased the cave from its owner, Thomas Edward Yorke of Bewerley Hall, and opened it to tourists at one shilling per head, as Stump Cross Caverns. To augment his income from the Cave, Newbould also ran the Moorcock Inn at Dry Gill, at the bottom of the hill towards Grassington. Here visitors could change into the protective clothing that he provided. Newbould remained as guide at least until 1890. One of the earliest visitors, T Curley, a Skipton surveyor noted the popular belief that the discoverers were Mark and William Newbould from Derbyshire[20], but they may have been William Bowes and David Gill[21]. Another early visitor, William W Maude of Rylstone, removed a collection of speleothems, which he gave to the Craven Museum in Skipton[22] in 1928.

Nidderdale's first topographer was William Grainge in 1863[23]. He gave a long account of Stump Cross Caves, and confirmed the length of the passages as being 1023m. Prophetically, he continued that, *"it is almost certain that other caverns lead from these; indeed, on the sides appear openings into deeper and darker dens than any yet explored, and new wonders may be added in time to those already known."* The new wonders kept their secrets for sixty years. By 1863 William Newbould had fitted a door and laid some steps into the Cave.

SLEETS GILL CAVE, LITTONDALE – 1861

During Whitsuntide 1861, Sleets Gill Cave in Littondale was discovered. It was described as being 541m long and up to 6m high with many fine speleothems. The proprietor was J R Tennant of Kildwick Hall, and the guide was Mr Harrison of Kilnsey[24].

ROBINSON POT, FOUNTAINS FELL – 1862

The builders of Darnbrook farmhouse on Fountains Fell must have known about Robinson Pot, because the entrance is immediately under the back wall of the house. It is not known when the house was erected, but it is believed that there has been a house on the site since the 13th century. The first recorded exploration of Robinson Pot was in 1862 by the farmer, James Metcalfe, and by John Gill who farmed East Garth at Litton. Walter Morrison of Malham Tarn House visited in 1867, accompanied by his gardener (Thomas Coulthard), by two gamekeepers (W Ward and John Colton) and by J Lee. Subsequently the entrance was lost until 1975, being hidden under a large water tank[25].

BRUNTSCAR CAVE – 1864

Although there was a strong financial incentive for the local residents to find spectacular new caves, some discoveries then, as now, were serendipitous. In 1864 John Kidd of Blue Hall, Ingleton, noticed a fissure in the limestone rock immediately behind his country seat at Bruntscar near Ribblehead. He thought that it would make a nice wine cellar, and therefore ordered his men to enlarge the opening[26]. Kidd was delighted when, instead of a wine cellar, he acquired 465m of decorated stream passage. By March the following year he had fitted an iron gate to preserve the formations[27].

John Kidd, the second son of Abraham Kidd of Blue Hall, was apprenticed to Mr Carruthers, a Lancaster chemist. By 1868 he had moved to Wood Green, north London, and had a coastal residence at St Peter's, Kent. In 1877 or 1878 he married Mrs Bella Goss Pearson of Nightingale Hall, Wood Green; and died on 5 April 1888, aged 69 years (Fig.7) leaving £28,000[28].

Figure 8: John Birkbeck III taken from the Alpine Journal (1918), 32(217), opp. 20. The Journal erroneously attributes this portrait to John Birkbeck II.

ROWTEN CAVE – PRE-1865

Apparently, a Mr Hunter made a partial descent of what was claimed to be Rowten Cave some time before 1865. The exaggerated account is taken from a guidebook that is now quite rare, and is therefore reproduced verbatim:

> *"Rowting Cave, which is a long rent in the rocks, varies exceedingly in breadth, and consists of multifarious openings and chinks. This chasm, which is 108 feet in length, runs to a point on the south, but in consequence of some upheaving force, the rocks on the west of the opposite termination have been broken into fragments and pitched into the yawning deep, so that the width is about 30 feet. Some of the large fragments are fixed like wedges in the opening of the dissevered rock. In the descending hollow, caused by a break in the side of the chasm, grow a variety of wild flowers, shrubs, and trees, whose tops do not reach the banks of the opening, and there are broken rocks thickly covered with feathery moss, which yields like a couch of down to the pressure of the human form. Descending from ledge to ledge, and then reposing on a moss-covered rock, because the next descent would have been perilous to the nimblest, and gazing as far as sight would aid one into the labyrinthian passages which run off in various directions, longing and yet being impotent in the matter to explore scenes which have hitherto been concealed from man, what a thrill of exquisite pleasure one feels when viewing from the margin this capacious gulf, and then what a reverse of sensation after one has descended over broken rocks to the depth of 40 or 50 feet, and looks and sees strata after strata of frowning rocks hanging over one's trembling frame, and then peers down where there is no pathway for human feet, and feels with what ease one might slide down the steep incline, and drop into one of those dark openings, and bound from rock to rock in depths unknown. ... Mr. Hunter, who was one of our party, gave us on the spot an interesting account of a descent made into one of these openings some years ago, by himself and other gentlemen, who were on a geological exploration. "The first descent was on a verdant ledge, but the second was into a dark pit over projecting rocks, to the depth of 351 feet, where their downward course was impeded in consequence of fallen rocks having formed an arch over the opening, which they could see contained much water. Seeing an horizontal passage, they followed it a considerable distance, and then meeting with a perpendicular opening, they twisted their flannel jackets, and let themselves down until they espied another flat opening, which they explored until they had to make another descent by means of their jackets into another passage, which they followed until they came to an opening where there was much water. One of the party, whose love for fun was not checked by the damp atmosphere of those dark chambers, made an attempt to carry on his back the more timorous, and then with waggish glee managed to upset his rider when up to the middle in water. This little incident provoked no wrath but mirth, and shortly after, on account of deep water, the exploring party with dripping garments ascended from a depth of not less than 600 feet. A cave of some hundred yards in length opens into the east end of Rowting Cave, in some parts of which there are numerous stalactites and stalagmites, and many encrustations of snowy whiteness, some soft and some hard, of a very nice appearance. This cave, which breaks out repeatedly at the surface, is of considerable height, with many sharp turns, and though a stream runs through it, the pebbles that lie in its bed are so plentiful and large that a person may pass through it without inconvenience. The real mouth of the cave, which is in the western break of Rowting Cave, is a fine rocky arch of 40 feet span, and at no great distance within the cave there is a beautiful water-spout, from the tunnelled rock into a deep circular pool of clear water. Over this pool there is a magnificent chamber 30 feet high, and in appearance like an excavated sugar loaf. This conical opening, and the water-worn crevices leading from it, are exceedingly fine; indeed, one of the party, who was so charmed with it, calling to a gentleman who had not entered it, said that "the sight was worth a shilling;" when another who was emerging from it replied, "It is worth ten shillings"; and yet this beautifully formed cave is open to all comers without charge. The gurgling stream as it leaves the cave flows through several rocky basins, and then after a succession of leaps, dashes into those dark openings in Rowting Cave".*

In context this gross exaggeration is surprising. Other caves mentioned in the same book, viz. Bruntscar Cave, Gatekirk Cave, Yordas Cave, Jingle Pot (plumbed to 49m), Gaping Gill (plumbed to >100m), Hurtle Pot, Jinglepot (Chapel-le-dale), Weathercote Cave, Douk Cave (Ingleborough), Little Douk Cave, Braithwaite Wife Hole (plumbed to 24m) and Meregill, are reasonably accurately, if extravagantly, described[29].

	Lud's Cave, Bolton Abbey
	Knave Knoll Hole (i.e. Elbolton Cave), Thorpe
❋	Doukerbottom Cave, Littondale
	(Scosca Cave), Littondale
❋	Douk Cave, Kettlewell
❋	Janet's Cave
❋	Dangerous Cave
❋	Staircase Cave
❋	Attermire Cave
❋	Victoria Cave
	Kelcowe Cave
❋	Doukgill Scar
❋	Thirl Pot (i.e. Hull Pot)
	Thund Pot (i.e. Hunt Pot)
	Ringle Pot Green
❋	Hellen Pot (i.e. Alum Pot)
❋	Upper & Lower Long Churn Caves
❋	Katnot Cave
	(Calf Holes)
❋	Browgill Cave
❋	Birkwith Cave
❋	Jackdaw Hole
	Sell Gill Hole
❋	Ingleborough Cave
	Gaping Gill
	Hurtle Pot
	Jingle Pot
❋	Weathercote Cave
❋	Gatekirk Cave
❋	Ivescar Cave
❋	Douk Cave, Ingleborough
	Meir Gill [sic]
	Barefoot Wives Hole
❋	Yordas Cave
	Gingling Cave, Kingsdale
	Rowtand Hole (i.e. Rowten Pot)
	Unspecified caves in Easegill

Table 1: Caves listed in Howson (1850);
❋ indicates site explored by Howson

THE REVEREND ADDISON CROFTON, 1865 *et seq*

The Reverend Addison Crofton, who was educated at Cheltenham, and Trinity College Oxford, was Vicar of Giggleswick from 1893 to 1900. While still at school in 1865 he had explored Dunald Mill Hole with his two brothers and a Kendal clergyman. In the same year he paid his first visit to Victoria Cave, which at that time still had the low entrance. While incumbent at Giggleswick he took an interest in the cave archaeology of the Attermire area and Giggleswick Scar. He interviewed several of the local residents, and recorded the conversations in his notebook. Unfortunately memories tend to be vague; and only one incident is dated.

John Hartley of Catteral Hall excavated Kelcow Cave, at the bottom end of Giggleswick Scar. He loaned specimens to John Birkbeck III, who failed to return them. Joseph Jackson and John Handby of Settle excavated Albert Cave, adjacent to Victoria Cave. A man called France, who lodged at the Hart's Head Inn, worked schoolboy's Cave on Giggleswick Scar for gravel. Dangerous Cave was re-discovered by Thomas Walker while getting limestone for his kilns. It was so renamed because, when Walker et al. were removing stalactites, the roof showed signs of collapsing[30]. In 1872 R H Hughes of the Geological Survey examined Cave Ha[31].

Figure 9: Bryan Charles Waller of Masongill Hall. Photo supplied by Mrs Mitten, Ingleton.

THOMAS MCKENNY HUGHES AND GAPING GILL – 1872

Thomas McKenny Hughes succeeded Adam Sedgwick as Woodwardian Professor of Geology at Cambridge. Like his predecessor, he took a great interest in the natural history of the Craven district. In particular he seems to have appreciated the speleological significance of Playfair's Cave (as White Scar Cave in Chapel-le-Dale was originally known)[32]. In July 1872 there was another great flood in the area, after which Hughes paid a visit to Gaping Gill. He was the first man to enter Jib Tunnel. He had no light, but progressed slowly throwing stones in front of him. He returned later with friends and candles, hoping to descend to the bottom of Gaping Gill in a series of easy steps. Instead he found a shaft, which he plumbed to -112m[33].

If Gaping Gill could not be descended from above, it was logical to attempt an entry from below. With this in mind, another trip into Ingleborough Cave was made shortly after the 1872 flood. Those involved were McKenny Hughes, John Birkbeck III (Fig.8), R H Tiddeman of the Geological Survey, Reverend George Style (Headmaster of Giggleswick School), the Reverend E T S Carr (St. Catherine's College, Cambridge) and the Reverend W Marriner of Baughurst Rectory, Basingstoke. They hoped that the flood would have washed away some of the sediment that choked passages at the end of the Cave, and opened up the anticipated way to Gaping Gill. This was

Figure 10: Alfred Ernest Clibborn. Photo supplied by the late Mrs E Constance Goodwin.

Cave	Year	Explorer(s)
Victoria Cave	1838	Michael Horner, John Jennings
Lower Long Churn	1847	Birkbeck, Metcalfe *et al.*
Alum Pot	1848	Birkbeck, Metcalfe *et al.*
Gaping Gill (to ledge)	c.1848	Birkbeck, Metcalfe *et al.*
Dangerous	pre-1850	William Howson
Staircase	pre-1850	William Howson
Douk Gill Rising	pre-1850	William Howson
Hull Pot	pre-1850	William Howson
Ringle Pot Green	pre-1850	William Howson
Browgill Cave	pre-1850	William Howson
Sell Gill (not bottomed)	pre-1850	? Birkbeck, Metcalfe *et al.*
Dowkabottom (excavated)	1856	James Farrer
Stump Cross Caverns	1860	? Newbould brothers
Sleets Gill, Littondale	1861	Unknown
Robinson Pot (rediscovery)	1862	James Metcalfe, John Gill
Bruntscar	1864	John Kidd
Rowten Cave	pre-1865	Mr Hunter *et al.*
Meregill (to the Mere)	1868	Thomas Richard Clapham, William Metcalfe
Albert	?	Unknown
Schoolboy	?	Unknown
Cave Ha	1872	R H Hughes
Jib Tunnel	1872	Professor T McKenny Hughes
Alum Pot, trees planted	c.1874	Robert Wilcock
Gaping Gill (unsuccessful)	1882	Alfred E Clibborn
Storrs Cave	1884	John Hewitson
Eglins Hole, Nidderdale	1884	F C Armstrong, Rev. C H Robinson
Gavel Pot, Leck Fell	1885	William Ecroyd, Cuthbert & Geoffrey Hastings
Otter's Cave Coverdale	pre-1887	Unknown [68]
Rowten Pot – first pitch	pre-1888	R R and M Balderston
Metcalfe's Passage, Goyden	1888	John Hawkridge Metcalfe
Blayshaw Gill Pot No. 1	1888	Jacob Walker
Penyghent Long Churn	1891	Thomas Thompson [69]
Hell Hole, Trollers' Gill	1892	Craven Naturalists and Scientific Association [70]
Calf Hole, Skythornes	1894	Sir Matthew Wilson
Old Ing Cave	1895	Yorkshire Ramblers' Club
Manchester Hole	1895	Yorkshire Ramblers' Club
Fox Holes, Cam Fell	1895	Yorkshire Ramblers' Club
Gaping Gill (first descent)	1895	Édouard Alfred Martel

Table 2: First explorations 1838 – 1895.

intended to be a reconnaissance expedition; and therefore a detailed record was not kept. They crawled along some bedding planes off the southeast corner of Giant's Hall. On the way out they found a water-filled fissure in which Birkbeck swam in a vain attempt to proceed further. No further expedition took place[34].

UNKNOWN INGLETON CAVE EXPLORERS, 1877

Not all the cave explorers sought publicity. Those who did were either the show cave proprietors, or the city gentlemen who could recoup some of the cost of their tour in the country by describing their visit in the newspapers and magazines. A local paper made a brief reference to some unknown cave explorers in 1877:

> *"On 13th. Nov. a man who resides not a hundred miles from the far famed Ingleborough, and who is noted for his mighty rambles to see and know that right is being done by a certain party of willing men who are at present engaged in exploring the bowels of the earth ..."*

There is no clue to the identity of the cavers involved. The story describes how one of the men at night surreptitiously borrowed a horse from the stable of an Ingleton inn, how the horse ran away, and how it was recaptured and returned to its stable before the ostler appeared in the morning[35].

Since the piece appeared in the Ingleton local news column, it is not unreasonable to assume that they were Ingleton men. By that time the potholing career of the Birkbecks had ended. Two possible identifications are Bryan Charles Waller (Fig.9) and Alfred Ernest Clibborn; they certainly knew each other[36]. Waller had been Lecturer in pathology at Edinburgh University, who abandoned an academic career to play the squire at Masongill Hall[37]. His verbal descriptions of his caving exploits inspired the Foley brothers to cave in the 1920s. Unfortunately the Foleys could not remember the details; and nothing in writing has survived.

Clibborn, mill manager at Bentham, was an Irishman born in 1852 at Moate in County Westmeath (Fig.10). He used to spend his spare time walking over Ingleborough, and travelling extensively in Europe. In 1882 he made an unsuccessful attempt to descend Gaping Gill. He failed because of *"lack of proper tackle"*. In 1895 he married Sarah Ann Amelia Bowling of Scotforth near Lancaster, and in 1910 emigrated to British Columbia where he died in 1937[38]. His friends in Bentham included James Bibby and Will Mercer[39]. There is no other record of Clibborn's potholing activities.

HYDROLOGICAL RESEARCH AT MALHAM MOOR, 1879

1879 saw the first prospective scientific attempt at water tracing in the north of England, as opposed to casual observation and hearsay. In July 1878 members of the Yorkshire Geological and Polytechnic Society (YGPS) visited Malham. In the months that followed there was much discussion about the source of the River Aire. To settle the matter, they returned on 9 May 1879 by kind permission of Walter Morrison, whose father had bought the Malham Tarn Estate from Lord Ribblesdale. The YGPS men divided into four parties. One party put some chaff into the sink on Streets near the old smelting mill; a second team dammed the efflux from Malham Tarn; the third group watched the rising at Malham Cove; while the fourth party watched the rising at Aire Head. On releasing the dam at the Tarn, the flood pulse took $1^1/_2$ hours to travel to Aire Head. The chaff was never seen again; and there was no change at the Cove[40]. It took the YGPS twenty years to solve the outstanding mysteries of the sink on Streets and of the Cove[41].

THE STORRS COMMON SHOW CAVE, 1884

In 1884 there was the beginning of an abortive attempt to open a show cave on Storrs Common. If successful it would have provided serious competition for Weathercote, Yordas and Ingleborough caves because Storrs Common is only 200m from Ingleton. At the end of April 1884 the lessee, John Hewitson of that village, set a gang of labourers to work digging out the boulder clay. Steps were installed at the entrance, and much publicity appeared in the local newspapers in the expectation that the cave would be ready for tourists by the Whitsuntide holiday. Unfortunately Storrs Cave was not the financial success that Hewitson had anticipated. At the end of 1885 the Lord of the Manor of Ingleton was owed $1^1/_2$ years rent. It seems that Hewitson was induced to pay his debt because a Mr Bonnick had offered to pay an annual rent of £5 in advance[42].

One of the Storrs Caves was eventually opened to the public on Good Friday, 19 April, 1889. Hewitson was described as having gone to the *"considerable expense"* of £50 – £60 in opening the one cave; a large sum of money was still required to open the other. Hewitson eventually sold out to Samuel Worthington, who for many years owned the Wheatsheaf Hotel at Ingleton. The latter tried to run it as a show cave, charging 6d per head. By 1891 the second cave had been opened[43]. As there was nothing but empty chambers to show, visitors tended to become abusive. One day a riot occurred, and Worthington had to close the caves.

The riot was not the end of the affair. When the caves were abandoned, the entrances had been covered with timber and soil. By 1898 the timbers had become so rotten that the entrances collapsed; and there followed the inevitable argument over who was responsible for making them safe. The Lord of the Manor ignored requests from the Ingleton Parish Council to do the work. The Settle Rural District Council (RDC) denied responsibility. Following pressure from the West Riding County Council, the Chairman of the Settle RDC instructed his Surveyor to inspect the holes. By December, the Steward to the Lord of the Manor had been persuaded to give the matter his *"close attention"*. Eventually it was reported that the County Council would pay the cost of any improvement. The Settle RDC instructed its Surveyor to act as he thought fit. Nothing further was done; and the matter died a natural death[44].

EGLINS HOLE, NIDDERDALE, 1884

Some time towards the end of 1884 two men made the first reliably documented exploration of Eglin's Hole at the top of Nidderdale. F C Armstrong and the Rev. C H Robinson took with them candles, food and 4650m. of cotton. After $3^1/_2$ hours they noted that the cave was 651m long. The first 46m were low, after which the roof became higher, and the end was marked by a low ceiling[45]. Robinson was curate at Pateley Bridge from 1884 to 1886, after which he emigrated to Australia[46].

GAVEL POT, LECK FELL, 1885

While shooting on Leck Fell some time during the early 1880s William Ecroyd, son of a Nelson worsted manufacturer, had noticed the enormous doline that is now called Gavel Pot. In those days it was known as Low Dowk Pot. He climbed into the doline, and ventured upstream as far as the bottom of the 4·7m pitch. To solve the technical problem of the pitch, Ecroyd got the mechanic at his father's mill to, *"cut two lengths of iron piping the height of the waterfall, cord rungs were fastened to them, and kept tight by iron rods fastened to the uprights with nuts and screws both top and bottom."*

One Saturday in August 1885, Ecroyd and Geoffrey and Cuthbert Hastings met at Melling Station with the iron ladder, a rope ladder to facilitate the descent into Gavel Pot, and other equipment. Hastings' father was a woollen manufacturer in Bradford. Ecroyd's father had an office in that city, and this may explain how the three men became associated. The party as planned was to consist of five men. At the last minute the wives of the two married men forbade their husbands to go potholing. They might climb mountains, but they may not descend caves. The following day the three bachelors used the iron ladder (Fig.11) to scale the waterfall pitch without incident. They continued upstream until the passage became uncomfortably narrow, then returned leaving the ladder in place. They approached to within a few metres of Short Drop Cave – but did not realize this until many years later[47]. The remains of the ladder survived until the 1960s.

Figure 11: William Ecroyd's ladder in Gavel Pot. Photo c. 1920 by the late Reg Hainsworth.

The Hastings brothers were also rowing men, and competed successfully in the Bradford Amateur Rowing Club's third annual regatta on 22 August[48]. Assuming that they had been training for the event, it is not unreasonable to assume that the iron ladder was placed on Sunday 30 August 1885. This was Cuthbert Hastings' first caving trip; he continued to cave with the Yorkshire Ramblers' Club, and later with the Gritstone Club. Geoffrey Hastings also joined the YRC and became well known as an Alpinist[49]. Ecroyd disappeared from the caving scene; by marriage he was related to William Cecil Slingsby of the YRC[50].

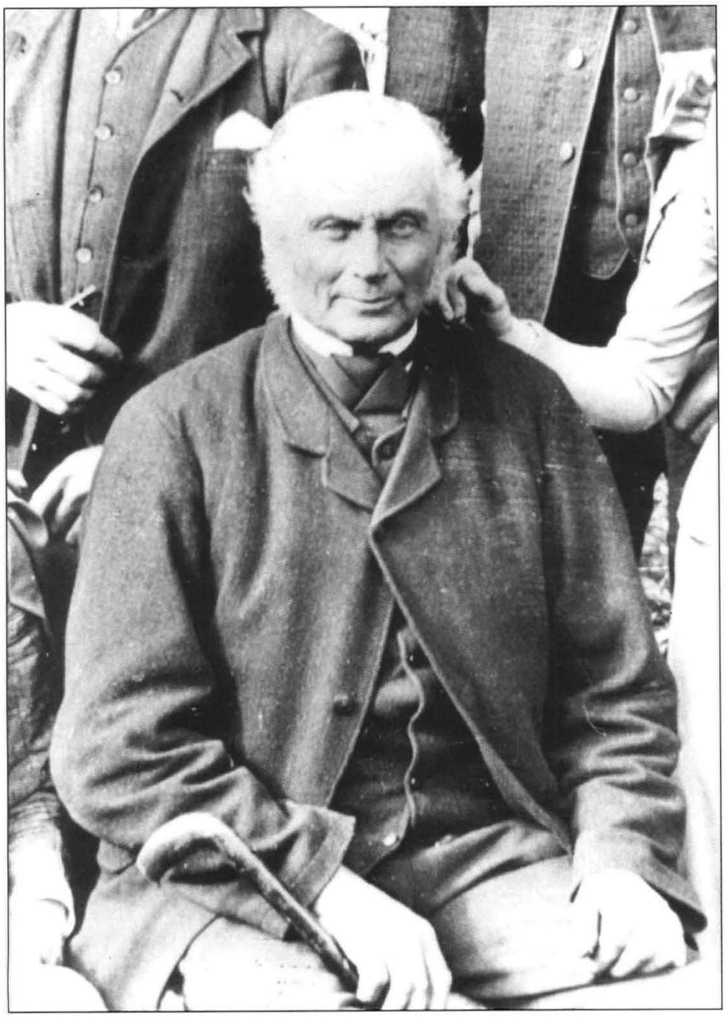

Figure 12: Jacob Walker of Blayshaw Farm. Photo supplied by Mrs E Walker.

GOYDEN POT, NIDDERDALE, 1888

In 1888 there appeared an anonymous account of an exploration of Goyden Pot, in which the author described a passage reached from a ledge above the Main Stream Passage. The only clue to the identity of the writer, who had visited the cave on three previous occasions, is this paragraph[51]:

> *"We were – the 'Captain', a stalwart officer in the local rifle corps, a dalesman born and bred – and the 'Skipper', a roving member of the Royal Canoe Club ..."*

E E Roberts of the Yorkshire Ramblers' Club stated, without quoting his sources, that the author was George V Gaskell of Chapel Allerton, Leeds[52]. Since then the passage has been known as *"Gaskell's Passage"*.

However, Kelly's and other trade directories list no one called *"Gaskell"* in the Leeds area. At that time the Pateley Bridge Rifle Volunteers had three commissioned officers. George Lumsden, the local doctor, was in charge. He was born and educated in Scotland, 2·03m tall, and weighed 108kg[53]. The Hon. H E Butler of Eagle Hall, who later became Lord Mountgarret, was raised on his father's estates in Ireland. Neither man can therefore have been the explorer in question. The third officer, a local man, was John Hawkridge Metcalfe of Grassfield House. He was also a member of the Humber Yawl Club, which was formerly the Hull branch of the Royal Canoe Club. His family owned the Glasshouses Flax Mills, the Nidderdale Brewery and the Scot Gate Ash Quarries. He was born on 22 May 1858, and died on 19 August 1923. Gaskell's Passage therefore ought to be renamed *"Metcalfe's Passage"*[54].

THE FIRST EFFECTIVE CAVE GUIDE BOOK, 1888

In November 1888 Richard R and Margaret Balderston, members of an old Ingleton family, published their well-known *"Ingleton Byegone and Present"* at 4s.6d. (22_p.). In it they devoted 46 pages to 55 caves and potholes under Ingleborough, Whernside and Gragareth. Clearly they had visited and explored every cave described. They did not have the technical facilities to descend any but the short and easy surface pitches, but all were plumbed accurately. They claimed only one original exploration – the first pitch in Rowten Pot – and gave explicit instructions (with map) on how to find all the conspicuous caves, potholes, sinks and risings[55]. Their work was so thorough that it was used as a standard guide by cavers until Norman Thornber published his *"Pennine Underground"* in 1947.

BLAYSHAW GILL POTS, NIDDERDALE, 1888

In September 1888 Jacob Walker, the twelfth generation of Walkers to farm at Blayshaw in upper Nidderdale, noticed that part of Blayshaw Beck disappeared through a fissure in the stream bed just below the saw-mill (Fig.12). He and some friends descended 9·3m by rope ladder into what is now called Blayshaw Gill Pot No.1. They found a well-decorated chamber, from which a narrow hole in the south side led to a dry stream passage[56].

THE YORKSHIRE RAMBLERS' CLUB: 1892 *et seq*

With the notable exception of Alum Pot, the descents of which required the technical assistance of railway contractors, all the successful explorations mentioned above were technically undemanding. The most that was required was a short fixed ladder, ropes and a few men. The deep open and wet pitches such as Gaping Gill and Meregill, although attempted, were not fully descended. They required the manpower and technical expertise that were beyond the resources of private individuals.

It was the Yorkshire Ramblers' Club, founded in Leeds on 6 October 1892[57], that provided the necessary manpower and other resources to facilitate these deep descents[58]. The intention of the founder members was to promote mountaineering; no provision was made in the constitution for cave exploration. Nevertheless some members, organised by Samuel Wells Cuttriss, did look to the caves. Fifteen members visited Yordas Cave during March 1893[59], and a "large party" was at Hull Pot the following year[60]. In 1895 Manchester Hole[61], Hell Hole[62], Fox Holes (Cam Fell)[63], Old Ing Cave[64] and Capnut Cave[65] were explored.

ÉDOUARD ALFRED MARTEL AT GAPING GILL, 1895

On Thursday 01 August 1895 Édouard Alfred Martel, a Parisian barrister who had abandoned that profession in favour of speleology, paid a brief visit to Clapham accompanied by his wife. Intending to make the first descent of Gaping Gill, he also brought with him a huge pile of rope and rope ladders. He had previously been corresponding with the landowner, James Anson Farrer, whose agent, J Bateman, had set the estate labourers to re-opening the Birkbeck Trench. Martel left Clapham at 0930 hours with Farrer and a crowd of spectators, and soon arrived at Gaping Gill. The tackle followed in a farm cart. Martel plumbed the Main Shaft and, realizing that he had insufficient ladder to reach the floor, arranged the tackle so that the ladder reached the bottom attached to a 31m-long belay. An oak post was driven into the ground at the top of the grassy slope, to which the belay was anchored. Martel rigged the pitch himself; nothing was delegated.

At 1325 hours Martel began the descent. To the bottom of his lifeline was tied a stout length of wood on which he could sit if necessary. He was lowered on this contraption until he reached the ladder, down which he climbed. At the 60m ledge he found, as have many since then, that the ladder was piled in a tangled heap. Having unravelled the ladder, he descended without incident to the bottom. Martel was the first man to set foot in the Main Chamber of Gaping Gill. Using candles and magnesium ribbon for illumination, he walked round the Main Chamber, which he reported as being 140m long x 39m wide x up to 31m high; the water temperature was 12°C.

Martel was short of time, and therefore made no attempt to explore beyond the Main Chamber; there was no immediately obvious exit. At 1557 hours he commenced the ascent. Unfortunately his telephone became waterlogged, and therefore failed to function properly. Because of this lack of communication he had a laborious climb, arriving on the surface at 1625 hours[66]. He immediately packed his bags and left for London where, the following day, he addressed the International Geographical Congress.

Thus the better organised and more experienced Martel made the first descent of a major pothole in the northern Pennines. His influence on the British caving scene has been recorded exhaustively elsewhere[67]; and there is no necessity to repeat it here.

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Invertebrate fauna of Manx caves and mines: a preliminary survey

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Abstract: The Isle of Man was heavily glaciated and thus all of its invertebrate fauna is the result of post-Pleistocene recolonization. Accordingly it presents the opportunity to observe an early stage of the active invasion and colonization of hypogean habitats on a maritime temperate island by epigean species. It also has many sea caves, some of which have diverse invertebrate communities. This paper reports the results of a preliminary speleo-biological survey of the island, which revealed an unexpectedly rich and diverse hypogean fauna.

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INTRODUCTION

The Isle of Man (Fig.1) is 572km^2 in area and is situated in the northern part of the Irish Sea approximately equidistant from England, Ireland and Scotland. The highest point is Snaefell (620m). The climate is maritime temperate, with an average mean temperature in the warmest month (August) of 14.3°C and 4.9°C in the coldest month (February).

Geologically most of the island is composed of hardened Ordovician Manx Group greywackes, siltstones, mudstones and breccias, commonly referred to collectively by their old name – the Manx Slates. These are flanked by younger rocks to the south and north. At the south end (around Castletown and Langness) there are exposures of Carboniferous rocks. The succession here comprises a limestone sequence underlain by 20m of Carboniferous Basement Conglomerate resting on the Manx Slates. The limestones comprise 100m or more of relatively thinly bedded limestones with shale partings (the Castletown Limestones) overlain by 60m of the largely reef facies Poyllvaaish Limestones, and lastly 6m of Black Limestones. Overlying these are volcanic rocks of the Scarlett Volcanic Formation. At the other end of the island (north of a line running from Kirk Michael in the west to Ramsey in the east) there is a low-lying area covered by thick glacial tills. Carboniferous rocks have been proved here too, below the tills at depth, but they are not at outcrop. Finally, around Peel there is a small outlier of Carboniferous red sandstone with shale, conglomerate and some impure lenticular limestones. (Taylor *et al.*, 1971).

There is only one confirmed report of a dissolutional cave in the limestones on the island: a small cave (no longer accessible) that was broken into some years ago in Turkeyland Quarry (SC295694) (Radcliffe, 1994, *pers. comm.*). There are two additional tentative reports. In the 19th century, a trial boring for coal at SC286669 was overwhelmed by a rush of fresh water, suggesting a flooded cave. Secondly, Garrad (1972, p.50) conjectured that a salt spring, discharging on the shore near Poyllvaaish (SC 245675), indicates the existence of hidden flooded caverns. However, because hypogean faunas occur not only in the relatively large cavities that we call caves but also in inaccessible interstitial spaces, the lack of dissolutional caves is unimportant biologically. The problem for the field biologist becomes merely the practical one of locating accessible sites. In the case of the Isle of Man there are numerous old sea caves and abandoned mine workings that constitute ecologically cave-like habitats and are places where this fauna may be sampled. There are also many active sea caves around the present day coastline.

The northern Irish Sea basin was glaciated extensively in the Devensian and thus all of the Manx invertebrate fauna has colonized the island since the final retreat of the ice approximately 10,000 years b.p. It is generally accepted that most species originally reached there by natural dispersal from mainland Britain, possibly (but not certainly) via a land bridge when the sea level was lower than today. Accidental introduction of many invertebrates by man as a result of sea-borne migration and trade has also undoubtedly played a part. The possibility

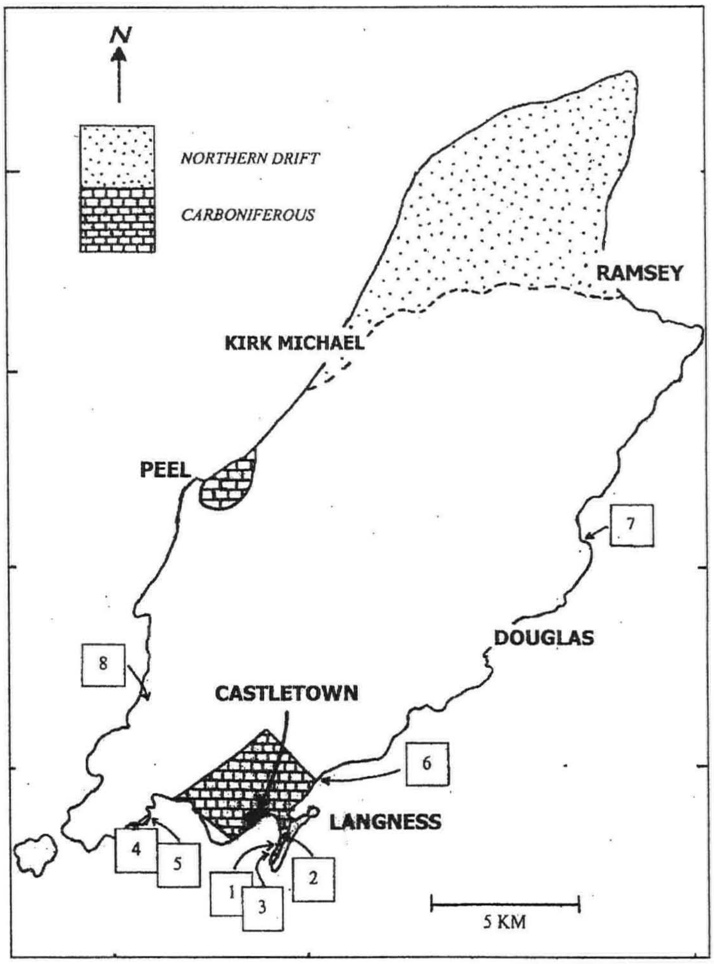

Figure 1: Geological sketch map of the Isle of Man, to show location of collecting sites (indicated by numbers – see Table 1 for key).

Site	Name	Collection dates	British National Grid Reference	Rock Type	Description
1	Langness Seacave	July September October November	SC 282656	Basement Conglomerate	Seacave. Entrance at HWST*; sea penetrates in storms. Gravel and pebble floor; brackish groundwater (pH 7.0). Decomposing seawrack (carried in by storms). Drip-fed pools (conductivity = 725-1100 uS.cm-1, pH 6.7-7.1). (see Moseley, 1997)
2	Langness Mine Day Level	June July October	SC 284659	Castletown Limestone	Mine adit. Near shore, but above HWST. Canal, drip-fed pools, some rotting timber. Has dark zone.
3	Unnamed seacaves	June	SC 282654	Basement Conglomerate	Shallow seacaves, at HWST level.
4	Perwick Cave	October	SC 206672	Manx Slates	Abandoned seacave; altitude c.10m. Associated with a raised beach. Pools, gravel, some calcareous dripstone. Has dark zone.
5	The Sheep Hole	August October	SC 218670	Manx Slates	Seacave. Partly tidal, but above HWST towards the back. Single rather low chamber with floor of beach pebbles; some seawrack and other flotsam.
6	Cass-ny-Hawin Cave	August	SC 298692	Manx Slates	Shallow seacave at HWST level.
7	Garwick Bay caves	September	SC 437 813	Manx Slates	Active (tidal) seacaves; also several dry rifts higher in cliffs.
8	Unnamed mine adit	September October	SC 215 733	Manx Slates	Mine adit. Altitude c.200m. About 100m long, with rotting timbers.

Table 1. List of collecting locations with site details. (HSWT = High Water Spring Tides.)

that the Manx fauna also includes a component of species that invaded from a conjectural ice-free periglacial refugium elsewhere in the Irish Sea basin has also been raised (Beirne, 1952). This idea was put forward to explain the northwestern distribution of certain invertebrates in Britain. However, despite much speculation, the *Refugium Hypothesis* is not supported by any strong evidence, and remains highly controversial.

Due presumably to the absence of accessible limestone caves, the hypogean invertebrate fauna of the island was almost totally neglected by biologists before 1990. The only records before then are of the Cave Spider *Meta menardi* from the "Isle of Man (Ordovician)" (Standen, 1909) and of a copepod (*Paracyclops sp.*) and the spider *Metellina merianae*, which were both collected in Laxey Mine in 1969 (Hazelton, 1971). Then, in the early 1990s local naturalists began looking at spiders and moths in underground sites. *M. menard* was taken in Laxey Mine in 1990 and then from various other cave and abandoned mine sites in subsequent years (Wright, 2001, *pers. comm.*). There are also more than thirty records of M. merianae from the entrances of caves and tunnels and other dark damp places (Wright, 2001, *pers. comm.*). In 1992 the Isle of Man Bat Group recorded finds of moths during a systematic survey of mines and caves (Craine, 2001, pers. comm.).

In 1994–1995 the present author carried out a field survey of selected caves and mines in order to make a preliminary assessment of the nature and diversity of the Manx hypogean invertebrate fauna. This resulted in some unexpected findings, pointing to ecological and possibly evolutionary relationships between maritime and hypogean fauna, and these have been the subject of previous papers. Moseley (1997) described the unusual invertebrate community in Langness Seacave, noting that it is dominated by cavernicoles yet dependent upon marine driftweed as the primary source of food, and speculated about the possible evolutionary significance of such sites as transitional habitats. Reynolds (1996) gave the records of the two common terrestrial lumbricids that were collected here. Moseley (2001) discussed the occurrence of the coastal terrestrial isopod *Trichoniscoides saeroeensis* in a Langness mine adit. In their separate work, Wright and Parker (1997) noted the upper littoral occurrence of *M. menardi* in sea caves at Port Soderick.

The present paper now reports the full results of the speleo-biological survey, briefly analyses them and discusses their significance.

METHODS

The purpose of the study was to make a preliminary assessment of the nature and taxonomic diversity of the Manx hypogean invertebrate fauna, based on qualitative collections from caves and mines. A variety of different sites was chosen: details are given in Table 1. Particular attention was paid to the limestone district at the south end of the island. Of the eight sites, five are either in the Carboniferous limestone or conglomerate beds (1, 2 and 3) or else close to the limestone-Manx Slates junction (4, 6). Following initial findings suggesting that sea caves might be of particular significance, collections were also made at two more such sites, elsewhere on the island, in the Manx Slates (5, 7). In total five (1, 3, 5, 6, 7) of the eight study sites are at least partly supralittoral, sea cave habitats. In addition, because all other sites are close to sea level, a mine adit at an altitude of approximately 200m was investigated (Site 8).

Fauna was sampled by means of hand searching, supplemented at Sites 1 and 2 by pitfall traps, light traps and cheese bait, and preserved using standard museum techniques. Identifications were made to the lowest possible level, with all taxa that were determined at species level being confirmed by specialist taxonomists. Voucher examples of most taxa are deposited in the author's collection, or retained by the relevant taxonomist. Where possible (Lepidoptera and Aranea), unpublished records were also obtained from other investigators.

RESULTS

The survey demonstrated the existence of a taxonomically diverse invertebrate fauna (Table 2): 57 taxa representing 46 families were identified in the collections. At the higher level, 18 classes were represented.

Of the 47 taxa whose status can be given, 38 (81%) are considered to be cavernicoles: 23 (49%) being troglophiles/stygophiles and 15 (32%) habitual trogloxenes. No stygobites or troglobites were found. There is also a significant component of 10 (21%) species that constitute a distinct sub-maritime and/or coastal element: three of these are of particular interest because they are also probably or possibly hypogean. Only 2 (4%) are classified as accidentals (strays).

DISCUSSION

The cavernicolous component in the invertebrate fauna

The relatively large number of cavernicoles found shows that the existence of a diverse hypogean fauna here does not depend on the presence of extensive natural dissolution caves. But, it was somewhat unexpected because so many of the sites were sea caves, where the invertebrate communities were anticipated to be dominated by sub-maritime animals.

In the case of troglophiles/stygophiles, the list includes many of the species that have been reported to occur in the British Isles as a whole,

			Site number							
			1	2	3	4	5	6	7	8
NEMATOMORPHA										
Gordidae			+							
OLIGOCHAETA										
Enchytraeidae			+++	++			++			
Naididae			+							
Tubificidae			+							
Lumbricidae	*Lumbricus rubellus* Hoffmeister	Tp	+	+						
	Eiseniella tetraedra (Savigny)	Tp	++							
COPEPODA										
Canthocamptidae	*Itunella tenuiremis* (T. Scott)	Tp, M	+++							
Cyclopoidae	*Paracyclops fimbriatus* (Fisher)	Tp	+++							
	Diacyclops bisetosus (Rehberg)	Tp	++							
	Eucyclops agilis (Koch)	Tp	++							
ISOPODA										
Trichoniscidae	*Trichoniscoides saeroeensis* Lohmander	Tp, C		++						
	Androniscus dentiger Verhoeff	Tp		++						
	Trichoniscus pusillus Brandt	Hb	+							
Oniscidae	*Oniscus asellus* (L.)	Tp	+	+						
Porcellionidae	*Porcellio scaber* Latreille	Hb		+				+		
Philoscidae	*Philoscia muscorum* (Scopoli)	Hb	+							
Ligidae	*Ligia oceanica* L.	M			++					
AMPHIPODA										
Gammaridae	*Gammarus pulex* (L.)	Tp		++						
	"*Marinogammarus*" sp.	M					+++			
CHILOPODA										
Geophilidae	*Strigamia maritima* (Leach)	M	+							
DIPLOPODA										
Craspedosomatidae	*Nanogona polydesmoides* (Leach)	Tp		+						
Blaniulidae	*Blaniulus guttulatus* (Fabricius)	Tp		+						
Polydesmidae	*Polydesmus denticulatus* Koch	A		+						
SYMPHYLA										
Scutigerellidae	*Scutigerella* sp.	?		++						
COLLEMBOLA										
Hypogastruridae	*Hypogastrura* sp.	?	+							
Neanuridae	*Anurida granaria* (Nicolet)	Tp	+							
Tomoceridae	*Tomoceros minor* (Lubbock)	Tp	+++	++		++				+
Entomobryidae	*Heteromurus nitidus* (Templeton)	Tp	++							
COLEOPTERA										
Dytiscidae	*Hydroporus obsoletus* Aube – adult	Tp	++							
	Agabus guttatus (Paykull) – larva, adult	Tp	++							
Staphylinidae	*Quedius mesomelinus* Marsh – larva, adult	Tp	++							
Carabidae	*Trechus fulvus* Dejean – adult	Tp, C	++							
Leiodidae	*Choleva agilis* group – adult	Hb								++
Hydrophilidae	*Cercyon depressus* Stephens – adult	M	+							
TRICHOPTERA										
Limnephilidae	*Stenophylax permistus* McLachlan – adult	Hb(Pa)		+						
LEPIDOPTERA										
Noctuidae	*Scoliopteryx libatrix* L. – adult	Hb(Pa)								
Geometridae	*Triphosa dubitata* L. – adult	Hb(Pa)								
DIPTERA										
Culicidae	*Culex pipiens* L. – adult female	Hb(Pa)	+			++	++		+++	++
Chironomidae	larva, adult	?	+							
Mycetophilidae	*Tarnania dziedzickii* (Edwards) – adult fem.	Hb(Pa)								++
	Speolepta leptogaster Winnertz – larva	Tp(Pa)							+	+
Psychodidae	larva, adult	?	++							
Phoridae	*Megaselia* sp	Hb(Pa)								++
Coelopidae	*Coelopa frigida* (Fabricius) – pupa, adult	M	+++				++			
Helomyzidae	*Helomyza capitosa* (Gorodkov)* – adult	Hb(Pa)								++
	Scoliocentra villosa (Meigen) – adult fem.	Hb(Pa)								+
Sphaeroceridae	*Thoracochaeta zosterae* (Haliday) larva, pupa, adult	M	+++				+++			
	Limosina silvatica (Meigen)	Hb(Pa)								++
HETEROPTERA										
Velidae	*Velia caprai* Tamamini	Hb		++						
ACARI										
Rhagididae			+++	+			++			
Parasitidae			++	++						
Bdellidae	*Molgus littoralis* (L.)	M			++					
ARANEIDA										
Metidae	*Meta menardi* (Latreille)	Tp(Pa)		+			++		++	
	Metellina merianae (Scopoli)	Tp(Pa)		+	+				+	
Linyphidae	*Porrhomma convexum* (Westring)	Tp	++			+				
OPILIONES										
Phalangidae	*Mitopus morio* (Fabricius) – sub-adult	A	+							
GASTEROPODA										
Hydrobidae	*Potamopyrgus antipodarium* (Gray)	Hb		+++						

* initially identified as *Helomyza serrata* (L.) but it is now doubtful that *serrata* occurs at all in Britain (Chandler 1998, *pers. comm.*)

Table 2: Invertebrate taxa recorded from Manx caves and mines. (see Table 1 for key to site numbers).
***Key**: Tp = troglophile or stygophile. Hb = habitual trogloxene. A = accidental (stray). M = sub-maritime or littoral. C = mainly coastal in distribution. Pa = member of the parietal association. + = scarce or occasional. ++ = common. +++ = abundant.*

and several of these are species particularly common and widespread in British caves, including *Androniscus dentiger, Nanogona polydesmoides, Tomoceros minor, Heteromurus nitidus, Quedius mesomelinus, Speolepta leptogaster, Porrhomma convexum* and the threshold trogophile spiders *Meta menardi* and *Metellina merianae*. Two species, *Hydroporus obsoletus* and *S. leptogaster*, are primarily subterranean and rarely found in surface habitats (Hazelton and Glennie, 1962).

The new Manx records have provided additional evidence that *Trichoniscoides saeroeensis* (see Moseley, 2001) and Trechus fulvus (see Moseley, 1997) are troglophiles. The ecological status of the copepod *Itunella tenuiremis* is uncertain. It was previously collected only in the marine plankton (e.g. Bruce *et al.*, 1963), but Moseley (1997) suggested that it might really be an interstitial species. New evidence in support of this is that it may be breeding in Site 1. All specimens collected in July were adults, with both males and females present. Females were in the majority but there were no egg sacs (Barnett, *pers. comm.*, 1994). However, females with eggs were present later in the year, in October (Moseley, unpublished).

Further study will add more troglophiles and stygophiles to the Isle of Man list, which is certainly far from complete. In the case of spiders, for example, the common threshold species *Nesticus cellulanus* (Clerck) is confirmed for the island by Wright (1996), though not yet collected from any cave or mine, and two linyphiid spiders also on the Manx list (Dalingwater and Wright, 1992), *Porrhomma pygmaeum* (Blackwall) and *Bathyphantes gracilis* (Blackwall), are recognised troglophiles elsewhere.

There is also a group of species that are characteristic of caves elsewhere in the British Isles, where they are considered to be habitual trogloxenes (Table 2). Most are members of the parietal association. *Scoliopteryx libatrix* is a common cosmopolitan moth, trapped on the Isle of Man in small numbers every year. Over 100 were found in various caves and mines by the Isle of Man Bat Group in a 1992 survey (Craine 2001, *pers. comm.*). *Triphosa dubitata* is another moth widespread elsewhere in Britain, where it is common in caves, but very scarce on the Isle of Man, with records in only ten years since recording began in 1859. A single specimen was found in Bradda Head Mine by the Bat Group in 1992 (Craine ,2001, pers. comm.). The food plant of this moth (Buckthorn *Rhamnus catharticus*) is absent from the Island. *Stenophylax permistus* adults use caves and mines for summer diapause. It is the only Isle of Man caddisfly likely to be so encountered (Wallace, 2001, *pers. comm.*). The beetle *Choleva agilis* is also reported to use caves for a period of summer diapause (Chapman, 1993). Adults identified as *"agilis"* were found at Site 8 in late summer. It should be noted that this species may hybridize with *C. septentrionis* in Ireland and central Great Britain (Schilthuizen, 1990). Whether this is the case on the Isle of Man is not yet known and hence this taxon is here designated *"Choleva agilis group"*. *Potamopyrgus antipodarium* and *Velia caprai* are both frequent in Britain in places such as mine drainage adits, where slowly flowing water is present in a threshold. I have often found both in such sites around Morecambe Bay, England, and it is reasonable to consider them as habitual trogloxenes because they are clearly *bonafide* members of the threshold community, although rarely found much farther in. The woodlice *Trichoniscus pusillus, Porcellio scaber* and *Philoscia muscorum* are similarly classified here as habitual trogloxenes, because they are also very common in cave entrances (see e.g. Chapman, 1993).

Two species, *Polydesmus denticulatus* and *Mitopus morio* must be considered as strays. However, there are previous British cave records of *M. morio* from a Cornish mine (Hazelton, 1970, p.3) and from a natural cave in Yorkshire (Hazelton, 1968, p.161), so this harvestman may in the future be found to be more common underground than previously thought.

Maritime component in the fauna
10 (21%) of the recorded invertebrates constitute a distinct maritime and coastal element. Most are sub-maritime organisms, normally found living in the supralittoral zone, that were collected in sea caves: *"Marinogammarus"* sp., *Ligia oceanica, Strigamia maritima, Cercyon depressus, Coelopa frigida, Thoracochaeta zosterae* and *Molgus littoralis*. There are two species (*T. saeroeensis* and *T. fulvus*), which are also mainly coastal and usually found in the supralittoral zone, but are occasionally found inland, usually in caves where they are troglophiles (see above). The status of *I. tenuiremis* is also discussed above.

Not included in the statistical total of maritime and coastal taxa, but relevant, are two of the woodlice collected from sea caves, *Philoscia muscorum* and *Porcellio scaber*. Both are very common and widespread in Britain, being found in a variety of habitats, but both are notably frequent under drift in the supralittoral zone (Marine Biological Association, 1957) and they are also commonly collected in cave thresholds inland (see above).

The two seashore "wrack flies" *C. frigida* and *T. zosterae* appear to be breeding inside suitable sea caves on the Isle of Man, and may be able to complete their life cycle in such sites. They normally breed in decaying seaweed along the strand line, and are found in the same habitat inside Manx sea caves.

In addition acari, microdrile oligochaetes (Enchytraeidae, Naididae and Tubificidae) and Chironomidae are well represented in beach sand meiofauna communities, under wrack and in similar situations, and it is almost certain that the unidentified sea cave collections of these include species normally living in such supralittoral habitats.

It is particularly notable that so many of the cavernicoles listed were recorded living and apparently able to survive in the supralittoral zone when they are within sea caves. Wright and Parker (1997) noted this phenomenon in the case of the occurrence of *Meta menardi* in sea caves at Port Soderick, Isle of Man, and the present survey found this spider also common at Site 5. The threshold troglophile *Metellina merianae* was found in a similar situation at Site 3: Wright and Parker (op. cit) had observed the same at a site in Scotland. Moseley (1997) reported a variety of other invertebrates collected at Site 1, and a more comprehensive list including other caves is now given in Table 2. This is a much larger group than the maritime/coastal group. Of 38 cavernicoles identified, 21 (55%) were collected from at least one sea cave.

These statistics highlight the existence of mixed communities of cavernicoles and maritime invertebrates in sea caves, and the rather remarkable dominance, at least in the current study, of their invertebrate communities by the former rather than the latter. The considerable overlap in coastal caves of terrestrial invertebrate cave communities with those of the supralittoral and related maritime habitats implies close ecological similarities between them, and this may have evolutionary significance (Moseley, 1997, 2001). In Hawaii, Howarth (1981) and Taiti and Howarth (1998) have found, respectively, a troglobitic cave cricket and a troglobitic woodlouse that probably arose in this way from sub-maritime ancestral forms.

Conservation implications
None of the sites were identified as under threat. However, Langness Seacave is recommended as worthy of special protection. The unusual ecology of the site is worth preserving, and also the colonies of *H. obsoletus* and *T. fulvus* in the cave are noteworthy: both are rare beetles.

CONCLUSIONS

The existence of a diverse hypogean fauna on the Isle of Man offers the opportunity to observe and investigate an early stage of the active invasion and colonization of the underground habitat of a glaciated temperate maritime island by epigean invertebrates. Further, unlike the case in mainland Britain and Ireland, it appears that the situation is not potentially confused by the survival of contaminating remnants of pre-Devensian cave faunas. However, there is one important note of caution in this regard: the Manx hypogean fauna remains under collected and thus the possibility that, for example, stygobites such as *Antrobathynella stanneri* may have reached the Island has not yet been ruled out. A similar reservation applies that, although no species was found that can be considered evidence for the *Refugium Hypothesis*, the admittedly remote possibility of periglacial survivors from ice-free refugia does still remain. A more comprehensive survey, involving collecting in additional caves and mines, in deep screes and the MSS, in wells and stream gravels, and in all seasons, is required to clarify these matters.

Secondly, the existence of this diverse fauna combined with the many sea caves around the coast makes the Isle of Man a potentially valuable location to investigate aspects of the rarely studied ecological, physiological and evolutionary relationships between maritime and terrestrial cave faunas.

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Gypsum karst near Sivas, Turkey

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Abstract: A large area of spectacular karst stands on thick Miocene gypsum in central Turkey. Numerous dolines coalesce into fine polygonal karst. Large collapse dolines and marginal poljes are also notable features. Few caves are known, but some sinkholes, stream passages and foot caves await complete exploration.

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TERRAIN

Massive gypsum extends across two large areas of outcrop in central Turkey (Fig.1), and has been eroded into some very fine karst landscapes. Though no long caves are yet known, there are some large collapse features and spectacular stretches of polygonal karst. The area around Sivas appears to constitute a gypsum karst terrain of exceptional quality in terms of its numerous, extensive and well-developed landforms.

Both the karst and the caves are very poorly documented. A number of caves in a small part of the karst east of Sivas were investigated by Mayer (1974), but he was in the field only briefly and did not have the time for thorough exploration. A few papers (cited below) describe individual aspects of the hydrology (Gunay, 2002) or geomorphology of parts of the karst. A longer thesis by Alagoz (1967) is written in Turkish, with a long abstract in French, but is not widely available. It documents many of the karstic surface features in the Kizilirmak valley between Sivas and Imranli, but has almost no data on caves. The writer's observations in the Sivas area derive from four brief visits (spread over 30 years), and this short review is intended to draw attention to a truly splendid gypsum karst that warrants further exploration and research.

The karst is an open rolling landscape with hills that are a mix of bare gypsum outcrop with grassland on thin soils (Fig.2). Alluviated basins and valley floors are cultivated, mainly for grain. Hills reach to altitudes of about 1500m, but local relief within the karsts is less than 300m. The interior climate has a low rainfall (around 400mm), with summers that are hot and dry, modest autumn rains, and light snow cover through cold winters. The area is very accessible for those with their own transport. Sivas is a regional centre, and Zara is a lively, small market town. The karst is crossed by the main Europe-Asia highway between Ankara and Erzerum, while a few small roads and a dense network of dirt tracks spread just about everywhere.

GEOLOGY

Miocene gypsum of the Hafik Formation reaches to thickness of 750m, but this includes a significant proportion of interbedded clays, and the greatest thicknesses may reflect some squeezing into diapiric structures. The structure of the gypsum is extremely complex as it is trapped in a compression belt between the Anatolian block and the mountain belt that fringes the Black Sea. Bedding is recognisable only locally, but east-west folds form the main structures. Much of the gypsum is fine-grained and massive, though there is extensive recrystalisation with blades of clear selenite over 200mm long. Some zones of the gypsum are heavily brecciated; domes and diapiric structures may be interpreted, though there is room for debate over these, and the presence or scale of any deep-seated breccia pipes also remains unknown.

Clastic rocks form the sequences both above and below the gypsum. Eocene sandstones form the anticlinal mountain ridge of the Gurlevik Dag, on the watershed between the Black Sea and the Arabian Gulf. Alluvium is extensive along the floors of the major valleys, on which all the main rivers maintain surface courses across the gypsum. Outcrops of

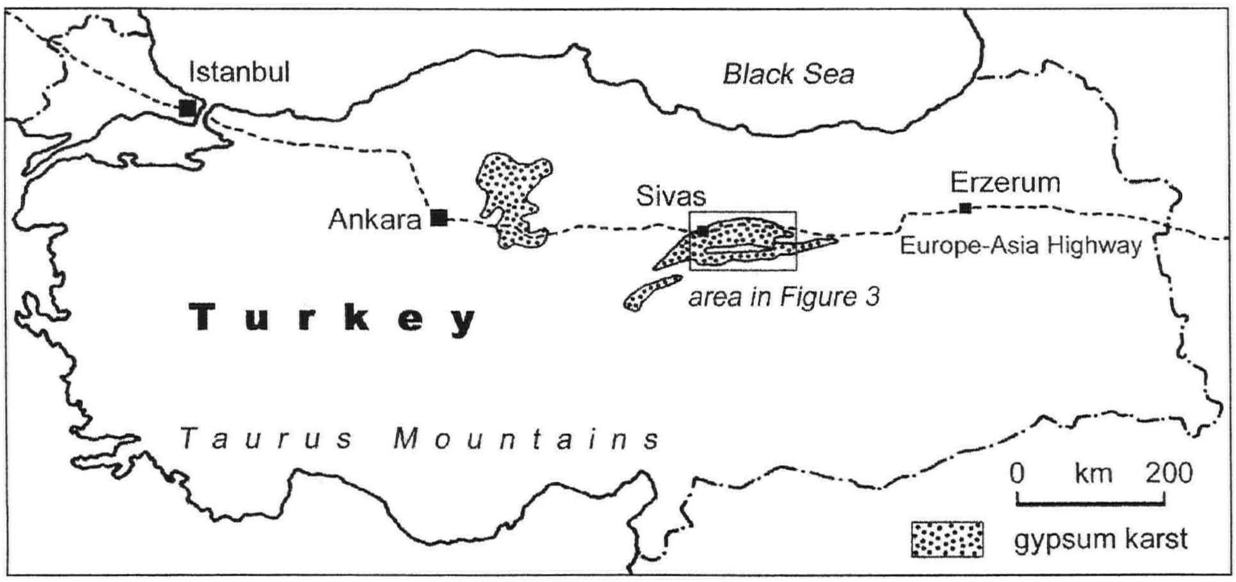

Figure 1. The main outcrops of Miocene gypsum in central Turkey.

Figure 2. Gypsum hills of the Sivas karst, south of Hafik.

the gypsum range from rounded hills of bare white rock on the more massive material, to rolling slopes and basins covered with thick clay soils that are at least in part dissolution residues. At outcrop there are no signs of anhydrite, which has been seen in boreholes at depth.

DOLINE KARST

A belt of high ground on the gypsum extends from Sivas east to Imranli. The Kizilirmak River cuts through its eastern end and then flows largely along its northern margin (Figs 3 and 4), whereas the Acisu River drains through a fine rocky canyon that is entrenched 150m below the karst plateau. The plateau surface is eroded into broad dolines that coalesce into shallow dry valleys where the overall slopes are steeper. There is enough clay interbedded with the gypsum to provide residual soils that are nearly continuous, with thicknesses of 1 to 5m across most of the karst. Small subsidence dolines are common within the soil cover, and many show signs of recent collapse (probably during wet weather).

Over much of the plateau a polygonal net of low interfluve ridges encloses shallow depressions with internal drainage into small sinks. Many individual basins are poorly defined and are 1 to 3km across, but some areas have smaller dolines within a tighter net, as in the area southeast of Demiryurt (Fig.4). The best of this polygonal terrain is immediately west of Imranli (Fig.3), where it constitutes a truly outstanding karst landscape (Fig.5). Dolines occur at densities of 80 to 100 per km^2. Each is 100 to 200m in diameter, with a soil floor about 50m across (cultivated and therefore largely flattened) below gentle slopes of bare gypsum and patchy soil rising 10 to 20m to the inter-doline ridge (Fig.6).

This polygonal karst creates a spectacular landscape. It occurs in all stages of development, recognisable by dolines increasing in size and decreasing in number. The Imranli karst appears to be the most youthful. An extensive area southwest of Sivas has well defined polygonal basins but their density is only about 10 per km^2. South of Zara and Hafik, an older landscape has poorly defined basins, each of which extends to more than $1km^2$.

Most rainfall sinks directly into the gypsum outcrops or their soil cover, but some collects on the doline floors and feeds into small sinkholes. On steeper overall slopes, some sinking streams resurge in the next doline, but most drainage is lost to deep circulation. Most of the groundwater appears to resurge into the beds of lakes and rivers that lie within the karst. Along the northern margin of the karst, Todurge Golu is just the largest of a number of lakes that have significant outflows but little or no visible inflow. Small risings are scattered through the karst, and most of them feed villages or farms. Just northeast of Sivas, the Seyfe and Goydun springs (Fig.4) have mean discharges of 0.25 and $1.15m^3/s$ respectively. These are significantly large karstic risings that have notably constant flows fed from extensive underground basins (Kacaroglu *et al.*, 1997).

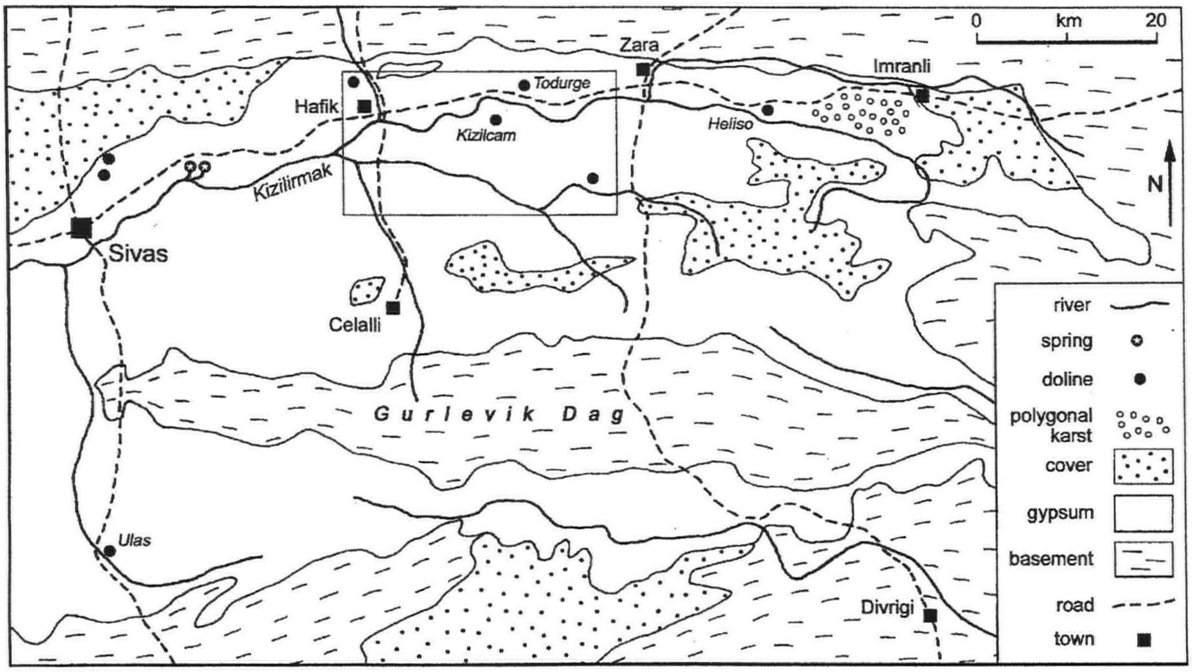

Figure 3. The extent of the gypsum karst east of Sivas. The basement comprises Jurassic to Eocene clastic rocks and the cover consists of various late Tertiary clastic sediments, some of which are interbedded with the gypsum. Alluvium (not shown) lies along the lower parts of the main river valleys. The only dolines marked are the larger collapse features. The area of this map is identified on Figure 1, and the boxed area east of Hafik is shown in Figure 4.

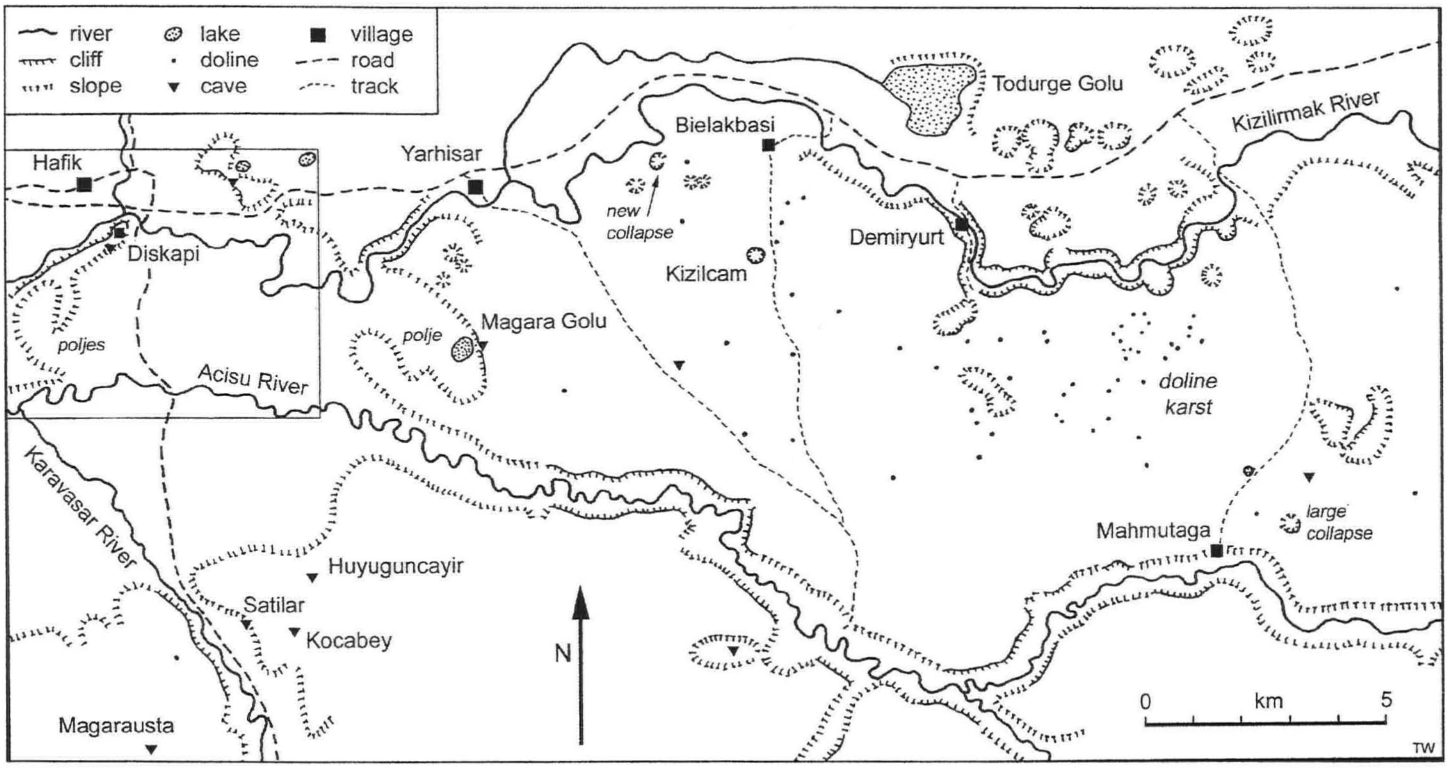

Figure 4. Some features of the geomorphology in the gypsum karst just east of Hafik. The area of this map is identified on Figure 3, and the boxed area around Diskapi is shown in Figure 10.

COLLAPSE DOLINES

The Sivas gypsum karst is distinguished by a number of large collapse features. These are scattered right across the areas of more mature karst, and they appear to be generally lacking in the more youthful polygonal karst. The finest single landform is the Kizilcam doline, east of Hafik (Fig.4). It contains a lake 220m in diameter surrounded by steep rock slopes that rise 30 to 50m to a rim about 350m in diameter (Fig.7). The doline breaks a gently graded gypsum surface that descends from the rim of the Acisu canyon northwards to the Kizilirmak River (which is not entrenched west of Bielakbasi village). The lake surface is at the same level as the latter river, 3km away. The depth of sediment or breakdown material below the lake is unknown. Kizilcam is a textbook collapse doline, except that its sides are now degrading so that it has already matured into a well-rounded shape.

The scale of the collapse event or events that formed the Kizilcam doline is open to debate, but may be indicated by processes in an active collapse doline that lies close to the Kizilirmak River, 2km west of Bielakbasi (Fig.7). This feature is about 200m across, floored partly by a chaos of breakdown blocks; it also has a small lake, ponded to the level of the adjacent river, only 10m below the surrounding terrain. The north wall of the doline is a cascade of gypsum blocks each about 4m across. The south wall has larger blocks of gypsum that appear to have dropped into a cave perhaps 25m across (Fig.8). The processes of dissolution, undercutting and block collapse are clearly active, with dissolution mainly at the water table level. The scale of breakdown suggests that the larger old collapse dolines (including Kizilcam) evolved by a long sequence of progressive breakdown failures. Few stable cave chambers in gypsum caves elsewhere in the world are more than 40m across, and this is commensurate with the size of cavity growth and collapse seen to be occurring in the Sivas gypsum.

Figure 5. Polygonal karst south of Imranli.

Figure 6. Dark ploughed soils on doline floors in the polygonal karst west of Imranli.

There is a group of large collapse dolines on the karst plateau near the village of Mahmutaga (Fig.4). The finest is a rocky bowl 400m in diameter, with a nearly flat floor 40m below the plateau surface (Fig.9), and over 100m above the Acisu River, just to the south. This appears to be a very old feature. Its original floor was probably within the zone of maximum dissolution at river level, prior to considerable entrenchment of the Acisu. It is also degraded and rounded, and its grassy floor may mask a considerable amount of breakdown debris, though Alagoz (1967) reports a temporary lake on its floor. Just to its northeast, two even larger basins, each nearly a kilometre across, appear to be even older collapse features, now alluviated, more degraded and perhaps coalesced from smaller original features; they also contain shallow temporary lakes. A smaller and younger collapse doline, beside the track to Mabanir, has a vertical wall on its down-dip (southeast) side, where it is still being undercut by dissolution as water drains down the gypsum bedding.

A very accessible collapse doline is Heliso Cukuru, beside the main road between Zara and Imranli. It is over 300m across and 50m deep, though it is old and degraded. Large collapse dolines just northeast of Sivas were noted by Karacan and Yilmaz (1997), and the Ulas lake appears to lie in another (Fig.3). The Kizilirmak River appears to have incorporated some collapse dolines during entrenchment of its gorge upstream of the village of Demiryurt. Two features in the south wall of the gorge, 4 and 5km east of Demiryurt, resemble cut-off incised meanders (Fig.4). However, they lie within a zone of collapse dolines of comparable size, and the gorge breaches the edge of another large doline (that is clearly not a cut-off meander) 1km south of Demiryurt. The implication may be that much of this gorge was excavated by serial cave development, collapse and unroofing.

POLJES AND BASINS OF THE KARST MARGIN

The largest dissolution landforms on the gypsum appear to lie along the northern margin of the karst. Todurge Golu is a shallow lake in a large karstic basin (Gunay, 2002) at the western end of a zone of massive dolines and collapse features (Fig.4). These all lie at the current base level, where dissolution along the trunk drainage routes appears to be undercutting and widening the dolines, until they coalesce into broader and degraded basins. Hafik Golu, just north of the town, is another lake of similar origin.

The next stage in the karstic surface lowering may be represented by alluviated basins on and along the courses of the trunk rivers. These are best seen south of Hafik, where the Kizilirmak and Acisu rivers emerge from the karst plateau and their valleys are separated only by lower gypsum ridges (Fig.10). Both rivers meander across alluviated floodplains and undercut the marginal gypsum slopes wherever they reach them. The base-level undercutting and collapse of the cliff west of Diskapi village is on a spectacular scale; one tilted block 100m long is now separated from the cliff by a box canyon formed by a combination of mass movement, cave unroofing and massive blockfall. Drainage from the small lake of Lota Golu passes through a gypsum ridge in a cave that has now almost completely collapsed to create a narrow gorge.

Between the two large rivers, two poljes drain entirely underground (Fig.10), and have the characteristic flat floors with eroded toes on their marginal slopes. These basins may once have been occupied by meander loops of either river, or they may be true poljes that evolved from features like those now active at and east of Todurge Golu.

Figure 7. The spectacular collapse doline of Kizilcam, with scale given by a person standing on the rim to the right.

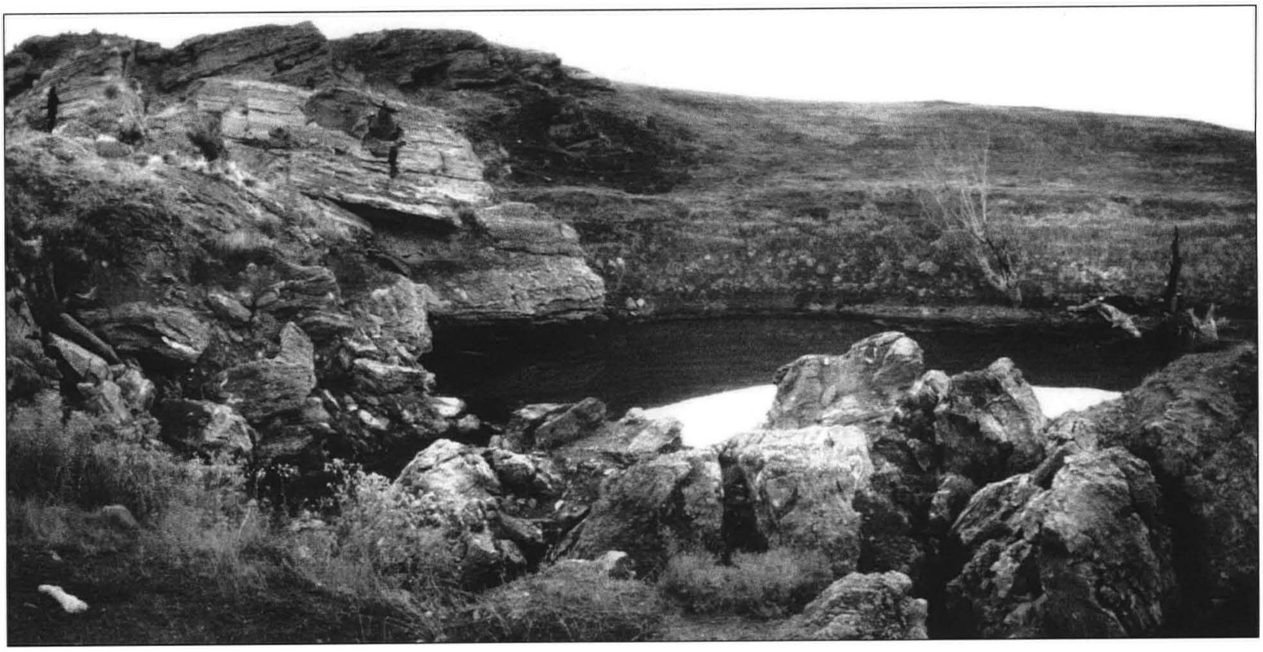

Figure 8. A corner of the active collapse doline east of Bielakbasi, with large and small fallen blocks of gypsum undermined by dissolution.

Subsidence troughs (elongate dolines formed over linear zones of rockhead dissolution) are recorded near Sivas (Kacaroglu *et al.*, 1997), but none has been recognised in the Hafik area.

CAVES

Though the Sivas gypsum karst is clearly cavernous, there are very few recorded or fully explored caves. The geological structure precludes development of long maze caves comparable to those in the Ukraine, and there are no cave chambers (yet known) to match the scale of the collapses that have formed the large dolines. Most of the known caves lie around Hafik.

The ridge straddled by Diskapi village has a variety of caves well worth further investigation (Fig.10). Near the top of the hill north of the village, there are at least two entrances (beside that to a large artificial tunnel). Both caves are dry systems of rifts and fissures, with signs of both landslip opening and dissolutional enlargement. Passages 1m wide and 5m high extend up and down various climbs and continue beyond the limits of the writer's hurried explorations. An impressive entrance (Fig.11) that clearly takes water under wet conditions flanks the polje south of the village. Inside, this spacious passage soon splits into a series of tubes that are partly choked by mud and flood debris, and only 100m of passages are easily reached. It is a classic foot cave cut cleanly across the steeply dipping gypsum beds. Passages must continue through the hill, though they may be too small or too choked for access. There are at least three cave entrances in the collapsing cliff on the northwestern side of the ridge. The western cave has an old series of dry and dusty rifts and chambers ending in chokes. The middle entrance is a water-table dissolution slot at the foot of the cliff; it requires a little digging and grovelling to enter, but a strong emerging wind suggests a link with caves higher within the hill. The eastern cave has an entrance 4m in diameter truncated 15m up the cliff face behind the main landslip block, but the villagers know a way in from another entrance.

East of Hafik, Lota Golu (Fig.10) drains into the breakdown that floors a collapse gorge through the gypsum ridge, where the only surviving cave is a passage fragment less than 50m long (Mayer, 1973). Several other partially collapsed caves, one with a chamber 30m across, are reported by Mayer (1974), with no reference to their exact locations. A cave entrance 15m high and 20m wide breaks the cliff beside Magara Golu (Cave Lake) (Fig.4). The large passage is only open for 40m to a breakdown pile below a collapse skylight (Mayer, 1973), though the cave takes overflow water from the lake, and smaller passages do continue.

Numerous cave entrances can be seen from the main road east from Sivas, and some look worthy of further investigation. The caves of Kaya Magaralar are sign-posted from the road between Hafik and Zara, and consist of a large number of natural entrances truncated in the cliff above the village of Demiryurt (Fig.4). Some have been enlarged artificially, probably to serve as hermitages, and whether any continue farther back into the hill is unknown.

The longest recorded caves were explored by Mayer (1973) in the gypsum hills south of Hafik. Kocabey Cave has a small stream passage that can be followed for 300m to a series of descending chambers where the water is lost into a narrow fissure. It is probably the same water that emerges from Satirlar Cave, 1000m to the west and 100m lower down (Fig.4). Another 300m of passage can be followed upstream before it becomes rather low (Mayer, 1973, 1974). This stream drains off a soil-covered outcrop of impure gypsum, but there are no known sinks where

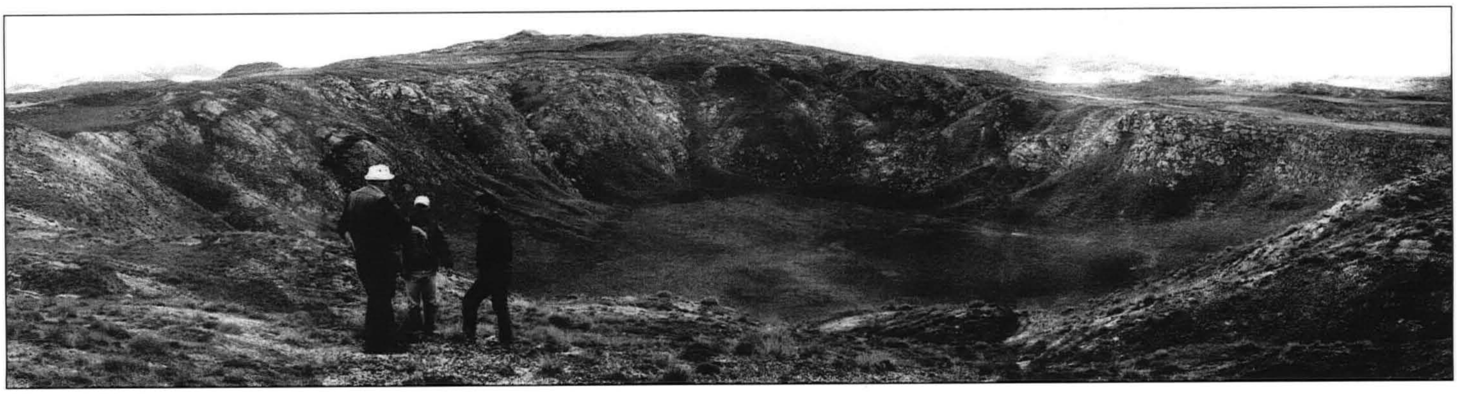

Figure 9. The large degraded collapse doline east of Mahmutaga.

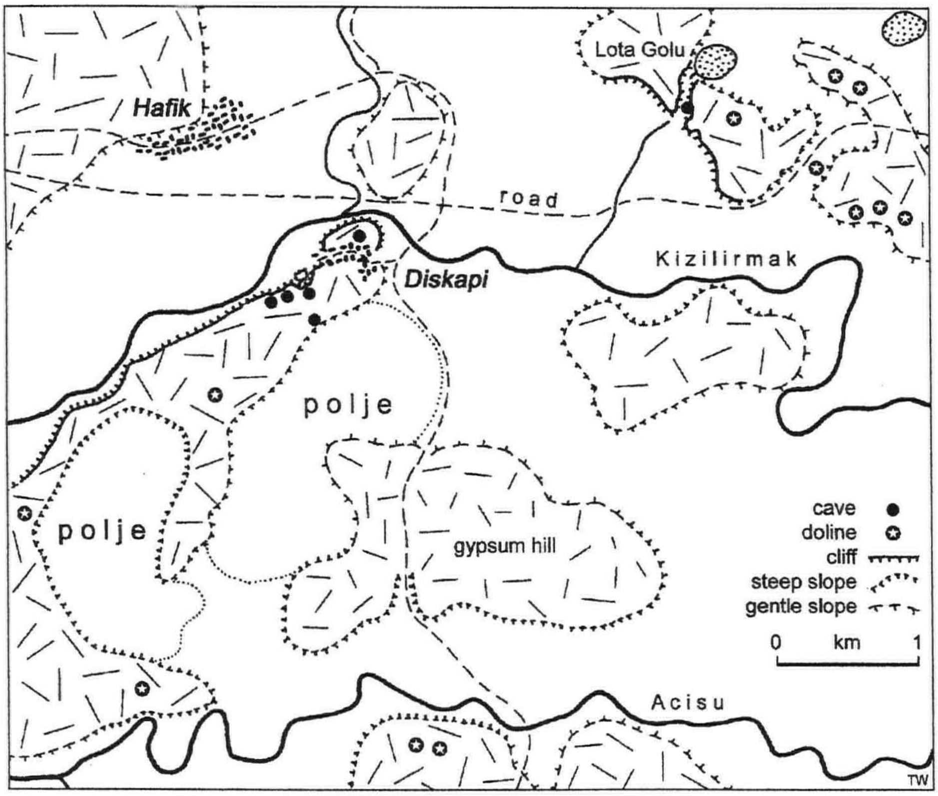

Figure 10. Poljes and caves around Diskapi, just south of Hafik. The area of this map is identified on Figure 4.

streams drain onto the gypsum from larger catchments on adjacent clastic rocks. Huyuguncayir Cave has a stream draining through three collapse chambers 10 to 15m across, and Magarausta Cave has at least 150m of small stream passages between a line of collapse entrances. These were both recorded by Mayer (1973), along with many other shorter caves in the hills towards Celalli.

The doline and polygonal karst areas farther east have many small sinks on the edges of the sediment floors in the depressions. Many are choked or narrow but some may reveal open cave passages after a little clearance. One open sink lies in the large doline south of the Acisu canyon (Fig.4). A short blind valley, cut 15m deep through the sediment fill, drains into a steep passage in cleanly washed gypsum. This narrows to a partial mud choke after only 20m, but the passage continues for a visitor prepared to contort gently, perhaps excavate a little, or hit lucky after a convenient flood. There is undoubtedly much more to be revealed in the splendid gypsum karst of Sivas.

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Figure 11. The entrance to the foot cave in the Diskapi gypsum ridge, on the north side of the adjacent polje.

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The impact of Cango Cave on the economy of Oudtshoorn, South Africa

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INTRODUCTION

Cango Cave, situated in the Swartberg foothills 27km north of Oudtshoorn in the (new) Western Cape Province, is South Africa's best known and most popular show cave. It was discovered by Europeans towards the end of the eighteenth century, and immediately attracted visitors, despite the lack of any facility for them. The only concessions to tourists were the wooden ladder to facilitate the descent into Van Zyl's Hall, and primitive portable lights. Simple accommodation was available at the nearby farmhouses, but the visitors would have had to take their hosts as they found them. The town of Oudtshoorn did not then exist. The first accommodation specifically for visitors, the Cango Hotel, probably coincided with the opening of the Swartberg Pass in 1888[1].

When in 1975 I first visited Oudtshoorn, I arrived in the early evening and could find nothing to eat. The only open establishment was the Queens Hotel, the bar of which was empty. Oudtshoorn was then a sleepy little town with a mixed economy. The major sources of income appeared to be agriculture, higher education, the army camp and, to a lesser extent, tourism. Indeed, the only tourist attractions were Cango Cave, the C P Nel Museum, Rus en Vrede in the Kleinlerouxriviervallei, and two ostrich farms to the south of the town.

The past quarter century has seen major economic changes in Oudtshoorn. Farming has been largely mechanised; and the ostrich market is depressed because of world overproduction. There is now no education college in the town. The army camp is under-utilized. Tourism is currently the dominant industry; and that industry appears to be dependent upon Cango Cave. This is evident from all the tourist attractions and facilities, most of which have appeared on and near the road to the Cave during the past two decades (tables 1 to 4). By comparison, there is very little for the visitor on the roads from the east, south and west.

DISCUSSION

It is worth considering why three of the traditional four major sources of employment in the Oudtshoorn district have declined. Drought, rising agricultural wages, and labour legislation that is detrimental to the interests of the employer have forced many farmers to mechanize. The demise of teacher training followed decreased Government expenditure thereon, which necessitated closure of the college. The army camp houses an infantry school that is redundant in the New South Africa, whose northern borders are no longer threatened.

The rise of tourism to dominance can be explained on the basis that it requires very little Government support beyond planning permission. The necessary finance can be found by big and small private enterprise and, in Oudtshoorn, has provided establishments ranging in size from the Queens Hotel complex to a modest pub.

It must be remembered that the standard and most popular tourist route in the southern Cape is the Garden Route nearer the coast viz. Plettenberg Bay, Knysna, George and Mossel Bay. Tourists have to make a detour over the Outeniqua Mountains to visit Oudtshoorn; and it is largely the Cave that attracts them. Less popular attractions specific to Oudtshoorn include Arbeidsgenot – the home of the late C J Langenhoven, promoter of the Afrikaans language. Tourists do not have to deviate to the town to see ostriches, rabbits, camels, cheetahs, crocodiles, and the like.

There are two basic economic principles relevant to business in general and to tourism in particular, including show caves:

1) It does not matter what is being managed, be it a show cave, coal mine, hospital, etc, a certain proportion of the profits should be returned for maintenance, research and development.
2) Whatever is being promoted as a tourist attraction, be it a cave, a palace, a game park, etc, there comes a time when the visitors become so numerous that they unwittingly damage that which they come to see. In the case of a stately home the builders can easily, if expensively, effect repairs. In the case of a show cave, remedial work is more problematical and requires appropriate monitoring and applied research on the basis of which long-term management plans can be prepared.

This is not the place to discuss show cave management in detail. Suffice it to say that very little money has been returned to the inside of Cango Cave during the past three decades, and it shows. Compared to the descriptions of visitors during the nineteenth century, the show cave is now but a shadow of its former glory. Further comparison with the formations in Cango II and Cango III, which are not open to visitors, confirms this deterioration[2].

I believe that some overseas tour operators have been, and are, tending to avoid Cango Cave. When in Switzerland in 1997, I found, on a railway station, a leaflet advertising package tours of South Africa. The promoters were going to fly their clients into Johannesburg, thence bus them to eastern Mpumulanga, round the coast through Transkei and along the Garden Route to Cape Town. Early in 1999 I received with some professional literature from England a similar brochure promoting a tour through Mpumulanga, Transkei, Garden Route and Cape Town. Oudtshoorn did not feature. A third unsolicited and thick brochure from England in 2000 promotes "*small group exploratory holidays*" throughout the world. The South Africa tour follows a similar route, and avoids Oudtshoorn and Cango Cave. Nevertheless overseas visitor numbers are slowly increasing (Table 5). A local up-market tour operator takes its clients over the Montagu Pass to an Oudtshoorn ostrich farm and wildlife ranch, but does not include Cango Cave in the package[3].

I returned to Oudtshoorn during the December 1999 holiday season, a time when Oudtshoorn is traditionally busy with visitors and when cars at Cango Cave are parked in the veld down to the Grobbelaars River. At the Cave the Manager and his guides said that business was slow. I saw for myself that only the top two car park terraces were occupied. In Oudtshoorn business was similarly bad. The tradesmen were

Town Centre	
West Side	East Side
C P Nel Museum	
	* Cango Crocodile Ranch and Cheetahland
* Oudtshoorn Ostrich Show Farm and Pottery	
	* Cango Ostrich Farm
* Cango Angora Rabbit Farm	
	Rus en Vrede
Cango Cave	

Table 1: Tourist attractions between Oudtshoorn Town Centre and Cango Cave on 19 September 1999. [indicates a post-1975 attraction.]*

Town Centre		
West Side		East Side
Queens Hotel Complex		
Kannaland Lodges		
Toms Mill B&B		
Shades of Africa B&B		
De Oude Pastorie		
La Pension B&B		
The Yacht Club B&B		Wepeners Oornagkamers
		Holiday Inn
		Baron's Palace
Country Estate Guest House		Backpackers Paradise
		Private B&B
		Hlangena Lodge
		Rosenhof
		Mini Fee
Kleinplaas		
Riempie Estate Hotel		
Cango Over-nite Lodge		
Caves Country Lodge		
Die Opstal Country Lodge		
Altes Landhaus		
Berluda d'Oue Werf B&B		
De Oude Meul Guest Farm		
		Stonebreakers Country Lodge
		De Poort Country Lodge
Schoemanspoort Cultural Centre		
Ou Tol B&B		
		Melville House Centre
		Cango Mountain Resort
		(site of former Cango Hotel)
Grootkraal B&B		
Cango Cave		

Table 2: Tourist accommodation between Oudtshoorn Town Centre and Cango Cave on 19 September 1999.

complaining bitterly; and the main car park was only about 10% occupied. In contrast, a friend who had been on the Garden Route at the same time told me that George and Knysna had been packed with visitors.

The poor state of Cango Cave is clearly not the only contributory factor to the fall in visitor numbers at Cango Cave. Others include:

1) The recent appearance of beggars on the Oudtshoorn streets.
2) The recent appearance of importuning hawkers in Oudtshoorn.
3) Overcharging – examples of which I noted were R299 per night for bed & breakfast, and R9 for a very small packet of ostrich biltong.
4) A recent (1999) assault on, and robbery of, an overseas visitor. This may have been kept out of the newspapers; but visitors and tour operators talk among themselves.
5) A recent (2000) armed robbery at the Cave[4].
6) The assault and subsequent death in April 2001 of a visitor from the Orange Free State who was attending the Klein Karoo Kunsfees. That story was published, with the additional information that "... *police have been inundated with reports of cellphone theft, car break-ins, handbags and purses being snatched and ugly incidents of public drunkenness*"[5].

Town Centre		
West Side		East Side
Loafer's Sandwich Bar		Saddles (steak house)
		Bernard's Taphuis
		Café Bistro and Restaurant
		Spur Steakhouse Santa Fe
Bokvet's Pub		Rock Art Café
		Wimpy
		Wilja's Pub
Xenia Curios and Takeaway		
Camp Road House Restaurant		Die Fyne Keuken
Yuppies Bistro		
Swiss Bistro Restaurant		
Zindago's Restaurant and Pub		
		Wilgewandel Coffee Shop
Cango Cave		

Table 3: Restaurants and pubs between Oudtshoorn Town Centre and Cango Cave on 19 September 1999.

Town Centre		
West Side		East Side
Headlines		
1 Hour Photo Workshop		
		Ostrich Products
Pearson Tree Gifts and Clothing		Flying Ostrich
		Botega Art Gallery
		Rijkshof Wine Sales
		Rustic Barn
		7-Nov
Million Hairs Bistro		
Michael Angelo's Superette		
		Swans Nursery and Pottery
		Wholesale Liquor Warehouse
Ostrich International Showrooms		
		Camel rides
Cango Cave		

Table 4: Other tourist facilities between Oudtshoorn Town Centre and Cango Cave on 19 September 1999.

These six potential local causes are speculative, but their postulated detrimental economic effects are supported by the attendance figures at Cango Cave. Since the Cave was electrified in 1928, annual attendance rose more or less exponentially from 8668 in 1928 to about 250,000 in 1997 [6] Thereafter total visitor numbers have declined but overseas visitors are slowly increasing. This trend may continue with the continuing fall in value of the rand.

Thus, it appears that the economy of Oudtshoorn depends largely upon a single and potentially wasting asset viz. Cango Cave. If the Cave is allowed to deteriorate further, I believe that Oudtshoorn will eventually cease to attract visitors, and become a ghost town.

Year	Total	Foreign
1995	235,766	96,126
1996	245,772	71,457
1997	247,579	73,693
1998	245,999	86,678
1999	240,096	100,544
2000	236,053	118,739

Table 5: Cango Cave: Annual attendence 1995-2000.

In conclusion it is pleasing to report that at long last in 2001 the Oudtshoorn Municipality is taking some action with a view to reducing the environmental damage done by visitors to the Cave. Low-energy efficient lighting is being installed, and an atmospheric monitoring system has been introduced [7]. Nevertheless the Town Councillors and Chamber of Commerce would be well advised to seek other sources of economic support for their town. It is a dangerous policy to rely on one single major source of income. Indeed, the Municipal finances are reported to be in a very parlous condition [8].

ACKNOWLEDGEMENT

I thank Professor M E Marker for her helpful comments on the early drafts of this Report.

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Forum

Readers are invited to offer thesis abstracts, review articles, scientific notes, comments on previously published papers and discussions of general interest for publication in the Forum of *Cave and Karst Science*.

All views expressed are those of the individual authors and do not necessarily represent the views of the Association unless this is expressly stated. Contributons to the *Cave and Karst Science* Forum are not subject to the normal refereeing process, but the Editors reserve the right to revise or shorten text. Such changes will only be shown to the authors if they affect scientific content. Opinions expressed by authors are their responsibility and will not be edited, although remarks that are considered derogatory or libellous will be removed, at the Editors' discretion.

ANNOUNCEMENT

"William Pengelly Cave Studies Trust have asked us to point out that the article by Stephen Craven on the history of the BSA, which appeared in *Cave and Karst Science*, Vol.28, No.3, was updated and expanded from an article that appeared previously in *Studies in Speleoleogy*, Vol.8 in 1991."

CORRIGENDA

We apologize to readers and to the authors of the contributions concerned for the following omissions from or errors within *Cave and Karst Science*, Vol.28, No.3:

A uranium series date from Malham Cove Rising, North Yorkshire, UK

Phillip J Murphy and Alf G Latham

The References list was inadvertently truncated. The full list is reproduced below:

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Thank you to Phil Murphy and Graham Proudlove for pointing out the omission of the References.

Speleothem decoration of giant domes in Bohemia Cave (New Zealand)

Radko TÁSLER, Václav CÍLEK, Helena HERCMAN

Plates 5 and 6 are transposed relative to their respective captions.

CORRESPONDENCE

Going back some considerable time, we asked for comments on the Cover Photo of *Cave and Karst Science*, Vol.28, No.1. Whereas we received a number of comments on the fact that the photograph's caption contained an error (see below), we received only one comment on the photo's subject matter. We apologize to the comment's author for the delayed publication as we awaited further suggestions...

Dear Editor,

The latest issue has just arrived in Cape Town. I note that you invite suggestions as to how the speleothem block on the floor got there in the absence of any tectonic activity. I would suggest that:

1. The stalactite block became too heavy for the 'glue' that attached it to the ceiling of the chamber;
2. Detachment did not occur simultaneously and uniformly. It commenced at one edge and proceeded towards the opposite edge, until detachment occurred;
3. At the time of detachment the block would have behaved like a hinge with a broken pin. Its momentum would have caused it to rotate through 180 degrees (NOT 90 degrees as stated in the caption), thereby landing upside-down on the floor.

I leave it to the karst specialists to explain why the 'glue' should have failed in this way.

Best wishes from,

Stephen A Craven
7 Amhurst Avenue
Newlands 7700
South Africa

REVIEW

U.S. Geological Survey Karst Interest Group Proceedings

Eve L Kuniansky (editor)
U.S. Geological Survey, Atlanta, Georgia, 2001, 211 pages, US$ 4.00.

This book was the result of the first workshop of the U.S. Geological Survey's Karst Interest Group held in St Petersburg, Florida from February 12-16, 2001. The mission of the Karst Interest Group is to promote better communication among researchers involved and interested in karst hydrology. As stated in the Preface: *"this workshop brought together U.S. Geological Survey scientists with other Department of the Interior scientists and managers and University researchers interested in karst hydrology and to serve as a springboard promoting future collaboration among scientists and researchers to improve our understanding of karst systems in the United States and its territories."*

The 211-page book includes 26 papers and 12 abstracts. Contributions are placed into 11 categories that include: *Karst Ecosystems, Geologic Framework of Karst Systems, Aquifer Hydraulics in Karst Systems, Programs Within the U.S. Department of Interior that Involve Karst, Numerical Modeling in Karst, Cave and Spring Species and Habitats, Geochemistry of Karst Systems, Geophysical Methods in Karst, Contaminant Transport in Karst, and Tracers in Karst.* A field trip guide provides discussions about karst features found in west-central Florida.

The efforts of over 60 scientists are presented in this book. Two contributions relate to karst ecosystems. Olson stresses that a multilayered GIS inventory is necessary to understand the relationships between cultural resources, ecosystems, and karst landscapes for the protection cave and karst resources. Loftus *et al.* provide the results of a study conducted under the Comprehensive Everglades Restoration Plan. They attempted to define the interactions between aquatic and animal communities with the geologic structure and hydrologic conditions at Rocky Glades in southern Florida.

Four contributions are devoted to the geologic framework of karst systems. Hudson *et al.* discuss the geologic framework along the western Buffalo River watershed in northern Arkansas. A conceptual model was developed by Orndorff *et al.* to better understand the impact that lead and zinc mining has on karst areas in south-central Missouri. Spechler proposes several mechanisms for intrusion of saltwater on the Floridan Aquifer and the relation to geologic structure. Epstein discusses the subsidence and collapse from the dissolution of gypsum and anhydrite in the Black Hills of South Dakota and Wyoming.

Two contributions describe aquifer hydraulics in karst systems. Martin and Screaton discuss the exchange of matrix and conduit water in the Floridan Aquifer. A short abstract is presented by Taylor concerning the characterization of quick flow and slow flow within a limestone and dolomite aquifer in south-central Louisville, Kentucky.

Two contributions discuss programs within the U.S. Department of the Interior that involve karst. Burger and Pate address their concerns about the cave resources at Carlsbad Caverns. Bailey provides the mission, goals, and current status of the National Cave and Karst research Institute.

Four contributions focus on numerical modeling in karst. The Hydrogeology Consortium has developed a new conceptual model to better address contaminant transport in karstic aquifers (Loper). Sepulveda presents a very detailed composition that analyzed seven groundwater flow models to identify simulated transmissivity in model overlap areas in southwest and south-central Florida. A study by Haugh presents the results on the Cave Springs groundwater system in Tennessee. This study used existing information on the spring's groundwater system to evaluate the annual water budget and current and planned increases in groundwater withdrawls. Kuniansky et al. provides an extended abstract that estimated flow path travel times through the structurally controlled Edwards Aquifer in Texas using simulated ground water levels from a finite element model.

Two contributions concentrate on cave and spring species and habitats. A literature review was conducted by Walsh that summarized the aquatic macrofauna of Florida karst habitats. Bruno *et al.* provided a study on microcrustacean communities in groundwater collected from wells at various depths in the Southern Everglades.

Three contributions provided studies on the geochemistry of karst systems. A brief abstract by Bradley focused on the geochemistry of the carbonates rocks in the Upper Knox Group of Tennessee. Another paper presented the results of a one-year sampling program on the Mammoth Cave System's underground Logsdon River. The objective of the study was to collect high-resolution data on both flow and chemical characteristics of the river to quantitatively evaluate the magnitudes and rates of change of carbonate chemistry and water/rock interactions at a variety of time scales (Groves and Meiman). Reich *et al.* investigated the potential for contamination from onshore karst aquifers to move to offshore marine environments.

Six contributions document the use of various geophysical techniques in karst investigations (Stanton and Shrader; Paillet; Kindinger *et al.*; Kramer *et al.*; Cunningham and Aviantara; Flocks *et al.*). Various methods used included electromagnetic conductivity surveys, magnetometer surveys, 2D-DC electrical resistivity surveys, image and flow logs, seismic profiles, ground penetrating radar, digital optical borehole images, high resolution single channel seismic profiling, and gamma-ray intensity profiles.

Five papers focus on contaminant transport in karst. Farmer and Williams present the preliminary findings of a study involving three contaminated springs in middle Tennessee. Preliminary results of a study conducted by Byl and Farmer demonstrate that a new technique may be used to identify sources of faecal bacteria in complex karst hydrological settings. Another paper presents field and laboratory data collected to determine the potential for biodegradation of jet fuel contamination in a karst aquifer in Southern Kentucky (Byl *et al.*). Wolfe and Haugh developed five conceptual models to show where dense non-aqueous phase liquids (DNAPLs) may accumulate in karst settings. Haugh and Bradley provided the results of cave air sampled from a diesel fuel release at Lookout Mountain in Tennessee.

Six contributions concentrate on water tracing in karst. Taylor and Greene discuss the usefulness of quantitative dye tracing investigations to characterize karst aquifer flow. Katz used a multi-tracer approach (chemical and isotopic) to examine the susceptibility of the Upper Floridan Aquifer to contamination. Dillion *et al.* used the artificial tracers SF_6, ^{131}I, PO_4, NO_3, and $^{32}PO_4$, to determine groundwater flow within a karst system underlying the Florida Keys. Meiman et al. discussed the results of a dye tracing program within the Mammoth Cave Karst Aquifer that obtained addition details regarding drainage basin divides to protect the caves aquatic ecosystem. Spangler employs the use of dye tracing to delineate recharge areas for three karst springs in the Alpine karst of northern Utah in addition to determination of the physical properties of spring water. The last paper discusses the potential for anthropogenic pollutants to discharge from submarine groundwater into the Upper Indian River Lagoon, Florida.

A field trip guide is provided at the end of the book (Tihansky and Knochenmus). This includes a discussion of the mantled karst of west-central Florida, associated hydrogeologic framework, and descriptions of four field stops.

This book covers a wide variety of research conducted in karst areas throughout most of the United States. All graphics are at a scale that provides clarity for the reader. Abundant references are cited for further reading and all papers are well presented and organized. I consider the Karst Interest Group Proceedings as a valuable addition to any personal library.

REFERENCES

Kuniansky, E L (editor), 2001. U.S. Geological Survey Karst Interest Group Proceedings. *Water Resources Investigations Report* 01-4011. U.S. Geological Survey, Atlanta, Georgia. 211 pages.

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RESEARCH FUNDS AND GRANTS

THE BCRA RESEARCH FUND

The British Cave Research Association has established the BCRA Research Fund to promote research into all aspects of speleology in Britain and abroad. A total of £2000 per year is currently available. The aims of the scheme are primarily:

a) To assist in the purchase of consumable items such as water-tracing dyes, sample holders or chemical reagents without which it would be impossible to carry out or complete a research project;

b) To provide funds for travel in association with fieldwork or to visit laboratories that could provide essential facilities;

c) To provide financial support for the preparation of scientific reports. This could cover, for example, the costs of photographic processing, cartographic materials or computing time;

d) To stimulate new research that the BCRA Research Committee considers could contribute significantly to emerging areas of speleology.

The award scheme will not support the salaries of the research worker(s) or assistants, attendance at conferences in Britain or abroad, nor the purchase of personal caving clothing, equipment or vehicles. The applicant must be the principal investigator, and must be a member of the BCRA in order to qualify. Grants may be made to individuals or groups (including BCRA Special Interest Groups), who need not be employed in universities or research establishments. Information about the Fund and application forms for Research Awards are available from the BCRA Honorary Secretary (address at foot of page or e-mail research-fund@bcra.org.uk).

GHAR PARAU FOUNDATION EXPEDITION AWARDS

An award, or awards, with a minimum of around £1000 available annually, to overseas caving expeditions originating from within the United Kingdom. Grants are normally given to those expeditions with an emphasis on a scientific approach and/or pure exploration in remote or little known areas. Application forms are available from the GPF Secretary, David Judson, Hurst Barn, Castlemorton, Malvern, Worcestershire, WR13 6LS, UK (e-mail: d.judson@bcra.org.uk). Closing dates for applications are: 31 August and 31 January.

THE E K TRATMAN AWARD

An annual award is made for the most stimulating contribution towards speleological literature published within the United Kingdom during the past 12 months. Suggestions are always welcome to members of the GPF Awards Committee, or its Secretary, David Judson (see above for contact details), not later than 31 January each year.

BRITISH CAVE RESEARCH ASSOCIATION PUBLICATIONS

CAVE AND KARST SCIENCE - published three times annually, a scientific journal comprising original research papers, reports, reviews and discussion forum, on all aspects of speleological investigation, geology and geomorphology related to karst and caves, archaeology, biospeleology, exploration and expedition reports.

Editors: Dr D J Lowe, c/o British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK, (e-mail d.lowe@bcra.org.uk) and Professor J Gunn, Limestone Research Group, University of Huddersfield, Queensgate, Huddersfield, HDI 3DH, UK (e-mail j.gunn@bcra.org.uk).

SPELEOLOGY - published three times annually and replacing BCRA's bulletin 'Caves & Caving'. A magazine promoting the scientific study of caves, caving technology, and the activity of cave exploration. The magazine also acts as a forum for BCRA's special interest groups and includes book reviews and reports of caving events.

Editor: David Gibson, 12 Well house Drive, Leeds, LS8 4BX, UK (e-mail: speleology@bcra.org.uk).

CAVE STUDIES SERIES - occasional series of booklets on various speleological or karst subjects.

No. 1 *Caves and Karst of the Yorkshire Dales*; by Tony Waltham and Martin Davies, 1987. Reprinted 1991.
No. 3 *Caves and Karst of the Peak District*; by Trevor Ford and John Gunn, 1990. Reprinted with corrections 1992.
No. 4 *An Introduction to Cave Photography*; by Sheena Stoddard, 1994.
No. 5 *An Introduction to British Limestone Karst Environments*; edited by John Gunn, 1994.
No. 7 *Caves and Karst of the Brecon Beacons National Park*; by Mike Simms, 1998.
No. 8 *Walks around the Caves and Karst of the Mendip Hills*; by Andy Farrant, 1999.
No. 9 *Sediments in Caves*; by Trevor Ford, 2001
No. 10 *Dictionary of Karst and Caves*; by D J Lowe and A C Waltham, 2002.
No. 11 *Cave Surveying*; by A J Day, 2002.

SPELEOHISTORY SERIES - an occasional series.

No.1 The Ease Gill System – Forty Years of Exploration; by Jim Eyre, 1989.

BCRA SPECIAL INTEREST GROUPS

SPECIAL INTEREST GROUPS are organised groups within the BCRA that issue their own publications and hold symposia, field meetings, etc.

Cave Radio and Electronics Group promotes the theoretical and practical study of cave radio and the uses of electronics in cave-related projects. The Group publishes a quarterly technical journal (c.32pp A4) and organises twice-yearly field meetings. Occasional publications include the *Bibliography of Underground Communications* (2nd edition, 36pp A4).

Explosives Users' Group, provides information to cavers using explosives for cave exploration and rescue, and liaises with relevant authorities. The Group produces a regular newsletter and organises field meetings. Occasional publications include a *Bibliography and Guide to Regulations*, etc.

Hydrology Group organises meetings around the country for the demonstration and discussion of water-tracing techniques, and organises programmes of tracer insertion, sampling, monitoring and so on. The Group publishes an occasional newsletter.

Speleohistory Group publishes an occasional newsletter on matters related to historical records of caves; documentary, photographic, biographical and so on.

Cave Surveying Group is a forum for discussion of matters relating to cave surveying, including methods of data recording, data processing, survey standards, instruments, archiving policy, etc. The Group publishes a quarterly newsletter, Compass Points (c.16pp A4), and organises seminars and field meetings.

Copies of BCRA Publications are obtainable from: Ernie Shield, Publication Sales, Village Farm, Great Thirkleby, Thirsk, North Yorkshire, Y07 2AT, UK.

BCRA Research Fund application forms and information about BCRA Special Interest Groups can be obtained from the BCRA Honorary Secretary: John Wilcock, 22 Kingsley Close, Stafford, ST17 9BT, UK.