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Volume 11 Number 4 December 1984

Karst Geomorphology in South China

Cave Explorations around Tresviso

Speleogenesis in the Picos de Europa

Palaeokarsts in Britain

BRITISH CAVE RESEARCH ASSOCIATION

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SOME FEATURES OF KARST GEOMORPHOLOGY IN SOUTH CHINA

A. C. Waltham

ABSTRACT

The karst geomorphology of South China is summarised, special reference is made to the relationships between cone (lithologically controlled), hill peak and tower (tectonically controlled) karsts. The Guizhou Plateau is a massive karst block with cave development mainly in its marginal zones. The Stone Forest of Lunan is a spectacular karren field. Comment is added on the state of cave and karst research in China.

INTRODUCTION

During the summer of 1984, the writer spent three weeks in China, taking the opportunity to see some of the very spectacular karst scenery, and also to discuss various aspects with Chinese karst scientists. This paper is submitted as a report of that visit. It conveys second-hand information by commenting on some of the current thinking and research by Chinese karst workers and describes first-hand some individual components of the karst landscape. As the English language literature on Chinese karst is rather limited, it also summarises some of the major features of the enormous area of karst in China.

KARST REGIONS OF CHINA

The statistics of the Chinese karst are amazing. It covers an area of 1,300,000 sq km, of which around half a million square kilometres form the almost unbroken karst block of Guangxi, Guizhou and Yunnan. The rocks of Cambrian to Triassic age in South China are nearly 70% limestone; locally unbroken carbonate sequences have stratigraphic thicknesses of 3000 m, and some individual limestone beds can be followed over an area of a million square kilometres. Combine these facts with a terrain variation from plain to plateau to mountain, a climatic range from tropical to alpine and it is easy to see why the Chinese karst is of such importance.

A map of limestone distribution in China (in Jennings, 1981) is unfairly dominated by the enormous outcrops of Xizang (Tibet). The cold, dry climate of this high altitude desert in the heart of the Asian continent is not conducive to limestone solution, and the karst is very poorly developed in this region. Infinitely more important is the great karst region south of the Chang Jiang (Yangtze River) reaching almost to the South China Sea, and to and across the border with Vietnam. This one vast outcrop embraces both the famous tower karst of the Guangxi lowlands, and also the high level karst of the Guizhou Plateau (Fig. 1). These are the most significant areas of karst in China, and both are further described below.

The Guizhou Plateau extends southwest into Yunnan and also northeast into Hunan and Hubei where the limestone is contorted into chains of fold mountains. Immediately to the north the huge Sichuan basin is floored by sandstone but almost ringed by limestone mountains, whose outcrops are connected at depth beneath the synclinal floor of the basin. The Yangtze River drains the entire basin and escapes eastwards through the famous gorges lying between Wanxian and Yichang in the provinces of Sichuan and Hubei. All the gorges are in limestone, formed where the river breaches a series of massive escarpments. Vertical walls of limestone rise hundreds of metres from the swirling brown waters, though river downcutting has dominated almost to exclusion any true karst landforms in the area close to the river. Some of the limestone is very massive, while parts are probably too thinly bedded to contain extensive caves. But high above, massive limestone cliffs, fringing the escarpments and plateaux, so resemble the characteristic cliffs of Europe's cavernous Urgonian limestone that the promise of some spectacular karst is undeniable.

Further north in China, karst is of less importance, largely due to the lack of limestone outcrops but also due to much lower solution rates in climatic regimes well removed from the hot, wet, tropical conditions of Guangxi. Only towards Beijing (Peking) do the limestones extend in mountain ranges fringing the great Yellow Plain of the lower Huang He river. Near Shijiazhuang on the borders of Shanxi and Hebei lies the great karst spring of Niangziguan. Its flow ranges from 14 to 17 cumecs; the small variation reflects the very large phreatic fissure storage and also the flow from storage in a permeable sandstone caprock and does not auger well for extensive cave development. Even nearer Peking is Zhoukoudian where fissure caves in the limestone yielded the half million year old remains of Peking Man.

Good reviews of the Chinese karst regions have been published in English by Zhang (1980) and Yuan (1981). In addition there is the famous photographic book "Karst of China" (Institute of Hydrogeology, 1976) which suffers from a complete lack of maps; a new and expanded edition of this is soon to be published. Finally it should be mentioned that China's karst is not restricted to limestone. Qingyan, in Hunan province, has a major sandstone karst, though it lacks underground development on anything like the scale of that in Venezuala. Manchuria has, in the area of Wudalainzhi, some large lava caves; these contain some lava glaze stalactites almost to rival those of Hawaii's lava tubes, except that the Chinese forms are dominated by large curtains instead of stalagmites.

KARST LANDFORMS

On the large scale, the karst of South China is dominated by the division between the Guizhou Plateau and the Guangxi Plain, together with the intermediate zones, and these aspects are considered below. But on the small scale the entire region has a chaotically disorganised landscape, typical of karst, with all shapes of isolated and coalesced hills within a local relief normally of only a few hundred metres. It is these hills, notably the towers, which have made China's tropical karst world famous and which continue to provoke considerable unresolved debate, both on their origins and the extent of their evolutionary relationships (if any).

In the classical literature on tropical karst, two main landform types are recognised - cone karst and tower karst. Cone karst is typified by that of Gunung Sewu in Java (Lehman, 1936; Waltham et al 1983) and the Cockpit Country in Jamaica. Individual cones have height:width ratios of around 0.25, are rarely higher than 100 m, and though their lower slopes tend to a constant 30^{o} their upper parts are well rounded, often to approach a hemispherical form (Fig. 2); valley floors between the cones are narrow and alluvial flats are unusual. It is significant that in both Java and Jamaica, the morphology of the cones is relatively constant over large areas. In China, there are areas of cone karst in the heart of the Guizhou Plateau, but the cones differ from those of the type areas. They are isolated and surrounded by alluvial flats, their slopes vary between localities and they are more truly conical with less rounded summits (Fig. 2).

The classic example of tower karst is the Yangshuo area of Guangxi (Fig. 3). Individual towers have height:width ratios of over 2, range in height from 30 m to over 200 m, and while many do have vertical sides, others are much more irregular though still have very steep walls somewhere in their profile (Waltham, 1983). Characteristically, towers rise from alluvial flats, and may be as isolated individuals or in clusters with precipitous internal valleys and depressions.

This two-fold division into cones and towers is however grossly inadequate to describe the myriad karst hills of China. There is a complete range of hill profiles between the extremes of cones and towers. Particularly on the margins of the Guizhou Plateau, there are vast numbers of intermediate forms, which cannot be described as cones, within the meaning of Lehman, and yet are in marked contrast to the true towers of Guangxi. The dominant forms have height:width ratios around unity, are irregular in profile, always steeper than cones and yet not attaining the verticality of towers (Fig. 2); valleys and dolines separate the hills with only limited alluvial flat development. The Chinese sometimes refer to these forms as "hill peaks" and, though this term in not as simple as cones or towers, there seems a glaring need for it to be more widely recognised and used.

The continuing debate on the origins of cones, hill peaks and towers may well benefit from considering evidence from both inside and outside China, which is not easy with current travel restrictions. Within China, true towers occur mainly on the Guangxi Plain, true cones are mostly on the Guizhou Plateau, and hill peaks occur in both areas and in the intermediate zone. All three forms can develop in massive limestone, though some of the Guizhou cones are in thinner bedded carbonate, and stronger beds form scars around some hills. Many hills have no structural geological control, while some have profiles clearly influenced by their being dissected remnants of cuestas or hogbacks; rock mechanics determine that the finest towers are mostly, but not exclusively, in nearly horizontal limestone. Most towers occur in the tropical climate of Guangxi with annual rainfalls of around 2000 mm and mean temperature around 21^{o}C, while the cones and more hill peaks are in the sub-tropical climate of Guizhou with a rainfall close to 1200 mm and a mean temperature about 15^{o}C. The South China karst is tectonically active; it was affected by the Himalayan orogeny 10-20 million years ago and uplift has continued into the Quaternary.

The distinguishing parameters, influential on hill genesis, are basically lithology, climate and tectonics. Many of the Guizhou cones are formed in weaker, thinner bedded, more shaley limestones - a distinction adequate to explain their morphology. However, the cone karst of Java is formed in massive limestone, where perhaps a crucial factor is the role of an allogenic soil cover; so cone hills may have to be regarded as polygenetic. The hill peak karst may be seen just as an extreme of disorganised karstic dissection formed in optimum conditions of massive limestone, tectonic uplift and high solution rates. The towers still require a genetic distinction, which in turn must have implications on the origins of the hill peaks.

The towers are not purely controlled by lithology; their limestone is similar to that of many other karsts. Similarly the climate of Guangxi is not unique; in other tropical karsts, such as Subis and Mulu in Sarawak, vertical margins to the karst blocks do occur but the interiors are doline fields without isolated tower development. Older theories on the Chinese towers, summarised by Silar (1965), were based on the role of climate and the considerable antiquity of the karst and saw the Guangxi tower karst as an erosional evolution from the Guizhou Plateau - though this cannot be supported by field evidence. Tseng (1964) saw the towers as residuals after evolution of the alluvial flats, but could not account for their scarcity elsewhere. The classification of the Guilin tower karst in Sweeting (1978) was purely descriptive of the degree of dissection and offers no genetic relationships. Williams (1978) gave a fuller classification and identified the role of vertical or horizontal drainage to distinguish respectively the cone and hill peak karst from the tower karst. The most convincing explanation comes from Zhang (1980) who related the contrasting karsts to tectonism. He claimed that the Guangxi towers developed by continued erosion at the margins of the alluvial flats where the uplift rate was equal to or slightly less than the rate of karst denudation, while the Guizhou hill peaks formed where uplift exceeded karst erosion rates. It appears that only this theory accounts for the differences within the Chinese karst and also the rarity of tower forms in most other tropical karsts. It should, however, be

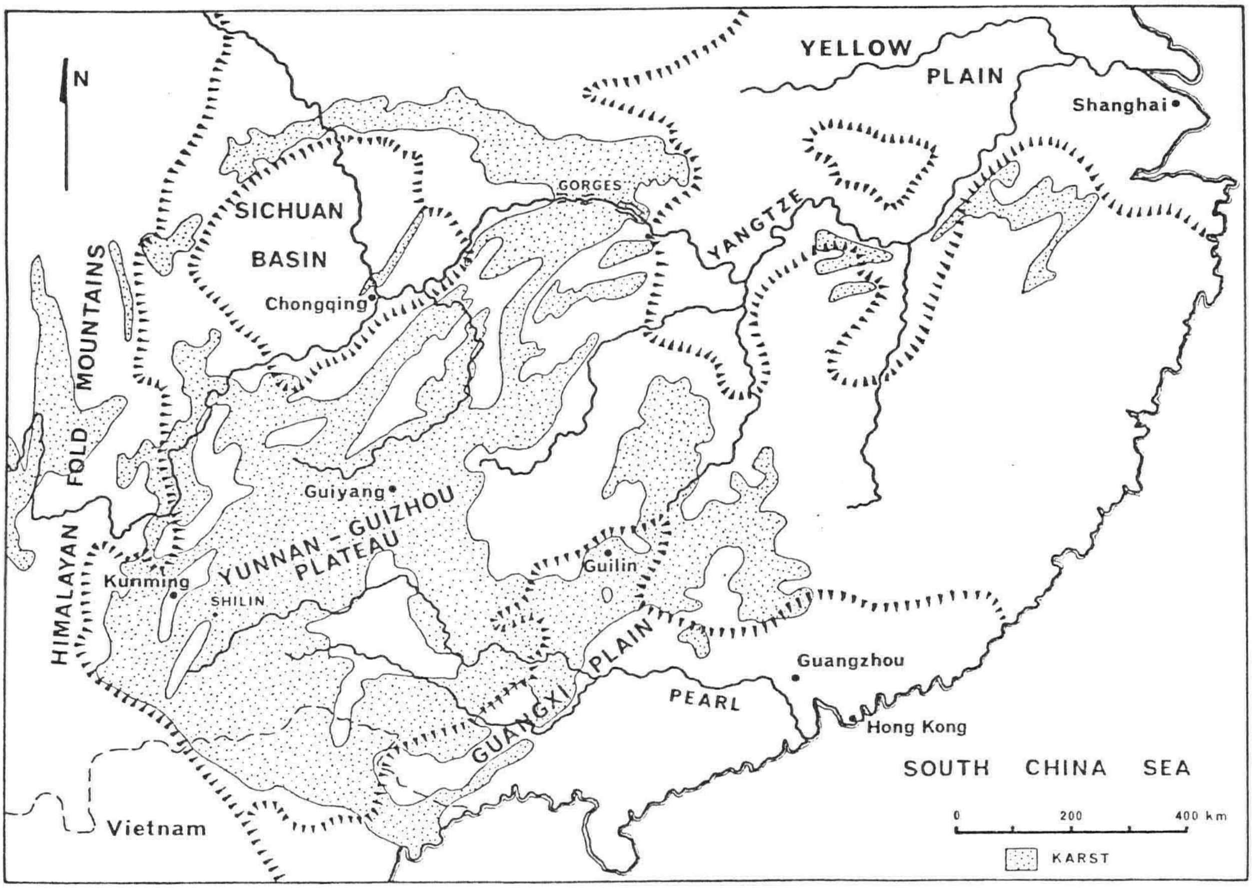


Fig. 1. The major topographic units and main karst areas of Southern China.

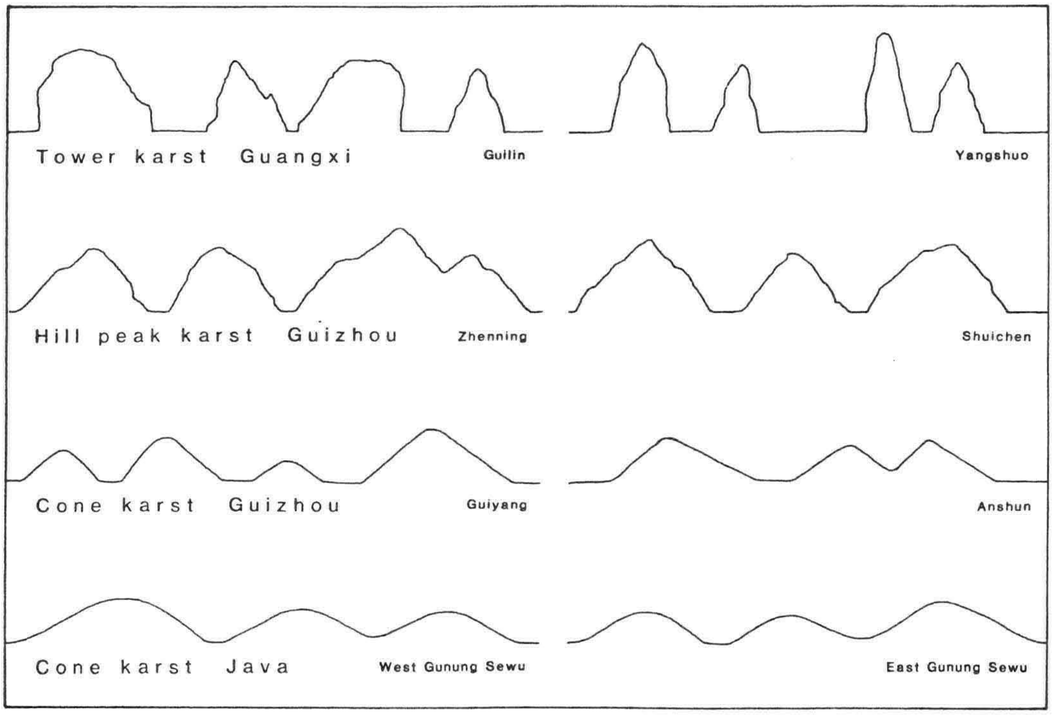


Fig.2. The contrasting hill shapes in the karst of South China and a comparison with the conical karst of Java. Drawn from photographs.

added that it is difficult to find field evidence to prove the relative uplift rates and there are still karst scientists in China who see the contrasting landforms as functions of a combination of lithology and climatic history.

THE GUIZHOU PLATEAU

The Guizhou Plateau is a huge block of limestone extending over an area more than 500 km by 300 km. The province of Guizhou is more than 70% karst, and the limestone plateau extends both northeast and southwest. In the central area around Guiyang it is at an altitude of little more than 1000m, but it rises on both sides to well over 2000m before it runs out of limestone in central Yunnan. Northwards it ends in the fold mountains bordering the high level basin of Sichuan, while to the south it falls away to the Guangxi Plain. Its climate is mostly sub-tropical, though tends to be more temperate at the higher elevations of Yunnan. The limestone bedrock does not benefit agriculture and Guizhou is one of the poorer provinces of China; it is still densely populated, and the industrial city of Guiyang has over a million inhabitants.

The main karst area falls broadly into two landscape types - the central plateau, and the more dissected marginal zones. The complex details of such a massive terrain do make any such divisions difficult to define, especially along the southern borders where the karst is contiguous with that of the Guangxi lowland. Chen et al (1981) make the hydrogeological distinctions between the Yunnan-Guizhou plateau, the Hunan-Guizhou-Guangxi slope-mountains and the Hunan-Guangxi-Guangdong-Jiangxi hill plain (extending the latter terrain into its other provinces). Zhang (1980), with a more detailed division, and Yan (1981) both follow broadly the same pattern. The boundaries on the map (Fig. 3) are only approximate.

The central plateau area is of low local relief, devoid of any deeply incised valleys. Partly because of the sheer extent of the plateau, hydraulic gradients to the margins are low and there is no extensive development of deep karst drainage. Trunk drainage is largely by surface rivers which flow on either bare limestone or a very thin alluvial cover; the sediment is nearly all residual from limestone solution, as there is very little source area for derived material. The surface alternates between broad, almost level, planed-off basins and areas of closely packed karst hills with local relief of less than 100 m. The hills are mostly cones in the thin bedded limestone around Guiyang, but are more spectacular hill peaks in more massive rock in the Anshun area. Boundaries with the basins are commonly straight and on fault lines. Tectonic fault movements of Quaternary age are invoked to account for the relief contrasts; this is certainly plausible in view of the proven events of young tectonism and the apparent lack of lithological control, but the chronological details of faulting and erosion histories appear to remain unresolved. Some of the basins are described as poljes; the Anshun basin is largely drained by ponors and is cut in gently dipping limestones with an eroded level floor and sharp margins to the surround hill peaks - it is indeed a spectacular valley.

With regional water tables near the level of the basin floors, cave development is limited in the central plateau karst. The Xiniu Cave, near Anshun, is a fossil phreatic system, with 400 m of passage ending in three fine chambers containing stalagmites and columns some 20m tall. Qiu (1984) has described a recrystallisation sequence of aragonite to columnar calcite to bladed calcite to granular calcite related to magnesium leaching in this cave. In the final chamber there is a large water table lake, at the same level as the basin floor outside, from which water is pumped through a 15 cm pipeline to irrigate local fields. At Guiyang, the Dixia Gongyuan cave (underground park) is 550 m long, a segment of phreatic conduit now isolated in a low hill; it contains some old, coarse, quartz river gravels and much calcite infill including some shield formations.

The plateau margins

Away from the central area of low relief, the plateau margins are increasingly dissected and the greater relief permits development of more spectacular and more cavernous karst. The boundaries of the marginal zone are difficult to define accurately and Fig. 3 can only be a generalisation; the landscapes are complicated by many local variations which could stand as sub-zones. The essential feature is fluvial dissection - Zhang (1980) referred to this as the canyon zone. Major surface rivers have eroded deep into the plateau; the Hongshui He along the south side is a prime example. Canyons may be incised 500 m or more, between high level blocks of spectacular hill peak karst. Within the karst, the water table is commonly 200 m below the depression floors, and this situation is optimum for major cave development.

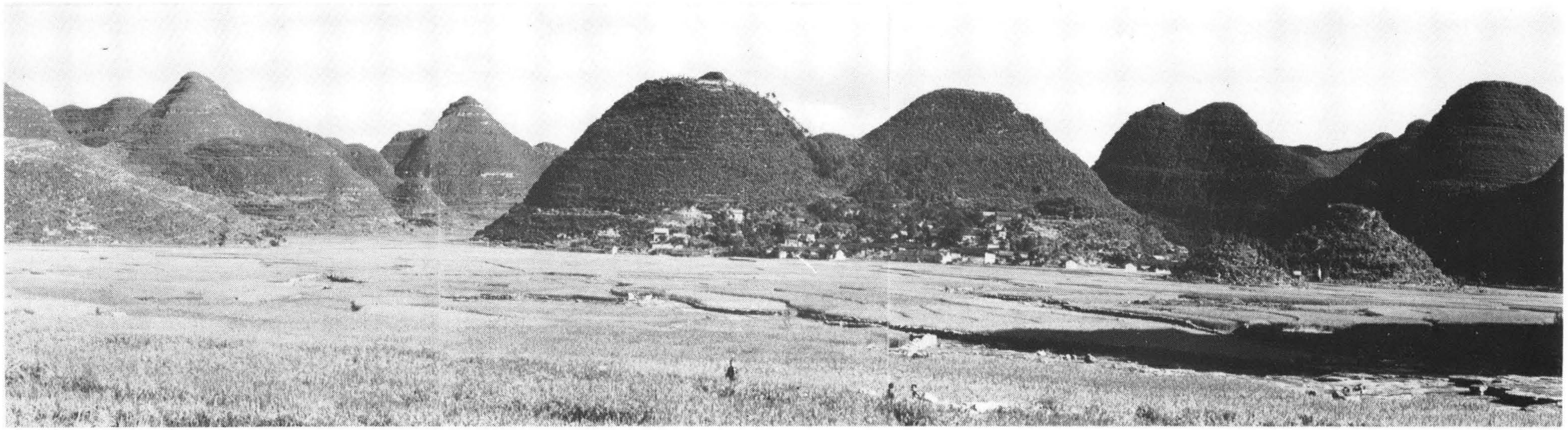
The famous railway line between Guilin and Kunming crosses the marginal zone on each side of Guiyang. Ascending the southeast flank from Luizhou is the line immortalised by the late Joe Jennings (1981) when he described seeing, from the train window, more cave entrances than he had been into in his whole life. There are entrances almost everywhere, including high level tubes 20 m in diameter, multi-level notch caves, some huge arches and steeply descending potholes. The hill peaks of this very spectacular karst are closely packed and vary considerably in profile, some being almost towers; a surprising number of streams occupy narrow valleys between the hills, and there are also many sinks and risings. West of Guiyang, the marginal zone of the karst plateau is equally spectacular. The Shuichen area is perhaps the finest, with endless vistas of hill peaks; there are numerous caves, valley floor sinkholes, open potholes and sinking streams.

Away from the railway, the Zhenning area contains some of the finest karst the writer has seen. It cannot be called tower karst, but the hill peaks are dramatically precipitous, rising 200 to 300 m above deep dolines and narrow valleys. One hill is pierced by a 60 m high arch. Along a road length of just a few kilometres there are four substantial stream sinks, one of which feeds to a resurgence 2 km away after passing beneath a deep doline subject to seasonal flooding as the cave water backs up. The potential of the area for caves, both active and fossil, must be considerable.

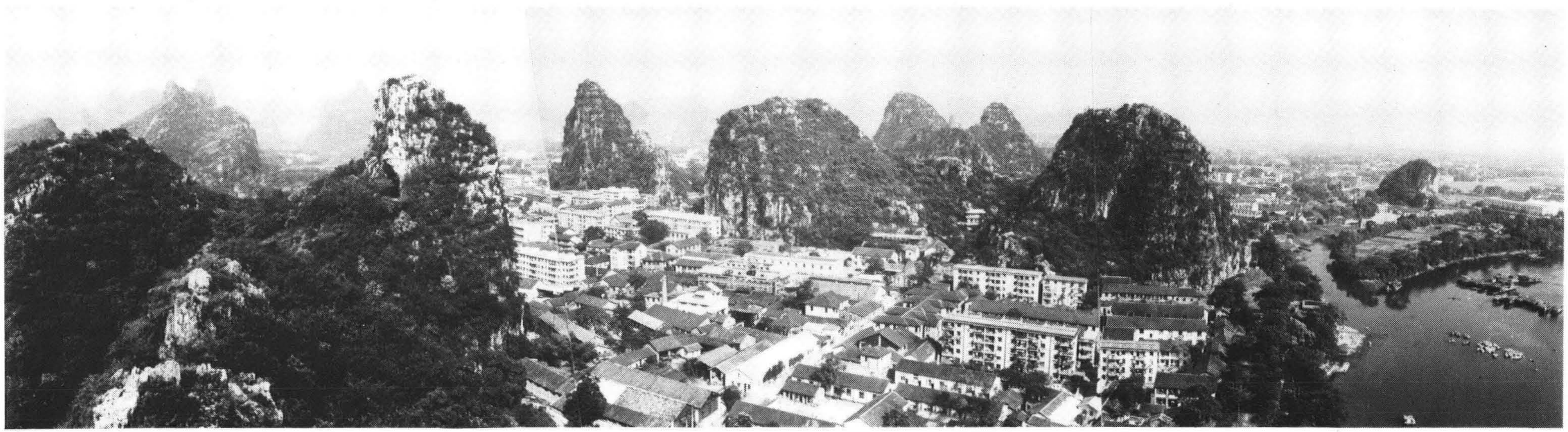
The karst plateau in western Guizhou, with endless limestone peaks.

Tower karst near Yangshuo, in Guangxi.

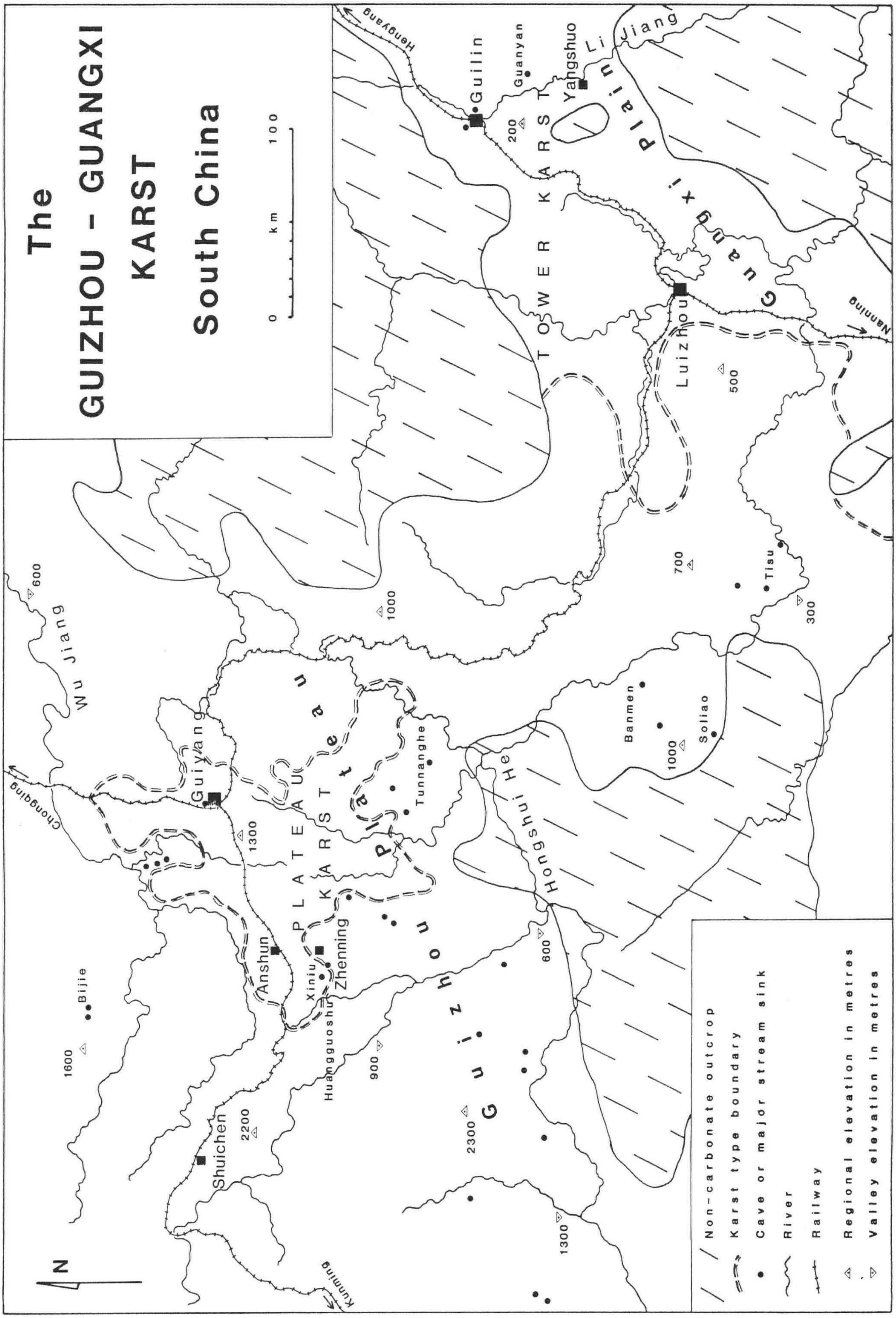
Limestone cliffs of the Wuxia Gorge on the Yangste River.



Hill peak and cone karst near Zhenning on the Guizhou Plateau.



Tower karst in the city of Guilin on the Guangxi Plain.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GUIZHOU - GUANGXI
KARST
South China
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Karst type boundary
Cave or major stream sink
River
Railway
Regional elevation in metres
Valley elevation in metres
Hengyang
Guilin
Guanyan
Yangshuo
Li Jiang
200
TOWER KARST
Guangxi Plain
Luizhou
Nanning
500
700
Tisu
300
1000
Banmen
Soliao
1000
Hongshui He
Guizhou Plateau
PLATEAU KARST
Tunnanghe
Guiyang
Chongqing
Wu Jiang
600
1300
Anshun
Xiniu
Zhenning
Huangguoshu
Bijie
1600
900
600
2200
Shuichen
2300
1300
Kunming

Caves of the plateau margins

Available literature in the English language describes various caves in the Guizhou Plateau margins; some of these are located on Fig. 3, along with a number of river sinks marked on available topographic maps. Yuan (1981) cited a total of over 600 known cave streams in the area, each with a flow in excess of 50 litres per second, including the Lulangdong with a catchment of 1000 km^2 and a discharge ranging 9 to 75 cumecs. Song (1981) described the Liuchonghe river which sinks six times along its course, though other rivers and streams do have longer uninterrrupted underground courses.

Northwest of Guiyang, the Bijie cave extends both ways in massive stream passages from a collapse entrance (Balazs, 1960). Also in the northwestern sector, the San Cha River sinks in a 100 m deep gorge to resurge 3 km away, while a dry high level cave represents an abandonned parallel route. Some of the water sinking in the Zhenning area resurges from the Dragon Palace Cave, which has a major stream passage partly navigable by boat. The Tunnanghe river has at least four underground sections where it flows in massive canyon passages over 50 m tall (Balazs, 1960). Much further west (and off Fig. 3), the Xeishuidong drainage system, in southern Yunnan, has a straight-line sink to rising distance of 21 km, with a descent of 480 m, as proved by salt tracing (Yuan, 1981).

The parts of the plateau margins which extend southeast, across the provincial border into Guangxi, also contain some long underground drainage routes. Sink to rising, straight-line distance for the Banmen stream (with a flow of 3 cumecs) is 10km (Yuan, 1983), and for the Soliao stream is 14 km over a vertical range of 150 m (Yuan 1981, 1981a). The latter has a major cave explored from the sinkhole, with 7600 m of passage, including a 4 km trunk river passage. The Tisu underground system drains 1050 km^2 of karst, with a low overall gradient; 169 caves have been explored within it, and the resurgence flow ranges between 4 and 390 cumecs (HEGTKAR, 1976).

On the eastern side of the plateau, 15 km of cave have been mapped in the Luota area, just over the provincial border into Hunan (Yuan, 1981). In eastern Guizhou, the Nine Dragon Cave has 1400 m of passage on two levels, the upper of which is a series of large fossil chambers; one of these, over 150 m square, contains a display of stalagmites which outshine those of the Aven Armand, with the tallest rising to 39 m. And near Dejiang (north of Fig. 3), a number of caves (Song et al, 1983) include that of Chilingang, over 80 m wide and 20 m high.

There are of course many, many more caves already known in the Guizhou Plateau karst. But it remains to be seen just how many more may be revealed when the prime objective is complete exploration as opposed to merely seeing what is accessible or what contains water resources.

The tufa waterfall of Huangguoshu

A notable feature of the Guizhou Plateau is the frequent occurrence of tufa being deposited in so many of the surface streams and rivers. Among the larger deposits is that of the Huangguoshu waterfall (the Orange Fall), where the Dabong River drops 70 m over a massive tufa screen. With a flow of around 20 cumecs this is a singularly beautiful waterfall, and one of the largest in China. It is formed right on the edge of the Guizhou Plateau where the river crosses the uppermost of three knick points which break its course through the marginal zone of the plateau.

At the present site of the falls, the bedrock limestone dips at 50° upstream, ensuring its stability. The tufa screen behind the cascade is up to 10 m thick, of complex overlapping form, even with a cave extending across it at mid-height, and carbon dates of 40,000 years have been obtained from near the back of it. Below the falls is an 800 m long retreat gorge (Fig. 4), with low tufa cascades in its upper part. It is possible that the downstream half of the gorge is a disintegrated cave (Zhang and Mo, 1982); though the evidence for this is not conclusive, the sequence outlined by Zhang, of underground development, capture by a west bank tributary and subsequent retreat, does also explain the westerly displacement of the river course out of its main valley and through the gorge.

THE STONE FOREST OF LUNAN

The karst plateau of Guizhou continues westwards into Yunnan province, rising steadily to around 2000 m altitude before the limestone outcrops start to break up in the vicinity of Kunming. Within the province there are some spectacular outcrops of mega-kerren, known as stone forests, the most famous of which is 120 km SE of Kunming and just NE of Lunan. Shilin is Chinese for stone forest, and that is the name given to both the karst formation and the adjacent village.

The Stone Forest is a karren on a monumental scale. The limestone has been carved into a series of closely packed vertical-sided pinnacles and towers individually up to 30 m high. It is not tower karst, but is just an extremely dissected lapiez, or karren field. It is formed in one bed of limestone, nearly 40 m thick, dipping a few degrees to the west across the crest of a gentle ridge. The rock is a strong, pale grey, uniform calcilutite, massive except for a couple of discontinuous bedding planes. Major vertical joints occur on a 10-20 m spacing, so that massive karren blocks are created; the most continuous joints are east-west and their downdip orientation may have significantly aided the exceptionally deep dissection.

The main Stone Forest is contained within 100 ha. It is a mass of tall pinnacles and deep fissures; Bogli (1960) would have classified it as spitzkarren. The pinnacles rise to sharp aretes, fretted by rillenkarren, wall scallops and high level kamenitzas; some are bladed where the joint spacing is closer in one direction. Their lower walls have massive vertical flutes, large pockets and typical rundkarren morphology. All surfaces are 90% covered by lichen or moss. Between the pinnacles are deep fissures, and, as Shilin is a major tourist attraction, footpaths give easy access to their depths. Fissure floors are mostly of soil or loose stone - or concrete - with some vegetation, though in parts there

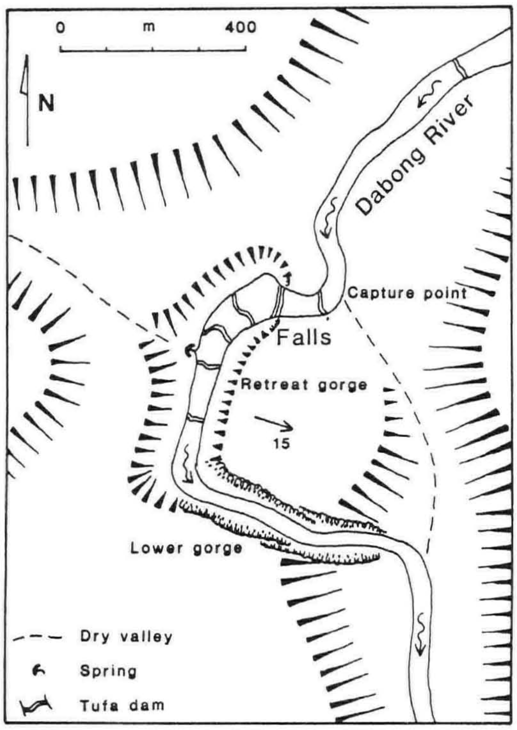


Fig.4.
The Hangguoshu Falls and associated features of the Dabong River Valley (adapted from Zhang, 1982).

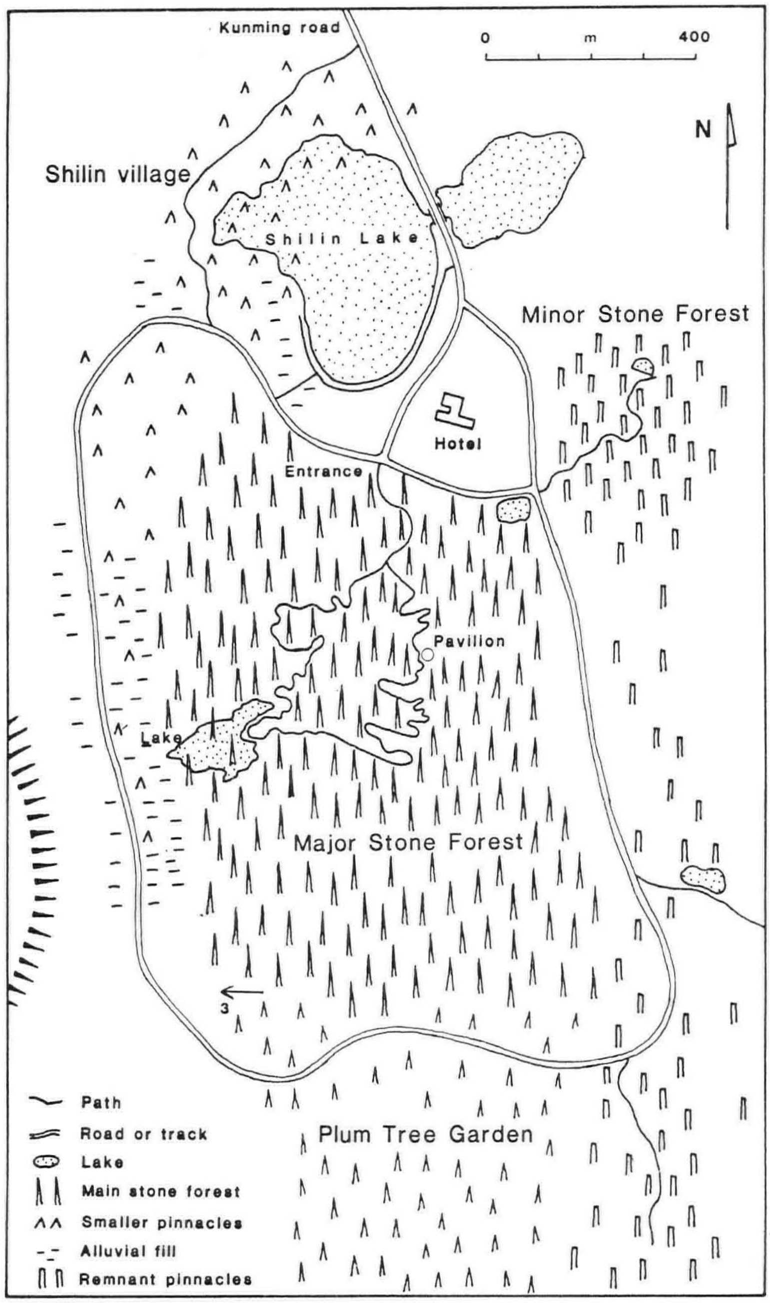


Fig.5.
Sketch map of the Stone Forest area.

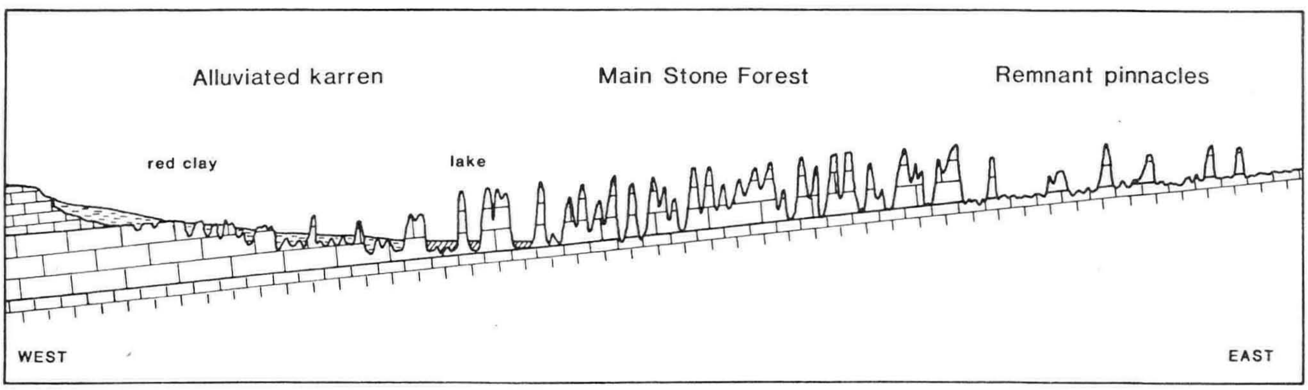
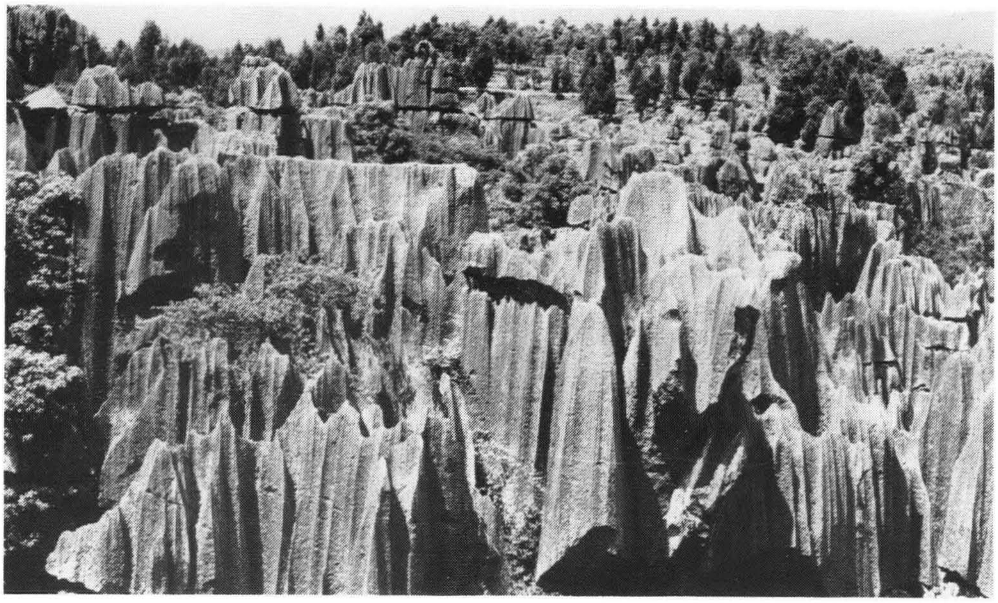


Fig.6. Representative cross section through the Stone Forest.



Fluted pinnacles and aretes in the Major Stone Forest, Shilin, Yunnan.

Remnant Pinnacles on the southeast side of the Stone Forest.

The Hangguoshu Waterfall.

are deep clean meandering trenches. Locally, fissures enlarge to potholes 1-10 m in diameter and the full depth of the karren. There are no undercut notches, except on a small scale in the few bedding planes, and fallen pinnacles are few.

To the south of the Major Stone Forest (Fig. 5), the karren continues over many hundreds of hectares, though on a slightly less spectacular scale, in an area known as the Plum Tree Garden; eventually the main outcrop is lost under cover rocks on a high part of the ridge. The landforms to the north are modified by man around Shilin lake and the tourist hotel, and further outcrops are broken by the morphology of the ridge.

West of the Stone Forest, the massive limestone bed dips gently beneath a low degraded escarpment in a thinly bedded limestone and a cover of red clay. In the depression below the scarp, alluvial red clay supports rice paddies through which protrude a few low pinnacles. A similar morphology with rundkarren pinnacles only a few metres high continues northwards through much of Shilin village, and an intermediate form of slightly, higher sharper pinnacles occupies the western margin of the Shilin lake.

East of the Major Stone Forest, the karren continue, but as a much more dissected type - forming the Minor Stone Forest and an area to the southeast (Fig. 5), and following the outcrop in between. This eastern type of karren has fewer, isolated, remnant pinnacles, commonly around 15 m in height, dotted across a karst surface of degraded rundkarren with partial soil cover and local relief of only a few metres. Even further east, the isolated pinnacles are more widely spaced, lower, and lacking the rillenkarren arete tops.

In profile, the karren appear to represent an evolutionary sequence progressively revealed as surface lowering exposes and modifies the dipping limestone (Fig. 6). The immature type in the west has rundkarren blocks emerging from a soil cover, with dissection increasing as the soil surface is lowered. The main karren fissure development, within the true Stone Forest type, takes place beneath a dense vegetation mat. Analogies with the active pinnacle landform in the rain forest of the Mulu area in Sarawak (Waltham and Brook, 1980) are inescapable; the Pinnacles of Gunong Api, at Mulu, are very similar to the Stone Forest except that they are a little taller, occupy a smaller area, and are more bladed due to the nature of the limestone jointing. The floors of the Stone Forest fissures may have running streams beneath the vegetation mat; the higher parts of the pinnacles, clear of the vegetation, increasingly develop sharper rillenkarren. Continued exposure leads to degradation of the pinnacles, leaving only remnants as in the type to the east.

In many respects therefore, the Stone Forest is just a normal karren, but an extreme form in terms of its scale due to fortuitous geological conditions. Its spectacular development is also a function of its tropical environment, and correlations with the Pinnacles of Mulu may have implications with respect to past climates in Yunnan.

THE GUILIN AREA

The lowlands of Guangxi province constitute the world's finest tower karst. The huge area of alluvial plain dotted with tall limestone towers is known in China as the fenlin karst type - translated as the peak forest plain. Its best known section is formed on a synclinal outcrop of Devonian and Carboniferous limestone which has the city of Guilin at its northern end. Within Guilin itself the towers rise 50 - 100 m, but further down the Li River the towers are taller and even more precipitous. They culminate in the incredibly spectacular landscapes around the little town of Yangshuo - generally reckoned among the Chinese to be the most beautiful scenery in their country. The tower karst of Guilin and Yangshuo has already been described in the English language (Williams, 1978; Zhang, 1980; Jennings, 1981; Waltham, 1983; and others).

Viewed as a whole, the Guangxi karst is a mature landscape with a very long history of surface lowering and matching uplift. The active tectonism is indicated by the erosion levels recognised in profiles of the tower summits and the alluvial plains; five levels are known in a vertical range of 500 m, and these have been ascribed to either intermittent uplift, or step faulting within the karst, or a combination of both, (Williams, 1978). Ages of over 500,000 years are ascribed to the alluviums of the Li River valley. Aggradational terraces correspond with cliff notches and cave levels within the adjacent towers, and provide further evidence of a long erosional history.

Caves in the Guilin area

While some of the karst towers have a clear geological control, the majority appear to be randomly distributed across the alluvial plain (Fig. 7). The isolated form of most towers is a natural restriction on the potential length of open caves, and Guilin must be recognised as an area of mostly short caves. However, some of the towers are clustered into groups and even the size of individual towers permits quite large segments of fossil cave to be preserved (for example Qixing and Lu Ti, described below). In addition, the limestone extends beneath the alluvium between the towers and hence beneath the water table; while flooded caves do exist in this environment, little is yet known of them.

As is to be expected in an alluviated tropical karst, cliff foot notches and caves are abundant, both active and also abandonned at various higher levels. Some of the higher level dry caves have been used by man - for example the Zhengpi cave, south of Guilin, which is a deeply undercut cliff foot cave containing sediments which have yielded human burial sites 9500 years old. The Yueya hill, just east of Guilin, has fine active and fossil notch caves. In Longyin cave carved wall inscriptions are scalloped to a height 2 m above the present water level - indicating changes of drainage, probably artificially induced, within the last 400 years. The back of the notch caves in Yueya hill reveal spectacular anastomoses on gently inclined bedding planes. A larger scale version of these is seen in Nanxi hill, just south of the town, where the White Snake Cave is a spectacular phreatic maze of tubes, mostly around 3 m in diameter, also containing a zone of large scale spongework. The cave was formed by shallow phreatic solution, within a vertical range of about 15 m, adjacent to an alluvial flat providing aggressive water. Later modifications in the White Snake Cave include calcite precipitation, leaving some fine false floors, and vadose canyon incision in some of the inclined tubes.

Two larger caves near Guilin (Fig. 7) are both now commercialised. Lu Ti Tung (Reed Flute Cave), northwest of the town, has a single chamber over 250 m long packed with massive stalagmite on a spectacular scale, with endless variety of flowstone, gours, stalactites and shields. Across the river, east of the town centre, Qixing Tung (Seven Star Cave) provides a through-route of around a kilometre in a fossilised segment of trunk passage. Most of the tunnel is 10-20 m high and wide, with a broad keyhole profile, a fine phreatic roof, four levels of wall notches and deep meander undercuts; it now contains quantities of massive stalagmite most of which is inactive.

Some indication of more extensive cave development in the Guilin region is provided by the Guanyan cave (Fig. 3). This lies where a river sinks off a non-carbonate catchment, with a flow ranging 1-20 cumecs which resurges on the banks of the Li River 7.5 km away. From the sink the cave river has been followed for 3500 m to a sump and there are various shafts giving access to the passage.

CAVE AND KARST RESEARCH IN SOUTH CHINA

Due to its sheer magnitude in China, karst occupies a significant part of environmental research. Recorded observations go back for many centuries, though research has expanded most dramatically in recent years, particularly since the restraints of the Cultural Revolution ended in 1976. The scale of modern work can be judged by the Institute of Karst Geology, created in Guilin, with a staff of 270 in massive new buildings.

In consequence, the Chinese understanding of karst is impressive, especially when compared to most western countries, though there is a concentration of effort on applied subjects and cave research lags significantly behind. The prime concern is over water resources. Accepting that karst hydrology is very different from the conventional hydrology of uniform aquifers, the Chinese exploit cave water with confidence and considerably more success than their western counterparts. Pump schemes, cave dams and underground diversions are all used, though there still remains enormous untapped potential. Hydro-electric power generation from resurging and underground rivers is common in both Guangxi and Guizhou. Another aspect of karst research concerns mineral ores; within the karst of South China, and partly within the caves, there are economic deposits of gypsum, phosphate, nitrate, detrital tin and even malachite copper ore.

Civil engineering activity on karst is also the subject of extensive research. Sophisticated geophysical techniques, including thermal imagery, ground radar and electromagnetic methods, have been applied with at least some success to the detection of underground voids. An enviable state of cooperation between research and industry allowed precise monitoring of an excavation site at Guilin with reference to the potential development of subsidence dolines in an alluvial

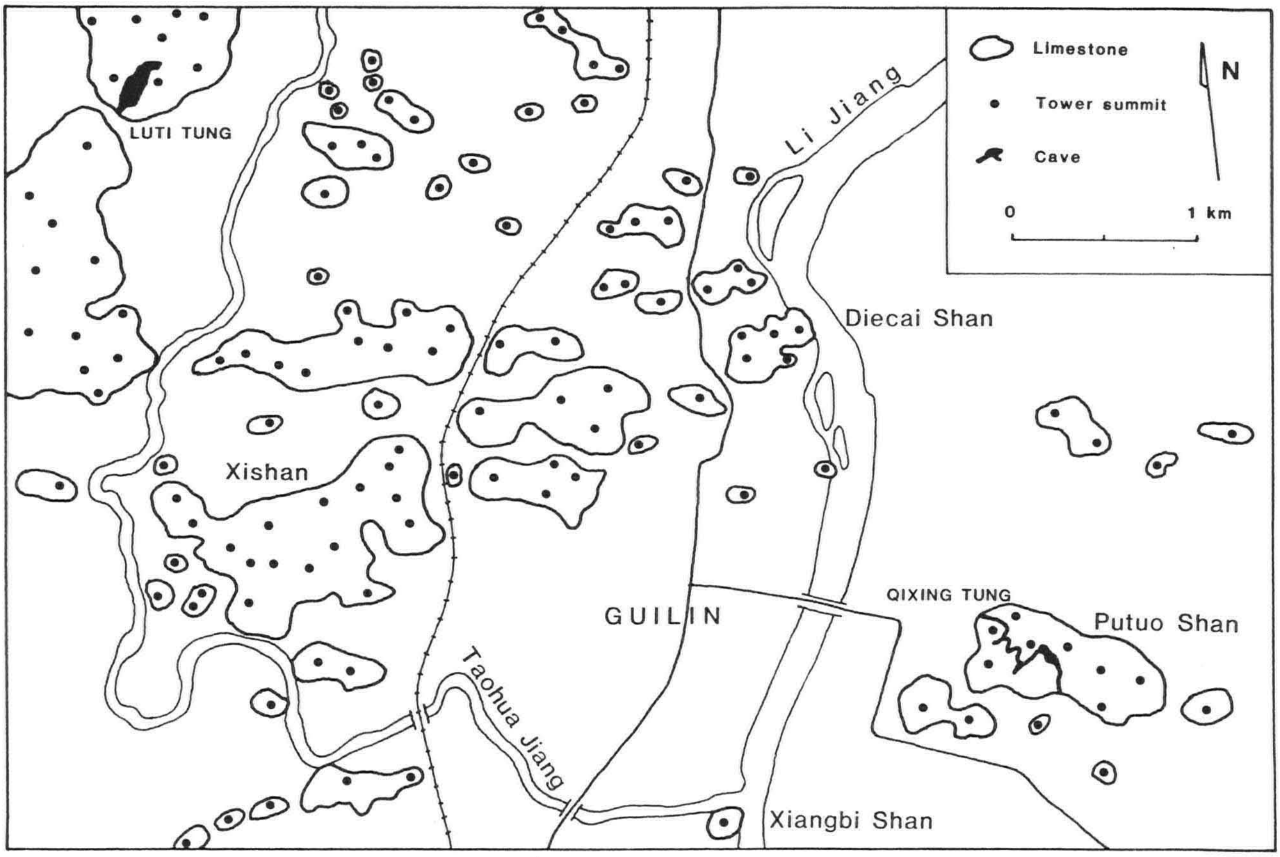


Fig.7. The distribution of limestone towers, both individual and clustered, across the alluvial plain at Guilin.

cover over limestone. The work clearly verified the relationship between soil cavities, pinnacled rockhead and the zone of water table fluctuation (Yuan, 1983).

A westerner may, however, be surprised by the extent to which even applied karst research has an underlying theoretical approach. While the purer veins of research are becoming less popular in the west, they still appear to be a major component within the Chinese way of thinking. This is not to suggest that they do not work, for the Chinese apply theory to practical problems in karst with a confidence stemming from vast experience. A massive dam on the Wu Jiang river (of northern Guizhou) was founded on deeply karsted limestone; the depth of its grout curtain was determined using the theory that higher level solution cavities should be more active, therefore sand-filled and needing grouting, while lower cavities in a zone of slower water movement should be clay-filled and hence not requiring grouting (Li, 1981). The dam and reservoir are still performing to design.

At least in part the theoretical approach to karst may be a function of the lack of knowledge of the caves. The underground half of the karst environment does not appear to receive its due share of attention and this is largely because of the low level of exploration techniques and philosophy. Cave maps of high quality are not the automatic consequence of cave exploration that they have become in the west; few maps appear to be available, and many of those that are lack desirable detail. High-speed explorations, involving S.R.T. and rapid survey methods, are not a part of karst research in China. Caving techniques appear to have progressed only to nylon rope ladders; yet some cave diving has been carried out. Then again, the use of man-carrying hydrogen balloons is a novel variant which the Chinese have applied to cave studies. Dye tracing is carried out, though there is still heavy emphasis on salt as a tracer, and cave dating techniques have progressed to the use of radio-carbon, uranium series, thermoluminescence and paleomagnetism.

Another contrast in Chinese research methods is provided by their use of manpower. Concentrated efforts by small exploration or research teams over short field seasons appear to be only a western principle. In China success is assured by weight of numbers. The study of the Tisu karst area, in Guangxi, involved the mobilisation of two thousand people; it revealed a total of 52 sites where groundwater was accessible in the caves. An unfortunate restraint on cave and karst research in China is the unavailability of maps; detailed topographic maps are still regarded as military secrets and this poses an enormous handicap to any geomorphological research.

A conclusion on karst research in China must be framed in terms of progress. More than anywhere else in the world, the Chinese have learned to live with karst. They already have specific laws which ban the dumping of waste into any sinkhole - though such environmental concern has still not filtered through to the grass roots, for China has serious pollution problems. New industrial development is forbidden in Guilin, so that the city may devote itself increasingly to tourism in the karst landscapes. Overall, the Chinese have unparalleled experience and understanding in karst research. Prospects for the future are exciting and, hopefully, will include more cooperative work and interchanges of ideas with karst scientists from the west. Much has already been done, but the potential is vast.

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CAVE EXPLORATIONS AROUND TRESVISO, PICOS DE EUROPA, NORTHERN SPAIN 1975-1983

Compiled and edited by Mark Sefton

with the assistance of D.Checkley

ABSTRACT

Every summer from 1975 to 1983 the Lancaster University Speleological Society and the Seccion De Espeleologia Ingenieros Industriales from Madrid (1978-1983) have visited the eastern massif of the Picos de Europa in Northern Spain to explore the caves of the region. A number of entrances in the area around the village of Treviso near the centre of the massif were examined and have led to the discovery of several important systems including La Cueva del Agua, an 11km long resurgence cave believed to drain an area of about 25km^2, and La Cueva de la Marniosa (length 2.8 km), a likely feeder to La Cueva del Agua.

From 1977 onwards the expeditions have also undertaken intensive exploration of the caves and mines among the high peaks to the south in a region known as Andara. Over 250 caves and mine entrances were investigated and this has led to the discovery of some of the deepest caves in Spain. These include Mazarrasa (depth,-318m), Torca Boulderosa (-313m), Sara (-648m), Tere (-792m), Flowerpot (-723m) and '56' (-1,169m). Dye-testing has shown that the streamway in Sara and at least one of the streams in '56' drain into La Cueva del Agua.

RESUMEN

Cada verano desde 1975 hasta 1983 ha visitado la Sociedad Espeleológica de la Universidad de Lancaster y el Seccion De Espeleologia Ingenieros Industriales de Madrid (1978-1983), la parte oriental de los Picos de Europa en el norte de España para explorar las cuevas de la región. Han examinado unas entradas en el área alrededor de la aldea de Tresviso cerca del centro del macizo y estas exploraciones han ilevado al descubrimiento de varios sistemas importantes, incluso la Cueva del Agua, una cueva de resurgimiento de 11 km de largo - se cree que esta cueva desagua una extensión de más o menos 25 km^2, y la Cueva de la Marniosa (2,8 kms de largo) que probablemente desemboca en la Cueva del Agua.

Desde 1977 hasta ahora han emprendido las expediciones una exploración intensiva de las cuevas y de las minas que existen en medio de los picos altos hacia el sur, una región que se llama Andara. Han investigado más de 250 cuevas y entradas de mina y esto ha conducido al descubrimiento de algunas de las cuevas más profundas de toda Espana. Estas incluyen Mazarrasa profundidad,-318m), Torca Boulderosa (-313m), Sara (-648m), Tere (-792m), Flowerpot (La Maceta) (-723m) y '56' (-1,169m). Unos análisis con tinte han demonstrado que el arroyo en Sara y por lo menos uno de los arroyos en '56' desaguan en la Cueva del Agua.

INTRODUCTION

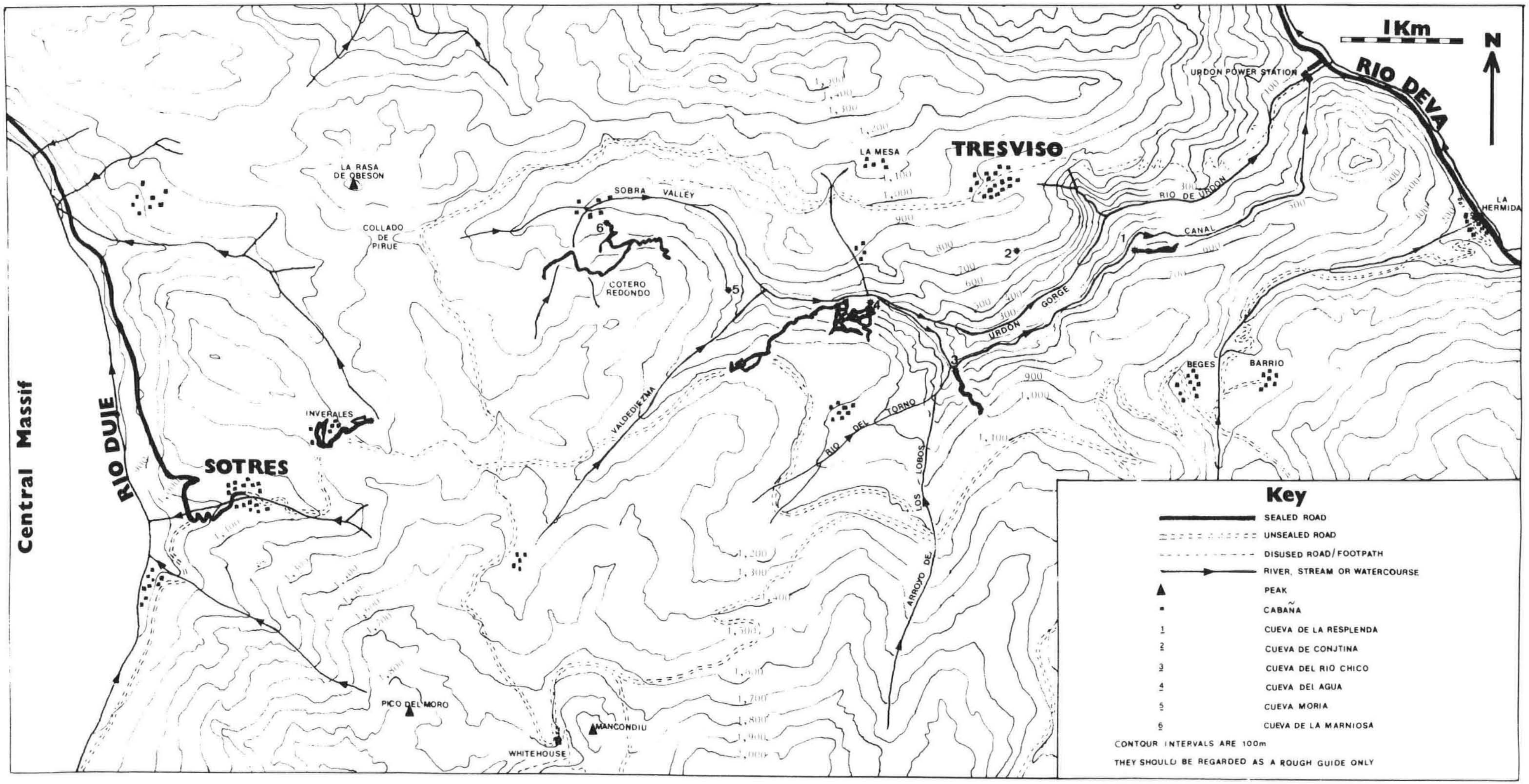
The three massifs of the Picos de Europa are the highest parts of the Cantabrian mountain range, an extension of the Pyrenees along the northern coast of Spain, and span the border between the provinces of Santander and Oviedo. The central massif contains the highest and best known peaks in the area such as the Naranjo de Bulnes and Pena Vieja and is a popular area for tourists as well as walkers and climbers. The eastern massif, bounded to the east by the spectacular gorge of the Rio Deva and to the west by the valley of the Rio Duje is seen by a relatively small number of visitors. It is to this area that the Lancaster University Speleological Society has mounted a caving expedition every summer since 1975. Since 1978 they have been joined by their Spanish friends of the Seccion De Espeleologia Ingenieros Industriales.

At the eastern end of the massif where the Rio Deva is joined by the Rio de Urdon is a small hydroelectric power station fed by a canal which runs along the side of the cliffs of the Urdon gorge. A track follows the bottom of the gorge at first then climbs steeply up the northern face to the little village of Tresviso, perched 700 m above. The Urdon gorge continues westward for 3 km to where its steep sides change to the broad U-shape of the glaciated Sobra valley. At the head of the Sobra is the Collado de Pirue overlooking the Duje valley and the central Picos, (Map 1).

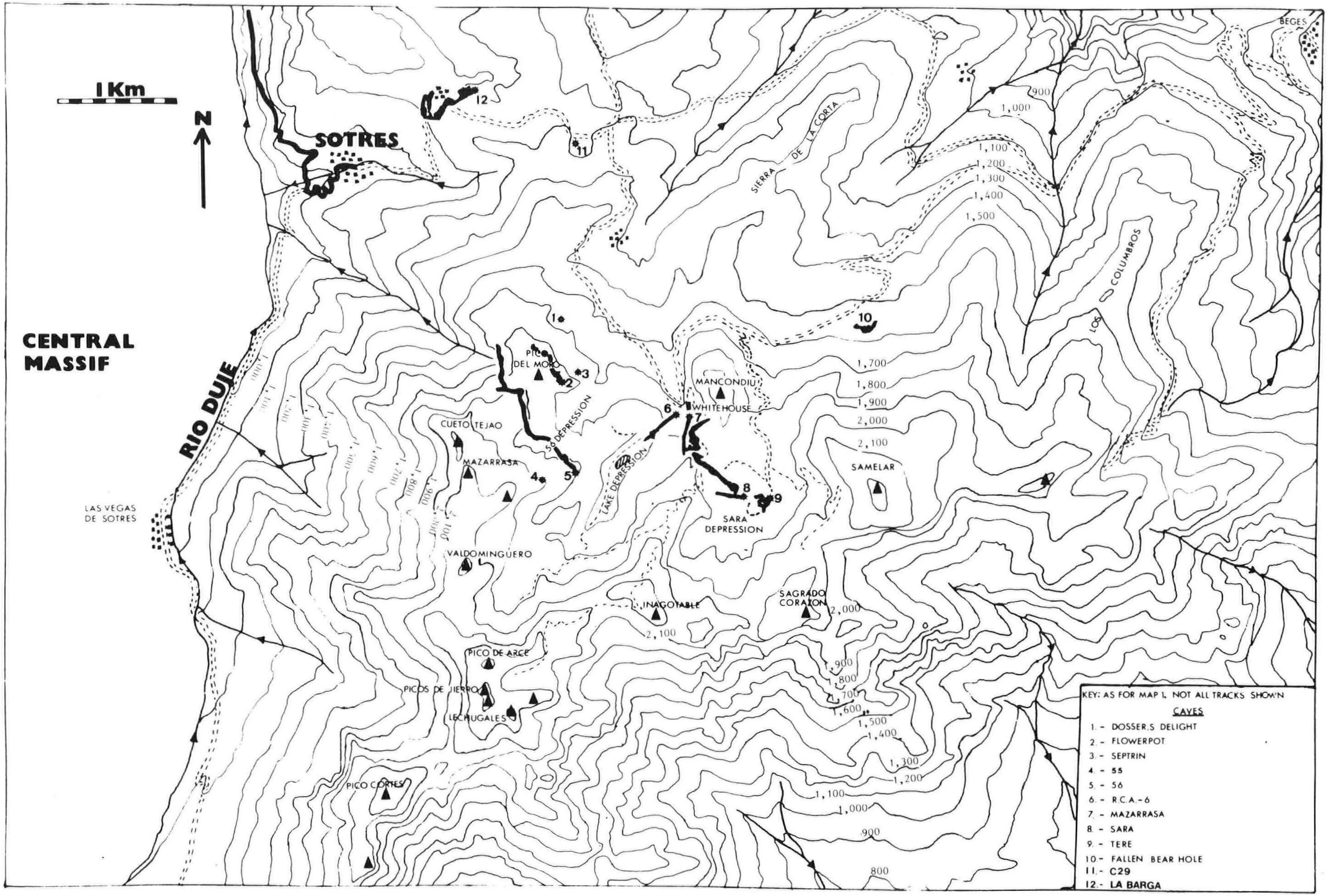
The most spectacular scenery in the massif is to the south, a region known as Andara. Here, numerous rugged peaks surround four major depressions. The largest of these are the Sara Depression (2 x 1.5 km) and Lake Depression (2.5 x 1 km).* The peaks in the southwest corner of Andara are the highest in the eastern massif and surround a small depression containing the Evangelista mines. Finally, the flat-floored 56 depression, lies at the northwest end of Andara. South of the Sara and Evangelista depressions soaring cliffs drop away in spectacular fashion to the upper Deva valley nearly 2000 m below. Two valleys run north from Andara down towards Tresviso - the Valdediezma which joins the Sobra valley at the head of the Urdon gorge and the valley of the Rio del Torno which ends as a hanging valley overlooking the Rio de Urdon (Map 2).

Our interest in the area was kindled in 1974 when local people from a nearby village told us of caves around Tresviso, and also by a report in a Birmingham University Speleological Society journal which mentioned that Tresviso is famous for its cheeses (which are stored in

*The names of these depressions have been coined by expedition members and are not found on Spanish maps.



Map 1 The Tresviso Region.



Map 2 The Andara area.

VIEW WEST FROM MANCONDIU

1, Pico Soriano. 2, Pica de Mazarrasa. 3, Cueto Tejao. 4, Pico del Moro. **5**, '55'. **6**, '56'. 7, '56' Depression. **8, Lake** Depression. **9**, Flowerpot. 10, Septrin. 11, Dosser's Delight. 12, R.C.A.-**6**, Lower Entrance. 13, Whitehouse and Cueva de Mazarrasa.

THE SARA DEPRESSION
1-MANCONDIU, 2-SARA, 3-TERE

draughting caves) and surrounded by sandstone cappings. In the summer of 1975 we visited Tresviso and explored a number of nearby caves and shafts (some used for garbage and sewage disposal by the villagers!) before descending a steep climb of 500 m down the side of the Urdon gorge to where the canal feeding the power station could be seen. To our surprise the canal originated, not from a dam across the gorge, but a deep resurgence pool, the entrance to La Cueva del Agua. This find led to the beginning of the exploration of the system which we now believe is the major resurgence for the caves in Andara.

Several other major caves around Agua were also found that year, perhaps the most important being Marniosa with its entrance in the side of the Sobra valley. In 1976, however, our attention became divided between Agua and the Andara region.

Andara is accessible only on foot, or by a deteriorating set of tracks once used by the Real Compania Asturiana (R.C.A.) mining company. The whole area consists of barren limestone littered with hundreds of abandoned sphalerite mines. We camped initially in the Lake depression but soon settled on a disused miners' hut, the White House, as a base. At first we explored a number of shafts but all of them were choked with snow plugs or by shattered rock. Our initial successes lay with the mines. With such a network of mined passages it was almost inevitable that some of them should intersect natural cave passages. These, when found, were free of ice and ice-shattered rubble and have led to some of the deepest caves in Spain. Since then we have discovered several other caves with natural entrances, mostly around the 56 depression. A connection of any of the caves in Andara to La Cueva del Agua will result in a system of 1,200 m to 1,500 m in depth.

EXPLORATION OF LA CUEVA DEL AGUA
(Figs.1 & 2).

We first entered Agua half way through the 1975 expedition. An icy swim across the dammed sump pool led to dry walking passage which soon dropped 5 m into a steep bedding plane with an ominous rumbling beyond. Excitement rose as we climbed the bedding plane, the noise growing louder and louder, until we popped out into a passage carrying a sizeable streamway. Walking upstream where the water thundered over cascades was impossible so we traversed up one side or another. After 100 m of some pretty exciting caving we reached an upstream sump. While the rest of the party stopped to console themselves with a fag the only non-smoker in the group decided to have a look up a tiny crawl which turned out to be the way on. There followed a maze of crawls and squeezes which finally entered a large phreatic passage with potholes in the floor. Soon we came to the Black Hole, a chamber seemingly larger than it really is because of the black deposit on the walls and floor. At the far end, a climb up orange flowstone led to Clapham Junction, the first major crossroads. The left hand fork which we named Outer Mongolia was dry with a mud and calcite floor and a number of sand-choked inlets. Straight ahead from Clapham Junction was the most obvious way on, a ramp up a steeply inclined phreatic tube but this looked like hard work so first we turned to the right hand branch, entering a chamber with a large brilliant white sandbank. Turning left just before this chamber gave access to a passage with a classical keyhole cross section. We made our way along the floor in some of the finest passage we had found so far, a clean-washed canyon with a small stream and scallops large enough to rest your forearm in. Sporting traverses and climbs in the canyon opened into the phreatic roof tube and a sand-floored chamber off to the right hand side.

We named the route we had just followed The Road to Ruin, the continuation of the steam passage The Road to Certain Death, the sand-floored chamber The Reprieve and the big, abandoned, phreatic passages that we now strolled into, The Roads to Freedom. On that, our first day in Agua, we also carried on up the ramp from Clapham Junction and as far as Boulder Hall where we stopped. In the Grade I survey we drew in the log that evening was inserted "All passages smaller than 3 m across omitted for clarity".

On subsequent trips more passage was found, though not at the same rate. At the point where the maze leading from the main streamway to the Black Hole enters the large phreatic passage a climb up to the left led eventually to a new high level entrance. Unfortunately, this route contained a long duck which sumped after rain and could not be used as a wet-weather alternative to the flood-prone streamway. The Road to Certain Death continued via more traverses to a chamber with an 8 m waterfall inlet. At the top of The Ramp, a steeply ascending tube of 100 m, another tube led off to the left into Stalagmite Chamber, exquisitely decorated with a row of seven glistening white stalagmites and other formations all over the wall. Beyond was a 9 m climb down into The Roads to Freedom. Finally, a bypass to the long hading rift from the right of the top of The Ramp to Boulder Hall was discovered. The Bypass was a series of climbs in and out of chambers connected by short wide sandy crawls and off to the right of one of these crawls a wide, steeply ascending tube, Orangeade Arcade, led over a series of orange mud-covered flowstone to a choke. In the end the expedition for 1975 drew to a close with many leads in all parts of the cave.

In 1976, we were back in Agua again, spurred on by the realisation that with such a large streamway (1.5 m^3s^{-1} in times of virtual dought), Agua must drain a very large catchment area. With the mountains of Andara towering up to 2,000 m above the entrance there was a distinct possibility of us having a really deep system on our hands, if only a top sink could be found. There were so many question marks on the survey from last year that several ways on were almost guaranteed. Our initial finds, however, did not live up to our expectations, as passages were either choked or went round in circles.

*Footnote: The history of the exploration of the caves discussed in this article is also intended to give an accurate description of these caves. All pitches, climbs and other obstacles encountered on the major routes are mentioned in the text and all pitch, climb and passage lengths quoted are taken from the relevant surveys.

Our most promising lead was the waterfall at the end of the Road to Certain Death. Climbing it was more hazardous than expected but in the end the top was reached. It turned out to be the lip of a large deep pool. As there was no way round, it had to be swum. On the far side was an impossibly narrow fissure, a disappointing conclusion to at least one lead.

It was only by luck that a way on was found at all, when a climb up old flowstone led from the roof of one passage to the floor of another. The party exploring the known leads in Boulder Hall had pushed them all to their conclusions and while everyone else sat around having a break, one enthusiastic member thrutched up a calcite wall. A few minutes later he returned with shouts of, "It's massive - large phreatic tubes leading off!". The other members of the party followed up the steeply-ascending calcite flow. Soon they halted at the head of a 22 m pitch. Below this lay Brian Boru's Place, a phreatic tube with pure white calcite flowstone, big stalagmites and helictites. Beyond, the tube ascended past several climbs, including a 10 m calcite slope before apparently halting at a second calcite slope. A faint roaring noise could be heard. Could it be the main streamway? It was not to be. After ascending the second calcite flow and several more climbs a blank wall was reached. In it was a 10 cm x 10 cm hole with a literally roaring draft. Many trips followed trying to find a bypass to "The Howling Hole". Again, the way on was found accidentally, this time on a photographic trip. One of the group wandered over to a hole in the side of a calcite slope. It only looked like a deep scallop or pothole at first but it was gushing cold air. Reluctantly the thinnest man wriggled through feet first. It got bigger, and then came his triumphant shout - the passage had opened out again. A 6 m pitch was followed by a large phreatic tube and from here on it was easy going. In the distance yet another roar could be heard. This time we were confronted with a sumped pool. The difference in air pressure between where we stood and the passage beyond was such that air was continuously driven through the sump with a foreboding booming noise. It was not till the next trip that someone tried the free dive. The sump turned out to be only a metre long so the rest of the party followed close behind. Once again the passage continued on past a series of climbs into a large chamber and a pitch below. With time running out the 13m pitch was descended into a small chamber and a 4 m climb took us to a larger chamber. There was only one apparent way on, following a hading rift to a beautifully decorated chamber, since named "The Oasis". From then on, detackling took priority with over 1½ km of passage explored in the last few days of the 1976 expedition.

The following year, 1977, our efforts were equally divided between Agua and the search for a top sink in the Andara region to the south. Exploration of Agua was thwarted for the first week as a few days rain had made the streamway totally impassable. Once the water had subsided, the cave was quickly tackled up and exploration of the known leads began. Eventually, the breakthrough was made. The hading rift up to The Oasis continued beyond, up a short calcite slope and then over a second larger flow. This led to a large boulder-filled chamber and the rift which followed ended at a 12 m pitch. The next day, another party descended the pitch into a large chamber with a sandy floor. This was called Consort Hall and was to be our future underground campsite. At the opposite end of Consort Hall was a sandy crawl into a large phreatic tube which continued past an intrusive stream (The Ripper) to the bottom of Son of Ramp, an exposed 35 m climb up a steeply ascending tube. Enthusiasm was higher than ever with hundreds of metres of well decorated passage found on every trip. Cavers literally queued to go on pushing trips and one man even went caving with a badly burnt leg that later needed hospital treatment.

A rift continued beyond Son of Ramp over several calcite slopes to a 12m calcite flow, an exposed climb for the first person up and subsequently laddered. At the top, a large phreatic tube continued to an obvious junction. Down eventually became too tight but up continued through very old phreatic passage to another junction. The smaller way on down ended after a 17 m pitch, and a climb up to the left where the old phreatic passage becomes smaller ended at the bottom of a shaft. This needed pegging.

By now, trips to the end and back were taking 15 - 18 hours and the idea of underground camps was becoming increasingly attractive. If much more passage was found at the far end camping would become essential. The next group down Agua tackled the 11m aven which had stopped the previous party. It was managed quite easily, thanks to a perfectly positioned crack up the right hand wall. The way on from the top did not seem all that promising, an old dusty honeycombed passage, but after only 15 m we reached a small chamber, adjacent to one of larger dimensions. A wide and impressive rift headed steeply downwards, obviously "the way on" but the only ladder left was not enough. Meanwhile, one of the group climbed the calcite flows on the right, just before the rift, and then over boulders to a 6 m downward pitch.

The next day, more ladder was taken in and the big rift descended. Disappointingly, it was choked 60 m below. The draught seemed to disappear half way down. The alternative way on was more successful: the 6 m pitch dropped into a large phreatic passage continuing upwards. The formations were beautiful and got better with every step. Fool's Paradise, a series of grottos at the end, was really magnificent. The walls were completely covered with helictites, the biggest of which were nearly a metre in length. We must have spent at least two hours staring at the formations - huge stalagmites and stalactites right down to incredibly delicate crystal growths - an amazing place.

On the way back we checked all the side passages. All of them choked except the last. While we collapsed at the entrance and waited, one of the party went to investigate. A few minutes later our reverie was shattered when he stuck his head out of the hole and shouted that he had found a big room.

Once again the formations were magnificent with more huge helictites. Unfortunately, we had reached saturation point. It was not until subsequent trips that the full beauty of Dan's Room, as we called it, was really appreciated. By the time we reached the surface we had been underground for 19 hours: the decision was unanimous - the next trip we would start underground camping.

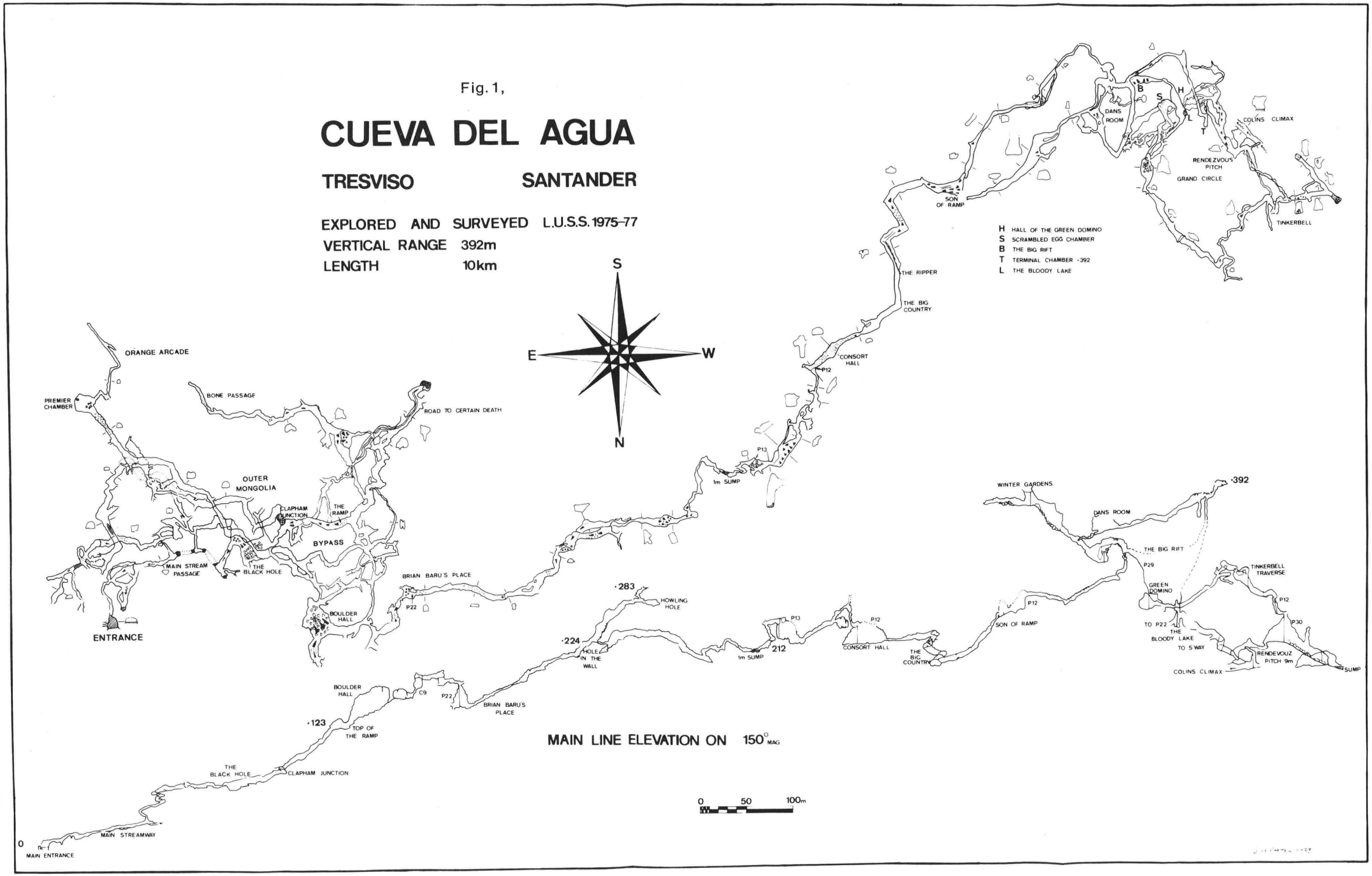
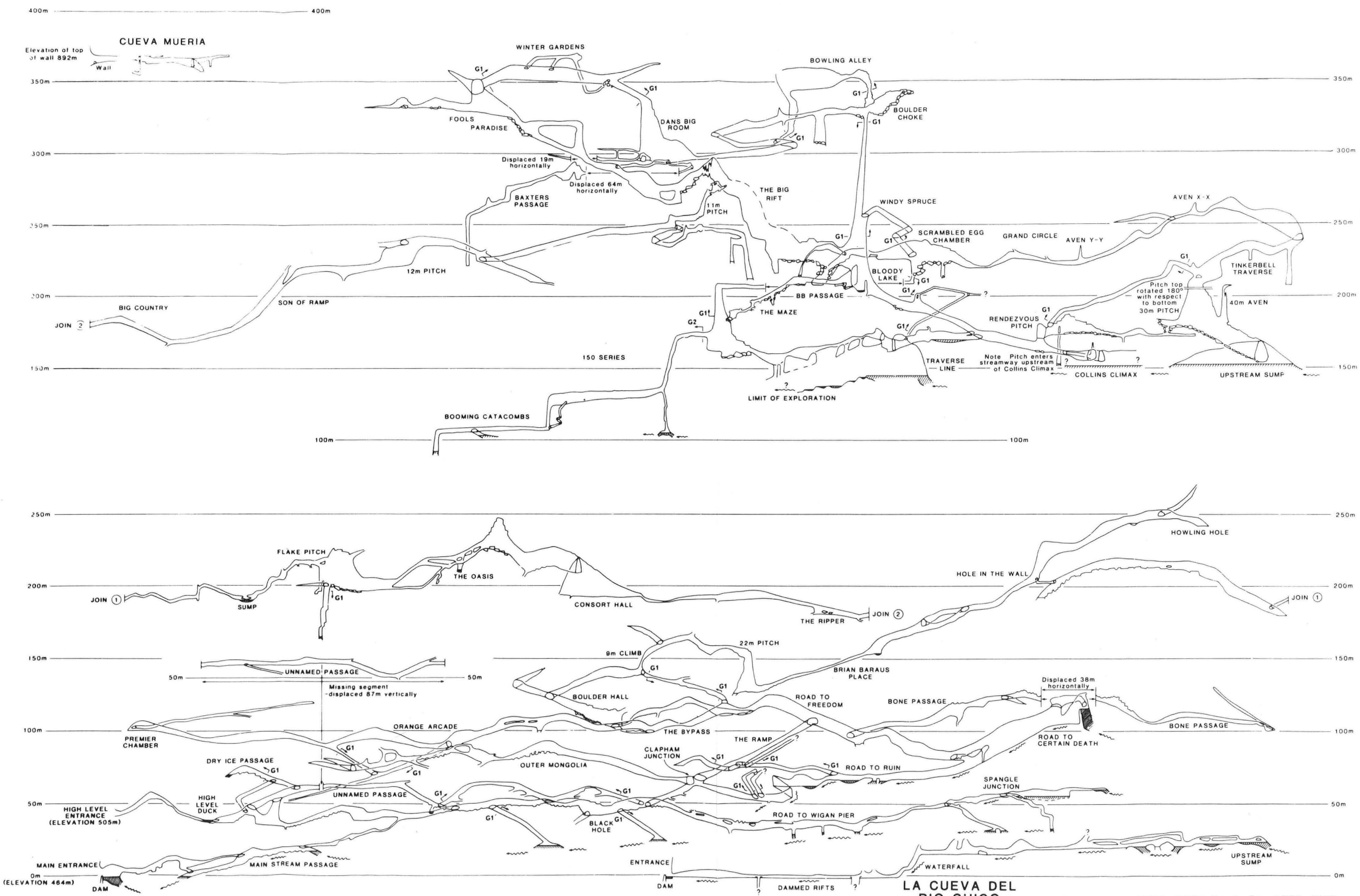


Fig. 1,
CUEVA DEL AGUA
TRESVISO
SANTANDER
EXPLORED AND SURVEYED L.U.S.S. 1975-77
VERTICAL RANGE 392m
LENGTH 10km
S
E
W
N
ORANGE ARCADE
PREMIER CHAMBER
BONE PASSAGE
ROAD TO CERTAIN DEATH
OUTER MONGOLIA
CLAPHAM JUNCTION
THE RAMP
BYPASS
MAIN STREAM PASSAGE
THE BLACK HOLE
BRIAN BARU'S PLACE
P22
BOULDER HALL
ENTRANCE
1m SUMP
P13
P12
CONSORT HALL
THE BIG COUNTRY
THE RIPPER
SON OF RAMP
DANS ROOM
B
S
H
L
T
COLINS CLIMAX
RENDEZVOUS PITCH
GRAND CIRCLE
TINKERBELL
H HALL OF THE GREEN DOMINO
S SCRAMBLED EGG CHAMBER
B THE BIG RIFT
T TERMINAL CHAMBER -392
L THE BLOODY LAKE
WINTER GARDENS
·392
THE BIG RIFT
P29
GREEN DOMINO
TINKERBELL TRAVERSE
P30
TO P22
THE BLOODY LAKE
TO S'WAY
RENDEVOUZ PITCH 9m
COLINS CLIMAX
SUMP
·283
HOWLING HOLE
·224
HOLE IN THE WALL
212
BOULDER HALL
C9
·123
TOP OF THE RAMP
THE BLACK HOLE
CLAPHAM JUNCTION
MAIN STREAMWAY
0
MAIN ENTRANCE
MAIN LINE ELEVATION ON 150° MAG
0
50
100m



Fig,.2. EXTENDED SECTION - CUEVA DEL AGUA, **TRESVISO**, SANTANDER, SPAIN

Surveyed by LUSS BCRA Grade 5c 1976-1979
Drawn by P.L.Smart Cartography by S.Godden
Notes on the section appear in TRESVISO 79
published by Lancaster University Spelaeological Society

Consort Hall was the obvious place for a campsite. The flat dry sandy floor was ideal and water was less than a hundred metres away. The camps were a great success. The first concentrated on surveying and photography, the second pushed a number of leads to their conclusion. The third and final camp for exploration opened up many new leads for next year. Then exploration gave way to the inevitable end of year detackling.

1978 was the first year in which exploration of Agua was based entirely from underground camps, with up to six cavers at a time at the campsite in Consort Hall. Each group of three cavers spent four nights in the cave. It was also the first year in which an effort was made to locate a "middle entrance" to Agua somewhere on the northern end of the Sierra de la Corta. A few entrances were discovered but unfortunately none went very far. That year we also took radiolocation equipment and with it were able to locate Consort Hall and Fool's Paradise from the surface on the Sierra de la Corta. In addition this was the first year that we were joined by a group from the Seccion de Espeleologia Ingenieros Industriales (S.E.I.I.) of Madrid in the exploration of Agua and the caves among the high peaks - the first of many fruitful joint ventures.

The first objective was a passage known to exit above a peg route climbed in 1977. This turned out to be a series of exquisitely decorated passages later called The Winter Gardens. Hopes were raised when a short sandy crawl was followed to a pitch into a large chamber. The next day the group returned with enough ladder to descend what turned out to be a 40 m pitch. Disappointment awaited. The pitch dropped straight back into Dan's Room.

Meanwhile another group had begun a bolt traverse across the top of the big rift. After three days of bolting there was still no end in sight so they decided to look for a route lower down. After a not too difficult traverse 13 m above the floor, the rift was left behind. A scramble over boulders ended with an 8 m pitch into a large chamber.

The next day the group returned carrying more tackle to the end. The 8 m pitch led down to a boulder-covered floor and on the far side an 11 m pitch dropped down to a pool, The Bloody Lake, that had formed in front of a massive and spectacular calcite wall. Most of the group followed the obvious route leading off to the left into an old complicated maze section. In the meantime one member climbed the calcite flow above The Bloody Lake for 8 m to a hole in the wall. Another ladder was dropped 9 m down the other side into a clean roomy passage which was hurriedly followed by all.

It was the Spanish member of the party who stopped to put his hand to his ear. The distant rumble was unmistakeable. Excitement turned almost to frenzy as everyone rushed towards the sound. We had once again hit upon the main streamway. The dry passage terminated at an impressive junction which for very good reasons became known as Colin's Climax. The first group through explored the stream passage as far as was possible. They also discovered another passage leading off. It seemed at first that this was dry but it soon led into another section of streamway.

The next important finds were made by returning to the rather unspectacular maze, where a 22 m pitch into a large chamber was reached. At the bottom large passages extended in two directions. Turning towards the sound of water the route soon developed into awkward walking passage, stumbling over boulders, climbing calcite flows and traversing holes that dropped into a streamway below. The passage ended with an 11 m pitch into a known part of the streamway. Opposite was the dry passage leading to Colin's Climax and another circle had been completed. The maze was abandoned for the time being.

Attention was next focused before the 11 m pitch down to The Bloody Lake, where a climb down between boulders ended in a chamber. A 2 m climb up on the far side had many small tubes heading away from it, most of which interconnected at various stages. At the northern end of this complex a rift opened out into another chamber - Scrambled Egg Chamber. A large phreatic tube at the end of this chamber rapidly turned to a flat-out crawl which thankfully did not last long. It opened out again into a pleasant walking passage, the floor covered with white calcite. Traversing around pools and stooping below formations we came to a 12 m pitch followed by a 30 m pitch. At the bottom a boulder slope ran down to a streamway sumped at both ends. Next we checked out a small rift running away from the streamway at the bottom of the 30 m pitch and eventually arrived at a 9 m pitch (Rendezvous Pitch) which dropped straight into the sandy passage just prior to Colin's Climax. A climb above the 30 m pitch led to a passage which also emerged at the head of Rendezvous Pitch. Thus we had completed the 1978 Grand Circle.

The last major find of 1978 was at the bottom of the 22 m pitch at the end of the maze, this time turning away from the water. A boulder-strewn passage led to the edge of a short drop that apparently choked at the bottom. Above this, however, a large phreatic passage led off into the darkness. Skillfully a small stalagmite was lassooed. Up a ladder, across a couple of pools and we were at the top of what appeared to be a considerable drop. The next day we returned carrying more ladders and bottomed the 30 m pitch. A descending rift led into a large sandy-floored chamber. More large passage led to a short pitch leading down into another rift. Across more pools and the main passage appeared to close down - a frustrating way to end the year's exploration in Agua.

The frustrations of 1978 continued in 1979. First was a daunting bold route up to the perched sump at the end of The Road to Certain Death and then for 20 m above to a ramp. To the dismay of all the ramp just split into numerous tubes too tight for even the smallest caver to crawl into.

At the far end of the cave things went no better. The rift leading away from the stream at the bottom of the 22 m pitch, the so-called 150 ft Series, was reinvestigated but, although a number of ways on were found below the 30 m pitch, they all ended in sumped pools or chokes. A hole in the floor of Scrambled Egg Chamber also ended with a 30 m descent into the start of the 150 ft Series. The streamway at Colin's Climax was swum and traversed to an upstream sump.

Meanwhile the phreatic route out of Dan's Room had been followed to a boulder-choked terminal chamber. A passage off from the left hand wall of this route also ended at the Terminal Chamber. Below the final climb up to the collapse area a vertical slot opened out into a 100 m pitch back down to The Bloody Lake. Many other leads similarly went round in circles or soon choked.

And so, after the last two years of intensive exploration, resulting in an increasingly complex interconnecting series of passages and shafts at the far end - but no major route on - our work in Agua was halted for the last time. In a way it was inevitable as exploration at the so-called top camp in the Andara region was producing discoveries of new deep systems every year and the temptation to switch all our efforts to this area was too strong. But it would be foolish to assume that a way further into the mountainside is not there to be discovered; perhaps one day it will be. In the meantime for all those of us who have explored the caves around Tresviso and in the Andara region, Agua is the one we remember best of all - and surely one of the finest cave systems in Spain.

EXPLORATION OF LA CUEVA DE LA MARNIOSA (Fig.3).

Marniosa was once used as a cheese cave by the people of Tresviso who had explored much of the entrance series. They had been down the first two pitches hand over hand on hemp ropes, quite an achievement as the second one was 12 m and free hanging. We began exploration of Marniosa during our first year at Tresviso, 1975. A strong draught blew through the cave, strong enough to blow out our carbide lamps on occasions. After several chambers, two pitches of 4 m and 12 m and a 4m climb down into a short rift took us to a large chamber- Morning Chamber.

Returning the next day with more tackle we descended a free-hanging 22 m pitch out of Morning Chamber. The pitch landed in another chamber and after scrambling down a boulder slope on the right hand side, entered a large boulder-strewn abandoned stream passage. A chamber off to the left was so well decorated that we had to stop for a break to enjoy the view. Then leaving Smoker's Corner we pushed on along the main rift passage. Sometimes it seemed criminal to continue, the knobbly green calcite-encrusted floor crunching beneath our feet as we left our muddy trail. The main way on appeared to close down but a 3 m taped climb into a roof passage led to a smaller but very well decorated section. Further along we again climbed back down to the main passage decorated with some very large calcite flows. At last, a slippery 15 m rope climb and then another 4m pitch straight into a streamway which ran along a very high but narrow rift passage.

Heading on downstream, we soon came to a 5 m pitch. The next 250 m were easier going until we came to where the water descended through an eyehole, fortunately bypassed by a traverse and easy climb. Then after a 4 m ladder climb the going got more difficult and climbing down waterfalls on loose chert made for some pretty sporting caving. We were nearly stopped on several occasions but always manged to find a bypass to the next pitch. Eventually, with no more tackle we came to a halt at a 10 m pitch and were forced to call it a day after a thoroughly exciting trip.

Marniosa carried on, but not far: a sump pool was soon reached and some climbs up after the 10 m pitch led to a series of old interconnecting passages which unfortunately only regained the stream before the sump.

The way upstream was more difficult as the rift was narrower and many roof falls had to be traversed over. Some 1.5 - 2 km was followed to an immense chamber, The Hall of the Mountain King. It consisted of numerous avens, some with waterfalls, others dry and anything up to 50 m high. Sandstone boulders littered the floor.

Work in Marniosa was never completed due to the tragic death of Tony Harrison who slipped on a handline climb in the cave. Exactly what happened we will never know but it certainly dampened enthusiasm for a very fine cave and it was four years before Marniosa was revisited.

Most of our new finds in 1979 were nearer the entrance. Part way down the slope below the 22m pitch a low concealed crawl to the right led into a rift, the start of the Extra Caverns Series. Over 300 m of cave, including a wetsuit-ripping rift were found and the expedition drew to a close for that year with several leads still remaining.

We have not been back to Marniosa since: the smaller teams visiting the Picos from 1980 onward having concentrated on explorations in the Andara region. Nevertheless, it is one of the most extensive caves we have explored in the Picos and will almost certainly reward a return visit with further discoveries.

OTHER FINDS IN THE TRESVISO AREA

While La Cueva del Agua and La Cueva de la Marniosa were undoubtedly the most important of our finds around Tresviso, the many other caves in the area should not be overlooked. These caves are all described in the 1977 report and include:

a) La Cueva del Rio Chico (Fig.4).

More than two thirds of this resurgence cave has been modified by blasting, and a small canal directs the stream from its original route for the first part of the cave. A further 100 m of walking and climbing upstream lead via a series of deep pools to a large deep sump pool with a strongly draughting but impassably tight hole above. Possible continuations include several steeply ascending ramps above the canal.

b) La Cueva de Resplenda (Fig.6).

"Resplenda" is basically a massive chamber 400 m long and up to 50 m high. The entire cave is splendidly decorated, especially the 170 m long final crescent-shaped section.

c) La Cueva de Conjtina (Fig.7).

A short tight section leads to a 5 m high vadose passage, past two shafts to another pitch and a series of choked rifts.

Fig. 3.

CUEVA DE LA MARNIOSA

Tresviso, Santander.

LUSS, 1975.1979
LENGH 2·8km
DEPTH 230m
GRADE 5

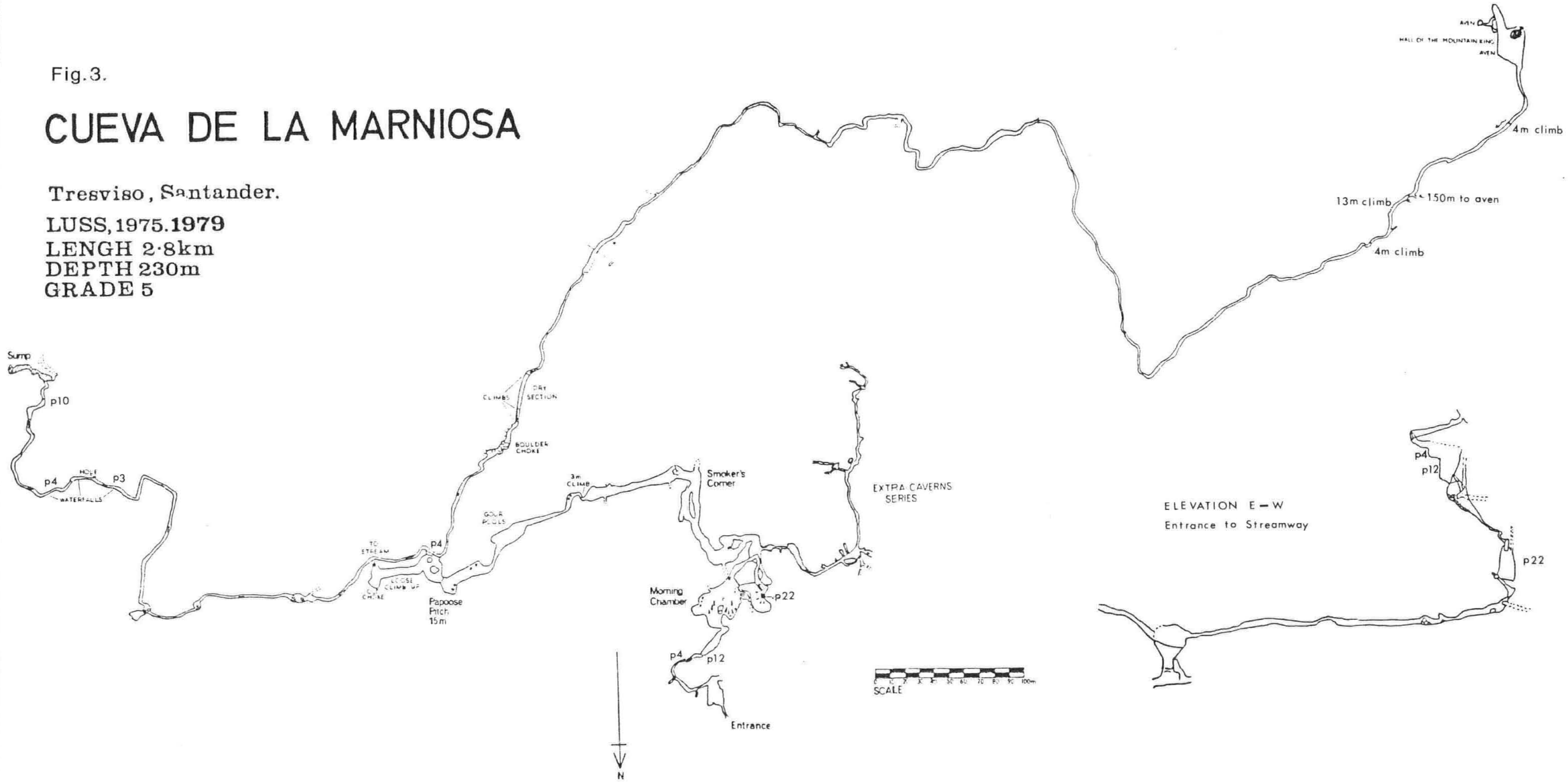


Fig. 4.

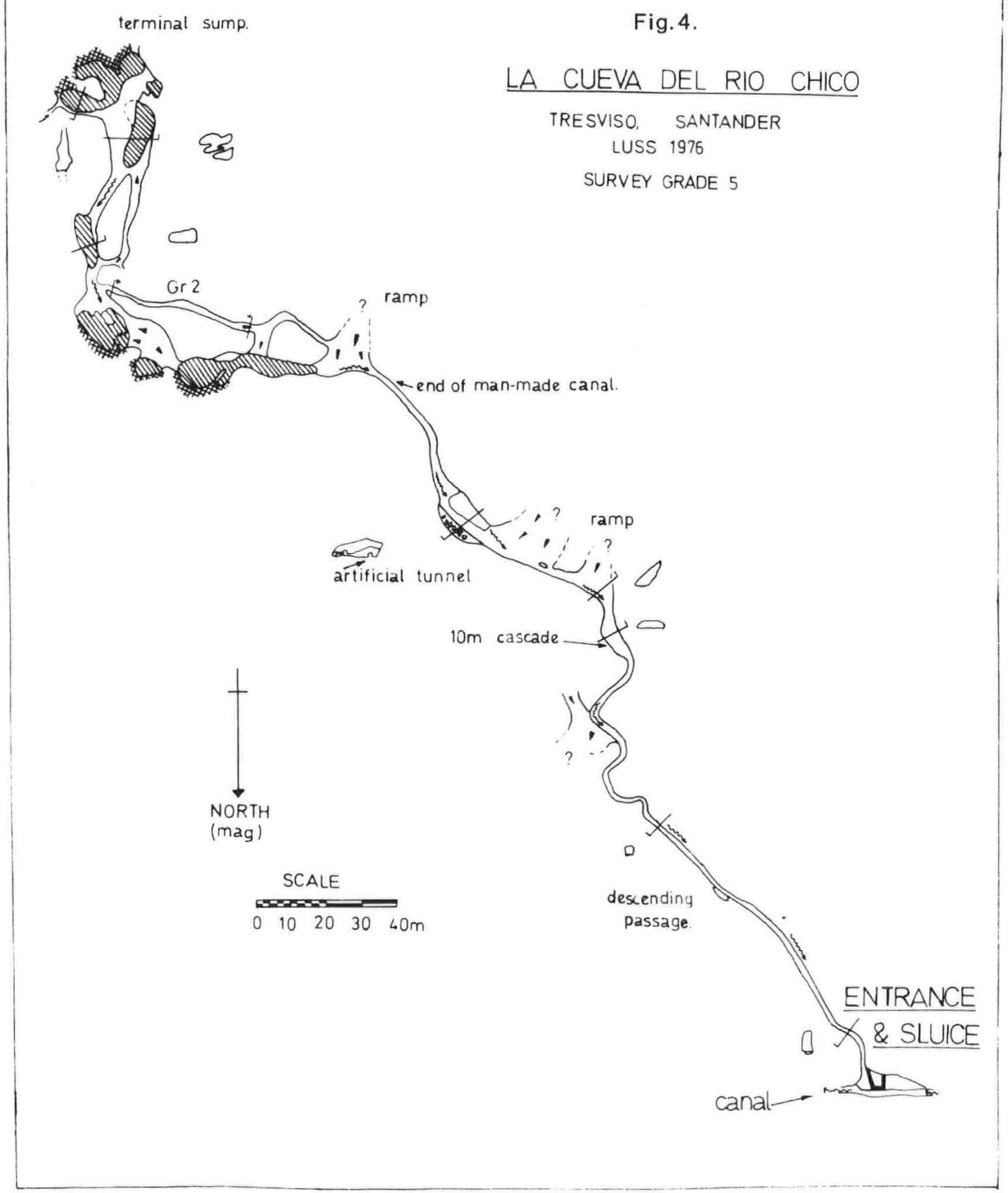
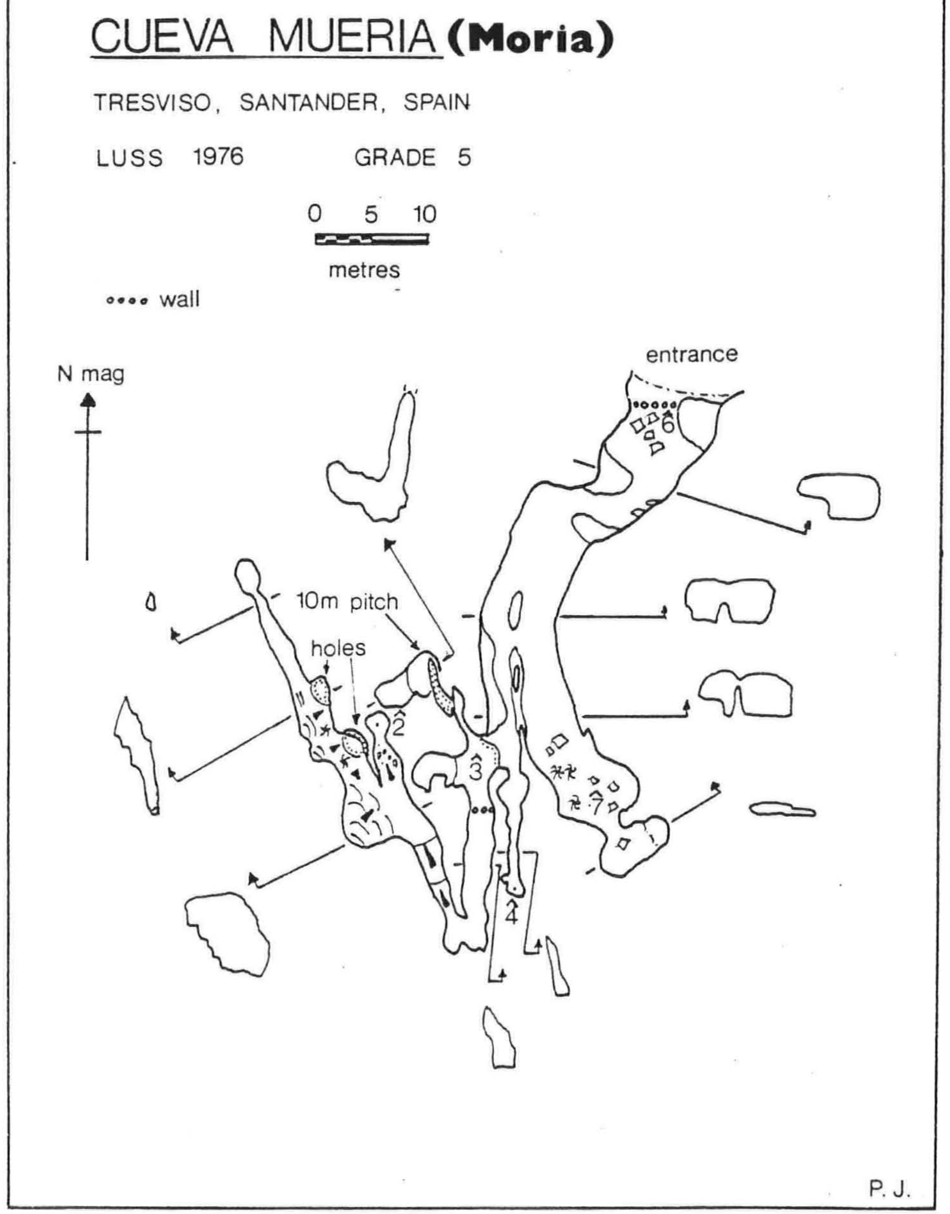

LA CUEVA DEL RIO CHICO
TRESVISO, SANTANDER
LUSS 1976
SURVEY GRADE 5
terminal sump.
Gr 2
ramp
end of man-made canal.
ramp
artificial tunnel
10m cascade
NORTH (mag)
SCALE
0 10 20 30 40m
descending passage.
ENTRANCE & SLUICE
canal

Fig. 5.


CUEVA MUERIA (Moria)
TRESVISO, SANTANDER, SPAIN
LUSS 1976
GRADE 5
0 5 10
metres
wall
N mag
entrance
10m pitch
holes
2
3
4
6
7
P. J.

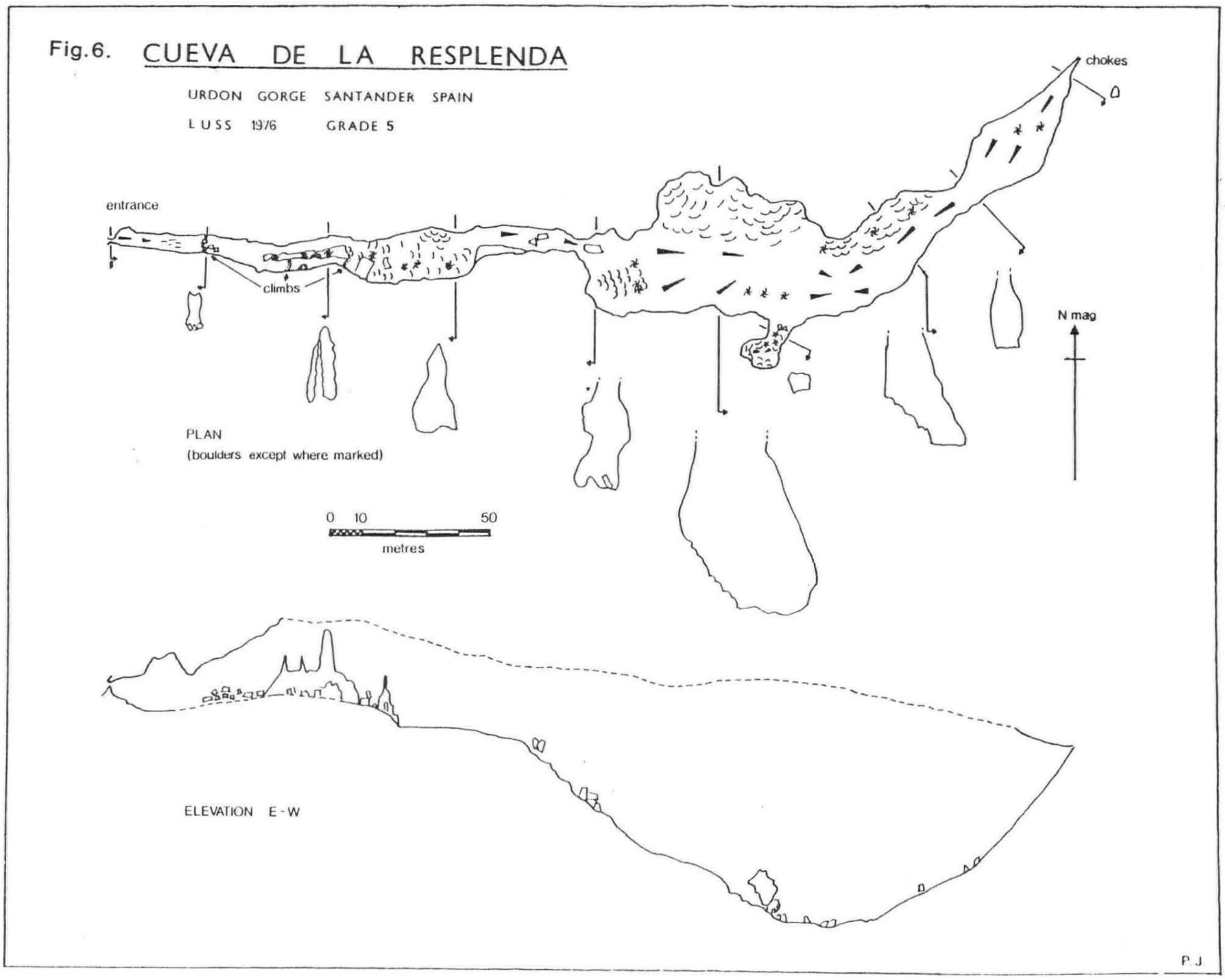


Fig.6. CUEVA DE LA RESPLENDA
URDON GORGE SANTANDER SPAIN
LUSS 1976 GRADE 5
chokes
entrance
climbs
N mag
PLAN
(boulders except where marked)
0 10 50
metres
ELEVATION E-W
P.J

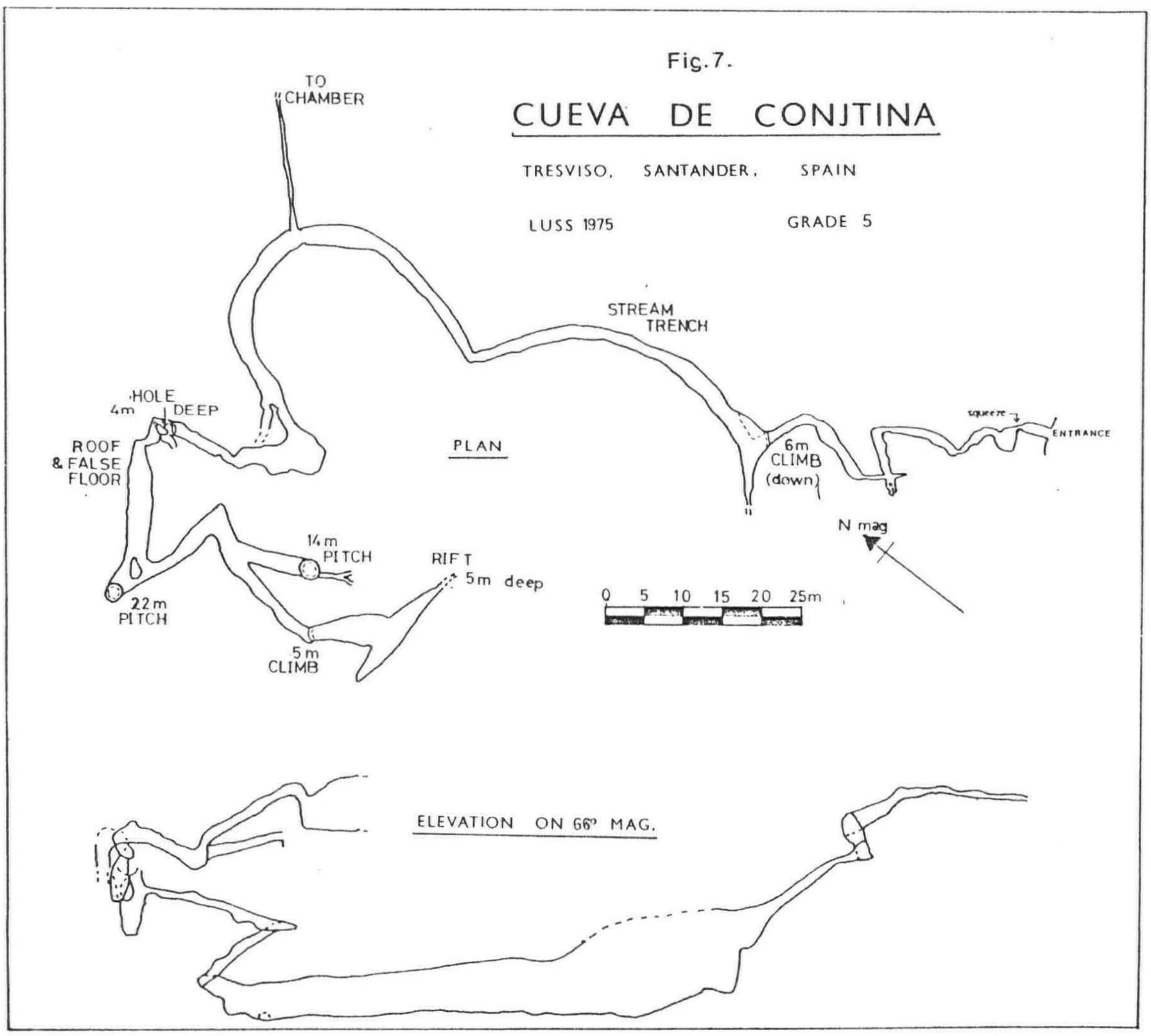


Fig.7.
CUEVA DE CONJTINA
TRESVISO, SANTANDER, SPAIN
LUSS 1975 GRADE 5
TO CHAMBER
STREAM TRENCH
HOLE 4m DEEP
ROOF & FALSE FLOOR
PLAN
squeeze
ENTRANCE
6m CLIMB (down)
N mag
14m PITCH
RIFT 5m deep
22m PITCH
5m CLIMB
0 5 10 15 20 25m
ELEVATION ON 66° MAG.

d) La Cueva Moria (Fig.5).
A large winding phreatic tunnel continues past two blind left hand forks to a climb down into a chamber with three ways on. On the left a walled entrance leads to a high rift with rotten wooden shelves once used for storing cheeses. This doglegs sharply and opens out into a 7 m high chamber with some fine old flowstone and many old massive formations.

e) Çueva C29
C29 lies just off the track from Sotres to Tresviso. It begins with a 2 m climb down into a small chamber and continues with a low muddy crawl leading to a high narrow trench and the first pitch (6 m), followed by two more of 11 m and 4 m. Stooping passage carries on to a junction. The right hand fork is a climb down a hading fault-formed rift and leads to a sizeable shaft split into two pitches of 23 m and 50 m by a ledge. A roomy passage at the bottom continues through various pools to a climb and a final pitch of 13 m. The passage below becomes wet and low and soon sumps.

f) Torca La Barga (explored and surveyed by Sheffield University Speleological Society)
This also lies off the track between Sotres and Tresviso, near Inverales. A short pitch out of the entrance chamber is followed by a 117 m shaft. A traverse then leads to a large abandoned passage followed by seven more pitches to an active streamway. This soon terminates at sumps in both directions at a depth of 361 m. (Fig.8).

EXPLORATION OF THE CAVES OF THE ANDARA REGION

R.C.A.-6, Sara and Mazarrasa (Figs.9,10 & 11).
Our search for possible sinks feeding La Cueva del Agua began in earnest in 1977. A permanent camp was set up, initially in the Lake Depression and then at the White House. On the first day a promising large depression (the Sara depression), which we had noted on our aerial photographs, was visited. To our dismay we saw that spoil from the mines covered the whole of the bottom. A dry stream bed petered out in the rubble and the only shakehole was choked. The miners had painted SARA and TERE by the entrances to the two biggest mines and these were the names we adopted. We also looked at a number of other mines nearer the campsite. One, with R.C.A.-6, painted outside, was a partly-mined natural rift along a fault. After passing a snow pinnacle at the entrance, a 10 m pitch led to the top of another pitch.

The Sara and R.C.A.-6 mines were tackled simultaneously. In Sara the draught was followed to a shored-up 16 m pitch, but after a series of steeply descending tubes and pitches the cave ended at a small silted sump. In R.C.A.-6 we had our first taste of arctic potholing, descending past steep snow ledges and ice walls. An ice pond containing suspended boulders was crossed to the head of a 30 m pitch which started as a mud ramp with numerous boulders delicately set in the surface. Then came a traverse over a 40 m shaft along a wooden pole, one end of which rested on a boulder slope that subsided a few feet during the exploration. We reached a stream, presumably originating from the lake in the Lake Depression and followed it along a mined passage, past a side passage to another pitch. Unfortunately these routes ended respectively at the top and bottom of the Spiral Staircase shaft which had been explored from the mine entrance directly opposite the White House by a reconnaissance party the previous year (Fig.9).

Meanwhile, another group had investigated the mine whose entrance lies literally a few metres from the White House. The mine, which we named Mazarrasa, was found to contain a natural shaft that turned out to be 140 m deep with three ledges. The ledges were loose scree runs and at the bottom we huddled under scant protection from the boulders which hurtled down if anyone was in the least bit clumsy above. At the bottom of this shaft a narrow rift led off but soon became too tight. Fortunately it was possible to pendulum into a passage 15 m above the floor.

Four more pitches of 13, 4, 29 and 24 m led to a large boulder-filled chamber and then through a boulder choke to a stream in a high rift passage. This was followed down five more short pitches but then the rift became too tight and only one man could get through. The passage soon widened again and started dropping down a series of climbs. A small boulder fall proved awkward but led into a phreatic passage. His joy on leaving the rift soon dampened when the passage ended in a sump, 318m below the entrance (Fig.10).

We next returned to the Sara mine to investigate a 7 m pitch in the floor of one of the mined passages, the beginning of Sara 2.* Two more pitches of 7 m and 12 m each with tight takeoffs followed and then came an equally tight rift ending with a 3 m climb down to a small pool. The water from the pool disappeared almost immediately down a slot in the floor. We moved forward and peered down the crack where the floor and walls vanished into an ominous blackness. The pitch turned out to be about 30 m to a ledge. From here, a stone was thrown over the edge. Six seconds of silence was followed by a resounding crash.

No one on the expedition had tackled such a shaft before and the news that Sara was going big was greeted with a certain amount of apprehension. After several near accidents due to a combination of inexperience and the highly fractured shaft walls, the bottom of the shaft was eventually reached by four pitches of 28, 32, 35 and 88 m, the last three divided by narrow loose sloping ledges. At the top end of the boulder slope that covered the floor of the shaft was a small gap that was enlarged by kicking rocks away from the edge. It appears to go down for 30 m through precariously perched boulders, but time had run out for that year.

*In the 1977 report the two separate natural cave systems entered via the Sara mine are called "Sara 1" and "Sara 2", the former being the first cave mentioned in this section. Sara 2, by far the deeper, is simply called "Sara" in subsequent reports. In this report also, "Sara" refers to "Sara 2".

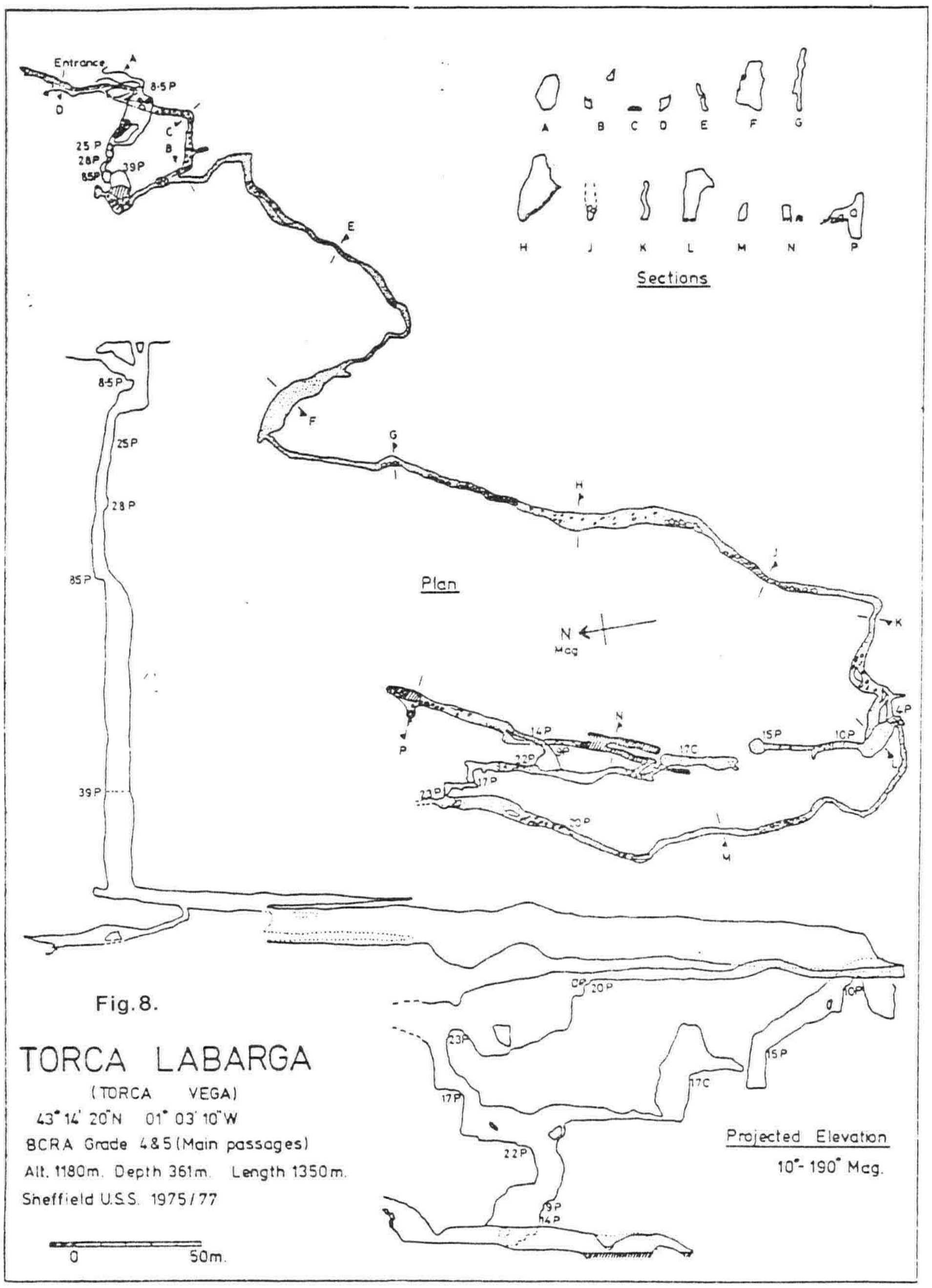


Fig. 8.

TORCA LABARGA

(TORCA VEGA)

43° 14' 20"N 01° 03' 10"W

BCRA Grade 4&5 (Main passages)

Alt. 1180m. Depth 361m. Length 1350m.

Sheffield U.S.S. 1975/77

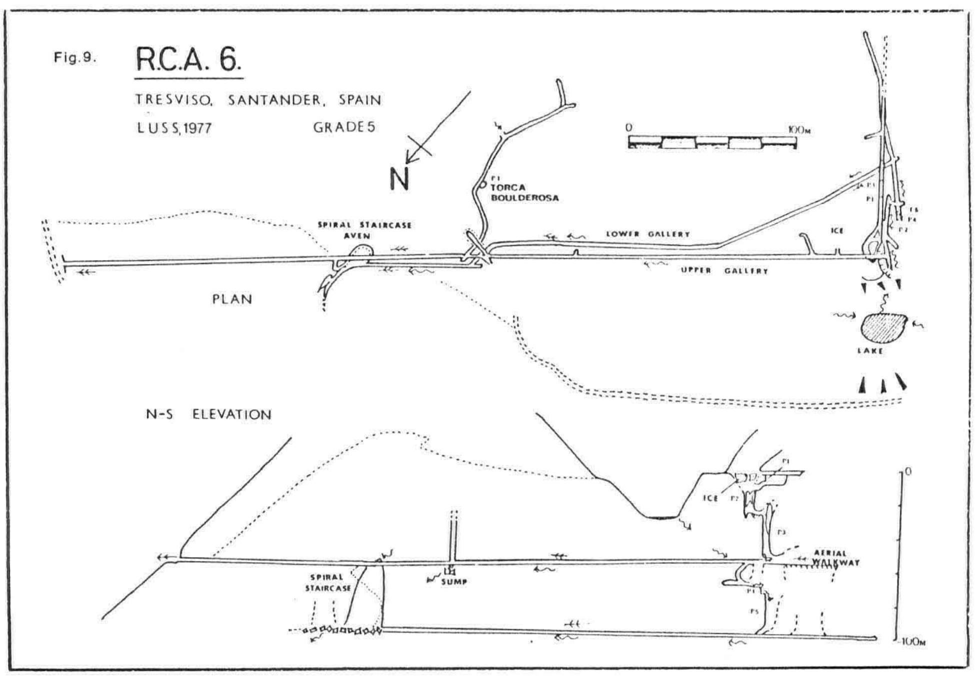


Fig. 9. R.C.A. 6.

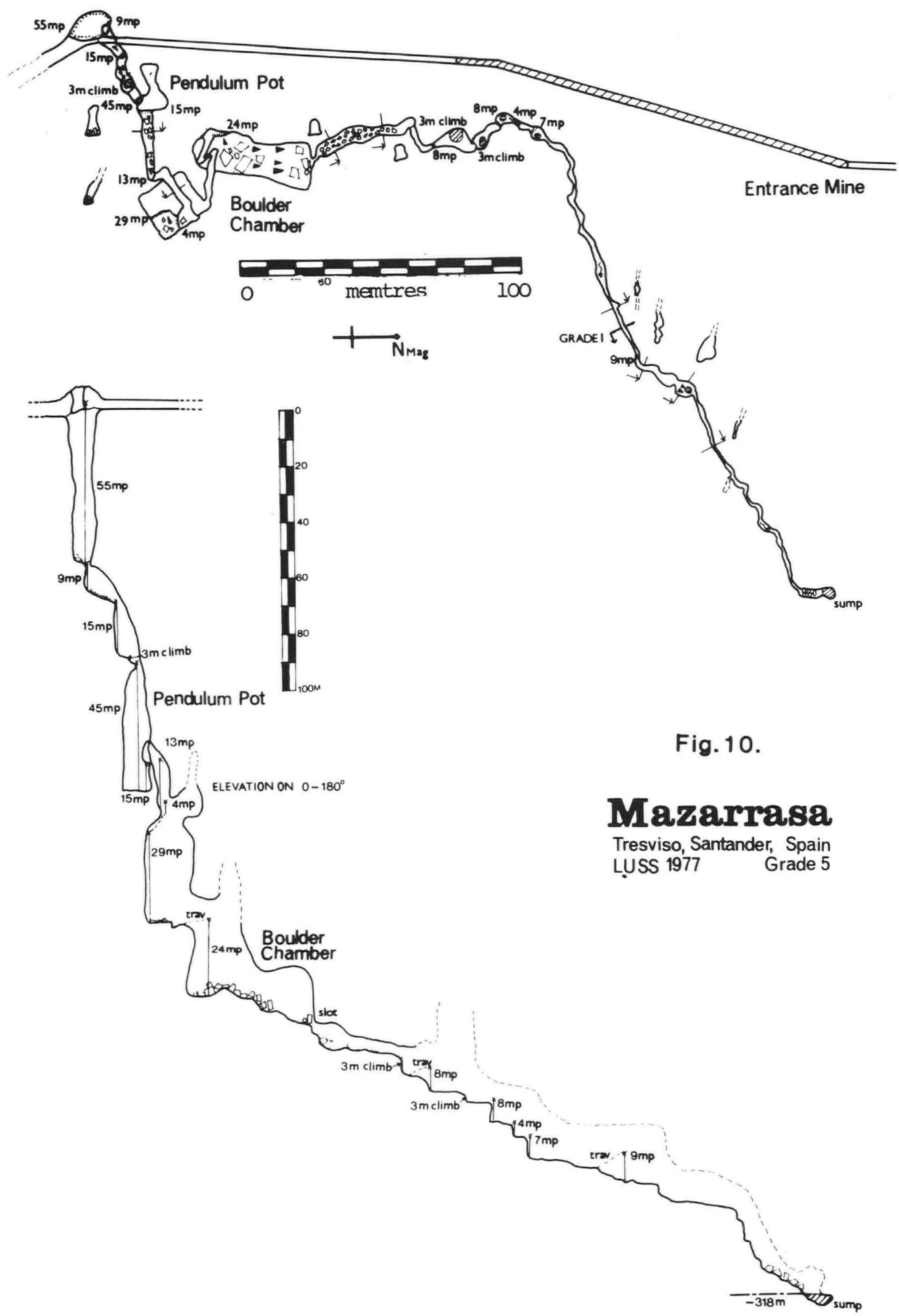


Fig. 10.

Mazarrasa

Tresviso, Santander, Spain

LUSS 1977 Grade 5

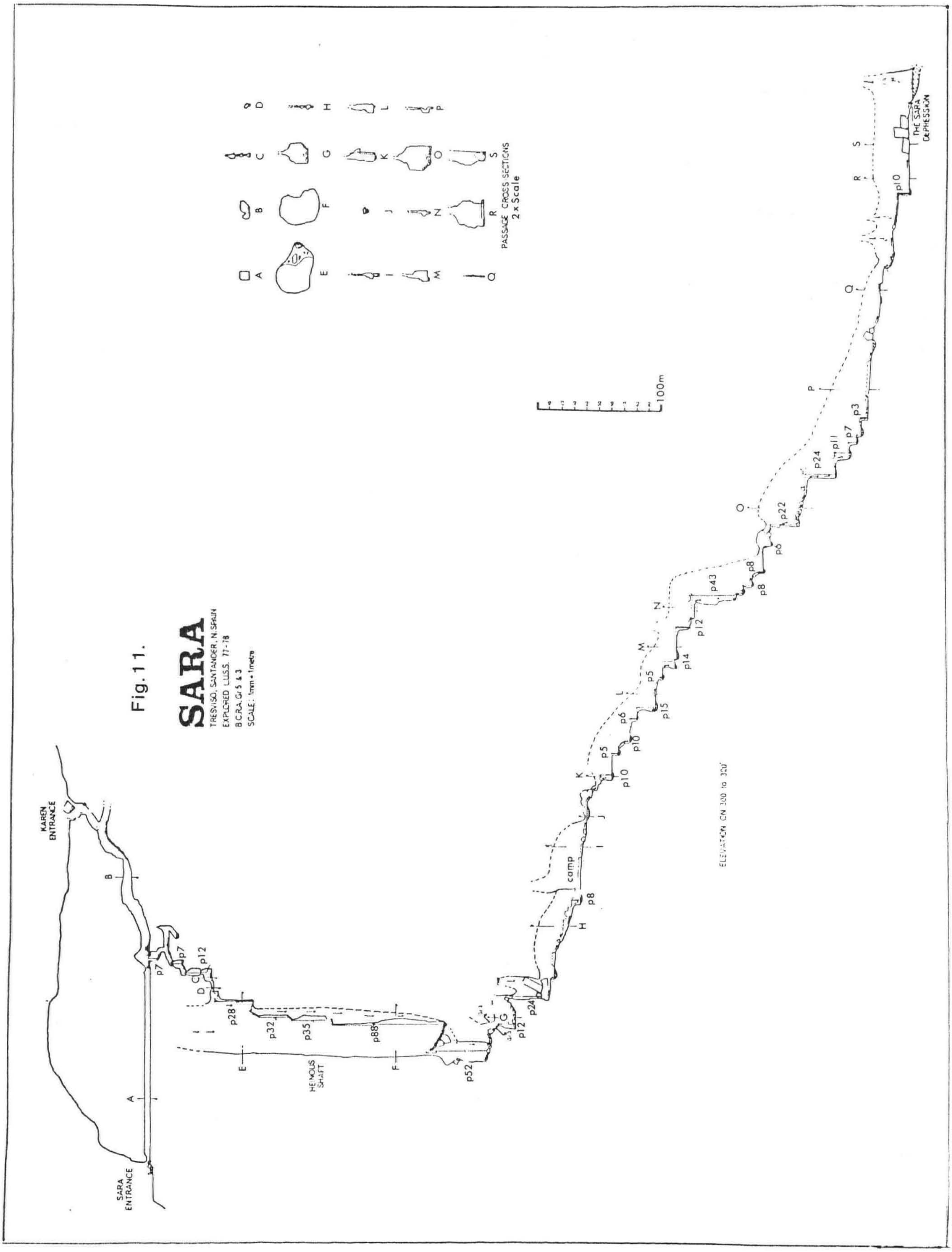


Fig. 11.
SARA
TRESVISO, SANTANDER, N. SPAIN
EXPLORED L.U.S.S. 77-78
B.C.R.A. Gr 5 & 3
SCALE: 1mm = 1metre
KAREN ENTRANCE
SARA ENTRANCE
HEINOUS SHAFT
camp
PASSAGE CROSS SECTIONS
2 x Scale
100m
ELEVATION ON 300 to 320
THE SARA DEPRESSION
p7
p12
p28
p32
p35
p88
p52
p24
p8
p10
p5
p6
p15
p14
p43
p22
p11
p3

The following year (1978) Sara was the main objective of the top camp team. It soon became obvious to all who had been to the region the previous two years that there was far more snow on the surface than normal and this was to prove a major hinderance. Tackling the tight entrance series was no problem but the big shaft was another matter. The copious quantities of snow melt had turned last year's dry hang into a very watery undertaking. It was ironic that the warmer and sunnier it was on the surface the more miserable it became underground. Several groups spent hours perched on tiny ledges amid spray and freezing draughts before the shaft was rigged and the previously undescended pitch reached. The hole down through the boulders opened out after 10 m into a huge rift and the bottom was reached 42 m further down, thankfully well away from the water. There was no way to keep dry on the next pitch, however, and icy water pounded off helmets and shoulders for most of the 12 m descent. The stream sank into boulders but the way on was obvious. Climbing steeply upwards and then over an awkward overhanging boulder we reached another large rift.

The next team descended a 24 m pitch, fortunately freehanging and dry. With no other pitches in sight, gear was dropped and they climbed over muddy boulders to regain the stream. Disappointingly the big walking passage we had hoped for never materialized. Instead, the pair (all groups were two men by this stage) followed a narrow meander, crawling, climbing and traversing until they came to an 8 m pitch. Then it was all the way back again to pick up the tackle. The pitch landed in a small chamber with a rocky ledge a metre out of the water. This was to be the site of underground bivouacs on later trips. 30 m further on, the roof lowered and the only way on appeared to be through a duck. This was 6 m long and opened out onto a series of cascades.

At this stage we received a major boost to morale. Fluorescene placed in the Sara streamway on an earlier trip had been observed in Agua. Charcoal markers were unnecessary, the whole Agua streamway had turned a deep fluorescent green.

Beyond the duck the passage changed from narrow muddy traverses to wide water-washed climbs, cascades and pitches in good solid rock. The next three groups followed a series of short cascades and climbs to a muddy ledge which was traversed to a 10 m pitch. Seven more of 5, 10, 6, 15, 5, 14 and 12 m followed. By this time much of the snow and ice on the surface had disappeared which was just as well, as several more inlets had helped boost the stream to quite respectable proportions.

Exploration had now reached the head of a pitch of unknown depth which was rigged dry by traversing out along a 30 cm wide ledge. The next pair descended the pitch which turned out to be 43 m. It was dry for most of the way but the last few metres were right in the spray. An 8 m pitch in the streamway was followed by another 8 m ladder climb which managed to miss the water, a welcome relief after the good drenching received on the previous two. Around the corner was a chance to get away from the wind and spray. The water had left a dry oxbow and the next pitch of 6 m was into a small chamber. At the far end was yet another pitch back into the streamway. Enough was enough and the pair exited after a 20 hour trip. The following group were also down for 20 hours. They descended the next pitch of 22 m and then another of 24 m. The latter was hung dry for the first 15 m but the rest of the descent lay in the full force of the water. Yet another pitch followed immediately with the water funnelling down a narrow chute.

Sara was now about 550 m deep and everyone agreed that from now on the cave was best tackled from underground bivouacs. After the campsite had been established there was time for only one more pushing trip before the detackling camps began. The 26th pitch was descended for 11 m into a deep pool. Two more of 7 m and 3 m followed. Gear was left at the bottom while the pair went on to look for the next pitch. Instead, they entered a superb section of big meandering streamway. After 100 m, the streamway narrowed and began to descend more rapidly. Several sharp awkward squeezes ended in a highly shattered boulder chamber. A climb up and over a large perched block led to more constricted passage and squeezes. This was followed by a 10 m climb down a cascade then more stream passage which continued to decrease in size. Around every corner they expected the passage to close down even more and become impassable.

Then the character of the passage changed yet again. Breaking out of the tight meandering rift the pair entered a large spacious passage. 30 m on, two large inlets joined the streamway. Walking on another 20 m they reached a 10 m pitch. Looking out over the drop, the streamway could be seen wandering between mudflats in what was definitely the biggest chamber in Sara.

Then came what was perhaps the most important decision of the expedition - whether or not to go all the way back for the tackle and rig the next pitch. In the end they decided to go back for just enough gear for this, and perhaps one more pitch. An hour later they were down in the chamber. A large rift, 10 m wide and higher than could be seen led off at right angles to the direction of the previous passage. Further on, the rift was full of mud - and then came what they had half expected to see since entering the rift, a huge sump pool with mud high up on the walls and an inlet entering on the far side. And so ended Sara, 635 m deep.

The following year a second entrance (Sara 3) to Sara was found within the Sara mine complex. It entered the top of the big shaft which turned out to be 280 m deep and added 13 m to the total depth of the natural cave. Another higher entrance (Karen) is also known but this leads to Sara via mined passage and is therefore not necessarily an integral part of the Sara cave.

Sara is by any standards a superb sporting cave. The massively developed vertical section down to the bottom of P24 might once have taken large quantities of glacial meltwater and judging by the number of inlets and the volume of water that flows even when there is little snow on the surface, the active streamway may well be the principal modern drain for the Sara Depression. Certainly the stream is much larger than those encountered elsewhere in the other Andara caves and the streamway quite unlike the tight and tortuous meanders so typical of Tere, Flowerpot and 56. Although Sara has only been surveyed to B.C.R.A. grade 3 standard the streamway appears to be heading northwest, towards The White House. No serious attempts were made to look for high level fossil passages in Sara and these may yet await discovery. Subsequently it was found that some bearings were missed and no reasonable survey could be drawn up so only a profile is presented here (Fig.11).

Torca Boulderosa (Fig.12).

Torca Boulderosa begins as a small outwardly draughting hole in the wall of a branch passage in the R.C.A.-6 mine. It was first descended during the 1977 expedition by several members from the Whernside Manor group. A 30 m pitch landed in a narrow rift that was partly filled with mining rubble. Because of the unstable nature of the rift it was explored only a little further.

The following year the cave was tackled by the Spanish group from the S.E.I.I. and they soon had the 125 m deep rift rigged with a series of ten pitches. Unfortunately, Boulderosa continued to live up to its name with loose rock an ever present hazard. On one occasion three cavers on a photographic trip hung helplessly on their respective ropes half way down the rift while a rockfall beginning high above them hurtled past just a few metres away.

The constrictions of this rift ended briefly with the final 30 m pitch and we were at last on the floor in a wide roomy passage with an inlet stream strickling down the wall at one end. Sadly the way on rapidly narrowed to a tight meander which had to be traversed several metres above floor level. After 30 m of thrutching the passage opened out at the top of a roomy shaft, the water having disappeared down another pitch halfway along the traverse.

The shaft was descended in two pitches of 10 m and 33 m, separated by a wide ledge. Once again, the way on was a narrow meander, 120 m long and most of which had to be traversed above the floor. The monotony was at last relieved with a 14 m pitch into a chamber. The only exits appeared to be through a duck or a tight rift over the top and there exploration halted for the time being.

The following year (1979) Boulderosa was the first Top Camp objective. The water levels were very much lower than in 1978 and the so called duck which we named Donald was nothing more than a crawl in a few centimetres of water. At the far end was an 11 m pitch which dropped onto a wide ledge looking out into a large shaft.

At last we had reached big development. The shaft was descended via a damp 49 m pitch that landed on the floor of a chamber 20 m across, with two wide rifts entering from the right and the water exiting via another wide rift straight ahead. On the floor lay a massive orange calcite block several metres across. We followed the stream for 50 m, down climbs and around pools to another pitch, which turned out to be the top of a 43 m drop into a huge breakdown chamber over 50 m across and covered with a massive boulder slope. An alternative route into this chamber was found by climbing up in the rift just before the final pitch and descending a 50 m drop down a parallel shaft connected at the bottom by several squeezes to the terminal chamber.

No way on was found through the boulder choke which was sufficiently complex to have required several trips to check out all the possibilities. With so many other systems going in the area our attention was diverted elsewhere, leaving Boulderosa explored to a depth of 313 m.

Boulderosa was the first priority of the 1979 expedition, mainly because of its proximity to the so-called main fault which controls the upper part of the Valdediezma. The narrow passages from the entrance to Donald Duck are basically a single inlet series which takes very little water. The cave below Donald Duck is more substantially developed and it is unfortunate that it ends so quickly at the terminal breakdown chamber which must lie very close to the intersection of the main fault and a second major fault which runs on a bearing of 300^{o}. There is still a possibility that a route may be found through the collapse and again, no serious attempts have been made to look for high level fossil passages. A tight rift above Donald Duck and an alternative route from the bottom of the entrance pitch have not been fully explored.

Tere (Figs.13 & 14).

Although we had looked at the Tere mine in 1977 and 1978 and found the beginning of a natural cave, it was not until 1979 that exploration commenced in earnest. The mine was not particularly complex and after descending a rotting wooden ladder to a pool in the lower level we reached a hole in the wall and a tiny natural rift passage with a stream and a strong outward draught. The rift contained three awkward constrictions and then opened straight out into a shaft. The ensuing 17 m pitch in the water was not exactly a pleasant way to begin a caving trip, nor was the tortuous rift that continued at the bottom. We followed it above stream level to where the rift opened out at an 8 m ladder climb down to the top of a 9 m pitch which landed in a small chamber at the side of a fine circular 32m deep shaft. Below was another narrow rift, entered via a 3 m climb up. After a few metres came a split 11 m pitch and another 4 m climb up. The rift continued as a narrow traverse to a 4 m pitch back down to floor level.

Next was a 30^{o} greasy shale ramp dropping straight to the head of a 16 m pitch into a large breakdown chamber that we called Pebble Hall. The stream trickled down a set of miserable wet climbs over slippery black rock before disappearing through a pile of rubble against a wall but just before this point was an old abandoned calcite passage, followed for 25 m to a short pitch.

Another group descended this 4 m pitch and a second of 16 m to a chamber in black limestone with white mineral veins. Two more pitches of 4 m and 7 m followed. The latter was constricted at the top and was surrounded with helictites so for obvious reasons it soon became known as Vandal Pitch. This landed in a small chamber, one wall of which was covered with small but beautifully formed helictites in pure white calcite. The rift continuation was similarly covered with white flowstone and helictites but most of these alas did not survive for long. The passage was followed to a grotto, down a 9m pitch and along more well decorated passage to another 7 m pitch. Below this, the cave suddenly opened out into impressive dimensions, a wide rift with no roof in sight.

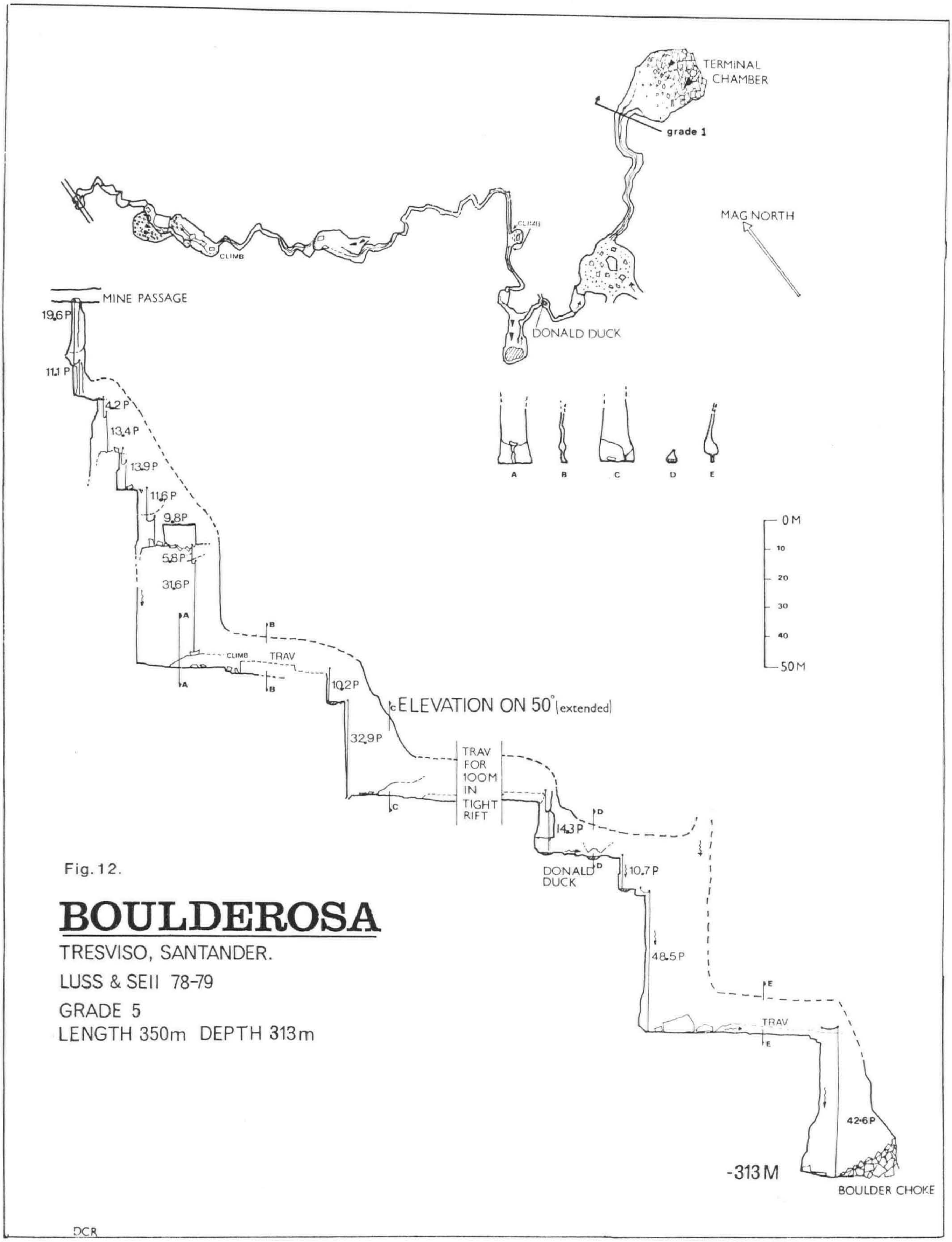


Fig. 12.

BOULDEROSA

TRESVISO, SANTANDER.

LUSS & SEII 78-79

GRADE 5

LENGTH 350m DEPTH 313m

Ignoring several repulsive looking muddy crawls in the floor, the pair traversed around to the head of a 37 m pitch. Another quickly followed but by this time they had run out of tackle.

The next two down explored four more pitches of 26, 19, 5 and 10 m in this massive rift. The last of these (subsequently named "Free Fall" after an episode in which a caver's cowstail snapped while he was passing a bolt) landed in a large block-floored chamber with a short climb down at the far end to a false floor. Here at last the roof reappeared, descending at 45° to within 30 cm of the floor. A squeeze through this slot led to a split 8 m pitch into a pool and was followed by another 10 m pitch. The way on was a roomy walking-sized passage which appeared to close down completely. Closer inspection, however, revealed a tight 20 cm squeeze through a very narrow rift. Only one person could get through to the head of a short drop with an exceedingly cramped takeoff.

Two more cavers went down the next day and spent several futile hours hammering away at the squeeze but still could not get to the pitch beyond. It was the next team who succeeded. They descended a 10 m drop into a small chamber with a false floor and followed a short passage to a deep chasm. An 87 m pitch with three rebelays in a rounded shaft landed on a wide ledge. The continuation was a 59 m deep slot, 15 m across and 2 m wide. The bottom was choked with boulders - there was no way on. Tere had seemingly ended 487 m below the surface.

There was only the fate of the water in Pebble Hall still to be checked. On the very first day's caving in the area in 1980, Tere was quickly tackled down to this point. A few minutes were all that was needed to pull enough rocks away from the wall to reveal a flat-out crawl taking the tiny streamway. It popped up almost immediately into a metre-high passage which gradually got bigger until a pitch in a perfectly rounded shaft was reached. The next day John's Pitch was descended, a fine free hanging 32 m drop with an appetizing view for most of the descent of a high rift leading off on the left. It landed on a pebble-covered floor with a semicircular balcony. The course of the water to a small sump was tight and tortuous but above in the rift was easy going. After about 10 m of traversing we descended three awkward climbs into Toad Hall, a chamber more easily reached by continuing the traverse over the top of these climbs and then descending a 10 m pitch. The familiar sequence of pitch-rift-pitch-rift, so typical of many of the caves of the Andara region, continued with a squeeze down in a narrow meander to consecutive pitches of 8 m and 4 m. Now came a parting of the ways. On the right was a substantial shaft, at least 30 m deep and 10 m across but instead we took the "Easy Option", a steeply descending 6 m diameter tube, quite out of character with the rest of the cave. It ended with a 4 m pitch and then a 10 m deep shaft (Pigs in Space). This choked at the bottom but fortunately halfway down it was possible to pendulum onto a ledge and into a small rift. A few metres beyond lay a considerable drop.

The follow up group rigged what turned out to be a splendid 116 m deep shaft named The Fabulous Furry Freak Brothers. The shaft was broken by ledges into four pitches of 25, 40, 26 and 25 m. Then came a keyhole-sectioned passage. Another pair continued down two more pitches of 16 and 9 m and two climbs of 3 m (later rigged as pitches) into a chamber with a very small exit. At first sight the exit appeared to be blind but 2 m in was an awkward right-angled bend and then a 7 m pitch into another small chamber. Norbert the Nark, as the next 8 m pitch was called, was a real problem. The rift was so narrow at the top that it was impossible to swing the bolting hammer more than a few centimetres. At least the bottom was roomier, as was the steep gully that followed. It ended at yet another pitch.

By now we were over 400 m down and certainly not on just another route to the 1979 terminus. Any doubts on this score were quickly laid to rest as more pitches followed. First, 12 m into an elongated chamber. Though there were three ways on they all united at the same shaft. The easiest route was down a gully on the right. Then came three more pitches of 37, 12 and 24 m. Partway down the 37 m pitch, a small stream trickled down the wall, the first water seen since the bottom of John's Pitch.

We got no further in 1980, mainly as a result of too few people trying to explore too many caves. In 1981 we decided to put all of our efforts in one cave at a time. Tere was the first. The final descent the previous year had landed on a boulder-covered floor with another drop at the far end. Two more pitches of 4 m and 16 m took us to a water splattered shelf. Half the water cascaded down a shaft in front of us, the rest disappeared down a tiny passage in a chamber just around the corner.

The shaft, a damp 59 m pitch, was tackled first. Unfortunately the only way on, The Pain, was an awkward winding passage with many projections on the wall. Pitches of 14 m and 7 m provided a brief interlude and then came more rift passage, too tight for further progress. Undeterred, the next team took down a lump hammer, intent on forcing a way through. After some persistant hammering they got through a tight squeeze and were able to continue climbing down the rift for another 25 m. In the end though, the stream flowed away down a diminutive passage that no amount of hammering would widen.

Meanwhile, other groups were busy investigating the shaft at the top of the Easy Option. This shaft could also be reached by a connecting rift at the bottom of the Easy Option, shortening the descent to a 24 m pitch. The way on was obvious, a set of climbs better treated as a broken 18 m pitch down a narrow water-washed gully into a chamber. The water sank down a narrow canyon running across the floor. A 17 m pitch, a few metres beyond, took us into another chamber where yet again another miserable little rift beckoned. Fortunately this only lasted for 15 m before giving way to more impressive development in the form of four splendid pitches of 20, 37, 40 and 58 m in what was basically a single shaft. Below the 58 m pitch a picturesque rift meandered away. Soon however, it became necessary to get down on hands and knees to pass through a pool of water with several centimetres of glutinous mud on the bottom. Aptly named Son of Sewer, this section continued for 40 m mostly on hands and knees in mud and water. Then an aven entered from above and the going got easier. A constricted climb down took us to a 2 m wide passage: Uphill, a 6 m climb up and short crawls ended at the chamber at the bottom of the 12 m pitch just below Norbert the Nark while "downhill" the water cascaded down the 37 m pitch

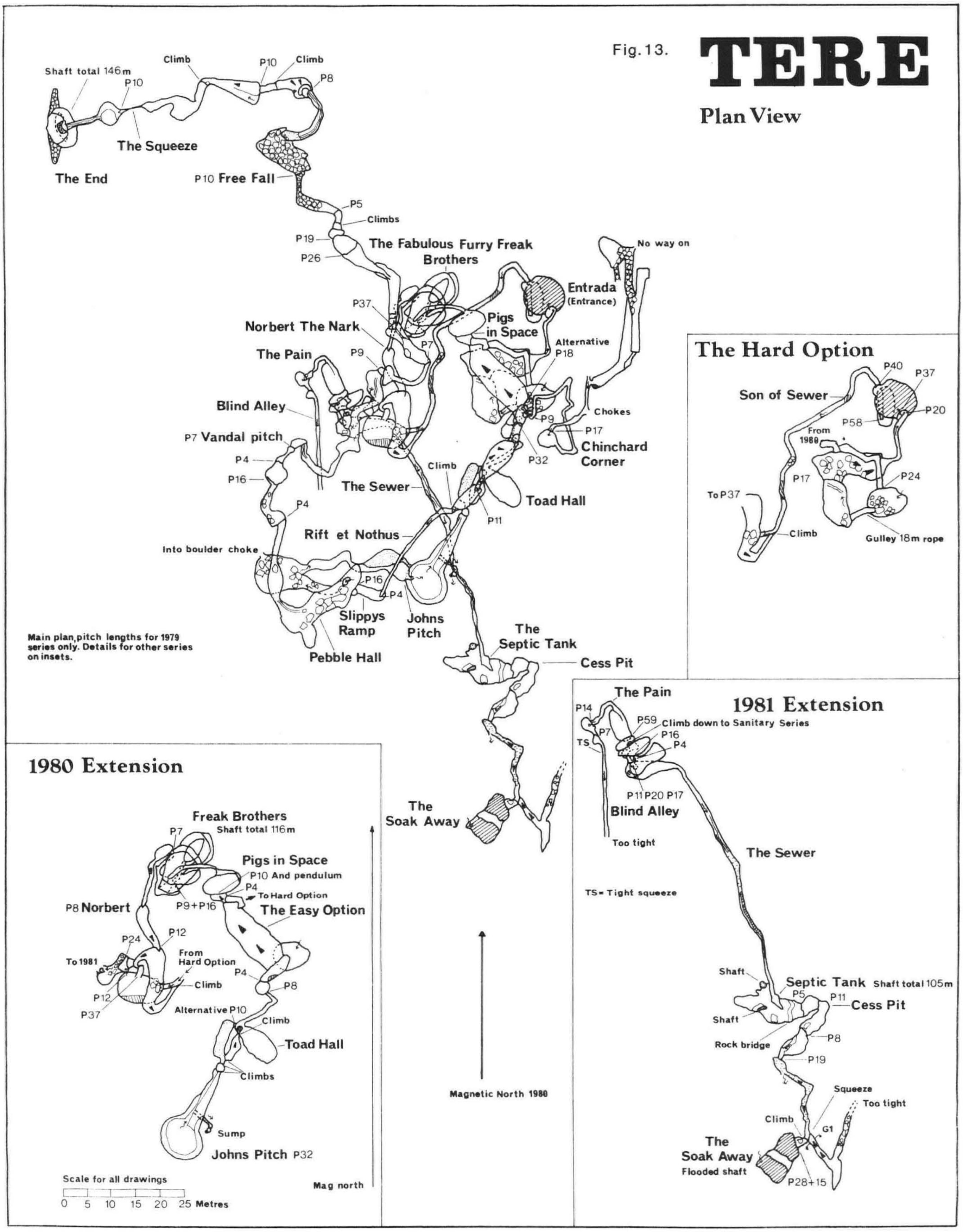


Fig. 13.
TERE
Plan View
Shaft total 146m
Climb
P10
P10
Climb
P8
The Squeeze
The End
P10 Free Fall
P5
Climbs
P19
P26
The Fabulous Furry Freak Brothers
No way on
Entrada (Entrance)
P37
Norbert The Nark
Pigs in Space
P7
The Pain
P9
Alternative P18
Blind Alley
Chokes
P9
P17
P7 Vandal pitch
Chinchard Corner
P4
P32
P16
Climb
The Sewer
Toad Hall
P4
P11
Rift et Nothus
Into boulder choke
P16
P4
Slippys Ramp
Johns Pitch
Main plan, pitch lengths for 1979 series only. Details for other series on insets.
Pebble Hall
The Septic Tank
Cess Pit
The Soak Away
The Hard Option
P40
P37
Son of Sewer
P20
P58
From 1980
P17
P24
To P37
Climb
Gulley 18m rope
The Pain
1981 Extension
P14
P59 Climb down to Sanitary Series
P7
P16
TS
P4
P11 P20 P17
Blind Alley
Too tight
The Sewer
TS= Tight squeeze
Shaft
Septic Tank Shaft total 105m
P5
P11
Cess Pit
Shaft
Rock bridge
P8
P19
Squeeze
Too tight
Climb
G1
The Soak Away
Flooded shaft
P28+15
1980 Extension
Freak Brothers
P7
Shaft total 116m
Pigs in Space
P10 And pendulum
P4
To Hard Option
P8 Norbert
P9+P16
The Easy Option
P24
P12
From Hard Option
To 1981
Climb
P4
P12
P8
P37
Alternative P10
Climb
Toad Hall
Climbs
Sump
Johns Pitch P32
Scale for all drawings
0 5 10 15 20 25 Metres
Mag north
Magnetic North 1980

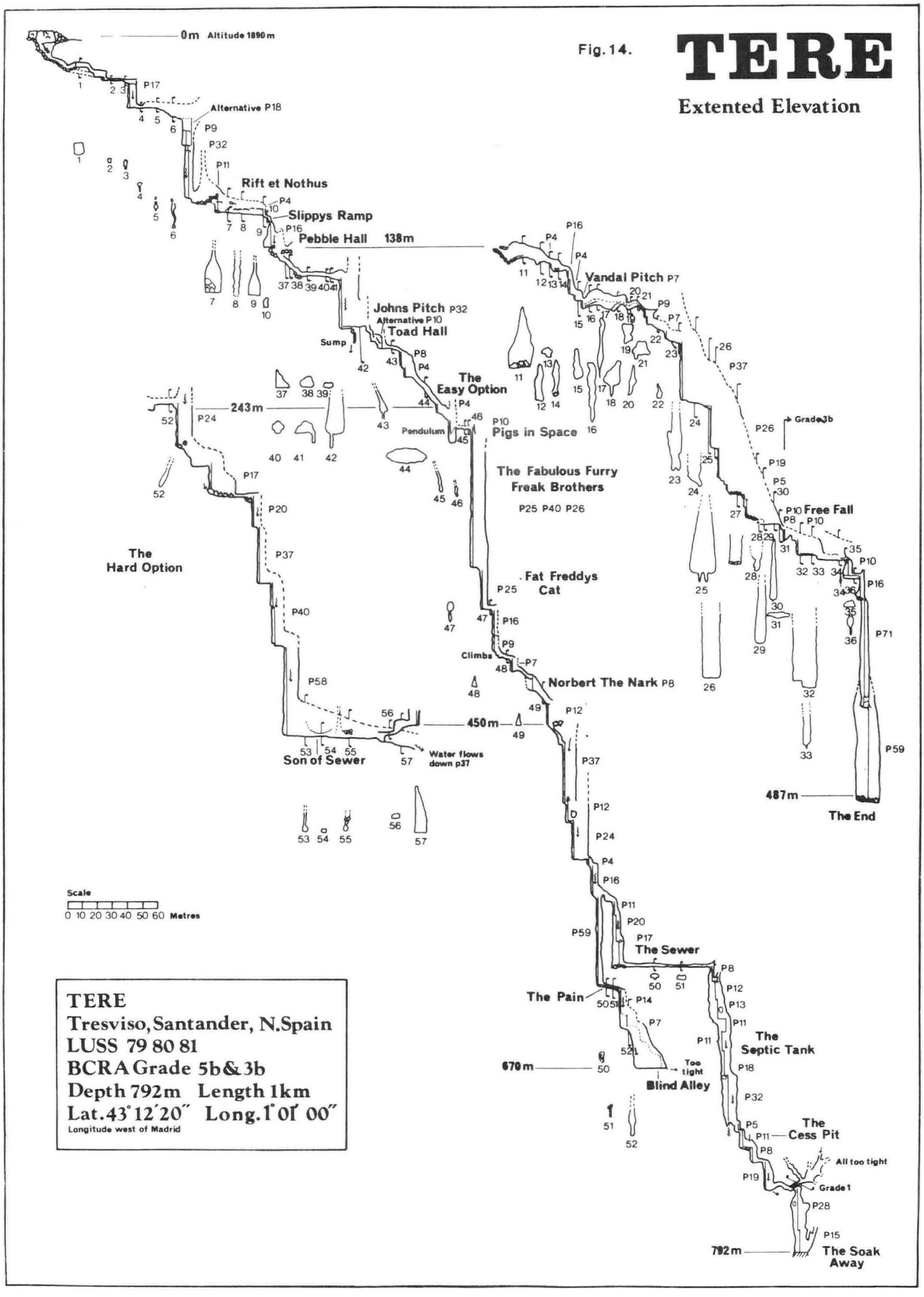


Fig. 14.
TERE
Extented Elevation
0m Altitude 1890m
P17
Alternative P18
P9
P32
P11
Rift et Nothus
P4
Slippys Ramp
P16
Pebble Hall 138m
P16
P4
P4
Vandal Pitch P7
P9
P7
P26
P37
Johns Pitch P32
Alternative P10
Toad Hall
Sump
P8
P4
The Easy Option
243m
P24
P4
Pendulum
P10
Pigs in Space
P26
Grade 3b
P19
P5
P10 Free Fall
P8
P10
P17
P20
The Fabulous Furry Freak Brothers
P25 P40 P26
P37
The Hard Option
P40
Fat Freddys Cat
P25
P16
P9
Climbs
P7
Norbert The Nark P8
P58
P10
P16
P71
450m
P12
Son of Sewer
Water flows down p37
P37
P59
487m
The End
P12
P24
P4
P16
Scale
0 10 20 30 40 50 60 Metres
P11
P20
P59
P17
The Sewer
P8
P12
The Pain
P14
P13
P7
P11
P11
The Septic Tank
670m
Too tight
Blind Alley
P18
P32
P5
P11
The Cess Pit
P8
All too tight
P19
Grade 1
P28
P15
792m
The Soak Away
TERE
Tresviso, Santander, N.Spain
LUSS 79 80 81
BCRA Grade 5b & 3b
Depth 792m Length 1km
Lat. 43°12'20" Long. 1°01' 00"
Longitude west of Madrid

immediately below. The way we had been following was simply a more difficult route to a known part of the cave and was logically named The Hard Option.

There was just one other lead left to investigate. At the top of the 59 m pitch some of the water vanished down a tiny hole in the wall of an adjoining chamber. The chert which blocked the entrance was hammered away and the little wet tube taking the water soon belled out at the top of a 48 m shaft. Two intermediate rebelays enabled us to miss the water for most of the descent. The passage which continued at the bottom was ominously lined with mud. It soon lowered to a flat-out wormway half-full of mud and water which we crawled down to the inevitable sump - except that there wasn't one. After 60 m of the most revolting passage in the Picos, appropriately christened the Sewer, the roof lifted and the stream sank down a slot in the floor. Peering up through a window in one wall we saw an ever-widening shaft disappearing out of carbide range.

On the next trip, this 105 m inclined shaft was rigged in five sections. Three alternative pitches at the bottom all united in the shaft below, most easily rigged as four pitches of 5, 11, 8 and 19 m. The theme which started with the Sewer continued, this last section became known as The Cess Pit and the 105 m shaft above it The Septic Tank. From the bottom of the 19 m pitch a muddy-walled passage led off to a squeeze. The passage continued on the other side, slanting up towards an aven and numerous tubes, all of which became too tight. Just before the squeeze was a 5 m climb up through a solution tube which ended with a 43 m pitch into a very terminal-looking sump. The bivouac set up just below Norbert the Nark the previous day must have been one of the shortest lived ever. The surveyed depth of Tere was -792 m, our deepest cave in the Picos so far. With no other leads left, the cave was detackled and our efforts turned towards Flowerpot.

Tere is quite unlike its next-door neighbour Sara. No large streams flow in the cave even during periods of heavy rain and it seems that it is at the most only a minor drain from the Sara depression. The development is almost entirely vertical with the entire cave covering an area of less than 150 m x 150 m. Many of the passages are directly underneath one another and may well be developed along the same lines of mechanical weakness. Exploration of Tere was thorough and prospects for future discoveries appear slight with one or two small roof tubes below Vandal pitch as the only known leads.

Flowerpot (Fig.15).

Flowerpot was discovered in 1980. Its picturesque entrance at the base of a small cliff on the eastern ridge below Pico del Moro was surrounded by a profusion of alpine flowers, a pleasant change to the more forbidding mine entrances. As with 56, its peculiar location had saved the 25 m entrance shaft from becoming blocked with ice and frost-shattered debris. A quick reconnaissance trip was sufficient to reveal two ways on. One was a second pitch of about 30 m, the other led to a large chamber with a low roof. At the far end was a 3 m climb down into a meander while another crawl out of the chamber led back to the top of the second pitch.

The second route, Bill's Series, was the first to be investigated, but closed down after a few pitches. The other route, Ben's Series, turned out to be considerably more successful, beginning with the 34 m Teddy's Pitch and then the all too familiar sequence of pitch-rift-pitch-rift etc. At least the cave was warm and dry so far, unlike Tere and Sara. Below Teddy's Pitch, a climb down in the meander and short traverse ended with three consecutive pitches of 28, 15 and 9 m. We now found ourselves in a collapse chamber which we called The Rock Garden. Here, the route we had followed met a major cross rift. We took the right hand fork (The Little Weed) and after following a convoluted route back, forth and down, descended a short ladder climb to the top of a 16 m pitch. This was soon bottomed, the meander followed down two more pitches of 16 m and 8 m, and along to a much wider section. From here a 23 m pitch was rigged and landed on a wide ledge, 5 m above a pool. The meander continued on over the top of a downstream sump, our limit of exploration for that year.

The following year a small group from the S.E.I.I. continued exploration of Flowerpot while we tackled Tere. After traversing over the downstream sump the meander was most easily followed at stream level at first and then well above the water. Soon they arrived at a shaft of about 40 m but the rock was so shattered that rigging it safely was out of the question. Instead, they traversed back a little and climbed down 10 m in the meander to where an 8 m pitch regained the stream. This time the shaft, Pozo Critico, was reached and safely descended as a 25 m pitch. The smooth-floored balcony above the water made an ideal campsite from which to base exploration for the next two days.

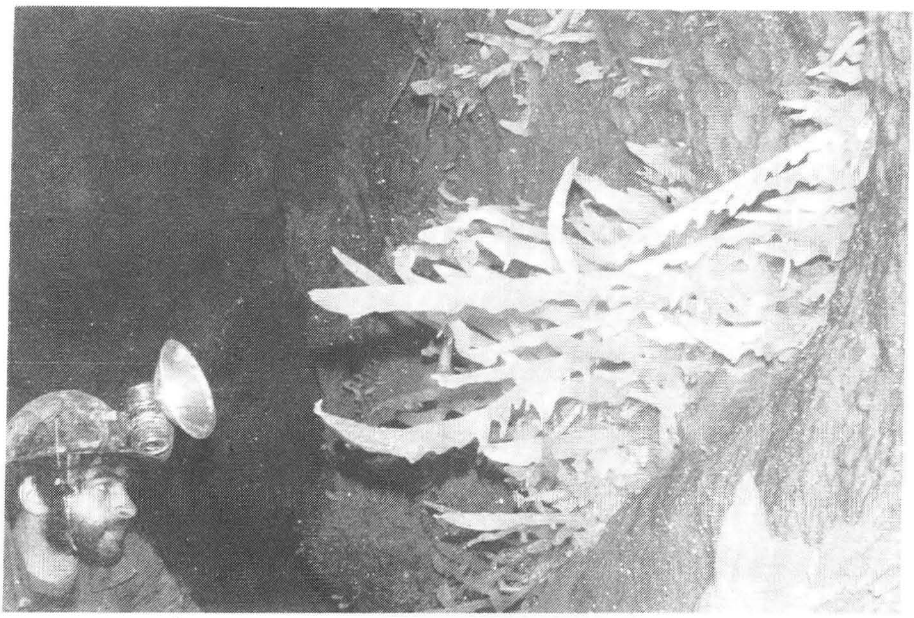
The cave continued as a meandering shaly rift with several awkward sections. Then came a 4 m pitch down to a pool with a sandy bank. Beyond, the rift passage seemed to get smaller and smaller, through one tight section and then they were halted at a flat-out crawl, too tight to squeeze through. Only a faint draught gave any encouragement. Nonetheless, the squeeze was enthusiastically attacked with a bolting hammer and after many hours of chipping away they were through the "Autopista Sangrienta" (Bloody Highway). Now the rift widened a little and traversing became easier, a second 4 m pitch providing a brief interlude. Staying near roof level above a deep fissure in the floor the end of the meander was reached. An open black void greeted them. Stones fell for three to four seconds, and then bounced for another ten. At last, Flowerpot was getting big.

Sadly, the Spanish group had no ropes long enough for "Pozo Comepiedra" - the Stone-Eater Pitch - and as they were due to join their friends in the Western Massif to explore Cemba Viella in a few days time they decided to detackle, having pushed what was certainly the hardest part of the cave to a depth of 350 m. A few days after they had gone, Tere was bottomed, surveyed and detackled, leaving a group of cavers keen to start on Flowerpot, spurred on by tales of an undescended 100 m shaft.

Pozo Comepiedra in fact turned out to be an extremely impressive rift up to 20 m across. The first pair down found themselves descending a superb freehanging 54 m pitch which landed on a floor that sloped steeply downwards to another drop of 17 m. From here it was a matter

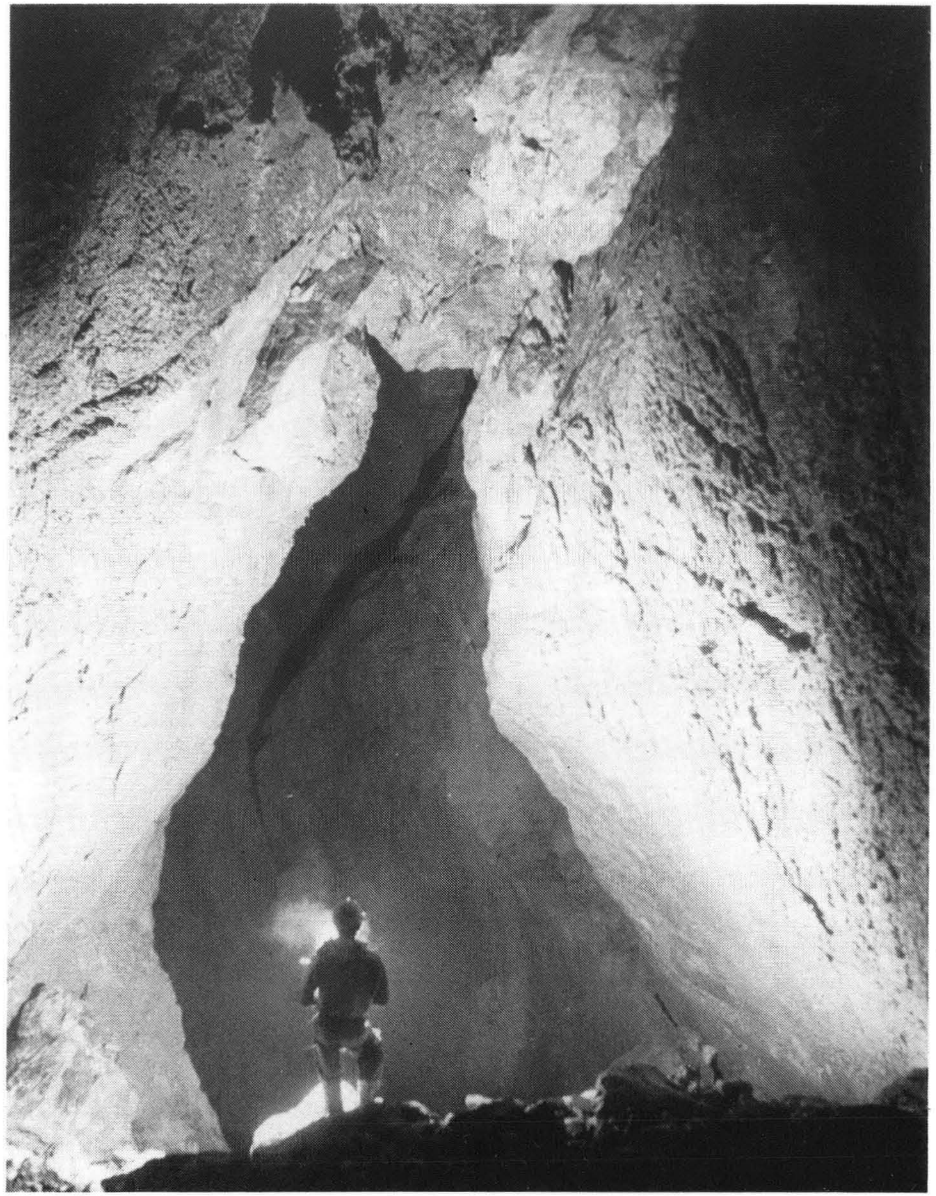
1. Crossing the entrance pool in Cueva del Agua, with the dam in the background.

2. The Main Streamway in Cueva del Agua.

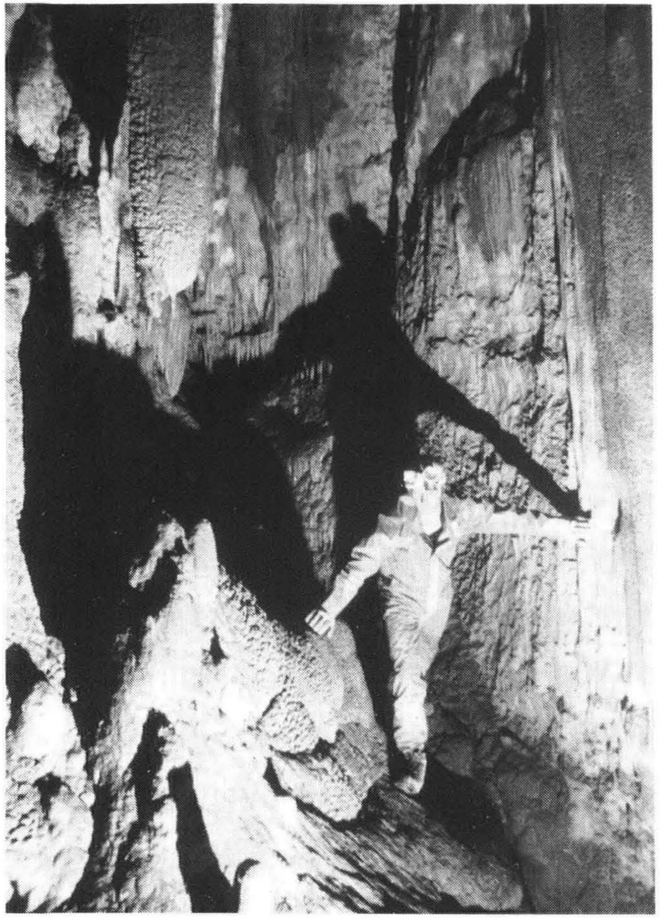


3. Helictites in Fools Paradise, Cueva del Agua (M.Avison).

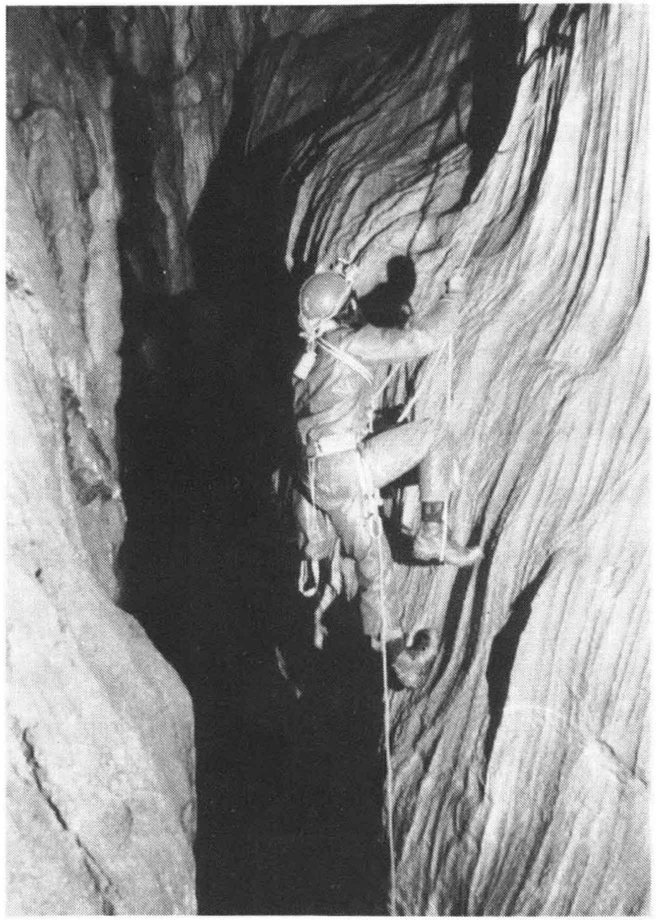
4. Tere Mine entrance - a descent through snow and loose rock leads to the natural cave.



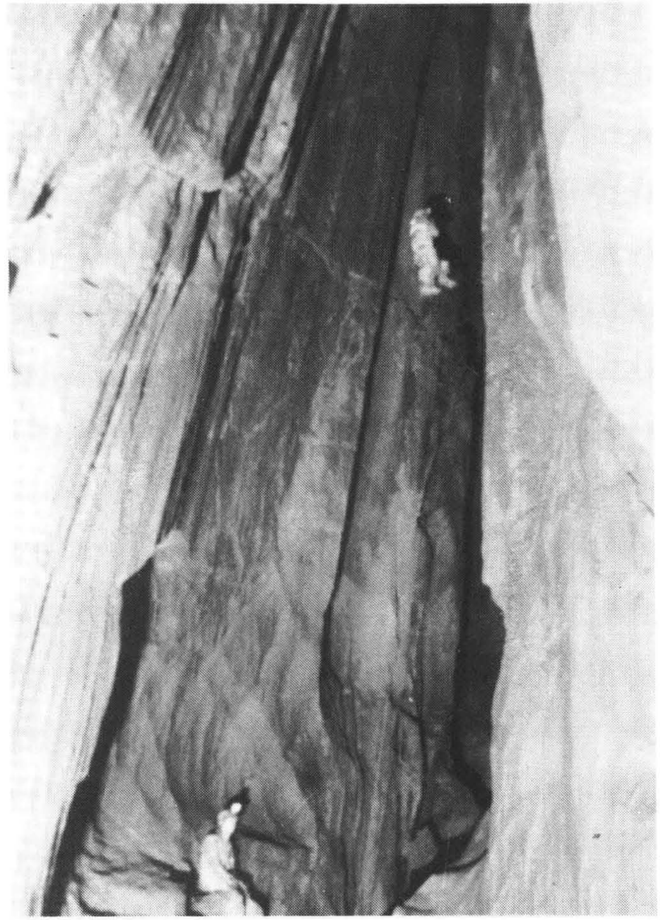
5. The Stone-eater, Flowerpot, 120 metres deep (C.Boothroyd).



6. Speleothems such as these in Flowerpot are a rare sight in the caves of Andara.

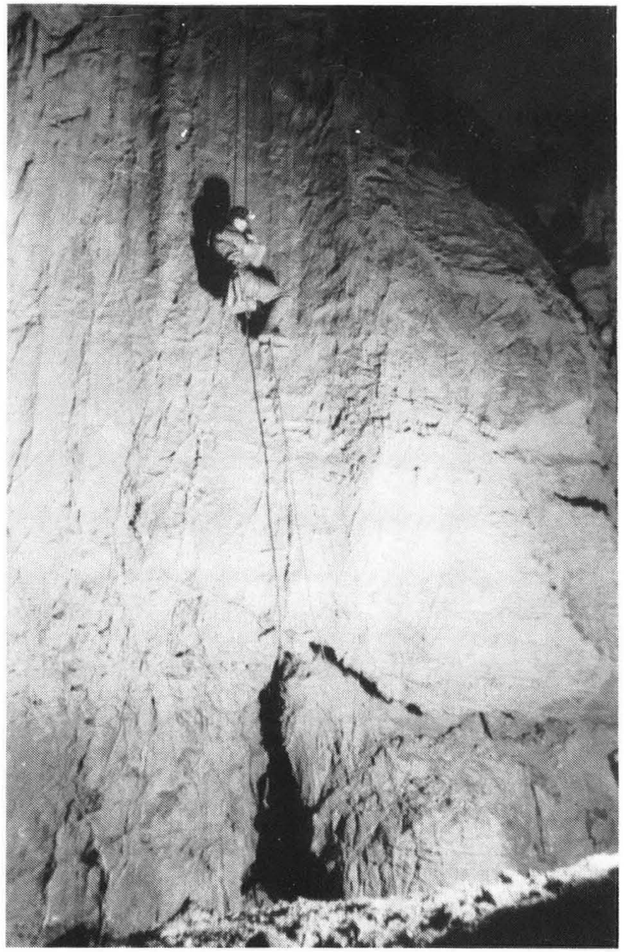


7. Dosser's Delight - 500 metres deep.

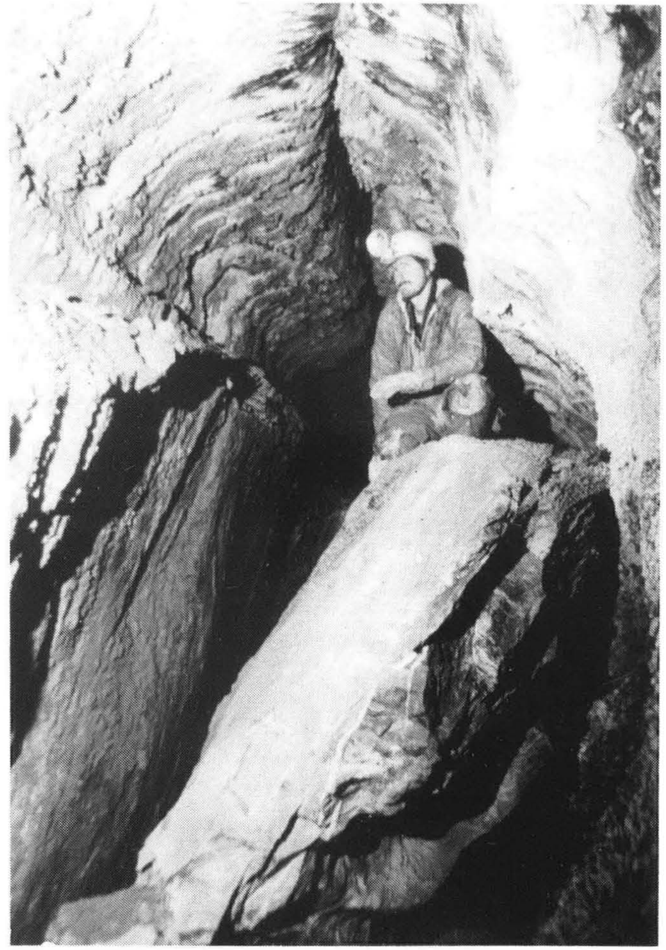


8. A typical Boulderosa rift.

9. The entrance to "56".



10. The 76m pitch near the entrance to 56.



11. In the phreatic maze of the 56 entrance series just before Humbug Hall.

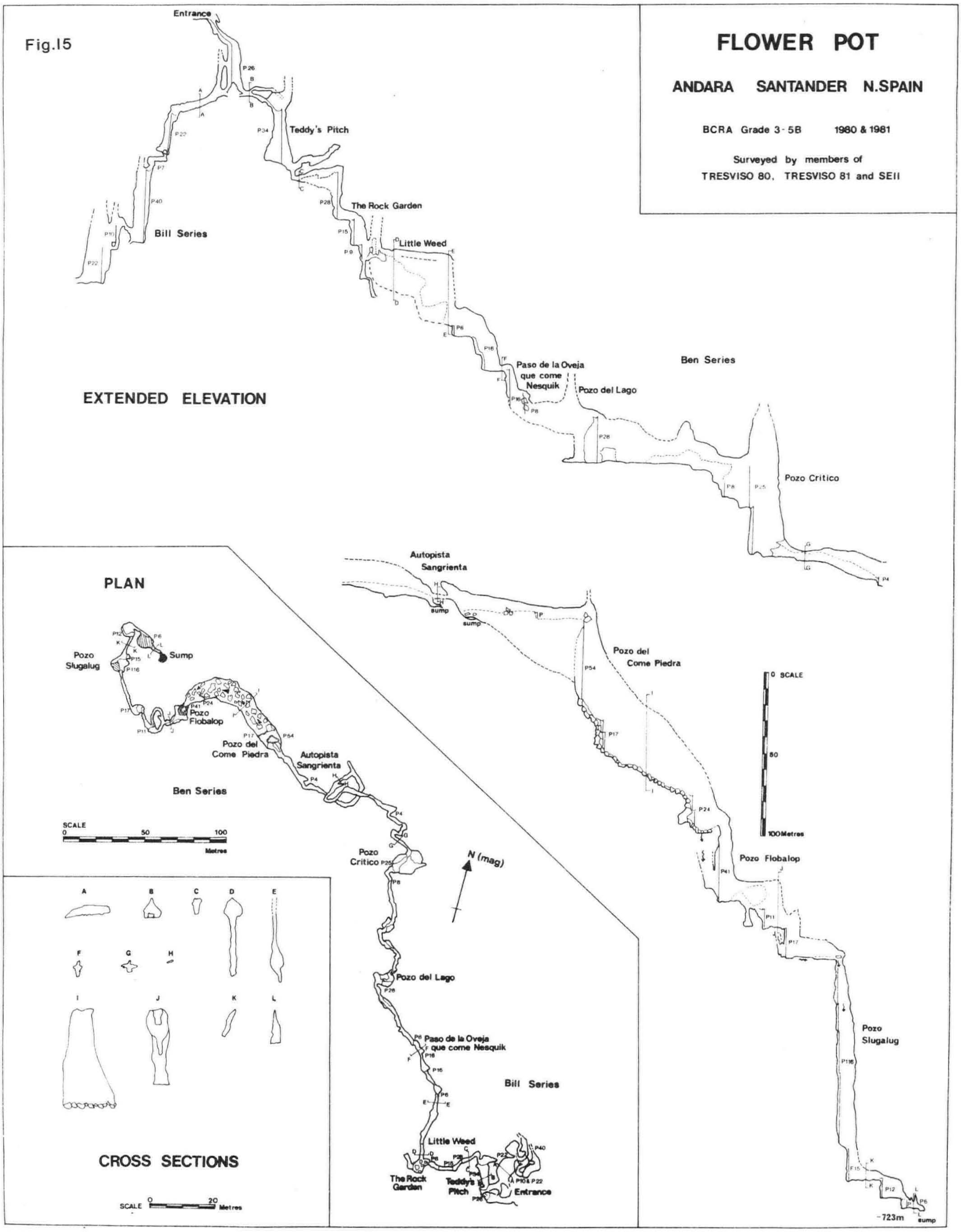


Fig.15
FLOWER POT
ANDARA SANTANDER N.SPAIN
BCRA Grade 3-5B 1980 & 1981
Surveyed by members of
TRESVISO 80, TRESVISO 81 and SEII
EXTENDED ELEVATION
Entrance
Teddy's Pitch
The Rock Garden
Bill Series
Little Weed
Paso de la Oveja
que come
Nesquik
Pozo del Lago
Ben Series
Pozo Critico
Autopista
Sangrienta
sump
Pozo del
Come Piedra
Pozo Flobalop
Pozo
Slugalug
-723m
PLAN
Sump
Pozo
Slugalug
Pozo
Flobalop
Pozo del
Come Piedra
Autopista
Sangrienta
Ben Series
Pozo
Critico
N (mag)
Pozo del Lago
Paso de la Oveja
que come Nesquik
Bill Series
Little Weed
The Rock
Garden
Teddy's
Pitch
Entrance
SCALE
0 50 100
Metres
CROSS SECTIONS
SCALE 0 20 Metres

of scrambling down the boulders until another overhang was reached. This was rigged but left to the next pair to descend.

With this pitch, a broken 24 m, the bottom of the 130 m deep rift was reached, certainly one of the most impressive cave passages we had explored among the high peaks. Pozo Flobalop, a 40 m deep shaft, came next. At the bottom the stream flowed along a high canyon and then sank into a cross rift. Here there were three choices. We could follow the stream or perhaps climb high up in the cross rift and traverse well above the water. Instead we took the third alternative, a small hole straight ahead which seemed to take most of the draught. This was the start of a short oxbow section and after a broken 11 m pitch and a 17 m pitch we were back with the water again. A short stream passage ended at the top of a deep shaft, Pozo Slugalug.

Pozo Slugalug marked the end of dry caving in Flowerpot. This damp spray-filled 116 m deep shaft was rigged as a series of short drops by the next two groups down. They then descended two more pitches of 15 m and 12 m before arriving at the top of yet another short pitch.

At this point efforts were diverted into setting up a campsite at the top of Pozo Comepiedra. It must have rivalled the camp in Tere as one of the shortest on record because on the next trip the undescended pitch was descended for 6 m straight into a terminal sump pool. One enthusiastic caver following a few hours behind on a solo trip to the bottom carrying 100 m of rope had nothing to do but turn around and take his rope all the way out again. All of us were greatly disappointed that the cave did not go beyond its 723 m depth. Only one major system now remained left to explore - 56.

Flowerpot is on the whole typical of the caves of the Andara region, consisting for the first half of a single extensive meander with several wider sections and taking a small stream which is followed all the way to the final sump. Much of this section is well decorated with old orange calcite, a rarity among the caves in this area. The cave from Pozo Comepiedra onwards is more grandly proportioned and Pozo Comepiedra itself is without doubt one of the most impressive passages in the Picos. There are no known leads in this latter section except perhaps high in the cross rift below Pozo Slugalug but in the first part of the cave there may still be several possibilities at roof level.

56 (Fig.16).

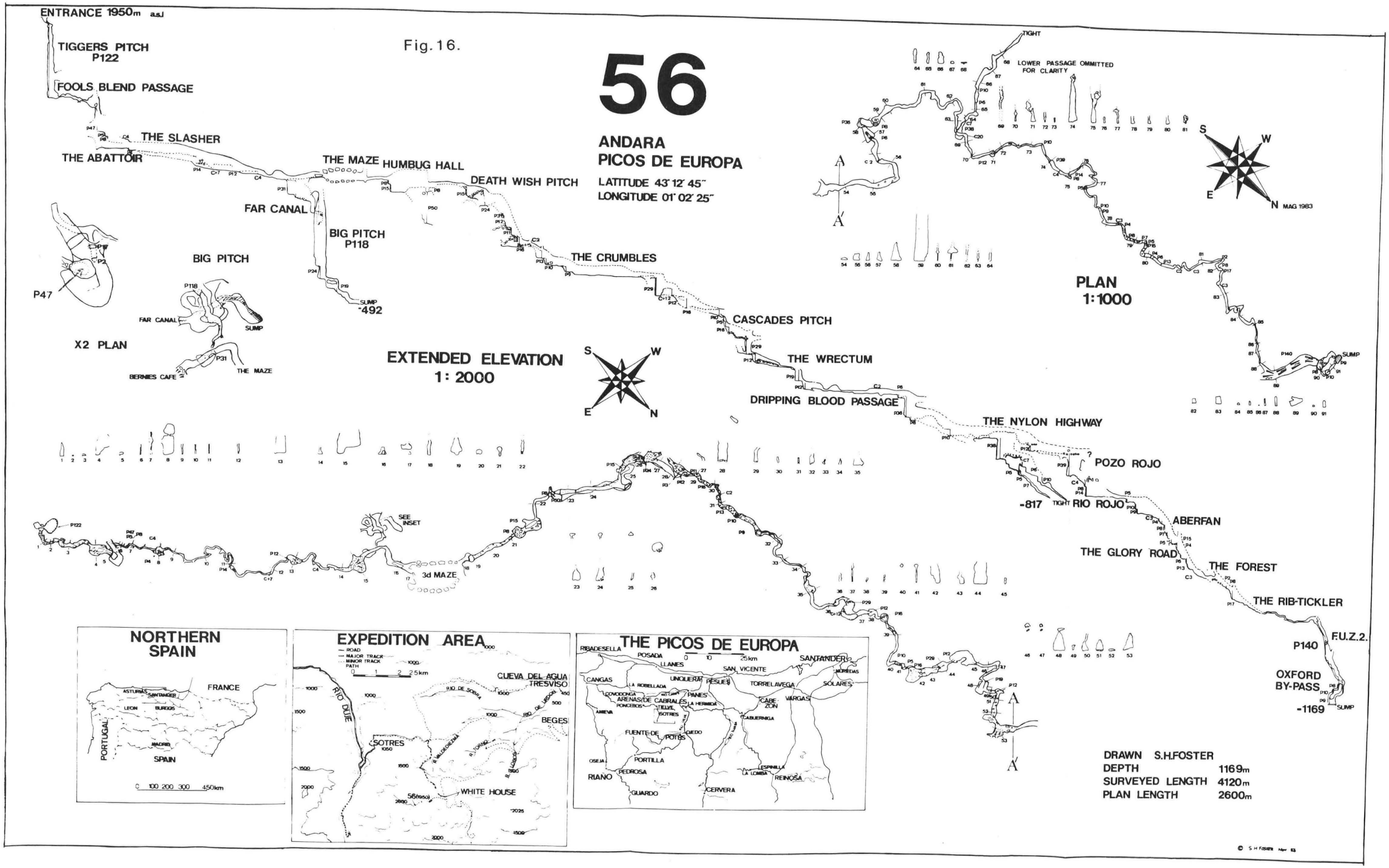
The entrance to 56 was discovered during the 1977 expedition when a small shakehole on top of the main ridge dividing the Lake and 56 depressions was found to have a small hole at the bottom. Stones thrown down appeared to fall for several seconds. The entrance was numbered 56 but not explored; it was just one of many entrances noted that year. In 1978, 56 was descended as part of the routine surface work carried out each year, but unlike all the other natural shafts investigated so far it was found to continue at the bottom. A short climb down a 3 m pitch at the entrance led straight onto the top of a splendid 122 m shaft. The first few descents and ascents of Tigger's Pitch were rather terrifying affairs as the pitch head was littered with fist-sized rocks that invariably poured down the shaft every time someone got on or off the rope at the top. At the bottom a roomy passage ended after only a few metres at a boulder choke.

Fortunately there was a way through into a series of small interconnected chambers in rock and clay impregnated with a yellow crystalline substance. One or two optimists thought this was high grade zinc blende and that we had struck it rich but the crystalline material turned out to be calcite and the name 'Fool's Blende Passage' was born. Beyond Fool's Blende Passage we arrived at a large chamber with a pitch at the far end. This was a broken descent of 47 m down a wide rift and onto a mud bank. Here it became apparent that we were at the junction of two inlet series, uniting at several levels. We reached the floor of the junction, known as the T-Junction Cafe, with another 17 m pitch down a hole virtually below the pitch we had just descended. The way on was a meander, very narrow at first with two upward squeezes but then widening a little. A climb down at an even wider section, Short Arses' Dilemma, led to another junction. The right-hand fork ended at a sump while the left-hand route continued to a 4 m climb down in the rift over jutting shale bands to a short pitch into a chamber. Some very large and very unstable blocks were perched at the top of this pitch and, although a narrow slot provided an alternative, those exploring this section were not keen on making the descent, so the cave was surveyed and detackled.

The following year one or two more determined individuals decided to have a second look. Traversing over the top of Short Arses' Dilemma, they arrived at the top of the so called "unstable chamber", discovered it was now perfectly safe and descended the 4 m pitch. The chamber (The Abattoir) had an active inlet entering on the left with a tiny stream disappearing down the rift continuation on the far side. This section was quite strenuous, especially with tackle, and was traversed for 110 m past several inlets to a pitch back down to the water. In several places (fortunately avoidable) the wall was covered with sharp calcite crystals which tore caving gear as we struggled through. The Slasher, as we called it, indiscriminately destroyed numerous caving suits and other equipment. One reason people left 56 alone was that they could not afford it!

Shortly afterwards, two gallons of concentrated Rhodamine solution were deposited in the stream in the chamber at the start of The Slasher. Ten days of very dry and sunny weather did not help to move the dye along and we spent several trips caving among pink cascades, pools and waterfalls. Then, after two days of torrential rain, reports started coming up from*Tresviso of dye appearing in the main streamway of La Cueva del Agua, 1,500 m below.*

After The Slasher we descended a 14 m pitch to a shelf some 6 m above the stream, then continued following the meander at various levels, up a 7 m climb, along, down a 12 m climb, along, down a 4 m climb and so on, sometimes moving with the water but more often above it. Beyond Bernie's Cafe, a large chamber used for a food dump, the water sank down a 31 m pitch. Below was a confluence with a choked inlet, discharging a larger stream than



ENTRANCE 1950m a.s.l.
TIGGERS PITCH P122
FOOLS BLEND PASSAGE
THE SLASHER
THE ABATTOIR
THE MAZE
HUMBUG HALL
DEATH WISH PITCH
FAR CANAL
BIG PITCH P118
SUMP -492
BIG PITCH
P47
X2 PLAN
FAR CANAL
SUMP
BERNIES CAFE
THE MAZE
THE CRUMBLES
CASCADES PITCH
THE WRECTUM
DRIPPING BLOOD PASSAGE
THE NYLON HIGHWAY
POZO ROJO
-817
RIO ROJO
ABERFAN
THE GLORY ROAD
THE FOREST
THE RIB-TICKLER
F.U.Z.2.
P140
OXFORD BY-PASS
-1169
SUMP
EXTENDED ELEVATION 1: 2000
56
ANDARA
PICOS DE EUROPA
LATITUDE 43°12′45″
LONGITUDE 01°02′25″
LOWER PASSAGE OMMITTED FOR CLARITY
TIGHT
PLAN 1:1000
MAG 1983
SEE INSET
3d MAZE
NORTHERN SPAIN
FRANCE
PORTUGAL
SPAIN
EXPEDITION AREA
CUEVA DEL AGUA
TRESVISO
BEGES
SOTRES
WHITE HOUSE
RIO DUJE
THE PICOS DE EUROPA
SANTANDER
SOLARES
TORRELAVEGA
SAN VICENTE
LLANES
POSADA
RIBADESELLA
CANGAS
UNQUERA
PESUES
PANES
ARENAS DE CABRALES
POTES
PORTILLA
PEDROSA
RIAÑO
GUARDO
CERVERA
REINOSA
VARGAS
CABEZON
DRAWN S.H.FOSTER
DEPTH 1169m
SURVEYED LENGTH 4120m
PLAN LENGTH 2600m
© S H Foster

Fig. 16.

the one we had been following. Further downstream the nature of the cave suddenly changed as the roof descended to the top of the 23 m Pink Pitch. The shaft was completely enclosed with beautifully fluted walls and the stream disappeared down a small tube at the bottom.

The tube gave almost immediately onto another long pitch, The Far Canal, which, due to the belling out of the shaft, could only be hung directly in the water. 5 m down and to the left a sloping shelf gave a dry alternative but this involved a precarious pendulum under the full force of the water to reach it. At the bottom of the dry alternative (a pitch of about 15 m) was a short passage back to the wet pitch, now a drop of about 3 seconds. The pitch head was bolted but not descended due to lack of tackle.

Fortunately, two cavers on a surveying trip discovered a huge dry parallel shaft by climbing up in the rift before the top of the Pink Pitch. This seemed a much more pleasant alternative to the Far Canal and so was the first objective of the next team down. The Big Pitch was a superb freehang for 118 m to a wide ledge and was followed by a 24 m pitch to the floor of the shaft. At the top of the 24 m pitch a small window gave a tantalizing view of a spray-filled parallel shaft. The water, which met us at the bottom, was a bright pink so we knew we had once again rejoined the stream last seen at the Far Canal. The water exited along a small rift and down a hole in the floor but we took the alternative of traversing over the top and down a 9 m ladder climb on the far side. The stream cascaded down a steeply inclining phreatic passage. At the bottom was a miserable looking sump with a narrow rift above that defied several attempts to get through. There were no alternatives below the Big Pitch and most people were convinced that 56 was finished at -492 m.

In 1980 a small team returned to investigate a possible continuation above the 31 m pitch. This turned out to be a large phreatic passage so obvious it was hard to imagine how we could have missed it in the first place. After a short distance the passage split up into three ways on, all of which were entrances to the same complicated maze. Several hours were spent crawling and climbing among sandy boulders before one route took us to a 15 m high rift passage. Ten metres further on was an aven, a sandy depression in the floor and a 3-4 m wide inwardly draughting phreatic tube on the far side. The tube was quickly followed to the head of a short pitch.

The next day another pair descended this 8 m pitch and then one of 15 m into Humbug Hall, a large elongated chamber in dark limestone with white mineral veins. Numerous huge boulders littered the floor. Between the largest of these (The Humbug) and the left hand wall a rift passage led off. The water sank down a pitch of considerable depth but instead they traversed along to another pitch of about 60 m. At the bottom was a very narrow meander which turned out to be the most unpleasant encountered so far. It was begrudgingly followed, at first above the water and then with it to a pitch of 8 m but by this time they were thoroughly fed up. The rock - if you could call it that - was so loose that one caver fell twice and the tight sections were only negotiable because the walls crumbled away as they struggled through. Needless to say the passage was not surveyed, nor was it ever returned to. There were better things afoot.

Above the 60m pitch it was possible to climb into an old 4 m wide phreatic roof tube. Here it was necessary to tread carefully as the rock was again very brittle. After 50 m the tube divided, both branches ending at pitches. We took the right hand route which was easier to rig, and descended pitches of 7 m and 19 m to a large canyon-like passage. The wider branch led underneath the way we had just come, back to the 60 m pitch. The other direction was apparently "the way on". Unfortunately this was as unpleasantly loose as anything we had met so far and great caution was required. After about 50 m of careful traversing a point was reached where it was possible to climb down for 20 m but still the floor was not reached. It was also possible to climb up instead of down and after two 3 m ascents we popped out into a large chamber. Up the boulder slope on the left we met the roof - and yet another pitch which was more or less over the top of the unfinished 20 m climb. This was the limit of exploration for 1980.

We did not return to 56 the following summer as our hands were full with Tere, Flowerpot and Dosser's Delight but in 1982, with all other top camp systems "finished", 56 was our sole objective. Some of the trips in 1980 had taken fifteen to eighteen hours so we decided to set up a campsite between Humbug Hall and the 60 m pitch right from the start. This time we took the left fork of the roof tube just past the 60 m pitch and descended Death Wish Pitch, a 15 m drop directly into the chamber which was the previous limit of exploration. Soon we were in new territory. The pitch at the top of the boulder slope was 24 m into what was effectively the start of a large canyon passage with what seemed like a narrow meander wandering back and forth underneath. The direct route down the canyon was too loose and dangerous so instead we clambered along and down a hading rift, Lavatory Pan Alley, finally popping out through a very narrow section to a 3 m pitch down to a balcony. A 12 m pitch then took us back into the canyon. We continued down the most obvious way via pitches of 11 m and 16 m and at last we were just above a streamway which we later found could be reached by climbing down in several places above and below the 16 m pitch. Although this whole canyon section contained several deep hopes in the floor at various levels, we were content to follow our noses along a more narrow rift below the 16 m pitch until we arrived at a 13 m pitch and were back in the streamway once again. After two more pitches of 10 m and 9 m the streamway narrowed and the water cascaded down a 3 m climb into the start of yet another narrow meander. The Crumbles. We crawled along just above the water for 150 m, our tackle bags constantly snagging on loose bits of chert which stuck out in all directions. A chamber provided a welcome relief towards the end before the meander began to widen.

The high level continuation looked very loose and nasty so instead we took the "middle road", a climb down in the rift to a 29 m pitch in a dry shaft. The water sank down another pitch further back in the rift to take a different course of its own. The only way out from

*Dye-testing in caves other than Sara and 56 has not yet been attempted.

the bottom of the 29 m shaft, yet another meander, was tight and awkward at the bottom so we climbed up for 11 m and traversed over the top, descending an 11 m pitch into a small chamber on the far side. After more traversing and a pitch of 16 m, we were back in a streamway again, perhaps the same one we had left in The Crumbles, perhaps not. Still there was no let up as we were forced to traverse more rift passage, this time along the roof. 50 m later, two climbs of 10 m and 4 m took us back to the water and to the head of the split 19 m Cascades Pitch. We arrived at a large boulder strewn chamber, a pleasant change from the ever present meanders. After clambering over boulders and down several climbs we descended a 29 m pitch into another chamber. A short rift, a 12 m pitch and suddenly the cave had closed down again to a wet 40 m crawl in a miserable little rift. Then came the inevitable pitch.

At this point exploration came to a halt for several days. Heavy rain for two days had made several of the pitches between Lavatory Pan Alley and The Crumbles as well as the Cascades Pitch very wet and unpleasant, not to mention potentially dangerous if the rain got any heavier. Still, after a couple of days of sunshine we were ready to go again, albeit with only enough time for three more groups to continue exploration. The first of these descended the pitch out of the Wrectum, the name we gave to the little wet crawl that marked the end of the last pushing trip. It was 19 m to the floor of a moderate sized chamber. Soon they were descending another pitch of 12 m, half expecting another meander to follow. Instead they entered a 150 m long phreatic section. Several creamy white stalagmites and flowstone were coated with deep red calcite. Dripping Blood Passage was a most welcome change from the somewhat monotonous style of caving that had preceded it. The stream disappeared at a small sump at the beginning, only to reappear at various intervals leaving a dry-floored tube, an ideal campsite should we ever need to move the present one deeper into the cave. Dripping Blood Passage ended with a 6 m pitch into a pool on the floor of a chamber. Straight ahead the water dropped down another shaft.

The second team continued down the 36 m deep shaft and subsequent 8 m pitch. Then it was back to the familiar meanders again. This one was traversed for 70 m at varying levels above the floor to a 10 m pitch back to the water. Soon after, the stream sank into the floor and was not seen again. A further 65 m of traversing ended with a 3 second drop down a shaft with the rift continuing over the top.

The final pair set off down from the entrance. By now, just getting down to the bottom was a hard enough task with over thirty pitches and numerous route-finding problems. It was twelve hours before they reached new territory. The 3 second drop was 38 m and was followed by more narrow meandering passage, The Grand Canyon. The rift was followed for 70 m, up a 3 m climb, along, down a 7 m climb, down a 6 m pitch, along and down a 10 m pitch. The passage closed down briefly to 1 m high, opening up again almost immediately beyond. They continued to climb down in the rift until it became too tight for further progress. A loud noise of running water could be heard beyond and there were possible routes over the top but it was a long way back to the camp and there was still the surveying and some detackling to be done. Thirty-four hours after setting off from the surface they were back at the campsite. A more welcome sight could hardly be imagined. 56 was now 817 m deep with over 230 m added by the last three teams.

The 1983 expedition began in an arduous fashion, taking the five cavers there at the beginning eight days to carry in the 36 bags of equipment needed to rig the known parts of the cave, the new campsite at Dripping Blood Passage and the unexplored passages beyond.

After a couple of trips to the far end, it was obvious that there was no way through The Grand Canyon. The rift at the bottom was too tight and there was no apparent way over the top. The sounds of water heard the previous year had vanished although a strong draught still persisted. Between the 6 m and 10 m pitches halfway through The Grand Canyon was a climb down to a 5 m pitch with a duck beyond, a miserable affair in dry gear. Then came two more pitches of 5 m and 7 m and hopes rose as a 100 m long walking-sized passage was followed, only to be quickly dashed as the passage ended at another impassably tight rift.

In the meantime a third team had rigged a traverse line, the Nylon Highway, well above the 38 m pitch into The Grand Canyon, and climbed down for 20 m on the far side to the floor of a rift whose walls were encrusted with tiny aragonite crystals. After 25 m was a 5 m climb down to Pozo Aragonito, an 11 m pitch similarly decorated with aragonite. The rift which continued at the bottom, Meandro Rojo y Blanco, was well decorated with white calcited walls and a dark red calcite floor. Forty metres long, it ended at Pozo Rojo, a 39 m pitch with dark red flowstone near the bottom.

So far, the newly discovered section contained some of the best sections of passage seen in 56, and what followed was even more impressive. Three short climbs down took the pair to an 8 m pitch, followed immediately by another of 14 m with a deep red calcite flow down the face of the pitch like a frozen, blood-red waterfall. Beyond lay the most colourful passage found so far, 70 m of narrow fossil streamway heavily decorated with red and white calcite and numerous pools along the floor. Named Rio Rojo, it ended at a 5 m pitch into a deep pool, requiring an awkward pendulum at the bottom to stay dry. A short rift followed and then came yet another pitch.

The news of these discoveries was enough to rekindle enthusiasm among those who had drawn a blank in The Grand Canyon and soon all the available tackle was at the far end. The pitch at the previous limit was 10 m deep and was followed by another of 9 m. Twenty metres further on the cave began to descend rapidly in staircase fashion. First a 2 m climb then a 4 m pitch, then another nasty 3 m climb down something resembling a crumbling coalface. Seven more pitches of 8, 7, 5, 15, 4, 6 and 13 m followed in quick succession before the tackle ran out and three very tired cavers returned to camp.

Back at the White House cautious optimism turned to excitement. 56 was now very close to 1,000 m deep and we were still in fossil passage. The next team of four took down another 250 m of rope and it was not long before they were in new territory. At the bottom of the 13 m pitch was a slope down to a 3 m climb. This was followed by a 30 m long calcite rift and then a small hading rift ending at successive pitches of 2, 8 and 17 m.

Now came a muddy rift passage with a slippery sloping floor. After two awkward climbs down they entered a phreatic section ominously lined with mud but still taking a discernible draught. A 3 m climb down was followed by a hands and knees crawl through a small tube then a 3 m climb up with a 3 m climb down on the other side. The only way on seemed to be a narrow slot in the floor, a pitch of about 5 m. The first person down found himself in a 3 m wide by 8 m high passage,descending at about 60°. It was rigged to a depth of 90 m with several rebelays before the last of the tackle ran out.

Few of us on the surface dared hope that the last group would actually use all of their rope and still not reach the bottom, but, just in case, 230 m of rope, the last remaining scraps of the 2,000 m we had brought on the expedition, were packed into tackle bags for one final pushing trip. A day later, four more cavers were at the campsite in Dripping Blood Passage. Two went down to the bottom first, continuing to rig F.U.Z. 2, the name given to the steeply descending ramp. This split up into two routes. The first began with a 12 m climb and then a 10 m pitch to the head of a 4 m climb. At the bottom was a 9 m pitch straight into a huge sump pool. The second route met the same fate, a 15 m pitch then 20 m pitch landed in the same pool, 1169 m below the entrance. There were still a number of possible alternative high level routes through the 1983 series as indeed there are throughout the entire cave but with the ferry due to sail in a week, it was time to begin the formidable task of detackling.

56 is without doubt the most complex and extensive of the caves of the Andara region. There are at least three separate streamways in the cave but their courses cannot be determined with certainty without extensive dye-testing. The first stream (dye-tested to La Cueva del Agua) begins at the Abattoir and is followed for most of its course to the 1979 terminus, the sump at -492 m. Numerous inlets feed the stream but even during wet periods it is not particularly large. Above P31 an older phreatic section of the cave is entered, leading to Humbug Hall. Here another small stream enters via an aven inlet and sinks down an undescended pitch. The water is presumably, but not necessarily, that which is encountered at the bottom of P60. The latter has been followed for some way but not to a conclusion. Instead, exploration has been concentrated on an upper phreatic level with subsequent vadose development for up to 60 m below it. The roof is eventually lost at P24 where the direction of cave development changes by almost 90°.

The next section is a steeply descending canyon-like passage and after several more pitches another active streamway is reached. This water rises above the level of the sump at 492 m and is therefore a separate stream from the first, but may be fed from the water below P60. Presumably it is the same stream which is followed all the way to Dripping Blood Passage although the water is temporarily lost for the three pitches which follow the Crumbles and also just before the Cascades Pitch. The stream does not increase appreciably in size during its visible course and is finally lost just before P38, the parting of the ways between the Grand Canyon and the 1983 discoveries.

The rift passages from the far side of P38 to the top of F.U.Z. 2 are mostly dry although standing pools in the Rio Rojo suggest that a stream may flow here during periods of high rainfall. The water in F.U.Z. 2 was a mere trickle when this steeply descending ramp was first explored, while the stream from The Crumbles to P38 was flowing appreciably. However, after several days of rain, F.U.Z. 2 took a sizeable stream, larger than those encountered anywhere else in 56. This stream is probably distinct from the others in the cave.

The significance of 56 as a drain for the surrounding area is obscure. The position of the massively developed entrance series, right under the main ridge separating the 56 and Lake Depressions suggests that the surface topography must have been very different at the time that the cave was formed. The general horizontal trend of cave development in 56 is roughly northwest, a feature shared by both Flowerpot and Sara and, although the cave is 2.6 km long, the far end is only 0.5 km closer to the upstream sump in Agua than is the entrance. Clearly, the task of joining these two caves is a formidable if not impossible one, with nearly 4 km still between them. There is, of course, no certainty that the passages beyond the first streamway in 56 will eventually head towards Agua at all, nor can we be sure of the fate of the water in the latter part of the cave. However, the sump at -1169 m is already below the level of the Rio Duje where it passes Sotres, and Agua is still the nearest of the possible resurgences.

Further progress in 56 will undoubtably depend on concentrating on upper level leads. The sump at -1169 m is already only 180 m above the upstream sump in Agua and actually below the highest point in this cave. Perhaps the best hopes for an eventual connection of these two caves lies in the discovery of other cave systems between them.

OTHER CAVES IN THE ANDARA AREA

a) Fallen Bear Hole (depth 180 m, explored 1978; Fig.17).

The entrance is a 50 m shaft into the roof of a most impressive chamber, 25 m high, 50 m wide and 70 m long. In one direction is a dry sandy passage containing an intact bear skeleton. In the other direction a steep boulder slope ends at successive pitches of 30 m and 25 m.

b) Dosser's Delight (depth 294 m, explored 1981; Fig.18).

After successive pitches of 12 m, 25 m and 34 m, the continuation is reached via a 9 m climb up in inlet passage. A 50 m pitch between parallel walls is followed immediately by a 43 m drop in a huge shaft. A short rift intervenes and then comes another pitch of 51 m also in an impressive shaft. An ascending traverse, two pitches of 15 m and 38 m, another traverse and 24 m pitch end at the lowest known part of the cave. From here a tricky climb up a calcite blockage reaches a fissure which emits a strong draught.

c) 55 (Explored 1977 and 1980)

This is a 200 m deep shaft blocked with snow at the bottom.

d) Septrin (depth 112 m, explored 1981; Fig.19).

A climb down to a chamber is followed by two pitches of 12 m and 8 m. The next pitch, 50 m, is extremely tight at the top and is followed by a final pitch of 25 m.

e) T207 (depth 83 m, explored 1981; Fig.20)

The entrance is a 24 m pitch into a chamber. A 7.5 m deep slot follows and then two pitches of 39 m and 9 m into a terminal chamber.

CAVES EXPLORED BY LES SPELEOS DROMOIS, LYON, FRANCE

f) Pozo Del Hasta Luego (FT14)

The entrances to these interconnecting mines and natural cave are just beyond the lake, in the lake depression, up 100 metres on the left hand side.

Various entrances lead to a mine level from which pitches of 40 and 90 metres lead to a choke.

g) Pozo Del Compromiso (FT39)

This mine entrance is 75 m above the lake on the left hand side of the depression.

Mixed mine and natural passages lead to a completely natural section which attains a depth of 180 m via two pitches of 12 and 17 m. It is too tight at the bottom.

h) Pozo Del Castillo (T145)

The entrance to this system is 100 m beyond the lake and 50 m up on the left hand side of the depression.

A complex series of over 1 km of mine leads to natural passage with pitches of 6, 5, 6, 30, 7, 12, 40, 7 and 10 m. The passage finally becomes too tight at an overall depth of 293 m.

i) Pozo Natacha

This series of natural passages is linked via mine workings to T145, Segura II and Pozo del Castillo.

Pitches of 30, 6, 4, 17, 15, 3, 15, 40, 25, 15, 12, 7, 25 and 8 m lead via a series of tight rifts to a point where it becomes too tight.

CAVES OF THE COTERO REDONDO AND VALDEDIEZMA REGION

We have begun an investigation of the caves in this region only recently and the area has by no means been thoroughly explored. Although the caves found so far are not extensive, the sizeable development in some of them and the ease with which new entrances have been found up to now suggest that continued work in this area may well be more fruitful, especially considering the location of the area; above Marniosa and the far end of La Cueva del Agua and below Andara.

a) Cueva de Entre Cuetos (local name)

This is situated in the bottom of the Valdediezma, 300 m above the track and begins as an old cheese cave with a wooden door. The entrance passage soon narrows to a squeeze into a bedding plane leading to an area of collapse. Here a further squeeze was evacuated down a hole in the floor to a broken 10 m pitch into a high rift. A 30 m pitch at the far end is followed by two more descents of 12 and 4 m.

b) Sima Bromista

The obscure entrance to this system may be found just below the summit of Cotero Redondo. It leads beneath several daylight connections to a tight and unstable 13 m pitch. The next pitch of 85 m follows immediately. After two decorated chambers is a final 20 m pitch.

CONCLUSION

There can be little doubt that the past nine years of exploration in the Eastern Massif of the Picos de Europa have opened up some of the finest caves in Spain. In La Cueva del Agua we have a system which is both richly varied and beautifully decorated. Its importance as the largest resurgence cave in the Eastern Massif, possibly draining most of the Andara region, cannot be over-emphasized. Marniosa, a major system in its own right, may well be one of the most important feeders to Agua in the Sobra valley. In addition there are also many other caves around Tresviso which, although on a much smaller scale, are still worth a visit and may yet lead to further discoveries.

The Andara region must now be regarded as one of the most important areas in Spain, if not the world, for vertical caving. Although there is much in all of the caves in this area which is awkward, strenuous or just tediously small, there is more than ample reward for future cavers who may visit them. Fallen Bear Hole and Dosser's Delight are examples of vertical caves which do not have to be spectacularly deep to be enjoyed while Sara, Tere, Flowerpot and 56 will all provide serious challenges for well organised expeditions of experienced cavers, as well as moments of fascination and splendour for those to whom caving is more than just a sport.

For those of us who have spent one or more of the past nine summers exploring these caves there will always be the memories of those exciting moments of new and sometimes spectacular discoveries, of trips good and bad, of successes and failures and of good times had with fellow cavers and with the people of Tresviso and Sotres. For the explorers of the future there is still the lure of new discoveries which must surely await those who are determined to find them. Perhaps these will yet lead to that elusive link between the deep systems of Andara and La Cueva del Agua.

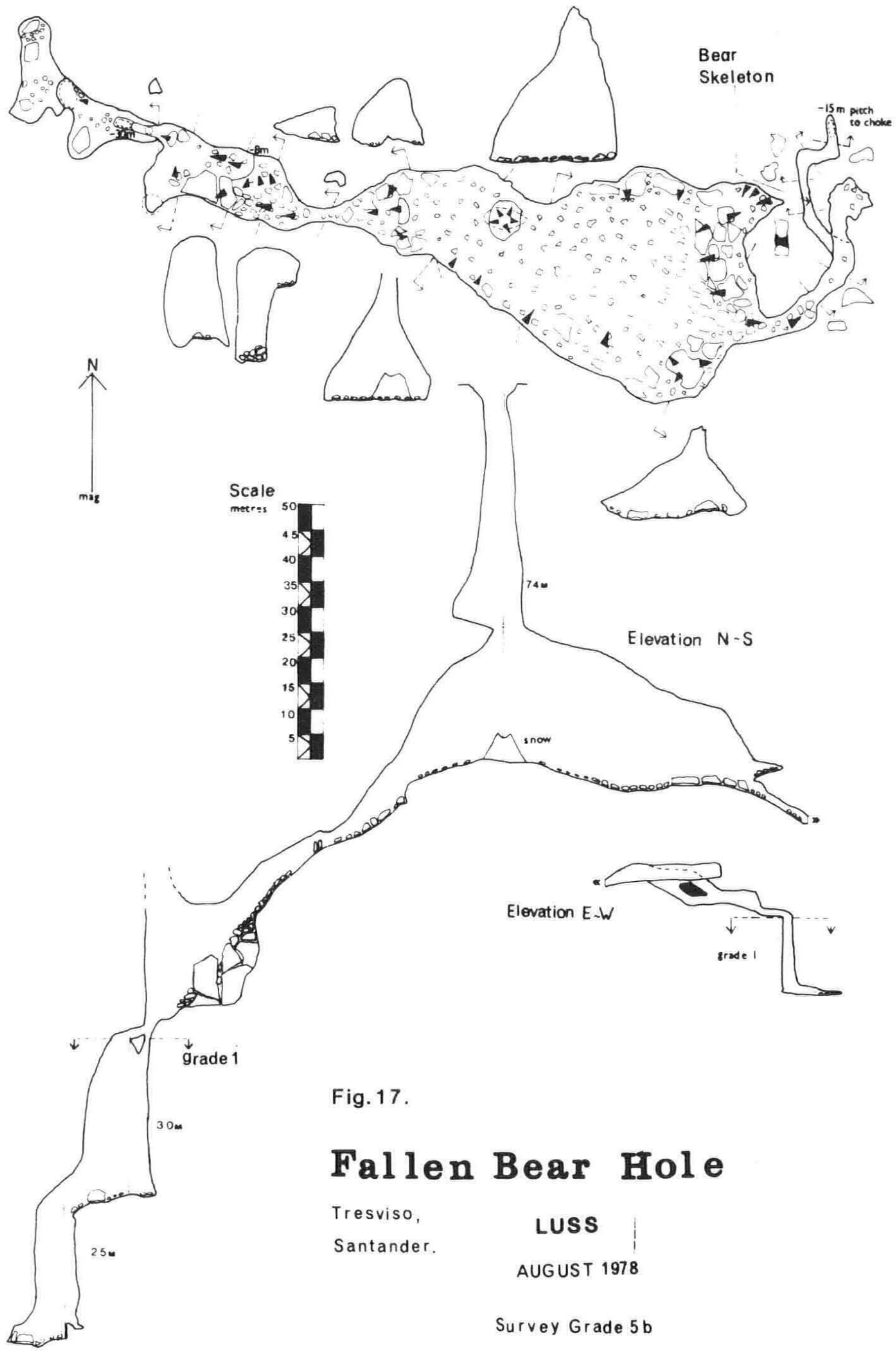


Fig. 17.

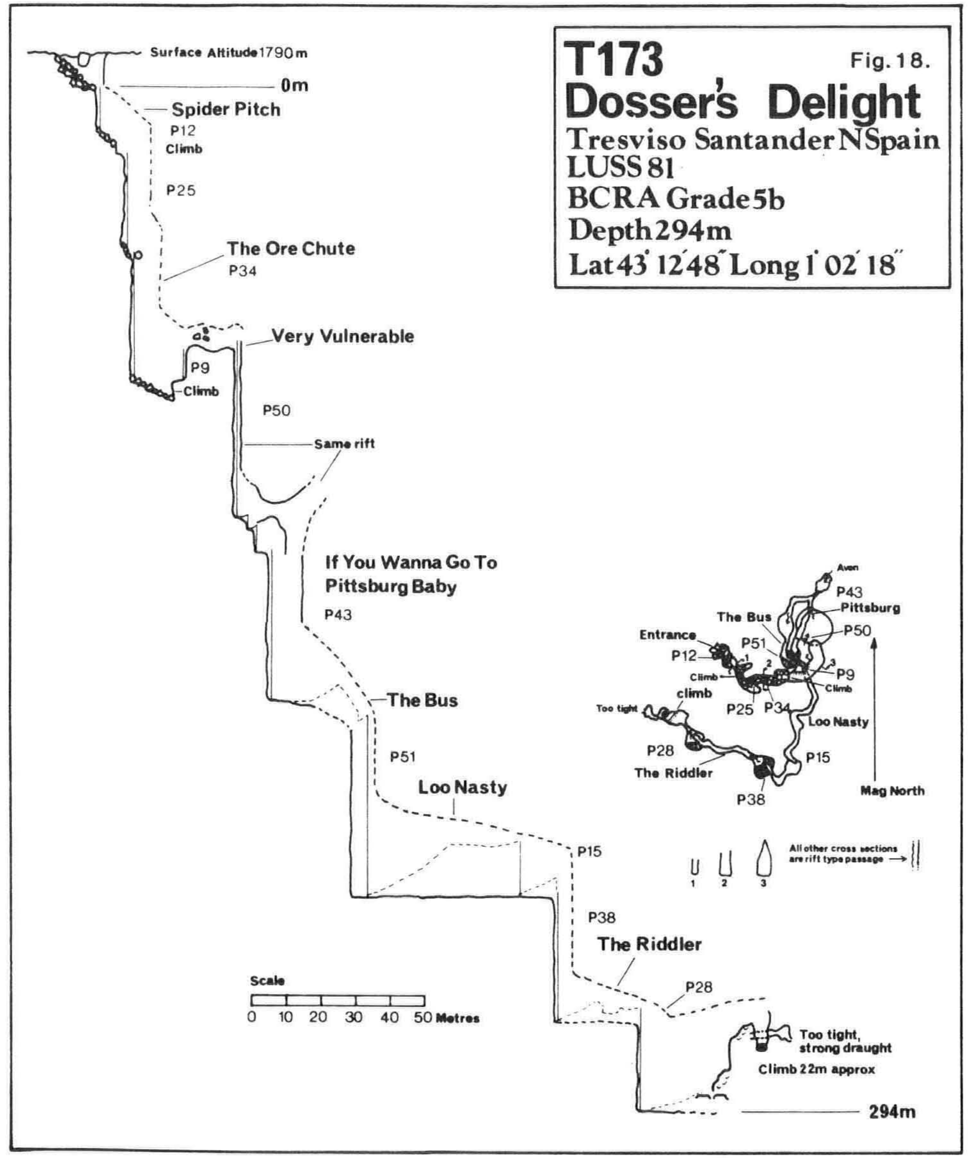
Fallen Bear Hole

Tresviso, Santander.

LUSS

AUGUST 1978

Survey Grade 5b



T173 Fig. 18.

Dosser's Delight

Tresviso Santander N Spain

LUSS 81

BCRA Grade 5b

Depth 294m

Lat 43° 12' 48" Long 1° 02' 18"

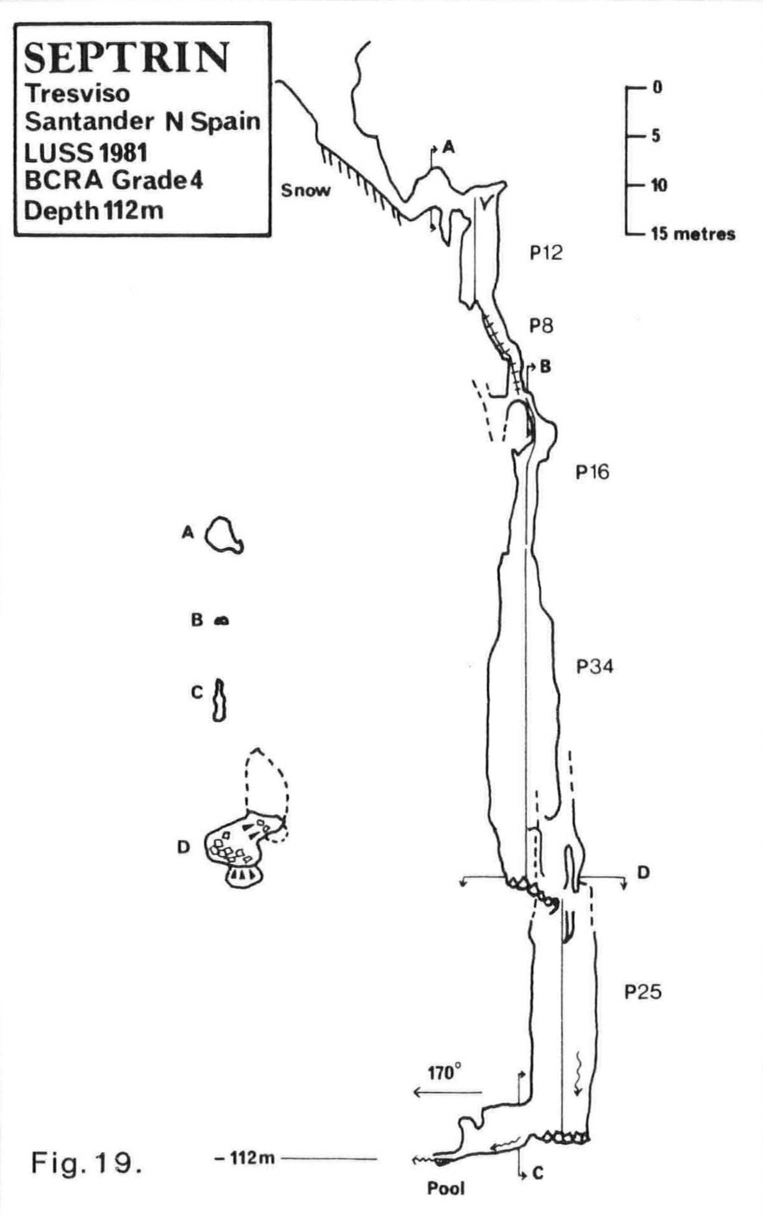

SEPTRIN
Tresviso
Santander N Spain
LUSS 1981
BCRA Grade 4
Depth 112m
Snow
A
P12
P8
B
P16
P34
D
P25
170°
C
Pool
-112m
0
5
10
15 metres
A
B
C
D

Fig. 19.

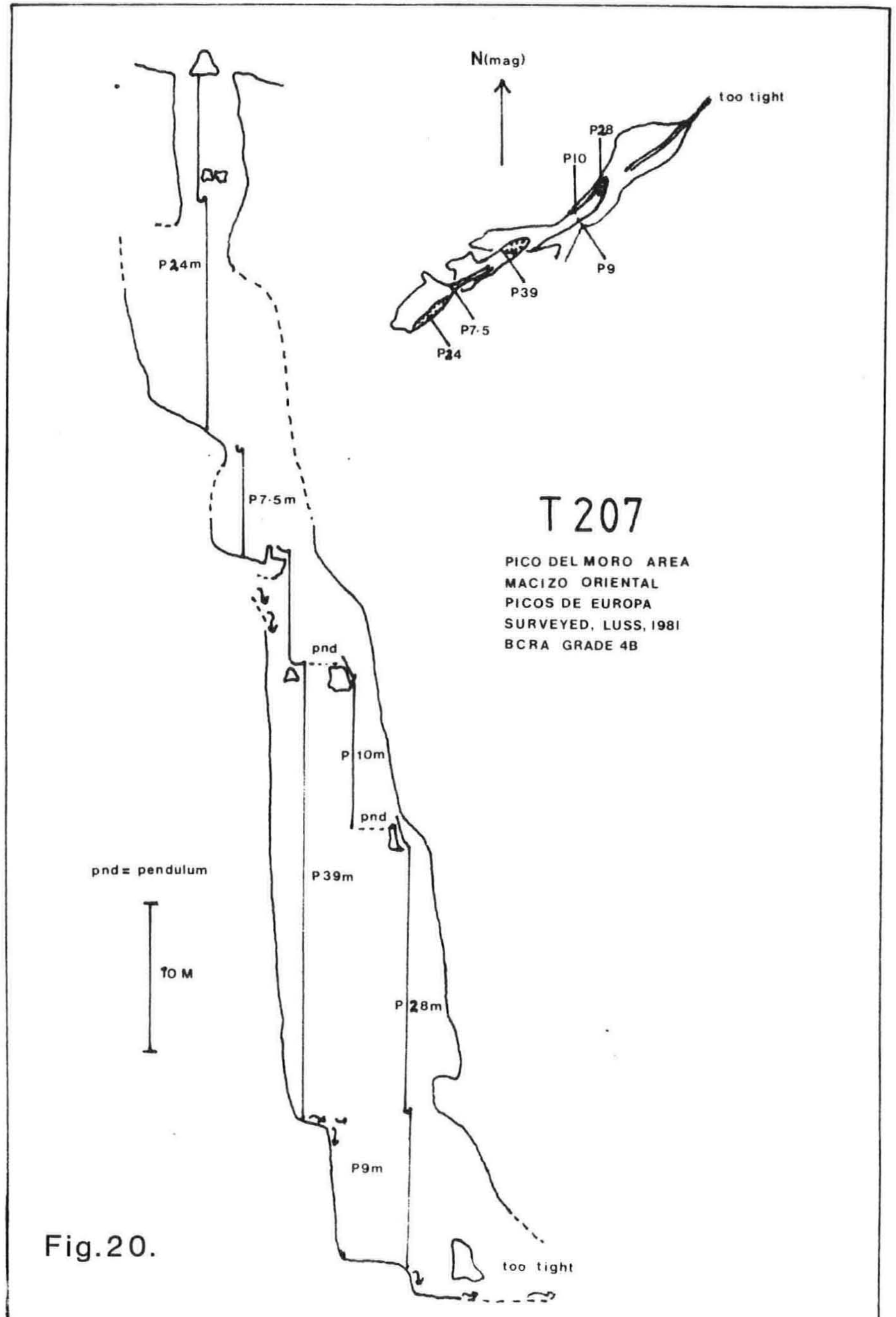

N(mag)
too tight
P28
P10
P9
P39
P7·5
P24
P24m
P7·5m
pnd
P10m
pnd
P39m
P28m
P9m
too tight
pnd = pendulum
10 M
T 207
PICO DEL MORO AREA
MACIZO ORIENTAL
PICOS DE EUROPA
SURVEYED, LUSS, 1981
BCRA GRADE 4B

Fig. 20.

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CAVE SCIENCE

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THE GEOLOGY, GEOMORPHOLOGY AND SPELEOGENESIS OF THE EASTERN MASSIFS, PICOS DE EUROPA, SPAIN

by Peter L. Smart

Abstract

In excess of 1000 m of limestones of Carboniferous age are developed in the Eastern Massif of the Picos de Europa and are overlain unconformably by Permian sandstones and shales. The structure is complex with ENE to WSW thrust faults repeating parts of the Carboniferous sequence. The area was elevated on the northern flank of the Cantabrian Mountains and major rivers have been deeply incised after stripping of the Mesozoic cover. During the Quaternary, the Picos de Europa were glaciated and cirque development gave rise to major high-level closed basins, which concentrated glacial meltwater into pre-existing caves. These shaft systems, which contain ancient high-level phreatic passages, are often lithologically perched and exhibit multiple phases of development. The resurgence systems are equally complex, but rapid base-level lowering causes abandonment of the phreatic passages before extensive vadose modification.

INTRODUCTION

This paper describes the geology and geomorphology of the Andara/Tresviso area in the Eastern Massif of the Picos de Europa. The work was conducted in co-operation with cavers from the many Lancaster University Spelaeological Society expeditions to the area, whose continuing assistance is gratefully acknowledged. Further details of the study area and the cave systems discussed are given in the accompanying compilation by Sefton (1985).

GEOLOGY

The geology of the Sotres/Treviso area has been mapped and described by Martinez-Garcia (pers.comm.). The oldest rocks are of Middle Cambrian age, and form a limited outcrop in the valley below Sotres. The karst is however developed on a thick sequence of Carboniferous rocks, greatly affected by thrust faulting, and capped in places by unconformable Permian deposits (Fig. 1). The Carboniferous sequence (Table 1) commences with the Genicera Formation of Viséan age, which comprises 10 to 40 m of red nodular limestones, interbedded with red and green shales and radiolarites. It is well exposed in the Lake Depression, where it forms the basal member of the thrust-sheet exposed in the cliffs of the northern wall. The Genicera Formation passes gradually upward into unfossiliferous, laminated, foetid limestones, the lowest parts of which are often cherty and sometimes spectacularly brecciated. This is the basal unit of the Caliza de Montaña, and is up to 350 m thick. Above, more massive, coarse-grained grey fossiliferous limestones are developed, giving a total thickness of some 500 m. Carbonate deposition continued with the overlying Picos de Europa Formation, 500 to 600 m thick, and also subdivided into two units. The lower unit varies from 0 to 100 m thick, and comprises dark, fine grained, laminated limestones with some chert (similar to those of the Caliza de Montaña), interbedded with dark marly shales up to 50 cm thick. The upper unit, which is extensively exposed in the Sierra de la Corta, is composed of massive white fine-grained limestones, interbedded with bioclastic limestones containing crinoids, brachiopods, foraminifera and bryozoans. Towards the top of the succession, distinctive pink stained and grey brecciated limestones occur. These are frequently interbedded with nodular limestones which wedge out rapidly laterally. The top of the Picos de Europa Formation is Upper Westphalian (late Muscovian or early Kasimovian) in age.

Table 1 LITHOSTRATIGRAPHIC SEQUENCE OF THE EASTERN MASSIF, PICOS DE EUROPA

(Pre-Carboniferous rocks are of limited extent and are therefore omitted)

Formation	Thickness m	Lithology
PERMIAN		
Sotres Fm.	130	Green shales
	100	Chocolate brown to red sandstones and shales, limestones and black shales.
CARBONIFEROUS		
Cavandi Fm.	700	Sandstones and turbiditic black shales with calcareous conglomerate.
Puentellés Fm.	30-500	Dark generally fine-grained, sometimes siliceous limestones.
	5-8	Black shales and sandstones.
Picos de Europa Fm.	400-500	Pink stained and grey brecciated limestones. Massive white fine-grained and bioclastic limestones.
	100	Dark fine-grained limestones and shales, some chert.
Caliza de Montaña Fm.	150	Massive coarse-grained grey fossiliferous limestones.
	350	Unfossiliferous dark laminated limestones, cherty and brecciated at base.
Genicera Fm.	10-40	Red nodular limestones with red and green shales.

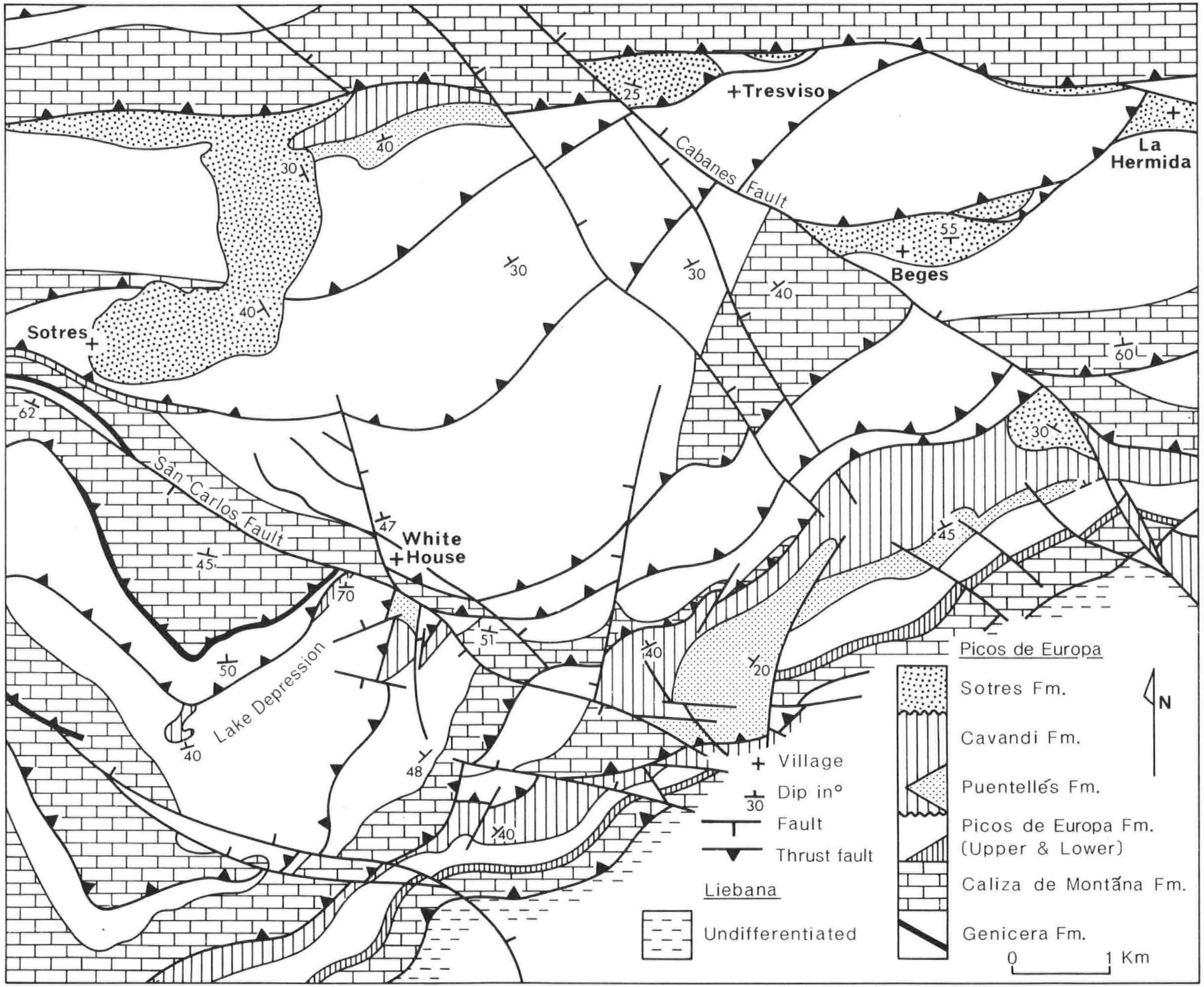

Figure 1 : Solid geology of the Sotres-Tresviso-Andora area.

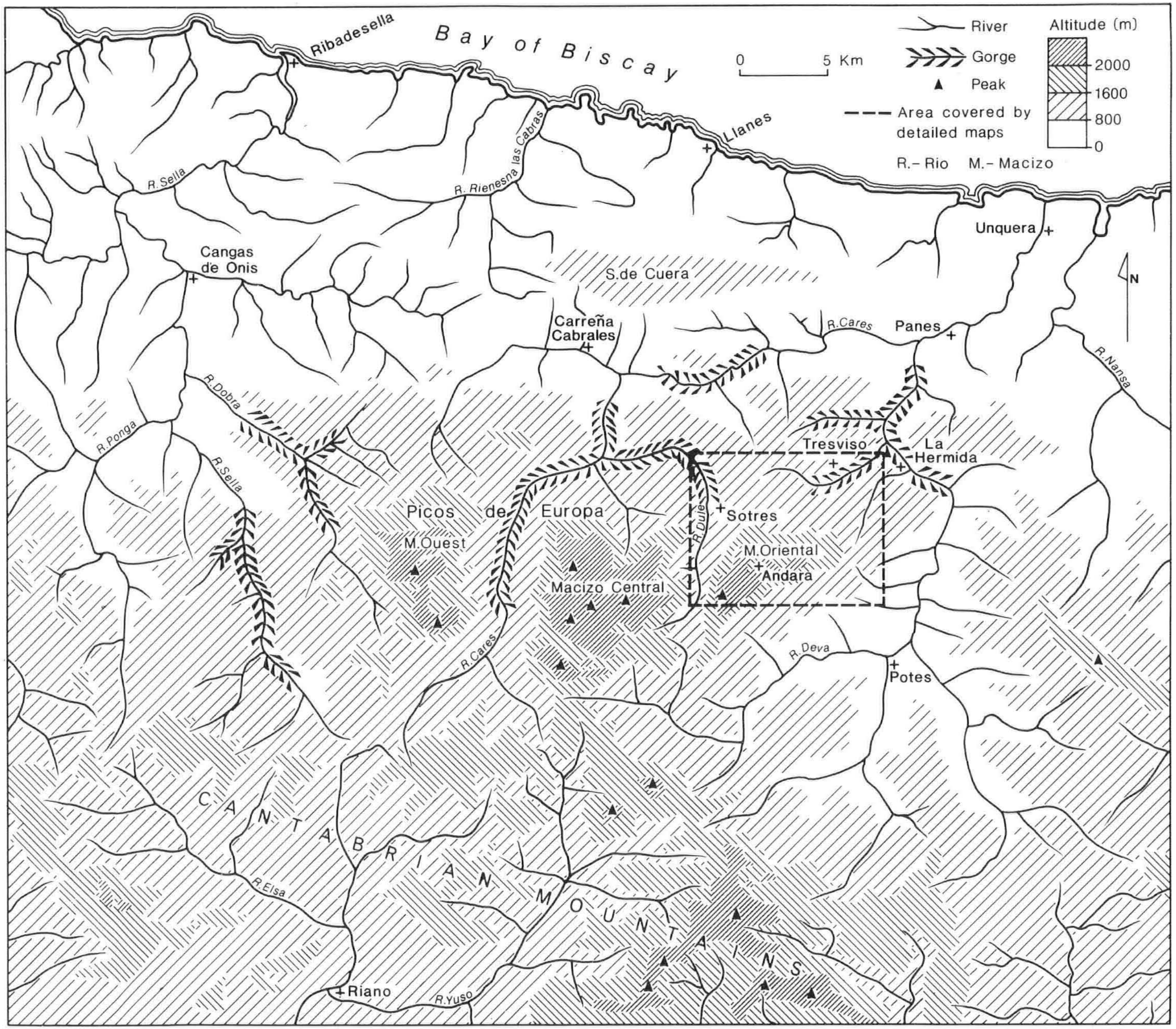

Figure 2 : Topography and drainage of the area around the Picos de Europa.

After a break in sedimentation, 5 to 8 m of sandstones and black shales precede more carbonate deposition in the Puentellés Formation (Uppermost Carboniferous) which may be seen in the floor of the Sara Depression. This consists of bedded and generally dark fine-grained limestones, which thicken northward from 30 to 500 m. It is overlain by a thick terrigenous unit of alternating sandstones and black turbiditic shales, the Cavandi Formation, which includes some calcareous conglomerate units.

Following folding uplift and erosion in the Variscan orogeny, Permian sediments were deposited unconformably on the Palaeozoic rocks. These are mapped as the Sotres Formation, and are crossed by the track from Sotres to the Sobra Valley. The most prominent unit is an interbedded sandstone and shale sequence with a distinctive chocolate brown to red colour. In the upper parts, the shales become dominant, and are of a green hue, while below up to 100 m of limestones interbedded with black shales are found. The total thickness is 230 m.

The area was strongly deformed during the Variscan orogeny, at the end of the Carboniferous period, when north/south compression caused the development of a complex sequence of folds and thrust sheets in the area. The incompetent Genicera Formation sometimes forms the base of the thrusts but frequently the planes of dislocation appear to transgress the bedding, and occur as far up the carbonate sequence as the Picos de Europa Formation. To the north, the thrust planes are steeply inclined, due to a later phase of deformation and were reactivated in post-Permian times, isolating the Permian units at the head of the Sobra Valley and north of Tresviso. In the Andara area, some of the planes are at a lower angle, and fragments of the Puentellés and Cavandi Formations at the top of the limestones are included. These are particularly extensive south of the major east/west topographic divide, but it is difficult to determine the attitude of the thrust planes, so it is not known if this impermeable formation underlies the Andara area.

In addition to the movement on thrust planes, sub-vertical faulting has also occurred with a major trend between 106° and 120° with orthogonal minor faults. The San Carlos Fault, which crosses the Andara area, is typical of these faults, with at least two phases of movement involving both horizontal and vertical components. Unlike the other major fault line (the Cabañes fault passing to the west of Beges and Tresviso) the San Carlos Fault is very complex, sub-dividing into subsidiary splay faults and reactivating pre-existing high-angle thrust planes. Overall, there appears to have been a dextral shear component, with uplift on the western block in both these major discontinuities. The fault planes are often brecciated, and have allowed the movement of mineralising solutions, giving rise to the sphalerite and galena deposits worked by miners in the area. There appears to be a close association between the presence of Permian capping deposits and the extent of the mineralisation.

GEOMORPHOLOGY

1) Evolution of the Relief.

The Picos de Europa form an upstanding massif on the flanks of the Cantabrian Mountains (Fig. 2). The area has been progressively elevated during Plio-Pleistocene times, and stripped of the Mesozoic cover, which remains intact only in down-faulted troughs (as above Sotres), or to the north and north-east, where there has been less uplift. The major surface rivers have developed down this regional gradient towards the north coast, and have been superimposed onto the Carboniferous strata from the overlying Mesozoic rocks. Both the Rio Cares and the Rio Deva were sufficiently powerful to maintain their courses by incision into the rising limestone massif, cutting deep and spectacular gorges through the limestones. Above the gorge at La Hermida, the Rio Deva has readily eroded the soft shaley rocks of the Liebana unit around Potes, capturing the headwaters of the Rio Duje, and giving rise to the remarkable contrast in elevations between Potes and Andara seen today.

During cold phases of the Quaternary, the Andara area acted as a local centre of ice accumulation (Fig. 3). The extensive rounding of rock surfaces and the lateral moraine followed by the White House road at Collado Bareda are clear evidence of its geomorphic effects. The ice accumulated primarily in the Sara and Lake Depressions, eventually over-riding their northern margins, and forming two valley glaciers in the Valdiezmo and La Llama valleys. The termination of the latter is marked by extensive morainic deposits. In the case of the Valdiezmo glacier, there is a marginal moraine in the mouth of the Sobra Valley, but remains of the terminal moraine have not been preserved on the steep cliffs at the head of the Urdon Gorge. Recessional phases, when the ice had retreated back to the major depressions, are marked by accumulations of outwash, and undercutting of the earlier cliff lines.

The major depressions are therefore glacial cirques, formed on the northern slopes of a major ridge, where insolation is limited. Snow accumulation may also have been favoured by the existence of karst depressions prior to glaciation. The depression floors have been deepened and elongated along the outcrop of the densely fractured, weak shales of the Puentellés Formation, attesting to the significance of mechanical erosion in the glacial action. However, depression deepening may also have been assisted by the action of basal meltwater which drained from the glacier into pre-existing karst cavities. Interglacial modification of these cirque basins is limited to solutional etching of the rock surfaces, deepening of the sediment filled surface irregularities by sub-soil solution, and infill by collapse of over-steepened and weakened rock slopes.

2) Development of the Caves.

Diffuse circulation in the limestones undoubtedly occurred at an early stage in the development of the area, as the initiation and incision of the major gorges created significant hydraulic gradients in the limestones. However, major cave development probably commenced with the exposure of the limestones from beneath the Mesozoic cover. The situation was probably rather similar to that at the present in the vicinity of Torca la Barga, with the development of stream sinks and closed depressions along the shale margins. This must have occurred earliest in the most elevated area, and it is

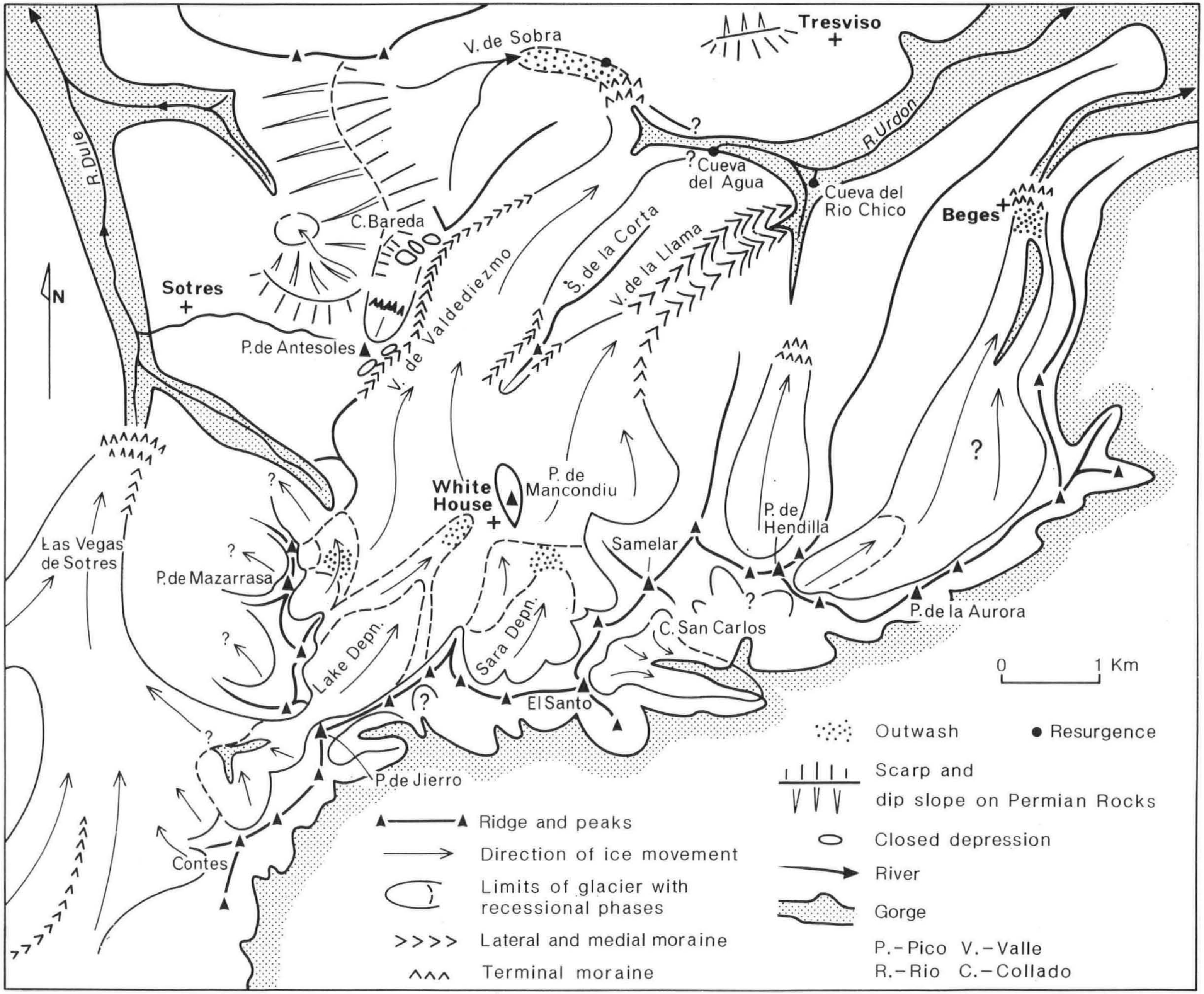

Figure 3 : The maximum extent of glaciation in the study area, derived from field mapping.

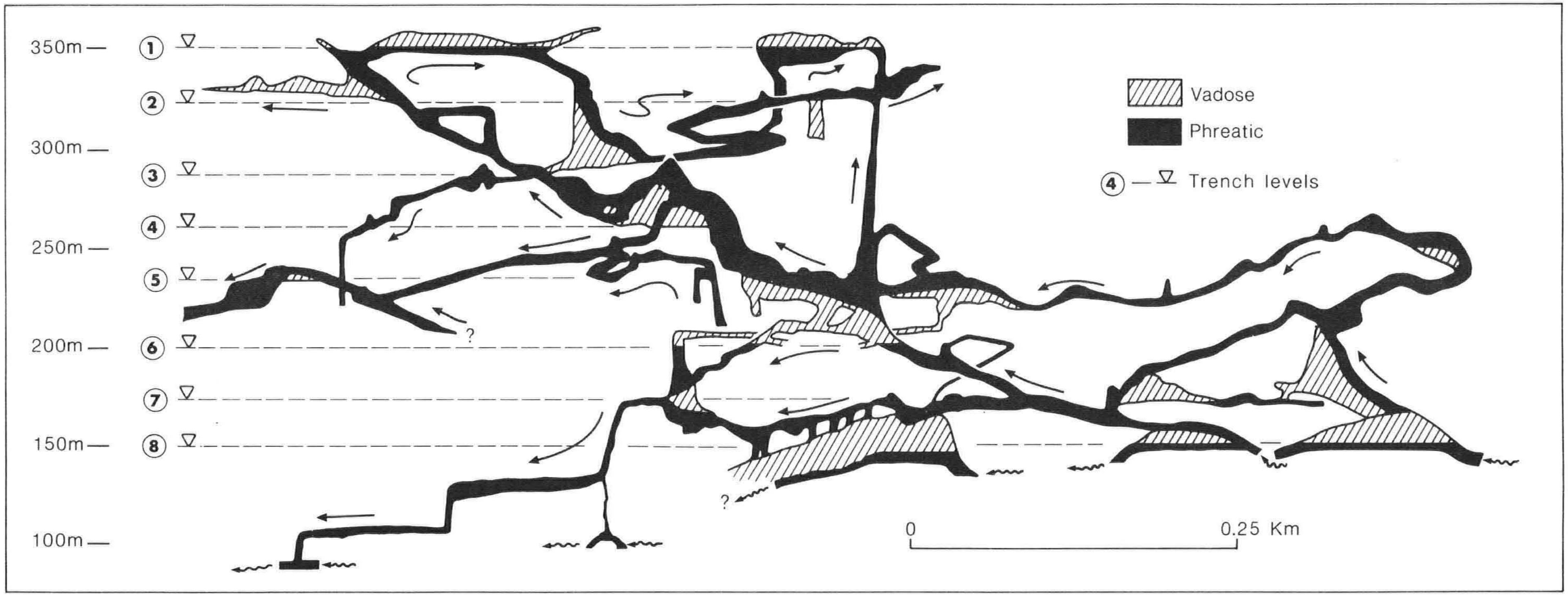

Figure 4 : Extended elevation of passages in the Grand Circle, Cueva del Agua, showing multiple phreatic phases and vadose trenches at loop crests.

therefore not surprising that 56 contains high level passages of an ancient and degraded appearance. In the vicinity of the Maze at 1660 m, there is a remarkable sponge-like network of irregular phreatic passages with sandy rotten wall rock, while the highest phreatic remnants occur at the base of Tiggers Pitch at 1884 m , 1070 m above the terminal sump, and some 1900 m above the floor of the Rio Deva gorge at La Hermida.

The present outlet for the Andara water is the Cueva de Agua, which resurges at the head of the Urdon Gorge below Tresviso. Earlier outlets were probably further downstream, associated with earlier positions of the nickpoint. The huge stalagmite-choked chambers of Resplenda, high on the south wall of the gorge, could possibly represent such an earlier resurgence.

Cueva del Agua is developed along the strike of the beds, but individual passage segments are frequently controlled by fractures other than bedding planes, giving a pseudo-rectilinear plan form. The abandoned passages are predominantly phreatic, and rising segments are common, giving a characteristic looping elevation. In the Grand Circle, several such loops can be recognised (Fig. 4). Their sequential abandonment can be demonstrated by the presence of isolated vadose trenches developed at the highest point on each loop. These define the water-surface elevation in the active conduit. As base-level fell, there was insufficient head to operate the higher loops, and lower phreatic passages became the major active conduits. Uranium series dating of speleothems from such passages suggests that the long-term rate of base-level lowering is about 0.3 m/ka, a very high value.

The efficacy of the development of the lower phreatic passages is partially due to the steep hydraulic gradients, which can drive water through the immature phreatic routes. The present streamway has, for example, a gradient of 170 m/km (straight line distance). Such high values are caused by the rapidity of base-level lowering, which does not permit adjustment of the cave passages to a particular elevation, as is amply demonstrated by the perched resurgence of the Cueva de Rio Chico. In Cueva del Agua, the present streamway has as yet insufficient capacity to accommodate the seasonal high flows associated with snow-melt. The smooth clean-washed walls of the passages in the Black Hole, 20 m above the streamway, and the fretting and pot-holing of the floor offer abundant evidence of the continuing modification of this abandoned phreatic passage. The overall rate of vadose erosion must however be low, otherwise more extensive trenches would be observed. This may well relate the the ephemeral nature of such high flows, and the limited aggressiveness of the water involved. Estimates obtained from uranium series analyses of speleothems on the walls of active trenches in both Cueva del Agua and Cueva de Marmiosa indicate vadose erosion rates of 0.1 to 0.15 m/ka.

The depth of the vadose zone has increased progressively, because base level (controlled by incision of the gorges) has fallen more rapidly that the general rate of surface lowering of the limestones in the Andara area. The vadose zone is now in excess of 1000 m deep and is traversed by several extensive, surveyed cave systems, some of which lead to active streamways. In contrast, relatively few systems of any size are known elsewhere in the area, except where recharge is concentrated into sinking streams on the margins of the impermeable Permian rocks, for instance, at Torca la Barga. Whilst it is true that location of entrances in the areas of bare limestone is easier than in the beech woods at lower elevations, and that mining activity has greatly assisted access in the Andara area, there are two possible geomorphological explanations. Karstification has proceeded for a greater time in the Andara area, thus there has been time for the development of extensive and complex vadose systems, even with the slow rate of erosion. In 56, it is clear that there are many different phases of vadose development, with capture of earlier trenches into more recent developments (for instance, just beyond Humbug Hall), multiphase trenches, and invasion shafts. However, the glaciation of the major depressions is probably of greater importance. The glaciers concentrated basal meltwater in the floor of the depressions (the topographically lowest position in the cirque) where it drained underground into shafts. This is particularly noticeable in the high-altitude depression south of Pico Jierro where numerous shafts are found in the base of the cirque depressions. The huge 281 m deep Heinous Shaft in Sara, which takes very little water at present, is thus an essentially fossil sub-glacial drain, formed when much larger volumes of water passed underground at this point. The sub-glacial origin also explains the formation of shafts at points which receive no significant present drainage, such as Tiggers Pitch at the entrance to 56. Ice flowing northward over the present edge of the Lake Depression was buckled and deeply creviced, directing surface meltwater to the glacier base at this point. Similarly, the numerous shaft systems such as Flower Pot in the Moro Depression, are formed on the rear walls of the cirques, where meltwater penetrates down the bergschrund.

The vadose caves are predominantly shaft systems due to the great depth of the unsaturated zone, although lower gradient sections such as the Sara streamway are found. These are associated with lithological perching, as, for instance, in the Crumbles in 56, which is held up by thick tabular cherts. However, many of the known systems do not demonstrate lithological perching as they are developed down vertically extensive fractures in the vicinity of the San Carlos fault zone. The complex superimposed shafts of Tere, which are known to cut through quite thick shale horizons, are probably the best illustration of this effect. In other areas, the passage may develop down-dip, guided by such shale bands. The Aberfan pitches in 56 have a bedding roof sloping at 60° developed above a thick black earthy shale. However, in 56 much of the known passage ignores the general attitude of the beds, and is controlled by abandoned phreatic passages, developed along joints and other fractures. The complex of multi-level canyons and multiple active streamways in the Humbug Hall area provides a classic example. Different routes have been developed at different times as the location of inputs has changed, and new routes have been opened from the floor of existing passages. Because of the antiquity of the caves, and the changes of input associated with glaciation, a bewildering complexity of vadose passages has developed, the current active route often being the most immature and poorly developed.

CONCLUSIONS

It has not been possible in this brief overview to present full and detailed evidence relating to the points discussed. Nevertheless, it is clear that the caves of the Picos de Europa have a very long and complex history, which is strongly affected by the repeated Quaternary glaciations of this area. More detailed work on the hydraulics and morphology of the cave systems, and their present-day erosion rates, is now necessary to quantify this effect.

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PALAEOKARSTS IN BRITAIN

Trevor D. Ford

ABSTRACT

The evidence within the stratigraphic record for the former presence of ancient karstic surfaces or underground features in Britain is reviewed. Bare or covered palaeokarsts occur with the Carboniferous Limestones of Derbyshire, the Mendip Hills, South and North Wales, and Yorkshire. Features of subterranean hydrothermal karst are present in Derbyshire and the Mendip Hills. Sub-Triassic "fissures" with vertebrate bones and plants are recorded in Somerset, Avon and South Wales. Similar features of early Jurassic age are present in the same areas, coupled with phenomena associated with marine planation. Solution pipes are widespread in the upper surface of the Chalk. A palaeokarst with solution collapse structures is noted from Cambrian limestones in Northwest Scotland.

INTRODUCTION

If palaeokarst is defined as the record of development of karstic landforms, either surface or underground, in any erosion cycle prior to the present, then it is widespread in the Carboniferous Limestone outcrop areas of Britain. Palaeokarstic features are particularly well developed in the Peak District of Derbyshire, in Wales and the Mendip Hills of Somerset. Published studies of palaeokarst in these areas are few and the studies have generally been made as a side-line to other aspects of stratigraphic or sedimentary history. A number of other areas have more limited palaeokarsts in rocks ranging in age from Cambrian to Cretaceous. Each area is considered separately.

Karst surfaces may be classified as (a) bare or uncovered karst, i.e. that which develops on a fully exposed limestone surface; (b) covered karst, i.e. that which develops under a cover of soil or other superficial deposits; (c) interstratal karst, i.e. that which develops by solution along a bedding plane or unconformity after the overlying beds have been deposited; and (d) buried karst, i.e. any of the above buried by younger strata after development. Most of the palaeokarsts discussed herein fall within category (b) in their genesis though they are now seen as within (d) owing to their being within the stratigraphic record. Some instances of interstratal karst are also considered herein.

THE PEAK DISTRICT OF DERBYSHIRE

Erosion surfaces within the Carboniferous Limestone and palaeokarstic features developed subsequently in the Peak District have been described previously by the present author (Ford, 1964, 1969, 1972, 1977); by Walsh et al (1972), Walkden (1974,1977, 1981) and Oakman (1984) (Fig.1.). The outcrop is some 40 km long from north to south and 15 km wide. The stratigraphic sequence of beds exposed totals some 500 m but at least another 1100 m are known from a deep borehole (Dunham, 1973). The base of the limestones is thus nowhere visible. The exposed sequence presents a wide variety of lithofacies broadly referrable to a palaeogeography of marginal reef complexes around the fringes of the outcrop and lagoonal calcarenites in the centre. The contemporary deep water facies outside the reefs is poorly exposed. Dips are generally low and do not often exceed 15°, but gentle folding on east-west axes in the east, and north-south axes in the west yields a complex outcrop pattern. Intermittent vulcanicity is manifested as a series of basaltic lava flows and tuffs interbedded with the limestones (Walters and Ineson, 1981; Ineson and Walters, 1983). Thin tuff horizons, usually less than 30 cm thick, are frequently present between the thicker lavas (Walkden, 1974).

Limestone sedimentation in the British Carboniferous was demonstrated by Ramsbottom (1973) to have proceeded as a series of cyclic transgressions and regressions reflected in cyclic changes in lithological characters and fossil content. Each cycle in theory can, at the time of maximum regression of the sea, result in exposure of the lime sediment surface. If the relative uplift is sufficient, erosion may occur with the consequent development of either palaeosols in the uppermost bed of limestone in each cycle or of surfaces characterized by karren,dolines and possible cenotes. Palaeosols have been shown to exist by the presence of sedimentary textures, rhizoliths, hard grounds and early diagenetic fabrics. Cyclic supratidal to intertidal sedimentation has been demonstrated through some hundreds of metres of beds in limited areas and almost every bedding plane in the Wirksworth area is a palaeosol or palaeokarst (Oakman,1984). Subaerial diagenesis yields an indurated caliche-like topmost few cms of each limestone bed. Karren appear to have developed on some such surfaces but are hard to determine and are often present only as macro-stylolite seams (Plate 1). Sedimentary cycles with caliches and palaeokarsts may be an expression of slow intermittent subsidence to only shallow depths. Many palaeokarst surfaces are associated with thin tuff horizons and these too provide evidence of palaeosols sometimes with evidence of a plant cover (Pl.2). Soil acids seem to have percolated into the underlying limestone locally with potholes up to 30cm in diameter and 1 m deep. (plate 3). Both tuffs and lavas often rest on otherwise undisturbed indurated limestones which Ineson & Waters (1983) have taken to indicate emergence before eruption. Indeed it may be that uprising magma caused local crustal swelling resulting in minor temporary uplift. In a few localities there are pits up to 10m wide and deep full of collapsed lava and limestone boulders and these may represent ancient cenotes.

Palaeosols and other diagenetic phenomena, usually associated with thin tuff horizons have been noted elsewhere in Derbyshire (Walkden, 1974). Adams (1980) has noted palaeosol development and diagenetic textures in limestones near Monyash as evidence of minor emergence in late Brigantian reefs. Calcarenite cyclothems in the Crich inler are similarly capped with palaeosols (Bridges, 1982).

Whilst no major present day karstic landforms can be interpreted as being inherited from the above processes, these stratigraphic interruptions to a continuous limestone sequence have undoubtedly provided pathways for percolation water in later erosion cycles and cave development has ensued at some levels. Initiation of some major phreatic tubes in the Castleton area may well have utilised such ancient palaeosols. For example, the Peak Cavern controlling bedding plane is on a clay some 5 cm thick at most and in places with a trace of a coal seam 1 cm thick.

Intermittent tectonic uplift of the limestone massif has also resulted in disconformities with more strongly developed 'potholed surfaces'. Walkden (1977) has described scoured erosion hollows in Millers Dale associated with local unconformities. Whilst they are palaeokarstic surfaces, they have not been shown to be of any wide extent and have not apparently been related to later cave development.

Post-Dinantian uplift and erosion

At the end of Dinantian times, carbonate sedimentation in the Peak District was brought to an abrupt halt by uplift with considerable erosion of parts of the limestone massif before resubmergence and unconformable cover by the advancing deltaic sediments of Namurian age. In both the Castleton and Upper Dovedale areas perhaps as much as 100 m of the upper beds of limestone were eroded from the marginal reef complex though further south the contemporary lagoonal sediments were preserved in downwarps. The eroded surface of the reef limestone complex around Castleton has fissures full of limestone boulders in a matrix variously of finely comminuted limestone or of shale, or of mixtures of these. They can be regarded as deep karren filled in during the Namurian transgression. Lower down the slopes, massive boulder beds accumulated as the debris from erosion of reef crests slid down into the deeper waters of the basin (Simpson and Broadhurst, 1969) (Fig. 2). Single blocks of transported limestone may reach 5 x 5 x 5 m in size, and voids beneath these were common. Some such voids became filled with finer matrix of either comminuted limestone or of shale, whilst others remained open for later processes to act upon, including both hydrothermal mineralisation and speleogenesis. The reef limestones beneath the erosion surface were at the same time subject to karstic drainage with the development of small phreatic tube cave systems. These were subsequently exploited by the mineralising fluids and infilled with Blue John fluorspar deposits.

Two kilometres east of Castleton, in the Blue Circle Cement works quarry, quarrying has breached a number of cavities in the limestone surface. These penetrate downwards through the topmost Brigantian beds by as much as 10 metres. They are generally vertical sided, oriented along joints rather than faults or veins, and are filled with brecciated Namurian shale, some weathered to a brown colour and some still fresh. The mode of transport of the shale is unclear and the occurrences may signify either the penecontemporary fill of dolines in the limestone surface soon after re-submergence by the Namurian sea, or interstratal solution at some subsequent date causing solution collapse of the shale cover. Indeed, there may well have been a combination of both factors operating here. Collapsed caves with fallen limestone blocks covered

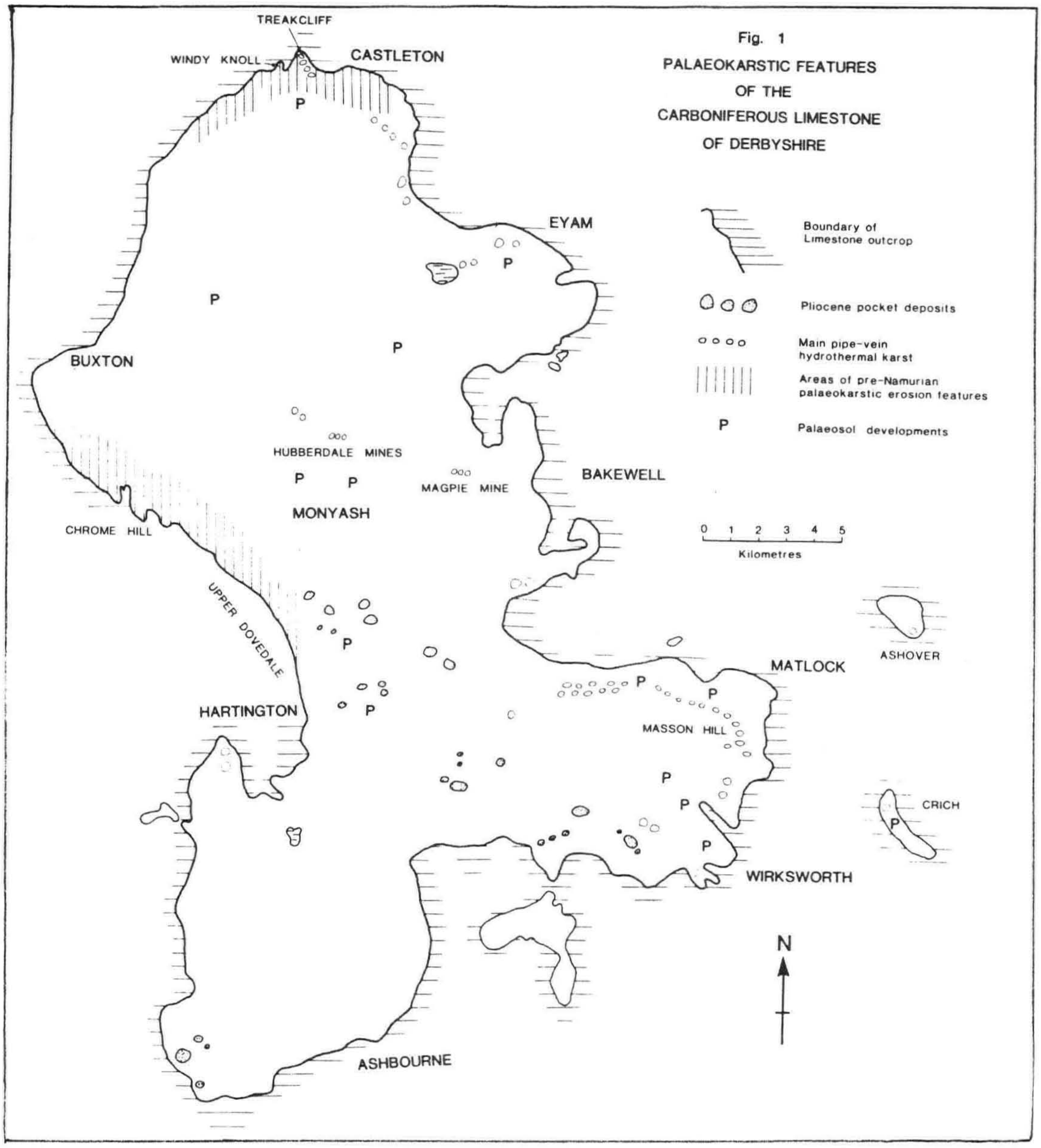


Fig.1. Sketch map showing the distribution of palaeokarstic features in the Carboniferous Limestone of the Peak District, Derbyshire.

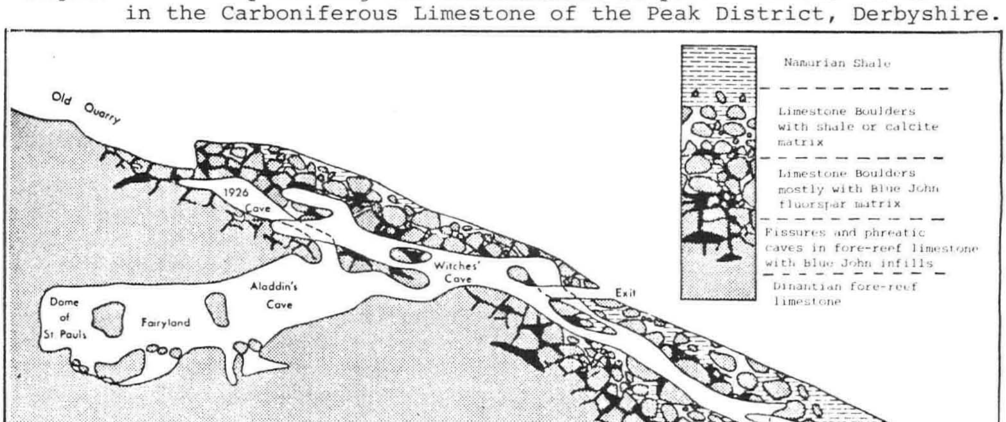


Fig.2. Diagrammatic section of Treak Cliff, Castleton, Derbyshire, showing the mid-Carboniferous boulder bed with voids filled with Blue John fluorspar. Ancient phreatic caves extending into the eroded reef limestone were similarly lined with Blue John (modified after Simpson & Broadhurst, 1969).

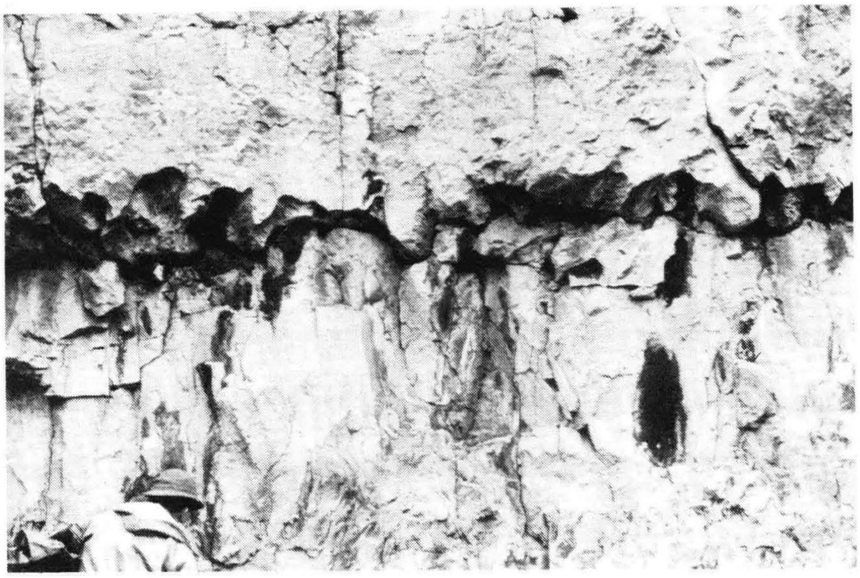


Plate 1. Large stylolites developed along a palaeokarstic surface in the Carboniferous Limestone. Peak Dale Quarry, Derbyshire.

Plate 2. Clay wayboard horizons representing ancient tuff falls in the Carboniferous Limestone. Ben Bennett's Quarry, Grangemill, Derbyshire.

Plate 3. Potholed surface revealed by stripping off a clay wayboard. Ben Bennett's Quarry, Grangemill, Derbyshire.

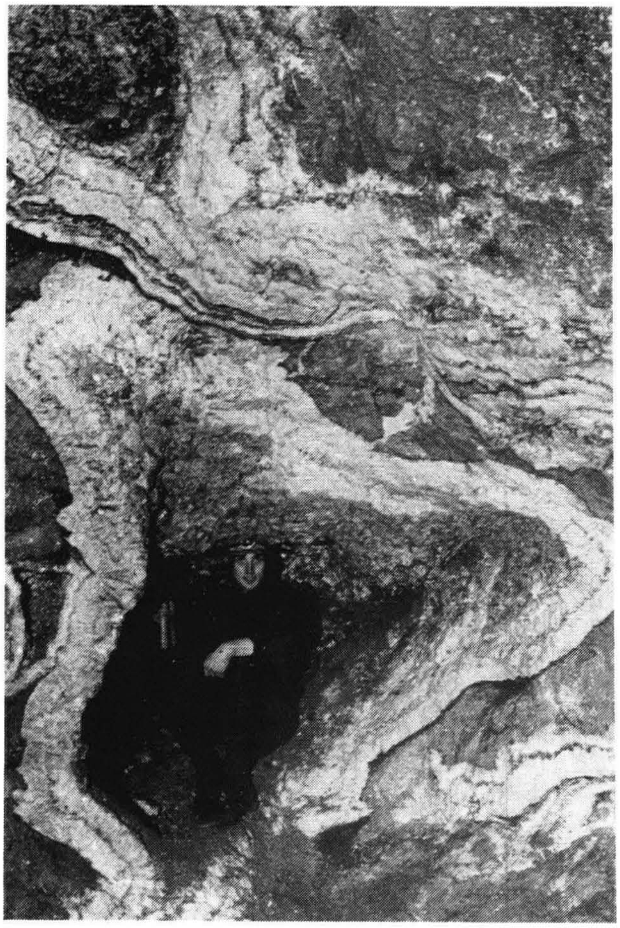


Plate 4. Calcite and sphalerite lining to a hydrothermal cavity. Magpie Mine, Derbyshire.

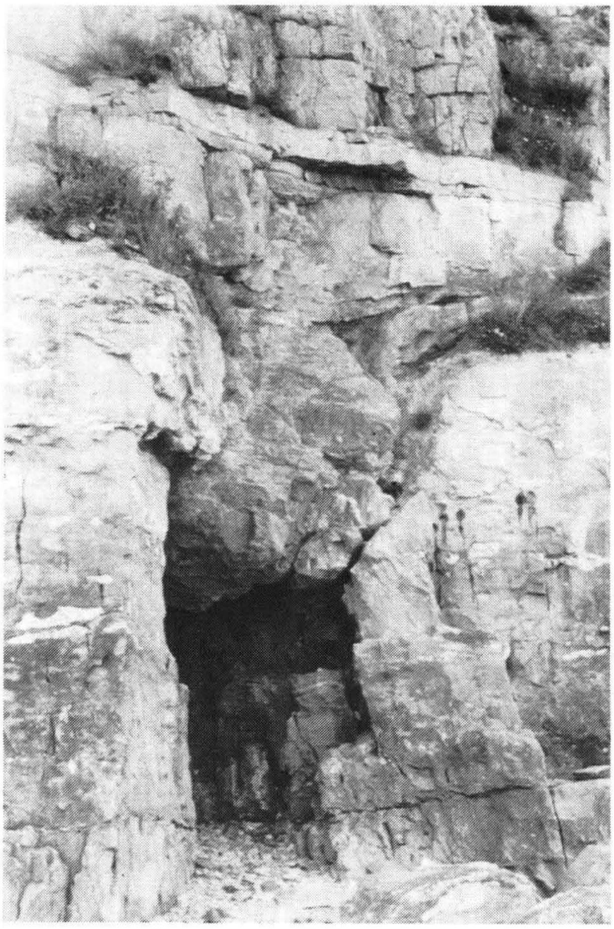


Plate 5. Sandstone-filled solution pipe in the Carboniferous Limestone, Trwyn Dwlban, Anglesey.

Plate 6. Section through hydrothermal palaeokarst cavity showing
a) calcite lining at the bottom,
b) dark precipitate of sulphide minerals on floor of cavity
c) fill of calcite with thin bands of sphalerite.
Magpie Mine, Sheldon, Derbyshire.

with fluvio-glacial silts and sands occur in the same quarry faces and indicate that solutional processes have continued into recent times, thereby suggesting that interstratal processes are more likely as an explanation for the shale-filled dolines.

Both around Castleton and elsewhere in Derbyshire rare patches of an insoluble residue of chert gravel suggest either late Dinantian or pre-Namurian weathering of the limestone surface or of interstratal solution at a later stage. The evidence is unfortunately sparse and equivocal.

Post-Carboniferous uplift and erosion

Following the first main phase of upfolding of the South Pennine anticline in late Carboniferous times, the region was subjected to erosion during Permian and Triassic times, in which a large part of the Upper Carboniferous delta-swamp sediments were removed. The evidence is sparse but it seems that a part of the southern end of the limestone massif became exposed by late Permian times and magnesium-rich brines percolated down from the evaporite-rich sea into the Carboniferous Limestone and resulted in areas of intense dolomitisation. The increased porosity has resulted in the development of karstic features at more recent dates, e.g. (1) the sub-Pliocene sink-holes, (2) caves along the dolomite-limestone boundary and (3) dolomite tors, discussed below. No actual landforms can be attributed to the Permian period. However, Triassic beds do rest directly on the limestone in a small area of the south-western part of the limestone massif. The unconformity is probably a palaeokarstic surface but it has not been described in detail.

At Breedon-on-the-Hill on the Derbyshire/Leicestershire border two inliers of dolomitized Carboniferous Limestone project through the cover of Upper Triassic Mercia Mudstone (formerly Keuper Marl). The inliers were effectively is islands in a Triassic desert lake and are variously flanked by coarse boulder breccias, screes of dolomite clasts and by Mercia Mudstone. A few fissures are filled with mudstone, sometimes with local enrichments of hydrothermal minerals. A few fissures have yielded sparse reptile bones.

Hydrothermal palaeokarst

The galena-sphalerite-fluorite-baryte-calcite deposits of Derbyshire are thought to have originated from hydrothermal solutions penetrating (a) into fault fractures and joints resulting from the late Carboniferous earth movements, (b) into favourable lithologies of limestone to yield replacement ore deposits and (c) into pre-existing cavities. The last two categories are commonly confused in Derbyshire under the local terms of 'flats' and 'pipes'. Broadly, a flat is a bedding-controlled ore-body, either by replacement or by filling a bedding cavity, whilst a pipe is any other form of cavity lined or filled by the mineral suite, often with associated metasomatic replacement. A review of processes of mineralisation has been published recently by Ineson and Ford (1982). What is more important from the palaeokarst point of view is the origin of the cavities and the processes of their formation (Fig. 3). Temperatures of mineralisation as shown by fluid inclusion studies were around 80° to 100°C and these, together with structural evidence, suggest that the limestone massif was still buried by Upper Carboniferous strata at the time of mineralisation to a depth of at least 2 km and possibly 3 km. The chemistry of the mineralising solutions indicates that they were extremely dilute, and the palaeokarstic implication is of large bodies of hot water moving through the limestone mass, probably escaping eventually at the surface as hot springs. The widespread deposition of calcite, often in freely grown crystals of large size, suggests that the hydrothermal waters were not aggressive during mineralisation, but that does not exclude an early, pre-mineralisation, aggressive phase being responsible for pipe-vein caverns.

Such hydrothermal fluid movement would exploit any geological weakness in the limestones. Faults and joints are obvious weaknesses but the more subtle ones include (a) the voids between the boulders of the pre-Namurian boulder bed, now partly filled with the Blue John variety of fluorite deposits in Treak Cliff at Castleton (Ford, 1969) (Fig. 2); (b) calcite-lined solution caverns at the boundary of porous dolomitised limestones resting on relatively impermeable unaltered limestone as in Masson Hill and the Golconda Mine (Ford and King, 1965, 1966); (c) solution cavities developed along the contacts with tuff horizons and lined or filled with hydrothermal minerals, as in Masson Hill, at Matlock and many other localities and (d) cavities developed from stromatactis porosity in buried reef limestones as in the Blende Vein cavern in Magpie Mine (Worley, 1976)(Plates 4 & 5). These and other types of hydrothermal mineralisation karst are illustrated in Fig. 3. Circulation of groundwater in these has, at various subsequent stages, resulted in their re-utilisation as phreatic drainage pathways, with resultant collapse of the mineral linings into alluvial breccias in the bottoms of pipes. Still later the introduction of allochthonous surface sediments in either paraphreatic or vadose conditions has modified the hydrothermal palaeokarstic features and has resulted in the mixture of the insoluble mineral residues with the inwashed sediments.

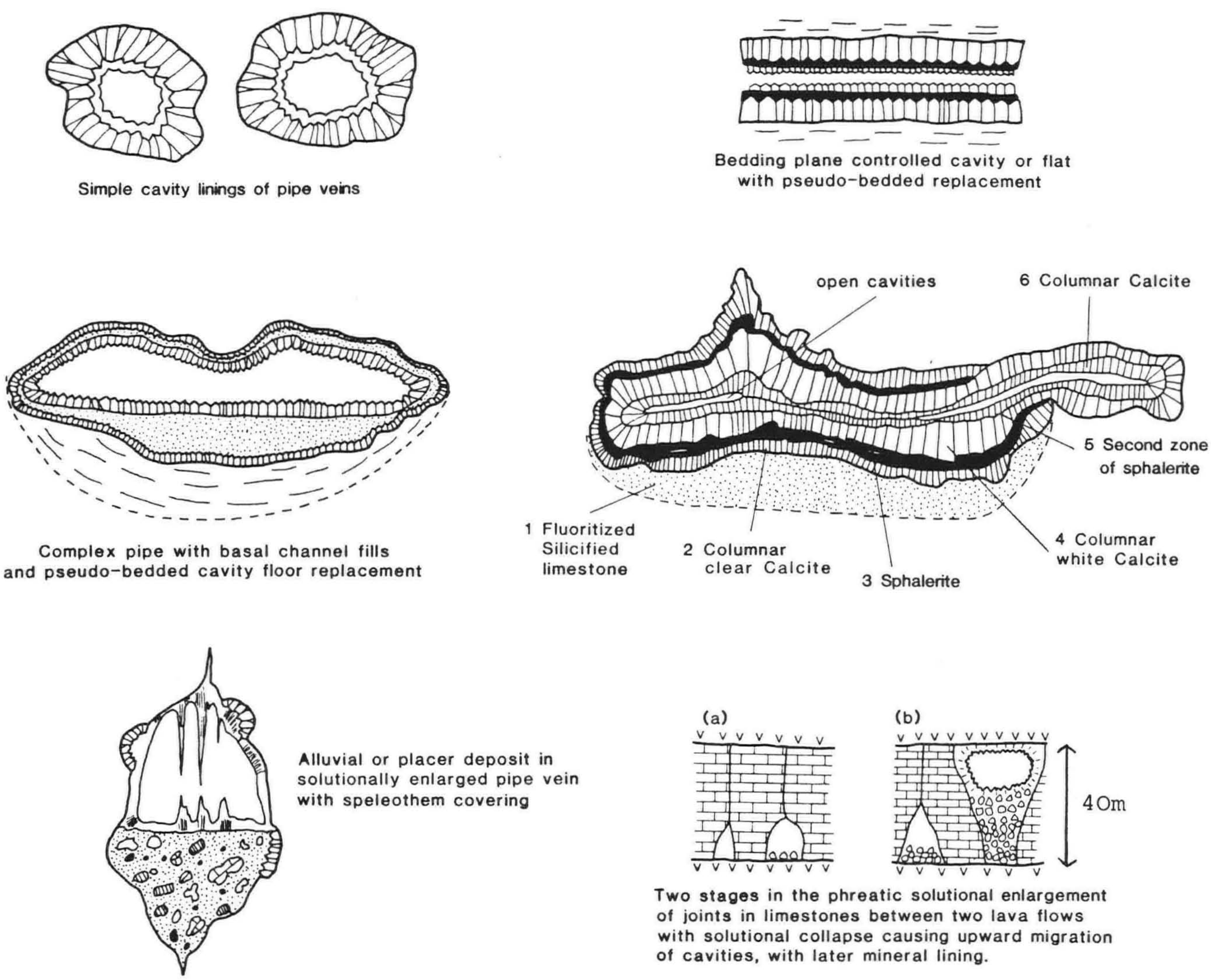


Fig.3. Diagrams of different types of hydrothermal karst in Derbyshire (partly after Worley, 1976).

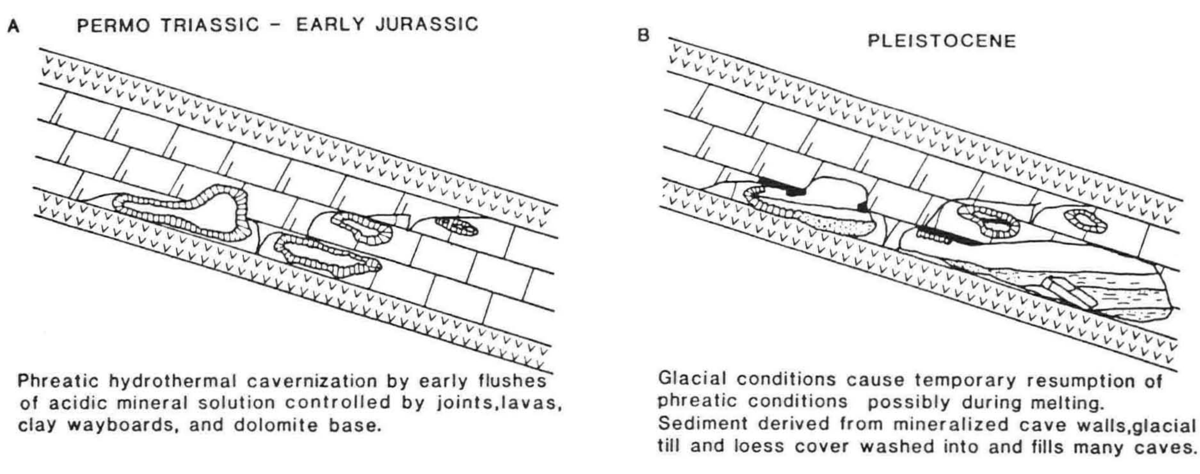


Fig.4. Diagrams to illustrate the development of hydrothermal karst in partly dolomitized limestones between two lava flows at Masson Hill, Matlock, Derbyshire (after Ford & Worley, 1977).

Hydrothermally mineralized caves of type (c) are common in Masson Hill (Fig.4) overlooking the gorge of the River Derwent at Matlock. Subsequent re-utilization of these old caves by phreatic water movement in Pleistocene (and possibly Pliocene) times was followed by the inwashing of fluvio-glacial fills (Noel, Shaw & Ford, 1985). Former extensions of these rejuvenated hydrothermal caves may have been signicant in the evolution of the Derwent gorge.

Another Pleistocene cave owing its initiation to the hydrothermal karst of the past is that in Treak Cliff at Castleton. Here the void system in the boulder bed partly infilled with Blue John fluorspar is associated with pre-Namurian phreatic caves within the reef limestones similarly filled with Blue John fluorspar. Both these caves and the remaining voids later provided a potential phreatic drainage route and this was used by allogenic drainage during the progressive removal of the Namurian shale cover. Inwashed loessic material later mixed with the collapsed insoluble Blue John residue partly filling the cave system.

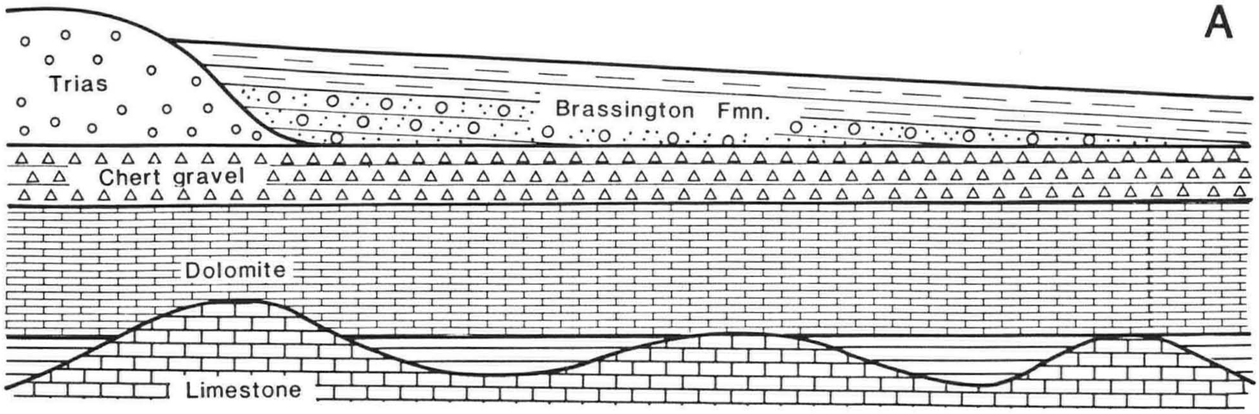
The Sub-Pliocene pockets and their deposits

From post-Triassic times to mid-Cenozoic the Carboniferous Limestone massif of the Peak District was almost certainly buried under a cover of Jurassic and Cretaceous sediments of which no trace survives. Whether any phreatic development took place as a result of slow-moving deep waters is unknown. By mid-Cenozoic times the Pennine fold was uplifted again and erosion was rejuvenated. Most of the Triassic, Permian and remaining Upper Carboniferous cover was removed from the limestone. Little can be reconstructed of this process, but by the end of Miocene times it can be argued that an escarpment of the Lower Triassic Sherwood Group conglomerates (formerly known as Bunter Pebble Beds) was retreating southwards from the southern margin of the limestone outcrop. Fans of pebble gravel, sand and clays spread northwards at the foot of the scarp into a braided low gradient river system draining the South Pennines leaving a sheet of clastic sediments, the Brassington Formation (Boulter et al. 1971; Walsh et al. 1972), resting on the limestone (Fig.5A). Relics of this sheet are now preserved only in a series of solution collapse structures and were formerly known as 'Pocket Deposits' (Yorke 1954-61). They have been worked for many years for their content of kaolinitic sands, used in refractory brick manufacture. The processes of dismemberment of the formerly continuous sheet have been described by Ford (1967, 1969, 1972, 1977) and Walsh et al. (1972, 1980). Quarrying operations for the refractory materials have revealed palaeokarstic phenomena at the margins of the pits. Patches of angular chert gravel up to 5 m thick resting on the dolomitised limestone surfaces and dragged down by collapse indicate the former presence of an insoluble chert residue over parts of the limestone surface. Resting on the chert gravel in a few cases are patches of Namurian shale, again about 5 m thick, and showing a weathering profile from unweathered blue-black shale below to reddish purple above, characteristic of warm temperate conditions. Whilst these relics are small and scattered they indicate the former presence of a combined covered and interstratal karst landscape in a warm climate - a palaeokarst having both a veneer of a former cover and of the insoluble residue present in the region before the deposition of the Brassington Formation sands and clays. The fossil plants in the clays are of Mio-Pliocene boundary age (Boulter 1971), so that this covered palaeokarst is probably of Miocene or even earlier age.

The margins of the pockets show deeply weathered dolomitised limestone, with joints etched out and filled with sand to a depth of several metres but structures in the pocket deposits themselves clearly indicate that these open joints are due to post-depositional collapse and the sagging of the Brassington Formation sands into interstratal karst cavities. The limestone solution necessary for the development of these in turn requires a hydrological drainage system in the sub-surface resurging in a nearby valley at lower altitude (Ford 1972)(Figs. 5B & C). Whilst Pleistocene erosion has destroyed the evidence of the latter, relics of the possible intermediate cave drainage have been discovered in caves penetrated by the Golconda lead and barytes mine (Ford and King 1965, 1966). Some of these are effectively developments of hydrothermal cavities.

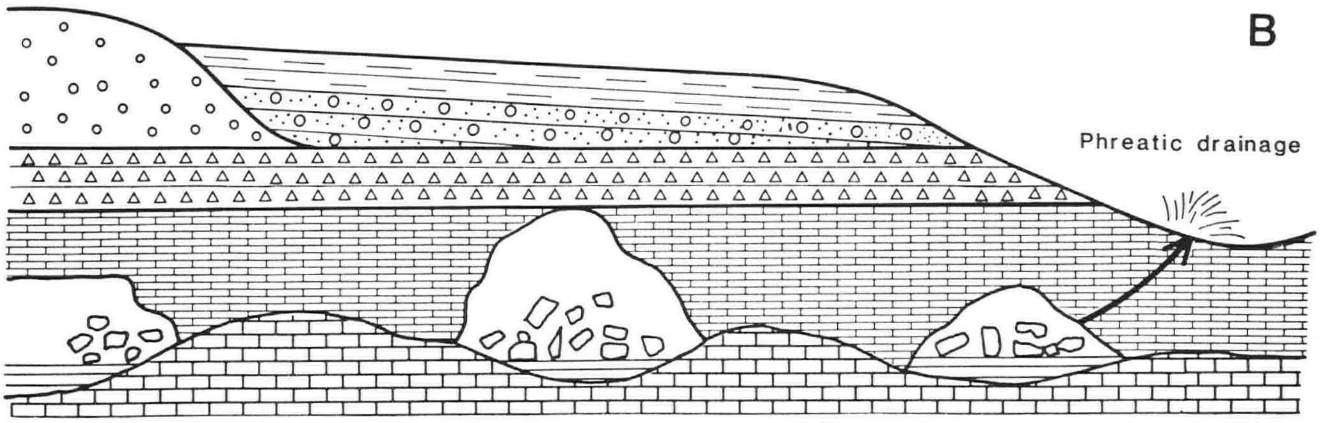
Thus a Mio-Pliocene covered palaeokarst is demonstrated by the presence of the Brassington Formation, by the residual chert gravels and shale patches, and by the caves of the Golconda Mine. The development of the interstratal karst by collapse took place before Pleistocene till covered the sagged deposits unconformably.

The same general area as the pits with the Brassington Formation sands and clays is also characterised by the presence of dolomite tors (Ford 1963, 1969). These crags are thought to have been developed by periglacial circumdenudation of decalcified partly dolomitised limestone during the later Pleistocene, but some may be survivors from a comparable glacial/periglacial/interglacial cycle in earlier Pleistocene times.



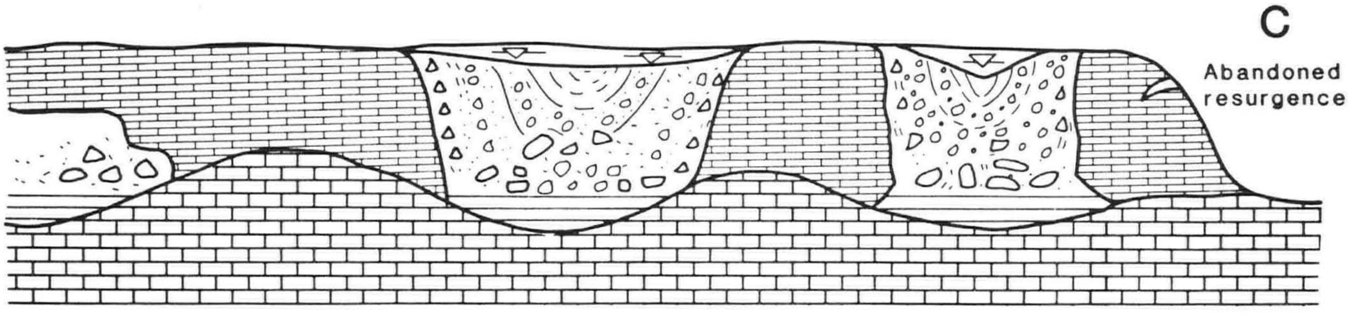
A EARLY PLIOCENE

Sands, gravels and clays of the Neogene Brassington Formation, largely derived from the receding Triassic escarpment on the left (south), overlie chert gravel residue from dissolved upper beds of dolomitized Carboniferous Limestone. Bedded galena-baryte mineral deposits lie in cavities a the base of the dolomitized limestone.



B LATE PLIOCENE OR EARLY PLEISTOCENE

Incision of a major valley into the dolomitized limestones allows a hydrological drainage system to initiate cavernization at the mineralized horizon by solution and roof collapse.



C PLEISTOCENE

Further solution allows collapse of Brassington Formation into "pockets" with subsequent erosion of most of the remaining horizontal Brassington Formation. Collapse drags down chert gravel (and some relics of Namurian shale) at the margins of the "pockets". Later, glaciation removes all remaining Brassington Formation from the plateau and deposits some till over collapse sites.

Fig. 5. Diagrammatic sections to illustrate the evolution of the Brassington, Derbyshire, "Pockets" filled with Neogene sediments and subsequent solution sag structures associated with interstratal solution.

The Carboniferous Limestone of the Mendip Hills also shows transgressive-regressive cycles (Ramsbottom 1973). Evidence of emergence is stronger in the Avon Gorge and Chipping Sodbury areas to the west and north of Bristol but exposure to sub-aerial processes is shown by the presence of stromatolitic horizons, mud-cracked bedding planes and very occasional thin coals, in both Bristol and Mendip areas. No detailed study of these has yet been published. The limestone of the Mendip Hills lies in a series of asymmetric east-west-trending periclines with considerable faulting. The folds have Devonian sandstone and Silurian volcanic cores. Folding took place at the end of Carboniferous times and there was no Permian sedimentation. By Triassic times the Upper Carboniferous cover had been eroded off and Upper Triassic sediments were deposited unconformably on the deeply eroded folds. Though most of the Triassic cover has been eroded off relics occur in three forms: conglomerate and breccia sheets; overlapping Triassic marls; and fissures filled with bone-bearing sediments. In the extreme east of the Mendip Hills the Trias was overlapped by marine Jurassic limestones, which rest directly on a planed-off Carboniferous surface, but with little evidence of marine karstic features, though oysters cemented themselves and mollusc borings penetrate a few centimetres downwards. Similar denuded folds of Carboniferous Limestone flanked by Triassic and Jurassic cover sediments occur around Bristol and Chipping Sodbury to the north of the Mendip Hills (Fig.6). An outline of the Triassic palaeokarst was given by Robinson (1957) as a background to her studies of the vertebrate faunas in the fissures. These were also described by Halstead and Nicholl (1971). Alabaster (1982) added comments relevant to his studies of Mendip mineralisation.

The Dolomitic Conglomerate is essentially a series of lithified scree deposits variously flanking the Carboniferous Limestone hills or lying in ancient wadis. Sections of the latter are to be seen in the Avon Gorge at Bristol, in Burrington Combe on the north flank of the Mendips, and around Wookey Hole on the south flank. The clasts are largely Carboniferous Limestone set in a patchily dolomitised sandy matrix. Away from the limestone hills the breccia fans pass into alluvial material, gravelly at first and progressively finer-grained further from the source. The implication of such deposits is that hills of folded limestones constituted a palaeokarst surface of arid to semi-arid character with little soil cover. Marine transgression seems to have occurred episodically in Rhaetian, Liassic and Middle Jurassic times. Limestones of Liassic age showing a littoral facies aspect are banked against the Carboniferous Limestone near Shepton Mallet in east Mendip. These overlap the earlier Dolomitic Conglomerate but in turn are transgressed by Middle Jurassic Inferior Oolite which lies on a marine planation surface across folded Carboniferous Limestones near Frome, well seen in Vallis Vale (Fig.7) and at Vobster (Pl. 4). The relationships of the Triassic and Jurassic deposits to the Carboniferous show that there has been little subsequent lowering of the Carboniferous Limestone plateau surface there by subsequent erosion though Tertiary and Quaternary erosion has modified the western Mendips. The Triassic climatic regime is likely to have been one of infrequent but heavy rainfall, not one which would lead to the development of cave systems. Progressive filling of adjacent lowland basins would, however, cause a rise in the water table and slow phreatic solution would then ensue.

Whilst there is little evidence of the development of karren beneath the transgressive Inferior Oolite at Vallis Vale, a few kilometres to the north in the tectonic outlier of Vobster, the Inferior Oolite limestones rest on karren developed across the steeply-dipping Carboniferous Limestone beneath (Plate 7).

Galena-baryte-calcite-haematite mineralisation permeates much of the Dolomitic Conglomerate and some areas around Priddy and Shipham have been intensively mined in old shallow pits. The few deep mines demonstrate that 'veins' in the Carboniferous Limestone are largely fractures filled by downward penetration of the mineralising fluids (Alabaster 1982).

Ancient caves or fissures with bone-bearing sediments have been intersected in a number of quarries (Fig.7). Halstead and Nicholl (1971) distinguished three types: (a) ancient cave system, e.g. Cromhall; (b) collapsed cavern, e.g. Durdham Down; and (c) neptunian dykes, e.g. Holwell. Other collapsed caverns have been noted at Emborough and Batscombe. The ecology of herbivorous and carnivorous lizard-like reptiles at Cromhall has been discussed by Fraser & Walkden (1983). On the basis of their sediment and fossil contents Halstead and Nicholl suggested different seasonal effects at successive levels in Cromhall Cave. On the basis of the fossil contents Robinson (1957,1971) distinguished two types of fissure: (a) those containing a late Triassic terrestrial reptilian fauna only and (b) those containing Rhaetian to Lower Liassic vertebrates, both reptilian and mammalian, with some evidence of marine input in a few cases. The fissures themselves are of two types - tectonically opened fractures and solutionally widened joints. Some of the former have evidence of successive

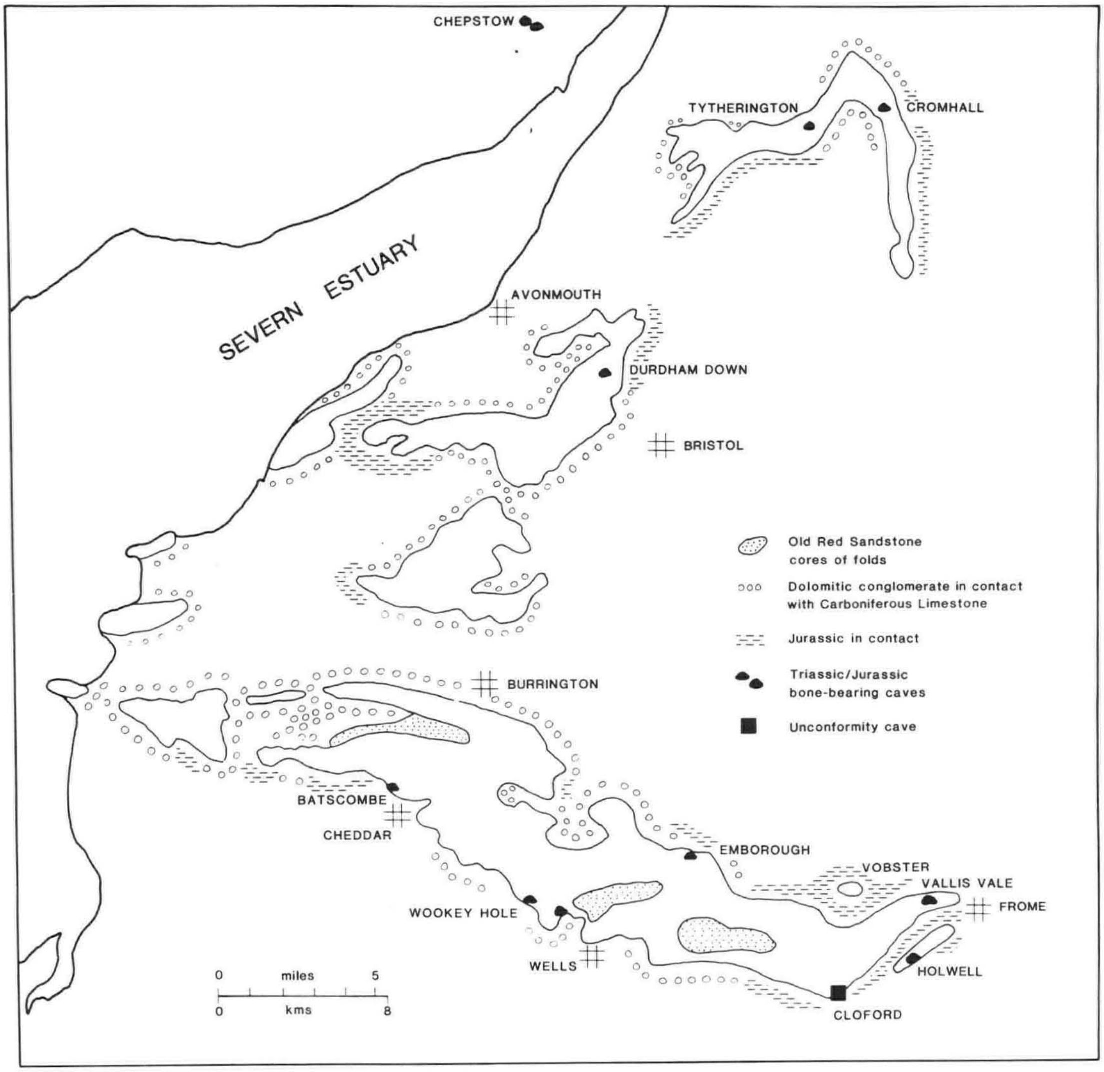


Fig.6. Sketch map showing the distribution of palaeokarstic features in the Mendip Hills and Bristol area.

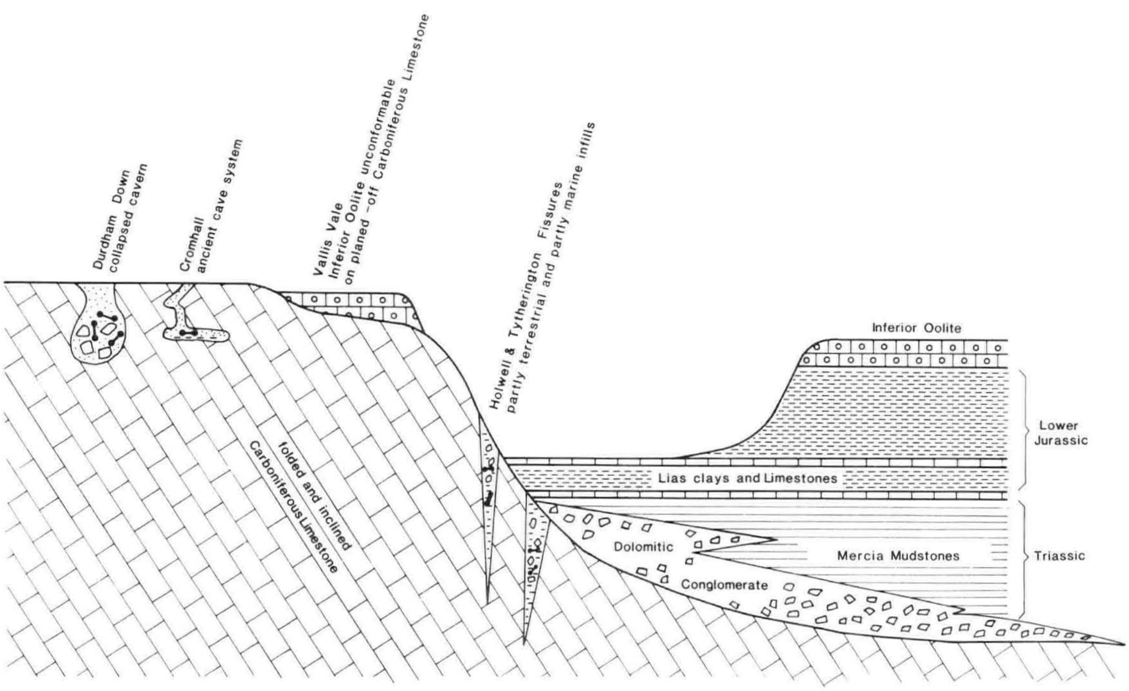


Fig.7. Diagrammatic sketch to show the relationships of ancient caves to overlapping covers of Triassic and Jurassic sediments (partly after Halstead & Nicholls, 1971, and Alabaster, 1982).

sagging layers of fill into them. Some fills indicate the former existence of thin Rhaetian or Liassic covers which were trimmed off by Middle Jurassic times, demonstrating that the inter-fissure surfaces are themselves planes of marine denudation. The faunas have been taken to suggest that they lived on upland areas well above sea-level but the discovery of glauconite grains and marine palynomorphs in the silts at Tytherington (Marshall and Whiteside 1980; Whiteside and Robinson 1983) suggests that the limestones may have formed low-lying islands and some fissures may have been effectively dolines, cenotes or even 'Blue Holes' like those of the Bahamas.

The present upland surface of the Mendip Hills is thus a rejuvenated Triassic island surface, which has been subjected both to tectonic strains opening fissures and to slow phreatic solution, with marine planation in the middle Jurassic, and some limited Pleistocene trimming. The fissures both acted as pitfall traps and had some small vertebrates washed in by storm run-off.

There is little evidence of lateral caves being developed off the fissures in Triassic times, though a few quarry sections suggest the formation of caves followed by roof collapse, as at Slickstones Quarry at Cromhall, north of Bristol. Fossil reptilian remains occur both in the silty sediments of the cave floors and in between the collapsed boulders. Reptile remains are locally dispersed in re-deposited derived Carboniferous Limestone microbreccias (Fraser & Walkden, 1983).

None of the major cave systems known today can be attributed directly to Triassic beginnings, though tectonic stresses may have initiated some of the opening of controlling joints and bedding planes. Wookey Hole cave is partly developed in the Dolomitic Conglomerate but extends without any obvious change in morphology into the Carboniferous Limestone behind. The high permeability of the Dolomitic Conglomerate may have been a factor in speleogenesis but here it is not in itself evidence of a subterranean Triassic palaeokarst.

A minor example of interstratal karst is the cave in Cloford Quarry developed along the unconformity between the middle Jurassic Inferior Oolite and the underlying Carboniferous Limestone (Drew and Ingle Smith 1972). The age of initiation is unknown but it may well be no older than Quaternary.

ANGLESEY

The coastal sections of the Carboniferous Limestone of Red Wharf Bay on the east coast of Anglesey have long been famed for their sandstone-filled potholes in the limestone (Fig.8; Pl.6). Noted by Greenly (1901) they have been described by Baughen & Walsh (1980) and by Walkden & Davies (1983). The coast near Trwyn Dwlban provide sections of several hundred sandstone pipes, which Walkden and Davies have shown to occur at nine different stratigraphic horizons, each terminating a carbonate regression cyclothem. The pipes are commonly 5 or 6 m deep and 1 or 2 m wide and contain sandstone showing bedding to various degrees. Most of the sandstone bodies are truncated on the foreshore by modern marine erosion but in the cliffs various relationships can be seen. Many are truncated and the next limestone cyclothem lies directly on top, but a few show a thin sandstone bed passing from one pipe to another a few metres away. Some evidence of channelling of cyclothems into each other is also present.

Walkden and Davies (1983) have concluded that the pipes are palaeokarstic phenomena due to overbank solution when regression took place at the end of a cycle. Some such overbank solution was beneath a sheet of fluvio-deltaic sand, presumably with a soil providing acidic meteoric waters. Removal of large parts of the sand sheet took place during channelling episodes and was completed in some cycles by the succeeding marine transgression.

A wider palaeogeographic view can be inferred by the Carboniferous Limestone here being deposited in a shelf sea environment close to the Ordovician volcanic mountains of Snowdonia whence the sand was derived. Regression exposed the limestone shelf to terminate the carbonate part of each cycle with palaeosols followed by the fluvial effects with channels, overbank spills of sand and the accompanying solutional effects (Walkden and Davies 1983). The pipes and related bedding surfaces may be classed as covered palaeokarst.

NORTH WALES

As in other areas, the Carboniferous Limestone sequence is marked by a number of palaeokarstic or palaeosol surfaces at the terminations of cyclothems (Somerville 1969a & b) but these do not seem to have any subsequent speleogenetic significance (Fig.8).

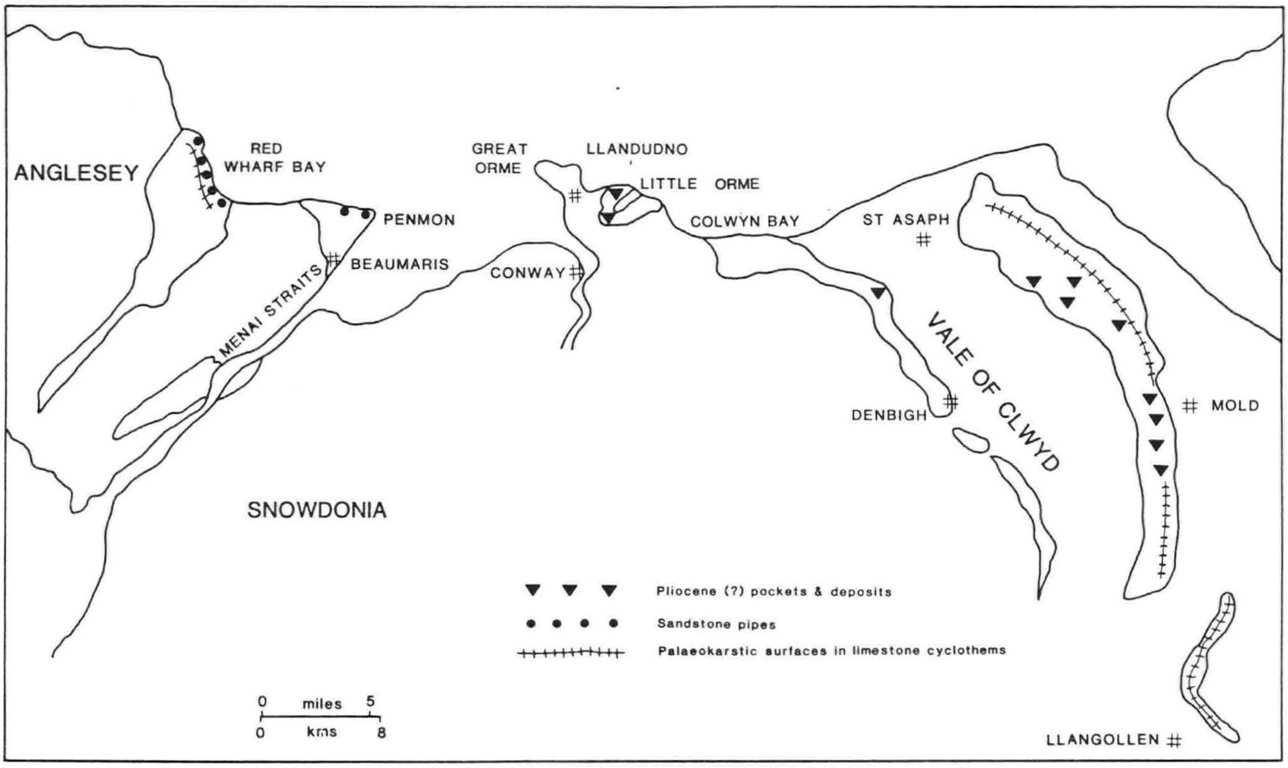


Fig.8. Sketch map showing the distribution of palaeokarstic features in North Wales and Anglesey.

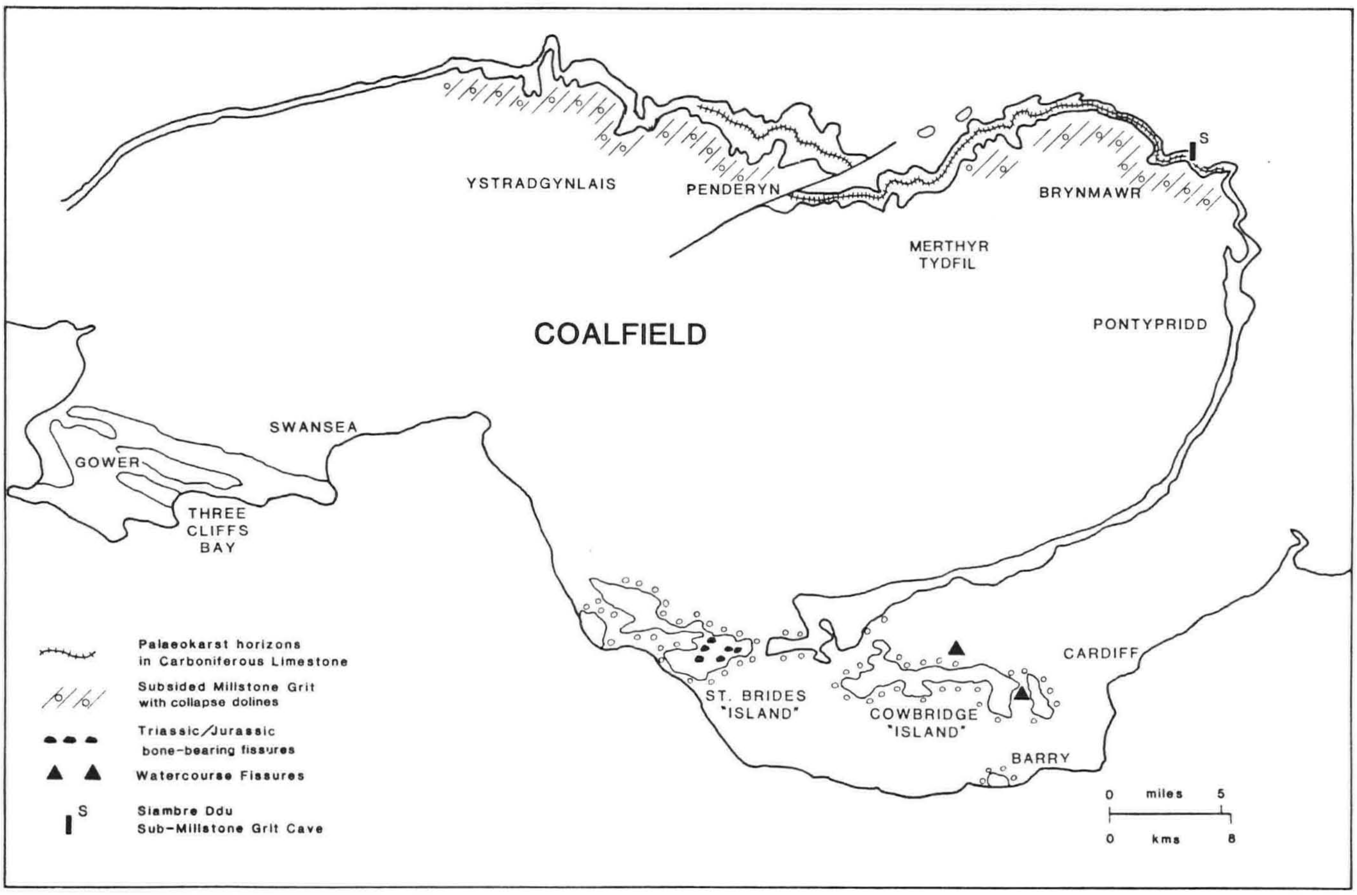


Fig.9. Sketch map showing the distribution of palaeokarstic features in South Wales.

Mining records in northeast Wales suggest the presence of hydrothermal karst there but no details have been described.

The outcrops of Carboniferous Limestone around Llandudno and in Flintshire are marked by some 20 solution subsidence outliers containing sands and clays with occasional lignite. Described by Walsh and Brown (1971) these bear close comparison with the Pocket Deposits and Brassington Formation of Derbyshire and seem to have formed in an analogous way.

SOUTH WALES

Carboniferous strata are folded into a large synclinal basin trending east-west so that the limestone outcrops in a narrow band on North and South Crops, on either side of the coalfield. The South Crop is steeply-dipping and has been greatly denuded and locally transgressed by Triassic strata. Triassic and Jurassic strata also lie unconformably on subsidiary folds in the Carboniferous Limestone in South Glamorgan (Fig.9). Comparable folds in the Carboniferous Limestone of the Gower Peninsula and South Pembrokeshire are characterised by small areas of coarse 'gash-breccia' regarded by some as relics of the Triassic transgression but there is no direct evidence of either age or origin of the breccias. Thomas (1971) regarded them as being of tectonic origin related to late Carboniferous folding, occasionally with solutional collapse features superimposed.

There is a general thinning of the Carboniferous Limestone towards the north-east in the eastern part of the North Crop. This is partly due to overstep by the lowest beds of the Millstone Grit across the various units of the limestone sequence, and partly due to progressive thinning of the units themselves. These thin limestone cyclothems are often bounded by emergence surfaces, characterised by palaeosols and palaeokarsts. Wright et al. (1981) Wright (1982, 1984a & b) have argued that these are largely evidence of intra-Dinantian covered karst. Mammilated and pot-holed surfaces have been noted in the Gower Peninsula whilst on the North Crop palaeosols are represented by textures including rhizoliths, glaebules and vadose cements overlying phreatic cements. Rubbly calcareous clays on such surfaces appear to represent collapsed kavornossen karren (Wright 1982). Needle-fibre cements suggest a relationship to microbiological soil activity possibly by fungi (Wright 1984b). A palaeokarstic surface at the top of the Gilwern Oolite shows extensive solution piping. Speleogenesis has occurred at the top of the Oolite, amongst other horizons, and it may be that intra-Dinantian palaeokarsts have been significant in the origin of Pleistocene cave passages.

The sub-Triassic landscape of South Glamorgan is one of Carboniferous Limestone islands surrounded by lithified fossil scree slopes. The 'islands' developed in Permo-Triassic times and, like the Mendip Hills, may be presumed to have been relict uplands in a Triassic semi-arid landscape. An outline description of a palaeokarstic surface has been published by Thomas (1952) and several fissures filled with bone-bearing sediments have been noted (e.g. Robinson, 1957, 1971). As in the Mendip Hills these contain a mixture of small reptile bones, with a few early mammals and fish remains in a fine clastic matrix and pitfall trapping mechanisms have been invoked. Fragments of coniferous wood and spores were also found (Lewarne and Pallot 1957; Harris 1957). These suggest a Rhaetic to Lowest Lias age and Harris suggested that their charcoal-like appearance indicated their possibly having been burnt in a scrub fire and then washed into the fissure.

On the North Crop the Carboniferous Limestone, generally some 200-300 m thick, is overlain unconformably by the basal Millstone Grit quartzitic sandstones. The junction is an unconformity with the base of the sandstones transgressing almost completely across the limestone outcrop in the extreme east. The contact is poorly exposed but where it is visible, minor solution features occur. Owen and Jones (1966) drew attention to small scale cave-like features beneath the unconformity filled with quartzitic sand and pebbles and Thomas (1973, p. 74) suggested that they might represent a karst landscape now buried below the Millstone Grit. However, the evidence is largely masked by subsequent collapse having led to extensive interstratal karst. Described by Thomas (1963, 1973, 1974) the features include an extensive collapse doline field, shallow subsidence depressions and foundered masses of the quartzitic sandstones. These features have resulted from the solution of limestone under a cover of sandstones up to 200 m thick and Thomas has proposed that the only possible mechanism for the chaotic jumble of collapsed blocks is collapsed caverns of vast size. None of these has yet been demonstrated to exist, though the Siambre Ddu cave, near Brynmawr, with its sandstone roof, may be an imminent collapse of this type (Thomas 1974, p. 150) (Fig.9).

The collapse dolines number some thousands spread over about 60 km length of limestone outcrop. Individual dolines may be as small as 25 m diameter but many are more than 100 m across. Foundered masses of Millstone Grit may be as much as 3 km in length. The depth of collapse is uncertain but Thomas thought that some foundered masses may have gone through the whole thickness of the Carboniferous Limestone, i.e. more than 200 m. The chronology of solution and collapse has not been worked out but Thomas suggested that many of the features were so freshly developed on a surface previously covered by Devensian glaciation that they were in effect post-glacial and hence not palaeokarst. However, he also suggested that some isolated foundered masses of sandstone on the limestone dip-slopes well-removed from parent Millstone Grit outcrops could be regarded as 'fossil inter-stratal karst'. Once isolated, they could be planed off by glacial erosion and may date back to early in the Pleistocene or perhaps even earlier.

Interstratal solution collapse on this scale has not been found elsewhere in Britain and the reason is probably because it is only in South Wales that the basal Millstone Grit beds are coarse permeable sandstones which allow acid waters to percolate directly into the limestone. Elsewhere in Britain thick shales intervene.

Comparable interstratal and buried karsts between the Carboniferous Limestone and Namurian have been noted in Belgium and West Germany (Wright 1984b).

'Pockets' of the limestone surface filled with deeply weathered material derived from the Millstone Grit have been described in the Vaynor and Cwar yr Ystrad quarries of the North Crop by Battiau-Queney (1980, 1984a & b). She has argued that the limestones between the pockets resemble buried tower karst and that the fill in the pockets between the towers was derived from tropical soils of ferralitic and ferruginous types such as would be generated in a relatively hot and wet climate. Later soil profiles suggest further pedogenesis after fill deposition. Whilst no dating evidence is available Battiau-Queney has suggested and early Tertiary age for the tower karst and a later (early Neogene) age for the burial and fill stage. Further research is obviously needed to determine the relationship between the features and interpretation of Battiau-Queney and the pre-Namurian and interstratal karsts described by Thomas.

NORTHERN ENGLAND

Palaeokarst in the classic caving area of the North Pennines is less obvious, being restricted to palaeosols at the end of transgression-regression cyclothems and to solution-pitting beneath shale bands (Waltham 1970, 1971, 1974). These pit features have only been seen underground where they have been intersected by caves. Waltham has observed cross-sections of depressions in the base of shale bands as much as one metre deep and 3 metres wide. Since they can only be seen in two dimensions it cannot be proved whether they are cross-sections of circular pits like those in Anglesey or whether they are sections through channel-fills. A few shale-filled fissures suggest the former presence of grykes in exposed erosion surfaces. A few of the shale bands carry thin coal seams indicating the former presence of terrestrial soils and vegetation cover on exposed limestone platforms. Waltham's work (1970, 1971, 1974) has amply demonstrated the significance of the shale beds in speleogenesis.

NORTHWEST SCOTLAND

The variously dolomitised Cambro-Ordovician Durness limestones of the extreme northwest of Scotland have recently been shown to contain a stratigraphic break encompassing most of Middle and Upper Cambrian time (Palmer, McKerrow and Cowie 1980; S.C. Wright 1983). The Sangomore Formation rests on a palaeokarst surface of the Sailmhor and Eilean Dubh Formations on the south shore of Balnakeil Bay. Breccia-filled fissures pass down from the palaeokarst surface into the lower formations by as much as 150 metres. The breccias have apparently yielded a few uppermost Cambrian marine fossils whose significance is not yet understood. The breccias have been attributed to the former presence of evaporites and collapse due to solution thereof on the same principle as the Broken Beds in the Purbeck rocks (Upper Jurassic) of Lulworth Cove in Dorset. No detailed description is yet available.

SOUTH DEVON

The folded and faulted Devonian limestones of Berry Head and the adjacent Shoalstone Beach near Brixham contain numerous sandstone dykes (Richter 1966). Although these give the impression of being true palaeokarstic features, detailed studies have shown that they are tectonic fissures opened, sometimes several times, by the stresses of folding. Some fissures close upwards, whilst others cut through earlier fissure-fills. The fills are of almost structureless

Plate 7. Karren in steeply dipping Carboniferous Limestone exposed by partial removal of Middle Jurassic Inferior Oolite.

Plate 8. Solution pipes in Chalk filled with collapsed Tertiary sediments. Castle Limeworks Quarry, South Mimms, Hertfordshire (photo by A.C.Waltham).

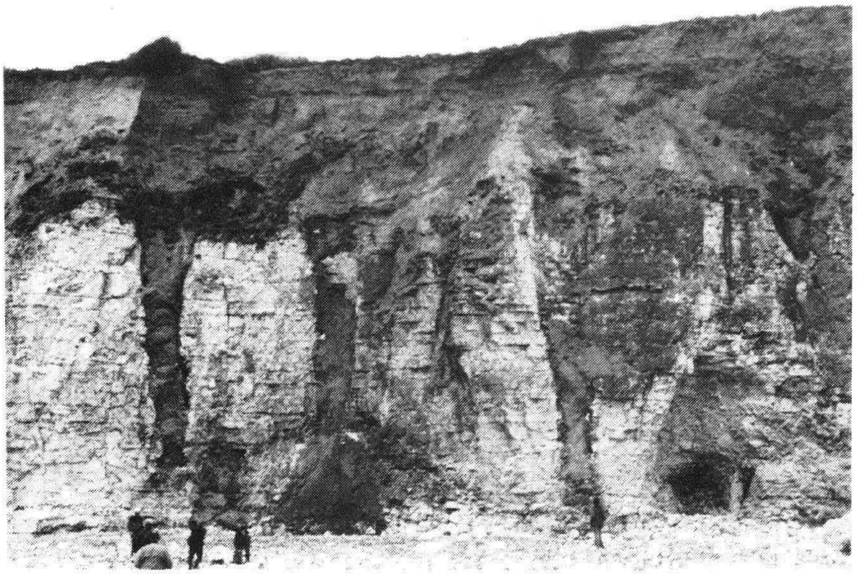


Plate 9. Solution pipes in Chalk beneath a cover of residual clay with flints, Cuckmere Haven, Sussex.

red sandstone, often with radial calcite growing inwards from the walls. The calcite probably indicates a stage of phreatic growth in open fissures and the sand was virtually sucked in from the unconformable cover of Permian fluvial sediments. A single instance of a true cave filled with red sandstones has been noted by Richter but otherwise there are no palaeokarstic features.

THE SUB-CHALK 'POTHOLES'

Throughout southern and eastern England the Upper Cretaceous Chalk is covered unconformably by fluvial or marine Palaeogene sands. Considerable thicknesses of chalk were eroded before deposition of the cover on a gently inclined surface. In almost every exposure of the contact there are sand-filled "pipes" extending down into the chalk to depths of more than 10 metres (Kirkaldy, 1950). They can be classified as inter-stratal karst and are generally thought to have originated by sub-surface solution of the soluble chalk below the unconformity. Particularly fine examples have been described at South Mimms to the north of London (Thorez et al. 1971) (Plate 8). Others occur in the cliffs of Studland Bay in east Dorset and at Cuckmere Haven in Sussex (Castleden 1982) (Plate 9). At the last locality pipes about 1.5 to 2m in diameter can be seen to penetrate the whole depth of the chalk cliff, some 20m, into the foreshore platform. The cover is a series of soliflucted sands and gravels, with components indicating derivation from the former Palaeogene cover, together with early Pleistocene gravels and wind-blown sands. These can be seen to sag into the pipes. The chalk margins of the pipes, particularly those seen on the foreshore, are indurated by deposition of a cryptocrystalline cement through a thickness of about 15 cm. Cylinders of indurated chalk from which the fill has been removed stand as much as a metre high on the wave-cut platform. Similar features have been described from the Norfolk coast near Sheringham, where the chalk is covered by early Pleistocene Weybourne Crag gravels (Burnaby, 1949). Here he noted that the topmost few cms of the chalk are indurated whether in pipes or not, and showed small scale desiccation cracks, from which he argued that the pipes were a bare karst landscape solution phenomenon. This deduction now needs re-examination, as it is difficult to see how a bare land surface of chalk could have concentrated run-off into the widely spaced pipes.

JURASSIC HARDGROUNDS

There are numerous horizons in the sequence of Jurassic limestones and clays throughout Britain where hardgrounds occur. These are surfaces within limestone clay successions characterised by encrustations of oysters and other bivalves and bearing vertical burrows by crustaceans, 'worms' and other organisms. (Palmer and Fürsich 1974; Sellwood 1978). The underlying limestones show evidence of early lithification but otherwise they indicate only a period of non-sedimentation with little evidence of emergence and the formation of sub-aerial palaeokarsts.

Interstratal karst in the Purbeck Beds of the Dorset Coast occurs in the form of Broken Beds - massive block breccias resulting from the subsurface solution of gypsum beds and collapse of the overlying strata.

SOUTHWEST IRELAND

A solution-collapse structure containing Cretaceous chalk in a depression in Upper Carboniferous greywackes, underlain by Carboniferous Limestone, in the Gweestin Valley, north of Killarney, has been described by Walsh (1966). He suggested a mechanism of 'rapid submarine intra-Cretaceous karstic subsidence'.

Solution hollows containing unconsolidated sands occur in several parts of central Ireland. Covered by thick Pleistocene boulder clay, relatively little is known about them, but they seem to be comparable with the Pocket Deposits of Derbyshire and may thus indicate a Pliocene palaeokarst (Murphy 1962).

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