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The Crocodile Caves of Ankarana: Expedition to Northern Madagascar, 1986

Edited by Jane WILSON

Abstract: Ankarana is a small but scientifically unique limestone massif, notable for its huge river caves where Nile Crocodiles find refuge from drought and hunters. The 98km of cave passages not only provide some spectacular caving but also comprise diverse habitats for a range of cave fauna as well as important palaeontological and archaeological sites. Although the amount of new passage found during the 1986 expedition was disappointing, the scientific findings are highly significant.

INTRODUCTION

The Ankarana Massif comprises a small but spectacular area of tsingy (pinnacle karst) which is mentioned in many books on Madagascar. The Guide Bleu for Madagascar (Hachette 1968) contains a detailed description of the sacred caves and mentions the crocodiles which live in some of the caves. Blanc (1981) wrote of crocodiles in the subterranean rivers of Ankarana, and Paulian (1981) described the caves at Ankarana where bats were hunted. Blanc (1984) suggested that Ankarana's caves are virtually the last stronghold for Madagascar's crocodiles. Ankarana has been a Special Reserve for 30 years but little scientific work has been done there.

An inventory of Madagascar's caves (Decary and Keiner 1971) highlighted Ankarana as an interesting area even before the major finds of this decade. Twenty years of meticulous searching by Jean Radofilao and colleagues (Ravelonanosy and Duflos 1965; Duflos 1966, 1968; Radofilao 1977) and two French expeditions (Peyre et al 1982, 1984) have resulted in the discovery and survey of 93km of cave passage. Ankarana boasts Madagascar's longest cave systems. Indeed Ankarana's caves must be amongst the most extensive in Africa. The large subterranean rivers of Ankarana make the caves quite different to most tropical caves and provide a great diversity of cave habitats suitable for a range of cave-adapted animals. The river caves form a natural irrigation system which allows rich canopy forests to flourish inside the Massif whilst outside the karst area the vegetation of the savannah becomes parched during the six month dry season. The subterranean rivers, then, support the rich fauna existing above ground at Ankarana (see Wilson et al 1987) as well as acting as a reservoir which ensures a reliable water supply to local villages downstream. A selection of papers have been published on the geology (Rossi, 1973, 1974), hydrology (Rossi, 1975, 1976a) and the vegetation zoning (Rossi 1976b) at Ankarana.

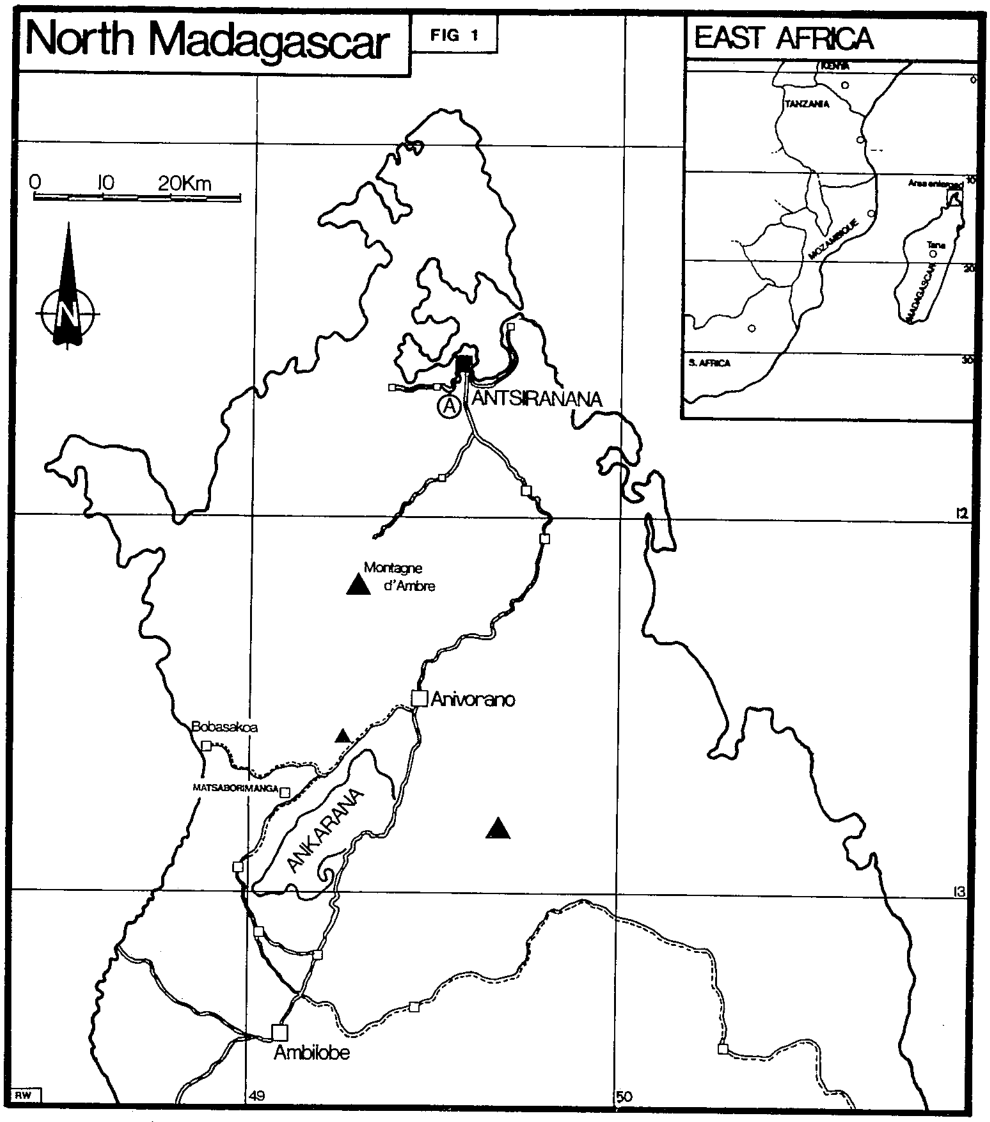
The 1981 Southampton University Expedition gave one of its leaders a tantalizing glimpse of the biological and speleological wealth hidden within the spectacular pinnacle karst and convinced us that the area was worthy of more thorough attention. The resulting return trip in 1986 showed Ankarana to be even richer than our predictions (Chapman et al 1987b).

HISTORY OF EXPLORATION
Jean Radofilao

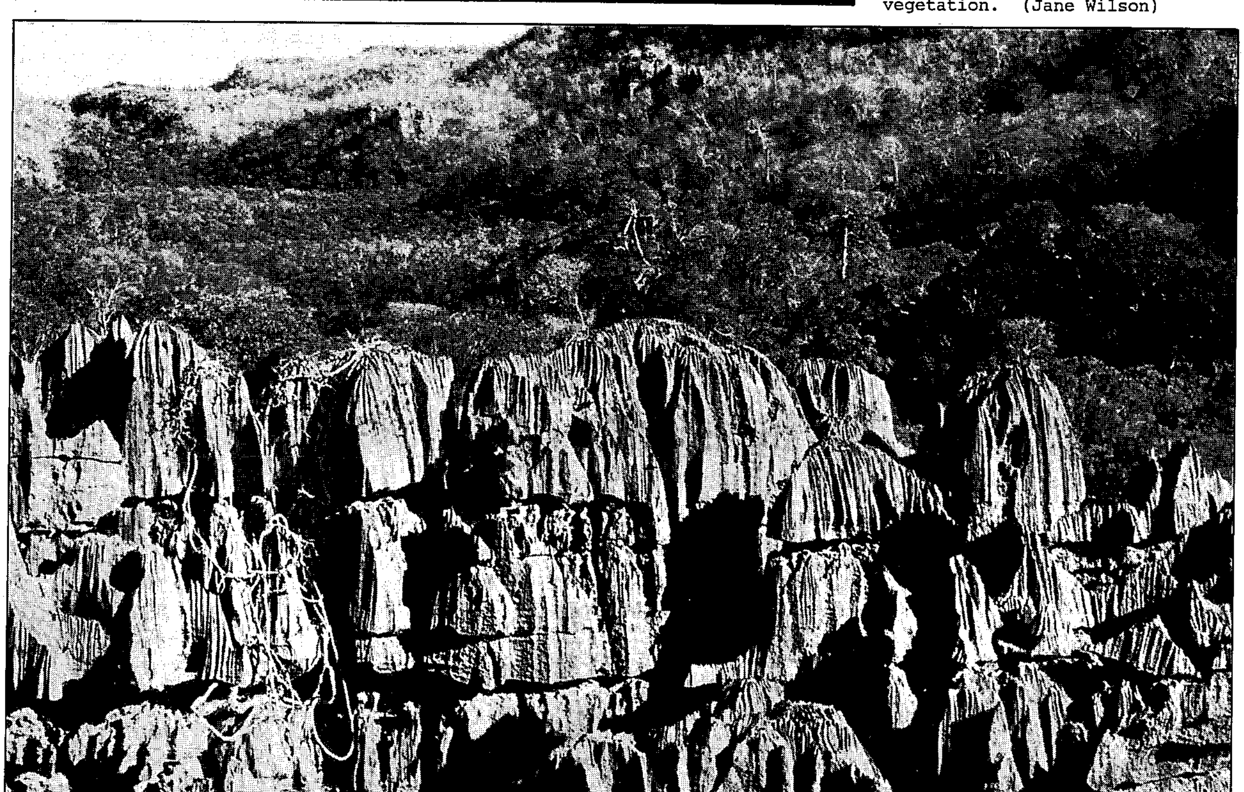
The Ankarana massif contains an extensive and complex system of cave passages, but most of the cave entrances are difficult to enter, and even to find, due to collapse. There are a few with huge entrances, accessible at the base of the cliff. These obvious caves (Andrafiabe, Ambatomanjamana and the Mananjeba subterranean river) have been known by the local people for a long time; they have explored them with palm leaf torches. Inside are remains of fires and fired earthenware pots. During the colonial era, several Frenchmen visited these caves, guided by the locals; they wrote picturesque accounts for the local papers, but made no scientific observations. Early work was reviewed by de Saint Ours (1959).

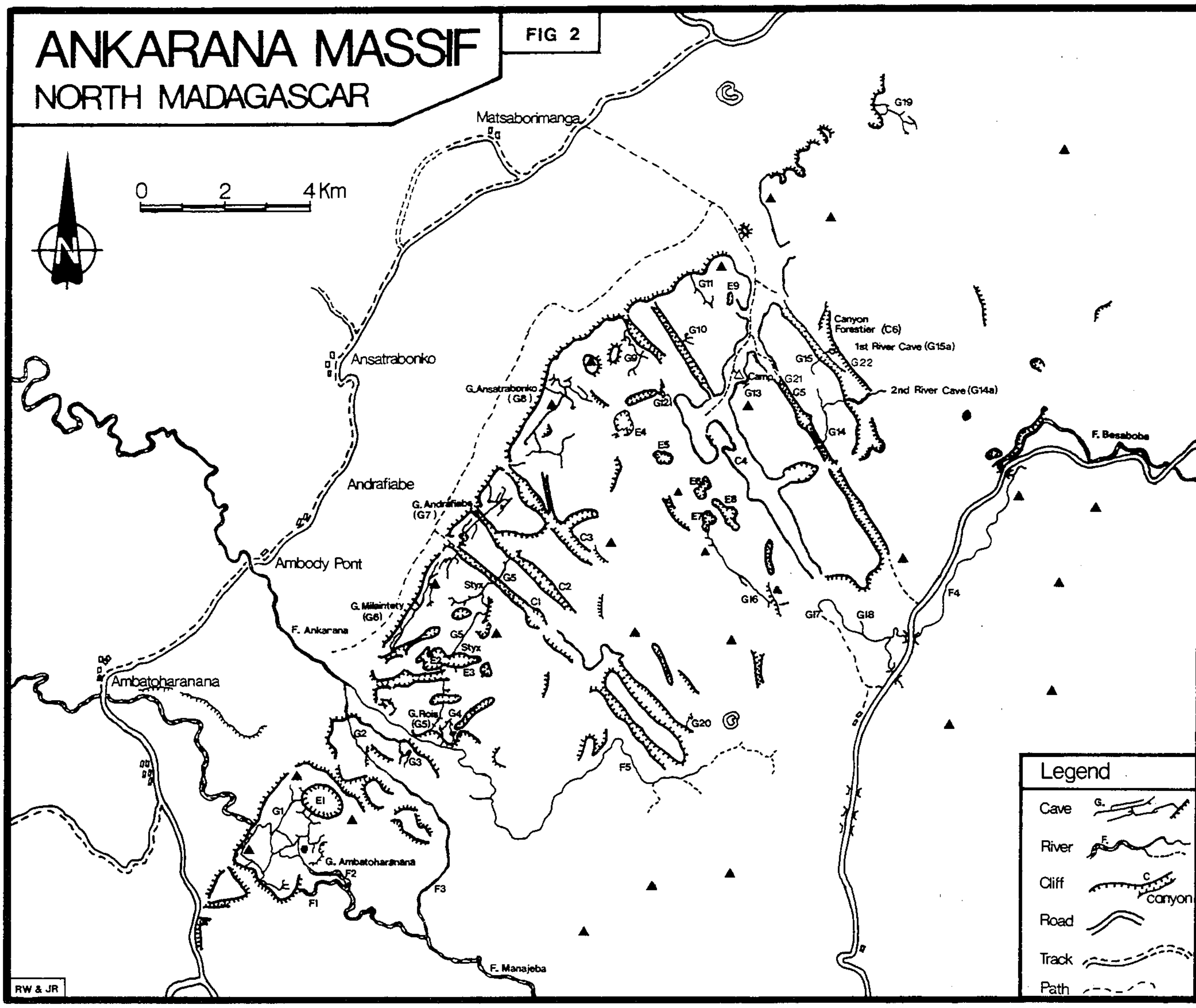
The first real cave exploration was done in 1963 when Jacques de Saint Ours accompanied by G Coquet surveyed 2.8km in the Grotte d'Andrafiabe and estimated that they had explored more than 5km. Almost every year between 1964 and 1972, building upon information provided by J de Saint Ours, the writer has explored the caves of Ankarana, leading a small team backed by the University of Madagascar. Initially we continued the exploration of la Grotte d'Andrafiabe and then searched for others. We explored Antsatrabonko,

Transport to our Ankarana base camp was by bullock cart. The photo shows a line of forest growing above a subterranean river and, in the background, the northern Ankarana limestones. (Phil Chapman)



The dry pinnacle karst tsingy is over 200m above the surrounding savannahs and canyon bottoms. This photo, taken above the Second River Cave, shows rich gallery forest in the foreground (growing above a subterranean river) and the Canyon Forestier stretching away to the left horizon. Some tsingy is covered in scrubby, thorny, xerophytic vegetation. (Jane Wilson)





Milaintety, Ambiky, the start of Ambatoharanana and the big river system and several smaller caves. When these explorations were stopped by lack of money, the total passage length surveyed was over 40km.

After 1972 the writer continued the exploration, usually alone. The largest caves surveyed during this period were Andetobe, Antsiroandoha and Ampandriampanihy (north). By 1980 the total of explored passages had reached 75km.

From 1981 several foreign expeditions came to Ankarana and made their contributions to exploration (whilst the writer continued alone during the rest of the dry season). These were:

August 1981 a team from University of Paris VI and a team from the Club Martel of Nice and Club Alpin Francaise (Peyre et al 1981).
September 1981 a team from Southampton University (Adamson et al 1984)
August 1982, 1984 and 1985 the team from Nice returned (Peyre et al 1982, 1984, 1985)
August - October 1986 a new multi-disciplinary team (cavers and scientists) from England (this report)

As a result of all this work the total passage length explored at Ankarana by the end of 1986 reached 98km.

THE GEOLOGY AND GEOMORPHOLOGY OF ANKARANA

J. Radofilao, P. Chapman, D. Checkley, S. Hurd and R. Walters

The Ankarana massif is situated about 30km north of Ambilobe and about 75km south of Antsiranana (Diego Suarez). It comprises a block of Middle Jurassic (Bajocian and Bathonian) limestone about 30km long by 8km wide and is bordered on the north-west by a cliff face up to 200m high, the 'Ankarana Wall' (Fig 2). The surface of the plateau is very difficult to cross, as it comprises unstable blocks of needle-like limestone pinnacles up to 20m high, separated by deep crevasses. This pinnacle karst, known locally as tsingy, supports a unique xerophytic vegetation. The massif is traversed by deep, straight, vertically-walled, fault-controlled canyons, the majority of which run NW-SE, almost at right angles to the Ankarana Wall. They are nearly always littered with huge limestone blocks and the wider canyons are thickly forested, especially where basaltic lavas have flowed in to form a substrate.

The Caves

Passage dimensions vary from very small crawling-sized tubes to the more common huge corridors which reach 50m width in Grotte d'Andrafiabe. Most of the biggest passages run NE-SW, parallel to the Ankarana cliffs.

Most of the explored passages are active or semi-active and situated close to the level of the foot of the cliff. Sumps are quite common and some sections have navigable underground rivers, the most notable being the 4km boat trip necessary to traverse the length of the River Styx (G5).

Higher, less active passages are smaller and much less numerous. Access to some need artificial climbing techniques. These higher levels are very well decorated and formations, debris, volcanic ash or clay often block the passage. La Grotte de Milaintety (G6) is probably the best decorated cave.

Collapsed Caves

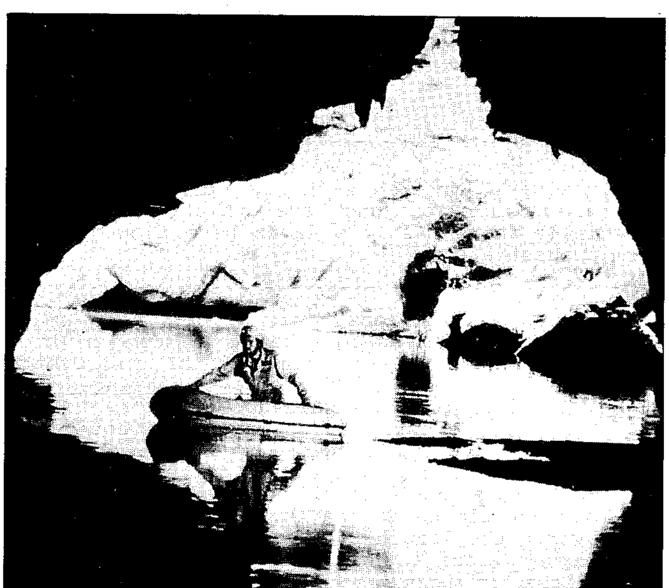
A huge collapsed cave was discovered during exploration in 1986. This was made up of several aligned collapses, with linking residual arches. This feature is very different from the fault canyons since the collapses are aligned over very short distances and are often sinuous, and their depth is clearly much less than that of the faults. This collapsed cave must have been huge and probably developed along a joint higher than the currently active streamway. Examination of air photos shows that there is no other comparable collapsed cave.

Very big collapsed chambers or 'interior plains', bordered on all sides by 100m sheer cliffs, exist in the heart of the plateau; access to these is generally possible only through the caves. The biggest is the Manily, in the southern part of the plateau. It is oval: 800m x 600m and 100m deep. In the centre is a curious calcite mound. Several large collapses lead off it and we suspect that it is all that remains of a vast chamber with a volume around 50 million cubic metres. The bottom of this and other collapses always contains an accumulation of lapiaz blocks. Some are also forested or occasionally marshy. Some are traversed by a river or stream.

Tectonics

The Ankarana Massif probably behaves as a rigid block. Earth movements in the Jurassic resulted in the downward displacement of the west of the massif. This continued to the Cretaceous with a general tipping of the massif to the west. Movement of the basement beds is thought to have occurred at this stage.

The first faulting brought about the sheer 200m Ankarana Wall bordering the NW of the massif. Simultaneously, the massif developed a shallow syncline with 4° dips to both east and west with an axis approximately 1km east of the cliff wall. This period of earth movement also produced a series of fault scarps approximately parallel to the main cliffs. Volcanic activity in the Pliocene formed the Montagne d'Ambre volcano and probably the canyons. The principal cave systems were truncated by this faulting. The massif at this stage was thrust upwards and the NW-SE syncline accentuated. These movements also led to jointing across the massif in the NW-SE direction. Cave development has frequently followed this the dominant joint direction. All major canyons are of tectonic origin being aligned along major joints or faults. None appear to be due to the



Simon Fowler entering the River Styx

The 'Russian Mountains' inside the 11km Grotte d'Andrafiabe (Paul Stewart)

collapse of cave passages.

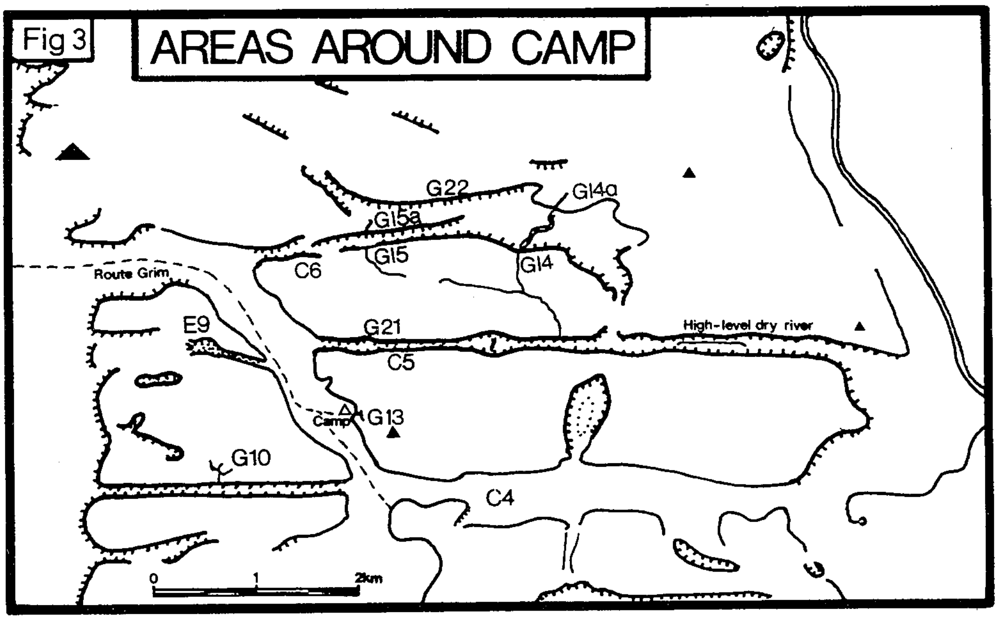
In the north of Ankarana, Quaternary volcanic activity formed a number of small ash cones which can be seen today. The lava penetrated some of the canyons and blocked a good number of the entrances in the north. In places the lava has backed up against the wall. Lava flows are less evident in the south.

Hydrology South of the Antenankarana River

The Mananjeba River (F1-3) continues to flow during the dry season, providing a reliable water supply for the villages downstream of Ankarana. It also floods frequently so the massif here has undergone strong solutional activity and only residual limestone blocks remain. The first of the three blocks is the largest. All underground flow in this southern part, depends purely on the Mananjeba River. It divides into three main branches, close to the plateau; the southern one skirts the southern flank of the third block and does not sink at all; the middle one flows under the second block for 2.7km in the very large passages of the Grotte d'Ambatoharana (G1) (which is 18.2km long); the northern branch flows for 600m through the first block, in part of the Grotte d'Ampanriampanihy (G1a) and by joining with the water flowing from the north, form the Antenankarana River.

Hydrology North of the Antenankarana River

The main karst region is north of the river. Numerous small rivers sink in the massif in the north and east, but only two flow in the dry season; a) Andranotsisiloha (meaning river without a start) comes from the Montagne d'Ambre and sinks into impenetrable boulders in the extreme north of the massif. Only some of the water disappears, the rest rejoins the Andranomandery which flows to the west of Ankarana. b) The Besaboba runs off the hills in the east and divides into numerous branches, most of which disappear into earth-filled hollows. The only two penetrable



sinks (G17, G18) both go for about 400m to a sump, and are only active in very heavy rains.

Little is known about the hydrology in the north and it is difficult to interpret. However, it appears that the waters from the north form the two large rivers and their associated caves in the Canyon Forestier (G14 and G15) and in canyon C5. We assume that these appear again as the river in Campsite Cave (G13) and eventually further south in the caves of Andetobe (G9), Antsatrabonko (G8), and the Andrafiabe gorge (C2). These then join to form single, strong flowing river, from the Buttes Chaumont, to the resurgence at Grotte du Rois (G5). Since much of the river is calm, deep and 10-20m wide, it is navigable. Flow rates (measured at the surface) at both the Buttes Chaumont and the resurgence were approximately 15cums/s. It appears, then, that the major north-south drainage follows the base of the syncline about 1km east of the Ankarana Wall and that most of the tributaries lead to this 'master' system.

CAVE AND ISOLATED FOREST EXPLORATION

R Walters

Our exploration efforts concentrated upon searching unworked areas of the massif and looking for links between mapped sections of cave. The areas neglected by previous French expeditions were largely in the north and east of Ankarana where much of the water sinks and very few caves are known. We also hoped that caves would provide access to many of the sunken forests which the biologists were keen to investigate.

Areas of study and exploration were selected using aerial photographs, taken in 1949 and available from FTM, the Government map shop at Ampasamieto, Antananarivo. We paid particular attention to obvious river sinks, steep-walled depressions where erosion debris was unlikely to have blocked cave entrances and deep gorges, since gorges elsewhere in the massif cut major cave systems. The large isolated forests of the central region (E4-E6) were considered worthy of the biologists' attention and a great deal of time and effort was spent trying to gain access to them.

Canyon Forestier

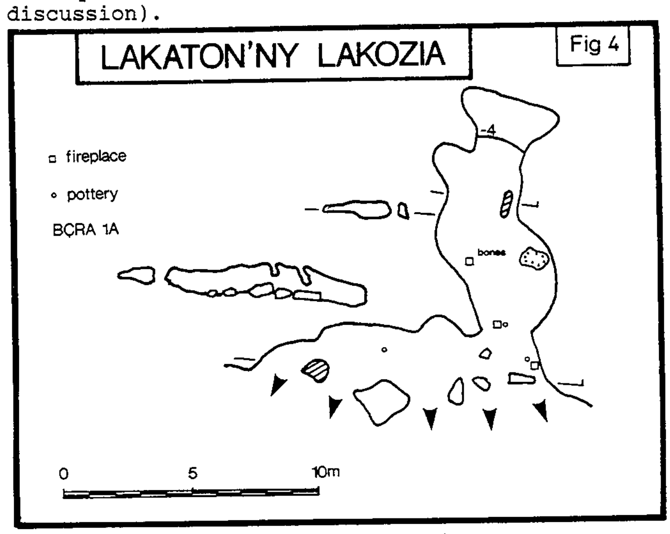
Here we wished to complete the exploration of the vast depression beyond the French discoveries of River Caves One and Two (G15a, G14a). En route both caves were explored and although no further discoveries were made, both yielded much to interest the biologists. The canyon area close to the River Cave One appeared to flood to a depth of 30m confirming an observation (Jean Radofilao, pers. com., 1986) that during the wet season storms some of the Ankarana canyons are completely flooded.

A rock shelter discovered between the First and Second River Caves, la Grotte Trans Sept, high in the north-east wall of Canyon Forestier yielded rich deposits of rodent bones.

River Cave Two was only about 3km from our base camp, but took around five hours to reach. Thick vegetation and lack of water made exploration slow and unpleasant. Beyond River Cave Two, a complete search of the depression revealed many small caves; these were all at relatively high levels in the walls of the depression.

Areas around the Camp

The first canyon (C5), just north of the camp, contained two rivers which had been thoroughly explored by the French (figure 3). Many small caves where found in the cliffs all along the canyon but all these were small and were 20-30m above the water levels in the nearest river caves. A rock shelter in the north-east wall of Canyon C5 which we called Kitchen Cave or Lakaton'ny Lakozia (figure 4) provided finds of pottery, hearths and bones to interest archaeologists. At the eastern end of the canyon an oddly situated dry river bed in a mixture of mud and boulders. It is some 5m deep and 10m across and runs across the canyon for its half kilometre width. The river appears to have sinks at both ends in boulder piles. A small entrance in the base of the dry river bed near the eastern end leads via a 30m climb to the water level where a sump and a boulder choke halt progress (see discussion).



A deep depression north of the camp (E9) looked promising. However, the canyon leading to it proved to be very hard going with very thick vegetation. Its walls contained many small caves but these all connected with the surface only 10-20m above and proved to be of no speleological interest. The depression itself is very deep but its walls are mantled by extensive debris which crushed our hopes of gaining access to any of the major caves. The central area showed signs of flooding, but there was no indication that the water comes from an underlying cave. One small shaft, at least 20m deep, was found in the WSW corner, but there was no draught. It looked dry and unpromising and was not descended.

South 'Table Massif' Area

This area (figure 5) acquired its name from the prominent large rectangular block of limestone about 3km long by 0.5km wide. Aerial photographs suggested that the entire Antanatsimanaja River (F7) sinks just south-east of the 'Table'. However, our explorations revealed that the river does not sink but merely breaks up into smaller rivers in a wooded area; these reform to flow south and join the Mananjeba River (F1)

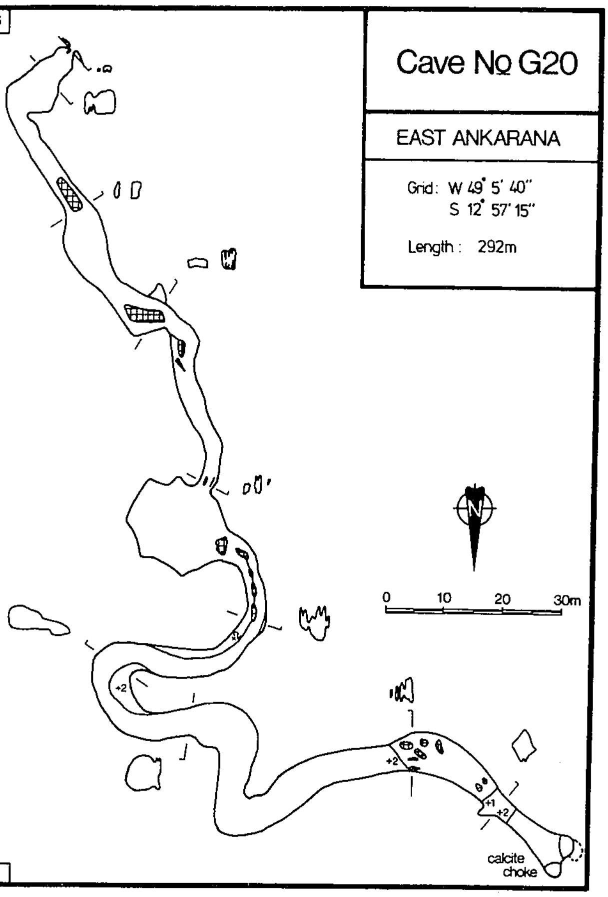
The steep-sided canyons around the 'Table' are not deep enough to reach the cave-bearing limestones and no major discoveries were made. One new cave (G20) was surveyed in the eastern canyon. It was very well decorated and had a strong draught, but ended in a calcite choke after only 290m (figure 6). The dry course of a river was followed north in the western canyon to the end of the 'Table' but it normally sank in an impenetrable mud choke.

Grotte d'Ampondriampanihy-Nord

We were tempted to explore this neglected area by two features: the sinks of the Besaboba River (G17, G18) and the Grotte d'Ampondriampanihy-Nord (G16). The first sink proved to be a spectacular location but the cave was totally blocked by debris after only 20m.

During our searches for the Grotte d'Ampondriampanihy-Nord (G16) another river was discovered beneath boulders in a depression to its south. It is presumed that this flows to the Grotte d'Ampondriampanihy-Nord as no other outlet was seen. The Grotte d'Ampondriampanihy-Nord itself is a most impressive cave. Its entrance, which is 60m wide and 50m high is hidden in a small depression at the extreme southern end of the massif. The entrance narrows to a passage 30m high and 20m wide which leads after 700m to a 700m long canal. To avoid possible encounters with crocodiles, negotiation of this part of the cave requires a boat since there is no dry land for its entire length. A further 2km of similar large cave leads to a boulder obstruction. An ascending passage on the right leads up to a depression (E7a) which had not been fully investigated. The cave requires a full survey but time did not allow us to complete this. We entered many passages from a large passage just on the other side of the canal, but surveys drawn by the French were rather inaccurate and gave no clues as to how much of the cave passages we were exploring was new. The depression was very deep with the river crossing the base of it beneath boulders, but no continuation of the cave was found. A route to the north led to a further depression (E7b) where the river was found again. This was particularly interesting as it showed that the river flowed north. However, the river emerged from an impenetrable boulder pile only to sink again in a cave which was sumped after a few metres.

Fig 6



The Northern Area

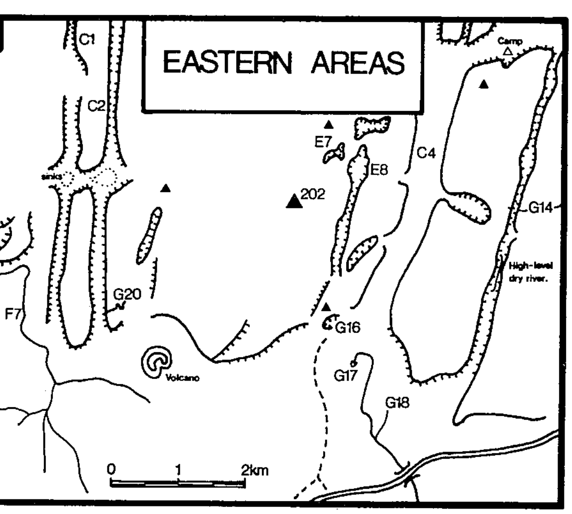
During two trips to the area north of the camp, we only succeeded in finding caves which had already been explored by the French. The desperate lack of surface water made this area very difficult to investigate at the height of the dry season.

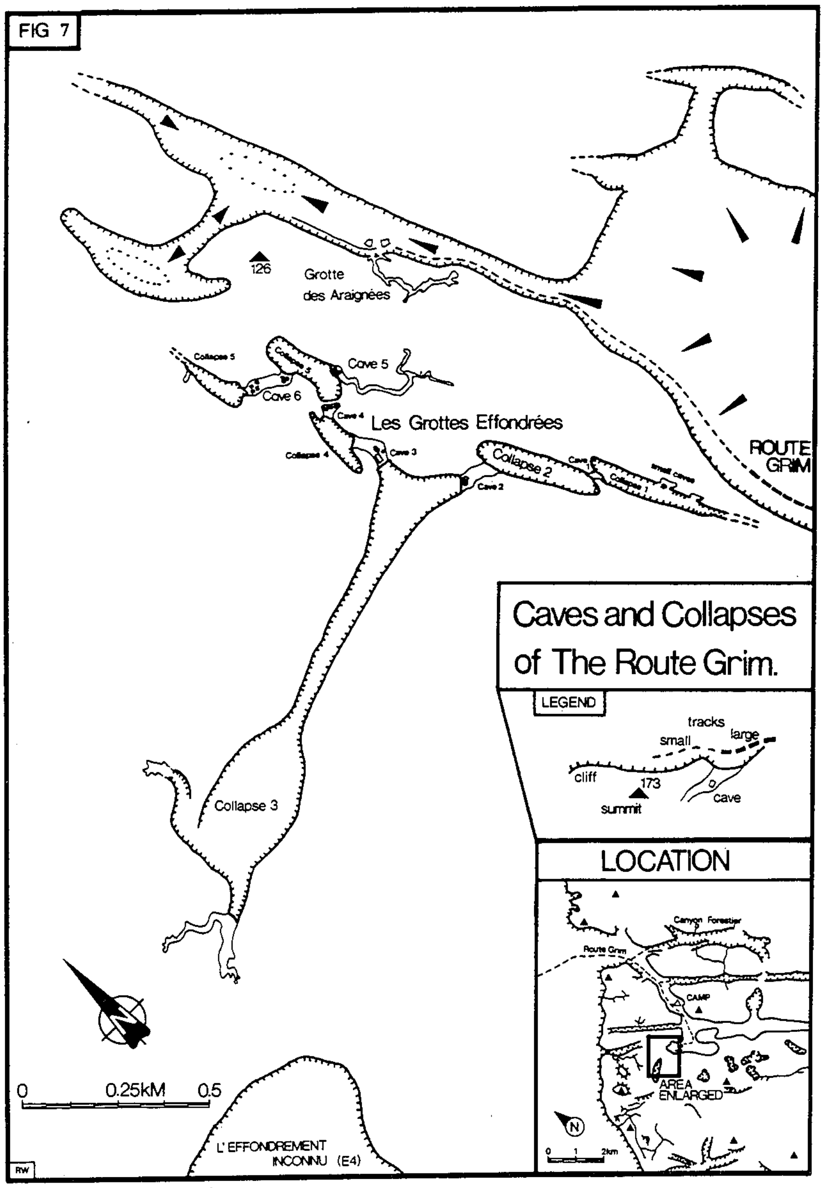
Isolated Forest Areas

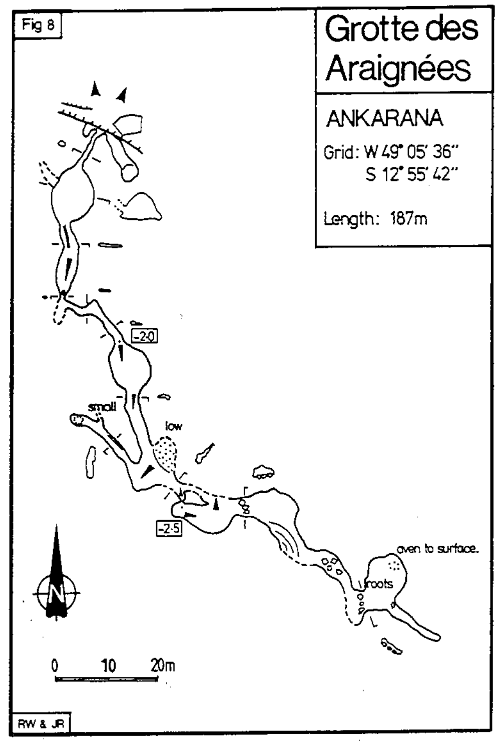
The depressions to the south of the end of the Route Grim (the track which led to our base camp) were extensively explored (figure 7). From the depression a deep canyon running north-west looked very promising. However, extensive debris along the canyon walls blocked any existing entrances. A small high-level cave, the Grotte des Araignees, was discovered and surveyed (figure 8). It comprised 220m of low passages connecting a series of chambers.

A narrow canyon was discovered to the south-west of the first depression. This led, via several collapsed areas and short caves, towards the isolated forest depression (E4), one of the big central depressions and a target for the biologists. The caves and collapses became known as Les Grottes Effondrees (G12). Time did not permit us to find the way to E4. However soon after most of the cavers had left Ankarana, Jean Radofilao told us that he had reached it.

Fig 5





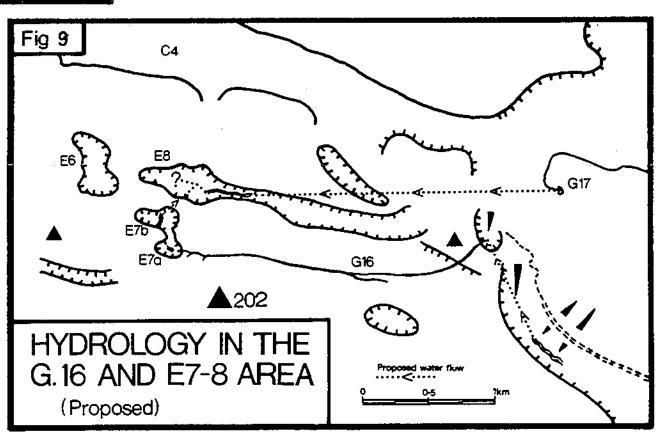


Other Caves Visited

During the course of the expedition, trips were made into Grotte d'Antsatrabonko (G8), Grotte d'Antsiroandoha (G11) and the Grotte des Rois (G5a) where the local kings are interred.

Discussion

The dry river in the first canyon, C5, near the camp, is interesting because it provides further evidence that the canyons flood to high levels on occasions. The dry river bed lies about 30m above normal water level in cave G14. The drainage in the area of the Grotte d'Ampondriampanihy (G16) seemed to differ from our initial predictions. A possible drainage pattern is shown in figure 9. The flows are all minute in the dry season and so dye testing was not practicable. Clearly the situation in the wet season is very different and drainage patterns may be completely altered. The river which sinks in the wet season at G17 and G18 appears to be very big indeed and yet the area around the sink shows only fairly local flooding and the river does not back up. It seems that the river does not go to G16 but further into the massif probably to the area around depression E8. This suggestion was supported by more recent aerial photographs than those taken in 1949 which are available from FTM in Antananarivo. These photographs indicate a large river draining into depression E8 which is situated directly north of depression E7. If this is so, then water is draining north through this part of the massif suggesting a more complicated pattern than has been suggested to date.



Conclusions

The cave exploration efforts covered many areas within Ankarana which had not been previously investigated. The French suggestion that new caves would only be found through a great deal of hard work was certainly proved to be true. However, a few cave discoveries were made by Expedition members and a number of tantalizing leads have been left. Routes into the central depressions have now been found and the drainage predictions in the East might yeild cave passages in depression E8. Any future trip must investigate these.

BATS
Mick McHale

The Chiroptera of Madagascar have affinities with both the African and Asian faunas, Rhinolophus is absent from Madagascar but the giant Pteropus fruit bats are present and considered a delicacy there. Few biologists have worked on the bats of Madagascar, an exception being Dorst (1948). The first study of the cave-frquenting bats of Ankarana was by members of the 1981 Southampton University expedition (Adamson et al 1984; Wilson 1985). We wished to extend the 1981 study by collecting those species roosting in caves and compare them to those which could be trapped flying in the adjacent forests.

Ankarana has a varied and interesting bat fauna and the caves provide an important refuge for many species. In some areas bats enjoy a fady (taboo) status and are not molested, but in several regions of Madagascar including Ankarana the largest species are considered much tastier than lemur meat! Whilst frugivorous bats may raid local fruit trees, the insectivorous species contribute to local agriculture by reducing insect pest populations. Future studies might do well to quantify the threat to bats posed by hunting and the extent to which they are susceptible to habitat destruction.

The cumbersome Alcan Harp Traps proved to be very efficient in trapping forest-flying bats. In contrast, despite repeated efforts, we caught only one bat using the compact and readily portable mist nets. Representatives of each bat species were killed by neck dislocation and preserved in formalin (10%) or local alcohol (rum!). Preservatives were changed after three weeks.

Bats were observed in all caves visited by expedition members; the most common was the tiny insectivorous Miniopterus minor. These roosted in caves singly or in groups of about nine individuals. They could be easily removed by hand from the walls or low roofs of caves because they seemed to be in a state of torpor. The bats were collected towards the end of the six month long dry season when there was a dearth of insect food; it is possible that the bats' apparent lowering of metabolic rate was in response to shortage of food.

Trouessart's Trident Bat (Triaenops furculus) female; this is a species endemic to Madagascar (Ben Gaskell)

Another cave-roosting species which occurs at Ankarana, but less commonly than M. minor is Miniopterus inflatus africanus. This proved to be the first record of this animal from Madagascar (J.E. Hill, pers. comm 1987).

The large Hipposideros commersoni roost in hundreds in the deeper (dark zone) sections of the Grotte d'Andrafiabe and skeletons found in other caves imply they roost in lesser numbers elsewhere in the massif. Paulian (1981) wrote of the killing of Rousettus at Ankarana and we certainly found evidence that the local people light fires in the caves to disturb the bats, then hit them with sticks as they try to escape. These bats, which have a 60cm wingspan, turned out to be Eidolon helvum dupraneum which has not previously been recorded as a cave-roosting species (Martin Nicoll pers. comm 1986). In the large entrance chamber of la Grotte d'Antsiroandoha we discovered a roost of several thousand of these fruit bats; they also seem to roost in crevices in the canyons within the massif. Faeces beneath these colonies implied that these bats subsist almost entirely upon a single type of fruit; this appears to be the ebony Diospyros sp. A rich, varied and unique invertebrate cave fauna is based upon food brought into the caves by bats. Any ecological changes in Ankarana's forests would not only endanger the bats but also the interesting and specialised ecosystem which relies upon them.

Bats collected from traps in the forest were generally different from species found roosting in caves. Some species were found roosting deep inside caves in the Dark Zone (DZ), while others roosted within sight of daylight in the Threshold (ThZ) or Entrance Zones (EZ).

Chiroptera recorded from Ankarana

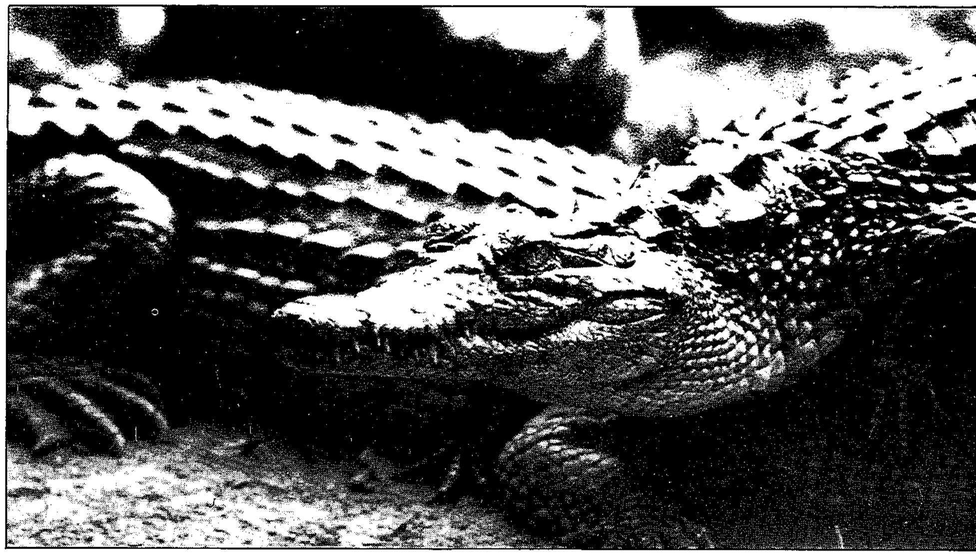
Species	Location	Zone
Eidolon helvum dupraneum	Grotte d'Antsiroandoha	EZ
Hipposideros commersoni	Grotte d'Antsiroandoha	DZ
	Grotte d'Andrafiabe	DZ
Miniopterus minor manavi	Campsite cave	ThZ
	First River Cave	ThZ
	Second River Cave	ThZ
	Grotte d'Andrafiabe	ThZ; DZ
	Grotte d'Antsatrabonko	ThZ; DZ
	other caves and rock shelters	
	also flying in forest	
Miniopterus inflatus africanus	Campsite cave	ThZ
	First River Cave	ThZ
Tadarida jugularis	Grotte d'Andrafiabe	ThZ
Myotis goudoti	forest	
Emballonura atrata	forest	
Triaenops furculus	forest	
Triaenops persicus rufus	forest	

CROCODILES
Paul Stewart

The Malagasy population of the Nile Crocodile, Crocodylus niloticus, is generally considered to be under considerable threat. The subterranean rivers of the Ankarana Massif have been cited by Blanc (1984) as one of the last refuges for the species on the island and Ankarana harbours what appears to be the only population worldwide were individuals are regularly found within a cave system. It is also one of the few sites in the world where 6m long crocodiles still survive.

The crocodiles reach their greatest densities at Ankarana in the southern caves of the River Styx which flows down through the massif from the north. It appears that the crocodiles retreat into these caves to escape the drought in the dry season (May to October), when areas of the southern marshes and rivers dry up. The crocodiles are hunted unsystematically in this region for sport by foreigners and for leather and perhaps meat by some locals. Despite repeated searches, no evidence of crocodiles was found in the caves of the northern part of the massif.

The Nile Crocodiles found in the Ankarana caves were of normal pigmentation (Jane Wilson)



Their absence might be explained by the fact that these caves are isolated from the southern systems by long sumps and white water sections and also lack suitable basking sites in the open. The northern subterranean rivers are also considerably colder than the southern waters. For example, water in the northern Second River was at 21°C, whereas water flowing through the southerly Ambanemero Fault cave system was from 25 to 27°C,

It is likely that the crocodiles feed while in the southern caves as the water temperatures correspond to the low end of the active temperature range for the species (26-27°C). A variety of prey is available including crabs, shrimps, crayfish, and fish. The larger crocodiles may not only prey on smaller individuals but also upon the large eels described in the section below.

OTHER CAVE FAUNA
Jane Wilson

More than 80% of Madagascar's animals and plants are peculiar to the island and the cave adapted animals (Troglobites) which have evolved from this unique and rich fauna have the scope for being even more interesting and quite different to that of any other karst region. Ankarana is unique for other reasons. It is probably contains the most extensive tropical cave systems in Central Africa and the size of its subterranean rivers provide unusual tropical cave environments. It is also an essential dry season refuge for certain epigean species. Flooding during the wet season seems to be on catastrophic proportions for some canyons are submerged under 30m of water. And it is interesting to consider the effects this might have upon speciation, which seems to be going on at a great rate in some caves: further studies are sure to reveal much more.

Although the literature on the cave-dwelling animals of Madagascar is quite extensive, it is principally limited to taxonomic descriptions (Paulian 1961; Decary and Keiner, 1970; Remillet, 1973). No cavernicoles had been recorded from Ankarana until 1981 (Wilson 1985).

The entire food chain within any cave ecosystem is absolutely dependent upon energy from the outside environment. At Ankarana food is provided by bat guano, material washed in by floods and to a much lesser extent swift and lemur excreta. This reliance on the outside is particularly relevant at Ankarana, where deforestation is threatening the food supply of both frugivorous and insectivorous bats. Deforestation is also allowing increasing soil erosion and redeposited sedimants could possibly block cave passages. This was seen (by RW) in the Grotte d'Analamisondrotra in the north of the massif where a high-level passage some 5m by 8m was completely blocked with mud.

Within Ankarana's 98km of surveyed cave passages, there is a wide range of habitat types: large subterranean rivers (where the crocodiles aestivate), high humidity dry chambers, guano beds and chambers desiccated by warm through draughts with only 50% humidity. Cave temperatures are high: at the terminal collapse of la Grotte d'Antsiroandoha it was 24°C, for example. The existence of many varied habitats, even within one cave, explains the diversity of fauna. It is perhaps surprising that this rich area had been neglected by speleologists and biologists.

Animals were collected from the eight richest caves visited. Many of the species listed from the Andrafiabe and Antsatrobonko caves (Wilson 1985) proved to exist in other Ankara caves but very many other invertebrates await identification.

The 1981 collections revealed a surprising number of shrimp species: nine inhabiting two caves (Gurney 1984) and the 1986 collections included at least two more new records. It seems likely thet _Caridina_ and _Parisia_ shrimps form large species complexes at Ankarana, with troglobites, troglophiles and epigean species representing various stages in troglomorphic evolution. Shrimps known from Ankarana so far are:

Parisia dentata	Caridina xiphias	Cardina craurispinata
P.macrophthalmia	C.parvocula	C.typus
P.microphthalmia	C.norvestica	C.unca
	C.nilotica	C.isaloensis

Other _Caridina_ and _Parisia_ species await description. The "crayfish" _Macrobrachium moorei_ also exists in the Ankarana streams but shows no cave adaptation. Other interesting finds included a new species of troglobitic millipede and probably the first Schizomid to be collected in Madagascar (Legendre 1972). An Amblypygid, probably _Charinus madagascariensis_ was common in the entrance and threshold zones of a number of Ankarana caves; this species is probably endemic to the massif. Most caves had a resident eel, often over 1.5m long. Unfortunately these extremely strong animals foiled all attempts at capture so remain unidentified. They are likely to be a new species.

River Cave Two in the Canyon Forestier was of particular biological interest. Regular visits by Crowned Lemurs, _Lemur coronatus_, to drink within the cave have polished rocks smooth and since this cave water hole is used by rare species such as the Fosa, _Cryptoprocta ferox_, it is an excellent place to study both trogloxenes and epigean species. The cave contains slowly-moving water which is about 2m deep at the entrance and is at 21°C. Populations of eyed and blind cave shrimps and three new species of fish also live there.

Two Glossogobius species (Peter Miller, pers comm 1987) have eyes, are pigmented and presumably arrived (just as their next meal will arrive) by way of flood waters. Interestingly, some of these fish were found in a deep pool which was glazed over by a 2mm layer of calcite. The third fish, probably a Gobius sp., is a toglobite and was found even in the Entrance and Threshold zones of this cave. This is almost certainly endemic to Ankarana which implies it is restricted to to rivers flowing within a range perhaps measuring 10 x 30km. Like the 39 known species of troglobitic fish it should be considered an endangered species.

USE OF CAVES BY LEMURS

Jane Wilson and Paul Stewart

Accessible drinking water for both people and animals is at a premium at Ankarana during the dry season. The most reliable water holes were at cave entrances and lemurs and other wildlife were regularly observed drinking at the entrances of the Second River Cave (G14a), la Grotte d'Andrafiabe (G7) and at the Syyx River Cave (G5).

It is likely that lemurs have needed to use cave water holes at Ankarana for centuries and this might explain why the sub-fossil site inside the Grotte d'Andrafiabe is so rich. All skeletons were found just beyond the limit of light penetration and most were complete skeletons which must have arrived in the cave while the carcass was relatively intact. Many were lying on tops of boulders in positions incompatible with having been washed in by floods. We were unable to find any avens nor any evidence supporting the idea that the bones could have arrived by falling through a hole in the roof. No talus cones were evident in the cave system.

The most likely explanation for the arrival of the lemurs at this site is that they had come into the cave, probably to drink at a water hole

Sub-fossilized lemur bones found inside Grotte d'Andrafiabe. Two skulls of Hapalemur simus are on the left and the skull of a Mesopropithecus is bottom right (Jane Wilson)

in the cave entrance, and were scared into the cave by a predator (the Fosa, Cryptoprocta ferox will take lemurs and seemed to be hunting Crowned Lemurs at the Second River Cave). When frightened, lemurs often flee upwards and once they had fled beyond the limit of light penetration they would have been unable to find a way out. There is a reliable water source in the Dark Zone just beyond the sub-fossil deposits but it seems unlikely that lemurs could have navigated to this in absolute darkness. Carcasses lying in the cave's Dark Zone would be unavailable to scavengers and also protected from the decomposing effects of leaf litter. This explains why more fossils have not survived in Ankarana's isolated forests.

None of the lemurs repesented as sub-fossils at this site still survive at Ankarana as far as we know and Ankarana's extant lemur species were poorly represented in the remains. This is consistent with the drinking hole hypothesis since the entrance water hole no longer contains water during the dry season.

PALAEONTOLOGY

Martine Vuillaume-Randramanantena and R Ralaiarison-Raharizelina

The Grotte d'Andrafiabe

In 1981 members of the Southampton University Expedition discovered a skull and limb bones of four Greater Bamboo Lemurs, Hapalemur simus (Wilson 1985). At this time museum skeletal specimens of this species totalled only about 15 worldwide (Vuillaume-Randriamanantena, Godfrey and Sutherland 1985). These finds implied that Ankarana might prove worthy of a special palaeontological survey. When we visited the same cave in 1986, the sub-fossil site at la Grotte d'Andrafiabe, proved to be unusually rich.

We were able to collect bones of 18 Hapalemur simus which is a great concentration of skeletons of a lemur rarely found in sub-fossil state. We left other sub-fossils in situ since they were too securely cemented to enable us to remove them, with the limited equipment we carried, without damage. Most sub-fossils (90%) were of Hpalemur simus. An unidentified tibia (a lower leg bone) probably a pathological lemur bone was also collected and skeletons of Lemur sp. were seen. Nearby were skulls of Propithecus diadema and Mesopropithicus. Propithecus has not been recorded from Ankarana previously and Mesopropithecus which is now extinct, was known only from a very few specimens collected more than 50 years ago in central and southern Madagascar. The first Mesopropithecus was described by Standing in 1905 and others were found by Lamberton in 1937 and 1939. The latter finds were in the cave site of la Grotte d'Ankazoabo on the south-west coast of Madagascar (Lamberton 1939, 1946, 1948). The 1986 finds included previously unknown bones of the Mesopropithecus which give valuable new information contributing to knowledge of the animal's lifestyle (Vuillaume-Randriamanantena and Ralaiarison-Raharizelina 1987).

One of the most interesting questions unanswered by palaeontologists, is the age of lemur sub-fossils. The most ancient Malagasy sub-fossils documented are from the deepest deposits at Ampazambazimba; these are about 8000 years old (MacPhee, Burney and Wells 1985). More commonly age estimations fall between 2000 and 1000 years before present (Dewar 1984). Other researchers, relying on oral evidence and reports of ancient travellers like Flacourt (1661), feel that the last Madagascar dwarf hippopotamus and the last flightless elephant birds only disappeared a few centuries ago. Sadly there were few sediments at the Andrafiabe sub-fossil site so excavations would be unlikely to reveal further information on the age of the skeletons although accurate dating would be possible if some bones were sacrificed. The remains seem to span a large time scale. Some of the sub-fossils might be a few hundred years old, others including bird and fruit bat bones are probably at most a few years old.

Micromammal Remains in Other Caves

We searched numerous rock shelters for skeletal remains and several proved to have rich deposits of recent origin. The richest was from the Grotte Trans-sept, in the north wall of Canyon Forestier. It seems that at Ankarana cosmopolitan rodents have not yet supplanted the local rodents which are endemic to Madagascar. In the Ankarana rock shelters surveyed, skeletons of local rodents outnumbered those of introduced species. This is in great contrast to the bones found in the caves of Anjohibe or in caves in the centre of Madagascar. On the contrary, introduced rats and mice represent the majority of species in these more southerly caves.

Part of the zoological work of the expedition was to attempt a comprehensive inventory of all animals inhabiting Ankarana, both in caves and on the surface. We expected to compile a species list of the local small mammals using Longworth Traps. However, even if the freight shipment containing the traps had arrived, such a survey would have failed since most small mammals were aestivating and inactive. Skeletal remains found in the rock shelters therefore provided unexpected information on the ecological isolation of forests within the Ankarana Massif.

ARCHAEOLOGY
Jane Wilson

Madagascar was probably only first settled by man about 2500 years ago. The first settlers were thought to have arrived by boat from Indonesia and the voyage across the Indian Ocean in a large out-rigger canoe was proved to be possible by the Sarimanok Expedition in 1985. Early archaeological discoveries are therefore most unlikely, although some people think that there was a population in Madagascar before the Indonesian settlement. When we discovered pottery, fire places and other evidence of human settlement at Ankarana we first assumed this to be evidence of people hiding at Ankarana between 1835 and 1838 when local people were hounded by the soldiers of Radama I. This may be the origin of some artifacts but it seems probable that the archaeological remains are from a range of dates. The Ankarana shards show similarities with pottery used on the islands off Madagascar's north-west coasts during the XVI - XVIII centuries (Dr Hilarion Rakotovololona, Musee de l'Universite, Antananarivo: pers comm, 1987). Dr Bob Dewar (University of Connecticut) felt that the pottery photographed in the huge entrance of the Grotte d'Antsiroandoha had been deliberately left in caves as offerings to a spirit or as part of a funerary ceremony. Ankarana seems to be a rich archaeological site, worthy of specialist attention.

CONCLUSIONS
Phil Chapman

The karst and caves of Ankarana, although packed into a small area of limestone, rank with other great karstic regions of the tropics such as the Mulu Caves in Sarawak or the Guangxi towers in China.

The intimate relationship between cave waters of Ankarana and the wildlife-rich forests which they support, lends the caves a biological significance over and above that afforded by their rich cavernicolous faunas. The caves also hold important palaeontological and archaeological remains.

Yet the area faces an uncertain future. Local, large scale deforestation maybe increasing silting within caves and is posing a direct threat to many forest species. Reducing forest habitats is likely to influence the food supply of cave communities which depend upon bats, swifts, etc. Uncontrolled hunting threatens Ankarana's unique subterranean crocodiles.

Intervention is required soon if this unique area is to be safeguarded for the future. The Malagasy Government has the political will to protect Ankarana, but sadly lacks the necessary resources. Thus an ambitious conservation project is underway to extend the work presented in this report. In autumn 1987 a small team, including some members of the 1986 Crocodile Caves of Ankarana Expedition, will make a film about the area, its caves and wildlife and it conservation needs. A parallel research project, involving mainly Madagascar-based personnel, will aim to draw up a Management Plan for Ankarana which will be implemented using money raised by public appeal through international conservation organisations.

We hope that the Crocodile Caves of Ankarana Expedition has started a process which will eventually lead to the permanent protection of this superb area for the enjoyment of cavers, scientists and the people of Madagascar.

KELIFELY RECONNAISSANCE
Dave Checkley

The Kelifely plateau, with 8000 sq km of limestone, is the second largest potential caving area in Madagascar. It is reputedly nearly all Jurassic limestone (Balazs 1980), and is approximately 60km long by 50km wide. The southern scarp rises nearly 1000m above the surrounding plain.

Kelifely is in a fairly remote area, 250km north-west of Antananarivo and 600km south-west of Ankarana. Road access may be difficult since several river crossings are required and the ferries no longer operate. However, there are regular flights from Antananarivo to Ambatomainty, a village 25km south of the massif with a good dry weather airstrip. The Mahakamba River lies between the massif and Ambatomainty, but this probably dries up for some of the year, as does the larger Mahavavy River to the east of the massif.

The only people to look for caves in the region previously were a French team that visited the most northerly area of Kelifely (Peyre et al 1981 and 1983). They found no significant caves, but their movements were severely ristricted by the presence of bandits in the region. The French approached the massif from the town of Sitampiky in the north and did not reach the massif proper. Bandits are no longer a significant problem.

We chartered a four-seater aircraft through Madagascar Airtours in Antananarivo at approximately £400 for the afternoon. We flew directly to Kelifely across the dry plains. From Ambatomainty we flew straight up to and along the southern scarp. West of Ambatomainty the scarp is steep and continuous. It has very few breaks in it and only occasional patches of woodland in the shallow valleys incised into it.

To the north east of Ambatomainty at the base of the massif there is an incredible landscape of tortuous canyons. These winding, steep-sided gorges were closely intertwined over a huge area. The gorges were perhaps 30m deep and were so closely packed that the area presented a vista of endless rocky pinnacles running up to the Kelifely scarp. There was no water in any of these gorges and no obvious caves at their heads in the massif. Woodland did however obscure many of these valley heads. At many gorge heads were steep cliffs, but with no sign of caves at their bases. The red sandstone in which the gorges have formed (Isalo formation) must be very soft to have been so heavily eroded by the limited run off from the Kelifely scarp. The scarp in this area has a stepped appearance with small (?limestone) cliffs and intervening grassy or sometimes wooded slopes.

North of the scarp is a plateau, an extensive area of grassland sloping very gently northward. These grasslands are only occasionally punctuated by clumps of trees in shallow depressions and by the winding, tree-lined river valleys. We saw only one region of apparently broken limestone pavement and a few shallow dolines. We followed the two major rivers draining the plateau for their entire lengths (the Kiananga and Tsiamadiovolana Rivers). Their blue-green waters occasionally plummeted perhaps 50m down great round bowls, forming spectacular waterfalls. We could not be certain that there were no caves at the bases of these wooded bowls, but the river gorges cut out of these bowls at their far sides appeared to carry the same quantity of water as went in at the top. The further north we went along these tributaries of the Mahavavy River, the wider and more wooded their valleys became. However, even in the higher frequently cliffed gorges of these rivers we saw not a single cave entrance. The rivers always flowed on the surface and generally there were very few karst features. We flew as far north as the Kasijy Forest.

Although we did not land at Kelifely we flew within 20m of much of the surface of the massif for one and a half hours. We were unable to certainly identify any cave entrances. I do not therefore believe that the area is worth a major speleological expedition. This comment is made in the knowledge that a small Malagasy team (based in Antananarivo) will visit the area this year (1987). It will be interesting to see what they find, but the development of major cave systems in the area does not seem very likely.

MEDICAL REPORT
Jane Wilson

During the dry season which is the most practicable time to work at Ankarana, the dearth of water on the surface makes it a remarkably pleasant and healthy place to be. It hardly rains so tents are unnecessary, there are no insects and the only noxious animals are the scorpions and centipedes. These animals do not really become a nuisance until the earliest rains in October, which is about the time that the biting insects appear. The largest and most unpleasant scorpion is Groophus palpator and the two of us who were stung by these were in great pain with rigors, sweating, etc for 24 hours and unwell for several days subsequently. Pain at the site of the sting resolved after just over a week but one victim was left with an anaesthetic finger for a month. Powerful pain-killers preferably opiate analgesics, should be available for the first 24 hours after such a sting. We used sustained release Morphine tablets, but parentral drugs might have been more appropriate. Scorpions favour hiding in dark corners during daylight hours and even manage to find their way into rucksack pockets when it has been suspended on a tree. Great care is needed to avoid stings which are reputedly rarely fatal on Madagascar (see also Wilson 1987).

Another important health risk at Ankarana is from trauma; the tsingy is sharp and unstable and very abrasive. Strong boots and leather gloves helped to protect us and we were fortunate that our most serious accident was a laceration from a palm leaf.

Other problems included travellers diarrhoea and sickness; Lasonil proved helpful subsequently for soothing over-active anal sphincters. Several of us were troubled by mouth ulcers which we eased by Tee-jel. Three of us caught worms which were diagnosed and treated after we returned to Britain.

We stayed healthy because of the easy conditions at Ankarana, having the right immunisations and malaria prophylaxis and good camp hygiene (with a latrine and compost heap away from the living area). We acquired most gastro-intestinal problems while we were sampling the excellent Malagasy food that is available in the towns. These usually settled within 24-48 hours taking only clear fluids but one of us required a course of Flagyl (Metronidozole) for presumed giardiasis. Malagasy doctors and local Aides Sanitaires are well trained and very competent but the service they can offer is extremely limited due to shortages of drugs and medical supplies. A more comprehensive account of the medical aspects of the Expedition, including a list of drugs taken, is in our report (Chapman et al 1987a).

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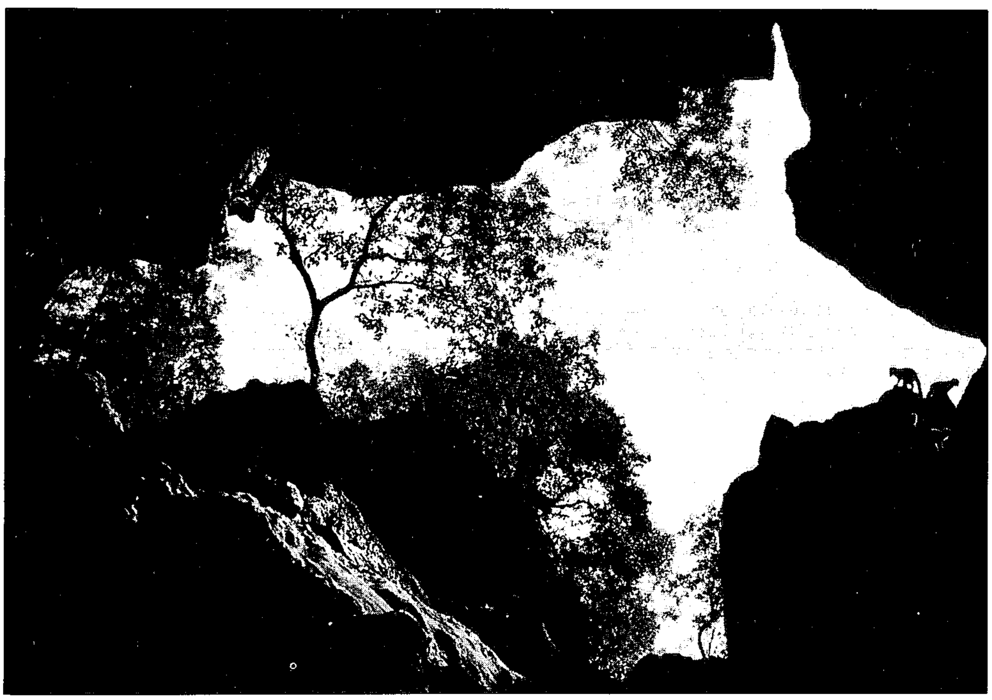

Troop of Crowned Lemurs entering the Second River Cave to drink (Jane Wilson)

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