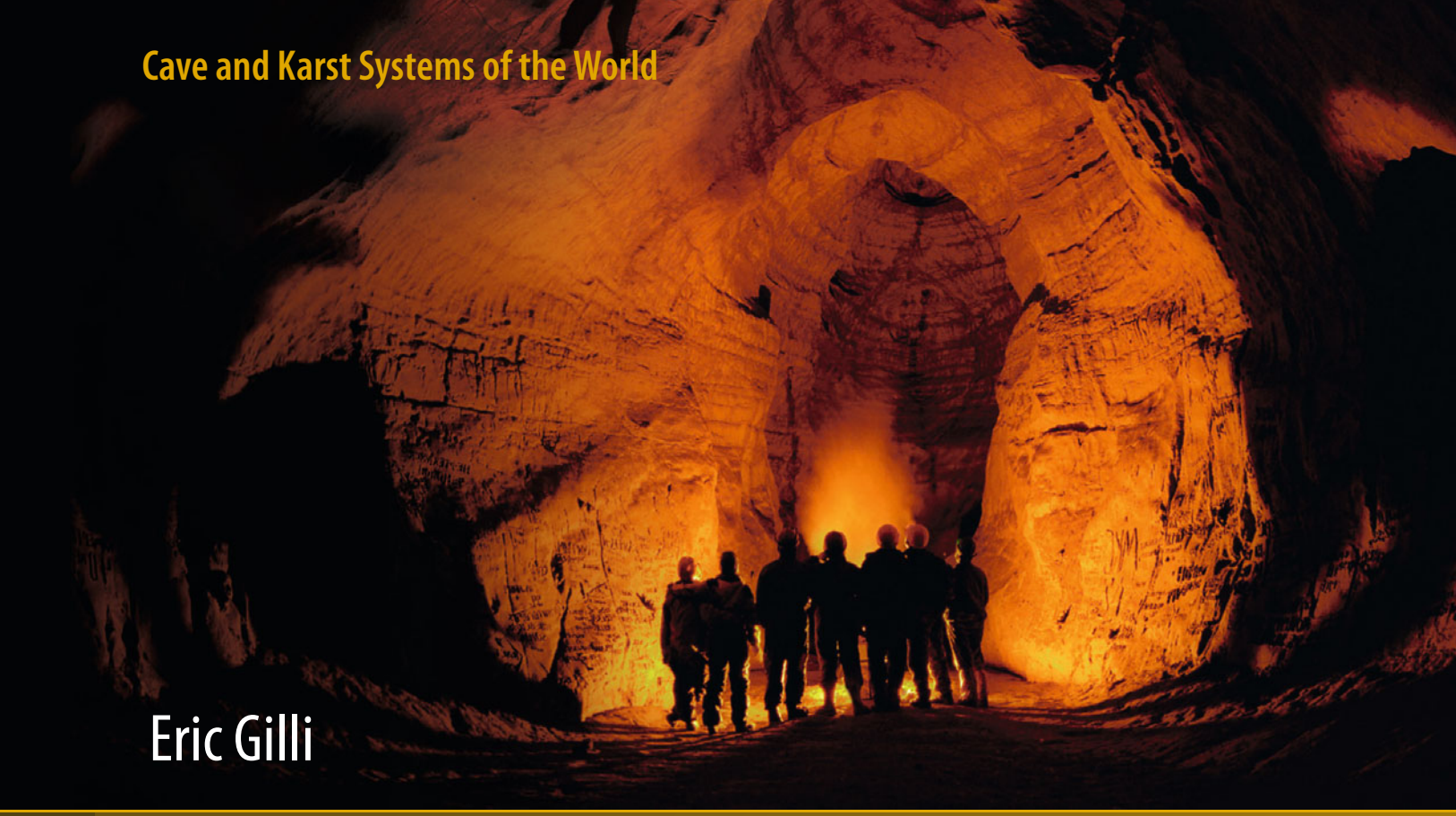
Cave and Karst Systems of the World



Eric Gilli

The Ankarana Plateau in Madagascar

Tsingy, Caves, Volcanoes and Sapphires

Springer

Cave and Karst Systems of the World

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To Jean Radofilao, intrepid and tireless explorer of the Ankarana caves

Preface

I discovered the existence of the Ankarana in 1981 when I was a geology student at Nice University attending the lessons of Prof. Julian, a famous French karstologist, along with three comrades who were also cavers. One day he showed us a map from a book based on work that had been carried out in the north of Madagascar: *The Ankarana Plateau* by Georges Rossi (1980). At first glance we were fascinated by the landscape represented on the map. Reading the book, an important part of which was devoted to the karst areas of Red Island (Madagascar), was the incentive we needed for us to put on on our cavers' boots and explore such a remote area.

We had tough negotiations with Air France to obtain discounts on airline tickets compatible with our meagre resources as students. The Vieux Campeur, a famous French outdoor gear supplier, also helped us by providing cave and camping equipment. A few months later we landed in Madagascar to explore the Kelifely Plateau, an unknown area in the centre of Madagascar.

However, the Malagasy authorities told us the area was full of bandits and, anxious to avoid problems (especially since Madagascar had only recently been opened to tourism), forbade us access to the massif. They invited us instead to go to the Ankarana Plateau, located in the north of Madagascar. Although disappointed we had little option but to follow this requirement.

The French Embassy greatly helped us by providing a Land Rover (Fig. 1), a four-wheel-drive vehicle. A few days later we reached Diego Suarez (Antsiranana) along a rutted track, interspersed with rivers that were only passable by boat. Access to the Ankarana would therefore be a real adventure.

This was my first visit to the Ankarana and, despite the disappointment of not being able to reach the Kelifely, I did not regret it at all. According to bibliographic descriptions we imagined an area already well known, instead we discovered a gigantic but still wild massif, bordered by a deep forest inhabited by lemurs. Much exploration work was clearly still needed. On the first day of our expedition, a few minutes from the camp (Fig. 2), we came across Analamisondrotra, a two-kilometer-long cave. This first trip was also an opportunity to meet Jean Radofila (alias J. Duflos), who has been patiently exploring caves in the Ankarana, mostly alone, since the 1960s and who shared with us his underground adventures. Long navigations through the caves revealed cave crocodiles, giant galleries and walls covered with helictites, all of which left unforgettable memories.

The twists and turns of life allowed me to return to the Ankarana in 2005, when the 1980's student had become an academic karst specialist. Intrigued by the relationship between volcanism and karstification and perhaps somewhat drawn by the nostalgia of the past, I decided to briefly return to the Ankarana with three former Ankarana explorers: Jean-Christophe Peyre, Daniel Bessaguet and Franck Tessier. This was the beginning of a new

Fig. 1 First trip to the Ankarana in 1981

Fig. 2 The camp close to Analamisondrotra Cave in 1981

series of explorations in the southern part of the plateau. This book presents the main findings of such explorations by both our predecessors and ourselves. It highlights the immensity of the work that remains to be done and we hope that it will serve as a basis for new research.

Nice, France Eric Gilli

Acknowledgements

This work involved input from several cavers: Jean Radofilao, Jean-Claude Dobrilla, Alain Recoules, Jean-Michel Frèrejean, Michel Chignoli, Franck Tessier, Paul Gilli, Guillaume Tennevin, Jean-Christophe Peyre and Daniel Bessaguet. Several cave surveys are their work.

I also had the local assistance of Jean-Christophe Peyre (Ibis Madagascar), Thierry Dalais (Miavana Hotel in Madagascar) and the technical help of Gabriel Monge (Ecole des Mines de Sophia Antipolis).

I would like to express my sincere gratitude to them all.

Contents

About the Author

Eric Gilli is a French karstologist. He was born in 1957 and studied geology and physical geography in Nice, Paris and Aix-Marseille. Formerly a consultant in Nice, he has been since 2001 a professor at the Geography Department at the University of Paris 8. His main topics are hydrogeology, karst, caves, groundwater, palaeo-environments, earthquakes, tsunamis and natural disasters. He has also been involved in shipwreck explorations and troglodyte studies. His international studies have taken him to many parts of Europe, Morocco, Tunisia, India, Madagascar, Belize, Guatemala, Haiti, USA, Iceland, Seychelles, Guyane, Brazil, Costa Rica, Papua New Guinea, China, Egypt and a few other countries.

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Abbreviations

ASUM	Association Sportive de l'Université de Madagascar
BRGM	Bureau des recherches géologiques et minières
CAF	Club Alpin Français
FTM	Foiben-Taosarintanin'i Madagasikara (Institut géographique de Madagascar)

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Presentation

1

1.1 Introduction

The Ankarana Plateau is located in the extreme north of Madagascar (Fig. 1.1), close to a major volcano, the Montagne d'Ambre. It is an exceptional limestone plateau covered with rock needles: the tsingy (Fig. 1.2). It contains a huge network of caves with dimensions that are often very large. The Ankarana is home to a rich fauna, where crocodiles share the space with lemurs, and a peculiar flora with baobabs, pachypodiums and lianas that root in the limestone carved by erosion.

The Ankarana is home to the Antankarana (or Antakarana) people who found it an ideal place to shelter during wars and to bury their kings in underground caves.

Nowadays, the Ankarana is a national park, but its integrity was threatened by the discovery a few years ago of corundum, which triggered a sapphire rush.

The plateau was not mentioned by De Flacourt (1628) in his famous description of Madagascar: *Histoire de la Grande Isle de Madagascar* (*History of the Great Island of Madagascar*). The first published text concerning the Ankarana is that of Nicolas Mayeur (1775). His description is very rough:

> On the 30th I left out at midnight, and continued to sail the coast to the North to the mouth of the river Amboise, where I arrived at daybreak. I went up to the East for about one hour, and I landed on the right bank. I left the canoes to go to Maha Foutoune, a village belonging to Lambouine, and situated on the bank of the river Anboye, between two hills whose basis is rocky and the top covered with branched coral. Both are without forest.
>
> I learned from the people accompanying me that, beyond these hills, there is a vast plain, which may contain about five hundred inhabitants, surrounded on all sides by almost inaccessible rocks covered with coral. The soil is fertile; culture is easy. It abounds mostly in cambarres (copal) and in honey. A beautiful river feeds it throughout its length. It is on this plain that, as said, is the tomb of the Lambouine's family and the deposit of its treasure. The natives assured me that after a certain time without going there, one is obliged to break the branches of coral which border the paths because they grow. I don't know if this assertion is founded: my little knowledge of natural history does not allow me to precise the opinion of the reader on this fact. I should have been curious to extend my observations beyond these hills, but the superstitious spirit of the Malagasy and their natural suspicion detained me, because I needed them for the success of operations which did not only concern me and all concerned the good of the service…..
>
> The mountain of Encaravaki, quite high and whose basis embraces a considerable extent of land, is all made of coral. On the summit of this mountain is a very extensive plain formed of an excellent soil, which produces in abundance all sorts of nutritive roots. The wood is frequent. It is crossed by a river which takes its source in one of the hills or pitons which border the enclosure. Its approach is defended on all sides by steep glacis covered with corals. There is no practicable road except for a very narrow path which can be easily defended and shelters the plain from the attacks of the enemy; thus it is the ordinary refuge of the inhabitants of the country when the war is started between them and the Seclaves or the peoples of Antongil Bay. This enclosure is the burial place of Lambouine's royal family. He has built a few houses where several of his relatives live, and where he maintains a considerable number of slaves, responsible for the care of the tombs and the care of his most precious belongings.

Note that Mayeur says the grave of Lamboina (the king of the Antankarana people) is located in a place where coral branches are growing, which is of course impossible. In fact, he describes the tsingy which is a karst feature. However, as the rock is a reef limestone, some parts do indeed show fossils of coral.

The main geological and geomorphologic features were first described by J. de Saint Ours (1958). The geological map (sheet Ambilobe-Betsiaka U32 V32) was published by the Geological Survey of Madagascar (Service Géologique de Madagascar) in 1963 under the direction of H. Besairie. Diverse geological and geomorphologic work was carried out by Battistini (1964) and later G. Rossi (1973, 1974). In 1980 the latter published an important thesis on the extreme north of Madagascar, in which the geomorphology of the Ankarana Plateau is detailed.

E. Gilli, *The Ankarana Plateau in Madagascar*, Cave and Karst Systems of the World,
https://doi.org/10.1007/978-3-319-99879-4_1

Fig. 1.1 Location of the natural reserves of the Montagne d'Ambre and the Ankarana

Fig. 1.2 The tsingy of the Ankarana at Andranomilika Butte

Several works on the flora and fauna of the Ankarana have been published but, apart from Rossi's thesis (1980), no book describes the caves or the geology of the Ankarana Plateau.

The present book is a synthesis of speleological and geological works, complemented by our research since 1981 that was undertaken during several field trips that were inevitably too short as a result of the distance from France.

Geography

2

2.1 Description

The Ankarana Plateau is located in Diana Province, at the northern tip of Madagascar, about 70 km southwest of Antsiranana (previously named Diego Suarez during the French colonial period) and 30 km northwest of Ambilobe (Fig. 1.1 in Chap. 1). It is a sedimentary basin where major Plio-Quaternary volcanic activity built the Montagne d'Ambre, a 1475-m-high volcano (Fig. 2.1), surrounded by numerous small strombolian cones (Figs. 2.2 and 2.3).

The Ankarana Plateau is about 35 km long, with a maximum width of 10 km and a general northeast–southwest orientation. The elevation ranges from 300 m in the northern part to a few tens of metres at its southern end (Fig. 2.4).

It is bordered to the northwest by a straight escarpment, the Ankarana Wall (Figs. 2.5 and 2.6), which reaches a height of 200 m and dominates the coastal plains that extend towards the west, to the Mozambique Channel, a place covered with mangroves.

To the north the limestone plateau is overlain by the southernmost lava flows of the Montagne d'Ambre. To the east the massif is bordered by a constant line of small hills, made of basalt, marls and sandstone that form the foothills of the Andrafiamena Mountains. The Besaboba River that circulates between these hills disappears into the limestone as soon as it reaches the limestone plateau.

The plateau is subdivided by a series of corridors, termed couloirs (Fig. 2.7), with vertical walls that are roughly perpendicular to the Ankarana Wall (Fig. 2.8).

To the south the width of the plateau decreases, while the corridors become larger. They dissect the plateau in a series of residual buttes. The plateau finally disappears below the alluvium of the Mahavavy River, the principal water course of that area.

On the surface of the plateau there is a specific landform termed the tsingy, a kind of pinnacle karst formed of rocky peaks, several metres high, that is as sharp as a knife blade (Veress et al. 2009; Salomon 2009) (Figs. 2.9 and 2.10). The tsingy often includes stone columns that easily collapse, which makes walking on the plateau very difficult if not impossible. Therefore, access to the internal areas of the massif is only possible by the corridors or the caves. The latter form a network that is more than 150 km long, with several underground rivers. The major part of the whole cave network remains unexplored (Fig. 2.11).

To the west the massif is bordered by a narrow rainforest. It sometimes extends inside the plateau thanks to the wider corridors whose volcanic soils are favourable to the growth of vegetation. The forest is a natural refuge for lemurs and birds. It contains baobabs and endemic species. Despite being situated in a nature protection area, the forest is now unfortunately endangered by illegal logging, hunting and sapphire mining (see Sect. 10.2).

The plateau can be divided into three clearly distinct units. From north to south these are (Fig. 2.12):

- The Northern Ankarana, which forms the main part of the plateau. It is intersected by deep and narrow couloirs. The water source of the Ankarana River is located at its southern end. Close to the water source is a group of sacred caves that contain royal graves.
- The Mananjeba Buttes. These three buttes are separated from the previous area by a significant enlargement of a couloir. This area is crossed by the Mananjeba River, which then disappears into a cave. The underground course of the river, populated by crocodiles, can be travelled in its entirety until its resurgence in the west.
- The Southern Buttes, at the southern end of the massif, are a set of five small isolated limestone hills where many burial places can be found and contain the largest underground karst chamber in Madagascar. The southernmost hill is bordered by a scenic oxbow lake formed by a meander of the Mahavavy River (Fig. 2.13).

E. Gilli, *The Ankarana Plateau in Madagascar*, Cave and Karst Systems of the World,
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Fig. 2.1 The Montagne d'Ambre Volcano

Fig. 2.2 Quaternary strombolian volcano south of the Montagne d'Ambre

Fig. 2.3 Quaternary strombolian volcano in the north of the Ankarana

2.2 Hydrography

To the north and the east are the Plio-Quaternary volcanic formations, the Jurassic marls and sandstone, and the Paleozoic basement rocks; all of which are impervious. They collect and concentrate rainfall which feeds several small rivers that disappear underground as soon as they reach the limestone.

From north to south the five most important streams are:

- The Andranotsisiloha River (= *river without spring*), which disappears underground at the north of the plateau (outside the map). It was diverted from its original course for irrigation purposes, but it returns to its natural sinkhole during the rainy season. The underground course it now follows is no longer accessible.
- The Besaboba River, which flows over basaltic formations in the eastern part of the plateau. When reaching the contact basalt/limestone, water partly seeps downwards along many parts of its course. Then it disappears totally in a huge shaft called the Besaboba Sinkhole (Fig. 2.14). During the rainy season the sinkhole is completely filled with water, but in the dry season it is possible to explore the cave for several hundred metres until a sump is met. Upstream of the area of water losses the Besaboba receives the water of a tributary, the Ampondrabe.
- At the southwestern end of the North Ankarana area there are two karst springs, the Ankara Spring and the Resurgence Maurice, which feed the Antenankarana River (Fig. 2.15) that runs towards the west to the sea. Discharge during the dry season is about 1.5 cubic meters per second. Both springs are the principal points of resurgence of water from the previous streams augmented by rainwater that infiltrates into the plateau. They are fed by underground rivers that are partly accessible to cavers.
- To the south are the Mananjeba River and the Mahavavy-du-Nord River (North Mahavavy), two allochtonous rivers that run through the vast Ambilobe Plain. They come from impervious formations that extend east of Ambilobe. Both flow over a wide alluvial area before reaching the plateau. The have great importance for the geomorphology of the Ankarana as they dissect the southern part of the limestone plateau, which is inclined towards the southeast and partly disappears beneath the alluvium. To the extreme south there is a group of residual buttes, bordered by sandy formations,

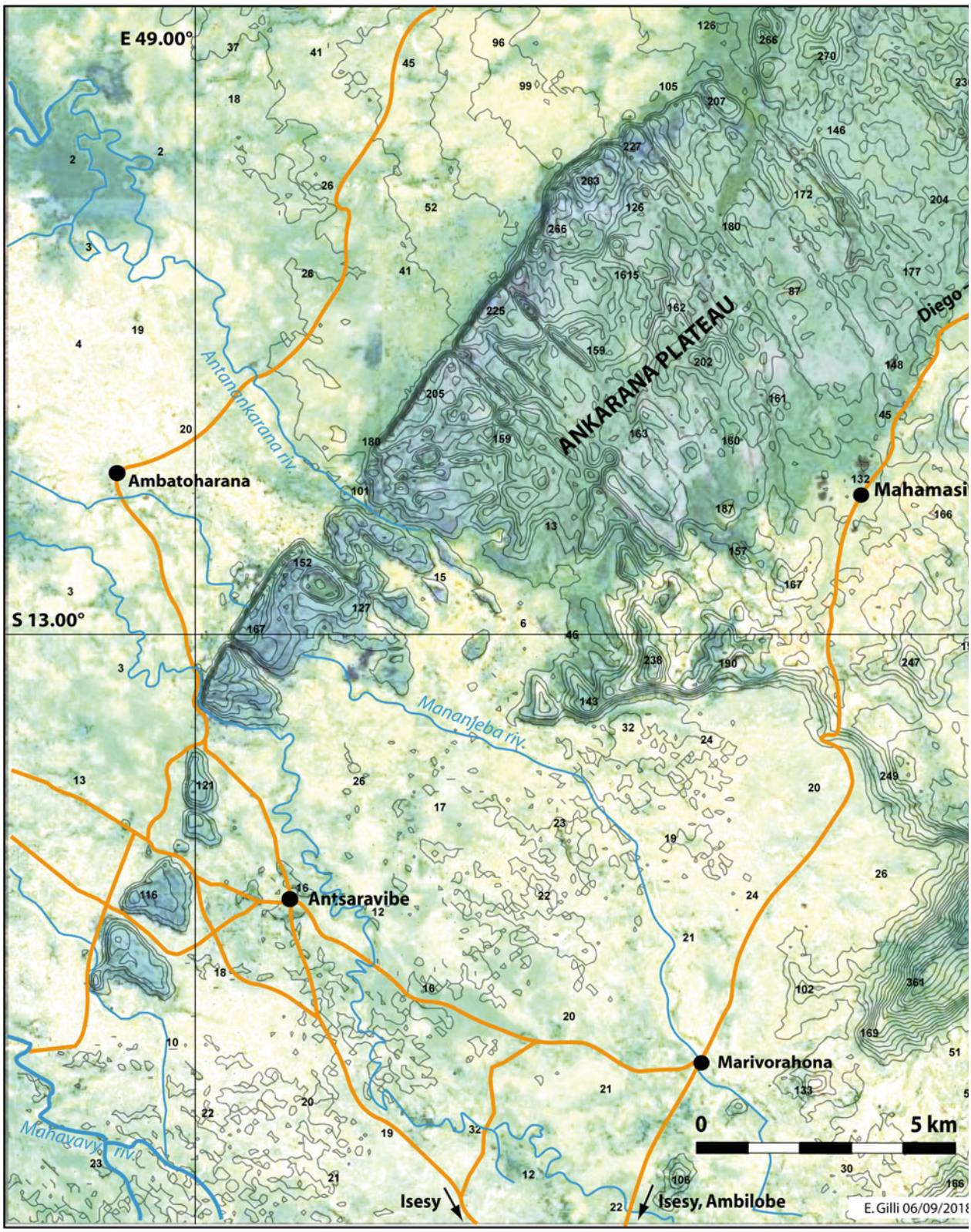

Fig. 2.4 Topographic map of the Ankarana area-contour interval 20 m (data from Nasa, Google Earth and FTM Madagascar, processed by QGIS, Open Source Geospatial Foundation Project)

Fig. 2.5 The Ankarana Wall

Fig. 2.6 The Ankarana Wall and a remnant of forest fringe

Fig. 2.7 Towards the west of the Ankarana viewed from the Ambohimalaza Volcano (note the corridors intersecting the limestone plateau)

Fig. 2.8 The Ankarana Wall and a corridor

Fig. 2.9 The tsingy

Fig. 2.10 Detail of the tsingy

which have been intensely karstified. Both rivers divagate into the limestone and create spectacular mazes such as those in Andranomidity or Mandresy caves.

The Mananjeba River divides into three branches. The southernmost branch (the Mananjebamaty) bypasses the plateau and has no underground flow. The central one circulates underground for 2700 m in the Ambatoharanana Cave which extends into a limestone residual butte whose dimensions are 2 × 2.5 km. The northern branch flows underground for 600 m into another residual butte and emerges to the north where it becomes a tributary of the Antenankarana River.

The Mahavavy is the main river in this area. Its source is in the Tsaratanana Mount, the highest mountain in Madagascar at an elevation of 2876 m. The river is 165 km long and its watershed extends 3300 km^2. The Mahavavy borders the last butte and at one point forms a picturesque oxbow lake.

Due to the low slopes and high discharge during the rainy season or when cyclones occur, both rivers may show important spatial variations of their courses. The whole southern area is a succession of swamps and abandoned channels.

2.3 Climate (from Rossi 1980)

The climate is tropical with an important dry season; there is an average of 90 rainy days a year. Temperature varies from 24.5 to 28.3 °C. During the wet season the rain comes from the northwest. During the dry season the wind blows from the east.

The main weather stations (Table 2.1) closest to the Ankarana are:

- Antsiranana in the north. Rainfall varies from 300 mm (1942) to 1800 mm (1959).
- Ambilobe in the south. Rainfall is more constant ranging from 1200 mm (1938) to 2400 mm (1937).

The Montagne d'Ambre forms a north–south barrier between the two stations. The rain gradient is important at around 300 mm per 100 m. Rainfall at the summit may reach 4000 mm per year.

Data collected at Les Roussettes Station (elev. 1000 m) on the Montagne d'Ambre show that rainfall is present the

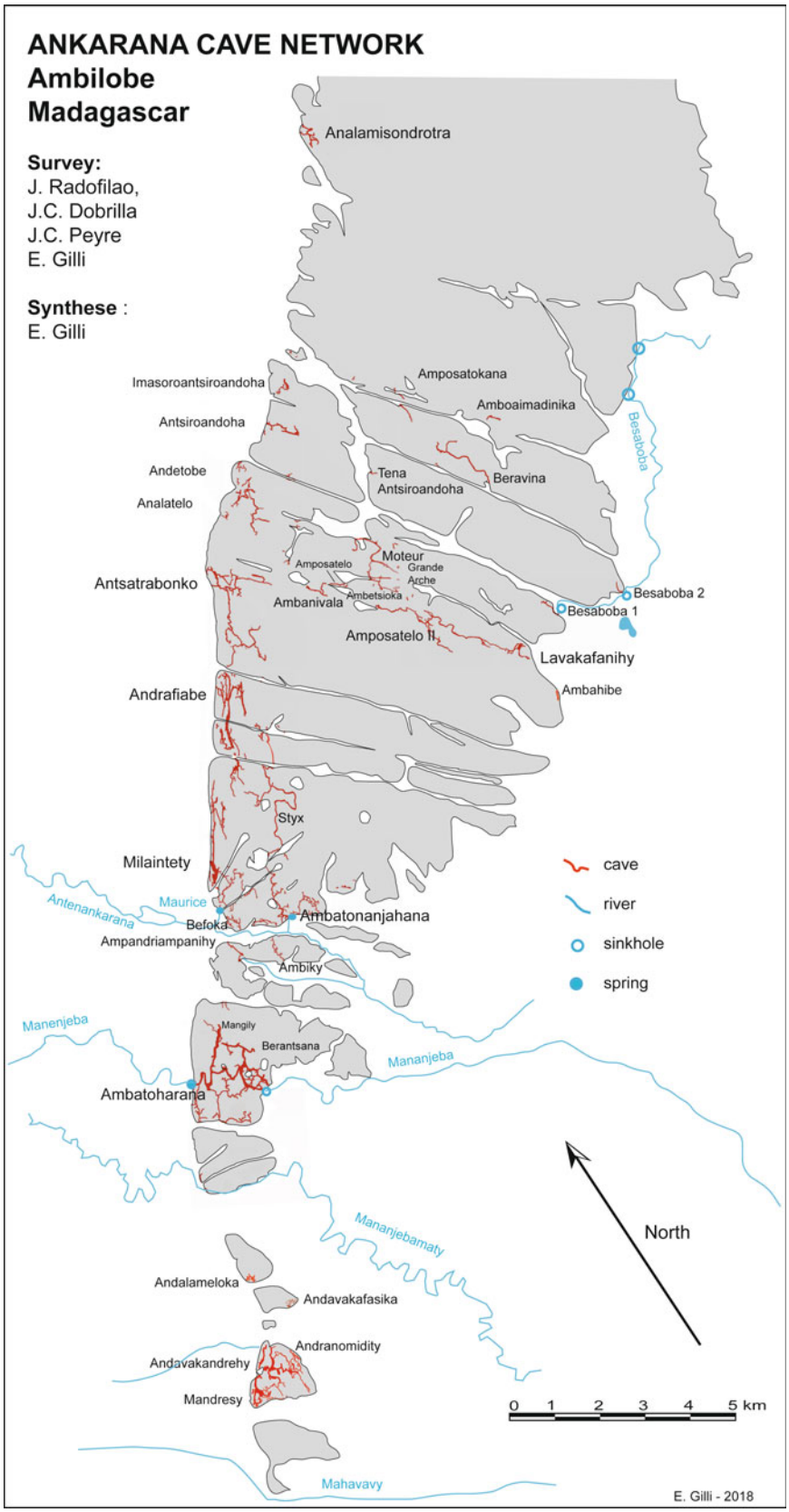

Fig. 2.11 The Ankarana cave network

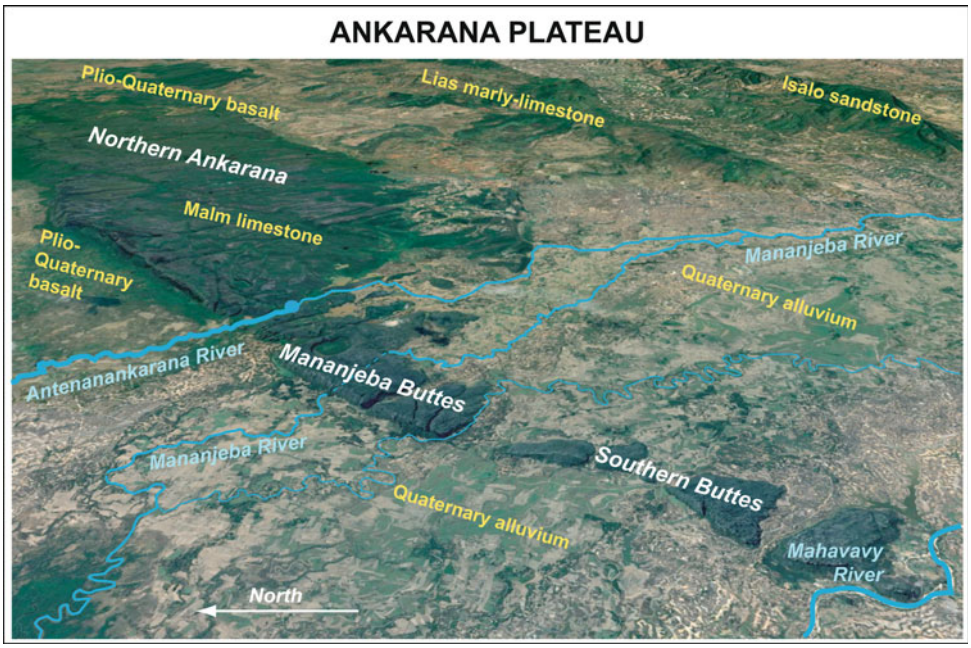

Fig. 2.12 Satellite view of the Ankarana Plateau (Map data: Google 2018, CNES/Airbus 2018)

Fig. 2.13 The Southern Buttes and the Mahavavy oxbow lake

Fig. 2.14 Besaboba Sinkhole No. 1

Fig. 2.15 Crossing the Antenankarana River

whole year round (Fig. 2.16). This area is considered one of the rainiest places in Madagascar.

Although the Ankarana Plateau does not have its own weather station, the nearby weather station of Anivorana gives an idea of the rainfall (1500 mm per year and a well-marked dry season from May to October). This is confirmed by a time series of precipitation (1983–2014) and temperature (1961–2014) reconstructed from in situ data and remote-sensing data (Fig. 2.17). This is the best time to explore or visit the caves. However, the massif is likely to receive a little precipitation over this period.

Table 2.1 Main weather stations monitoring the Ankarana Plateau

Station	Elevation (m)	Mean rainfall (mm)	Dry months	Duration of data (year)
Antsiranana (Diego)	115	900	8 (April–November)	25 (1935–1960)
Ambilobe	74	1870	6 (May–October)	
Les Roussettes	1000	3585	0	
Anivorana	405	1473	6 (May–October)	

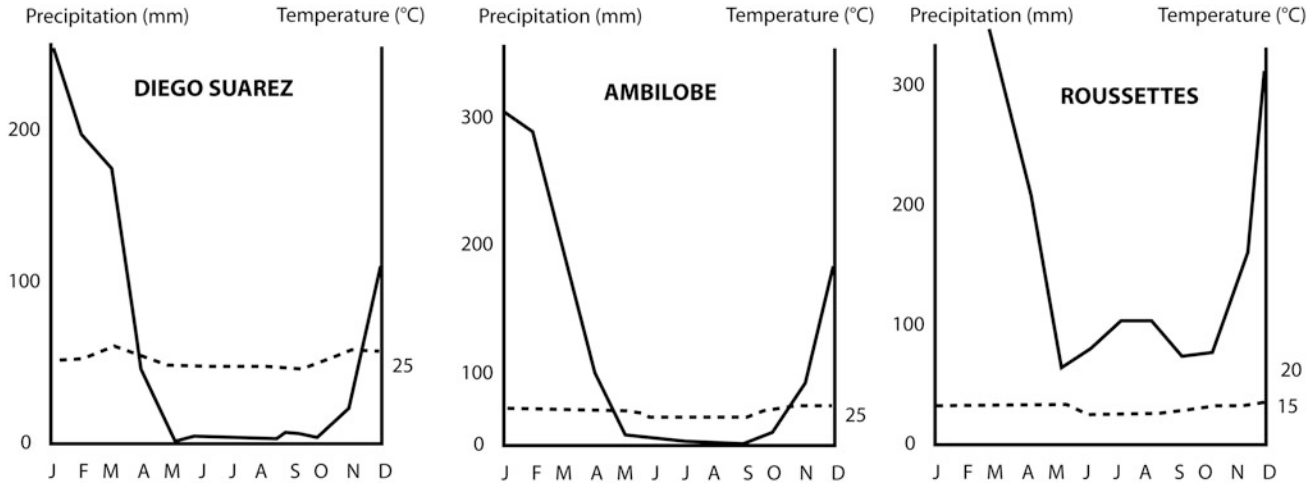

Fig. 2.16 Ombrothermal sketches of three stations to the north and south of the Ankarana

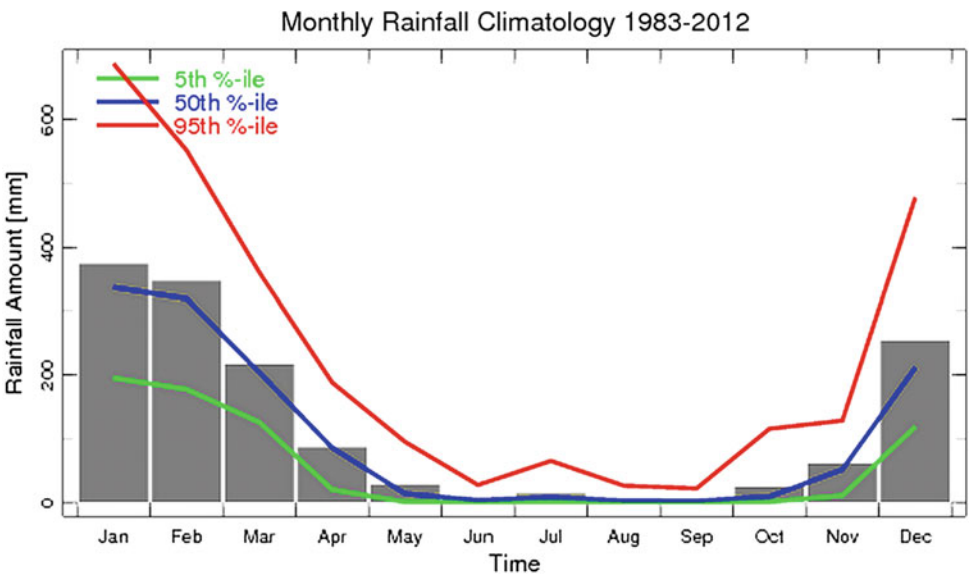

Fig. 2.17 Monthly rainfall in Ankarana (from http://map.meteomadagascar.mg)

Fig. 2.18 Grocer's store in the Andranomilika Butte area

2.4 Population

Remnants of ancient underground camps have been discovered in several caves of the massif. Some objects, like the ones found in a rock shelter north of Analamisondrotra, are covered with calcite. However, since the concretion is fast an age greater than a few hundred years is doubtful. Nevertheless, south of the Anjohibe Caves (Majunga Province), anthropogenic traces on dwarf hippopotamus bones testify to a human presence 4000 years ago (Gommery et al 2011).

This area is inhabited by the Antakarana people, the dominant ethnic group. Their main activities are agriculture and tending livestock. The social structure is dominated by the traditional Antakarana community led by a king. In the past the Antakarana used the caves as a shelter at various times, mainly during wars with the Merina tribes that came from Antananarivo in the highlands of Madagascar. Some of these caves shelter the tombs of the kings and many areas of the plateau are *fady* ("taboo"). Underground burial places for commoners are also frequently found in the southern caves.

The main village is Ambatoharanana. It has the status of a royal place. It is located on the western plain. There are other small villages like Antsaravibe, but most of the population live in small hamlets or isolated houses surrounded by crop areas (Fig. 2.18). Roads are rare and those that exist are in poor condition except for the one that reaches Ambatoharanana. Nowadays, Chinese bicycles or motorbikes are used over an intense network of narrow trails making it possible to reach most places.

Most of the plateau is a protected area termed the National Park of Ankarana. Development of the park has been accompanied by the creation of numerous small hotels in Mahamisina, along the national road east of the massif.

Tourism aside, the traditional source of income for the Antankarana people is agriculture (especially sugar cane) and shrimp farming. The discovery of gems in the 1990s gave rise to a sapphire rush and resulted in the development of a few villages along the national road, northeast of the massif, such as Ambondromifeny and Andranoakoho. Logging is another source of income, but is of course illegal.

2.5 Access

Access to the plateau is possible either from the main national road which extends from Diego Suarez to Ambilobe or from a completely battered track that starts from Anivorana. The area of the Mananjeba River and the Southern Buttes is crisscrossed by a series of sandy car tracks that reach the villages of Antsaravibe and Ambatoharanana. They start from the national road, 6 km north of Ambilobe at the village of Isesy. During the rainy season they can be reached with a four-wheel-drive car.

The Northern Ankarana and the Mananjeba Buttes are included in another nature protection area called the

Ankarana Special Reserve (Sect. 11.1). Access is forbidden without a permit. This can be bought in Mahamasina on the national road, where the eastern entrance and the office of the park can be found. Accommodation is available as are guides (see Appendix E).

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Fauna and Flora of the Ankarana

3

3.1 Surface Fauna

The difficulty encountered when trying to traverse the massif coupled with the presence of water, even in the dry season, has the advantage of making the Ankarana an area where animals and plants are naturally protected. The following lists are a very rough inventory of what may be encountered while visiting the place. Small animals like insects are too numerous to be presented here, but one to look out for is the larva of *Phromnia rosea*. It looks like a small white inflorescence gently moving on some plants (Fig. 3.1).

3.1.1 Dangerous Animals

In addition to the *Anopheles* mosquito, which transmits malaria, there are a few dangerous animals in the Ankarana. The main predators are crocodiles, but there are two carnivorous mammals, the fossa (*Cryptoprocta ferox*) and the ring-tailed mongoose (*Galidia elegans*), both of which are difficult to observe. Mygals (a type of spider) and the venomous spider called *menavoda* ("Black Widow") by the local people are more impressive than dangerous. Conversely, scorpions are frequent and have caused several accidents.

3.1.2 Reptiles

Except for crocodiles (*Crocodylus niloticus*) (Fig. 3.2) there are no dangerous reptiles.

There are many species of snakes, chameleons (Fig. 3.3) and lizards of all sizes. The following species can be observed: *Amphiglossus stumpffi*, *Boa manditra*, *Brookesia ebenaui*, *Brookesia stumpffi*, *Brookesia tuberculata*, *Calumma brevicornis*, *Furcifer pardalis*, *Furcifier petteri*, *Mabuya elegans*, *Mantidactylus curtus*, *Mantidactylus pseudoasper*, *Paroedura stumpffi*, *Phelsuma madagascariensis* (Fig. 3.4), *Uroplatus ebenaui*, *Uroplatus fimbriatus*, *Uroplatus sikorae*, *Zonosaurus haroldmeieri*, …

3.1.3 Mammals

Lemurs: There are 11 species of lemur in the park, where they are the main attraction: *Avahi laniger*, *Cheirogaleus medius*, *Daubentonia madagascariensis*, *Eulemur coronatus* (Fig. 3.5), *Eulemur fulvus*, *Hapalemur griseus*, *Lepilemur septentrionalis*, *Microcebus murinus*, *Microcebus myoxinus*, *Phaner furcifer*, *Propithecus perrieri*.

They inhabit all the forest areas of the massif but, being hunted by men, they become difficult to observe in places that are not protected around the reserve. Apart from man, their natural predator is the fossa (*C. ferox*). Within the perimeter of the park they have no fear of visitors and can be friendly.

The following species of mammals are also present in the Ankarana:

Tenrecs (hedgehogs): *Tenrec ecaudatus*, *Setifer setosus.*
Rodents: *Eliurus myoxinus*, *Eliurus majori*, *Eliurus webbi*, *Rattus rattus*.
Carnivores: *C. ferox*, *G. elegans* (Fig. 3.6), *Fossa fossana* (civet).
Bushpigs: *Potamochoerus larvatus*.
Bats: There are 13 known species in the Ankarana, including fruit bats (*Roussettus madagascarensis*), flying foxes (*Pteropus rufus*) and Martienssen's free-tailed bats (*Otomops martiensseni*). Unfortunately, local people hunt and eat the largest species and enter the caves where they roost to collect guano, which disturbs and endangers them (Fig. 3.7).

E. Gilli, *The Ankarana Plateau in Madagascar*, Cave and Karst Systems of the World,
https://doi.org/10.1007/978-3-319-99879-4_3

Fig. 3.1 *Phromnia rosea*, a very strange animal

3.1.4 Birds

Table 3.1 presents some of the bird species encountered in the Ankarana.

3.2 Underground Fauna

3.2.1 Underground Invertebrates

During the few naturalist field trips scientists have identified the following species, much work remains to be done:

Collemboles: *Troglopedetes madagascarensis*, *Isotomellia minor*, *Troglobius coprophaga*.
Dipteres: *Blattodea Periplaneta americana*.
Isopodes: *Synarmadillo madagascarensis*.
Amphipodes: *Caridina crurispinata*, *Caridina isaloensis*, *Caridina nilotica*, *Caridina norvestica*, *Caridina parvocula*, *Caridina typus*, *Caridina unca*, *Caridina xiphias*, *Parisia dentata*, *Parisia microphthalmia*.
Decapodes: *Crabe* spp. (Fig. 3.8), *Macrobachium moorei*.
Chilopodes: *Cormocephalus lambertoni*.
Amblypyges: *Charinus madagascarensis*.

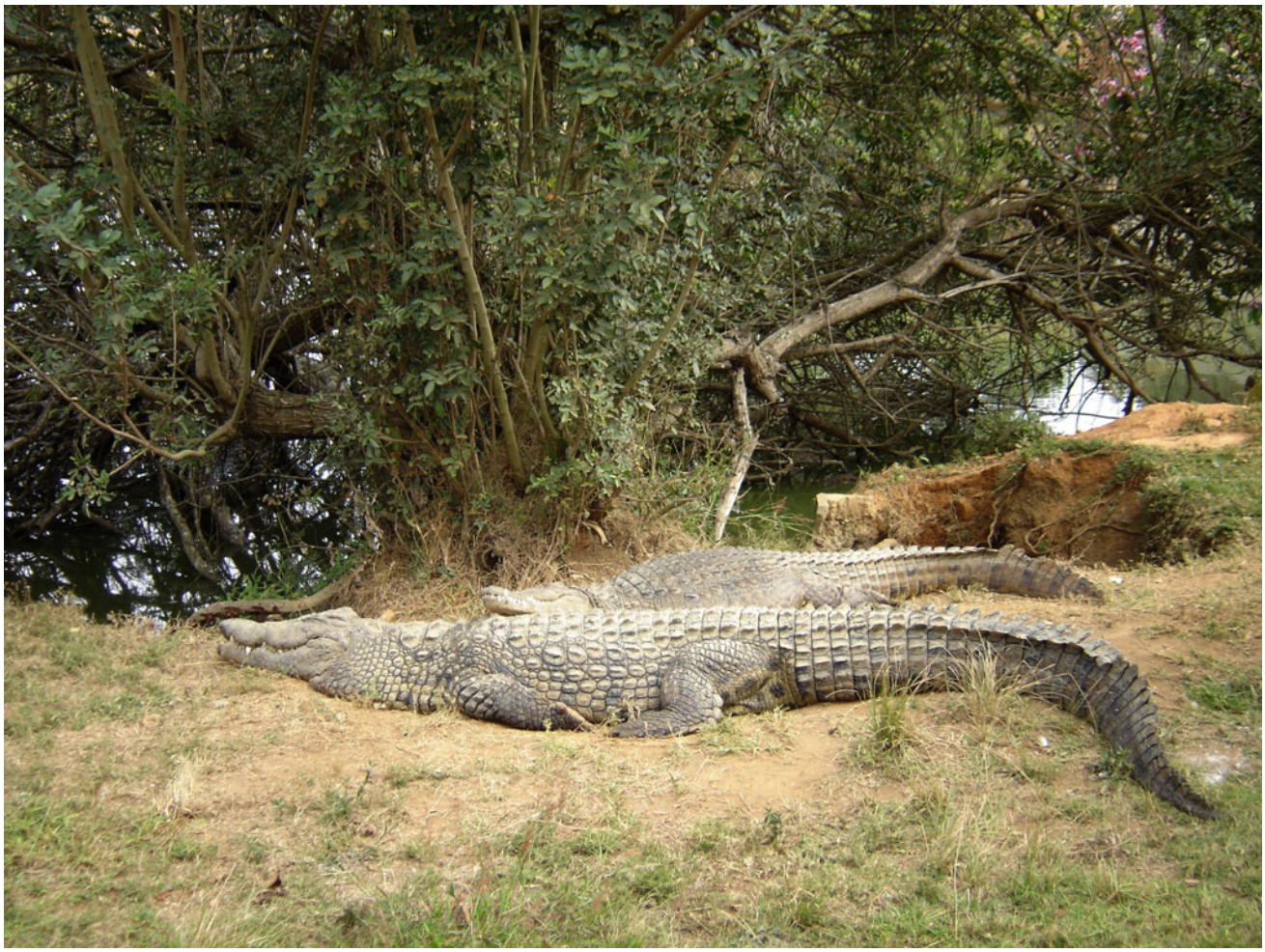

Fig. 3.2 Nile crocodile

Opiliones: *Fageibantes bicornis*.
Spiders: Mygals (Figs. 3.9 and 3.10) and tarantulas (Fig. 3.11).

3.2.2 Underground Vertebrates

(a) Reptiles

Boas: *Acrantophis madagascariensis* (*do* in Malagasy) (Figs. 3.12 and 3.13). They are common in caves where they hunt bats, birds and frogs. Like other species in Madagascar, this snake is not dangerous.

Crocodiles (*C. niloticus*): they are common in the wild areas of Madagascar and are present around the Ankarana.
In the dry season crocodiles take refuge in the caves where they can be observed several kilometres from the entrances (Fig. 3.14). They are wary and timid, and no underground accidents have been reported. However, there is a report of an attack on a person crossing the Ankarana River, downstream of the limestone massif. The last member of a group was bitten on the rear by a crocodile, but survived by chance. An albino specimen has been captured in the Ankarana (Allorge-Boiteau and Allorge 2007).

According to local beliefs, these cave crocodiles are reincarnated ancestors of the Antakarana. Their local name *antandrano* means “those who live in water”.

Fig. 3.3 Chameleon

Fig. 3.4 *Phelsuma madagascariensis*, the typical species of green lizard

Fig. 3.5 *Eulemur coronatus* (male). A very common and familiar lemur

(b) Fishes
In most underground rivers there are fishes and large eels. The latter have a stout body, sometimes 20 cm in diameter, and are mottled, similar to moray eels. Though very impressive, they do not seem aggressive. When exploring the Andavakandrehy River in the hills of the Southern Buttes, one of them placidly passed between the legs of one of our group.

(c) Bats
Bats are very common in the caves, but the number of those species hunted for food decreases each year. We observed the following species in the caves: *Eidolon depreanum*, *Emballonura atrata*, *Hipposideros commersoni*, *Triaenops persicus rufus*, *Miniopterus inflatus africanus*, *Pteropus rufus*, *Otomops martiensseni*.

(d) Fossils
There are fossils of lemurs in the Ankarana caves (Fig. 3.15). Some studies (e.g., Godfrey et al. 1990) have been conducted after the early discoveries by Jean Radofilao and J. C. Peyre and two English–Malagasy reconnaissance expeditions in 1981 and 1986–1987.

A major discovery was that of *Babakotia radofilai* (Fig. 3.16), which was the only known member of the genus *Babakotia* and belonged to the family Palaeopropithecidae, which included three other genera of sloth lemurs:

Fig. 3.6 *Galidia elegans*

Palaeopropithecus, *Archaeoindris* and *Mesopropithecus*. This family in turn belongs to the infraorder Lemuriformes, which includes all the Malagasy lemurs (Mittermeier et al. 2006; Nowak 1999). In 1988 the anthropologist E. Simons found a nearly complete skeleton and skull in addition to the remains of roughly a dozen other individuals in the Antsiroandoha Cave. Radiocarbon dating gave an age of 3100–2800 BCE (Simons et al. 1995).

B. radofilai lived during the Late Pleistocene/Early Holocene (the current period) and is thought to have disappeared shortly after the arrival of humans to the island, possibly within the last 1000 years (Nowak 1999).

Fig. 3.7 Guano collecting in the caves of the Ankarana

Table 3.1 Ankarana birds and their French, English and Malagasy names

Latin name	French name	English name	Malagasy name
Accipiter madagascariensis	Epervier de Madagascar	Madagascar goshawk	Firasambalala
Agapornis cana madagascariensis	Inséparable à tête grise	Grey-headed lovebird	Sarivazo
Anhinga melanogaster	Anhinga roux	Oriental darter	Ramangara
Asio madagascariensis	Hibou malgache	Malagasy owl	Vorondolo
Bubulcus ibis	Héron garde-bœufs	Cattle egret	Vano
Caprimulgus enarratus	Engoulevent à nuque rousse	Red-necked nightjar	Tataro
Caprimulgus madagascariensis	Engoulevent malgache	Madagascar nightjar	Vikiviky
Centropus toulou	Coucal malgache	Madagascar coucal	Taitoaka
Cisticola chernia	Cisticole	Madagascar cisticola	Vorombararata
Coracina cinerea	Echenilleur malgache	Ashy cuckoo shrike	Firirina
Coracopsis nigra	Perroquet noir	Black parrot	Boloky
Coracopsis vasa	Perroquet vasa	Vasa parrot	Boloky
Corvus albus	Corbeau pie	Pied crow	Firirinabe
Corythornis vintsioides	Martin pêcheur malachite	Malachite kingfisher	Vintsirano
Coturnix coturnix	Caille des blés	Common quail	Papelika
Coua cristata	Coua huppé	Crested coua	Tsipara
Dicrurus forficatus	Drongo malgache	Crested drongo	Tsingetry
Eurystomus glaucurus	Rolle de Madagascar	Broad-billed roller	Kirio
Falco newtoni	Crécerelle malgache	Madagascar kestrel	Roatelo
Falco zoniventris	Faucon à ventre rayé	Banded kestrel	Akanga
Falculea palliata	Falculie mantelée	Sickle-billed vanga	Voronjaza
Haliaeetus vociferoides	Pygargue de Madagascar	Madagascar fish eagle	Ankoay
Hypsipetes madagascariensis	Bulbul de Madagascar	Madagascar black bulbul	Tsikatekateka
Ispidina madagascariensis	Martin-pêcheur malgache	Madagascar pygmy kingfisher	Tsakokomanga
Leptopterus chabert	Artamie chabert	Chabert vanga	Torotoroka
Lophotibis cristata	Ibis huppé de Madagascar	Madagascar crested ibis	Akohonala
Margaroperdix madagascariensis	Perdrix malgache	Madagascar partridge	Tsipoy
Merops superciliosus	Guêpier de Madagascar	Madagascar bee-eater	Taotaonkafo
Mesitornis variegata	Mésite variée	White-breasted mesite	Manganahitra
Mirafra hova	Alouette malgache	Madagascar lark	Soriotra
Nectarinia notata	Drongo malgache	Long-billed green sunbird	Fodiala
Numida meleagris	Pintade de Numidie	Helmeted guineafowl	Akohondrano
Oena capensis	Tourterelle masquée	Masked dove	Tsakatoto
Phalacrocorax africanus	Cormoran africain	Long-tailed cormorant	Vorondolo
Polyboroides radiatus	Gymnogène de Madagascar ou Serpentaire rayé	Madagascar harrier hawk	Fandrasabe
Scopus umbretta	Ombrette africaine	Hamerkop, hammerhead	Akoholahinala
Terpsiphone mutata	Gobe-mouche de paradis de Madagascar	Madagascar paradise flycatcher	Soimanga
Treron australis	Pigeon vert de Madagascar	Madagascar green pigeon	Vintsirano
Upupa epops marginata	Huppe fasciée	Madagascar hoopoe	Takidara
Vanga curvirostris	Vanga écorcheur	Hook-billed vanga	Todikarasoka

Fig. 3.8 Underground freshwater crab

Fig. 3.9 Mygal. They are frequent near cave entrances or in places close to the surface where the limestone is thin. They are dangerous but not aggressive

Fig. 3.10 Mygal

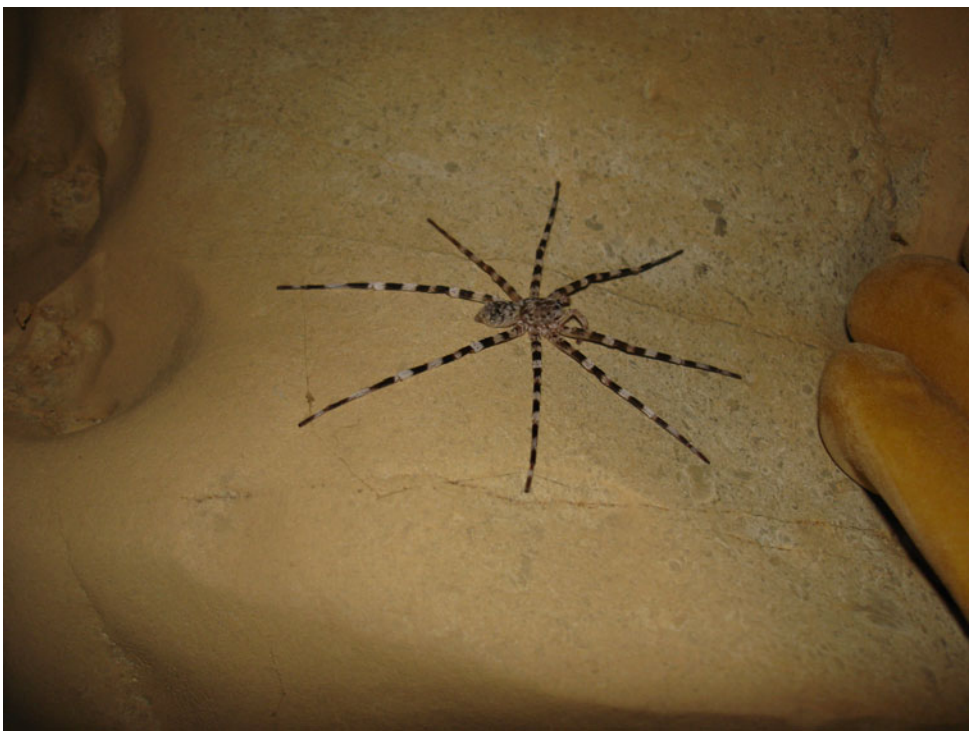

Fig. 3.11 Underground tarantula (10 cm across)

Fig. 3.12 An underground small boa

Fig. 3.13 Boa (*Acrantophis madagascariensis*)

Fig. 3.14 Footprints of a crocodile in the Ambatoharanana Cave

Fig. 3.15 Fossil of an *Archaeolemur* species in the Mandresy Cave

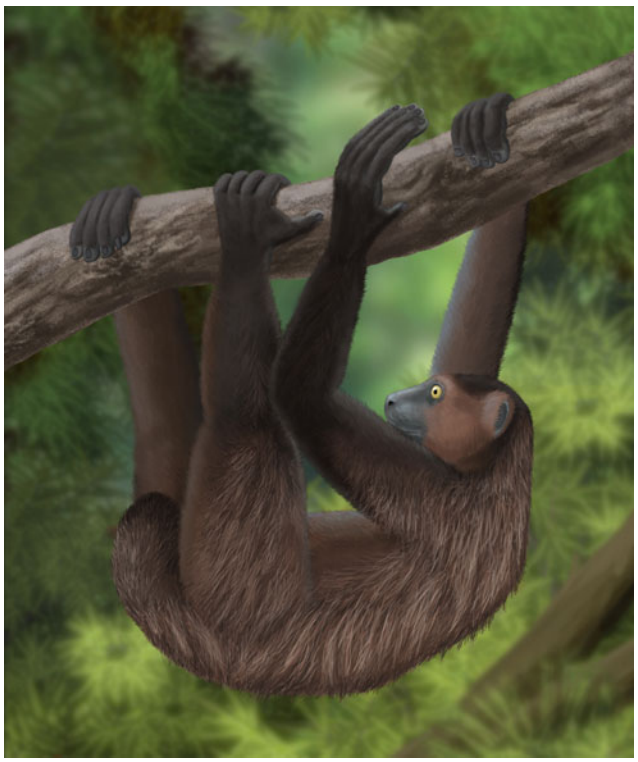

Fig. 3.16 *Babakotia radofilai* (copyright Smokeybjb, Travail personnel, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=9688657)

3.2.3 Flora

The diversity of soils makes possible the existence of a varied flora with several endemic species. Tsingy and limestone areas, where surface water is rare, contain a sparse xerophytic vegetation. The typical species are:

- *Adenia lapiazicola* (Passifloraceae), a species of vine whose trunk contains a water reserve (Fig. 3.17).
- *Cyphostemma macrocarpa*, another species of vine (Fig. 3.18).
- *Tacca ankaranensis*, a flowering plant in the yam family, widespread over tsingy areas.
- *Euphorbia ankarensis*, a tree with a thick spiny trunk and red flowers.
- *Commiphora* spp., locally called "the tree that peels off". During the dry season the trunk is covered with very thin and transparent flakes.

Evergreen plants can be found on basaltic soils in the forest that borders the limestone plateau, in some corridors like Forest Canyon or in circular depressions such as Mangily or Antavy Circus.

The flora include *Pandanus* (Pandanaceae), *Zanthoxylum* (Rutaceae), *Ficus* (Moraceae), *Dalbergia* and *Cassia* (Fabaceae), *Diospyros* (Ebenaceae), *Canarium*

Fig. 3.17 *Adenia lapiazicola*, a vine whose trunk contains a water reserve

(Burseraceae), *Pachypodium* (Apocynaceae) (Fig. 3.19) and an endemic baobab *A. madagascariensis*. Local guides in Mahamasina bring tourists to observe them on the Tourelles de Tsingy trail and on the footpath to the Besaboba Sinkhole.

The western forest includes *Dalbergia*, *Commiphora* (Burseraceae), *Hildegardia* (Sterculiaceae) and *Adansonia*.

Of the plants of the Ankarana there is one that is unforgettable, the *takilotra* (*Mucuna pruriens*) (Fig. 3.20). It is a tiny vine whose cloves are covered with stinging hairs. When disturbed by visitors walking under the trees where they grow they cause a painful and durable itching. The only remedy is heat, and Malagasy people use a mixture of sand and hot embers to rub affected parts of the body. They occur mainly along the edge of the massif in dry or deforested areas. The stinging hairs are frequently transported by the wind, which can cause slight itching when the *varatraz* (trade winds) blows.

Fig. 3.18 *Cyphostemma macrocarpa*

Fig. 3.19 *Pachypodium* sp

Fig. 3.20 *Takilotra* (*Mucuna pruriens*), a vine with unforgettable itching cloves

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Geology and Hydrogeology

4

4.1 Generalities on Madagascar and the Antsiranana Region

4.1.1 Geological Formations

The extreme north of Madagascar, where the Ankarana Massif is located, comprises three large geological complexes (Fig. 4.1):

- A Precambrian substratum oriented east–west, formed of granites and granodiorites, as well as volcanic and metamorphic series.
- A sedimentary basin that includes a sandstone formation (the Karoo) and a Lias-Jurassic marl and limestone formation that includes the Ankarana.
- An important Plio-Quaternary volcanic complex: the Montagne d'Ambre system.

4.1.2 Geological History (from Battistini 1996)

Following the Pan-African orogeny the Madagascan Precambrian domain remained on the surface until the Carboniferous when formations, similar to the Karoo series of Southern Africa, were deposited. The settlement of these sedimentary series corresponded to an intracontinental rifting phase called the Karoo Rifting, an initial phase of the dislocation of Gondwana, from the Upper Carboniferous to the Lower Jurassic. The Karoo series are deposited in the Diego collapse basin. They comprise sandstone and carbonate rocks from the Permian to the Lias. Many sedimentary gaps make the series incomplete. The entire basin forms a monoclinic series with a low dip to the northwest.

The area that included the future Madagascar broke away from Gondwana (Africa, Australia, Antarctica, South America) in the Middle Jurassic (165 Ma), beginning with the future India drifting towards its present position from the sector now occupied by Somalia, Tanzania and Kenya. This movement created a pre–Mozambique Channel, a basin in which active sedimentation allowed the deposition of the important carbonate deposits of western Madagascar, along with marine series including fossiliferous limestone like that of the Ankarana.

It continued until the Lower Cretaceous (125 Ma). The development of this basin was then blocked by Indo-Malagasy rifting in the Upper Cretaceous, when a phase of distension caused the Mascareigne Basin to open up in the north and east of Madagascar along with large north-northwest–south-southeast and north-northeast–south-southwest fractures (respectively, in Bongolava and the East Coast) and associated volcanism.

In the Neogene the whole of the island underwent generalized tilting towards the west, with the reactivation of ancient submeridian faults.

4.1.3 Structure

Brittle tectonics played an important role in structuring the landform in the sedimentary zones (Rossi 1980). In the Antsiranana region the rifting and tilting movements revealed:

- A few faults oriented north–south that may affect the substratum.
- A 40°N accident stretching from the west coast, south of the Ambato Peninsula, to the east coast at the level of the Loky River. This accident is marked to the west by a disharmonic contact Lias/Isalo that changes to a flexure in the Ambilobe area and then to a true fault farther east, in the region of Beramanja.
- This major accident is accompanied by smaller fractures also oriented 40ºN–45°E, such as those bordering the Ankarana to the east and west.
- There is also a northwest–southeast orientation, perpendicular to the main orientation, along which karst structures are frequently aligned.

E. Gilli, *The Ankarana Plateau in Madagascar*, Cave and Karst Systems of the World,
https://doi.org/10.1007/978-3-319-99879-4_4

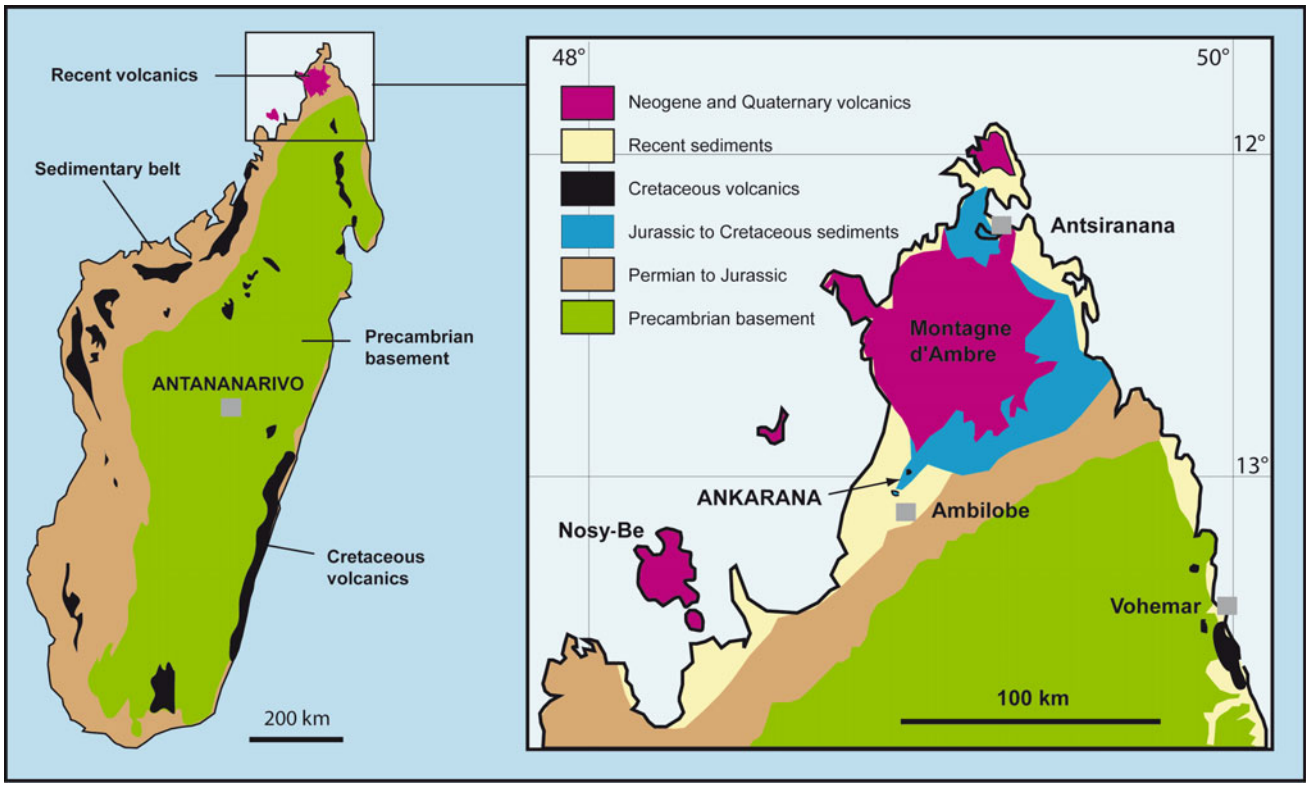

Fig. 4.1 Geology of Madagascar and the extreme north

4.1.4 Volcanism

Volcanism also played a very important role in the creation of the landforms and corresponded to two main phases (Besairie 1973) (Fig. 4.1):

- During the separation of Madagascar and Greater India from Africa in the Late Jurassic to Mid-Cretaceous there occurred a number of fissure-type volcanic events (−90, −80 Ma). They are expressed as massive flows, tuffs, dikes and vein networks in coastal sedimentary formations. On the western and the eastern coasts of Madagascar the dikes are frequently oriented northwest–southeast (Mahoney et al. 1991).
- Cenozoic alkaline volcanism (Miocene to Quaternary), which was responsible for the installation of large current volcanic edifices such as the Montagne d'Ambre, the Nosy-Be island and the Tsaratanana Mount. This volcanic phase stretched from −10 Ma up to very recently, as evidenced by the presence of many strombolian cones still perfectly preserved with flanks scarcely incised by erosion.

In the extreme north of Madagascar this volcanism gave rise to numerous lava flows extending from the Montagne d'Ambre to the Ankarana (Rossi 1980). They cover the limestone plateau in the northern part. They border it to the east and to the west, and they penetrate into some corridors like the Forest Canyon (Fig. 4.2).

4.2 Geology of the Ankarana Plateau

4.2.1 Studies

The main features of the geology and geomorphology of the Ankarana Plateau were defined by de Saint Ours (1958). A geological map (sheet Ambilobe Betsiaka U32-V32) was published in 1963 by the Geological Survey of Madagascar under the direction of Besairie (1973). Various geological and geomorphological studies were undertaken by Battistini (1965) and Rossi (1973, 1974). The latter published an important work on the extreme north of Madagascar (Rossi 1980) in which he detailed the Ankarana geomorphology. Recent work has been undertaken characterizing the tsingy

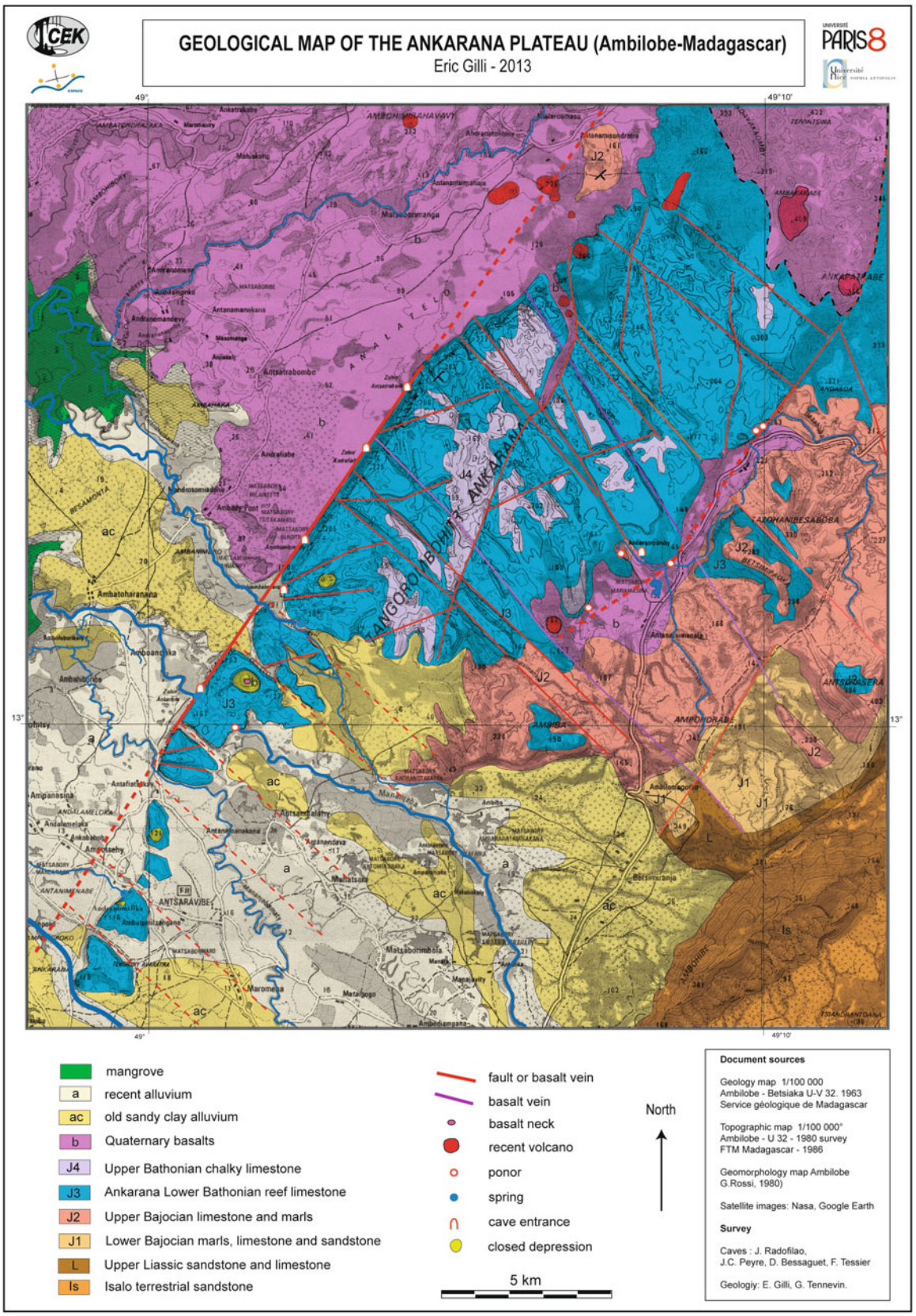

Fig. 4.2 Geological map of the Ankarana

(Veress et al. 2009; Salomon 2003). However, few studies have investigated the genesis of the Ankarana caves and landforms. To this end we present a geological map (Fig. 4.2) and propose a hypothesis on the geomorphology of the plateau and the genesis of the caves.

4.2.2 Stratigraphy

The Ankarana is a triangular karst plateau of Bajocian–Bathonian epicontinental limestone.

The geological section made by de Saint Ours (1958) and Rossi (1980) shows the following sequence, from bottom to top (Fig. 4.3):

- About 60 m of Liassic marly-limestone.
- Between 100 and 150 m of Bajocian marls and marly-limestone with limestone becoming predominant at the top intercalating with oolithic limestone and reef limestone.
- Highly karstified Bajocian–Bathonian limestone with a thickness of around 200 m. From top to bottom, it includes crystalline limestone with corals and urchins, then sub-lithographic limestone. Facies are variable; in a few metres it is possible to pass from a true fossil reef with coral branches to an entrochal limestone and then to a limestone rich in belemnite rostrums.
- Chalky limestone, sometimes with a sandstone facies. Its permeability is low. It forms the upper mounds of the Ankarana Plateau, where vegetation can grow.

The Cretaceous seems to be absent in this area, although marine sedimentation was continuous until the Lower Cretaceous. It was probably completely stripped away by erosion.

4.2.3 Structure

The Plateau is a syncline oriented northeast–southwest. The dips do not exceed 10° (Fig. 4.3). The Ankarana Block behaved like a rigid slab and recorded all movements in the region.

These movements brought about fractures along several orientations:

- The Ankarana Wall, which marks the western edge of the plateau, is a major fault scarp oriented northeast–southwest, whose throw probably exceeds 400 m. To the east, in the Besaboba Valley, a similar but smaller fault limits

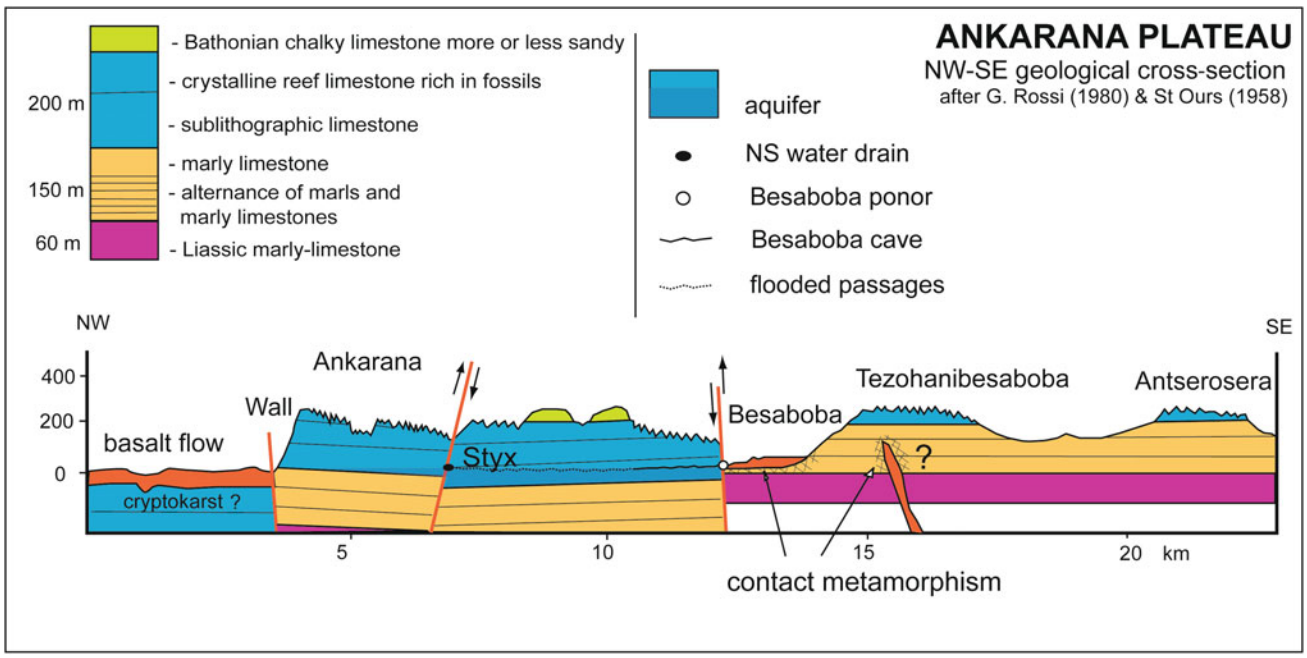

Fig. 4.3 Northwest-southeast schematic cross section of the Ankarana (after Rossi 1980)

Fig. 4.4 Main fracture orientations observed at the outcrop scale

the plateau. Conjugate faulting is also observed at 130–145°N and 70–80°N.

- The couloirs (corridors) are oriented northwest–southeast. Several dikes that extend to the east have the same orientation.
- A north–south orientation can also be observed, but it appears to be less important.
- In the central zone a 25–30°N reverse fault can be seen (Karche 1972; Rossi 1980).

The density and orientation of the fractures and the presence of several volcanoes around and inside the limestone area suggest the whole zone is subject to uplift and a volcanic bulge.

Fig. 4.5 View to the north. From the foreground to the background: Ankarana limestone, recent basalt flow, strombolian cones and Mountagne d'Ambre (in the clouds)

This network of fractures, which is very dense, can also be observed at the metric scale and has determined the geometry of the lapies intersecting the surface of the Ankarana and forming the tsingy (Fig. 4.4).

4.2.4 Volcanism of the Ankarana

As explained above, volcanism in Madagascar was active during two distinct periods, the Cretaceous and the Cenozoic. In the area under study there are a number of volcanic features making the presence of both ages possible.

To the north the Montagne d'Ambre volcano is a Miocene–Holocene system (Besairie 1973; Rossi 1980; Cucciniello et al. 2011). Basalt completely covers the northern part of the Ankarana Plateau. It flows into the main topographic depressions of the eastern part (Besaboba Valley) and runs alongside the Ankarana Wall in the western part, where it penetrates into a few corridors (Forest Canyon). Small strombolian cones are present on both sides of the plateau (Figs. 4.4 and 4.5). The poorly eroded flanks indicate a Holocene age for the younger ones (Fig. 4.5). To the east there are dikes that could be older (Sect. 4.4.4a). Dikes

Fig. 4.6 Weathered basalt flow

were also observed in caves during the explorations (e.g., the Analamisondrotra Cave).

The whole coastal zone, to the west and northwest of the massif, is covered with basaltic flows below which Jurassic terranes sometimes appear. The basalt alternates between a red clay and residual basalt spheres (Fig. 4.6).

Since these forms are poorly weathered they must be recent and therefore do not play a role in speleogenesis, except by concentrating rainfall, as in the area of the Besaboba River. However, recent observations made by us show that an older volcanism period played a very important role in the morphogenesis of the Ankarana.

The origin of corridors and circular collapses has most often been attributed to dissolution or tectonics. Satellite images of the area show that several corridors extend to the east by lineaments. During a field trip in 2005 we noticed these lineaments were basalt veins that intrude in the calcareous, or marl-limestone, series that extends east of the Antsiranana road. Rossi (1980) points out these veins.

The age of these veins, which cut through the Jurassic limestones, remains to be defined, but could be linked to the Late Cretaceous or Paleocene distension phase, when the Mozambique Canal opened up. This was accompanied by the basaltic fissural volcanism that can be encountered throughout almost the whole island.

Basalt can also be found in the large circular depressions that obliterate the plateau in several places. For instance, in 2005 we rediscovered a small basalt hill originally reported

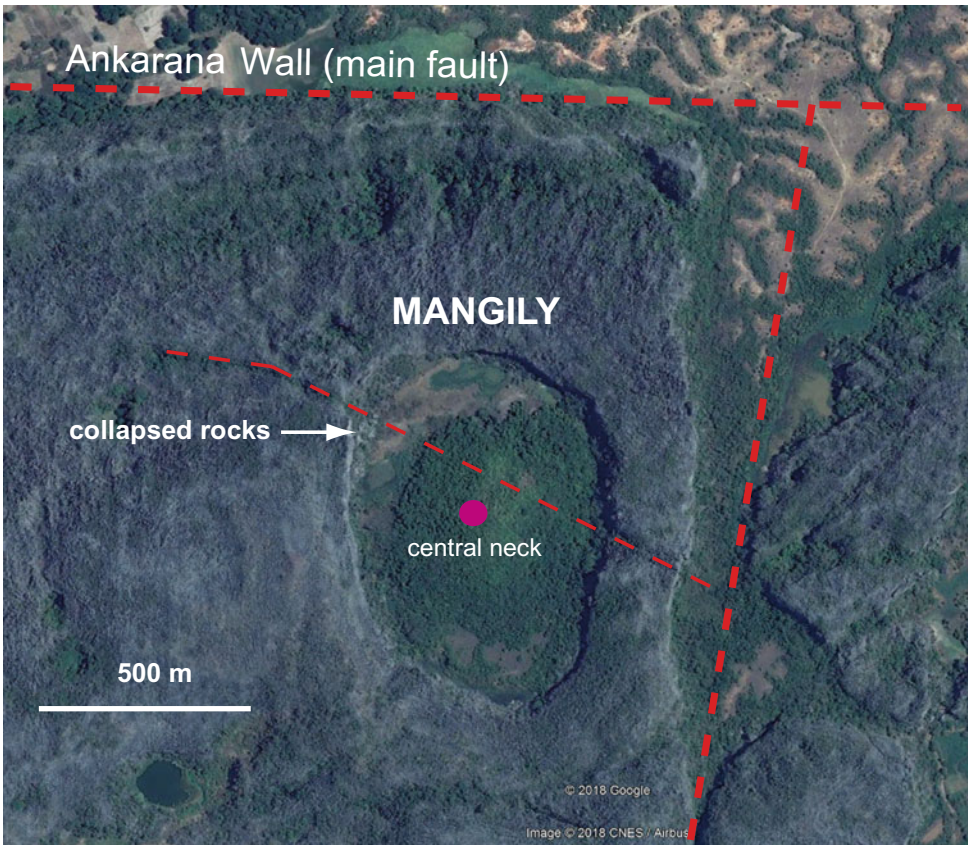

Fig. 4.7 The Mangily and its basalt hill

by Rossi (1980) in the centre of the Mangily, a large circus in the Mananjeba Buttes (Fig. 4.7). It is probable that other circular structures in the south of the Central Ankarana, such as Antavy (or Tsimiharo Circus) where the Kings are buried, contain similar volcanic structures. Indeed, the Antankarana people used to take refuge there during intertribal wars, some of which lasted for up to 3 years (Decary and Kiener 1970). This tends to prove that the soil must have been suitable for agriculture, something confirmed by satellite and aerial views. Volcanism is therefore important (Fig. 4.8). We will propose a mechanism of morphogenesis that associates volcanism and karst corrosion in Sect. 4.4.

4.3 Hydrogeology of the Ankarana Plateau

4.3.1 Underground Network and Hydrogeology

Water input to the plateau is threefold: rainfall, several ponors and the two previously described large rivers that pass through the plateau in the southern zone.

The plateau is divided into two distinct parts hydrogeologically:

- In the north a vast system drains the limestone plateau towards the southwest, to the main source of the Antenankarana River (or Ankara River) and its tributary, the Maurice Resurgence. J. de Saint Ours (1959) suggested the existence of a main drain called the collecteur, which should drive the water towards the sources of the Antenankarana, along the synclinal axis of the plateau. The collecteur was discovered in 1984 (Peyre et al. 1984) who named it the Styx. This underground river was so large that cavers were able to use a motorboat to explore it. Most of the underground tributaries join this central drain. The corridors, which are oriented east–west, do not form an obstacle to drainage and are crossed by underground rivers. This system also receives water from the rivers that flow from the Montagne d'Ambre, the Andranotsisiloha River and the Besaboba River. Both rivers disappear underground in swallow holes (a type of sinkhole), but during the rainy season the diameter of the

Fig. 4.8 Horizontal basalt prisms at the top of the neck in the centre of the Mangily Basin. Their orientation indicates the vertical ascent of the basalt

galleries is insufficient to absorb all the water and the karst system overflows.
- In the south several buttes form independent water systems. Their watersheds are reduced, but both rivers (the Mananjeba and Mahavavy) frequently flood the whole area during the rainy season. Large quantities of water carrying a significant amount of sand and clay pass through the buttes. This results in intense karstification and causes the deposition of thick layers of sediments.

The hydrologic system of the karst can be vertically divided into several parts:

- inactive galleries with no perennial runoff;
- a network of galleries where the tributaries of large rivers feed the perennial springs;
- a deep karst aquifer connected to the alluvial aquifers of the Mananjeba and Mahavavy, as suggested by the inspection of water wells located west of the Ankarana. The water table in these wells is a few metres below the land surface. The sea shore is nearby (12 km) and the global sea level drop that occurred during glacial periods made incision of the valley and deepening of the karst aquifer possible.

4.4 Karst Landforms

4.4.1 Particularity of the Ankarana Plateau

In addition to the tsingy, which is present in most of the karst area in Madagascar, some karst features that were described above are specific to the Ankarana:

- The couloirs, which are often called canyons, a misnomer since they are not a riverbed. They are deep and narrow corridors that dissect the plateau.

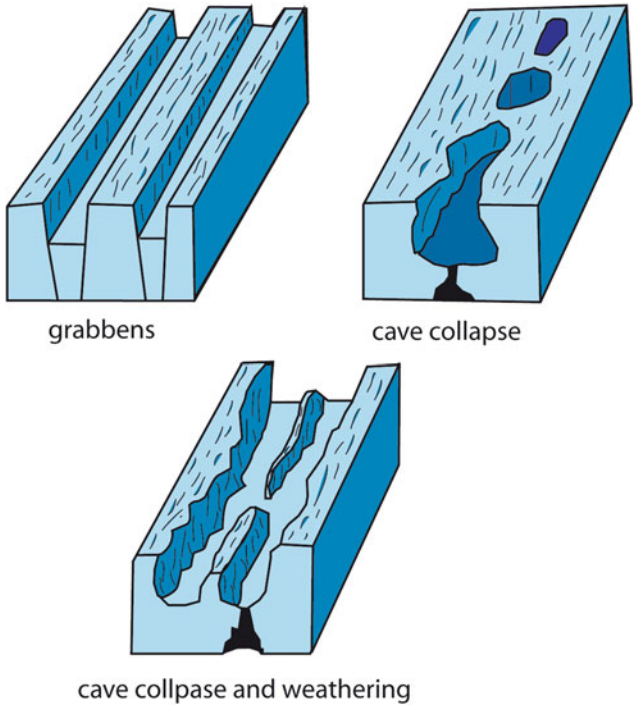

Fig. 4.9 Different genetic hypothesis for the Ankarana couloirs (from Rossi 1980)

- The closed depressions (Mangily, Tsimiharo Hole, etc.), which are present in several parts of the northern Ankarana and the Mananjeba Buttes.

The couloirs extend towards the east, perpendicular to the Ankarana Wall. They often cross the entire plateau, but sometimes they end suddenly, such as in a pocket valley. Rossi (1980) proposes either a karst dissolution origin, or a tectonic one in which the couloirs are micro-grabens (Fig. 4.9).

Several large closed depressions are also present on the plateau, the most important being the Mangily. It is a large 800 × 500-m circular basin with vertical walls that perforates the Mananjeba Buttes (Fig. 2.6) in Chap. 2. Rossi (1980) proposed a volcano-tectonic origin and Wilson (1987) supposed it to be a huge collapsed underground chamber. A similar feature is the Antavy Circus or Tsimiharo Hole, a place used by the Ankarana people to take refuge at times of war. However, both places are devoid of blocks, which excludes the hypothesis of a collapsed chamber. In addition, as pointed out earlier, a small basalt hill can be observed in the centre of the Mangily closed basin, reinforcing the hypothesis of a volcanic origin.

4.4.2 The Role of Volcanism in Surface Modelling

This section is a modified excerpt of a paper published in the *International Journal of Speleology* (Gilli 2014).

In addition to the presence of basalt in the Mangily, other observations confirm the role of volcanism. Indeed, aerial views show that the main karst corridors are lengthened by lineaments that extend several kilometres east of the Ankarana. A field trip shown that these lineaments are basalt dikes. They are easily seen east of the asphalt national road in a recently denuded area, where they intrude into the limestone or the marly-limestone series (Fig. 4.10).

A basalt extrusion can clearly be observed in Fig. 4.10. This brought about contact metamorphism with a clear limit

Fig. 4.10 Pre-corridor with basalt dike and metamorphosed area. The recently denuded limestone is little altered (*top*, general view; *bottom*, detail)

between the limestone and the metamorphosed band. Differential erosion forms a vertical limestone wall, close to which the limestone metamorphosed zone quickly dissolves, while the basalt is affected by intense spheroidal weathering (Fig. 4.10, *bottom*). This is a juvenile form of the corridor whose older aspect can be observed to the west in the nearby Ankarana Plateau. This observation, which also concerns a second lineament–corridor system, could be extended to the other couloirs, but more field work is necessary.

Volcanism is therefore an important phenomenon. A morphogenetic process combining volcanism, corrosion, metamorphism and selective erosion can be advanced to explain the genesis of both features.

4.4.3 Hypothesis on the Genesis of Couloirs and Closed Depressions

(a) Action of basalt on limestone

When lava flows on a rock surface, thermal exchanges with air and water result in rapid cooling and the lava alters the limestone to a small extent. For instance, in Ambohimalaza (3 km southwest of Mahamasina), on the eastern side of Ankarana, the basalt fossilises karst pinnacles (Rossi 1980).

However, deep beneath the earth's surface, cooling is limited by the low thermal conduction of the limestone (thermal conductivity is 5.5×10^{-7} m^2/s). Metamorphism is then responsible for the recrystallisation of calcite (Kjølle 2000) or for the formation of marbles, if the pressure is high enough and if silicates are present. The size and nature of the metamorphosed aureole are a function of the depth and temperature of the igneous material. It may be reduced to a few centimetres, as observed in the limestone of the Buchan Caves (Barker and Bone 1995), or be a few kilometres wide in plutonic areas. Modelling a 5.3-m-thick dike in Killala Bay (Ireland) shows that temperatures in the limestone, a few metres from the dike, remain very high (500 °C) for several months (Joesten and Van Horn 1999).

One hypothesis for the Ankarana Plateau is that very close to the basalt, in a low-pressure context, the heat causes the limestone to calcinate releasing carbon dioxide and turning into calcium oxide (quicklime) at 900 °C. When combined with water it can form calcium hydroxide (slaked lime).

$$CaCO_3 \rightarrow CO_{2(g)} + CaO(\text{calcium oxide})$$

$$CaO + H_2O \rightarrow Ca(OH)_2(\text{calcium hydroxide})$$

The solubility of calcium oxide or calcium hydroxide (1650 and 1590 mg L^{-1}, respectively) is much higher than that of pure limestone (15 mg L^{-1}, or 250 mg L^{-1} in its bicarbonate form) and this could explain the more intense weathering in limestone. However, there are no examples of CaO outcrops and only rare ones of $Ca(OH)_2$ (portlandite) in nature.

A second hypothesis is based on the existence of a basalt–limestone assimilation process, where basalt is enriched in CaO while limestone loses CO_2 and gains SiO_2. Laboratory experiments on basalt and limestone show that the decomposition and degassing of $CaCO_3$ may start at 600 °C making melting between magma and CaO possible (Deegan et al. 2010). Thus basalt may partially "digest" limestone. This process forms different types of rocks depending on the temperature, the pressure and the respective proportions of CaO, SiO_2 and H_2O (Baker and Black 1980; Iacono-Marziano et al. 2007). This basalt–limestone assimilation process, combined with hydrothermal activity, makes the basalt more susceptible to erosion (McGreevy 1982). The pseudo-lapies observed in the Ankarana basalt may be the result of such an assimilation (Fig. 4.11). It may also transform calcite in silicates that are more likely to weather than pure calcite. Thus the whole area affected by the transformation (basalt and metamorphosed belt) becomes more susceptible to erosion than the surrounding limestone.

(b) Genesis of the couloirs

The process outlined in the second hypothesis may explain the genesis of the couloirs (Fig. 4.12). The narrow dikes and their metamorphosed zones do not constitute a hydrogeological barrier and can easily be crossed by underground water flows, an occurrence that has been observed by cavers in the Analamisondrotra Cave. In most of the large caves, such as the Andrafiabe or the Milaintety, the main galleries are cut by corridors. This proves that the latter are younger than the caves, while the basalt dikes are older. The dikes could be of Cenozoic age, as is the case with Montagne d'Ambre volcanism, but their northwest–southeast orientation also supports a Cretaceous age (Besairie 1973; Mahoney et al. 1991).

Fig. 4.11 Pseudo-lapies on basalt

Below the surface the karst system evolves into cave networks that can pass through narrow veins of basalt and metamorphosed areas. They may or may not be eroded, depending on the direction of water circulation. Flow direction depends on the geometry of the impermeable substratum and on the elevation of the springs. When the hydraulic gradient causes the groundwater to flow north–south, perpendicular to the veins, it simply passes through, whereas when it establishes in an east–west direction the water circulation is driven by the dikes. It can alter the basalt and the metamorphosed belt and enlarge them.

When the limestone and basalt veins are covered by a layer of marls at the surface, they are protected from weathering. But, when the cover becomes thin enough, active karstification begins beneath the cover. Then, when the cover is totally eroded the tsingy develops intensely. This also promotes alteration of the basalt dikes, which evolve rapidly becoming larger and deeper. In most cases the weathered rocks are completely leached away and limestone blocks, collapsing from the walls, mask the bedrock. Thus it is impossible to observe remnants of the dikes. However, occasionally, some elements of basalt are visible among the tsingy, or on the corridor walls (J. Radofilao, pers. comm.).

This phenomenon may be more or less widespread, depending on the extent of the metamorphosed area. But, it also depends on the nature of the dikes, which range from basalt veins that are several kilometres long to ones only a few tens of metres long. This allows a variety of corridor

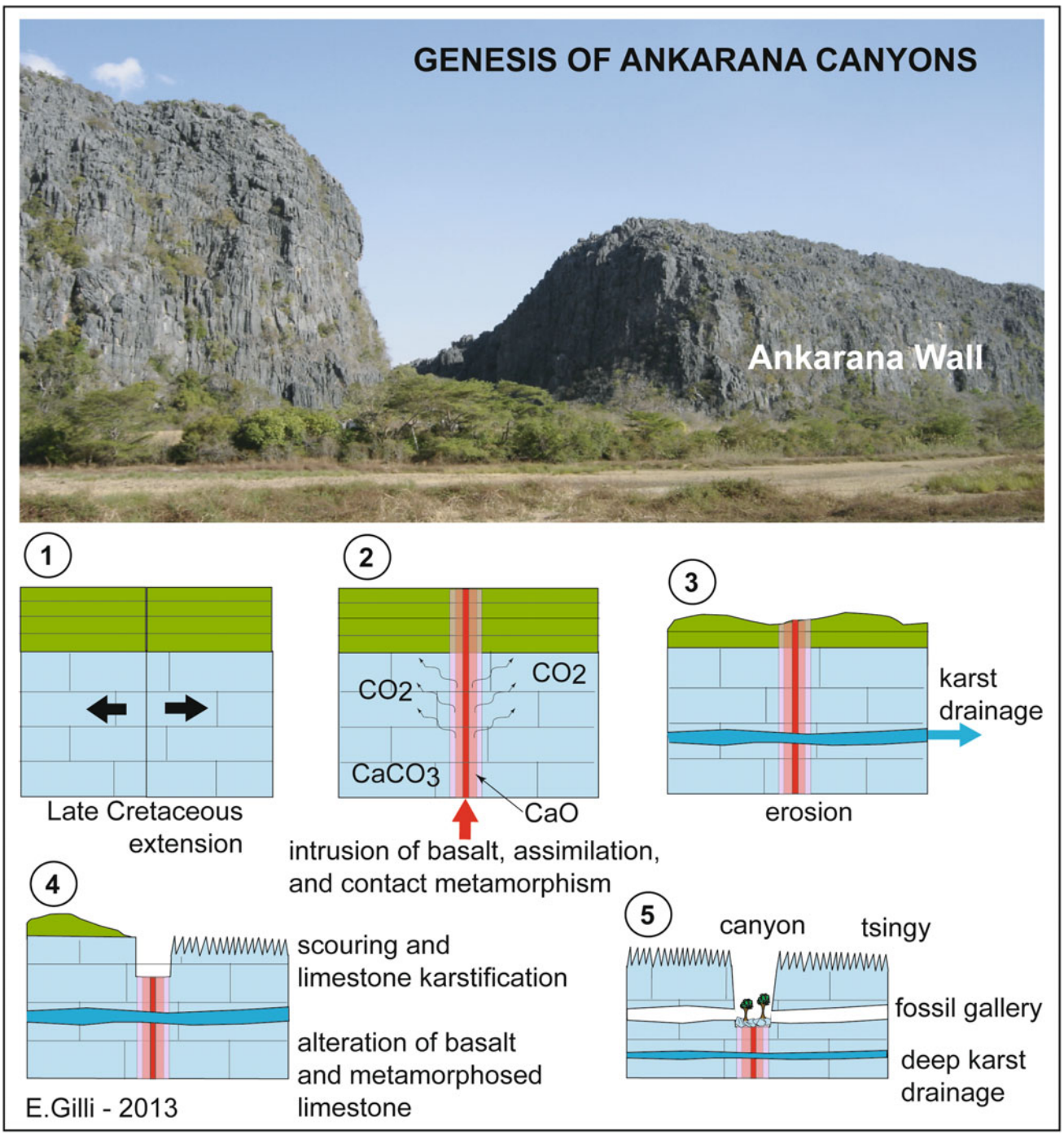

Fig. 4.12 Hypothetical genesis of the Ankarana couloirs

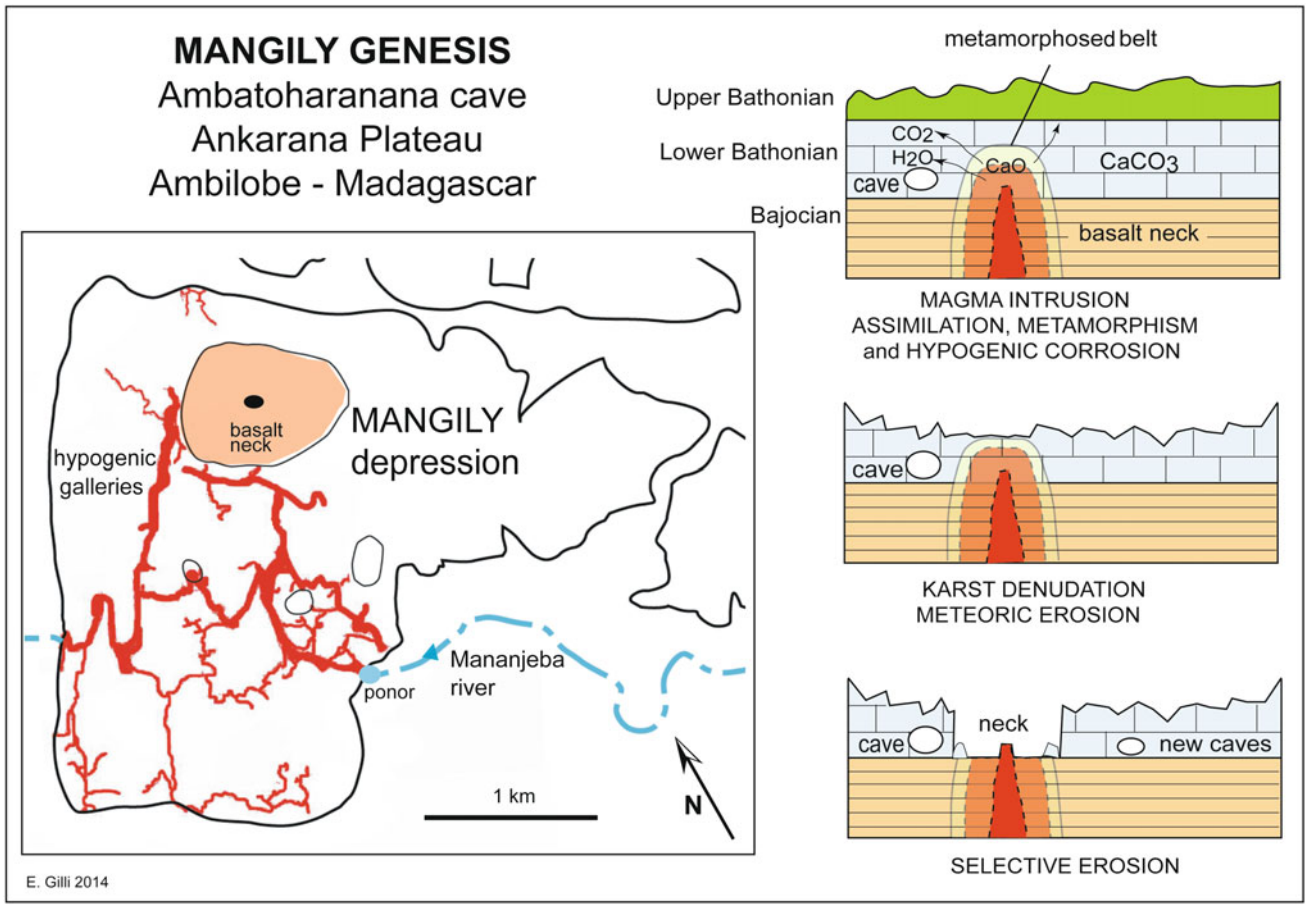

Fig. 4.13 Hypothetical genesis of the Mangily Basin in the Ankarana Plateau

shapes, ranging from simple fracture enlargements to vast corridors with vertical walls. This also explains why some corridors are continuous while others are interrupted (Rossi 1980).

As long as the karst substratum remains unaltered, deep water circulation is still possible below the corridor floors, as proven by the presence of a single main spring south of the plateau. The largest corridors and those that have long since lost their impermeable cover can broaden and deepen, until they reach the Liassic substrate. This completely isolates the karst system and individualises limestone buttes, such as those observed in the south of the plateau, where the Ankarana Plateau is gradually buried beneath the Mahavavy alluvium.

(c) Genesis of the closed depressions

The Mangily Basin is a closed depression, which is the result of a similar mechanism (Fig. 4.13). A basalt neck in its centre shows the orientation of basalt prisms confirming vertical ascent of the lava (Fig. 4.8). One hypothesis is that during neck intrusion the heat metamorphosed the limestone (or highly transformed its porosity) and the basalt was enriched in CaO. The limestone and the aureole started being affected by the hypogenic process of dissolution or ghost-rock karstification (Dubois et al. 2014) below the overlying cover by the CO_2 and H_2O issued from the degassing magma or by metamorphic reactions. Then, when the plateau started being denuded the whole metamorphic aureole, the transformed basalt or the ghost-rock alterites, were quickly dissolved or washed away by meteoric water. The residue could be evacuated by the connected cave system. This hypothesis is supported by the huge size of the galleries that are present south to the Mangily (Fig. 4.13).

Aerial pictures suggest the presence of a basalt hill in the centre of the Tsimiaro Hole, the second largest depression of the Ankarana (Fig. 4.14). At times of intertribal war in the nineteenth century the Antankarana people and their cattle took refuge in these depressions, which are only accessible by the caves. They would stay there for long periods and cultivated their crops in the closed depressions (Decary and Kiener 1970), which reinforces the probability of the soil there being basaltic. Future studies will have to be undertaken to confirm this.

Fig. 4.14 Tsimiaro Hole and its central hill which is supposedly a basalt volcano

4.4.4 Speleogenesis

(a) Volcanism and speleogenesis

The mechanism put forward to explain the surface landforms of the Ankarana (see previous section) could be extended to the genesis of a part of the cave network (Figs. 2.13 and 4.13). The role of volcanism in speleogenesis was suggested to explain greater karstification in the Apennines (Central Italy) near volcanic edifices. The role of magmatic CO_2, SO_2 or H_2S, first discussed by Demangeot (1963), is supported by cave observations in Italy (Menichetti 2009; Galdenzi 2009).

In Turkey the formation of obruks, a type of mega doline, is explained by heat and by a considerable amount of carbon dioxide supplied by a magmatic source (Bayari et al. 2009).

In Mexico the deep Zatacon system is also related to a hypogenic mechanism related to volcanism (Gary and Sharp 2006).

In addition to the production of fluids, volcanism also brings about constraints and distortions that fracture the limestone and guide the erosion process (Salomon 2009).

(b) Hypothesis on Ankarana speleogenesis

Most of the caves in the Ankarana were created by dissolution, in which water penetrates into the limestone from the surface or from the borders. In addition to this normal epigenic process, there are also two mechanisms that contribute to the spectacular size of the Ankarana galleries.

Hypogenic process

The Ankarana Wall is a major normal fault that placed the Mid-Jurassic limestone into contact with more recent impermeable series (Jurassic and Cretaceous marls and marly-limestone). Before these impermeable series were eroded the Ankarana Wall had been a hydrologic boundary for karstic groundwater.

A primitive network of large caves and mazes has established itself in the Northern Ankarana. It runs parallel to the Ankarana Wall (e.g., Andrafiabe, Milaintety, and Antsatrabonko). The Southern Buttes also have remnants of large galleries that ran more or less parallel to the wall. This confirms the importance of this main fault in driving Ankarana speleogenesis. However, the position and size of this primitive network are difficult to understand. It is located close to the wall, but far from the synclinal axis where groundwater is now drained (Fig. 2.13). Moreover, the presence of Upper Jurassic residual mounds at the surface of the plateau shows that the karst was previously covered by impervious rocks. Thus it was not a suitable place for water infiltration and limestone dissolution. Our hypothesis is that a hypogenic process took place with fluids (CO_2, H_2O, H_2S and SO_2) coming from the underlying magma.

Terrestrial magmas may contain significant concentrations of CO_2 and H_2O from a few thousandths to about 10% in weight in subduction zones (Wallace 2005). These fluids significantly alter the physical and chemical properties of magmas. This affects fundamental geological processes such as partial melting, ascent, eruption, degassing and crystallisation of magmas. Their role in the transport and redistribution of metals in hydrothermal ore bodies is well known, and their possible impact on speleogenesis has occasionally been proposed (Gunn 2004; Gary and Sharp 2006; Klimchouk and Ford 2009).

Such high-pressure magmatic fluids can degas when magma approaches the surface. Maximum degassing occurs during the eruption, but degassing can also occur before the lava reaches the surface (Lesne et al. 2011). For example, continuous degassing of the Stromboli active volcano resulted in quantities being estimated between 6,000 and 12,000 ton/day of gas, primarily H_2O, CO_2 and SO_2 (Allard et al. 1994). On Tenerife (Spain) in the Canaries rift zone, total diffused CO_2 values measured over a 72-km^2 area were estimated at 146 ton/day. Peak values are spatially correlated with volcanic alignments suggesting structural control over the mechanism of diffuse degassing (Martin et al. 2003). Limestone assimilation by magma is also an important source of volcanic CO_2 (Iacono-Marziano and Gaillard 2006). However, active volcanoes are not the only source of deep CO_2; large quantities are also observed in quiet volcanic areas or in tectonically active areas, which produce non-volcanic earth degassing CO_2 (Cardellini et al. 2011).

Volcanism in limestone regions can therefore produce large quantities of water acidified by CO_2, which will promote the dissolution of carbonates. It is therefore very likely that the different phases involved in Ankarana volcanism were accompanied by fluid circulation leading to the dissolution of limestone in a hypogenic speleogenesis mechanism.

Some hypogenic caves develop in the atmosphere or above the water table, mainly by condensation and corrosion, due to the combination of thermal convection with carbonic and sulphuric corrosion (Audra et al. 2009, 2010).

Carbonic corrosion

The several steps involved in carbonic corrosion can be described in a simplified manner:

$$\text{Volcanic } CO_2 \text{ dissolution}: CO_2(g) \leftrightarrow CO_2(l)$$
$$\text{Volcanic } CO_2 \text{ (l) hydrolysis}: CO_2(l) + H_2O \leftrightarrow HCO_3^- + H^+$$
$$\text{Ionic dissociation}: CaCO_3 \leftrightarrow Ca^{2+} + CO_3^{2-}$$
$$\text{Calcium hydrogen carbonate formation}: HCO_3^- + H^+ + Ca^{2+} + CO_3^{2-} \leftrightarrow (HCO_3)_2Ca^{2+}$$

Calcium bicarbonate is approximately 10 times more soluble in water than calcium carbonate. Thanks to this intermediary step, it is therefore possible to dissolve 300 mg L^{-1} of $CaCO_3$ at room temperature. It is the same process as that in epigenic caves where CO_2 comes from the atmosphere or the soil and the water origin is rainfall. Here both fluids (CO_2 and H_2O) may have a volcanic origin. CO_2 may also come from dissociation of the limestone by heat.

Sulphuric corrosion

If oxygen and water are present the degassing of SO_2 from the magma promotes the production of sulphuric acid, which reacts with limestone to produce gypsum (Hill 1987; Ford 1989; Klimchouk 1997):

Fig. 4.15 Gypsum flower in the Andalameloka Cave

$$2SO_2(g) + O_2(g) + 2H_2O\ (l) \rightarrow 2H_2SO_4(aq)$$
$$H_2SO_4(aq) \Rightarrow 2H_3O^+ + SO_4^{2-}$$
$$CaCO_3 + 2H_3O^+ + SO_4^{2-} \Rightarrow CO_2 + (CaSO_4 2H_2O)$$

However, this mechanism is doubtfull due to the absence of massive gypsum layers in the Ankarana caves; only small gypsum flowers were encountered (Fig. 4.15).

Hypogenic process observations

The carbonic hypogenic process is supported by several facts or observations:

- The position of the main galleries close to the wall on the western flank of the syncline, which is not a normal position for water circulation.
- The importance of regional volcanism.
- The presence of a metamorphic belt in the couloirs and the circus.
- Possible hydrothermal events (Fig. 4.16), evidence of which can be seen in the Mandresy Cave where box-works are also present (Fig. 4.17).
- Solution rills, which could be related to convection, can be observed on the walls of the Andrafiabe Cave and Mandresy Cave (Figs. 4.18 and 4.19).

In addition to a normal epigenic process the cave system featured another that involves bats (as described below).

An interesting place to study these different mechanisms is the westernmost gallery of the Mandresy Cave in Andranomilika Butte (Southern Buttes). This gallery is very close to the Ankarana Wall and is aligned on a fault where breccia is observed. This gallery, high in altitude, was more or less disconnected from the rest of the cave by the collapse of the chamber where bats roosted. The sediments and underground forms were then saved from the action of running water. Nevertheless, they were intensely corroded by water dripping from the ceiling and probably also affected by bat excrement. Bats have inhabited this gallery for thousands of years.

Bats erosion

A new field in tropical speleogenesis involving the role of bats has recently opened up (Forti et al. 2006; Lundberg and McFarlane 2009, 2012, 2015). Delaty et al. (2006) described the bell holes that grow on the ceiling of caves in Madagascar inhabited by bats. In an attempt to explain their formation, it has been proposed by authors that the moisture released by the bats and the CO_2 released when they breathe bring about a condensation–corrosion effect. They also

Fig. 4.16 Possible hydrothermal event in the Mandresy Cave

pointed out the existence of niches filled with guano on the floor below the bells, further evidence of the corrosive effect of bat excreta. The effects of the presence of bats are summarized by Audra et al. (2017).

In the caves of the Southern Buttes there are several bat-related formations: bell holes (Fig. 4.20), guano pots (Fig. 4.21) and pinnacles. The latter are spectacular at the end of the westernmost gallery of the Mandresy Cave (Andranomilika Butte) (Fig. 4.22). The difference in size between a bell hole and its related guano pot (Fig. 4.23) gives an idea of the important role bat excreta plays in corrosion.

In addition to these formations, other observations support erosion caused by bats:

- An important deposit of grey powder is observed in the western gallery of the Mandresy Cave, covered by a more or less thick crust (Fig. 4.24). Acid and hardness tests show that this crust is not calcite while RX diffraction supports a phosphate crust.
- Yellow formations, which are probably apatite, can also be seen in the Mandresy Cave (Fig. 4.25).
- The top of some pinnacles is covered with the remnants of a layer in which calcite and phosphate are mixed (Figs. 4.26 and 4.27).

These formations concord with the evolution of thick guano deposits and provide evidence that bat erosion is an important speleogenesis process at some underground places in the Ankarana cave network.

(c) Hypothesis on the late evolution of the karst system

The karst system evolved both vertically and horizontally depending on denudation of the Bathonian limestone allowing the infiltration of rainfall and the development of a classical epigenic karstification driven by cracks and joints. Underground circulation enlarged the discontinuities and partially reused previous hypogenic networks, while differential erosion in metamorphic zones on the surface resulted in the birth of corridors and closed basins.

This evolution gradually led to individualisation of the southernmost parts of the plateau, which are now drained by their own hydrological systems.

Fig. 4.17 Boxwork in the Mandresy Cave. An acid test revealed that part of the cement is not calcite

In the Southern Buttes, which are flooded yearly by the Mananjeba and Mahavavy rivers, a significant amount of water circulates into the limestone. The water transports abrasive particles that come from the Isalo sandstone. This resulted in the birth of underground mazes and spectacular erosional features in the eastern part of the buttes, such as a spear-shaped form in the Andranomidity Cave (Fig. 4.28).

In addition, some parts of the cave network are inhabited by bats when living conditions are favourable. They may provoke caves enlargement.

Fig. 4.18 Wall solution rills in the Andrafiabe Cave

(d) Possible age of the karst

The northwest–southeast orientation of the dikes suggests a Cretaceous age (Besairie 1973; Mahoney et al. 1991).

The following chronology can be proposed (Fig. 4.29):

- *Late Cretaceous (pre-rifting phase)*: bulging and intense fracturing of the Ankarana area; first basalt intrusions within the limestone block; deep confined hypogenic karstification.
- *Tertiary*: partial denudation of limestone and early meteoric karstification; individualisation of the buttes in the southern part of the plateau.

Fig. 4.19 More wall solution rills in the Andrafiabe cave (*upper right*)

Fig. 4.20 Bat bell holes in the ceiling of the Mandresy Cave

Fig. 4.21 Guano pot bordered with apatite

- *Plio-Quaternary*: denudation of the limestone; effusive volcanism from Montagne d'Ambre and invasion of landforms by basalt; complete individualisation of the Southern Buttes and northward migration of the source of the Ankarana River to its present position.

(e) Future work to be done

The plateau is surrounded by lava flows and there are some small strombolian cones above the limestone. Thus there is little doubt that volcanism played an important role in the origin of the karst landforms of the Ankarana. However, this book only presents hypotheses and preliminary observations. Much work is necessary to better characterise the mechanisms that produce karst landforms and caves.

The presence of basalt dikes or necks in some corridors and the largest closed depression is clear, but their existence remains to be investigated in other similar places such that the common origin of the same landforms can be ascertained. Accurate identification of the rocks and minerals present in the metamorphic belts is also necessary to better understand the basalt–limestone assimilation process.

Fig. 4.22 Underground pinnacles probably caused by bat excreta corrosion in the westernmost gallery of the Mandresy Cave (Andranomilika Butte)

The main large galleries are abnormally positioned, parallel to the wall or to the Mangily Basin in its southern part. This position, which is not concordant with normal water drainage, suggests a hypogenic origin for the cave system. In addition to the abnormal cave network geometry, gypsum and underground solution rills that can be observed in some caves support that hypothesis. Future research will have to focus on several features described by Audra et al. (2010) and Klimchouk (2004) that characterise hypogenic caves, such as mineralisation, cupolas, boxworks and large crystals. For instance, the presence of large transparent calcite rhombohedra was reported in the Andrafiabe Cave (de

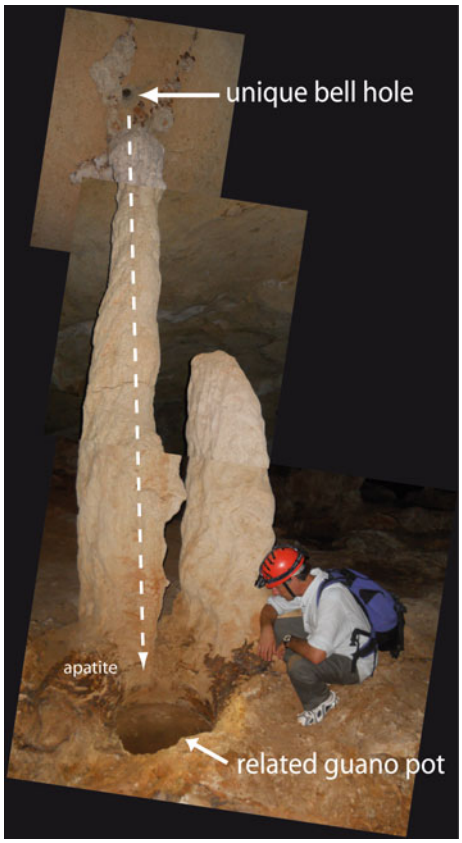

Fig. 4.23 Bell hole and its related guano pot. Note the difference in the size of both holes

Saint Ours 1959) and needs to be confirmed. Moreover, the origin of the underground solution rills observed on cave walls (Fig. 4.18) remains to be studied.

New surveys of the main caves and their upper levels are also necessary to better characterise the relationship between the different cave levels and the water table. Indeed, most of the cave systems are horizontal, and few data are available concerning the elevation of the galleries. It is therefore impossible to characterise the different levels and ascertain whether the presumed hypogenic speleogenesis occurred at depth or at the piezometric surface.

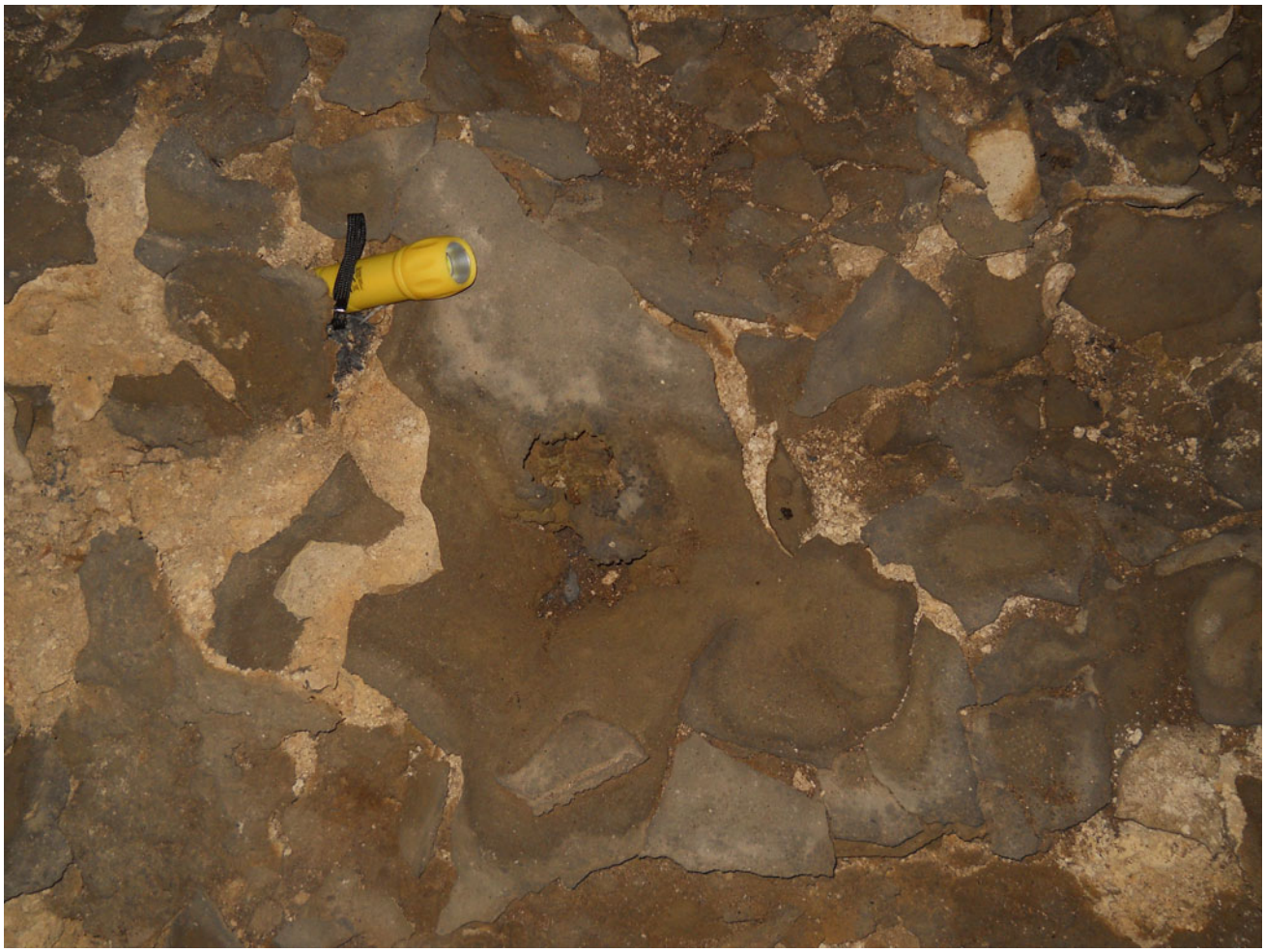

Fig. 4.24 Phosphate crust above grey guano powder

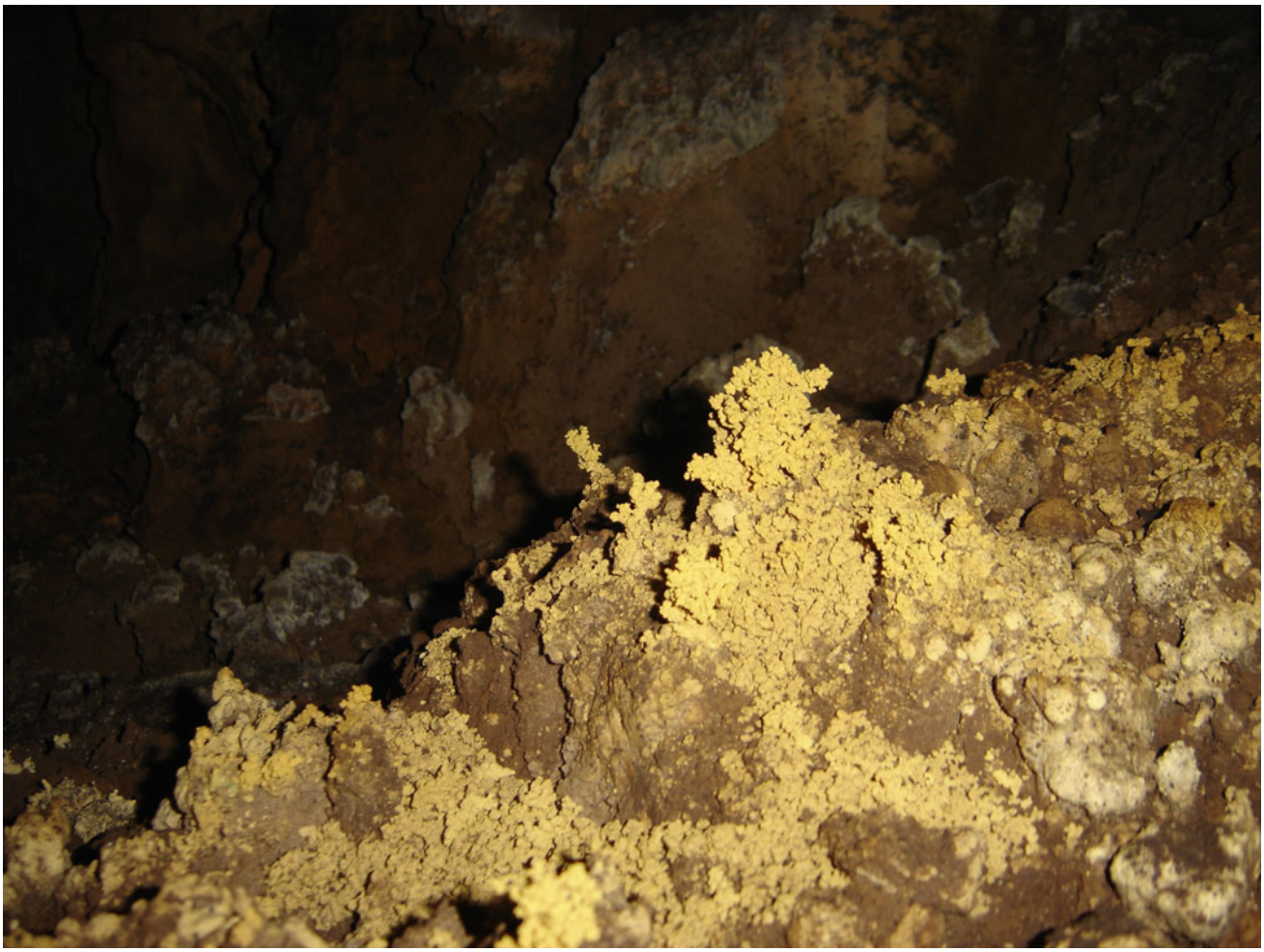

Fig. 4.25 Probable apatite formations in the Mandresy Cave

Fig. 4.26 Acid test on a pinnacle in the Mandresy Cave. The base is limestone and the top is a mixture of phosphate and calcite

Fig. 4.27 Underground breccia pinnacle. This formation was found in a dry part of the Mandresy Cave. Pinnacles are limestone breccia with a mixture of calcite and phosphate

Fig. 4.28 Spear-shaped erosion form in the Andranomidity Cave

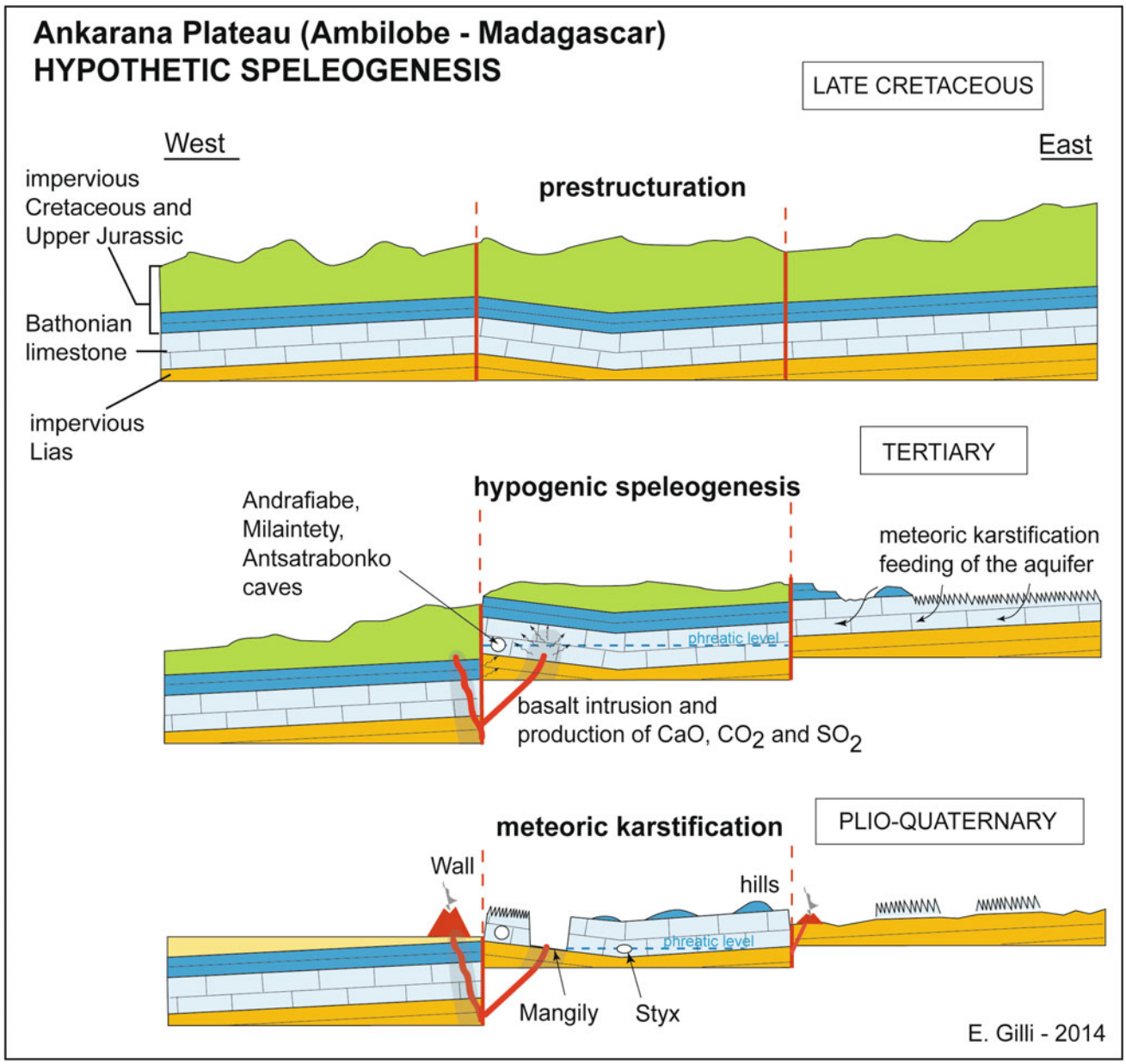

Fig. 4.29 Hypothetical speleogenesis of the Ankarana system. The karst first evolved hypogenically when volcanism was active and when the limestone was covered with an impermeable layer of marls. Surface denudation then made possible weathering and epigenic karst evolution

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Speleology in the Ankarana

5

5.1 Generalities

The caves have long been frequented by humans who used them for shelter and as a burial place. When the caves were first explored by humans is not known. The prehistory of Madagascar remains poorly known. Settlement seems to have begun around the sixth century. The first important human settlement was discovered in Irodo in the extreme north of the island dating to around 1000 years ago (Vérin 1990). The cultivation of rice seems to start around the eleventh century (Battistini 1996) in the Highlands. The first underground incursions probably date back to that time. Very rustic pottery is frequently found during cave exploration, but their age is unknown. They are sometimes associated with reliefs where meals are believed to have been eaten.

Sites of passage between the world of the ancestors and that of the living, the caves have been and still are today sacred places of burial (*fady* in Malagasy). They also have an important place in the history of the Antakarana as it was here they took refuge during the wars against the Merina and where they installed the tombs of their kings.

Pottery and fireplaces are commonly found as a result of deep incursions into some caves. Putting aside the use of the caves for burial purposes and for shelter by the Ankarana People in the Tsimiharo Hole, most of the caves long remained unexplored and no survey of the caves had been undertaken until the 1960s.

The geologist J. de Saint Ours discovered the Andrafiabe Cave during his geological work in that area. Accompanied by G. Coquet, he began to survey the cave in 1963 and explored 5 km of underground passages. In the following years a caving group from the ASUM (*Association Sportive de l'Université de Madagascar*, Madagascar University Sports Association) and the local caver J. Radofilao carried out some expeditions in the Ankarana with the aim of continuing its exploration and surveying the caves.

The expeditions were stopped in 1971 as a result of lack of funding, but J. Radofilao continued to explore alone or with individual cavers. After the 1972 Malagasy Revolution the country was more or less inaccessible to foreigners. Tourism started again in 1981. The author of this book organised the first expedition following that date (Gilli et al. 1981). It was followed by a series of expeditions led by J. C. Peyre from 1982 to 1985 (Peyre et al. 1983, 1984, 1985). This opened up the possibility of exploring new caves in the Ankarana in collaboration with J. Radofilao and revealed to the international community of cavers the speleological potential of the Ankarana Plateau and other areas of Madagascar where karst occurs. Since then, several English (Wilson 1985, 1987), German and French expeditions have taken place in the North Ankarana.

In 2005 the author started to explore the southern part of the Ankarana (Gilli 2016) and discovered around 10 km of caves in the Andranomilika Butte. At the same time J. C. Dobrilla discovered important caves in the unexplored karst area of Analamera, northeast of the plateau. He also started to explore the Andranomilika and Iharana buttes and their surroundings. The work of both cavers added tens of kilometres of new galleries to the Ankarana cave system.

The total length of the caves explored and surveyed in the Ankarana Massif and the Southern Buttes is now around 150 km. The caves have varied aspects ranging from alternating subterranean rivers, large galleries cluttered with high dunes of clays, richly decorated upper levels to narrow passages, huge screes and sumps, none of which have been explored by divers. The dimensions can be considerable with many galleries more than 50 m wide (Andrafiabe, Ambatoharanana, Mandresy).

The longest cave in the Ankarana is the Mandresy cave network in Andranomilika Butte (28 km). The longest

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navigable river is the Styx (5 km). The largest chamber is in the Mandresy Cave (220 × 110 m). Comparing what has been explored with what has not makes it possible to calculate that the total length of galleries probably exceeds 500 km.

5.2 Jean Radofilao

One name stands out when discussing exploration of the Ankarana caves: Jean Radofilao. He began exploring the Ankarana during the French presence. He has been exploring the caves for the last 60 years, most often alone (Fig. 5.1).

A mathematician, Jean Radofilao was admitted to the mathematics community in 1960. He taught mathematics at the Faculty of Science in Antananarivo and then at the University of Antsiranana (Diego Suarez). In 1983 he founded the ENS (Teacher Training College) of Antsiranana, which he directed until his retirement. He is author of a book in six volumes on mathematics published by Editions Européennes Universitaires.

After the 1972 Malagasy Revolution he decided to stay in Madagascar and changed his name from Jean Duflos to Jean Radofilao. He complemented his professional and family life with numerous cave explorations.

He started exploring the Ankarana caves as early as 1964 with the Madagascar University Sports Association (ASUM). For several years the main caves of the massif were recognized and mapped under his direction. The 1972 Malagasy Revolution stopped the activities of ASUM. However, he was still able to survey the main cave of the Ankarana, Ambatoharanana (18 km), in 1974 with fellow cavers Ph. Aandrianbololona and F. Raoelison.

In 1977 J. Radofilao moved to Diego Suarez (Antsirananana) and continued exploring alone or sometimes accompanied by other cavers. In 1981 the total extent of caves in the Ankarana reached 75 km as a result of his efforts.

He had no qualms about exploring long underground rivers, navigating them in a small inflatable and wearing a life jacket—scant protection against the crocodiles that inhabit some caves! Most of the maps of the Northern Ankarana and the Mananjeba Butte published in this book are his work.

Closely associated to the management of the National Reserve of Ankarana, he trained the guides in the niceties of caving.

The mapping work carried out by J. Radofilao is remarkable. His maps are plotted on a multi-sheet plan (see Sect. 5.6). We attempted a corrected assembly from Google Earth images, but differences exist between Radofilao's handmade map and modern documents such as Airbus or satellite images. Table A.1 in Appendix A indicates the GPS waypoints of cave entrances, but for the most part these coordinates have not been verified in the field.

5.3 Details of the Explorations

The massif is easy to reach during the dry season (from May to November). During the last decade we have been experimenting with off-road motorcycles (Fig. 5.2), which proved

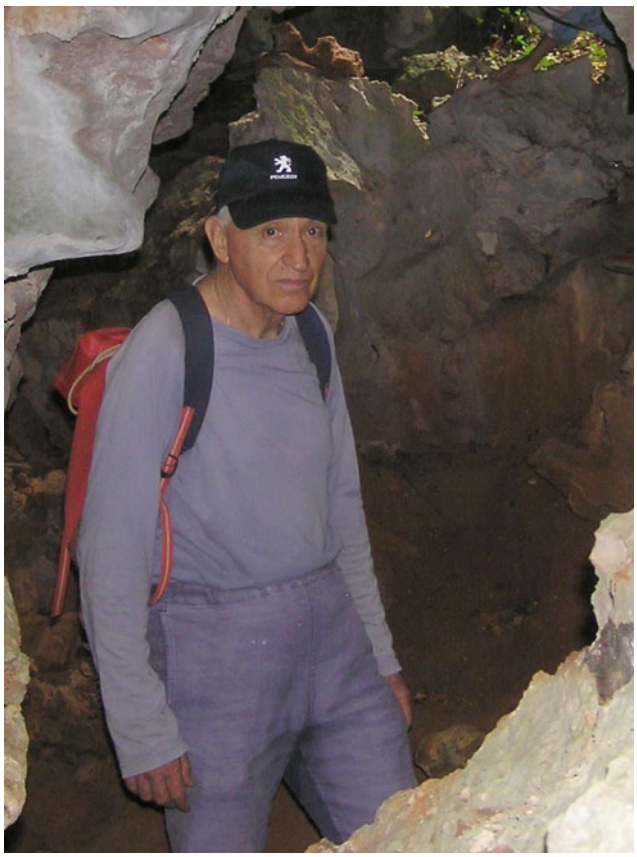

Fig. 5.1 Jean Radofilao (Photo S. Duflos-Radofilao)

Fig. 5.2 Moto-speleo exploration

Fig. 5.3 Tonton Robert's Lodge was the base camp

Fig. 5.5 Sometimes the dinghy has to be briefly abandoned and swimming resorted to

well suited to travelling around the massif thanks to the high density of zebu trails and bicycle paths. The latter have increased in number dramatically thanks to massive imports of Chinese bikes into Madagascar. Loaded with cave equipment, water and food the motorbikes make it possible to quickly reach the remote areas of the massif and return to base camp in the evening. For the Southern Buttes our base camp was Tonton Robert's Lodge (Fig. 5.3).

Moving in caves is surprisingly easy as a result of the large size of the galleries and their being horizontal. Difficulties are linked either to the lack of water to drink or to the existence of rivers which sometimes means navigating for several kilometres (the Milaintety, Styx, Andavakandrehy caves). They are populated by large eels and crocodiles which are not very engaging to swim with. Although the water is hot the use of a dinghy is particularly recommended (Figs. 5.4 and 5.5).

Fig. 5.4 Underground navigation of a river inhabited by giant eels and crocodiles

Fig. 5.6 Progressing through the tsingy

In contrast to the caves, moving on the surface of the plateau among the tsingy needles is very difficult (Fig. 5.6). For instance, although several entries of shafts are visible on satellite images, few of them have been explored from outside. Vertical caving starts from the bottom and by involves underground climbs to reach the upper levels.

Caves are not only good places for camping as they are free of mosquitoes, they are often the only place to find water.

5.4 Map of the Main Caves of the Ankarana Plateau

The synthesis map (Fig. 5.7) and the following documents are taken from the work carried out by J. Radofilao since the beginning of explorations in the 1960s. The maps had been drawn on a series of original layers, including the edges of

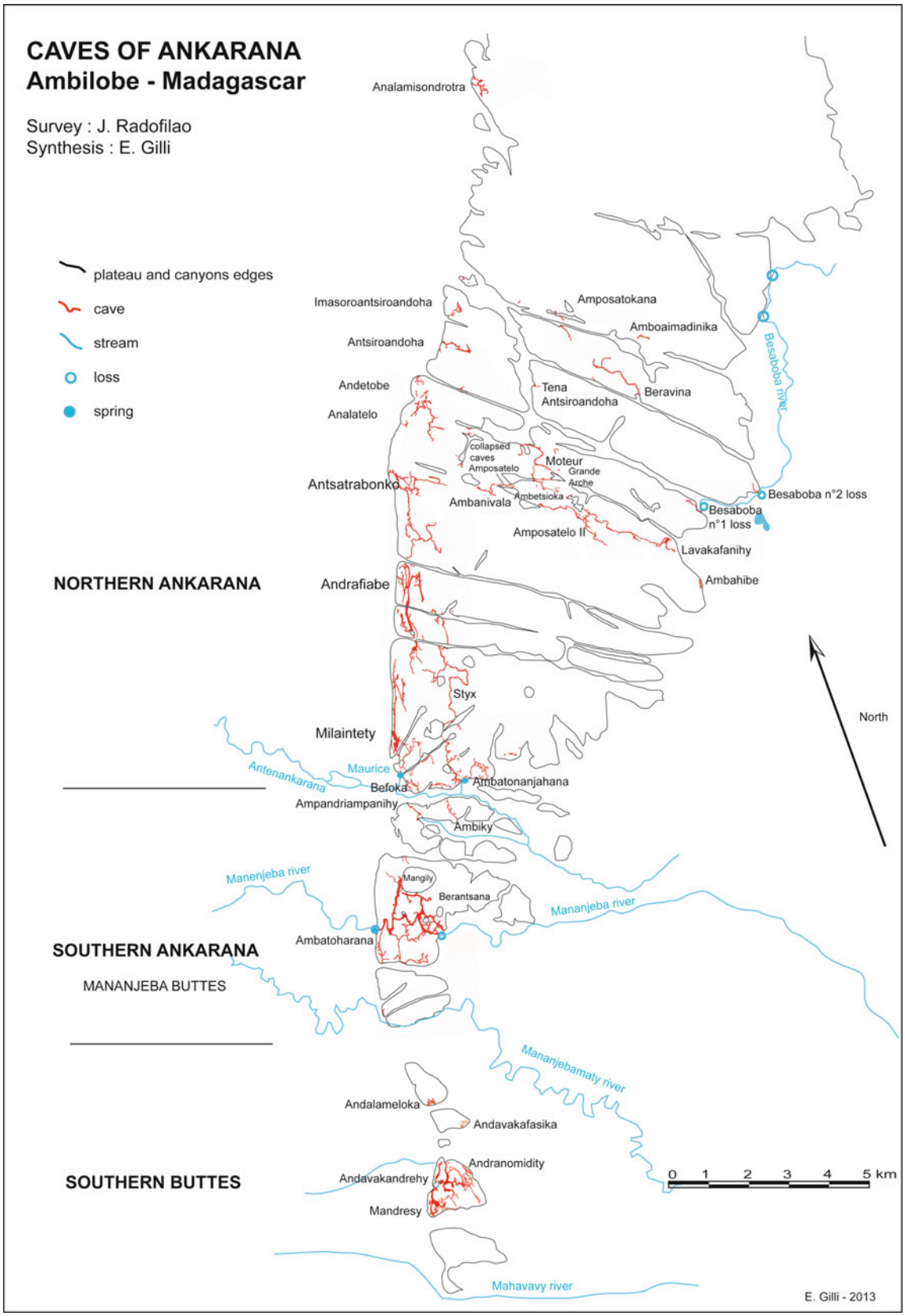

Fig. 5.7 Synthesis map of the Ankarana (from maps by Radofilao, Gilli and Dobrilla)

the massif and the contours of the couloirs. The morphology of the couloirs enabled J. Radofilao to position the entrances to the cavities without using a GPS.

We scanned these layers and tried to assemble and compare them with Google Earth images. This work revealed some errors on the original documents, related to the definition of geographic north and some deformations affecting the layers due to moisture. They have been corrected as best we could. However, it is likely that several inaccuracies remain, mainly for the central zone of the plateau.

The synthesis map shows the main caves. The cave list and GPS waypoints are given in Table A.1 in Appendix A.

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Caves of the Northern Ankarana

6

The very northern part of Northern Ankarana is almost unexplored and contains many caves, most of which belong to a single network that drains towards the Ankara Spring. The explorations conducted by J. Radofilao aimed at trying to connect these different caves but several possible connections are sumps. This poses the problem of cave diving in rivers frequented by crocodiles.

6.1 Western Part of the Northern Ankarana

Most of the entrances to these caves are located along the Ankarana Wall. They were previously accessible by taking the Anivorana–Ambatoharanana trail, which is now very degraded and difficult to use even with a four-wheel-drive car.

6.1.1 Analamisondrotra

The Analamisondrotra Cave is 1900 m long and was explored in 1981 by the Club Martel CAF (Club Alpin Français) of Nice (Gilli et al. 1981) (Fig. 6.1). It is mainly a large dry gallery. Passages to the west make it possible to reach the groundwater table. To the north the main entrance is hidden by blocks and mostly invisible.

6.1.2 Matsaborimanga

Several small caves in the Matsaborimanga area were explored by J. Radofilao (Fig. 6.2) and French cavers in the 1980s (Figs. 6.3 and 6.4).

6.1.3 Andetobe

The Andetobe Cave was explored and surveyed by J. Radofilao (Fig. 6.5). An upper level was reached by J. C. Peyre and his team in 1982 (Fig. 6.6).

6.1.4 Antsatrabonko

The Antsatrabonko Cave is one of the longest in the Northern Ankarana at 10,475 m. It was explored by the ASUM between 1966 and 1970 for a length of 5760 m, then by J. Radofilao between 1977 and 1978. It contains a river with rapids and a waterfall. Several passages end in sumps (Fig. 6.7).

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https://doi.org/10.1007/978-3-319-99879-4_6

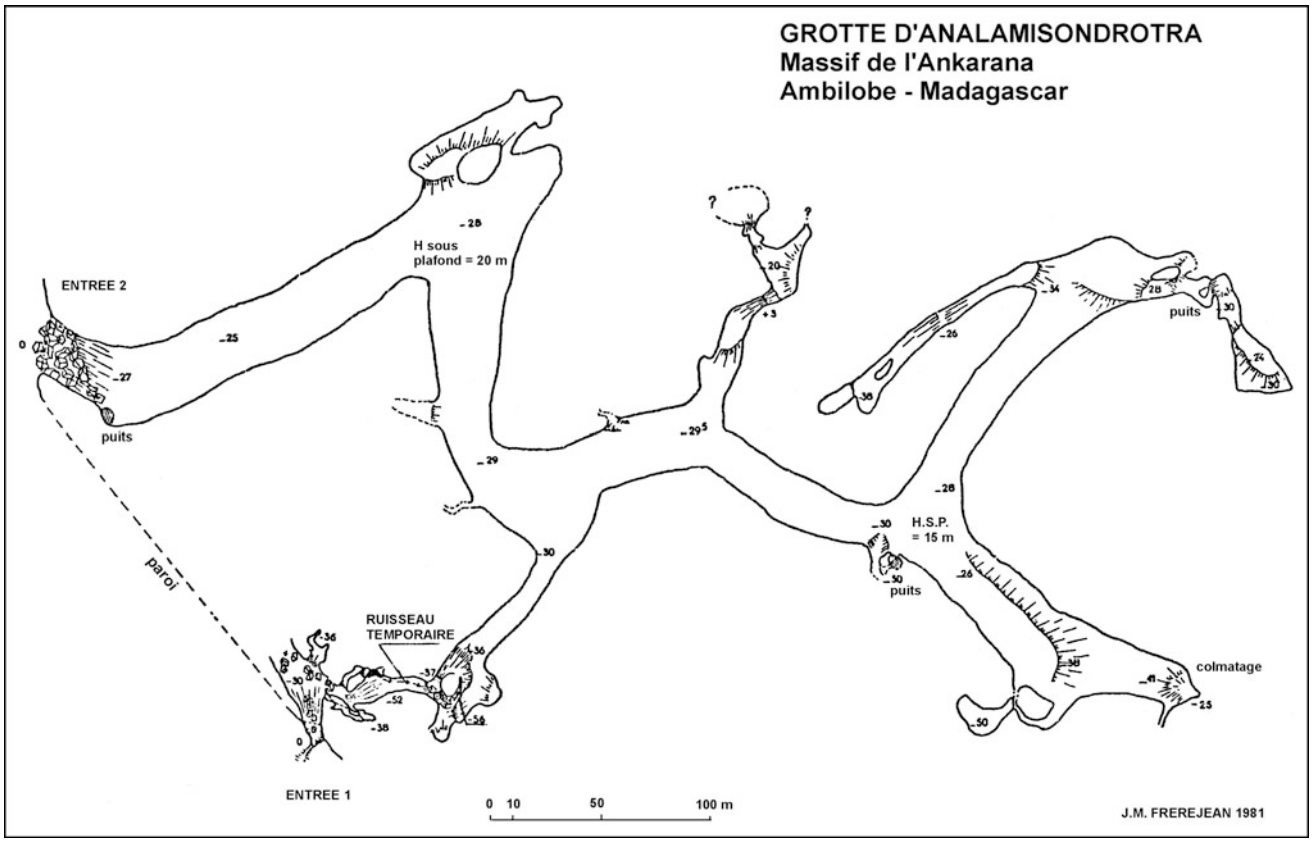
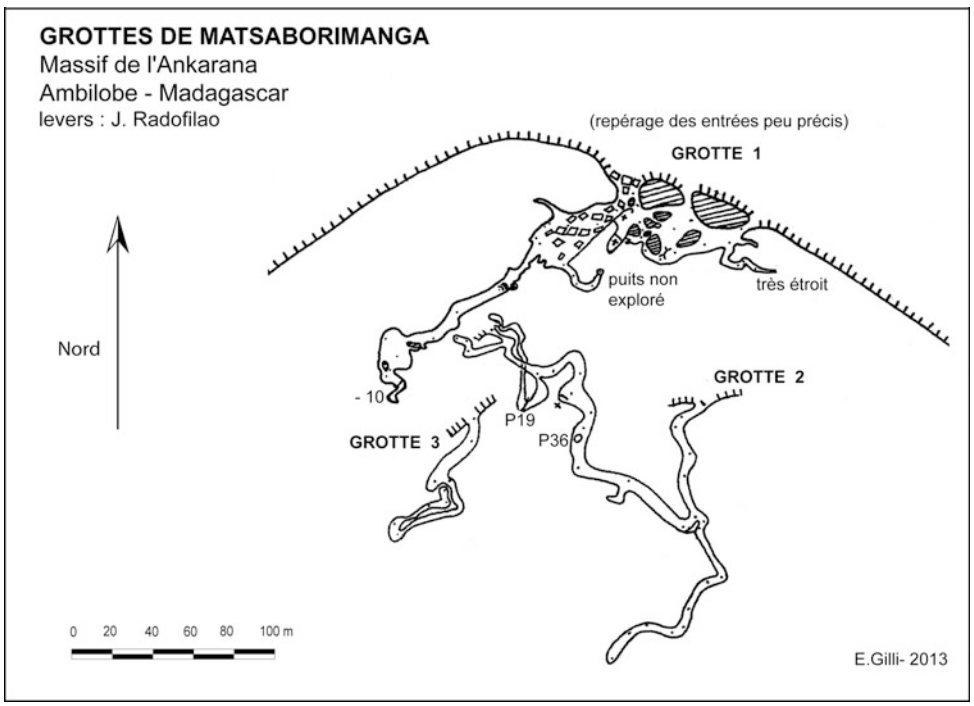


Fig. 6.1 The Analamisondrotra Cave

Fig. 6.2 The Matsaborimanga Cave



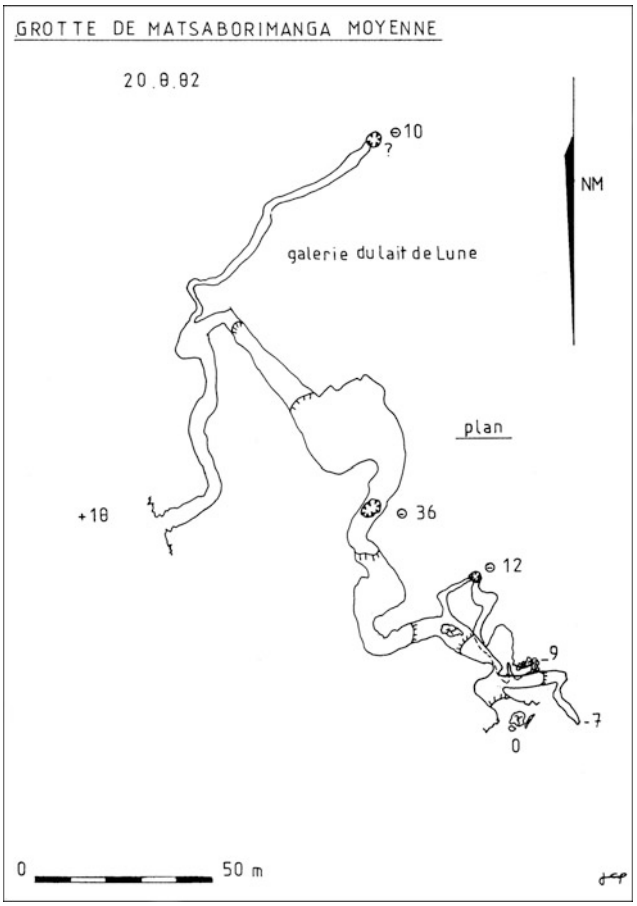


Fig. 6.3 Matsaborimanga Cave No. 2

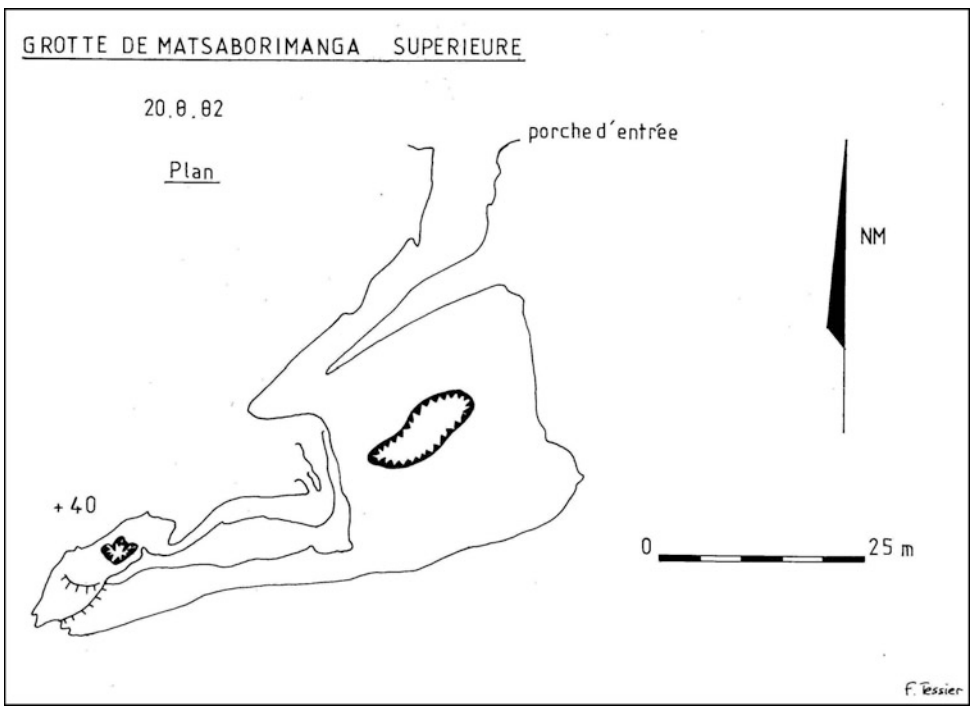


Fig. 6.4 Matsaborimanga Cave No. 3

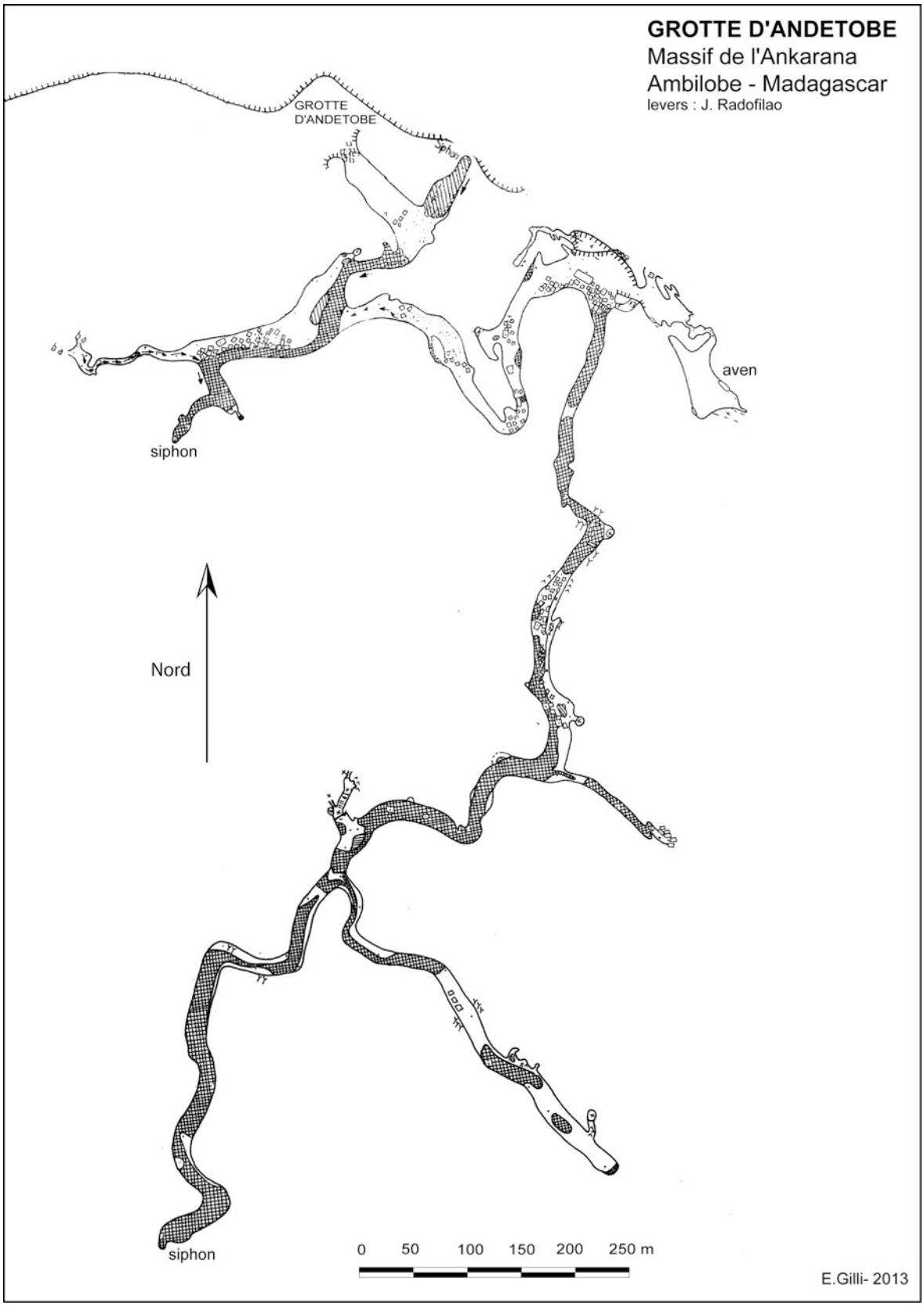


Fig. 6.5 The Andetobe Cave

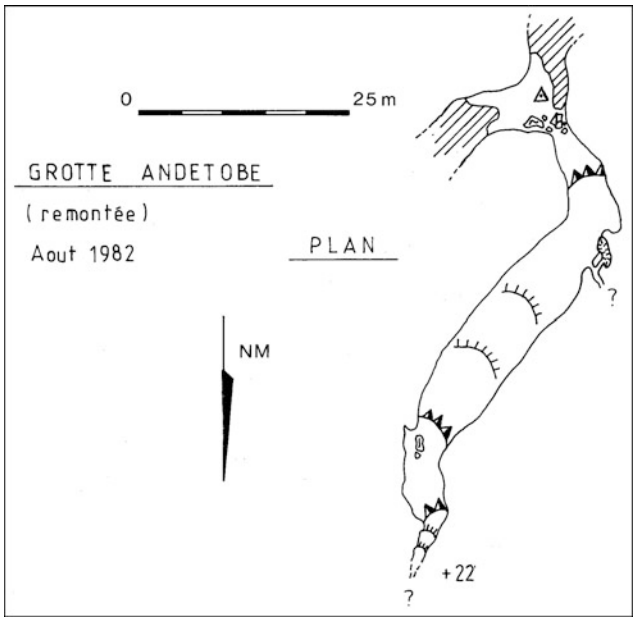


Fig. 6.6 Detail of the 1982 climb in the Andetobe Cave

6.1.5 Gaby Shaft

The Gaby Shaft is 1280 m long and reaches a depth of 140 m. Located among the tsingy it was explored and surveyed by J. C. Dobrilla in 2012 (Fig. 6.8). Reaching the entrance is difficult even with a GPS (12° 54′ 35.89″S, 49° 05′ 02.00″E, elevation 195 m). This vertical pit gives access to a large room (90 × 60 m). An entrance on its western wall leads to a large gallery. Both ends are sumps. The eastern one is very close to the sump of the nearby Andetobe Cave.

6.1.6 Andrafiabe

The Andrafiabe Cave is the longest in the Northern Ankarana at 12,030 m. It was explored by the French geologist J. de Saint-Ours in 1961 and 1963 to a depth of 2800 m, then by the ASUM between 1964 and 1966 to a depth of 9900 m, then by the same group between 1970 and 1971 to a depth of 11,200 m and then by J. Radofilao since 1980 (Fig. 6.9). It contains very large galleries (Figs. 6.10, 6.11, 6.12, 6.13 and 6.14) and decorated passages (Figs. 6.15 and 6.16). The cave system is cut by two main corridors. Several climbs towards upper galleries were done by the Club Martel CAF (Nice) in the 1980s (Figs. 6.17, 6.18 and 6.19). In its southern part there are possible connections with the nearby caves of Ambatomanjahana and Milaintety.

6.1.7 Anjohi Milaintety

The Anjohi Milaintety Cave is 9005 m long and was explored by the ASUM between 1966 and 1972, and then by J. Radofilao and the Club Martel CAF (Nice) between 1980 and 1984 (Fig. 6.20). It is traversed by a river roughly parallel to the Ankarana Wall (Fig. 6.21), which feeds the Maurice Resurgence. Upper galleries (Figs. 6.22, 6.23 and 6.24), accessible by a narrowing located at the edge of the river, allow a well-decorated area with helictites (Figs. 6.25 and 6.26) (Gilli et al. 1981) to be reached (Peyre et al. 1983, 1984).

6.1.8 Small Caves of the Western Area

Some small caves were explored by French teams in the 1980s. They include two karst windows on the underground water table (Figs. 6.27 and 6.28) and a cave where remnants of an old camp were discovered (Figs. 6.29 and 6.30).

6.2 Southern Part of the Northern Ankarana

6.2.1 Befoka

The Befoka Cave is 1940 m long and was explored in 1971 by the ASUM (Fig. 6.31).

6.2.2 Ambatomanjahana and the Styx

Explored in 1983 by the Club Martel CAF (Nice) the Ambatomanjahana Cave is 10,810 m long and aligned on the syncline axis of the plateau. The underground river that flows through it constitutes the main drain of the Ankarana cave system towards the Ankara Spring (Figs. 6.32 and 6.33). The course of this 5 km-long river includes navigating a 3700 m-long stretch of the Styx, permitting use of a motorboat in 1984 to explore it (Fig. 6.34).

On the right bank of the river a passage (Fig. 6.35) leads to a well-decorated dry level (labelled étage fossile on the map) (Figs. 6.36 and 6.37).

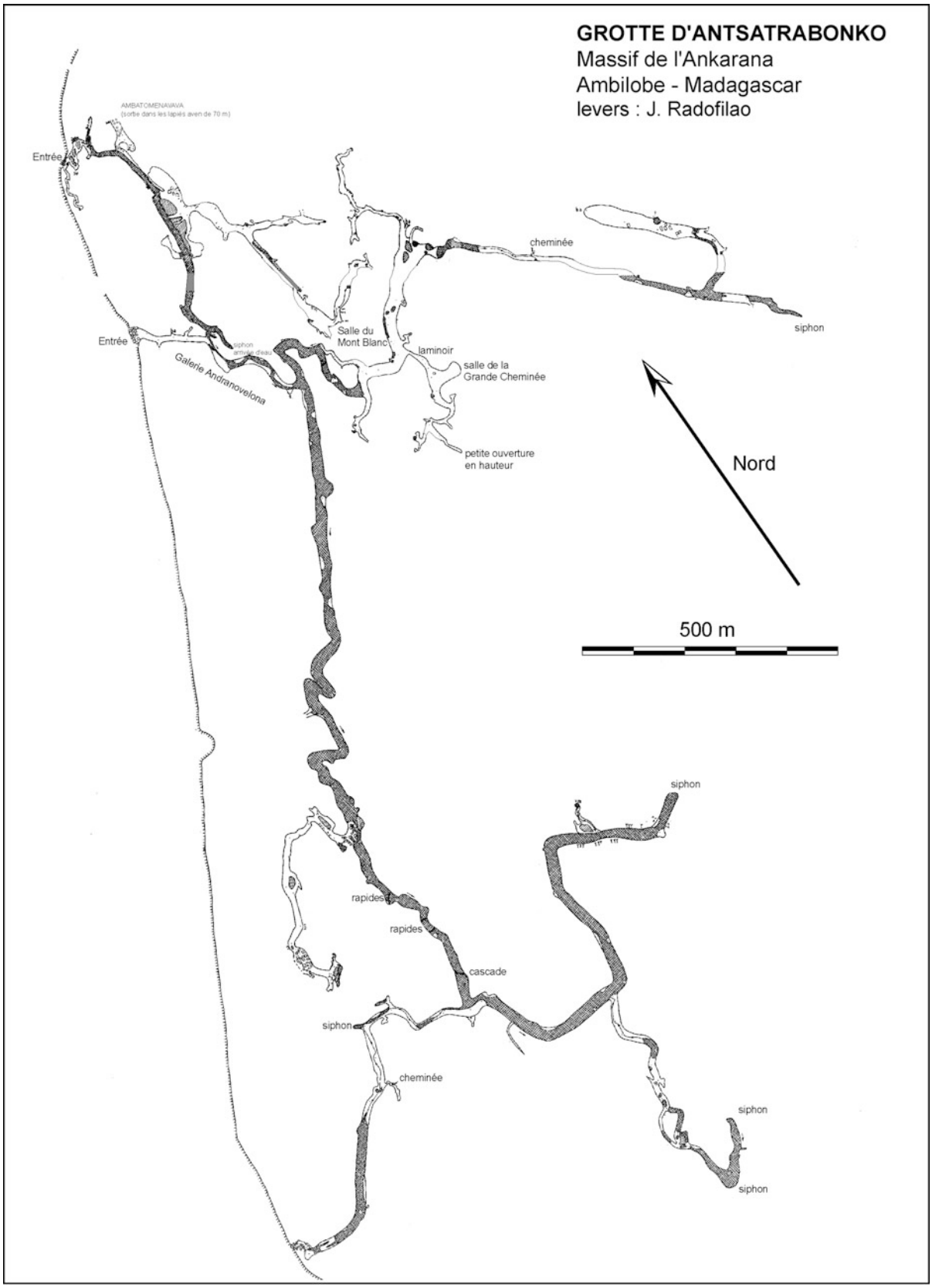


Fig. 6.7 The Antsatrabonko Cave

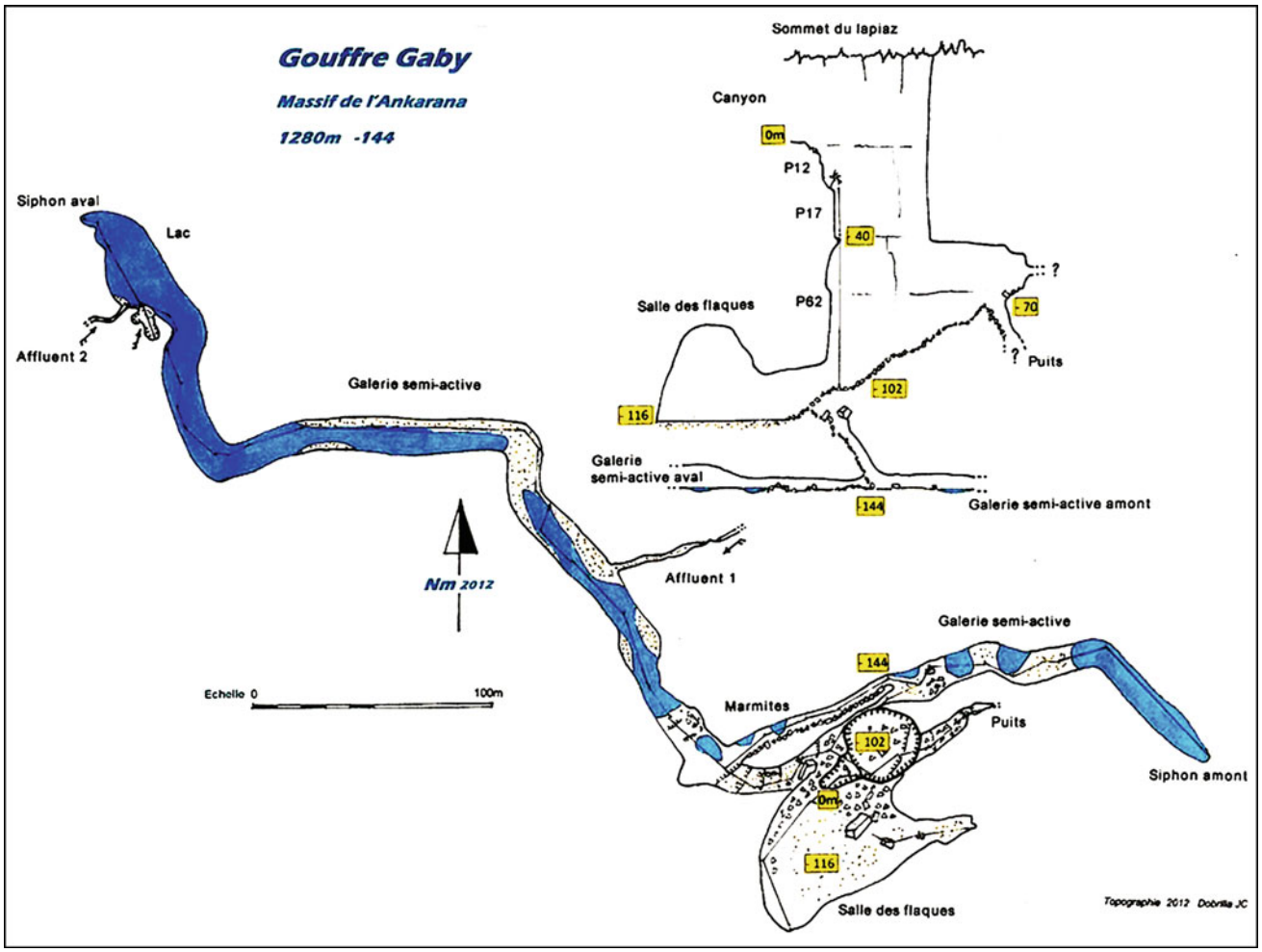


Fig. 6.8 Gaby Shaft (from J. C. Dobrilla)

The southern part of the cave system forms the *Grotte des Rois* (Kings' Cave) (Fig. 6.38), a place of great significance to the Antankarana People as it was the burial place (*doany* in Malagasy) of their ancient kings. They still go there for some ceremonies. It also served as a fortress during wars against the Sakalava in the eighteenth century and then the Merina in the nineteenth century. The wars were the consequence of the policy of expansion of King Radama I. The vast circus (Antavy), named today the *Trou de Tsimiharo* (Tsimiharo Hole), served as a shelter for the population. It is accessible only by a cave about a kilometre long, which was defended by a wall built at the level of a narrowing (Fig. 6.39). The assailants attempted to confine the Antankarana by throwing stones into a shaft to plug the gallery. The barrier the enemy erected could not have exceeded 2 m in height and they gave up after 3 years of siege. Since that time certain caves of the Ankarana are forbidden to the Merina. The cave is taboo and no photographs are available.

The place is *fady* (taboo), but it is possible to visit the tombs by respecting a particular rite. No cloth is allowed between the legs. Thus, clothing such as shorts, trousers or underpants must not be worn. Only a *lamba* (loincloth) is allowed. It is also forbidden to smoke and the guide must be of royal origin to enter certain caves. It is advisable to seek an audience with the traditional King of Ankarana, Tsimiharo III, who lives in Ambilobe to get his consent and ask for his assistance.

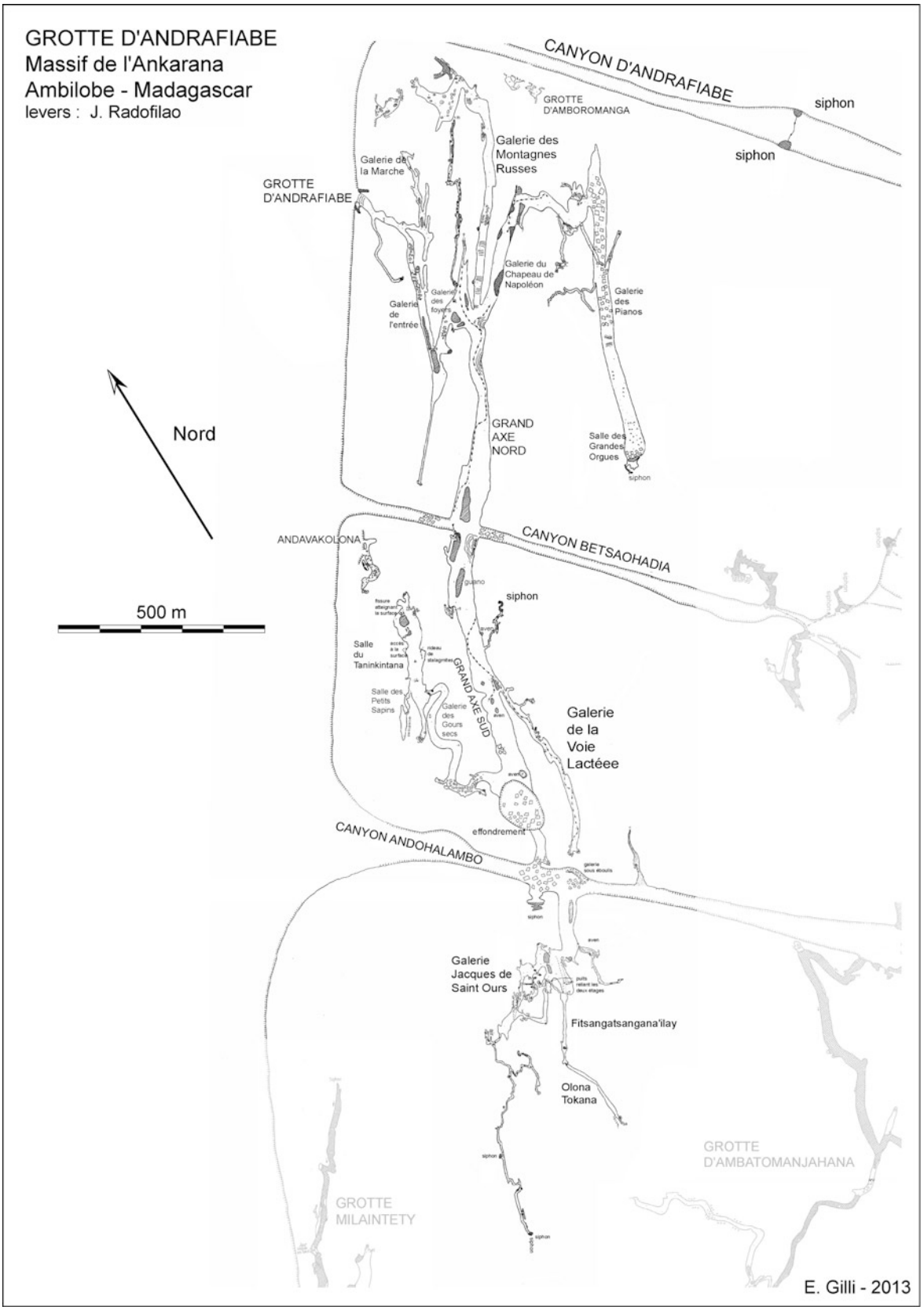


Fig. 6.9 Synthesis map of the network of the Andrafiabe Cave

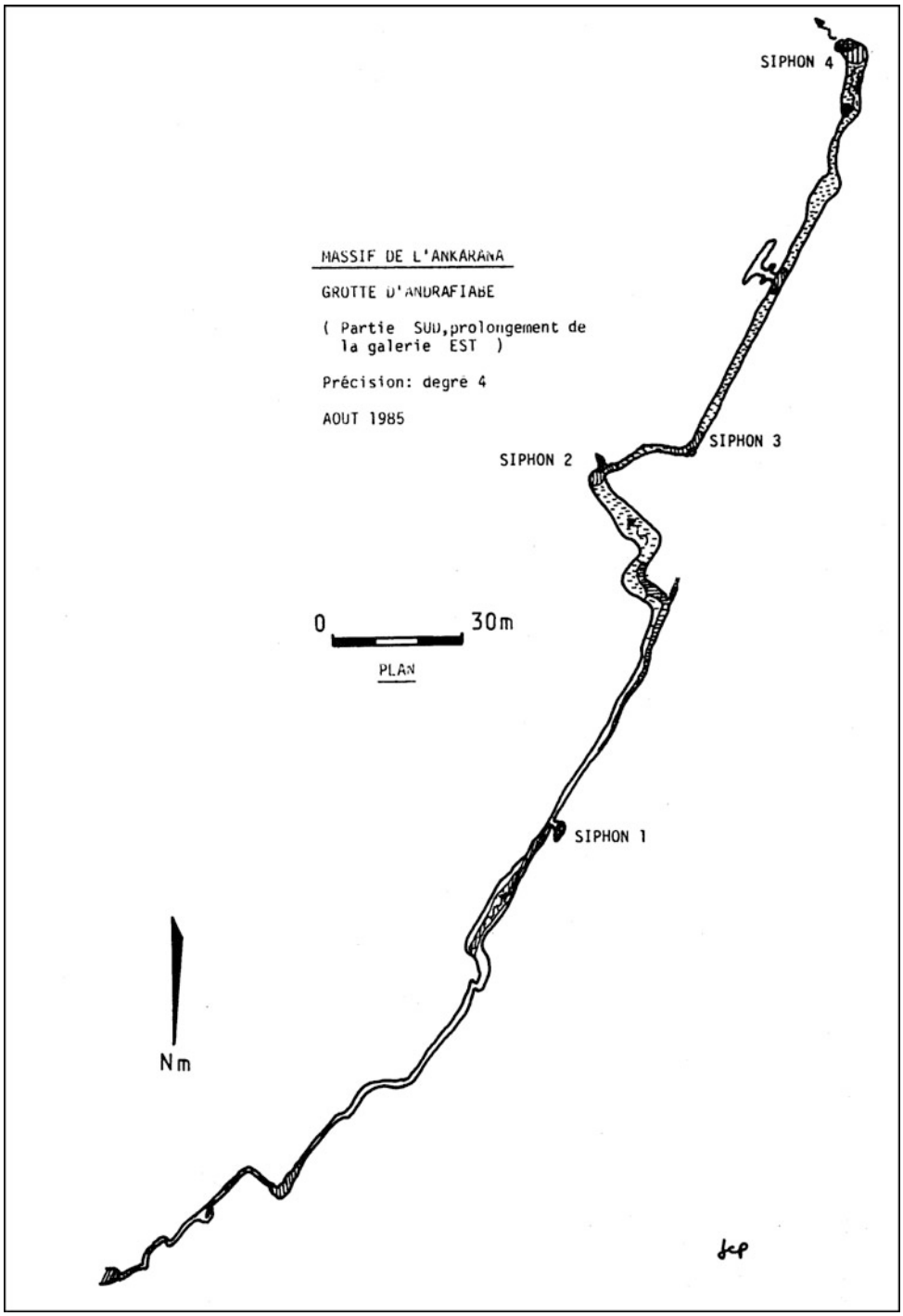


Fig. 6.10 Detail of the eastern gallery in the southern part of the Andrafiabe Cave (note that north is to the bottom)

Fig. 6.11 The main gallery of the Andrafiabe Cave

Fig. 6.12 Another view of the main gallery in the Andrafiabe Cave

Fig. 6.13 Reaching the Galerie des Pianos in the Andrafiabe Cave

Fig. 6.14 The natural bridge in the Andrafiabe Cave

Fig. 6.15 Dry gallery in the Andrafiabe Cave

Fig. 6.16 Well-decorated area in the Andrafiabe Cave

Fig. 6.17 Climbing in the Galerie des Pianos to reach an upper level

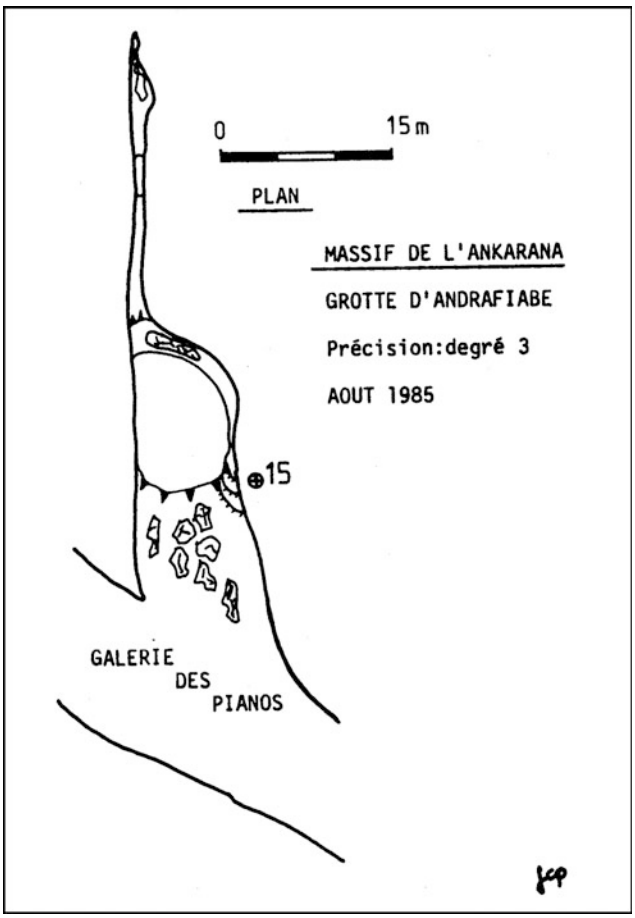


Fig. 6.18 Detail of the climb in the Galerie des Pianos in the Andrafiabe Cave

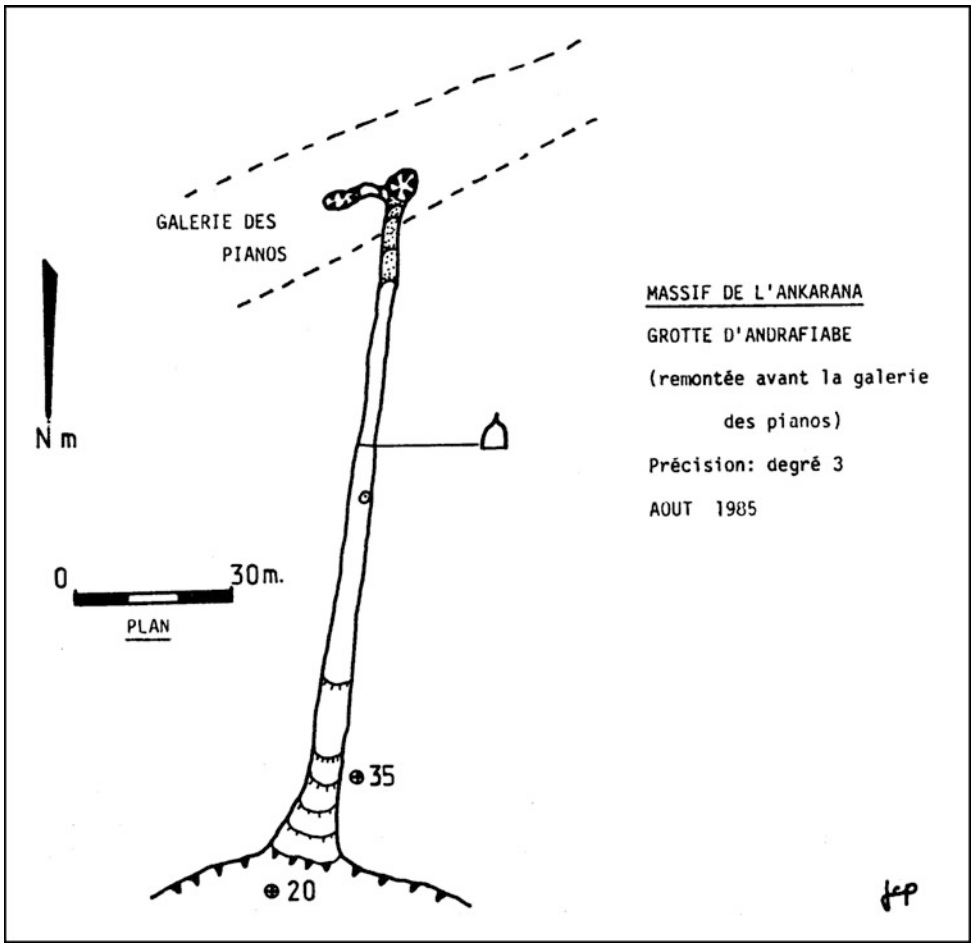


Fig. 6.19 Detail of the climb above the Galerie des Pianos in the Andrafiabe Cave

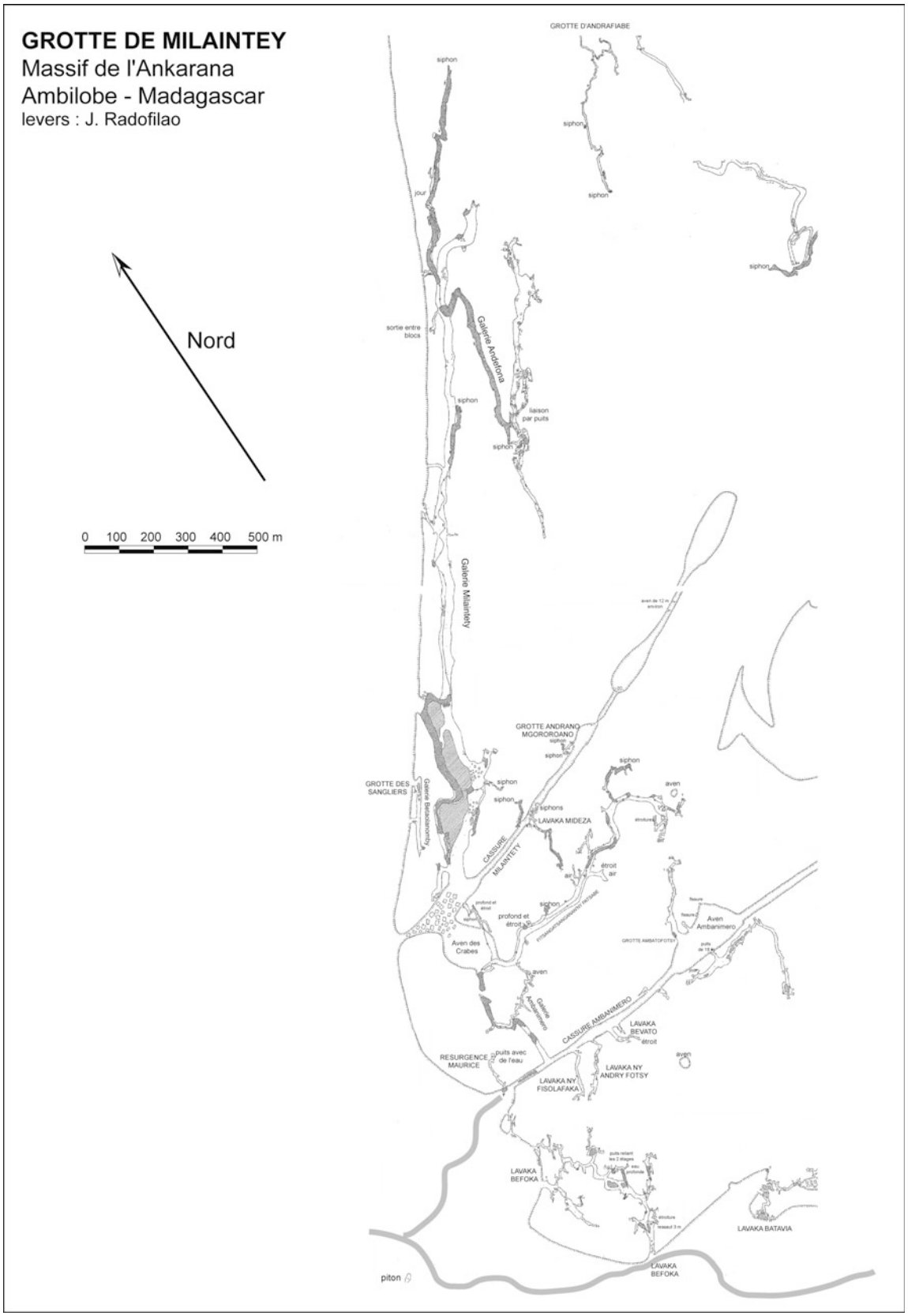


Fig. 6.20 The Milaintety Cave

Fig. 6.21 Walking in the river in the Milaintety Cave

Decary (1962) made a description of the visit:

> The tomb is in a truly dantesque site. When one arrives in his neighborhood, everyone takes hat off, and then begins the climbing of collapsed blocks. A cave opening is visible 20 m high: this is where Tsimiharo is, his coffin is about 3 m long; It is covered with a metal sheet which protects it against stones falling from the vault. Next to it is placed his royal armchair, of which only remain the uprights made of turned wood. A few meters further, in a narrow cavity of the wall, are the remains of Tsimiharo's father; There is not much left: no coffins, but only scattered bones, with some pieces of red lamba, completely rotten. Pell-mell in a corner, a dozen perfume burners that seem recent, and have never been used.
>
> The family of Bakariandriana, who was brother of Tsimiharo is buried in another place, just as wild. Once you have reached the foot of the escarpment, you must undertake a risky climb, in a vertical chimney, filled with unstable blocks that are more or less in cantilever. At about fifty meters high, in a rock shelter, are four coffins in two groups, men and women. The coffins of the former belong to Bakariandriana and his descendants. Besides them, are bottles, carafes, perfume-burners and white clothes. All these objects don't look very old. The coffins are made of mandrorofo wood (copaltree), which is rot-proof; That of Bakariandriana has on the lid, red, black and white geometric designs. They are lozenges, broken lines and some circles, whose colors are well preserved despite the age. That of his son shows only a few geometric lines carved with a knife. The women coffins are devoid of ornaments.

Another description by Vial (1954) is given in Appendix B.

6.2.3 Ambarabanja

The Ambarabanja Cave is 2325 m long and located east of Kings' Cave (Ambatomanjahana). It was explored in 1972 by the ASUM (Fig. 6.40).

6.3 Eastern and Central Part of the Northern Ankarana

The caves in the eastern and central part of the Northern Ankarana are accessible from the Ankarana Reserve entrance in Mahamasina on the Antsiranana–Ambilobe asphalt road.

6.3.1 Besaboba Swallow Hole No. 1

The Besaboba Swallow Hole No. 1 (Fig. 6.41) has an entrance shaft that is spectacular (Fig. 6.40). It is easily accessible from the eastern entrance of the Ankarana Reserve in Mahamasina. A popular destination for tourist excursions, it can easily be reached following the riverbed of the Besaboba. During the dry season the Besaboba's water totally disappears underground, but in the rainy season the cave is totally flooded and the aquifer overflows. The Besaboba River continues flowing downstream.

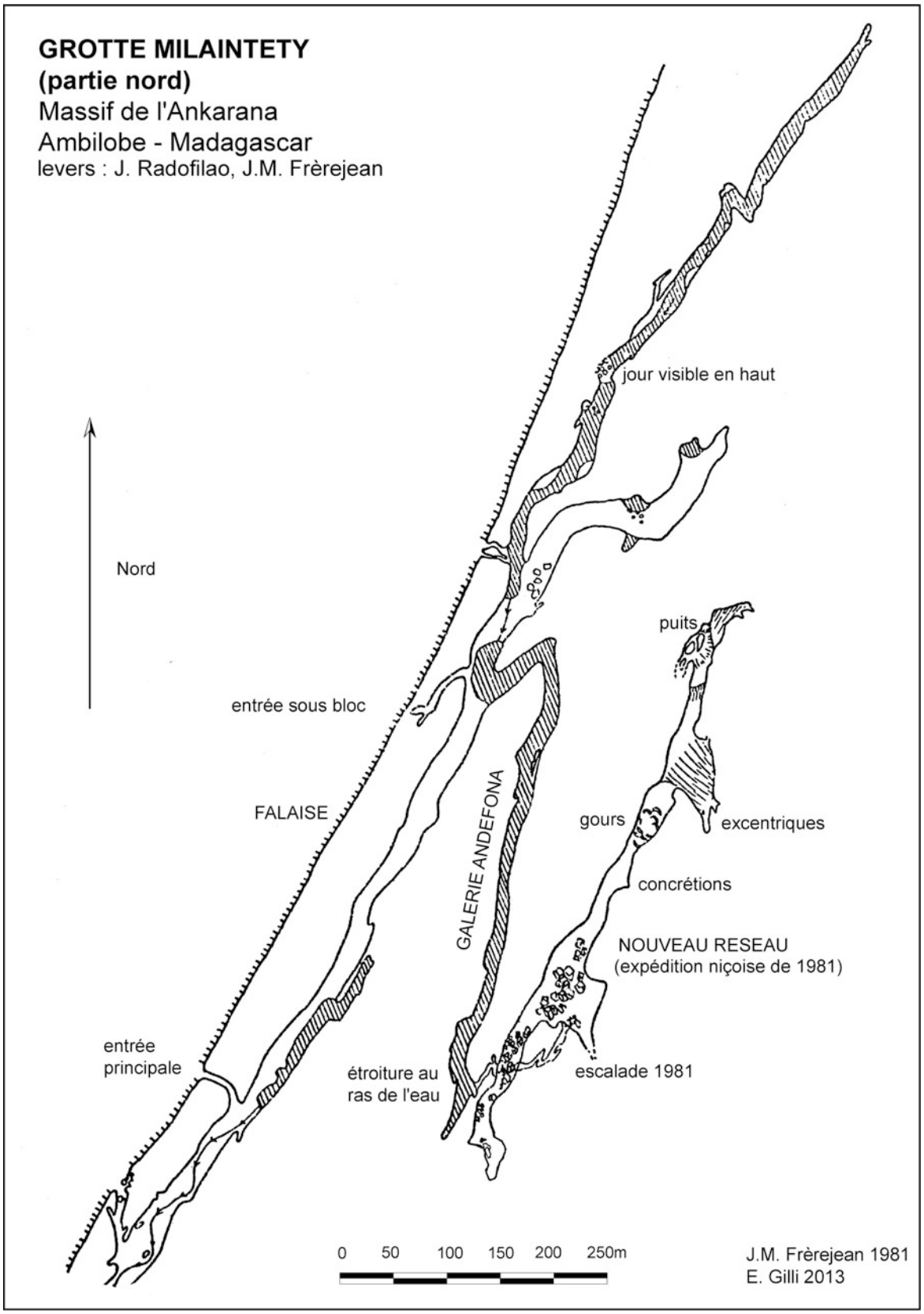


Fig. 6.22 Detail of the areas in the Milaintety Cave explored in 1981

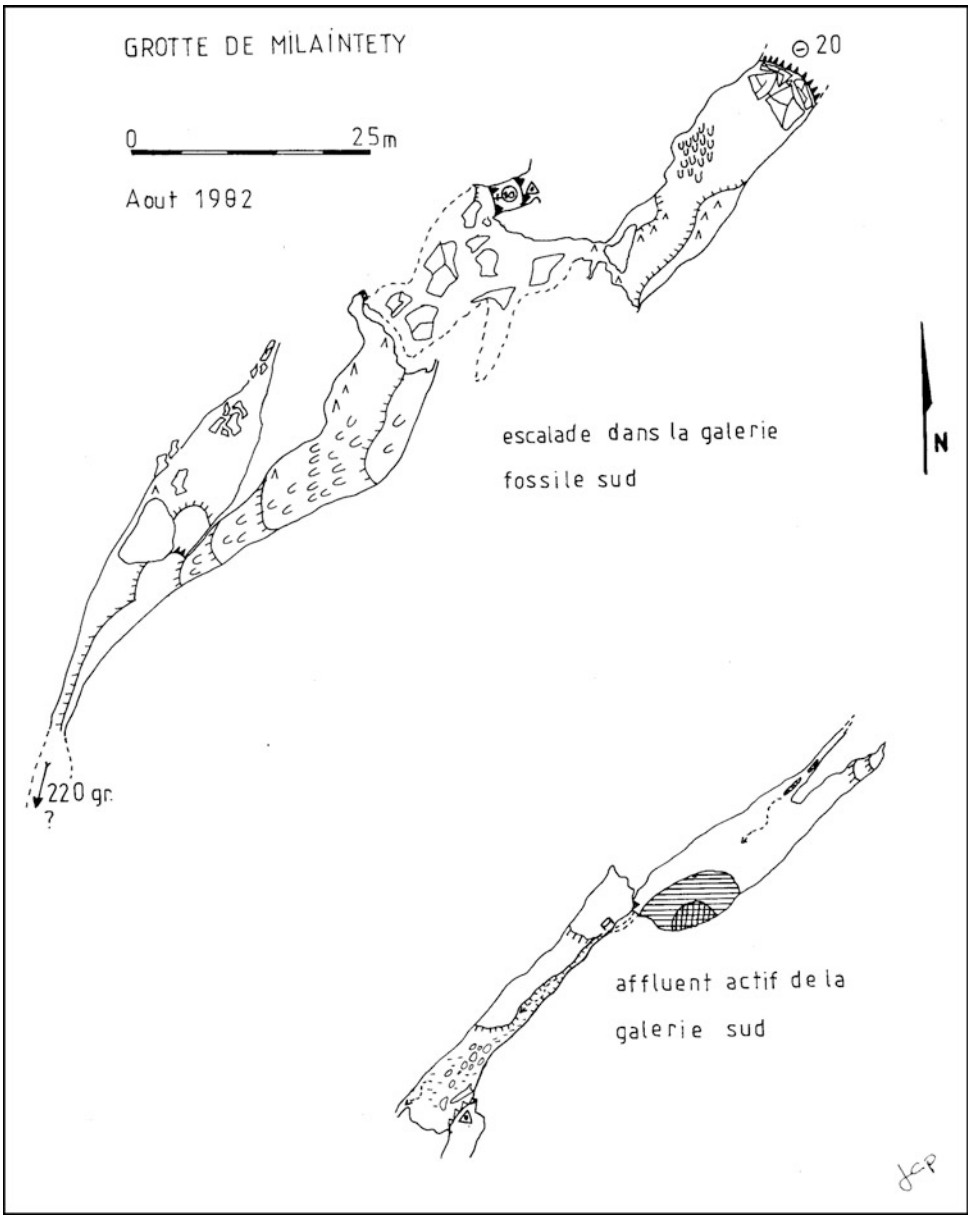


Fig. 6.23 Detail of the areas in the Milaintety Cave explored in 1982

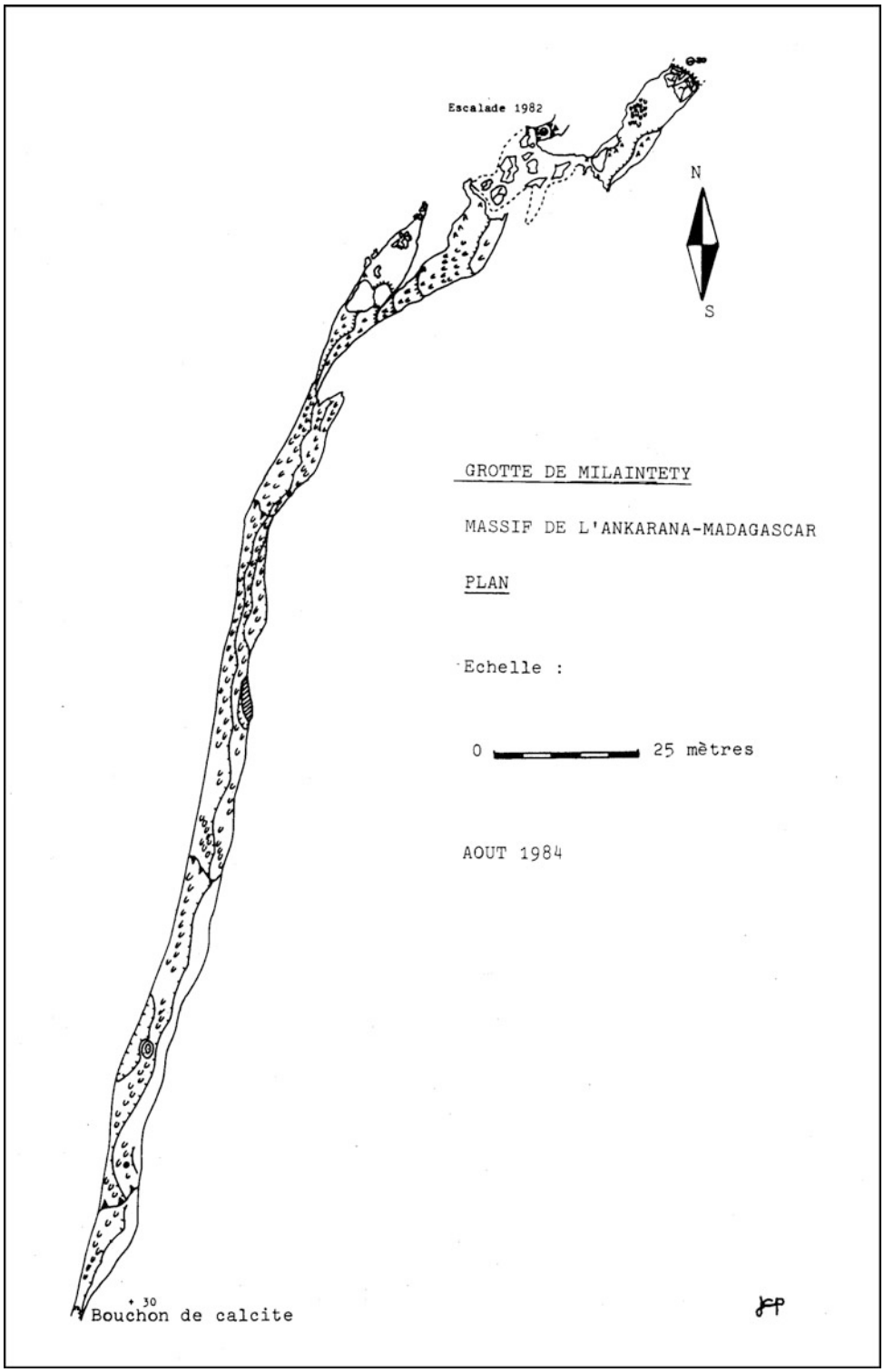


Fig. 6.24 Detail of the areas in the Milaintety Cave explored in 1984

Fig. 6.25 Helictites in the Milaintety Cave

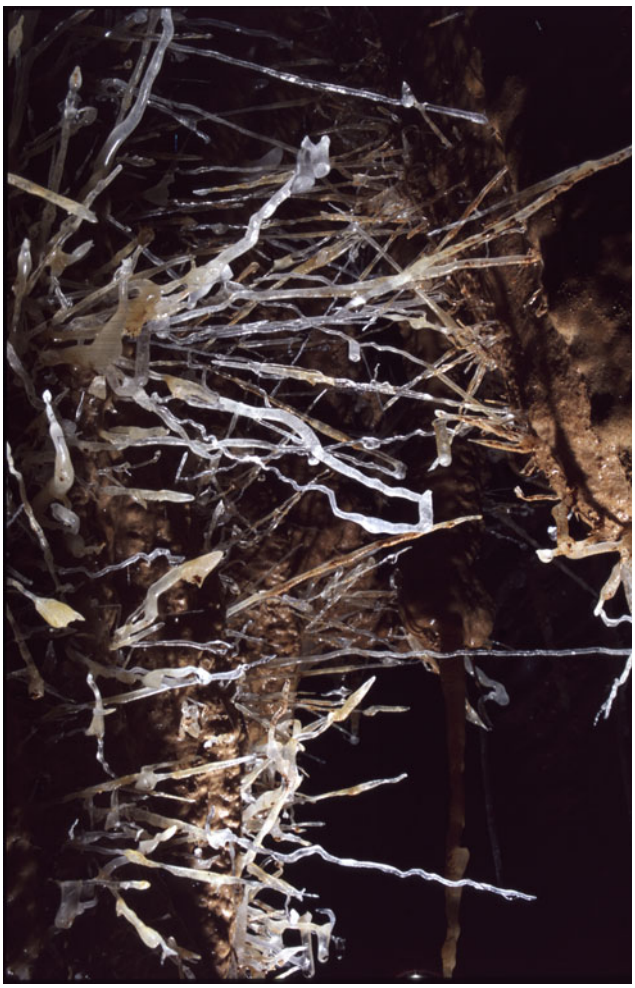


Fig. 6.26 More helictites in the Milaintety Cave

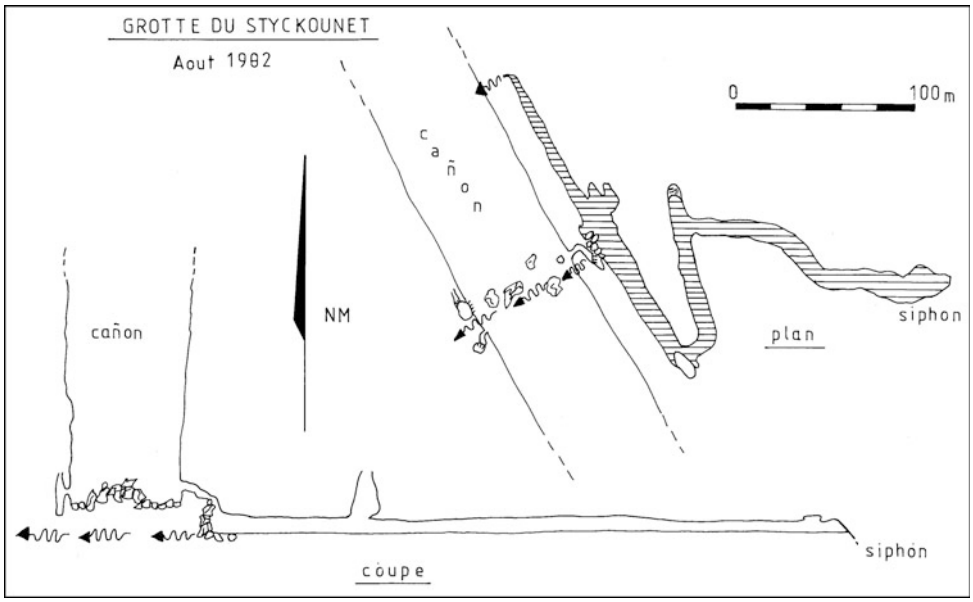


Fig. 6.27 The Styckounet Cave

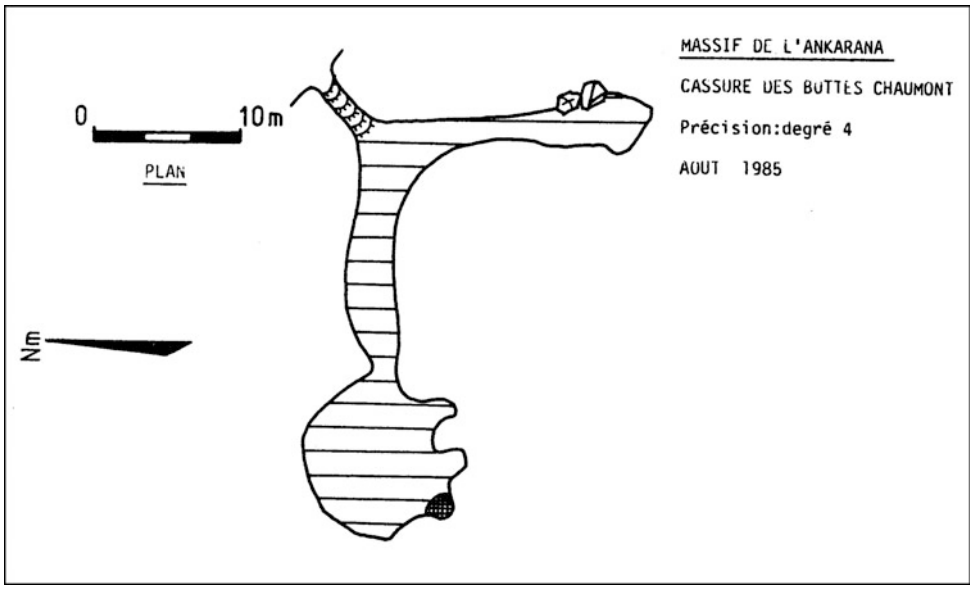


Fig. 6.28 Break in the Buttes-Chaumont Cave

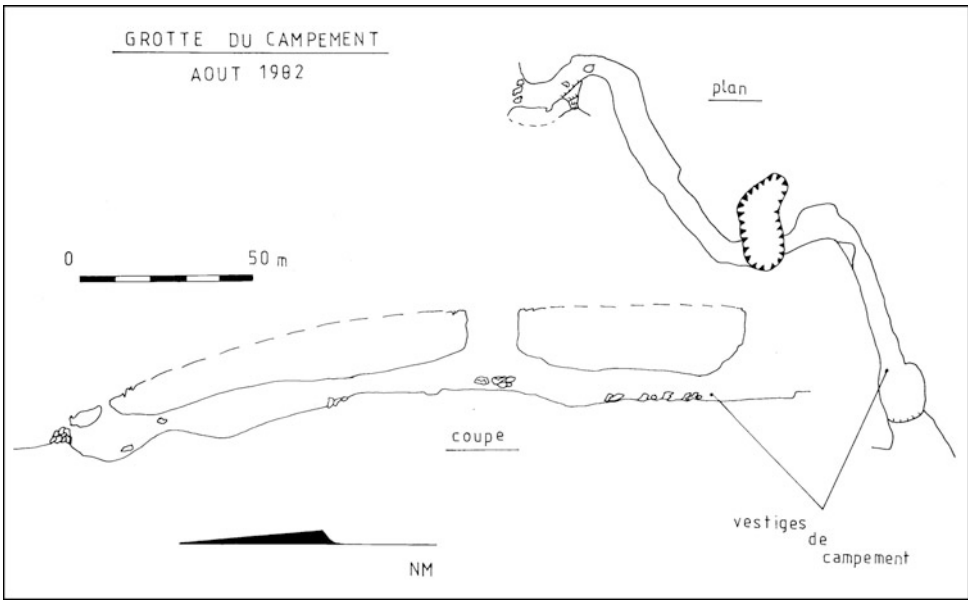


Fig. 6.29 Camp Cave

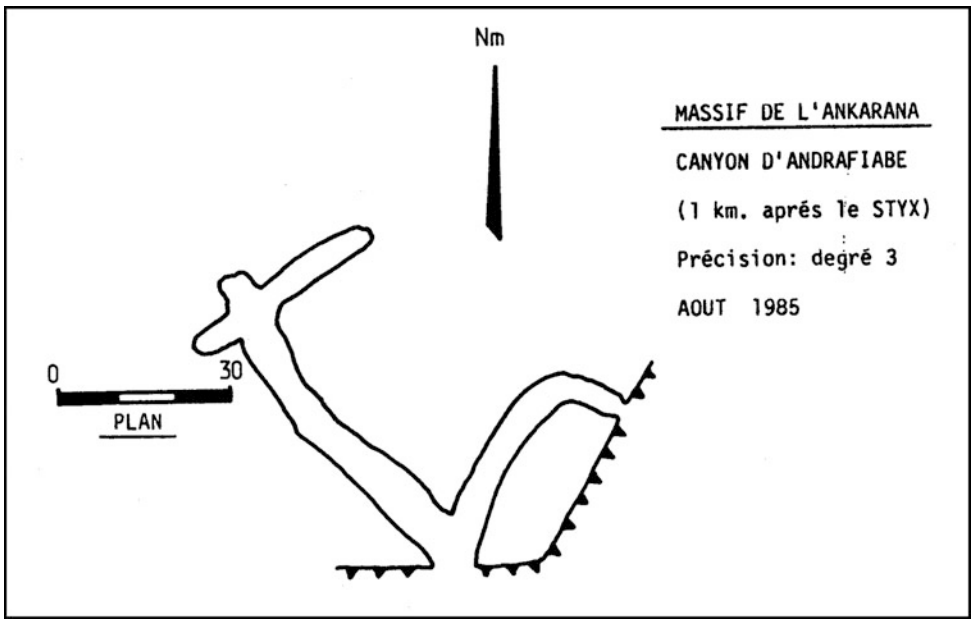


Fig. 6.30 Corridor in the Andrafiabe Cave, 1 km east of the Styx

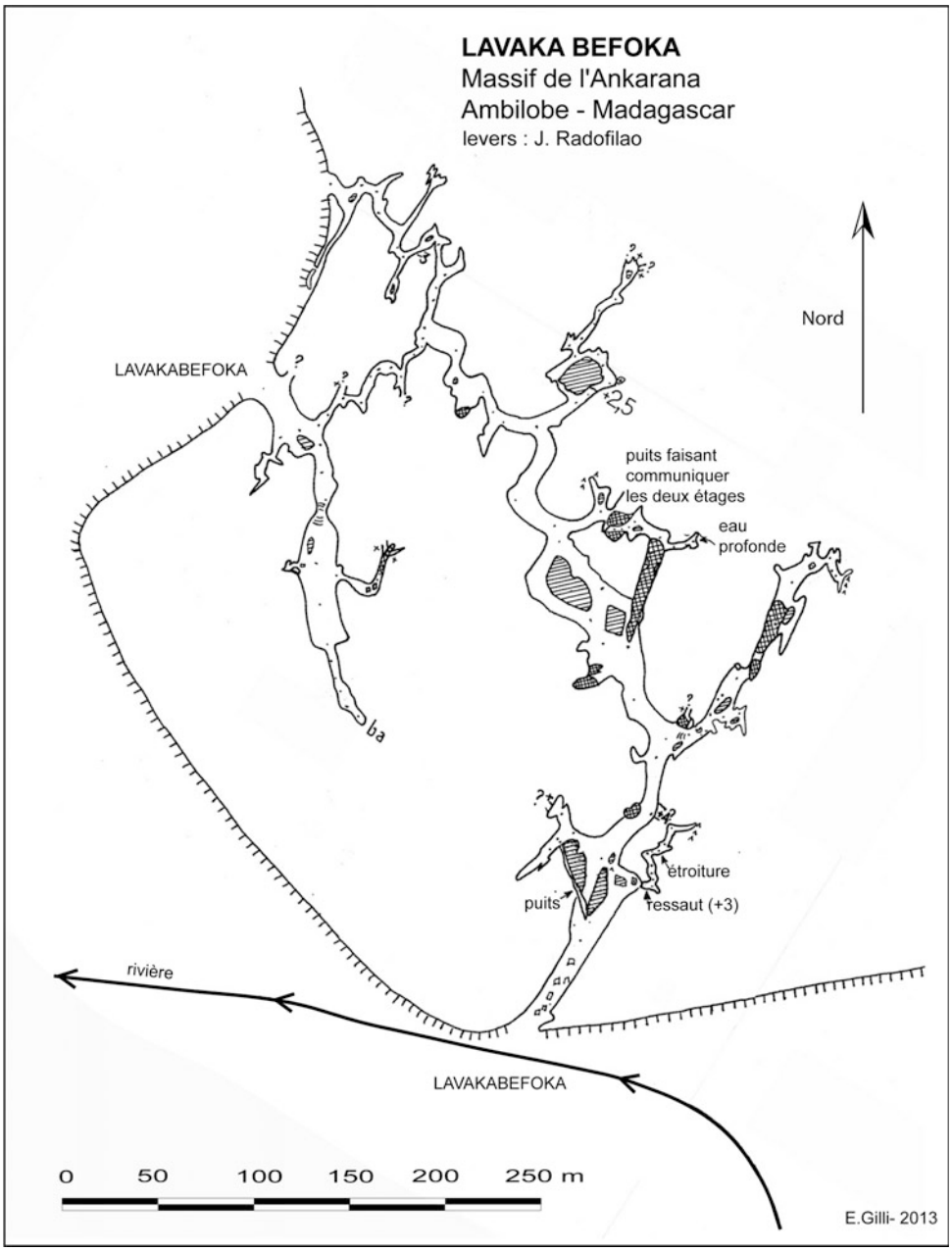


Fig. 6.31 The Befoka Cave

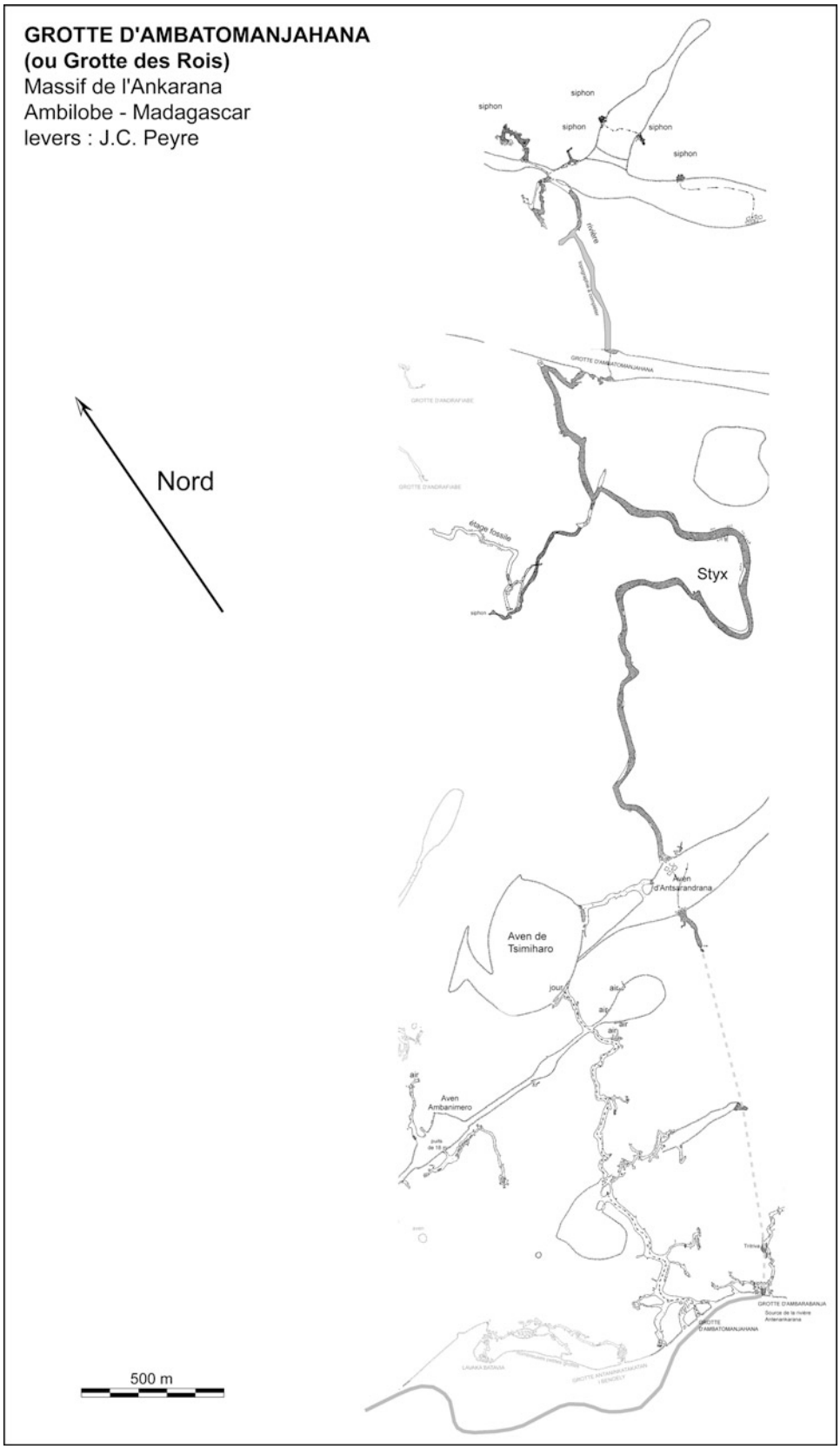


Fig. 6.32 General map of the Ambatomanjahana Cave including the Styx River and Kings' Cave (*Grotte des Rois*)

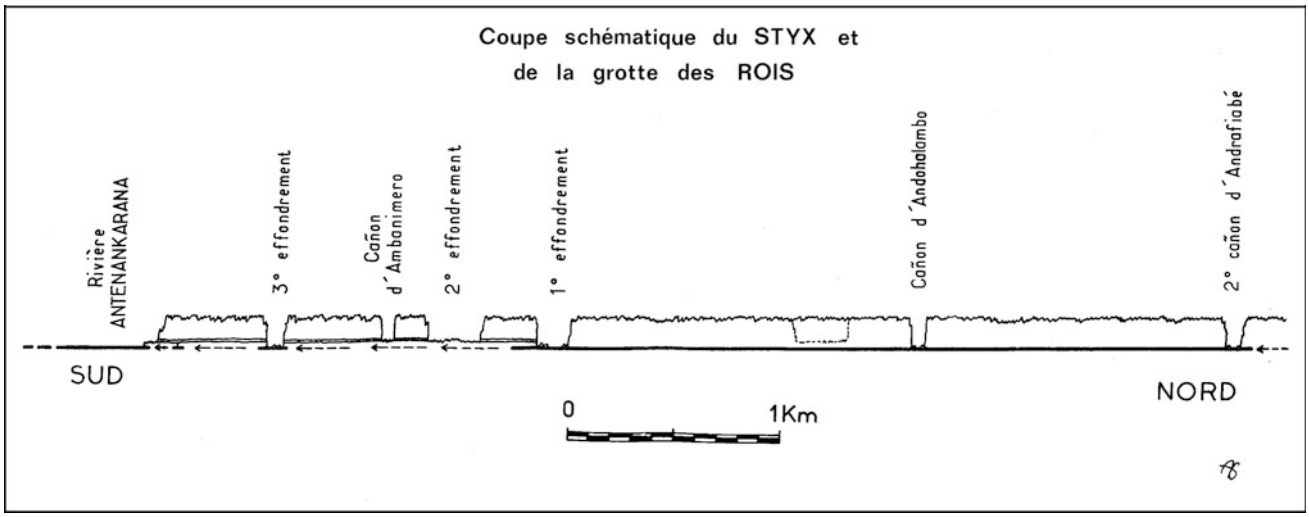


Fig. 6.33 North–south cross-section of the Ambatomanjahana Cave

Fig. 6.34 Exit of the Styx River (*Photo* J. C. Peyre)

Fig. 6.35 Exploring the tributary on the right bank of the Styx (*Photo* J. C. Peyre)

Fig. 6.36 Dry level in the Styx River (*Photo* J. C. Peyre)

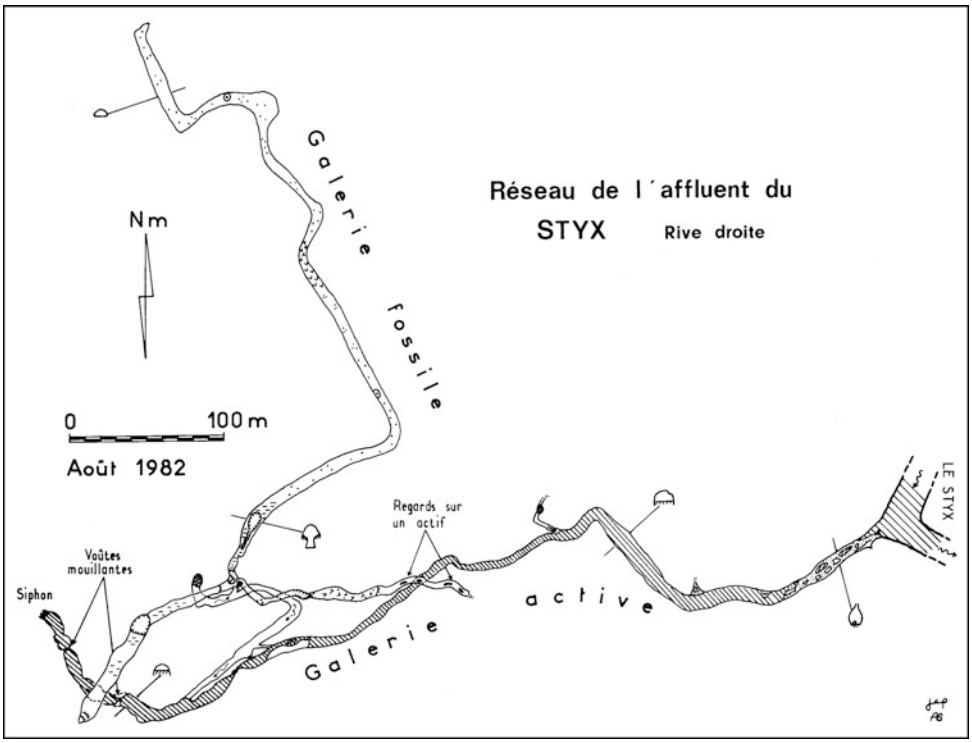


Fig. 6.37 Detail of the tributary on the right bank of the Styx in the Ambatomanjahana Cave

6.3.2 Besaboba Swallow Hole No. 2

The second swallow hole of the Besaboba River (Fig. 6.42) is located upstream of the previous one in the riverbed itself. It absorbs only part of the river water. There are other impenetrable points of infiltration located along the riverbed that are usually clogged by wood debris.

6.3.3 Motor Cave

Motor Cave is located in the northeastern part of the massif and reachable from Mahamasina on the Antsiranana–Ambilobe road. It was explored by J. Radofilao. The name comes from the noise the watercourse makes between the blocks (Fig. 6.43).

6.3.4 Amposatelo 2 and Fanihy

The Amposatelo 2 and Fanihy caves (Fig. 6.44) are accessible from the eastern entrance of the national park in Mahamasina. The Fanihy Cave, also known as *Grotte des Chauves-Souris* (Bats' Cave), is a popular excursion site for tourists.

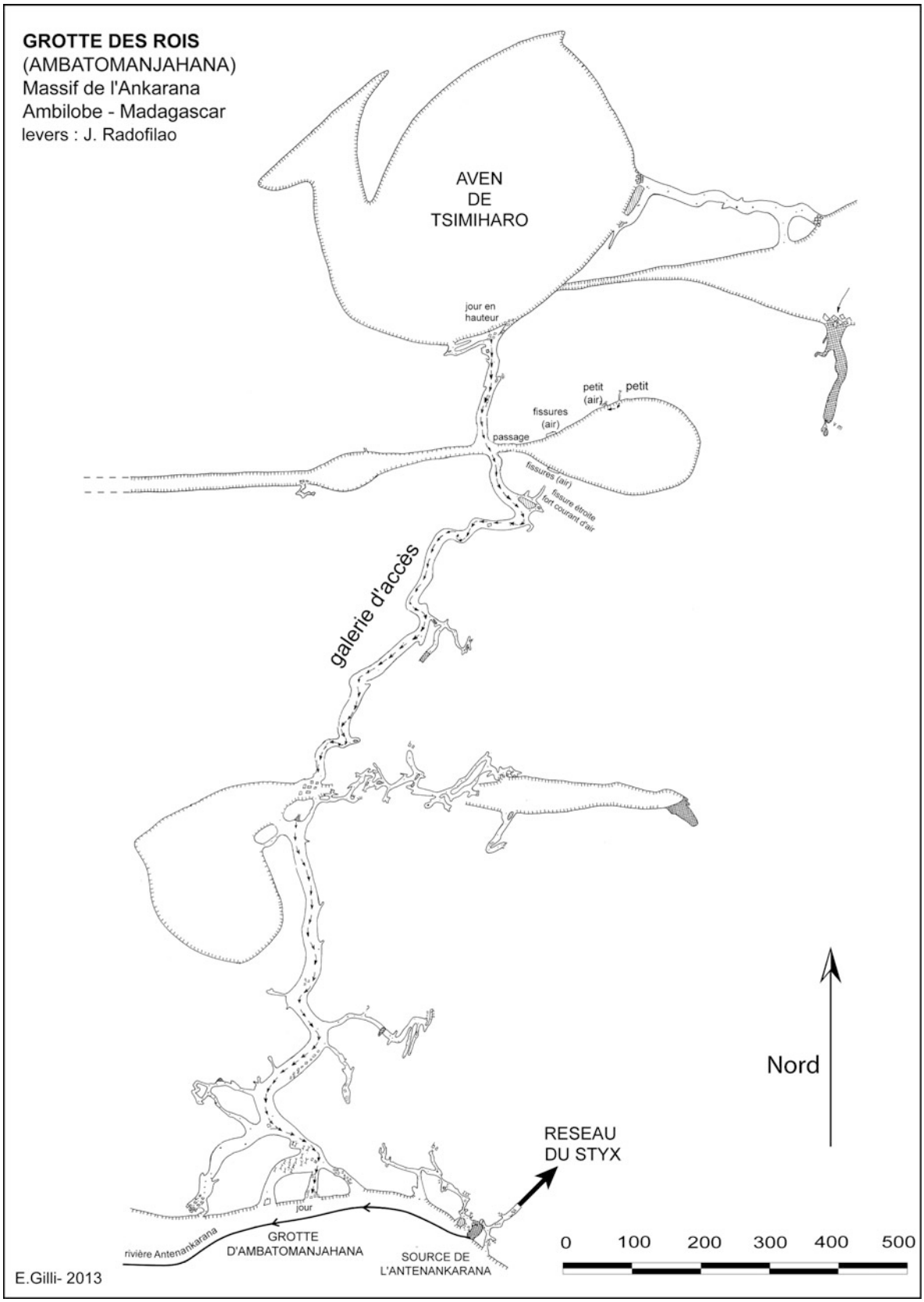


Fig. 6.38 *Grotte des Rois* (Kings' Cave), part of the Ambatomanjahana Cave

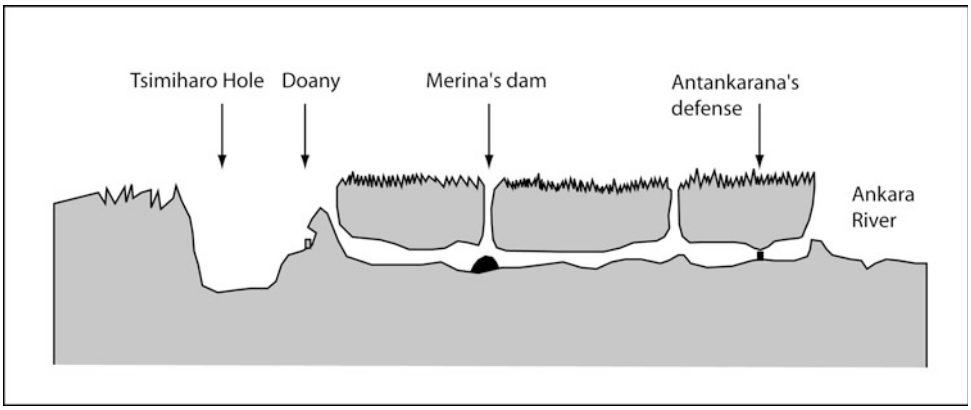


Fig. 6.39 North–south section of Kings' Cave and its fortifications (from Decary and Kiener, 1971)

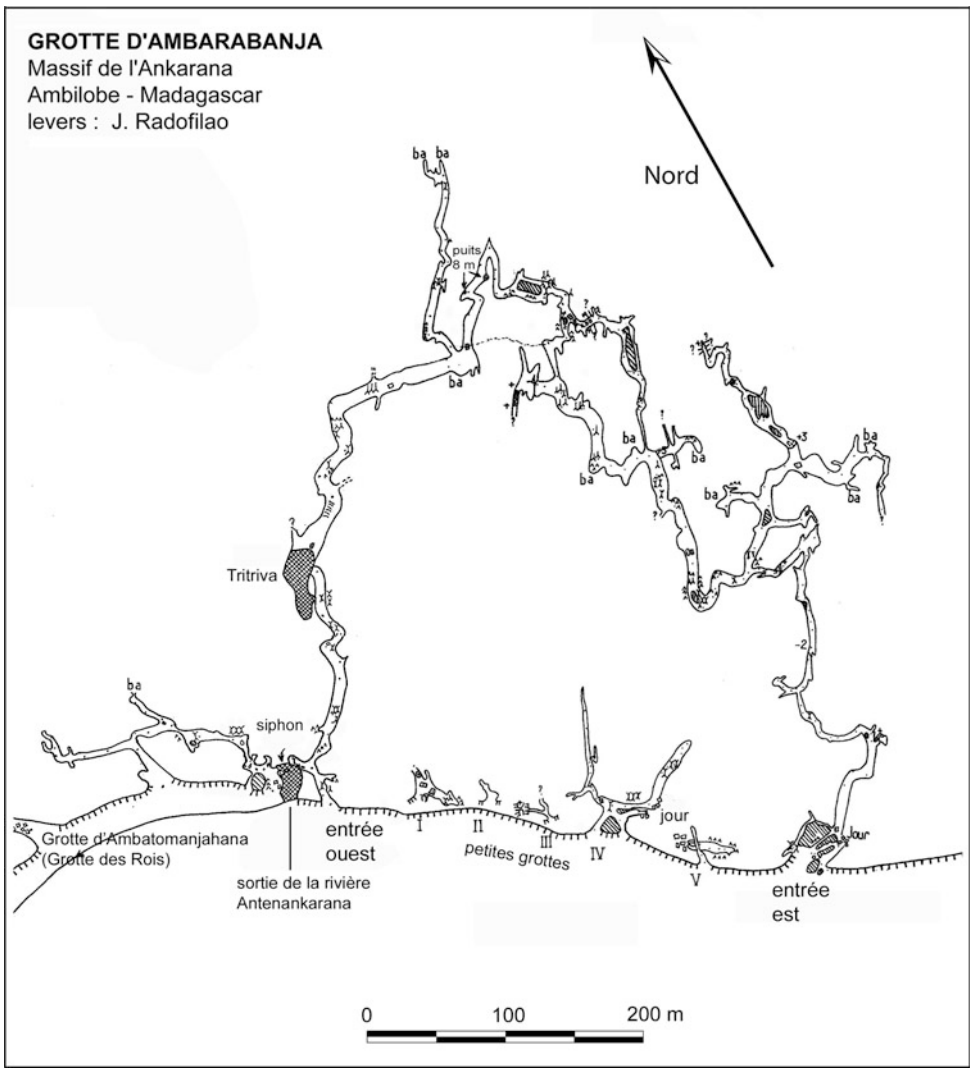


Fig. 6.40 The Ambarabanja Cave

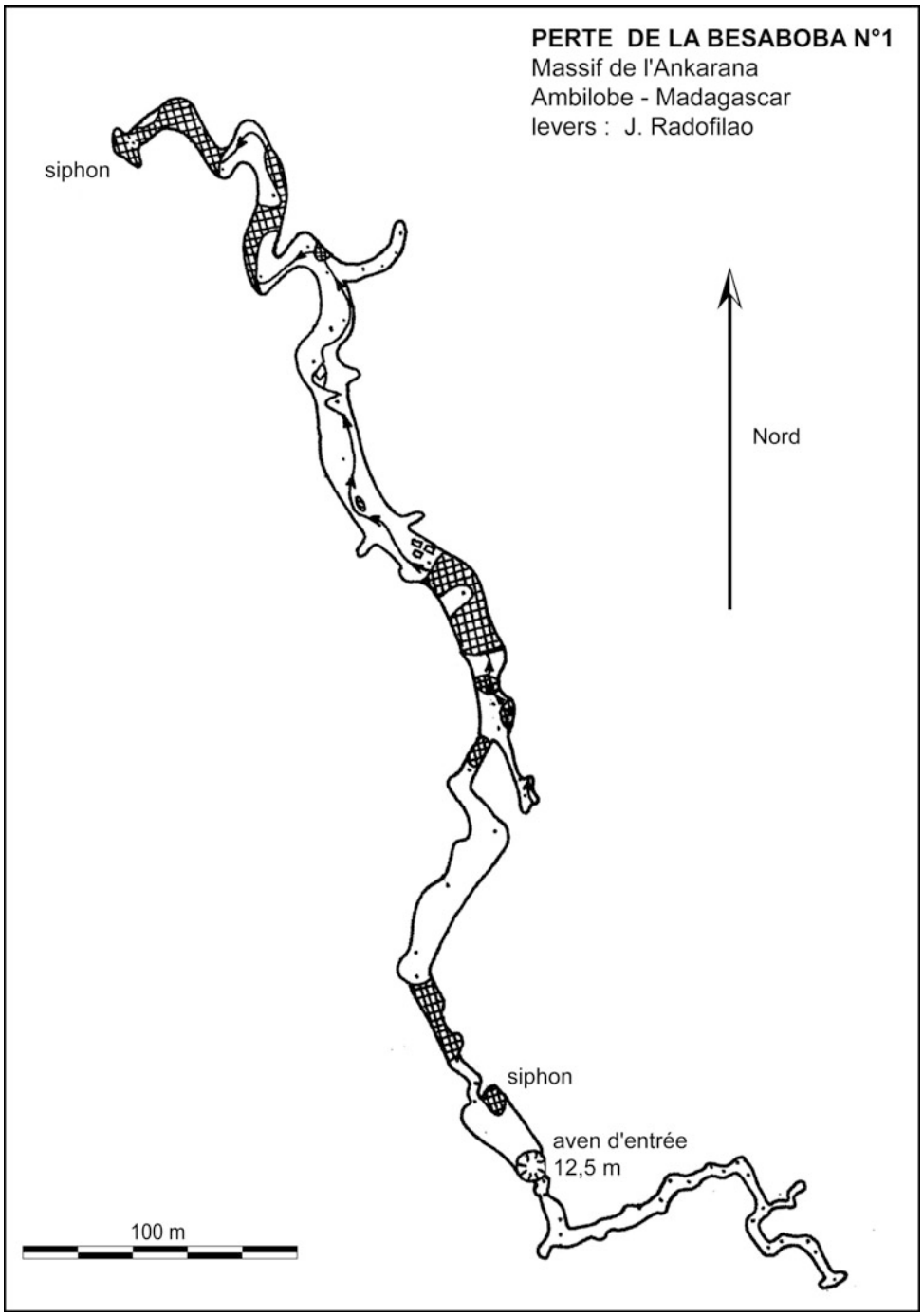


Fig. 6.41 The Besaboba Swallow Hole No. 1

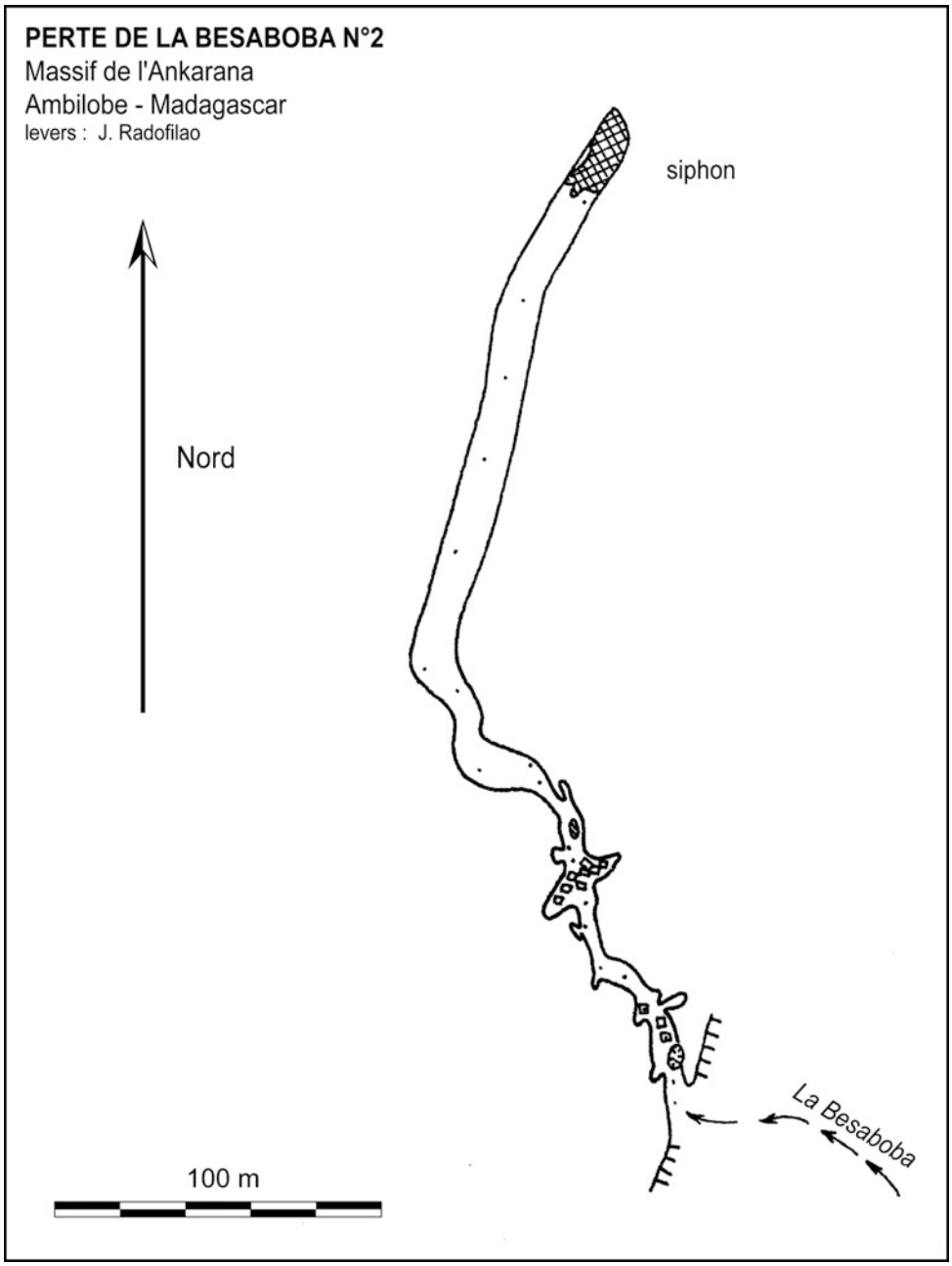


Fig. 6.42 The Besaboba Swallow Hole No. 2

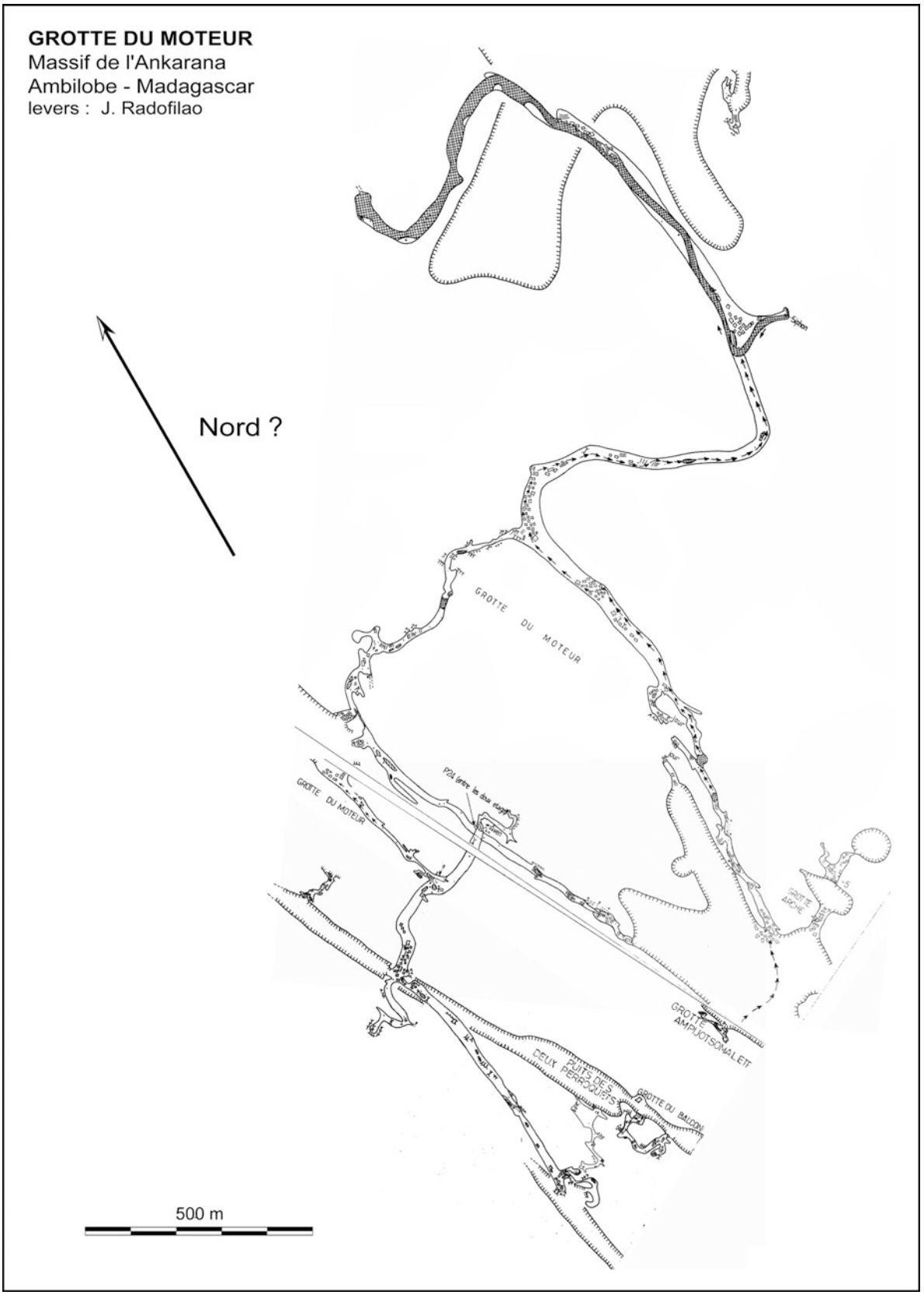


Fig. 6.43 Motor Cave

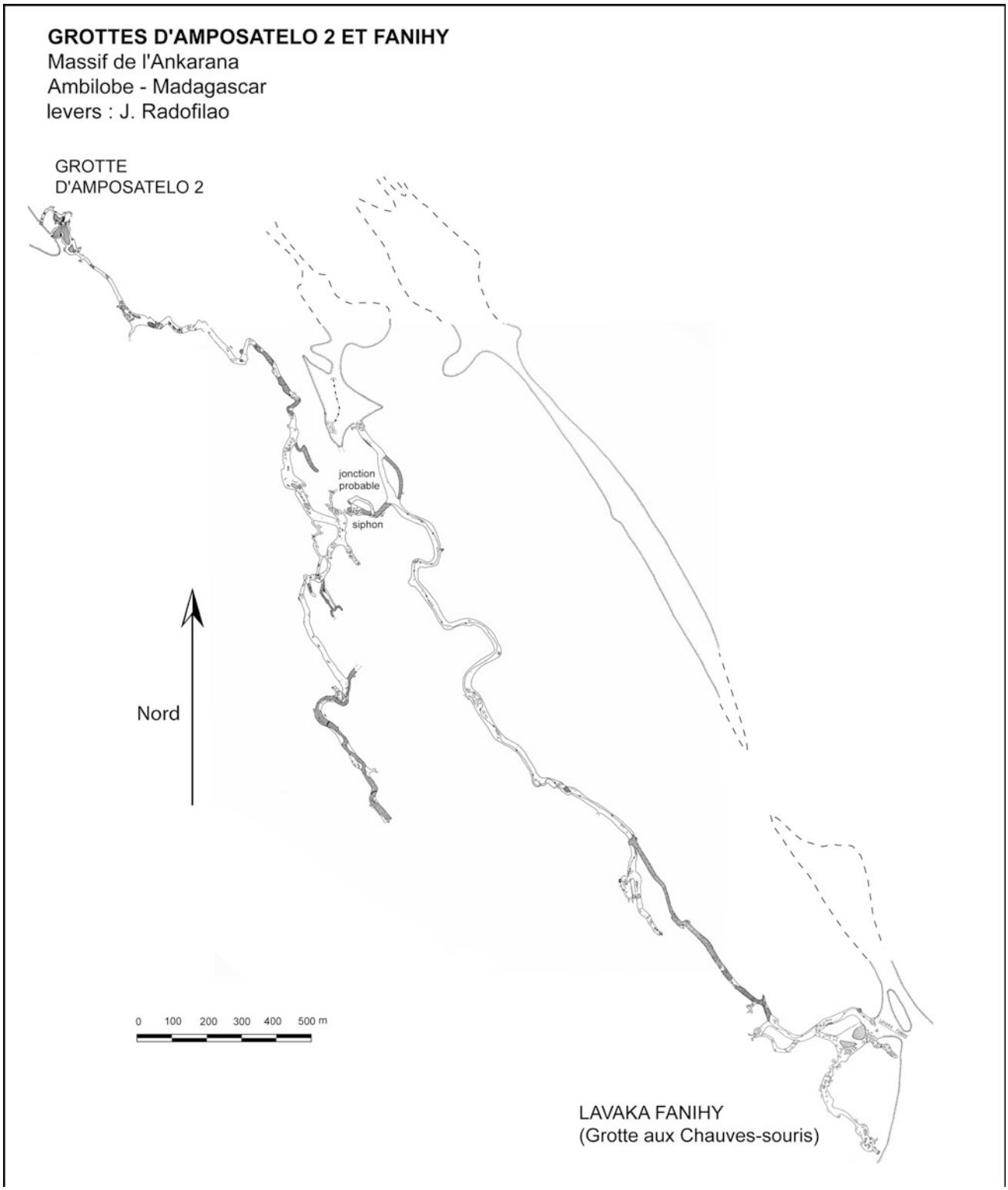


Fig. 6.44 The Fanihy Cave (*Lavaka Fanihy* in Malagasy, Bats' Cave) and the Amposatelo 2 Cave

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Caves of the Mananjeba Buttes

7

The Mananjeba Buttes comprise a group of three hills isolated from the Northern Ankarana by the widening and deepening of one of the main couloirs that cut the plateau. The northernmost butte is crossed by a side branch of the Mananjeba River. The central butte is crossed by the main stream of the Mananjeba and contains the second longest cave in the Ankarana: Ambatoharanana. No major cave has yet been found in the southernmost butte, but there is little doubt that a long cave network exists there.

7.1 Ampandriampanihy

A branch of the Mananjeba River uses the Ampandriampanihy Cave (Fig. 7.1) to cross through the northernmost butte.

7.2 Ambatoharanana

The Ambatoharanana Cave is 18,100 m long and is also known as the Mananjeba Underground River or the Crocodiles' Cave. It is crossed from east to west by the Mananjeba River which then crosses the Ankarana limestone ridge before reaching the Mozambique Channel.

It is a maze through which the river can be followed for 2700 m (Figs. 7.2, 7.3 and 7.4). During the rainy season it is navigable by canoe as a result of its large passages. A few dry galleries give access to a vast closed circus (Figs. 7.5 and 7.6). It named Mangily on Radifilao's maps however, it is possible that this name is not correct; The bottom of the circus is flat and marshy, except for its centre where a small prominence corresponding to the neck of calco-alkaline basalt can be found (Sect. 4.2.4). The circus is a form of

E. Gilli, *The Ankarana Plateau in Madagascar*, Cave and Karst Systems of the World,
https://doi.org/10.1007/978-3-319-99879-4_7

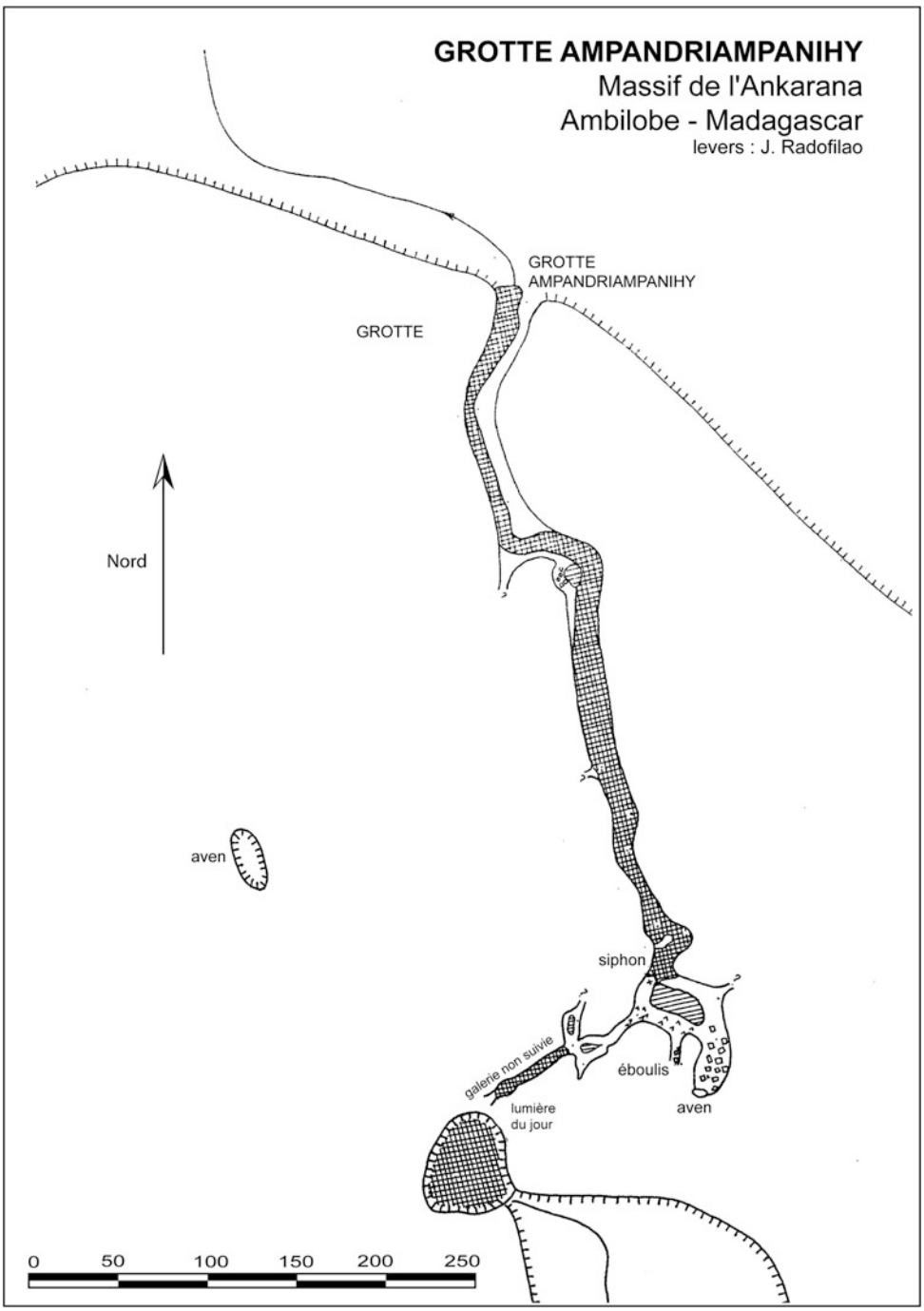

Fig. 7.1 The Ampandriampanihy Cave and the Mananjeba River

Fig. 7.2 Underground stream of the Mananjeba River in the Ambatoharanana Cave

Fig. 7.3 Another view of the underground stream of the Mananjeba River

erosion that develops into a halo of contact metamorphism (Sect. 4.4.3). The cave is home to small crocodiles that shelter there during the dry season and whose footprints can often be seen on the banks of the underground riverbed (Fig. 3.14 in Chap. 3). The cave was explored for about 6000 m of its length by J. de Saint-Ours. It was further surveyed for 2700 m in 1972 by the ASUM. Then, in 1974 J. Radofilao, Ph. Andriambololona and F. Raoelison undertook an expedition with the aim of surveying the lateral branches of the underground stream. In a 3-week period a good part of these branches were explored and surveyed, bringing the total length to 18,100 m (Figs. 7.4, 7.5 and 7.6).

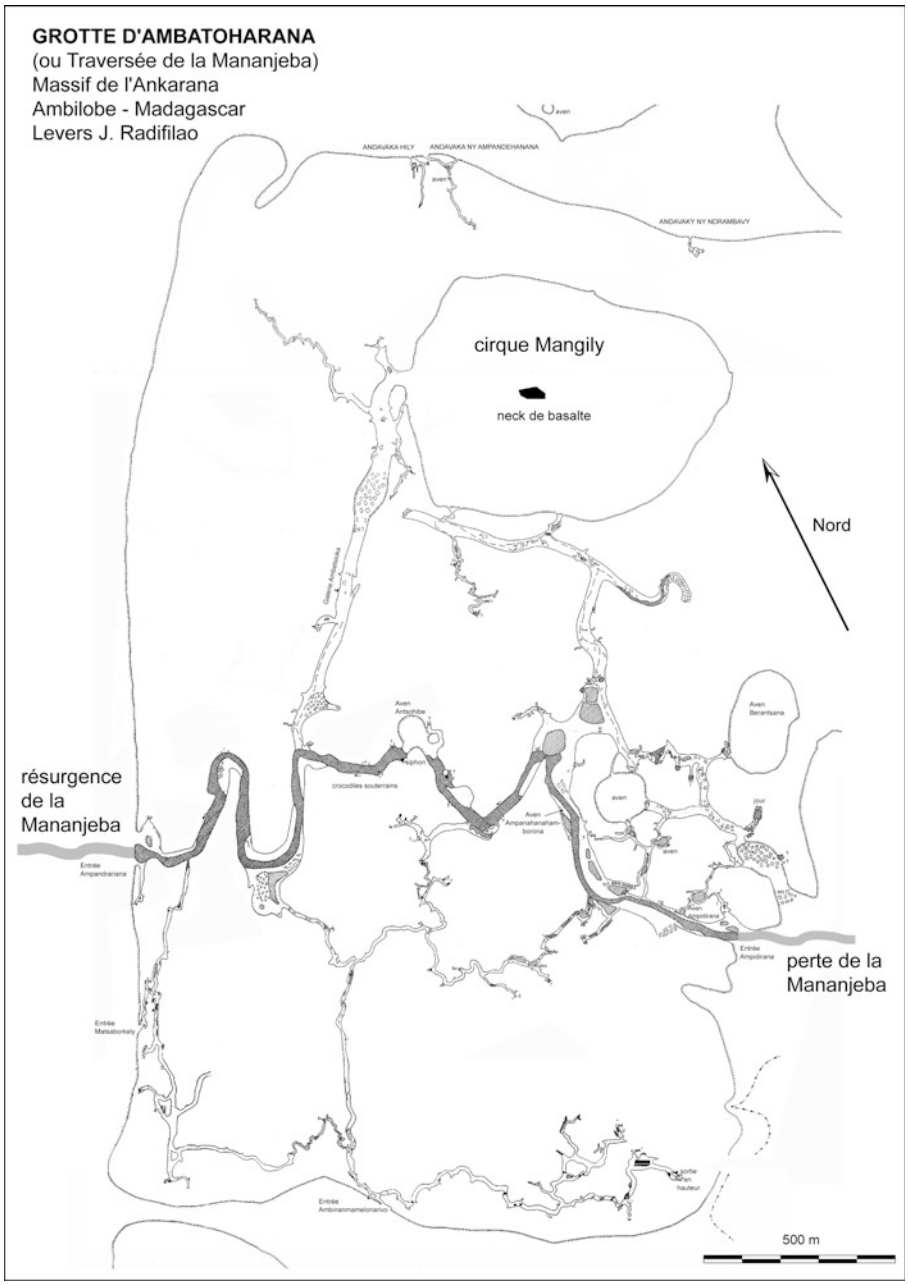

Fig. 7.4 The Ambatoharanana Cave

Fig. 7.5 Ambatoharanana dry gallery before reaching the Mangily

Fig. 7.6 Reaching the Mangily

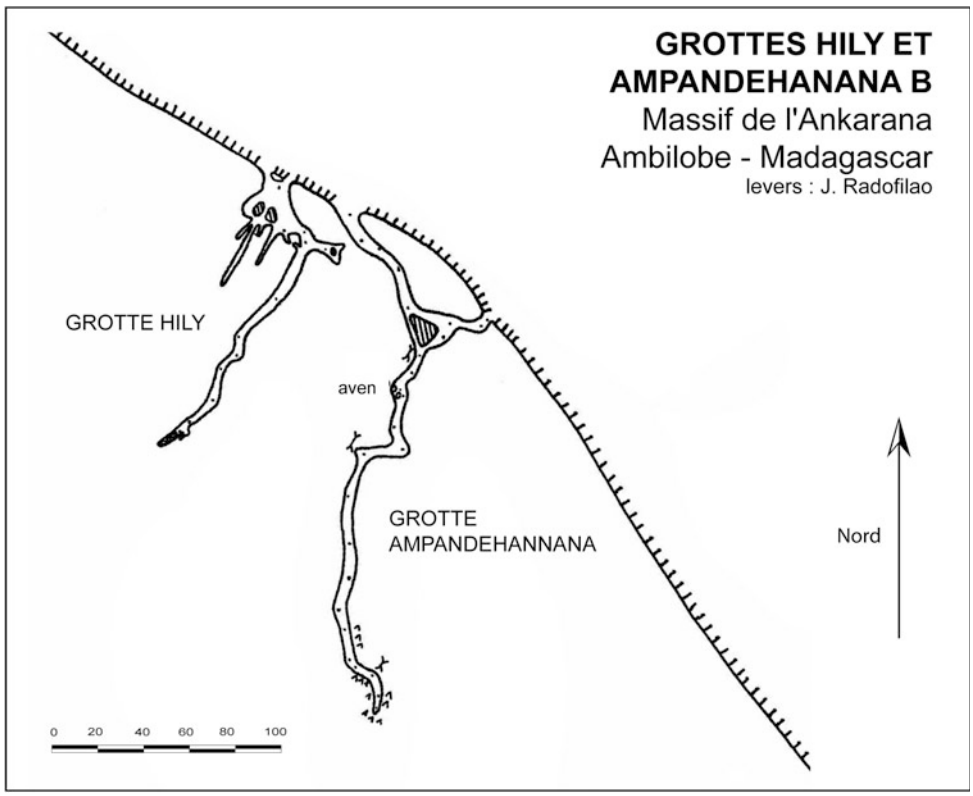

Fig. 7.7 The Hily and Ampandehanana B caves

7.3 Other Small Caves

The north wall of the butte contains several small caves including those of Hily and Ampandehanana (Fig. 7.7). It is probable that some of them give access to the Mangily Circus because there is evidence in the caves that the forest was exploited for timber. It is unlikely that tree trunks could be evacuated via the Ambatoharanana cave network; direct access from the north is therefore more probable.

Caves of the Southern Buttes

8

Recently explored the Southern Buttes demonstrate a hitherto unsuspected speleological potential. They are a dismantled prolongation of the Southern Ankarana. Crossed as they are by the Mahavavy and the Mananjeba rivers the cave density is massive; voids probably exceed 30% of the volume of the rock.

All the caves in the Andranomilika Butte form a network of about 28 km, which is the longest in the Ankarana. Some places are unexplored and the whole length will certainly surpass 30 km. It is the second longest cave network in Africa, the first being the Namoroka cave network, which is also in Madagascar and more than 100 km long.

8.1 Andalameloka Butte

8.1.1 Andalameloka

The small Andalameloka Cave is 1,000 m long and was explored in 2005 by the Club Martel CAF (Nice) (Figs. 8.1 and 8.2).

8.2 Anjombavola Butte

The small Anjombavola Butte measures 700 × 380 m and contains two caves that have been explored by J. C. Dobrilla. The Andavakafasika Cave (Fig. 8.3) is 4,063 m long and has several entrances that are located at the base of a cliff, a few metres above a dry riverbed. It is a maze that extends parallel to the cliff. Speleothems are not abundant. During the rainy season it is flooded by water coming from the nearby river. There is a crocodile entrance at 13°02′28.0″S, 49°00′20.3″E at an elevation of 18 m and a main entrance at 13°02′26.5″S, 49°00′19.6″E at an elevation of 17 m.

The second cave in the Anjombavola Butte is the Andavakamanga. Two entrances are located in the northern cliff, close to a large mango tree. The entrance on the right is large and gives access to a small gallery and then a small chamber. The left entrance gives access to a larger gallery and then a lake.

8.3 Andranomilika Butte

There are differences between the names written on the topographic map and the local names: Andranomilika, Andranomifika or Andranomiditra. The latter, which means "place where water disappears" is the most likely, but as Andranomilika is written on the Foiben-Taosarintanin'i Madagasikara (FTM) official topographic maps we keep that name.

8.3.1 Main Cave System

The network includes several caves: Mandresy, Andavakandrehy, Antanim'bary and Andranomidity. They have all been connected by new explorations in 2016. The total length is now 28,000 m, longest cave network in

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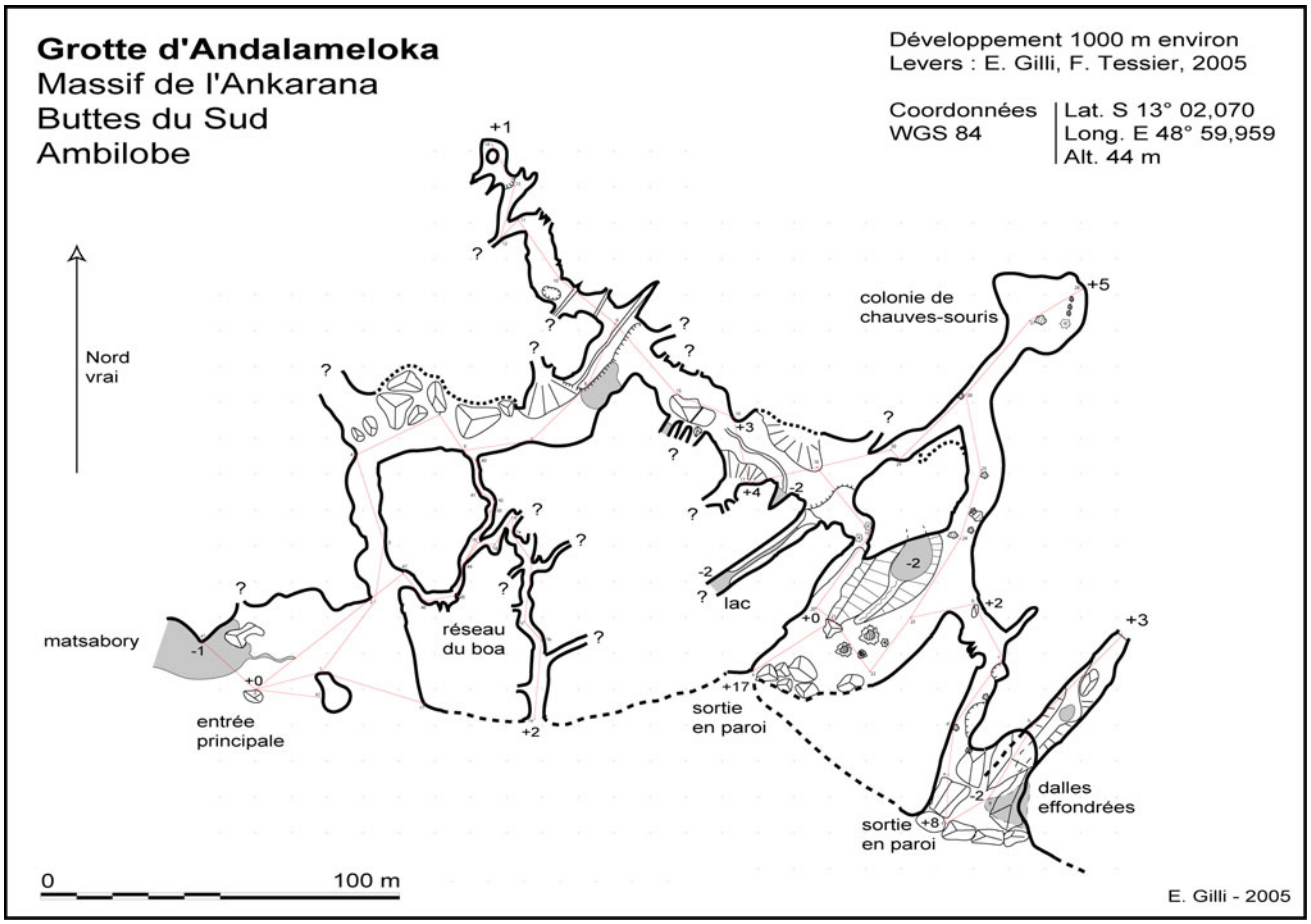

Fig. 8.1 Survey of the Andalameloka Cave

Fig. 8.2 Main passage in the Andalameloka Cave

Madagascar and Africa. Exploration is still in progress. The map by Dobrilla summarizes the discoveries made between 2005 and 2017 (Fig. 8.4).

We made a synthesis map of the different surveys on the georeferenced satellite image of the butte (Fig. 8.5). Note the density of voids in that small limestone hill. New explorations need to focus on the southern part and will certainly add several kilometres to the current length. A total length in excess of 30 km is certain.

As in the Northern Ankarana there is a difference between the larger galleries on the west, that run parallel to the Ankarana Wall, and the smaller galleries and mazes on the eastern part. The former correspond to previous drainage in a hypogenic process while the latter are the result of a recent epigenic process (Sect. 4.4.4).

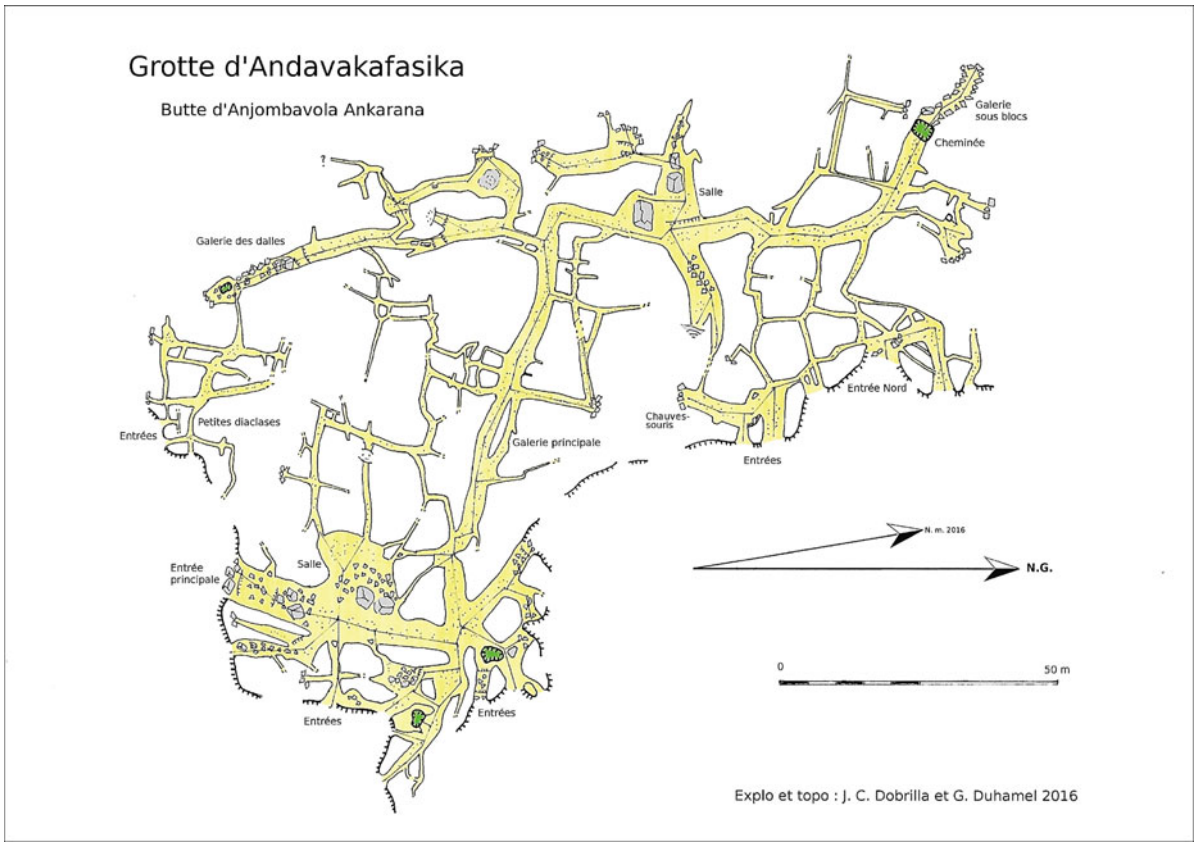

Fig. 8.3 The Andavakafasika Cave

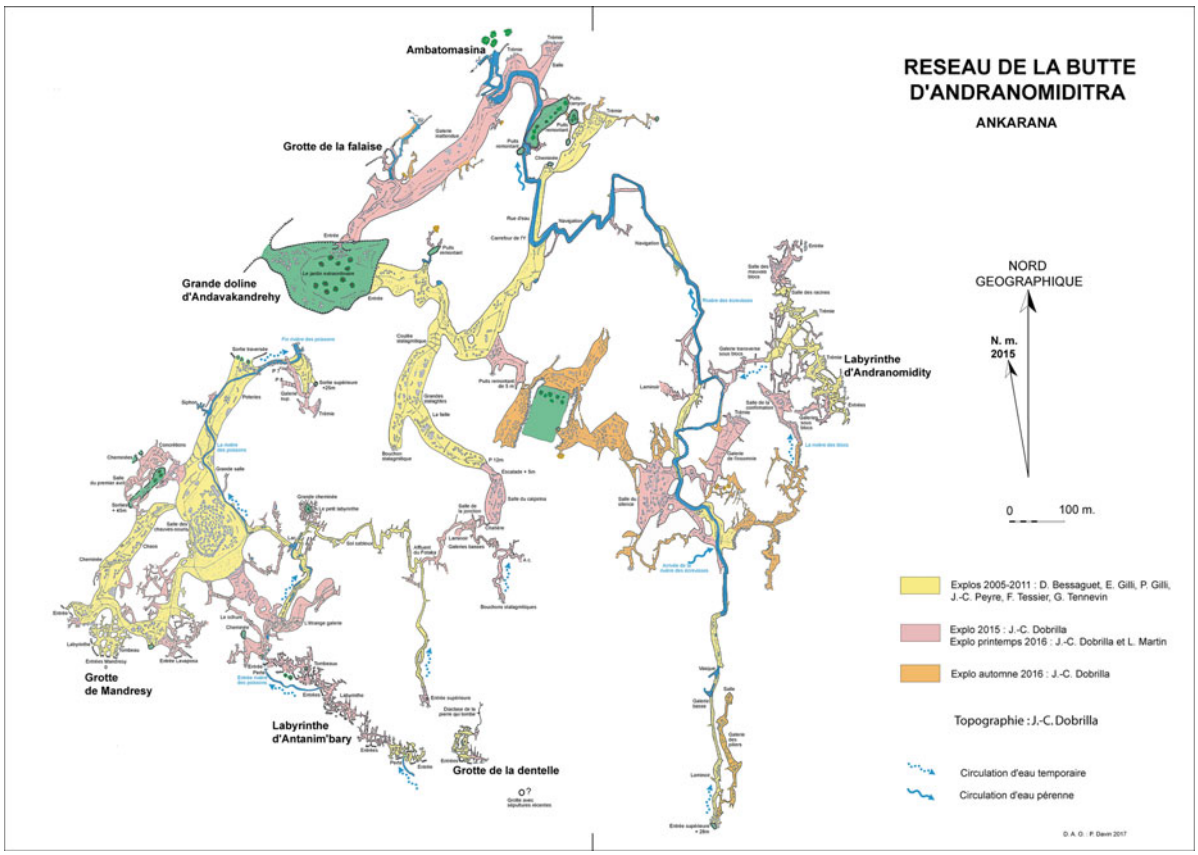

Fig. 8.4 Dobrilla's 2016 map of the Andranomilika cave system

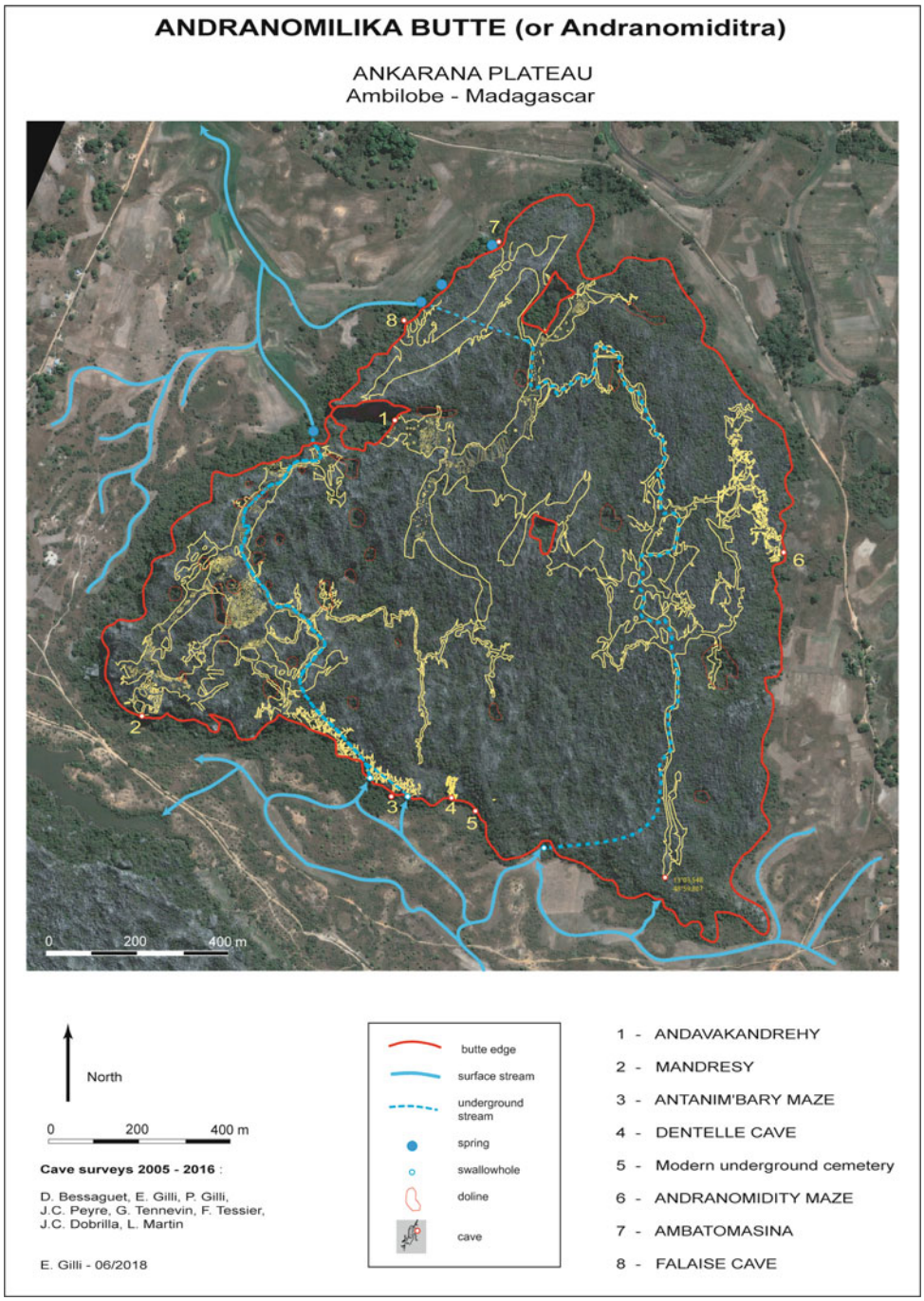

Fig. 8.5 General map of the Andranomilika Butte

Fig. 8.6 GPS survey at the entrance of the Mandresy Cave

8.3.2 Mandresy

The Mandresy Cave is 7800 m long and was explored in 2006 and 2007 by the Club Martel CAF (Nice) (Gilli 2011, 2014, 2016), and then further explored by J. C. Dobrilla (Dobrilla and Martin 2015, 2016). There are several entrances in the cliffs of the Andranomilika Butte. The southeastern one (Fig. 8.6) leads to a labyrinth containing several burial places, some of which contain the remains of members of the royal family. Some of these graves have been destroyed by flooding of the Mahavavy River.

The maze gives access to two large galleries (Fig. 8.7). The western branch is more or less blocked by cemented blocks and alluvial deposits through which water has percolated creating forms of erosion that resemble a

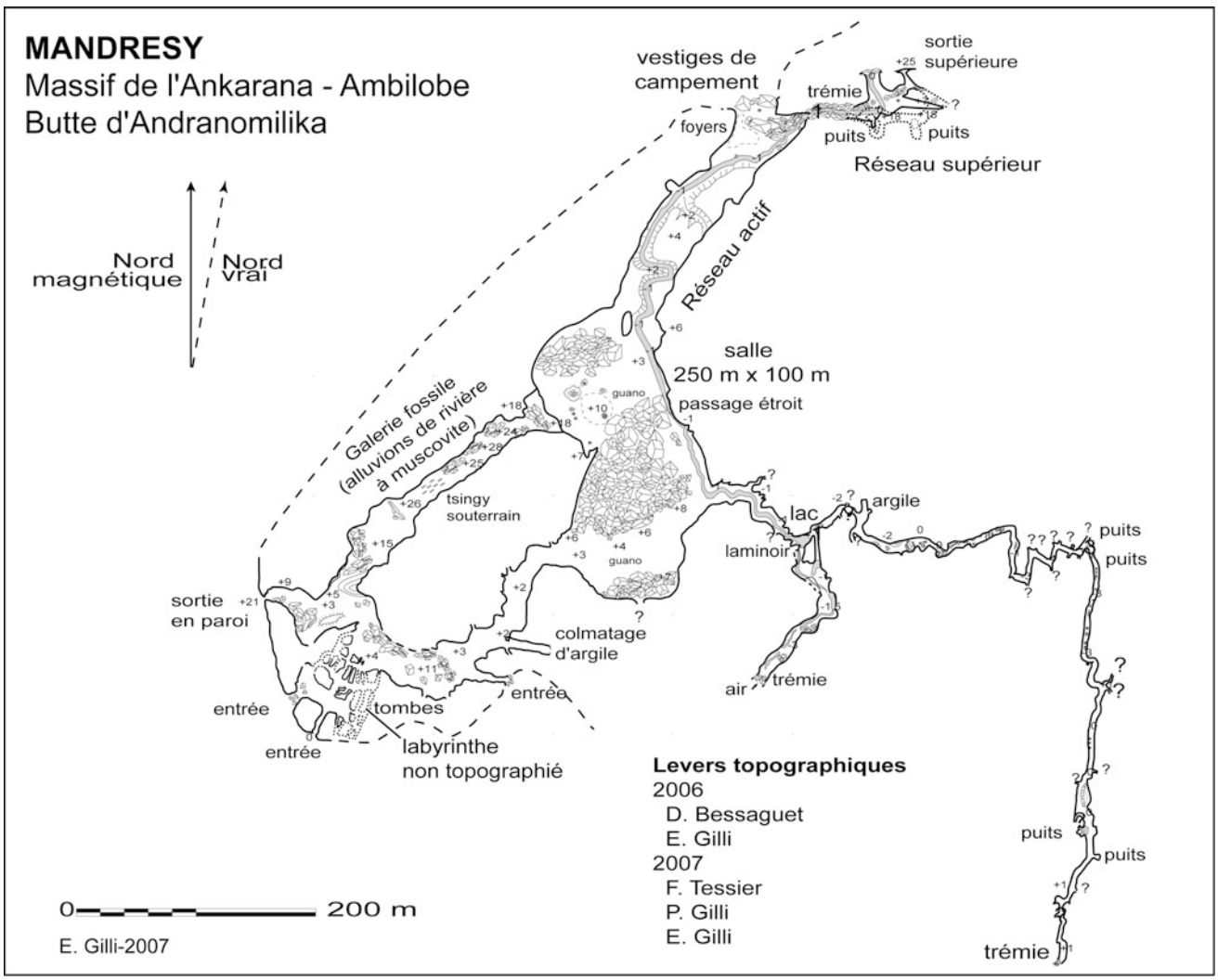

Fig. 8.7 The author's map of the Mandresy Cave in 2007

Fig. 8.8 The Big Chamber in the Mandresy Cave

subterranean tsingy. The gallery ends in a small chamber filled with large blocks stopping any attempt to go further.

The eastern gallery allows the Grande Salle (Big Chamber) (Fig. 8.8) to be reached. This is a very large hall measuring 220 × 110 m, probably the largest underground chamber in Madagascar. It is home to an important population of bats. Its centre is blocked by a series of large rocks that reach the vault. In the southeastern part of the cave the floor is more or less horizontal, making it easy to cross the chamber. The chamber gives access to a riverbed that during the dry season can easily be followed. Downstream, the river ends in a sump close to the edge of the butte. In this part a small dry gallery extends over 800 m and approaches the southern limit of the massif.

Upstream, following a narrow passage between the wall and the blocks, the river runs along the northeast edge of the chamber. It ends in a new series of blocks after traversing a flat flowstone area.

In this part of the cave, just after the main chamber, the gallery widens to 50 m. The river runs between two high clay banks. After a few hundred metres, close to the end of the river, a vast opening overlooks the plain outside. Remains of an ancient encampment with fireplaces, pottery and bones (zebus) can be seen (Sect. 8.3.7).

Above the river level, the cave has two dry levels at elevations of 4 and 20 m.

8.3.3 Andavakandrehy

The Andavakandrehy Cave is around 4,200 m long and was explored in 2006, 2007, 2010 and 2011 by the Club Martel CAF (Nice) (Gilli 2011, 2014, 2016) (Fig. 8.9). It was further explored in 2015 and 2016 by J. C. Dobrilla (Fig. 8.4). The main entrance is located in a large karst depression the center of which is a natural tropical garden, which we termed the Secret Garden (Fig. 8.10). The presence of water and bat guano promotes plant growth but makes progression difficult (Fig. 8.11).

The cave entrance leads to a large room (Fig. 8.12) where pottery was found in a side passage. Then, a large temporary riverbed gives access to a dry area filled with large rocks. To the left of the cave there is an upper passage that extends to a well-decorated gallery (Figs. 8.13 and 8.14), which ends in a large room where a narrow passage allows connection with a side gallery of the Mandresy Cave. The thickness of limestone overhead is probably quite low as plant roots reach the gallery (Fig. 8.15). In the central part of the cave a doline can be reached by passing through a series of chambers. Then, the upstream part of the Andavakandrehy River is accessible. To the right of the cave there is a dry gallery with a clay floor that extends to a downstream part of the Andavakandrehy River.

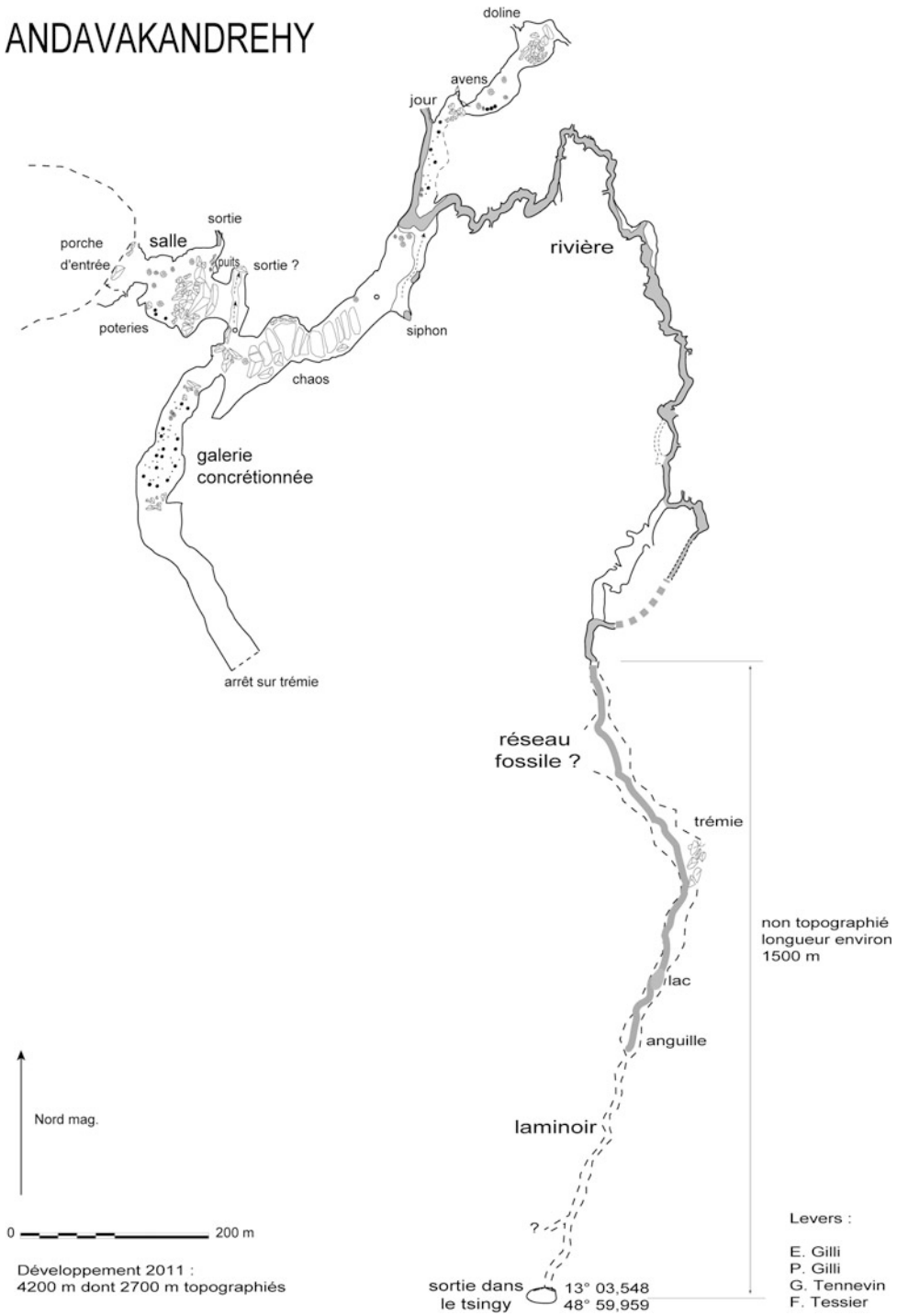

Fig. 8.9 Survey of the Andavakandrehy Cave that took place in 2011

8.3.4 Cliff Cave (Grotte de la Falaise) and Ambatomasina

Cliff Cave was explored by J. C. Dobrilla in 2016. It contains a large gallery (Fig. 8.16) that eventually leads to the Andavakandrehy River. Following it upstream a swamp in a doline can be reached.

8.3.5 Andranomidity

The Andranomidity Cave was explored in 2006 and 2007 by the Club Martel CAF (Nice) (Gilli 2016) and later by J. C. Dobrilla. It is a maze (Figs. 8.17 and 8.18) that extends parallel to the northeastern edge of the Andranomilika Butte. During the rainy season the water level rises by about 2 m.

Fig. 8.10 The Secret Garden

Fig. 8.11 Trying to cross the Secret Garden

Fig. 8.12 Entrance chamber to the Andavakandrehy Cave

Fig. 8.13 Decorated gallery in the Andavakandrehy Cave

Fig. 8.14 Stalagmites in the decorated gallery of the Andavakandrehy Cave

Fig. 8.15 Calcified plant roots in the Andavakandrehy Cave

The cave has a small dry upper level at an elevation of about 5 m. The cave network is connected to the upstream part of the Andavakandrehy River.

8.3.6 Dentelle Cave (Lace Cave)

Dentelle Cave, explored in 2010, is located on the southern edge of a hill (Fig. 8.17). It contains several burial sites. One of its main attractions is the erosion in deep areas that has sculpted the rock imparting it the appearance of limestone lace (Figs. 8.19 and 8.20).

8.3.7 Underground Historical Remains

All cave entrances in the Andranomilika Butte contain traces of temporary human occupation (Fig. 8.21). Fireplaces, pottery and bones are common (Figs. 8.22 and 8.23). The age of these artefacts is unknown. The pottery is rough, very thin and rarely decorated. They are made with sandy red clay that probably came from the banks of the underground rivers. The largest ones, pots or hollow dishes 30–40 cm in diameter, were either left near the fireplaces or hidden in alcoves near the cave entrances. These camps could be

Fig. 8.16 Cliff Cave (*Grotte de la Falaise*)

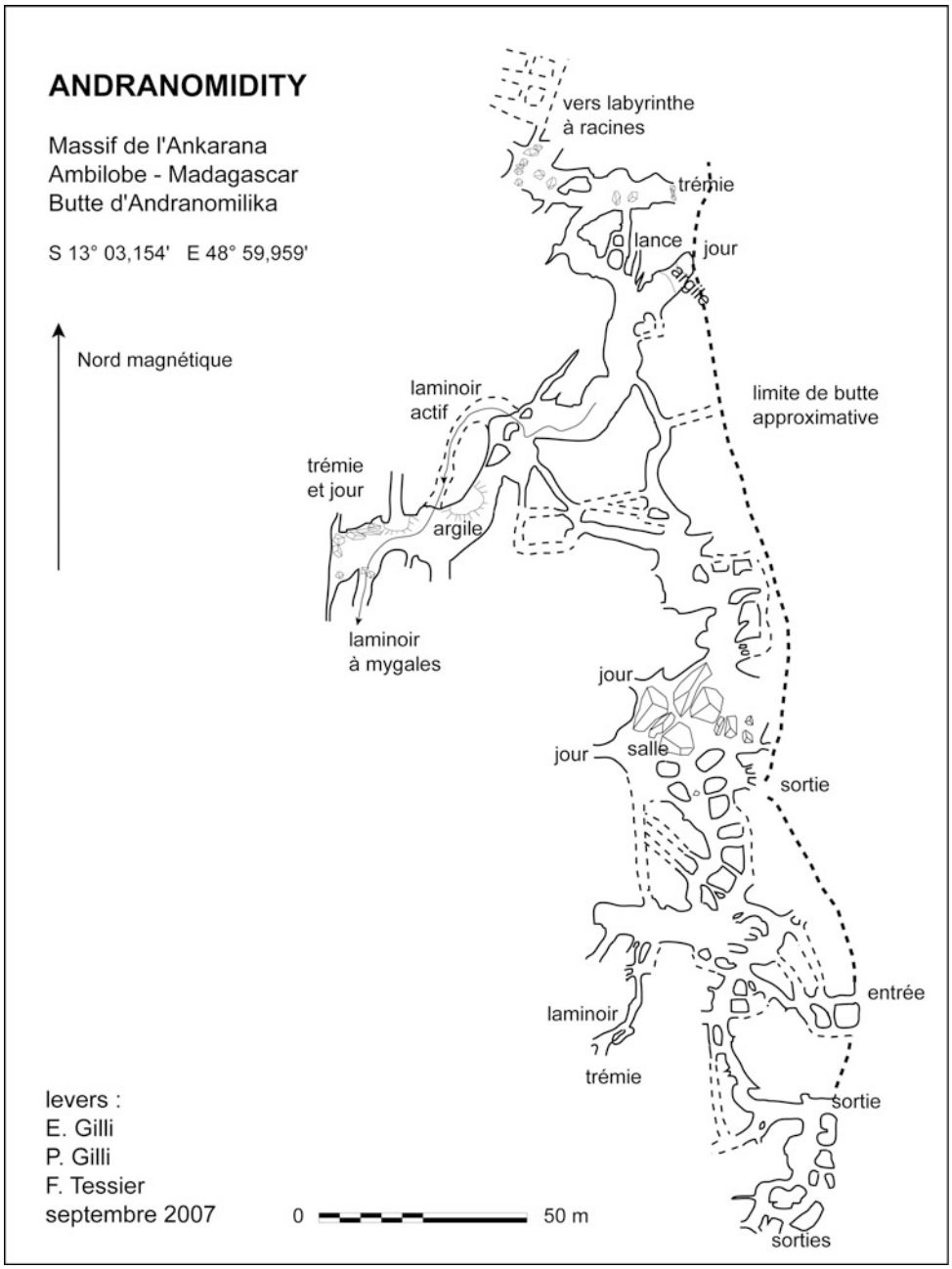

Fig. 8.17 Survey of the Andranomidity labyrinth cave in 2007

places where hunters would temporarily stay and make use of the terracotta dishware they had made in situ on earlier visits. Then, once the stay was over they hid them again for later use.

Some caves contain burial sites that have different ages (Figs. 8.24 and 8.25). They usually include a wooden coffin carved from a tree trunk in much the same way as a dugout

Fig. 8.18 The Andranomidity maze

Fig. 8.20 Dentelle Cave

Fig. 8.19 Lace Cave (*Dentelle Cave*)

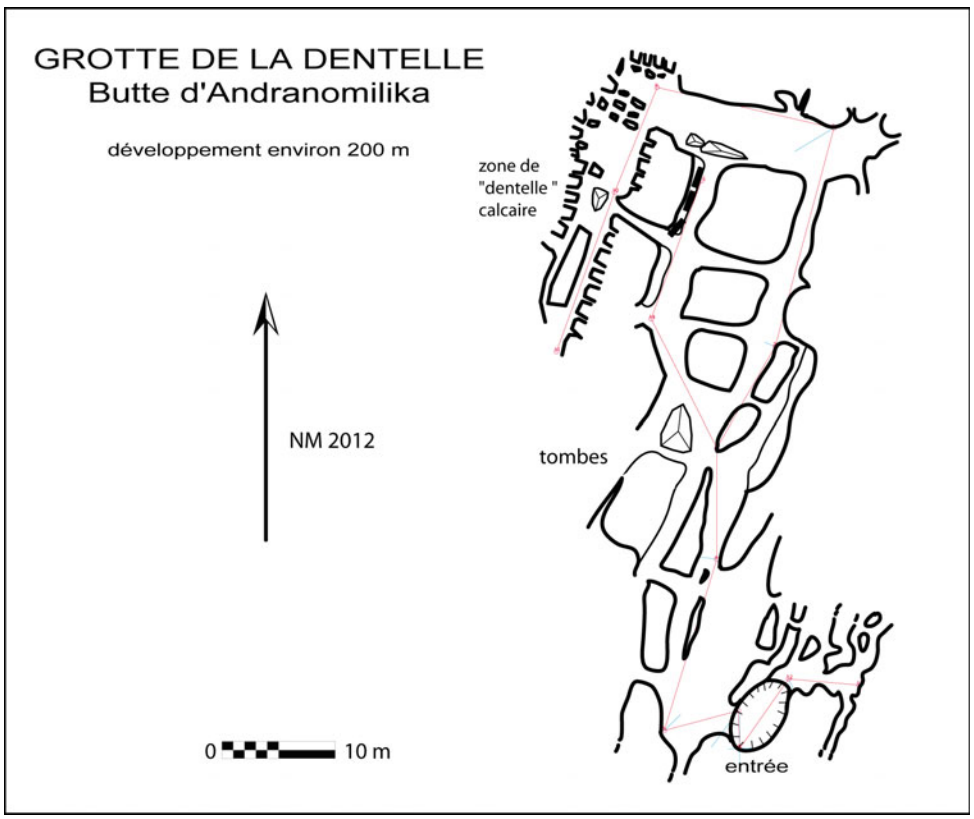

Fig. 8.21 Pottery hidden in an alcove in the Andavakandrehy Cave

Fig. 8.22 Remains of a meal in a historical camp in the Mandresy Cave

canoe and are accompanied by European or Chinese crockery, goblets and glass bottles, as well as small candle holders or terracotta incense burners. More modern burials have coffins made in sheet metal. In some places the body was directly laid on a rock without a coffin (Fig. 8.26).

Fig. 8.23 One of the fireplaces in a historical camp in the Mandresy Cave

Fig. 8.24 Underground burial dating from the nineteenth century in the Mandresy Cave

Fig. 8.25 Another underground burial dating from the nineteenth century in the Mandresy Cave

Fig. 8.26 Simple burial at the entrance to Dentelle Cave

8.3.8 Speleometry

Although Andranomilika Butte can be viewed as a limestone triangle measuring 1.5 × 1 km the cave network it contains has a total length of more than 28 km. The chamber in the Mandresy Cave measures approximately 220 × 110 m and the height of the ceiling is several tens of metres. The thickness of the limestone at this level is only 60 m. The room is therefore separated from the surface by a limestone roof whose thickness is less than the chamber width, which makes its stability surprising. The density of voids in the limestone block is exceptional and probably surpasses 30%.

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Other Caves Near the Ankarana Plateau

9

9.1 Antsarahaso Maze

A large karst area, the Analamera, extends northeast of the Ankarana Plateau. Recent exploration northeast of the Ankarana Plateau, led by the French caver J. C. Dobrilla, has indicated important speleological potential. He found an incredible maze, the Antsarahaso, whose length of 20 km makes it the third longest cave in Madagascar (Fig. 9.1).

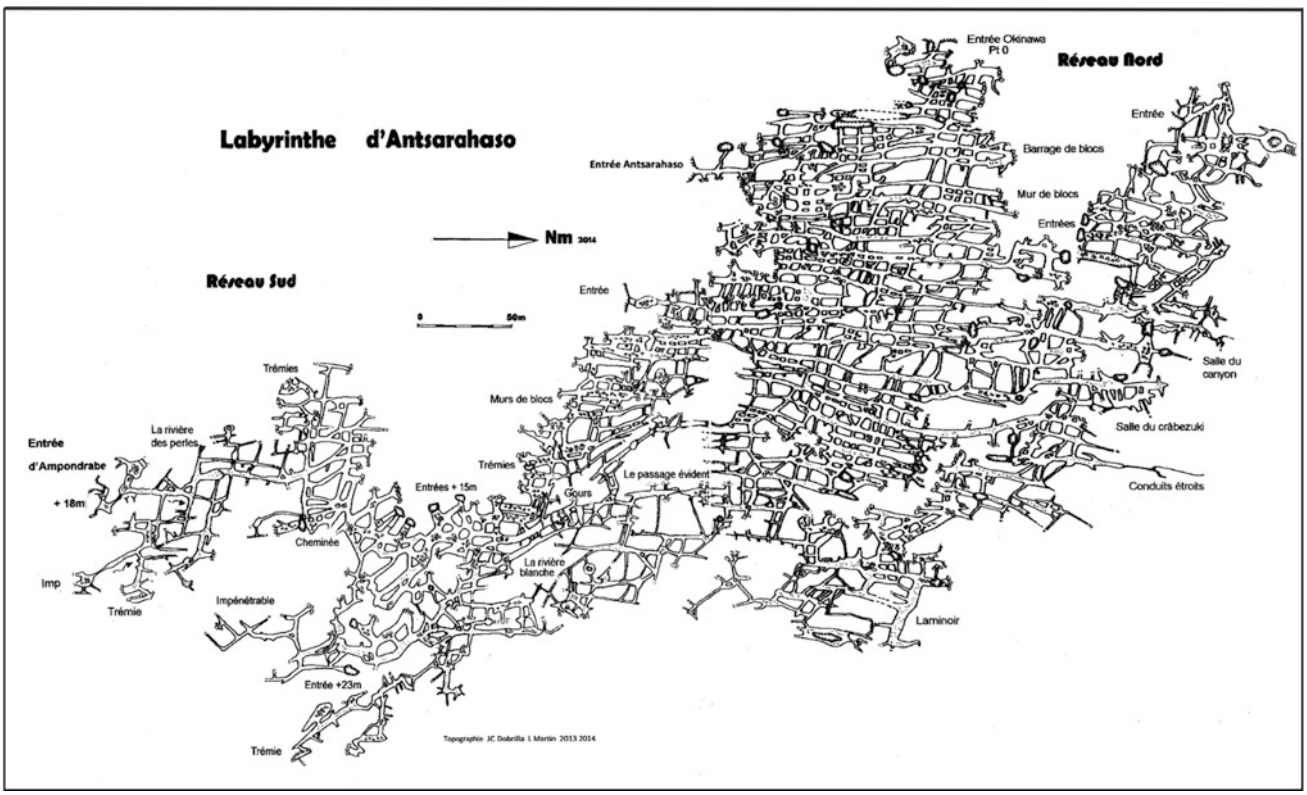

Fig. 9.1 The Antsarahaso maze (from Dobrilla)

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https://doi.org/10.1007/978-3-319-99879-4_9

The People of the Ankarana

10

10.1 The Antankarana Kingdom

The Antankarana people inhabit the extreme north of Madagascar, from Ambilobe to Cap d'Ambre and, in particular, the regions of the Montagne d'Ambre and the Ankarana. Their name means "those of the Ankarana". The region's name stems from the Malagasy word *harana* which originally designated white coral, then by extension the white rocks of this massif, carved by weathering (Oberlé 1979).

They come from the Zafinifotsy Sakalava tribes who were pushed to the north by wars. They settled on the Mitsio Islands, off the northern coast of the Mozambique Channel, and in the Ankarana region where they mixed with the indigenous tribes. At their head was a king, the *Mpanjaka*, whose genealogy is given in Fig. 10.1.

The first kings were buried in the Mitsio Islands. Then they were buried in the Ankarana, in the Ambatomanjahana Cave, near the source of the Antenanankara River. Since 1924 they have been buried in the Ambatoharanana Cemetery.

The caves also served as a refuge for the Antakarana people during the wars with the Hova and Merina (tribes of the Highlands) during the eighteenth century, as well as in recent clashes linked to the 2002 political crisis in Madagascar.

The remains of underground fortifications are still visible in the Ambatoanbanjahana Cave. Access to the caves is *fady* (taboo) and is especially prohibited to the Merina since the wars of the eighteenth century.

In 1841, during the reign of Tsimiaro (or Tsimiharo), the Antankarana Kingdom gave allegiance to France. The text of the treaty is given in Appendix 4.

The royal village is Ambatoharanana, located to the west of the massif. However, the current king, Tsimiaro III, lives in Ambilobe. Internal rivalries between the various royal branches, mainly for economic reasons, have weakened the power of the royalty.

The history of the Antankarana Royalty was written by the French colonial administrator Maurice Vial (1954). A translation of his text is given in Appendix 2. Vial describes the tombs and the ceremonies for visiting the ancestors: the *Fidirana Andavaka*. He also writes about the main ceremony of the Antankarana, the *tsangan-tsaigny*, which involves erecting a flag mast: the *Hazosaïna* flag. This symbol of the Antankarana Kingdom is a mast erected to the south of the village of Ambatoharanana, in memory of the provenance of the Zafinifotsy. It bears a flag consisting of a star with six branches and a red crescent on a white background (Fig. 10.2). The mast is made up of two parts symbolising man and woman. It is left in place until it collapses naturally and then it is changed, something that happens about every 5 years.

10.2 The Sapphire Mines of the Ankarana

10.2.1 The Sapphire Rush

In the 1990s the Ankarana region underwent the Sapphire Rush. Several villages sprang up alongside the reserve on both sides of the Diego–Ambilobe national road, in Andranoakoho and Ambondromifehy (Fig. 10.3), despite the government prohibiting such activity. Ankarana's sapphires can be green, yellow or blue and are often zoned. Some pieces are idiomorphic, but the vast majority are only small debris of crystals.

The gems are included in clayey-gravelly sediments that miners extract from the riverbeds or cave galleries, which they reach from the surface by incredible digging works (Fig. 10.4). The heat they have to endure is suffocating. The washing of the sediments to sort the gems is done by means of sieves in the turbid water of the Besaboba (Fig. 10.5).

The work is generally shared between men who excavate the materials, young boys who transport the sediment (Fig. 10.6), women who wash the sediment (Fig. 10.7) and children who sort the gravel.

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https://doi.org/10.1007/978-3-319-99879-4_10

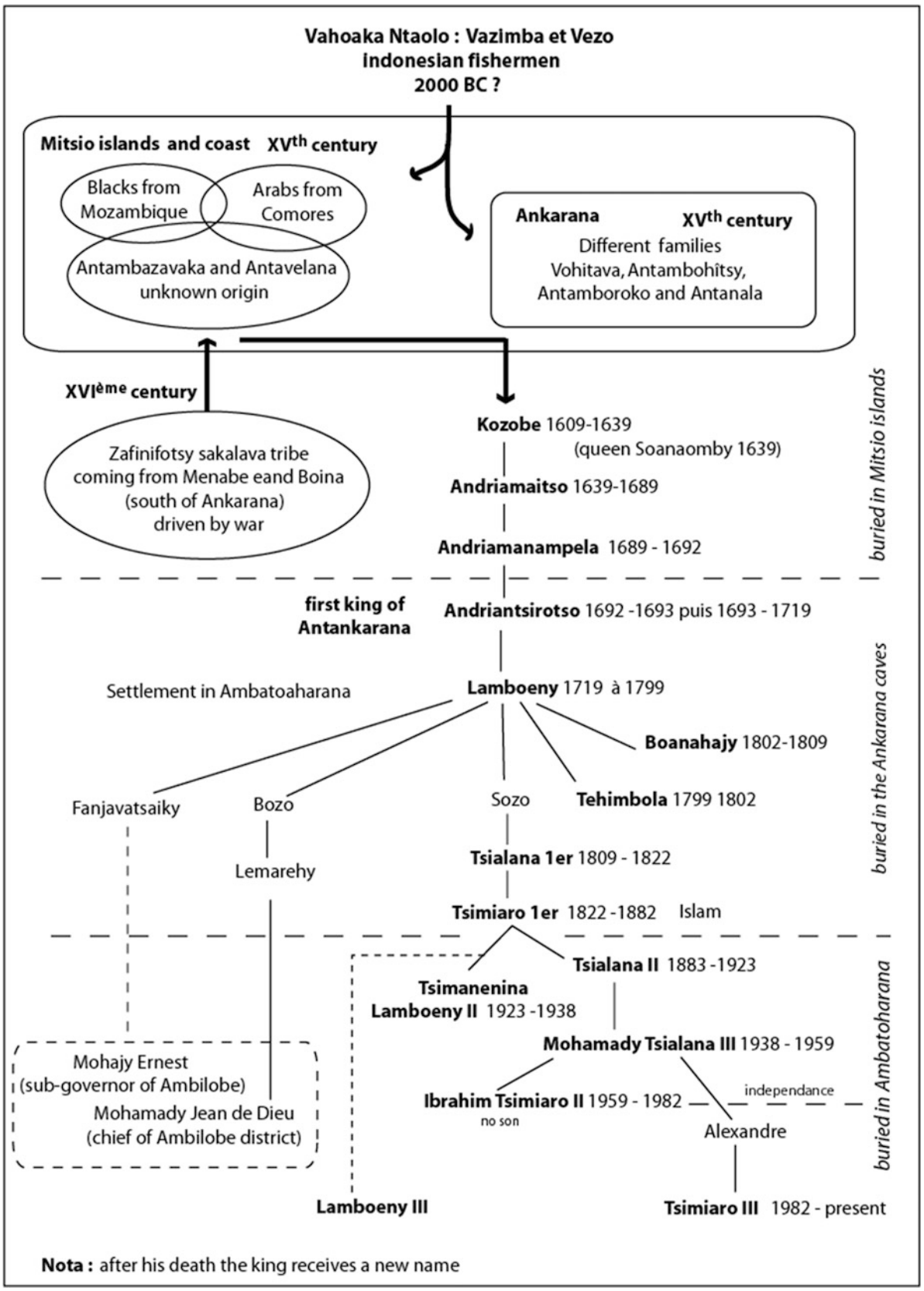

Fig. 10.1 Antankarana royalty (from Vial 1954; Oberlé 1979; Jeannot 2004)

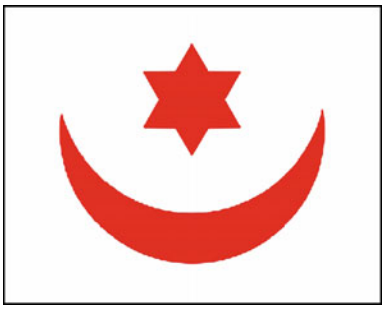

Fig. 10.2 The Ankarana people's flag

Fig. 10.3 Huts of recently arrived sapphire workers in Andranoakoho

Fig. 10.4 A vertical mineshaft that reaches a cave

The gems are sorted according to their size, colour and clarity (Fig. 10.8). The work is entrusted to young girls, because the delicacy of their fingers makes for easy sorting of the small stones (Fig. 10.9). Then they are sold in little shops at the roadside (Fig. 10.10).

Fig. 10.5 Washing sediment rich in sapphires

Fig. 10.6 Boys carrying cave sediment

Fig. 10.7 Family members washing the sediment

Fig. 10.8 A handful of multicoloured sapphires from the Ankarana

Fig. 10.9 Children sorting gems

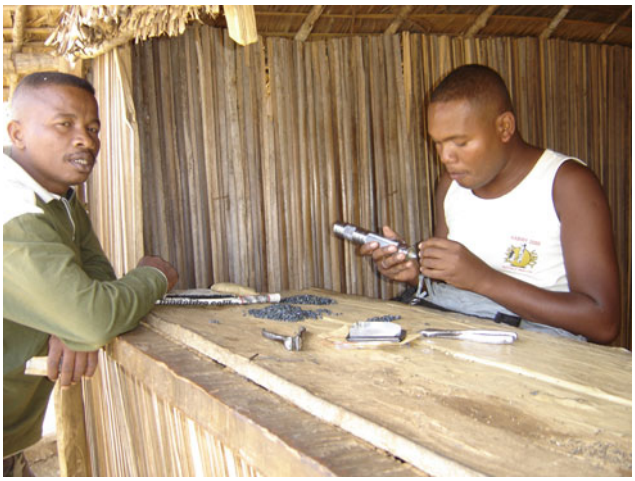

Fig. 10.10 Grinding gems, sorting them and making a batch

10.2.2 Origin of the Sapphires

Sapphires are corundum gemstones. Their presence may be related to the metamorphism of carbonate rocks rich in evaporites. Recent studies have shown that the transport of Ankarana sapphires towards the surface was done by basalts containing corundum (Rakotosamizanany 2009). The sapphires could therefore come from deep metamorphic series traversed by the basalt during the volcanic phases of the geological history of the Ankarana (Sect. 4.4). The miners are empirically aware of this basaltic origin and this knowledge dictates how they do their prospecting. Indeed, karst erosion makes dissolution of the matrix and concentration of the corundum crystals possible. Their hardness allows them to be transported by karst water circulation over long distances. They are thus present in cave sediments, thus providing the incentive for the miners to go underground to extract and wash them.

Such mining activity is similar to that undertaken in Sri Lanka, as described by Siffre (1975).

10.2.3 Environmental Damage

The surface of the land around the villages that sprang up is riddled with excavation pits dug in the sediments that fill the thalwegs, karst cracks and caves.

Traces of the intrusion of workers and survey holes are frequent in the caves of the national park despite their prohibition. They dig into the undergound soil and sometimes look for sediment below flowstones and cave formations. In this way they destroy the underground landscape. The Sapphire Rush has taken them to all of the Ankarana caves, including those of the Southern Buttes where sterile survey holes can be observed (Fig. 10.11).

The local Malagasy administration does not have adequate resources or personnel to enforce the laws and prevent the damage.

The miners, of both sexes and all ages, are a population of a few hundred people, but the numbers are clearly

Fig. 10.11 Sterile hole left by sapphire hunters in the Andavakandrehy cave. Note the leaf (*top right*) used for finding the way back

decreasing since the discovery of sapphires in Ilakaka (Southern Madagascar), which led to an exodus when more productive areas than those of the Ankarana were discovered.

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Tourism in the Ankarana

11

11.1 Ankarana Special Reserve

11.1.1 History and Administration

The reserve was set up in 1956 in response to the first explorations of caves, which quickly revealed the extraordinary tourism potential of the Ankarana. The reserve has now become a national park which is managed by Madagascar National Parks (formerly ANGAP). This NGO is the main interlocutor for all that concerns the natural parks in Madagascar. It manages 43 nature protection areas including those of the Montagne d'Ambre and the Ankarana (http://www.parcs-madagascar.com).

11.1.2 Limits and Settlements

The Ankarana Park extends over 18,220 ha and has a peripheral area of 48,301 ha (Fig. 11.1).

The park is sacred (*fady* in Malagasy) to the Antankarana people and, in addition to any of the park's own restrictions (gathering, hunting and the removal of anything are all prohibited), special rules and taboos apply to visitors (Fig. 11.2).

11.1.3 Infrastructure

The infrastructure for tourism is mainly located on both sides of the national road in Mahamasina at the eastern and main entrance of the Ankarana National Park. Most of the accommodation is pretty rough (Figs. 11.3 and 11.4).

There are a few bungalows just outside the park, in front of the entrance. It is not possible to book. Inside the park there is an area called Princes Camp where camping is allowed on six sites that include two toilets, two showers and four unsheltered tables. Access trails in the park are maintained. To the west the park is bordered by a very rough trail that gives access to another two campsites.

Outside the park, in the southern area close to Ambatoharanana, two lodges welcome tourists and a third is under construction.

A more inclusive list of the park infrastructure is given in Appendix E.

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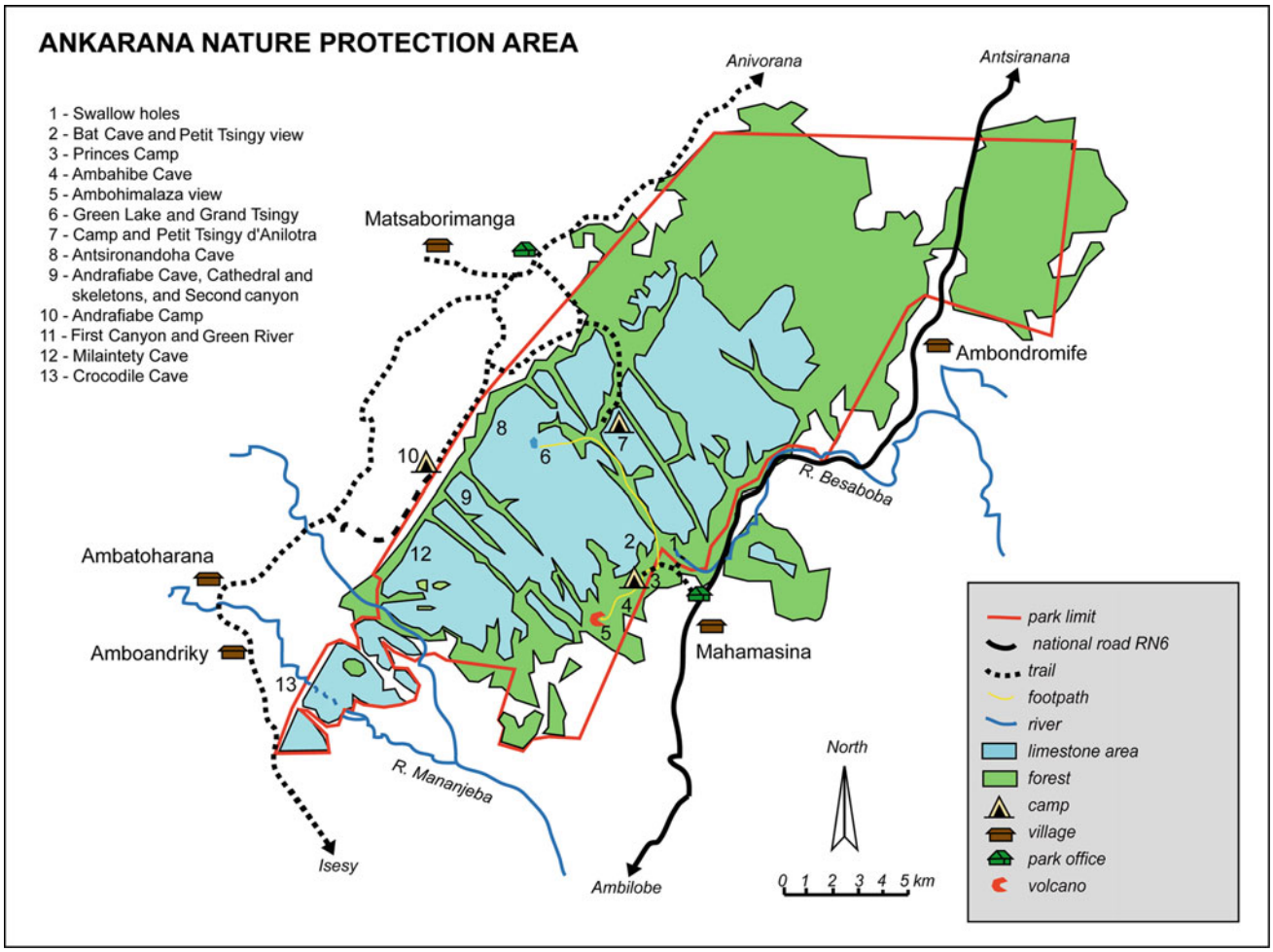

Fig. 11.1 Limits and settlements of the Ankarana park

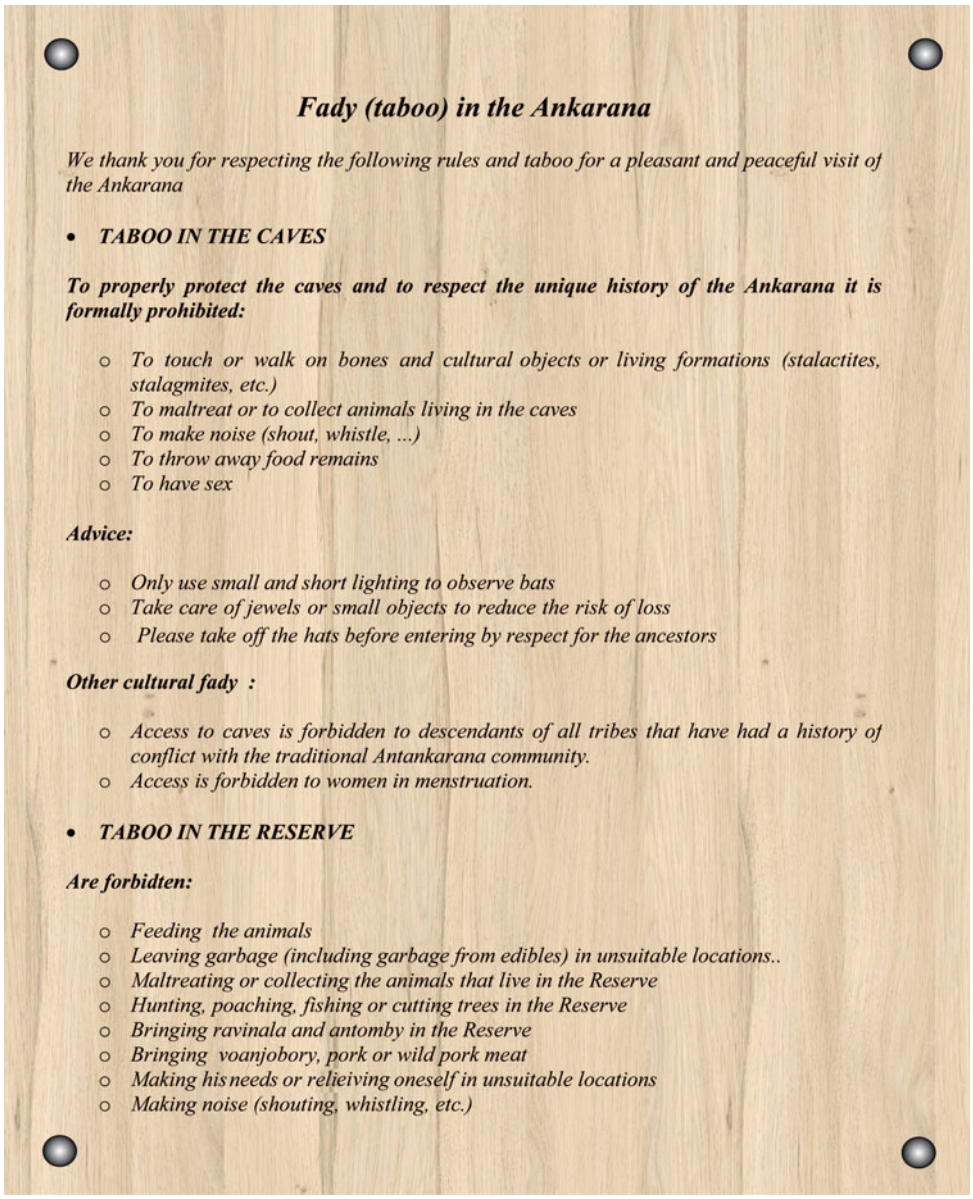

Fig. 11.2 Visitor rules and taboos in the Ankarana

Fady (taboo) in the Ankarana

We thank you for respecting the following rules and taboo for a pleasant and peaceful visit of the Ankarana

- ***TABOO IN THE CAVES***

To properly protect the caves and to respect the unique history of the Ankarana it is formally prohibited:

- *To touch or walk on bones and cultural objects or living formations (stalactites, stalagmites, etc.)*
- *To maltreat or to collect animals living in the caves*
- *To make noise (shout, whistle, ...)*
- *To throw away food remains*
- *To have sex*

Advice:

- *Only use small and short lighting to observe bats*
- *Take care of jewels or small objects to reduce the risk of loss*
- *Please take off the hats before entering by respect for the ancestors*

Other cultural fady :

- *Access to caves is forbidden to descendants of all tribes that have had a history of conflict with the traditional Antankarana community.*
- *Access is forbidden to women in menstruation.*

- ***TABOO IN THE RESERVE***

Are forbidten:

- *Feeding the animals*
- *Leaving garbage (including garbage from edibles) in unsuitable locations..*
- *Maltreating or collecting the animals that live in the Reserve*
- *Hunting, poaching, fishing or cutting trees in the Reserve*
- *Bringing ravinala and antomby in the Reserve*
- *Bringing voanjobory, pork or wild pork meat*
- *Making his needs or relieiving oneself in unsuitable locations*
- *Making noise (shouting, whistling, etc.)*

Fig. 11.3 Bungalow in Mahamasina

Fig. 11.4 Bar de Routard (Goolam Lodge) in Mahamasina

Appendix A: Georeferenced List of the Ankarana Caves

Note: Coordinates were deduced from J. Radofilao's raster maps pasted in a GIS. Coordinates for most of the caves were not verified. The list (Table A.1) is intended purely as a guide.

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Table A.1 List and coordinates of the Ankarana caves

Name	Latitude	Longitude	Latitude		Longitude		Length
	(°)	(°)	(°)	(min)	(°)	(min)	(m)
Ambarabanja (cave)	−12.979529	49.051176	−12	58.772	49	03.071	2,352
Ambarabanja 4 (small cave)	−12.978534	49.050196	−12	58.712	49	03.012	375
Ambarabanja tunnel NE	−12.977389	49.055076	−12	58.643	49	03.305	120
Ambarambanja (cave)	−12.977298	49.048604	−12	58.638	49	02.916	717
Ambatofotsy (cave)	−12.966827	49.041761	−12	58.010	49	02.506	1,130
Ambatoharanana mangily SW (cave)	−12.990769	49.02227	−12	59.446	49	01.336	–
Ambatoharanana entrance (cave)	−13.002695	49.023183	−13	00.162	49	01.391	18,100
Ambatoharanana mangily NW (cave)	−12.987293	49.022834	−12	59.238	49	01.370	–
Ambatoharanana mangily S (cave)	−12.992092	49.02442	−12	59.526	49	01.465	–
Ambatoharanana matsaborikely	−12.9973	49.009455	−12	59.838	49	00.567	–
Ambatoharanana exit (cave)	−12.993665	49.01161	−12	59.620	49	00.697	–
Ambatomanjahana (cave)	−12.942858	49.063446	−12	56.571	49	03.807	10,810
Ambatomanjahana (cave)	−12.94936	49.06125	−12	56.962	49	03.675	–
Ambatomanjahana: Styx	−12.96427	49.053435	−12	57.856	49	03.206	–
Ambatomanjahana south (cave)	−12.9768	49.046273	−12	58.608	49	02.776	–
Ambatomitsioka (cave)	−12.933881	49.10482	−12	56.033	49	06.289	300
Ambiky (cave)	−12.978118	49.041658	−12	58.687	49	02.499	1,100
Ambiky south (cave)	−12.983402	49.04112	−12	59.004	49	02.467	–
Ampandehanana (andavaky ny) (cave)	−12.983279	49.025901	−12	58.997	49	01.554	320
Ampandriampanihy entrance (cave)	−12.978702	49.033567	−12	58.722	49	02.014	4,480
Ampandriampanihy exit (cave)	−12.973888	49.033359	−12	58.433	49	02.002	–
Amposatelo (sinkhole)	−12.926439	49.093761	−12	55.586	49	05.626	350
Amposatelo 2 (cave)	−12.934635	49.096549	−12	56.078	49	05.793	3,350
Analamisondrotra N (unprecise)	−12.847374	49.137173	−12	50.842	49	08.230	80
Analamisondrotra W (unprecise)	−12.848921	49.135984	−12	50.935	49	08.159	1,900
Analatelo (cave)	−12.901757	49.080963	−12	54.105	49	04.858	350
Andalameloka (cave)	−13.0345	48.999317	−13	02.070	48	59.959	1,000
Andavakandrehy (cave)	−13.050021	48.991241	−13	03.001	48	59.474	–
Andavakandrehy (exit)	−13.059123	48.996777	−13	03.547	48	59.807	–
Andavakafasika	−13.040694	49.005444	−13	02.442	49	00.327	4,063
Andetobe (cave)	−12.899926	49.086115	−12	53.996	49	05.167	4,260
Andetobe 2 (cave)	−12.900002	49.087165	−12	54.000	49	05.230	–
Andrafiabe centre (canyon) (cave)	−12.93712	49.05817	−12	56.227	49	03.490	12,800
Andrafiabe north (cave)	−12.93007	49.059811	−12	55.804	49	03.589	–
Andrafiabe south (canyon) (cave)	−12.943885	49.055569	−12	56.633	49	03.334	–
Andrano migororoana (cave)	−12.961368	49.042216	−12	57.682	49	02.533	70
Andranofanjava	−12.917353	49.12243	−12	55.041	49	07.346	150
Andranofanjava (cave)	−12.917353	49.122436	−12	55.041	49	07.346	130
Andry fotsy (lavaka)	−12.96822	49.038371	−12	58.093	49	02.302	210
Ankarana 1 (spring)	−12.968198	49.035542	−12	58.092	49	02.133	–
Ankarana 2 (spring)	−12.977527	49.049114	−12	58.652	49	02.947	–
Antaninkatakatan i benoely N (cave)	−12.965349	49.048447	−12	57.921	49	02.907	1,090
Antaninkatakatan i benoely S (cave)	−12.976878	49.043367	−12	58.613	49	02.602	–
Antenankarana (spring)	−12.977298	49.048604	−12	58.638	49	02.916	–
Antsatrabonko (cave)	−12.912419	49.070756	−12	54.745	49	04.245	10,850
Antsatrabonko north 2 (cave)	−12.908595	49.071795	−12	54.516	49	04.308	–
Antsatrabonko south (unprecise)	−12.927257	49.063036	−12	55.635	49	03.782	–
Antsiroandoha (cave)	−12.891189	49.098011	−12	53.471	49	05.881	1,250
Antsiroandoha (small cave in the SW)	−12.892156	49.096578	−12	53.529	49	05.795	125

(continued)

Table A.1 (continued)

Name	Latitude	Longitude	Latitude		Longitude		Length
	(°)	(°)	(°)	(min)	(°)	(min)	(m)
Araignées (cave)	−12.910998	49.092987	−12	54.660	49	05.579	187
Aven ambanimero (cave)	−12.967929	49.042238	−12	58.076	49	02.534	610
Aven de 10 m (shaft)	−12.899971	49.093972	−12	53.998	49	05.638	10
Balcon (cave)	−12.932702	49.102477	−12	55.962	49	06.149	150
Batavia (lavaka) (cave)	−12.974626	49.0397	−12	58.478	49	02.382	225
Befoka north (lavaka) (cave)	−12.970949	49.035426	−12	58.257	49	02.126	1,940
Befoka south (lavaka) (cave)	−12.973681	49.036765	−12	58.421	49	02.206	–
Benoely (cave) (unprecise)	−12.978278	49.061504	−12	58.697	49	03.690	400
Beravina (cave) (cave)	−12.925221	49.127328	−12	55.513	49	07.640	2,400
Besaboba 1 (sinkhole)	−12.954797	49.127119	−12	57.288	49	07.627	815
Besaboba 2 (sinkhole)	−12.958403	49.140995	−12	57.504	49	08.460	350
Bevato (lavaka) (cave)	−12.968263	49.038917	−12	58.096	49	02.335	100
Boite aux lettres (cave)	−12.90244	49.095826	−12	54.146	49	05.750	280
Boribe (cave)	−13.010462	49.002091	−13	00.628	49	00.125	225
Borikely (cave)	−13.012964	49.001864	−13	00.778	49	00.112	180
Campement (cave)	−12.897511	49.087045	−12	53.851	49	05.223	200
Canyon andohalambo (cave)	−12.945386	49.057332	−12	56.723	49	03.440	160
Canyon caché (cave)	−12.935807	49.102982	−12	56.148	49	06.179	80
Canyon caché (N river)	−12.936616	49.103383	−12	56.197	49	06.203	–
Canyon caché (sinkhole S)	−12.938794	49.103723	−12	56.328	49	06.223	50
Canyon forestier (cave du)	−12.902345	49.123196	−12	54.141	49	07.392	510
Canyon forestier NW (sinkhole)	−12.901467	49.12199	−12	54.088	49	07.319	150
Canyon forestier SE (sinkhole)	−12.915008	49.131301	−12	54.900	49	07.878	–
Chien (cave)	−12.881404	49.1104	−12	52.884	49	06.624	100
Dentelle (cave)	−13.057584	48.992484	−13	03.455	48	59.549	200
Deux perroquets (shaft)	−12.932639	49.101928	−12	55.958	49	06.116	10
Fanihy (lavaka) or Chauves souris cave	−12.955995	49.117515	−12	57.360	49	07.051	4,460
Fisoafaka (lavaka ny)	−12.968249	49.037805	−12	58.095	49	02.268	190
G20	−12.975224	49.099062	−12	58.513	49	05.944	292
Galidias (cave)	−12.903235	49.096233	−12	54.194	49	05.774	230
Gros pilier (cave)	−12.883143	49.110462	−12	52.989	49	06.628	40
Hélice (shaft)	−12.881024	49.10926	−12	52.861	49	06.556	25
Hily (andavaka or cave) (unprecise)	−12.98311	49.025571	−12	58.987	49	01.534	200
Imasoroanantsiroandoha (cave)	−12.887217	49.104773	−12	53.233	49	06.286	800
Lac vert (cave)	−12.92361	49.086839	−12	55.417	49	05.210	900
Mampangetaheta (cave)	−12.914961	49.135663	−12	54.898	49	08.140	390
Mandresy 1 (necropolis entrance)	−13.055832	48.98622	−13	03.350	48	59.173	28,000
Mandresy (andavakandrehy doline entrance)	−13.049772	48.990231	−13	02.986	48	59.414	–
Mandresy andranomidity (cave)	−13.052577	48.999324	−13	03.155	48	59.959	–
Matsaborimalio (cave)	−12.978849	49.059797	−12	58.731	49	03.588	385
Matsaborimanga (caves)	−12.894941	49.089363	−12	53.696	49	05.362	370
Matsaborimanga 2 (cave)	−12.895993	49.089532	−12	53.760	49	05.372	430
Matsaborimanga 3 (cave)	−12.896101	49.088446	−12	53.766	49	05.307	130
Maurice (Andranomanilotra) (spring)	−12.968348	49.035737	−12	58.101	49	02.144	140
Mideza (lavaka)	−12.96247	49.040274	−12	57.748	49	02.416	390
Milaintety (cave)	−12.958594	49.039551	−12	57.516	49	02.373	9,005
Milaintety (Crabes entrance) (cave)	−12.963154	49.03767	−12	57.789	49	02.260	–
Milaintety north (cave)	−12.949477	49.045652	−12	56.969	49	02.739	–
Milaintety south (cave)	−12.968239	49.037213	−12	58.094	49	02.233	–

(continued)

Table A.1 (continued)

Name	Latitude	Longitude	Latitude		Longitude		Length
	(°)	(°)	(°)	(min)	(°)	(min)	(m)
Milantety centre (cave)	−12.967507	49.042711	−12	58.050	49	02.563	–
Moteur (cave) in Deux perroquets canyon	−12.930988	49.099459	−12	55.859	49	05.968	4,200
Moteur (cave) in Deux perroquets canyon	−12.928563	49.098791	−12	55.714	49	05.927	0
Norambavy (andavaky ny or cave)	−12.988007	49.030566	−12	59.280	49	01.834	60
Olona (andavaka)	−12.936402	49.055915	−12	56.184	49	03.355	250
Poterie (cave)							70
Puits delta (shaft)	−12.895811	49.091986	−12	53.749	49	05.519	50
River	−12.942065	49.062976	−12	56.524	49	03.779	–
River	−12.933884	49.068701	−12	56.033	49	04.122	–
Sangliers (caves)	−12.960254	49.038196	−12	57.615	49	02.292	260
Scorpion (cave)	−12.893079	49.116937	−12	53.585	49	07.016	90
Sinkhole	−12.947384	49.068339	−12	56.843	49	04.100	–
Small caves	−12.887213	49.104773	−12	53.233	49	06.286	50
Sortie Besaboba Ankarana?							340
Sump	−12.941914	49.065636	−12	56.515	49	03.938	–
Sump	−12.94294	49.066615	−12	56.576	49	03.997	–
Sump	−12.944866	49.066984	−12	56.692	49	04.019	–
Sump du canyon caché	−12.936449	49.103739	−12	56.187	49	06.224	–
Tena antsiroandoha	−12.910964	49.110217	−12	54.658	49	06.613	150
426 (sinkhole)	−13.057659	48.991465	−13	03.460	48	59.488	150
						Total length	142,911

Appendix B: The Antankarana Royalty

This appendix is a translation of a text by Maurice Vial entitled "La royauté Antankarana. Faire connaître le peuple antankarana et ses rites", which was published in the *Bulletin of the Madagascar Academy* (Vial 1954). Maurice Vial was an administrator of Overseas France during the French colonial period. The original text was also published in Antsiranana by Aly Ndandahizara Cassam (cassam-aly@moov.mg).

B.1 History

B.1.1 History of the Antankarana Royalty

B.1.1.1 Prehistoric Period

The first inhabitants of the region were the Vohitava, Antambohitsy, Antamboroko and Antanala. They were probably living in the Ankarana caves, which explains their name Antankarana ("living in Ankarana"). They are also named Antakarana. They were hunter-gatherers and it is believed they only used wood and stone tools.

On the coast and the Mitsio Archipelago there were two fishermen tribes, the Antambazavaka and the Antavelana, whose origin remains unknown. One hypothesis is they were a mixing of Blacks from Mozambique established there since the fifteenth century and Arabs from the Comores or farther afield (Zanzibar, Persian Gulf) who arrived in the sixteenth century.

B.1.1.2 Semi-historic Period

During the sixteenth century the Sakalava tribe from Menabe and Boeni, who had been pushed to the north by wars, were defeated in another war.

The Zafinifotsy, defeated by their cousins the Zafinimena, fled to the north and stopped close to the Sofia River. Their names stemmed from those of two brothers, eponymous heroes and ancestors of these two tribes: Zafimbolafotsy and Zafimbolamena.

A few years later the Zafinimena, under the command of their chief Andriambolamena, aided by the Hova, hunted down the Zafinifotsy who fled even farther north and divided in two groups. One was led by two chiefs, Fanananimena and Laigara, and went to Androna or Marangibato on the eastern plateaus in the Mandritsara region. The other was led by Rasoa (a woman) and her sons Kozobe and Tsirisahy. This second group settled in Mangabe in the lower Sambirano River and then took refuge on the islands of Nosy-Komba and Nosy-Be.

Kozobe was elected chief in 1609 and died in 1639 after 30 years on the thrown. He was the first known Zafinifotsy king and all the royal genealogy of the Antankarana can be traced back to him. He was buried at Nosy-Komba in a place called Antenianaomby.

The group that went to Marangibato started the Tsimihety noble branch called the Antimarangibato. It explains the kinship between the Tsimihety and the Antankarana.

However, it was from the group that settled in the Sambirano and from the islands that the royal family emerged: Andriamaitso, Kozobe's son, succeeded him in 1639 and reigned in Ambohimalaza (now called Antafondro) for 50 years. He died in 1689 and was buried in Andokobe or Lokobe on Nosy-Be. His son Andriamanampela acceded to the throne in 1689.

Tsitavana, a Sakalava Zafinimena king from Boeni, who was also called Andriantahora in Antankarana or Andrianiveniarivo ("the one who makes a thousand men row"), attacked the Zafinifotsy of the Sambirano. He asked Andriamanampela to come from Nossi-Be to the mainland to discuss terms. The latter, believing there was no threat, went to the rendezvous. However, his nephew Andriantsirotso, the son of Soalandy (the fourth child of Kozobe), sprang a trap set up by the Sakalava and opened fire on the warriors of Tsitavana, and then fled north with his warriors as fugitives. Andriamanampela was taken prisoner and beheaded in Bejofo, north of Ambanja. His head was thrown into the Ankazokogniny River, where ever since the Antankarana are

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forbidden to drink and bathe. He had reigned for 3 years (1689–1692). The princes and nobles who had not accompanied Andriantsirotso swore an oath of obedience to the Sakalava chief. The others who had gone north settled in Ambatoloho near Bobasatrana (Ambilobe district) and formed the Antinosy–Ambatoloho tribe.

When Andriantsirotso and his warriors met the Antankarana tribes (the Antamboroko, Antambohitsy, Antanala, etc.) they recognized him as king and handed over their lands to him (1692). He settled in the north of Ambatoharanana. A year later, Andriantahora pursued the fugitive Andriantsirotso and his warriors and with the assistance of the Zafinifotsy attacked him. Andriantsirotso escaped into the Ankarana caves where he resisted for one year, after which he fled to Maroantsetra on the Antongil Bay where the Betsimisaraka king Zafirabay Ratoro (or Raholo) welcomed him and stopped Andriantahora in his pursuit of the fugitives. Andriantahora settled in Ambatoharanana and reigned there for 3 years. Zafinimena Sakalava tombs are still present in the hills of western Ankarana. Then, as a result of the Boeni areas being threatened by enemies from Ambongo and Menabe, Andriantahora returned to the Ankarana with all his people.

The Antambohitsy and the Antanala, who had remained in the caves, went to Maroantsetra to warn their king, Zafirabay. He returned with them and some of his warriors around 1697. He moved to Ananjaka (Marivorahona township) and settled in Mahavanona (now Ambilobe) with Tsimatahodrafy, a young magician girl he brought back from his journey. She had a long life and a great influence on the formation of the Antakarana Kingdom, and the 70 years of peace and prosperity that followed are attributed to her. In later life she became a bit of a witch.

The true beginning of the kingdom can be fixed at the return of Andriantsirotso from Maroantsetra. He died around 1710 after 18 years on the throne and was buried in the Antavy Circus. After his death his name was changed to Andrinilihaniarivo ("the nobleman who made many trips"). He left a pacified and strong kingdom.

The related to Occident history of the Ankarana started when Andriantsirotso's son Lamboeni succeeded him. He lived a long life, since he is said to have reigned for 80 years (60 years according to other versions). There was not a single war during all that time in spite of the efforts of a number of troublemakers. He had 33 children and he is the ancestor of all the noble Antankarana of the first rank. He clearly was able to maintain relations with the Antongil Bay people, since in 1776 his name appeared on the act of engagement of the Antongil tribe chiefs, signed on 11 October at Louisbourg (now Maroantsetra) between them and the famous Baron de Benyowsky, Governor of Madagascar.

On 7 July 1785, Benyowsky returned from Baltimore on the *Intrepid*, an American vessel, which anchored at the mouth of the Mahavavy River. Lamboeni came to welcome him with his warriors who let off some musket salvoes, which at first made the valiant captain want to escape! Benyowsky and his companions, including his French lieutenant Jacques de Lassalle, remained with Lamboeni for 6 months. Health conditions in this warm and marshy country did not suit Europeans and there were several deaths. Thus, on 8 January 1786, Benyowsky decided to go to the east coast, presumably through the villages of Betsiaka and Daraina, to reach the valley of Manambato and Vohemar, where they arrived on 3 February. Lamboeni died shortly after, about 1790, and received the name of Andriamanolotsoarivo.

One of his sons, Tehimbola, ascended the throne and reigned for 12 years. According to tradition, he forced the female magician Tsimatahodrafy to help him declare war on the Sakalava Zafimbolamena. After being defeated at Sengaloka by them, he had to resort to the good offices of the magician to drive them out. He had no children. When he died in about 1802, Boanahajy, one of his brothers, succeeded him. Tehimbola's posthumous name is Andriamandresiarivo. Boanahajy settled in Marivorahona and reigned for 7 years, when his nephews Tsialana I, son of his elder sister Sozo, and Andrianjalahy, son of his brother Lehilahy, dispossessed him by force.

The throne was taken by Tsialana I in 1809. His cousin Andrianjalahy became his aide-de-camp and lived in Berantsana. Andrianjalahy was entrusted with administering the Antankarana of the south and set up residence in Nosy-Faly. He formed the Antiberantsagna Clan and his descendants currently inhabit Nosy-Faly in Antafiambotry (Ambanja district), Ambatobeanjavy and Beramanja (Ambilobe district).

Except for Andrianjalahy, who was buried in the caves of the Ankarana, the tombs of this part of the family are farther afield (in Ambato and Andavakantsantsa). These places can be found in the foothills of the Leviky Range, immediately south of the exit from the Mahavavy Gorge, 1 km upstream of Ambilobe.

Tsimamindra, the son of Andrianjalahy, succeeded him. At his death his brother Tsimatahoro expected to succeed him, but King Tsimiaro (or Tsimiharo) chose Tsimamindra's son, Andrianjalahy II (François-Xavier), who was studying in Reunion Island. Tsimatahotra was incensed. His anger got more intense and finally in 1865 he declared civil war on Tsimiaro, but he was killed; he left no children. Fanahibe succeeded Andrianjalahy II. He was appointed as political sub-governor in 1899 by the French commander of the Grande-Terre in Ambato. He then moved to Beramanja, where he died in 1926.

He was replaced by his nephew Andriamanjaka, also political sub-governor, in 1928. In 1930, following a problem with this sub-governorship, Andriamanjaka was forced to resign and ended up living on very bad terms with the Mpanjaka of the Tsialana Family. In April 1947 he was involved in the Malagasy Revolution and was arrested. He was released in early 1949 and then returned to Beramanja.

B.1.1.3 Historical and Modern Period

Tsialana I took power in 1809, but had to fight to consolidate himself on the throne by defeating the supporters of Boanahajy, the dethroned king, in Anonina and Ampombiantambo. He then settled in Ambatoharanana.

In 1810 a Hova army under the orders of Andriamanetaka, the brother of the Merina king Radama I, arrived in Ambatoharanana to subdue the Antankarana people.

When Tsialana I made an act of vasselage the Hova moved south. Sometime later, King Radama I himself, who came from the eastern coast where he had subjected the Betsimisaraka, arrived in Ambatoharanana. Tsialana I confirmed his submission and Radama placed military posts commanded by his officers in Antomboko or Ambohimarina, near Diego and in Amboanio near Vohemar. Afterwards, he too went south.

Tsimandroho, a descendant of the Sakalava kings from Boeni, started a war with the Antankarana but was forced to submit to Radama I along with them. Radama appointed him governor of Vohemar but he revolted in 1835 and returned to Boeni.

Ranavalona I, who succeeded Radama I, entered Boeni in 1836 in an attempt to capture Tsimandroho. At that time Maka, the king of the Bemazava Sakalava in the region of Sambirano and who was beaten by Andriantsoly, the Sakalava Bemihisatra king, sought refuge in the Ankarana region. Tsialana I allowed him to settle in the region at Anjiamankotroko, near the village of Bedara (Beramanja township). Maka lived there for several years, and when he died he was buried with great pomp at Nosy-Faly, which is now the resting place of the royal Sakalava family. Tsialana I reigned for 13 years and died in 1822. He was then given the name Andriamitoarivo.

Tsimiaro, his son, succeeded him (Fig. B.1). He fought against the Hova military post at Ambohimiarina from 1835 to 1837. He was defeated and took refuge in the caves of Ankarana where he resisted for 2 years. Betrayed by an Antankarana man named Njakalagnitsy who showed the Hova the way to the caves in 1838, he escaped to Nosy-Mitsiou. He vowed to convert to Islam if Allah ridded him of the Hova. His whole family followed him to Nosy-Mitsiou.

Tsimiaro settled on the west coast of Nosy-Mitsiou, near the peak of the Anoron'Ankarana (96 m), in Ampasindava

Fig. B.1 Tsimiaro around 1840 (from Vial, 1954)

where the stone base of his palace and his throne can still be seen. The throne is a flat stone set on four vertical stones in the shadow of a mandresy, a kind of banyan tree with enormous roots, in which are embedded the polyhedra of basalt that were erected at the time of ritual celebrations.

Tsimiaro, still obsessed with revenge against the Hova, agreed with Tsiomeko, the queen of the people living in Boeni who had taken refuge with her people at Nosy-Komba, Nosy-Be and Nosy-Aaly, to send Antankarana and Sakalava nobles as ambassadors to Zanzibar.

On 4 November 1838 the Sultan of Zanzibar sent a warship with some soldiers and ammunition. A fort was built at Ambavatobe, opposite Nosy-Be. Some 200 Hova warriors from the post of Anorontsagana attacked the fort on 5 March 1839 and were repulsed. However, the Arab warship returned to Zanzibar and the Sakalava were again abandoned to their own devices. They had to take refuge in Nosy-Be with Tsiomeko, who had been in Nosy-Komba since June 1837.

Tsimiaro, meanwhile, had sent another messenger to Mauritius to ask for the help of the British government, without result. Soon after, the *Colibri*, a French ship, anchored at Nosy-Be. Onboard was Captain Passot, a French naval infantry officer, charged with exploring the north of Madagascar by Admiral de Hell, governor of Bourbon. Tsiomeko asked for his help. He promised it and told the Hova governor of the peninsula of Anorontsangana that Nosy-Be was under French protection. Since then the Hova abstained from all hostility. On Nosy-Mitsiou, Tsimiaro also asked for the support of the French and declared that he

would cede his rights over the Ankarana and the islands to France.

On the 14th of July, 1840, M. Passot signed a treaty with Tsiomeko, who yielded his territory to France. On May 5, 1841, the French flag was solemnly worn at Hell-ville to mark the taking of possession.

Tsimiaro did not receive a definitive answer and decided to go himself to Bourbon island in a sailing canoe. There, in March 1841, he concluded the treaty by which he ceded all his rights over the archipelago of the Mitsiou, Nosy-Faly, Nosy-komba and Nosy-Be and throughout its territory of the Great Earth (see the treaty in Appendix D).

Meanwhile the Sakalava chiefs of Boeni and Menabe accused Tsimiaro of having called the Europeans. They wanted to oblige him to cancel the treaty, and to dismiss the French. Tsimiaro refused and was attacked. The Sakalava were defeated at Nosy-Faly.

A few years later Tsimiaro was appointed Chevalier of the Legion of Honour and received from the King of the French a complete uniform with bicorn and sabre and an annual pension of 100 francs. He died in 1882 after 60 years on the throne at his residence of Ampasindava in Nosy-Mitsiou. Previously, his family members were buried on the island and the surrounding islets of Anoronkarana, Nosy-Ankareha, Nosy-Lava and Nosy-Antoloho, where their tombs can still be located. However, Tsimiaro was buried in the caves of the Ankarana, after which his name was changed to Andriamandambanarivo.

His son Tsialana II succeeded him in 1883 (Figs. B.2 and B.3). However, Franco-Hova hostilities broke out again. In 1881 the Hova had in defiance of the treaty of 1862 raised their flag in Ankify in front of the island of Nosy-Komba. In June 1882 Captain Le Timbre, on board the *Forfait*, destroyed it. In April 1883 Admiral Pierre arrived at Nosy-Be with a small squadron, set up military posts all along the northwest coast and occupied the city of Majunga on 17 May. In October 1884 Admiral Miot asked Tsialana II to supply 2000 Antankarana warriors to join the French column and embark on the *Allier* towards Vohemar. Tsialana II gave command of this expedition to his brothers Mamba and Tsimanenina, while Tsialana II himself embarked with 300 men on the *Beautemps-Beauprés* warship under the command of Commander Escande.

The expeditionary force, under the command of Captain Bergeolle of the French naval infantry, occupied Vohemar on 20 and 21 November 1884, and 190 men took the fort of Ambanio on 27 November and that of Andramparany, 30 km southeast of the latter, on 4 December. The fighting was intense and the Hova had defended well. Nevertheless, they left 250 dead, 5 guns and a great deal of booty on the field, while the French suffered one fatality. The Antankarana contingent had also done well. Tsialana II and several notables were summoned to Tamatave by Admiral Miot, who congratulated them and awarded the Madagascar Commemorative Medal to the Mpanjaka. The President of the Republic, Sadi-Carnot sent him a Sabre of Honour which his descendants preserve to this day along with that of King Louis Philippe.

Fig. B.2 Tsialana II and his family. Copyright l'Illustration August 1890

Fig. B.3 Tsialana II around 1910

The Antankarana still helped the French troops to occupy and hold the port of Diego Suarez (Antsiranana). The Hova were expelled from Namakia on 14 February 1885 and from Antanamitarana on 11 March. The Franco-Hova war ended with the peace treaty signed at Tamatave on 17 December 1885 aboard the *Naïade* by Admiral Miot and the Minister Plenipotentiary Patrimonio on the French side and by the Englishman General Willoughby on behalf of the Hova government and its queen Ranavalona I, the widow of Radama I.

Article 15 of the treaty stipulated:

> The Queen's Government expressly undertakes to treat the Sakalava and Antakarana with kindness. However, the Government of the (French) Republic reserves the right to occupy the bay of Diégo-Suarez and to make facilities thereon at its convenience.

In 1894 Tsialana II provided another 150 men to help the French Expeditionary Force at Marovoay, which had gone from Majunga to Antananarivo. That same year Tsialana II went from Nosy-Mitsiou to attack Governor Ratovelo, head of the Ambohimiarina military post (Raynaud Mount), 30 km south of Antsiranana, on the confines of his territory in Tsarakibany and forced Ratovelo to retreat to Sadjoavato, after tricking him into believing he would be given a supply of armaments. Ratovelo avenged himself by returning with the rest of his soldiers to ravage the Low Mahavavy area. The Antakarana were surprised at Betamboho, beside Ambodibonara, and escaped to the islands, leaving the area to the invaders who ran amok, took 15,000 head of cattle, burnt the villages and forests, and destroyed the crops. This was the last Hova foray.

Annexation of Madagascar by the French on 6 August 1896 put an end to all the difficulties and a long era of peace opened up for the Antankarana, who were able to re-enter their villages of the Grande-Terre without fear.

Several members of the royal families were appointed sub-governors by the French as a token of political goodwill.

Tsialana II died in October 1924 in Ambatoharanana after reigning for 40 years. His name then changed to Andriamanorinarivo. He was the first Mpanjaka who was not buried in the caves of the Ankarana. His successor was Mohamady Tsialana III.

Even though the French colonial administration and then the Malagasy Republic cancelled the former royal powers the royal tradition still exists and local power remains important. The present king is Tsimiaro III, but his legitimacy is contested by his cousin Lamboeny III (http://latribune.cyber-diego.com/societe/29-royaute-antakarana-va-t-on-vers-un-nouveau-conflit-royal.html) (Fig. B.4).

B.2 Main Institutions

On the death of a Mpanjaka (an Antankarana king), his successor is elected in principle by all the Antankarana population, at a gathering of both men and women. Indeed, Antankarana women are known for giving their opinion and even if they do not lead they sometimes exert great influence. It should be noted that, unlike the Sakalava, there has never been an Antankarana queen; custom forbids choosing a woman as Mpanjaka.

Formerly, when there were several candidates supporters would come to rally on a particular candidate's behalf. Very often the choice of nobles and advisors had already been done, as nothing should be put in the way of a small oligarchy trying to get the crowd to confirm the choice of king.

The Mpanjaka has above all religious power. He is the intermediary between the ancestors and the people. He is the

Fig. B.4 The Antankarana king Tsimiaro III welcomes the French consul during the ceremony of tsangantsainy in 1968 (from Lambek and Walsh 1999) (*Photo* Rouméguère)

only one who can specifically ask them for their protection during royal ceremonies. He is thus the protector and guarantor of the prosperity of the Antankarana. The flag mast, symbolising the presence of the ancestors and the continuity of the kingdom, remains standing at the royal village, Ambatoharanana, near the Mpanjaka's home. The latter has for its subjects a sacred character; he really embodies for them not only the entire royal line, but the entire people. He is the master of the earth. When touring his own territory, everywhere is his home and the *Andriana* (nobles) or the *Rangahy* (advisors) happily allow him to stay at their houses.

He is also the ultimate adjudicator in civil conflicts. The complainant starts by taking his case to the local Rangahy or Andriana, then if unresolved to the *Manantany* (prime minister), and then he can make a final appeal to the Mpanjaka. The Mpanjaka listens to the complaint, questions the witnesses, consults the interested Rangahy or Manantany who play the role of assessors. In large cases, especially those that have political repercussions, only the Manantany is consulted. Although notables may also be called, the Andriana are not because their jurisdiction is restricted to civil matters such as disputes about rice fields, herds, land, estates, inheritance, etc. Royal rulings are the last resort and it is rare for the loser to appeal to the civil administration, but it does happen.

Before establishment of the French administration, the Mpanjaka judged offenses and crimes according to the customs: if found guilty the individual concerned would be pilloried for several hours (but not days), have to pay fines and damages, be beaten with a bullwhip (rarely), have his property confiscated, put to death by immersion in the sea, tied up with a stone attached to his neck. Only the traitor Njakalagnitsy had his head cut off and his body remained exposed at the mercy of scavengers. This is the only example of execution involving blood, as the outpouring of blood is repugnant to the Antankarana except of course at times of war.

The adjudicators for criminal affairs were the Rangahy, Andriana or the Mpanjaka. Sometimes the latter permanently delegated his power to a prince assisted by a Rangahy. In this case any final appeal would go before the Mpanjaka.

The Mpanjaka never minted coins. For a very long time the monetary unit was the European 5-franc coin called the parata. There were two other coins: the loso (2.50 F) and the kirobovaky (1.25 F). Shells were never used as currency.

Tax in the Antankarana Kingdom was neither compulsory nor permanent. When the Mpanjaka needed money, he would ask the Rangahy and the Manantany to collect it. The *tatibato* (tax) was paid, either in money or in kind, depending on the circumstances.

When the Mpanjaka threw large feasts, it was customary for each community, family or even individual to bring gifts, in kind or in cash, to cover the expenses. They would hand these over directly to the Mpanjaka, or through the Manantany.

The Mpanjaka had his own land, which was cultivated by Makoa slaves sold to him by the Arabs. These slaves could be freed and enter the tribe of their masters. They then had the right to marry an Antankarana woman without dishonour for her. Antankarana men equally had the right to marry Makoa women. In this case the wife would be called *Sindrano* and her children *Zanaka aminny Sindrano*. They had the same status as the Antankarana of pure race, but no right to the throne.

The modern-day Mpanjaka has no executive power and nothing in common with primitive kings or tyrants who quite simply obliged hundreds or thousands of men to obey them. When he wants to make a decision, he summons his council of wise men and submits his proposal to them. After deliberation the council advises the Mpanjaka of its decision. The council has the power to reject the royal project. The council (*fivoriana*) comprises:

- all the nobles (Andriana) divided into six tribes, the first in rank being that of the Antandrona;
- royal officials (Rangahy and Manantany), made up of the pure but common people of the Ankarana, which avoids the concentration of authority in the hands of the nobles and stops oppression of the people by a privileged caste.

These officials are appointed by the Mpanjaka on the proposal of the concerned fokonolona (village community). He empowers them in a ceremony in front of the flag mast or, failing that, in front of the Tsangambato (stone), invoking the

ancestors. The officials are then marked with white earth on the forehead and on the temples and sworn to be faithful officials.

The Rangahy is responsible for royal interests in a group of villages (no more than three or four). He is under the command of the Manantany (possessor of the land awarded by the Mpanjaka), who is a kind of governor chosen hereditarily by the same family.

There are only two Manantany, one in Ampotsehy (canton of Andranofotsy, district of Ambilobe) and another in the peninsula of Anorontany (canton of Andranofanjava, district of Diego Suarez).

The number of Rangahy may vary; there are currently about 60 distributed throughout the district of Ambilobe, Nosy-Faly (district of Ambanja), in the cantons of Ampombiantambo, Andranofanjava, Diego Suarez, Sadjoavato, Anivorano-North, Irodo (Diégo district), plus three in the cantons of Daraina and Ampisikina (district of Vohémar).

For important regional business all the members of the council, even the most remote, come to a meeting called by the Mpanjaka at Ambilobe. For less important business only members of the council from the district of Ambilobe are involved.

This very simple organisation makes it possible to balance the power, protect the people against abuse and avoid tyranny.

B.3 Rites and Ceremonies

B.3.1 Visit to the Royal Graves in the Cliff of the Ankarana

Before any important royal ceremony or at times of war, disasters or epidemics the Mpanjaka has to go in great pomp and ceremony to pray to his ancestors buried in the caves of the Ankarana cliff.

For instance, members of the council could ask their ancestors for protection when they undergo future ceremonies at the flag mast. In principle, this visit must take place one year before the ceremony, but this delay can be shorter.

The day before the visit the Mpanjaka, with his suite and all the population go to Ampamahambahiny ("the place where foreigners can go"), a small valley enclosed in a cut in the cliff. That night is celebrated without special ceremony, but it is forbidden to lie down to the north or to the east, for the tombs of the kings are in these directions. On the following day, always a Friday, at sunrise the elder sister of the Mpanjaka, the *Andriambavibe*, asks the princesses to sew the cloth intended to be placed on the tomb of Tsialana I. They sing *rary* or sacred songs in a sitting position. The entire event is an exceptional thing to witness.

Next, two or four sacred dances are performed. They are of Sakalava origin. Two dancers wear the *sabaka*, a mitre-shaped lattice-leaf bonnet widening towards the tip and covered with a cloth bearing a crescent and a white star. This cloth falls like a sail to the shoulders.

They wear on their shoulders a cloth matching the colour of their cap, and on their loins a girdle of tissue containing a kind of bundle. They have a coloured loincloth (*lamba*). They hold a rifle with their right hand, and between their thumbs and fingers of their left hand a handkerchief (*tsi-ahifiky*, "which cannot be thrown away"). When the dancer is a prince, he is surrounded by two dancers who hold a wand (*fihozoko*) in their right hand, and if he does not have that rank he is only accompanied by one dancer. They also hold a handkerchief. Women usually perform these dances and are accompanied by one or two men.

The caps, the various draperies, the loincloths and the wands are kept at the home of the Mpanjaka and are only used for ceremonies.

The dances are warlike and consist of a stamp from back to front, from front to back, from right to left and then from left to right. The rifle is sometimes brandished, sometimes pointing towards an opponent who retreats, following the rhythm of the two *hazolahy* (elongated drums covered with cowhide, hung on a post, allowing the drummers to tap on the inner side with the hand and on the upper side with a stick) and a horn (*tandrokaka*), probably made of antelope horn and imported from Africa.

At the end of the show the dancers kneel in front of the Mpanjaka, lowering their foreheads and presenting the rifle which lies flat on their open hands. They receive a reward of silver. Note that in Ambatoharanana they only incline in front of the flag mast.

Afterwards everyone, with the Mpanjaka at the head of the procession, goes to the north, crosses the Ankarana River by means of a tree trunk and enters the cave that leads to the Antavy Circus where the kings Andriantsirotso and Lamboeni are buried. The princesses wear the Tsontso and other sacred objects. You have to enter the caves wearing only a loincloth (pants and underpants are not allowed). The Europeans have to put it on their shoulders so that the ancestors do not confuse them with the Hovas because of their clear skin.

Before entering, the Mpanjaka announces that the Hova, Antaimoro, Bestileo, Betanimena and the Antankarana descendants of Njakalagnitsy, the traitor who showed the secret passage to the Hova warriors, must not enter.

Walking on the scree at the base of the wall the Hova of Ambohimarina had built in 1835–1837 to blockade King Tsimiaro you reach a sort of very narrow natural gate after about 5 min. This is the passage where the Antankarana stopped their enemies. Finally, after walking for another 10 min illuminated by torches made of latanier palm leaves,

you reach an opening that gives access to the open Antavy Circus.

In the lower part of the cave, which is the most spacious area, the sacred dances and the *rary* take place again. Then, after climbing up to a higher level you come across the tomb of Tsialana I. A ceremony takes place and the white material sewn in the morning is placed in the tomb. This king died of smallpox and was buried, simply wrapped in a cloth, without a coffin.

Then, after ascending a few steps you reach the coffin of Tsimiaro, placed on the ground and protected from moisture by metal roofing sheets installed below a natural limestone vault. Behind him is an old armchair he liked. In his invocation the Mpanjaka, Mohamady Tsialana, recalls that Tsimiaro signed the treaty of 1841 and that he was the first to be converted to Islam. Hence, the Fatiha is recited before leaving. Returning to Ampamahambahiny the Mpanjaka, his suite and the assistants spend the next night there "sleeping the prayer" (*Mampandrijoro*) and only the next day return to Ambatoharanana.

The kings Tehimbola and Boanahajy were also buried in the Antavy Circus, but their graves were violated and destroyed by the Hova, as well as those of several princes. They have been sealed off and nobody goes there anymore. There are many other tombs of nobles or princes throughout the cliff. At present, only those nobles or princes with pagan beliefs are buried there.

Tsialana II, a Muslim by birth, built a family cemetery on a hill in the north of Ambatoharanana in 1905. It is a vast stone enclosure named Anjombavola (Silver Palace). He was buried in the northeast corner as have been all the princes and princesses closely related to the Mpanjaka. In 1938 Mpanjaka Mohamady Tsialana, who had just been elected, built a separate tomb in the southeast corner for his predecessor Tsimanegniny, beside whom a place was reserved for himself.

These ceremonies are undoubtedly similar to those of the other populations of Madagascar, but they have a magnitude and even a strangeness, in the petrified and tormented landscape of the Ankarana cliff, which resembles a fortress or a ruined temple.

B.3.2 Circumcision in the Royal Village (Savatsa)

Circumcision is mandatory for all Antankarana males before the age of 7. This custom has nothing to do with Islam as it probably dates back to Andriantsirotso. Private individuals can perform this operation whenever they want and with an operator of their choice. This gives rise to a simple family celebration.

When the royal family have children to circumcise the Mpanjaka proceeds with this operation with great pomp and ceremony and all the Antankarana, nobles or not, benefit by getting their sons circumcised at the same time.

Such mass circumcisions took place in 1927, 1933 and 1945. In 1949 it was decided that such events would coincide with raising the flag mast. This took place in Ambatoharanana on 4 and 5 November of that year when 154 boys were circumcised. This was after the royal ancestors had been warned or invoked between 1 and 3 September. In the early hours of the day before, after invoking the ancestors and having deposited a silver chain with six rings (*Masompanjava*) at the foot of the tree, two masts about 3 m long are cut. Called *Hazomahity* ("right wood") the men bring them solemnly to the main square. The women, their hair untied, come to meet them at the entrance of the village singing and throwing on them water and white rice. A second team carries satrana leaves and a third brings raffia fibres with the same ceremonial. They are deposited not far from the flag mast and the former Hazomahity are lined up from north to south on mats made of fresh and green latanier palm leaves.

The masts are shaped: one is pointed and symbolises the male sex, the other forms a fork with two separate branches and symbolises the female sex. It is between these two branches that the heads of sacrificed zebus are hung. They are positioned following the former Hazomahity, with the male to the south. The waste wood is carefully collected in the mats of latanier palm and thrown in fresh water not far from the village. Women sing *rary* and once again scatter white rice.

In the afternoon, under the direction of the first princess (Andriambavibe), the eldest sister of the Mpanjaka, the women prepare the headdresses of the boys to circumcise, cutting into the hair a sort of circle (*boangy*) around the head. Then, the boys' maternal uncles, wearing a crown made of raffia fibers, take the boys on their backs and surround their heads with a very clean white cloth (*lambantsaiky*), which the boys will wear after the operation for a week. The aunts, maternal or paternal, stand next to each other looking as cheerful as possible.

The four zebu bulls destined for sacrifice are chosen for their size and their conformation with respect to pelage. They are brought one by one, tied by the horns and a back foot. Uncles and aunts rush to meet each animal, uttering cries and waving their arms. There is competition among the men to grab the head and be dragged by the zebu. It is a true bullfight.

Each bull is laid on its left flank, its head facing east, just behind the Hazomahity row (thus to the west). The Mpanjaka, dressed in his traditional cocked hat and full uniform, stands west of the first bull (north of the row), and invokes his ancestors, one by one, not only the kings, but their whole

families, beginning with the oldest members. Every time he changes a generation he knocks the flank of the animal with the flat side of his sabre.

A choir, made up of princesses and women led by the eldest princess, sings the rary during the invocation. The boys with their uncles and aunts sit in front of the Mpanjaka on the other side of the zebu. The audience also sits on the ground.

After the prayer to the ancestors ends and the Mpanjaka returns home, uncles with their nephews on their back and spears in their hand, jump over the animals, still lying down, sacrificing and striking them with their spears. Only the bull lying in front of the Mpanjaka when he made his invocation is spared. It is released and is supposed to represent the life of the community. It returns back to the flock and can only be used for another ceremony. It cannot be sold.

At nightfall a vigil prayer (*mandrango*) begins with special songs that announce the ceremony. The boys sleep. At the second cock-crow in the early morning they are presented by their family to the operator in his hut. He circumcises them with a special razor-shaped knife made of iron. This instrument belongs to the operator's family. Indeed, circumcision is a hereditary function of the Ara family of Ambolipamba (canton of Ampombiantambo, district of Diego). At present (1949), the operator is Tsibany Ara, a young man aged about 27 years. Arriving in Ambatoharanana a week before he remains locked in a hut until the morning of the ceremony without communication with anyone. He must have no relationship with a woman, but he is allowed his usual food. When he needs to come out for natural reasons he is accompanied. The purpose of his isolation is the prevention of bad influences.

During the operation a volunteer washes the part to be operated on with ordinary water, but does not wash it after removal of the foreskin. The circumcised boys then go home. The foreskins are collected by the circumciser who will throw them himself into a freshwater marsh, such as a neighbouring *matsabory* ("pond"). The idea behind throwing the foreskins into cool water, as for the Hazomahity wood waste, is to refresh the patients' sores by imitative magic. Some families put the foreskin in the barrel of a rifle and shoot it in the air. The operator then passes from hut to hut and pours a secret preparation made from plants on the wounds. The payment he receives comes from the Mpanjaka, the families do not have to pay. The Mpanjaka then visits each child. Everyone can leave at the end of circumcision. A *sasasandry* feast follows 8 days later, but not all patients are required to attend, especially those who live far away. The boys can then remove their lambantsaiky. If there is a complication the parents ask the operator to come back and cure the boy himself.

B.3.3 Hazosaina: Erecting the Royal Flag Mast

The Hazosaina custom is believed to have been created by Andriantsirotso when he returned from Maroantsetra around 1697. *Saina* means "flag". It is emblematic of the Antankarana Kingdom as long as it persists.

The flag consists of a six-pointed star and a red crescent on a white background. It seems these symbols were copied by a successor of Andriantsirotso from the Muslim people of the Comores or Zanzibar, but this is only a hypothesis.

This mast is raised in the royal village of Ambatoharanana in the main square, north of the previous Hazomahity. It is only replaced when it falls naturally. The last one was erected by Mpanjaka Tsialana II in 1916 and was destroyed by the wind in 1947. It was made of very hard wood. In 1948 the circumstances were not very favourable, with political instability and bad harvests. In June 1949, Mpanjaka Mohamady Tsialana summoned his council in Ambilobe and proposed erecting the mast for this year. After deliberation the council fixed the date of the ceremony and appointed the deputy governor Mohajy Emest, a member of the royal family, to organise it, because in 1916 it was his uncle, the governor Nflarana, who was in charge of the ceremony. Monday, 24 October 1949, the beginning of the new moon, was chosen for the wood cutting. Indeed, all Antankarana ritual ceremonies must take place between the new moon and the end of the full moon. They never take place in the descending phase. Moreover, they do not take place on Tuesdays as they are considered a bad day whilst Fridays are considered the best.

A month before, a commission composed of eight persons, princes and councilors, had been sent to the Ambatofomena Forest, in the foothills of the Leviky range, to choose two trees. The site always has to be south of the royal village of Ambatoharanana, in commemoration of the dynasty, which came from this direction. *Hazomafana* ("unlucky trees") are automatically excluded. It is not the quality of the wood that is considered, but the name of the tree. It must have happiness associated with it. So, this time the *hazoambo* was chosen, because this appellation means "tree that grows well", which is auspicious. It is a simple white wood.

On Friday, 21 October 1949, six princesses appointed by the council had to manufacture (in one day and in the village designated by the council, Antanimiavotra) the following objects:

- four clay cups with feet (*fagnimbohagna*);
- a pair of bottle-shaped calabashes (*tsontso*) in which the *barisanantely* (boiled honey with water) is poured;

- incense prepared from the roots and leaves of a kind of vetiver called *volihera*, quite distinct from the ordinary incense that is found among Muslim traders named *robany*;
- four or six small baskets (*sobika*) made from the leaves of latanier palms (*satrana*), in which the incense is placed.

The day before the ceremony, the entire population spends the night in the forest near the trees to be cut, except for the Mpanjaka who waits in Ambatoharanana. On the day of the ceremony, the population is brought on the spot by the eight members of the commission. The women, their hair untied, sing sacred songs (*rary*).

People sit at the foot of the first tree and take their hats off, then the old prince *Antandrona* (in 1949 it was Meriny Tsitindry) puts embers and incense in each of the four clay cups arranged around the trunk facing north, south, east and west. A descendant of the Kelimandreha family, who helped the current Mpanjaka branch (Tsialana) to take power in 1809, approaches and prays invoking God (*Zanahary*), the Earth (*Tanimasina*) and the community of ancestors (*Ndazana*) in its entirety. The privilege of invoking the ancestors one by one is reserved for the Mpanjaka. He announces that when they come to cut this tree, it is not to play but to serve as a sacred mast and he wishes that it will be a lucky charm for the country. The women sing the rary and leave at the foot of the tree, as an offering, a special chain in silver called *Masom-panjava*, consisting of six rings.

He takes an axe and applies six blows to the tree, stops for a moment, pronouncing the formula *tsiota zaba tsiota avilomana* ("six chances, six lives"), then he applies another two blows and says on the eighth *Mivalovalo amin'ny Zanahary ("we implore God")*. Then he passes the axe to the other men who finish the work. The same ceremonial is observed for the second tree except that there are neither incense cups nor a silver chain. The bark of the tree trunks is removed. They must be of the same essence, which symbolises unity.

Then, the master of ceremonies designates four women or girls among the princesses and four men or young men among the princes to spread the honey contained in the Tsontso on to the two trunks. They are then transported to the place where the mast is to be made, on the left bank of the Mahavavy, almost in front of Ambilobe. The two parts are interlocked with tenon and mortice joints, then reinforced with sheet metal. This operation is called *Manohy* ("assemble and continue") and means that the kingdom, symbolised by the mast, must always continue. This work lasts until Monday evening. Tuesday is considered a bad day and so everyone rests. Many people attend these rites and spend the night eating and drinking a lot: more than 100 zebus are consumed and everybody brings several baskets of rice.

On Wednesday morning the mast is transported to Antsaravibe on the back of the men. Women and men follow singing. The night is spent in Antsaravibe (Marivorahona township) and the mast is carefully placed on two tree trunks, because it must never touch the ground. Finally, on Thursday morning it arrives in Ambatoharanana where the Mpanjaka solemnly welcomes it. Feasting continues all night. On Friday morning an old noble member of the royal family, Njaka Said of Nosy-Mitsiou, designated by the Mpanjaka, starts digging with an *angady* ("spade") invoking God and the Souls and asking for their protection. After which a hole is dug by the men. Then, Njaka Said throws a 5-franc silver coin into it, uttering a new invocation.

The lower end of the mast is placed in the hole. It is inclined towards the east and supported by forks. After another rary is sung and sacred warrior dances, it is gradually raised higher by ever longer forks and pulled westward by two ropes attached to its top. When it falls to the bottom of the hole and stands upright, exclamations resound with gunshots. Six princesses then leave the house of the Mpanjaka singing another rary. They carry on their heads a plate in which are deposited, along with water taken from the Ankeriky River or the Ankarana River, amulets composed of 5-franc silver coins and pearls, some the size of a black olive, streaked with yellow. They meet the women's choir, which goes back and forth, singing near the mast. On returning, they sprinkle the crowd with the water contained in the plates. When the mast is in place a young man climbs and detaches the tow ropes. Then those assembled remove their hats and the French flag and the Antankarana flag are simultaneously hoisted. The latter is sewn on the spot by the princesses under the direction of the Andriambavibe while a rary is sung.

The Mpanjaka, dressed in full uniform and surrounded by old counsellors, attends the scene from the veranda of his house. He climbs into a *filanjana* ("sedan chair") and makes eight turns around the new flag mast amid shouts and cheers, while the women's choir sings the rary *Ninay Manjaka*.

The noonday sun, the haze of dust, the multicoloured clothes of the women, the movement, the songs and the cries combine to make a unique scene full of colour and life.

"NINAY MANJAKA"… Long live the Royalty and the Antakarana people.

B.3.4 Tsimatahodrafy and the Mandresirafy Amulets (*Mandresy* Means "Conquest" and *Rafy* Means "Enemy")

When Andriantsirotso returned from Maroantsetra, he brought back a very young girl named Tsimatahodrafy (which means "who is not afraid of the adversary"). Legend has it that she was a witch who did all sorts of wonderful things. On one occasion she entered the marsh of Mahamasina to the north of Antsambalahy and lit a fire under the water from which smoke emanated, she cooked bananas there and then came out as if nothing had happened. On another occasion she stayed under the water with a child in her arms for hours and returned without difficulty to the open air with the child safe and sound. Another time she asked to be buried alive, and the villagers reluctantly agreed to do so. However, when the villagers returned from work in the fields, they found her in her usual place as if nothing had happened.

Putting legend aside, she lived for a long time and died in the reign of Tehimbola, which means she lived more than 100 years. She never married and had no children. She baptised the royal residence giving it the name *Mahavagnono* ("which makes it prosperous") and the river nearby the name *Mahavavy* ("which makes it weak"). She handed out amulets during the Mandresirafy ceremonies held at the time of wars or major festivals (erection of the flag mast, circumcision, prayers to ancestors, etc.). These amulets are 5-franc silver coins (or rather covered in silver leaf). They are today enclosed in a chest in the house of the Mpanjaka. It is Mora, the elder sister of the present Mpanjaka, who singing a rary removes them or places them in the chest. She must be dressed in white, her hair untied and accompanied by several women, but no more than four or six. The amulets are supposed to preserve the strength of the kingship and the Antankarana people and are handed down with great care from Mpanjaka to Mpanjaka.

While she lived with the two kings Andriantsirotso and Lamboeni, peace and prosperity reigned in the country. During the reign of the latter king, three of his sons, one of his nephews and many nobles were impatient to go to war as far away as Fort Dauphin. The wise Lamboeni went to Tsimatabodrafy and asked her to rid him of these trouble-makers despite them being family members. She made an amulet in the shape of a dhow, told them to get on board and bring back some booty. They took to the sea at Antenina and never returned.

Finally, Lamboeni's successor Tehimbola, accompanied by a group of angry young men, took up the war project and pestered her so much (they even went and fired gunshots into the roof of her hut) that she ceded and called for war on the Sakalava Bemazava. The latter tribe with the famous Andriantahora at their head then arrived on the banks of the Mahavavy after beating the Antankarana at Sengaloka. Tehimbola returned to find Tsimatahodrafy, begging him this time to force the enemy to back off and came up with a plan to make this happen. Legend has it that she ordered him to dress in red and present himself before the Sakalava; they were decimated by an epidemic of dysentery and eventually fled back to their homes. This is why Tehimbola, after his death, was named Andriamandresiarivo.

When she died a short time after these events, she left a testimony asking not to be buried but to be left outside on a kind of high stage. Her wish was not respected and she was finally buried. Her tomb was later found to have opened and her body disappeared. The hole is still visible north of Antsambalahy.

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Appendix C: The Legend of Tsimatahodrafy and the Tsangatsaina (from Tsintidry 1987)

Andriantsirotso (King of Ankarana) could not resist to his enemy Andriantahora and was obliged to escape to Maroantsetra. Raholo was then King of Maroantsetra. He was also a Zafinifotsy prince or prince of the silver line thus he was the brother of Andriantsirotso.

Andriantsirotso remained in Maroantsetra for three years.

He was about to return to the land of Antankarana with the soldiers of King Raholo, when a girl aged about eight years arrived at Maroantsetra.

This child did not mingle with the inhabitants except for several days after her arrival.

It was from that moment that she began to go with all the children of the village. No one knew exactly what fascinated these children in her, but still they did not want to return home again. So their parents complained to King Raholo.

The king sent a spy to watch the children. He surprised them playing on the bank of a river. At the time of the meal the little girl plunged into the river and brought back from the bottom of the water grilled bananas.

The spy ran to inform the king of what he had witnessed.

The king was amazed and made the children come to him. He asked them if the bananas they had eaten really came from the bottom of the water. The children said it was true.

"Who are you and where do you come from," asked the King to the little girl?

"I am the sister of Rasikajy, son of an astrologer, a native of Lavalohaliky. My arrival on that place is the result of a bad fate that my brothers threw at me because they saw in dreams the stars and the moon kneeling in front of me. They sent me far from them because they were afraid I could take their portion of rice."

"She is a magician," exclaimed King Raholo. "Take her with you too!"

"Are not you afraid of this country that is still at war," asked her comrades to the little girl?

"I am Tsimatahodrafy (*the one who does not dread rivals*). So leave before me," she said to Andriantsirotso. "After six days I will come. The one who wanted to seize your throne (*Andriantahora*) is no longer there; he returned to the Boeny, so return back to your home, and I will come to consecrate your kingdom.

She gave him a plant leaf with the following recommendation:

"As soon as you leave this village, throw this leaf out."

Andriantsirotso did that and the leaf turned into a trail of fire that traced the path until Hianiny. Before arriving there, he left his brother Andriantsifahaha in Bemarivo because he did not really believe that Andriantahora had really gone.

"If anything ever happens to me, you will survive as the root of the royal lineage."

Today the Antibemarivo (those of Bemarivo) are the descendant princes from Andriantsifahaha.

Six days after the arrival of Andriantsirotso at Hianiny, Tsimatahodrafy presented herself:

"Here I am, I come to found your kingdom. Henceforth, Mahavanono (*what makes prosperous*) will be the name of Hianiny and Mahavavy (*what makes hesitate*) will be the name of this river. Your enemies who come from the south will hesitate from the sight of this river and nobody will fight you. Seek for a Tsitakonala (*what the forest cannot hide*) to found the Antankarana kingdom."

"In this Antankarana country there is no tree bearing the name of Tsitakonala," declared the emissaries of Tsimatahodrafy.

"Ask the Antanala (*those of the forest*). The Tsitakohala exists in Arialamahavelono (*forest of life*), south of the Mahavavy. Take two, a female and a male," ordered Tsimatahodrafy.

"The Tsitakonala is a tree that the forest cannot hide; a very high tree called Hazoambo," explained the Antanala.

Since then two Hazoambo trunks are assembled to erect the flag mast of the Antankarana kings.

Reference

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E. Gilli, *The Ankarana Plateau in Madagascar*, Cave and Karst Systems of the World,
https://doi.org/10.1007/978-3-319-99879-4

Appendix D: Treaty of 5 March 1841

Text of the treaty concluded on 5 March 1841 between the King of France Louis Philippe and King Tsimiaro for the cession of the land of Ankara (including the Ankarana caves) and the surrounding islands.

I, Tsimiarou, son of Tsialou, King of Ankara, Nossi-Bé, Nosi Mitsiou, Nossi-Faly and other isles that surround our Great-Land possessions.

Declare, in presence of my Brothers and my Greats, that I give to His Majesty, the King Louis-Philippe 1st, King of France, all my rights on Madagascar Land, rights that I have from my ancestors; and that I give him all the isles that surround my Ankara kingdom.

We ask to be considered by the Great King as French citizens and to be treated like them.

I am convinced that His Majesty the Great King to whom I donate all my states will consider myself as his son, will protect me against any enemy and will depart from me every evil.

I am also convinced that his Highness the King of the French may wish to extend its caring on our people. We now have the name of French; whoever is the enemy of the Great King will be ours and we will use weapons against him; anyone who is an ally will be of ours and we shall help him with all means in our power.

If his majesty the King of the French, plants its flag on any point of our lands, we swear by God and the Last Judgment that we shall descend to death to protect it.

I pray His Majesty the Great King to send soldiers to stay in Nossi Mitsiou and a warship to protect us against the Hovas and other enemies.

This act was written by myself in the presence of Mr M. Passot officer of His Majesty the King of the French and send Mr Governor of Bourbon Mr GN commanding the King's scow "La Prévoyante" and all the officers in this vessel.

TSIMIAROU PASSOT, JEHENNE, G. CLOUE
March 5, 1841

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https://doi.org/10.1007/978-3-319-99879-4

Appendix E: Tourism Infrastructure in 2018

Note: This list is intended purely as a guide and is likely to change.

ANKARANA SPECIAL RESERVE
Management: Madagascar National Parks
Phone: +261 20 22 415 54
Website: http://www.parcs-madagascar.com/
http://www.parcs-madagascar.com/aire-protégée/réserve-spéciale-ankarana
Coordinates of Mahamasina entrance: 12.968051°S, 49.138496°E
Fares (per person)

Adult	65,000 Ar
Child	25,000 Ar
Malagasy adult	2000 Ar
Malagasy child	500 Ar

EASTERN ENTRANCE OF THE ANKARANA PARK IN MAHAMASINA

Hotels and lodges

- Le Relais de l'Ankarana

Website: http://relaisdelankarana.unblog.fr/
Phone: +261.32 05 057 24; +261.32 02 222 94
Email: ankarana_lerelais@yahoo.fr
6 bungalows; double and twin rooms; separate WC and bathroom with solar-powered warm water; electricity 18–22 h.
Breakfast and meals
Car park

- Goolam Lodges

100 m inside the park
Phone: +261.32 02 691 06; +261.34 01 832 75; +261.33 11 459 05
Bar ("Bar de Routard"), restaurant and small grocery
Electricity at night and in the evening
8 bungalows with 2 double beds
1 bungalow with 1 double bed.
3 outside WCs and 4 showers

- Ankarana Lodge (ex-Tsingy Lodge)

1 km from the eastern entrance of the park
Phone: +261.32 04 908 10; +261.32 02 440 97
Website: http://ankarana-lodge.com
Ecolodge.
Bar/restaurant
Rooms with bathrooms
Bungalows with mosquito nets
WC and showers with warm water outside;
Solar electricity and generator
Shuttle from/to Ankify and Diego Suarez

Camp areas

- Ankarana Village

Campement Diego-Guide
50 m south of the eastern entrance to the park
Phone: +261.32 40 722 02; +261.32 07 906 91
Water and electricity at certain hours

- Aurélien guide camp

+261.32 02 786 00; +261.32 40 630 14
50 m before Goolam Lodge

- Chez Laurent Camp

+261.32 07 992 89
Bungalows with outside facilities
Bungalow with bathroom
Meals

- There are also several other small camping places and bungalows close to the entrance.

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WESTERN ENTRANCE OF THE PARK

Access is **very** difficult (four-wheel-drive cars only). Check in advance to see whether these facilities are still available.

Camp areas

King de la Piste (King of the trail) camp in Andrafiabe

Information: King de la Piste
Boulevard Etienne in front of Hôtel de la Poste in Diego Suarez
Phone: +261 020 82 225 99; 020 82 903 69; 020 82 235 60

- American Camp in Andrafiabe area (Matsaborimanga):

Information: Madagascar National Parks
Phone: +261 20 22 415 54
4 camping areas without shelters; 5 sheltered camping areas; 1 simple camping area
Amenities: 2 WCs, 2 showers, a 10,000-L tank with a hand pump for water supply, 2 camping tables with parasols, 3 camping tables without parasols

SOUTHERN ANKARANA

Access is possible from the national road from Isesy, 7 km north of Ambilobe. A sandy trail goes to Antsaravibe, then Ambatoharanana. It is accessible all the year but may be difficult during the rainy season without a four-wheel-drive car.

- *Tsingy Relais "Chez Tonton Robert", BP 96, Ambilobe 204*

Phone: 020 82 065 65; 032 02 759 30
On the same road a short distance after Antsaravibe village.
Several nungalows made of local materials; warm water and WC; electricity at night.
Note: It seems that the Relais was closed in 2017.

- *Iharana Bush camp*

A few kilometres after Tonton Robert
Booking c/o Océane Aventures
22, rue Andrianary Ratianarivo, 101 Ampasamadinika, Antananarivo, Madagascar, BP 1056
Phone/mobile: (+261) 20 22 312 10; Mob: (+261) 32 11 062 96; Fax: (+261) 20 22 312 22
GPS coordinates: 13.159725°S, 49.04022°E
16 individual cabanas and a restaurant on the shore of a lake. Local guides are available to visit the caves and the tsingy.

- *Miavana Private Islands*

A private park is undergoing construction in Andranomilika Butte. It includes a nature protection area, a tsingy trail, several undergound trails and an ecolodge. Access will be possible either by car or by helicopter from the resort of Miavana (Fig. E.1).
https://timeandtideafrica.com/miavana

Fig. E.1 Trip by helicopter from Miavana in the Andranomilika Butte