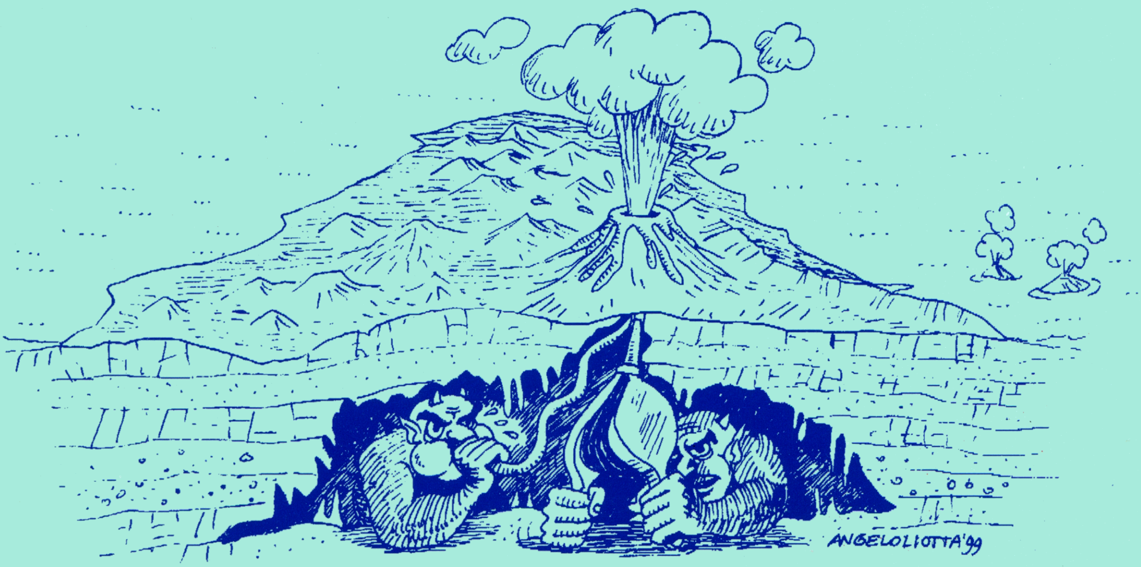
INSIDE VOLCANOES

IXth International Symposium on Vulcanospeleology

Catania, Italy, 11-19 september 1999



EXCURSION GUIDE

LAVA TUBES AND LAVA CAVES ON ETNA VOLCANO

Sonia Calvari and Marco Liuzzo

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LAVA TUBES AND LAVA CAVES ON ETNA VOLCANO

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Printed with financial support from:
Gruppo Nazionale per la Vulcanologia
via Nizza, 128
00198 Roma

Realisation:
Centro Speleologico Etneo
via Cagliari, 15
95127 Catania

INDEX

INTRODUCTION

Mt Etna is the highest and most active volcano in Europe. It extends north of Catania, and with its 3300 m of altitude it influences the climate of the area. The presence of the volcano allows the existence of persistent ice into a few lava caves, as for example the Grotta del Gelo and the Abisso del Ghiaccio, a fact that is exceptional at this latitude.

Etna has been called Mons Gebel by Arabians, which literally means "The Mountain". Mt Etna conceals inside it all kinds of volcanic caves recognised by modern classifications. Another record of this volcano is given by the many rare secondary minerals discovered into its caves, many of them found here for the first time [Del Monte et al., 1983; Forti e Marino, 1990; Forti et al., 1994].

The eruptive activity of Etna started about 500,000 years ago. With time, the accumulation of eruptive products through the millennia caused the growth of a strato-volcano, where the feeding system gradually migrated from the Ionic coast of Sicily towards west.

There are more than 200 lava caves described for the Etna region. A few are in prehistoric lava flows, such as those of S. Gregorio, but they are more commonly found in recent lava flows.

PART I: GEOLOGICAL BACKGROUND

1.1. Regional setting

Mt Etna is the largest active volcano in Europe, and in view of its virtually continuous activity it represents an ideal laboratory for scientists interested in investigating volcanic processes. The volcano is located in a very complex geodynamic setting governed by the general compressive regime due to the collision between the African and Eurasian Plates. Two first-order structural geodynamic elements merge beneath Mt Etna. The first is a segment of the Appennine-Maghrebian chain in the northern sector of Etna. It comprises a series of thrust-sheets made up of marine sedimentary sequences deposited in different paleogeographic domains along the northern margin of the African Plate. These have been progressively thrust over each other from Eocene to Quaternary [Lentini, 1982]. The second is the Iblean Foreland, which is located in the southern sector of Etna, and forms the northern margin of the African Plate [McKenzie, 1970; Barberi et al., 1974]. This comprises a thick Triassic to Oligocene succession of limestone with volcanic intercalation [Lentini, 1982]. The Iblean Foreland is dislocated to the east by a swarm of steep faults belonging to the Malta Escarpment. This major crustal fault separates eastern Sicily from the more than 4 km deep Ionic Abyssal Plain. The faults of the Malta Escarpment are considered to migrate westwards, producing a progressive collapse of the western boundary of the Ionic border of Sicily [Scandone et al., 1981; Lentini, 1982] and an apparent westward migration of the volcanic activity in the Etna region [Borgia et al., 1992].

Etna formed on a zone of structural high at the level of the deep crust with respect to the Ionic Basin and inner Sicily [Hirn et al., 1997]. The crustal weakness responsible for volcanism is produced by the convergence of three fundamental structures: (1) the NNW-SSE trending Ionic faults of the Malta Escarpment; (2) the NNE-SSW trending faults of the Comiso-Messina line; and (3) the E-W faults of central Sicily belonging to the Mt Kumeta-Alcantara line [Ghisetti and Vezzani, 1984]. This regional geodynamic arrangement induces an anomalous stress field in the Etna area which is uncommon for an intraplate volcano [Lo Giudice and Rasà, 1992]. East-west tensile stresses are superimposed on compressive stresses acting in a north-south direction [Lo Giudice and Rasà, 1992]. The statistical analysis of the whole Etnean area shows essentially compressive conditions in a NNE-SSW direction and a tensional pattern in a WNW-ESE direction [Frazzetta and Villari, 1981; Lo Giudice et al., 1982].

1.2. History and evolution of Mt Etna

The volcano began to form 500,000 years ago [Romano, 1982], with pillow lavas erupted from fissures on the floor of a vast bay [Rittmann, 1973] that was located in the area currently occupied by the volcano. Gradually the active vents, through overlapping of many volcanic edifices [Ferrari et al., 1989; Calvari et al., 1994c; Coltelli et al., 1994], migrated westwards to the present summit zone, eventually producing a 3,330 m high stratovolcano with a mean basal diameter of 40 kilometres.

The composition of lavas erupted by the volcano has changed significantly during the past 0.5 Myr. Early submarine lavas and shallow intrusions are tholeiitic in composition [Cristofolini, 1972], and are now well exposed along the coast between Aci Castello and Acitrezza. As the eruptive activity gradually changed from fissure eruptions to central vents [Rittmann, 1973; Romano, 1982], the composition of magmas evolved through transitional members [Tanguy, 1978] towards the present mildly alkaline, sodic association [Armienti et al., 1994]. More evolved magmas of benmoreitic and trachitic compositions have been erupted during the lifespan of the Ellittico volcano [D'Orazio et al., 1997], which was active between 40,000 and 15,000 years BP [Calvari et al., 1994c; Coltelli et al., 1994]. Following a major caldera collapse about 15,000 years ago [De Rita et al., 1991], later products became less evolved and with a nearly constant hawaiitic composition [Armienti et al., 1994].

The present volcanic cone is constructed on the remains of a number of previous volcanoes, which are beautifully exposed along the inner walls of Valle del Bove [Ferrari et al., 1989; Calvari et al., 1994c; Coltelli et al., 1994]. During its life Mount Etna was also the site of caldera collapse events in the summit region, and this is reflected in the morphology of the upper reaches of the volcano. The oldest recognisable is the Ellittico Caldera [Romano and Guest, 1979], formed about 15,000 years ago during a highly explosive eruption that emplaced the Biancavilla ignimbrite [De Rita et al., 1991]. A more recent caldera collapse formed the Il Piano caldera about 2000 years ago [Kieffer, 1975; Romano, 1982]. A smaller, more recent caldera collapse took place during the 1669 eruption, the largest historic Etna eruption [Corsaro et al., 1996], that produced 1 km3 of lava and partially destroyed the city of Catania [Romano and Sturiale, 1982].

The volcanic pile of Mt Etna does not have the shape of a symmetric cone, as would be expected of a central volcano, but it is elongated in an N-S direction. An analysis of structural lineaments suggests that this shape is mainly the result of the regional stress field [Frazzetta and Villari, 1981]. The tensional field is oriented N-S across the summit craters and this produced two main rift zones that bisect the summit of the volcano in this direction [Frazzetta and Villari, 1981].

1.3. Shape of Mt Etna

The profile of Etna is punctuated by over 260 parasitic cones distributed along its flanks, from the summit down to 100 m a.s.l. [Romano et al., 1979]. These cones witness the importance of past eccentric and flank eruptions. The main morphologic feature of the eastern slope of Etna is Valle del Bove, a 5 km wide, 8 km long valley elongated E-W that cuts the volcano from an altitude of 2600 m to 1000 m a.s.l.. Its maximum depth is about 1000 m to the west, and it gently decreases eastwards. Previous workers have suggested that it formed by glacial erosion [Vagliasindi, 1949], caldera collapse [Kieffer, 1970; Kieffer, 1985; McGuire, 1982; Romano, 1982; Romano and Sturiale, 1981], or major slope failure [Borgia et al., 1992; Chester et al., 1987; Duncan et al., 1984; Guest et al., 1984; Lo Giudice and Rasà, 1992]. A new interpretation based on new geologic and stratigraphic data [Calvari and Groppelli, 1996; Calvari et al., 1998b] shows that the Valle del Bove is the product of a flank collapse occurred about 10,000 years ago.

The present summit cone lies inside the Il Piano Caldera, it has a basal width of 1 km, and rises from 3000 to 3300 m a.s.l.. The persistent activity typical of the summit region is currently implemented from four active craters. Two of them, the North-East Crater and the South-East Crater, are located in two parasitic cones that formed in 1911 and 1971 [Guest, 1973; Guest, 1982; Calvari et al., 1994a], respectively on the NE flank and SE base of the summit cone. Inside the summit cone two larger craters are separated by a thin N-S septum. The Chasm, to the east, which has been observed at least since the beginning of this century [Guest, 1973; Guest, 1982; Chester et al., 1985], and the Bocca Nuova, to the west, opened in 1968 initially as a 2 m wide hole [Calvari et al., 1998a]. Both craters are now approximately 200 m wide and 100 m deep, but the change in level of the magma inside the feeding conduit produces significant variations in the morphology and depth of the crater floor [Guest, 1973; Guest, 1982; Calvari et al., 1994a; Calvari et al., 1995; Calvari et al., 1998a], especially during phases preceding and following major eruptions [Bertagnini et al., 1990; Calvari et al., 1994b].

Flank eruptions result in the emission of lava flows from low-altitude eruptive fissures. These flows represent major volcanic hazards on Etna [Frazzetta and Romano, 1978; Frazzetta and Romano, 1984; Guest and Murray, 1979; Villari, 1983a; Villari, 1983b]. Although lava flows on Etna are generally not a major threat to the population, the sudden opening of eruptive fissures on the lower reaches of the volcano [Frazzetta and Romano, 1978; Frazzetta and Romano, 1984; Guest and Murray, 1979; Villari, 1983a; Villari, 1983b] can result in exceptional velocities, such as the speed of 1 km/h measured during of the 1981 eruption [Cosentino et al., 1981; Guest et al., 1987]. Lava containment by earth barriers, or lava diversion by breaching the side of the main lava channel or of the master tube, are at present the most effective ways of stopping or reducing advance rates of lava [Barberi et al., 1993].

PART II: LAVA TUBES AND CAVES ON ETNA

2.1 Introduction

Etnean lava tubes and caves have been explored since the start of this century, and the actual lava tubes mapped in the Etna region are over 200. Lava tubes form during the emplacement of the flow itself, and it can occur one week to a few months to produce a lava tube inside a lava flow [Mattox et al., 1993; Calvari e Pinkerton, 1998].

Lava tubes form both in aa and pahoehoe lava flows, although tubes formed in pahoehoe flows are better known and considered more common. On Etna, most of the tubes open into aa lava flows, but there are also a few examples of tubes in pahoehoe lavas, such as the Micio Conti tube and many small and surficial tubes in the 1614-1624 flow field, also known on Etna as the Dammusi flow field.

Licitra [1978] distinguished two main kinds of caves in lavas: 1) caves formed inside eruptive fissures, and 2) caves formed inside lavas during their flowage on the surface. Caves into fissures are usually difficult to explore because they extend in depth, whereas lava tubes are commonly surficial. The geological processes that produce these two kinds of caves are very different. Lava tubes generally start in forming along lava channels that progressively roof over. The processes of progressive sealing of lava channels on Etna have been recently described in detail [Calvari and Pinkerton, 1998]. Caves that open into eruptive fissures formed as a consequence of surficial earthquakes that generally precede eruptions. They produce a crack in the soil that is suddenly filled in by lava erupting on the surface. Later drainage of the lava from the fissure leaves a narrow and deep cave. There are also caves that have features in between the two kinds just described, because the drainage of a fissure can occur through a surface lava flow which eventually produces a tube. These tubes are pretty rare, but good examples on Etna are given by the famous Tre Livelli tube [Corsaro et al., 1990] and by the Serracozzo cave.

2.2 Lava tubes and volcanic hazard

Caves that develop in limestone have an important role in conditioning the hydrology of the area where they are distributed. In the same way, the knowledge of the extension of lava caves in the environment is very important for planning the use of land and especially for hazard purposes. An interesting example comes from Hawaii, where it was found that old lava tubes can be reactivated during effusive eruptions, allowing longer distances to be reached by magma [Mattox et al., 1993; Kauahikaua et al., 1998]. It is then essential to know the hidden path of the main and larger lava tubes in a way to prevent similar events on Etna. In fact, lava tubes have often a thin roof that can be easily broken by the overlapping of a new thick flow.

The reactivation of old lava tubes has never been reported at Etna, but it is possible that there was lack of attention, and then information, about this kind of events. Here we resume some of the recently published theories that explain the mechanisms of formation of lava tubes and their role in the emplacement of lava flows.

2.3 An example from Etna's history

Mt Etna is a volcano that typically shows effusive activity and sometimes paroxysmal explosive phases from the summit craters. Volcanic activity is almost continuously present at the summit craters, but every 5 to 10 years there is a major flank eruption [Wadge, 1978]. It generally produces lava flows having velocities of a few meters per hour, then not dangerous for people's safety. However, lava flows can produce damages to villages and properties because they destroy everything along their path.

Unfortunately, it is not always possible to forecast when an eruption will occur, how long it will last, and what the maximum distance covered by lava flows will be. Recent studies showed that it is possible to estimate the maximum extent of lava flows using the maximum effusion rate measured at the start of an eruption [Calvari and Pinkerton, 1998]. However, the calculated maximum flow length is close to reality only if lava tubes do not develop. But how can lava tubes increase the maximum length of lava flows?

Lava tubes had an important role in most of the effusive eruptions that occurred on Etna. A revealing example was that of the large 1669 eruption. This eruption had a total output of 1 km^3 of lava, with flows over 16 km long, which destroyed the western part of Catania. The initial phase of the eruption was characterised by surficial earthquakes that destroyed Nicolosi, 16 km distance from Catania. Eruptive activity shortly followed earlier seismic events, and a few explosive vents opened near Nicolosi. Spatters produced by strombolian activity accumulated around the vents and formed three cones, called Monti Rossi. The start of effusive activity from the base of these cones produced lava flows which reached Catania after 6 weeks from the start of the eruption [Corsaro et al., 1996]. For the following 2.5 months more flows threatened Catania, destroying many of those buildings that survived the previous flows. Active flows and vents near Catania disappeared only when supply at the source halted. But what allowed new flows to start from the distal margins of the flow field? And how could lava travel for 16 km from the source without cooling?

2.4 Lava tubes

In order to understand the volcanic processes that allow long lava flows to form, we should consider the formation of lava tubes. A lava flow looses heat from its surface by thermal exchange with the atmosphere. This causes the formation and growth of a solid crust, which becomes more rigid and thick with time and cooling. Walker [1971] recognised that lava flow length is related to effusion rate. High effusion rates produce very long lava flows. Later studies [Calvari e Pinkerton, 1998] showed that, on Etna, an effusion rate of about 20 m3/s produces lava flows of 5 km length. This value was typical of the first phase of the 1991-1993 eruption which threatened Zafferana Etnea, the strongest eruption at Etna during the last three centuries [Calvari et al., 1994]. However, for the 1669 case, to suggest a high effusion rate does not explain how lava flows could travel 16 km without forming a crust and stopping. A recent analysis of this eruption [Corsaro et al., 1996] showed that the flows expanding towards Catania slowed down many times. The mechanism that allowed further expansion is the formation of lava tubes [Corsaro et al., 1996].

The formation of solid crust around a lava flow allows very little heat loss. This crust gradually grows forming a lava tube, which prevents the flow from further thermal exchange. Many mechanisms of tube formation have been described for Hawaiian volcanoes. The lavas from Mt Etna have a composition slightly different from the Hawaiian lavas. These are very fluid, and mainly form pahoehoe, smooth flows. Etnean lavas are more viscous, and their common surface is very rough, or aa. Because lava tubes have been mainly studied in Hawaii, many scientists believed that these structures form exclusively in pahoehoe, smooth lavas. Recent studies showed that lava tubes are very common also in aa, rough lavas. Three mechanisms of tube formation have been recognised on Etna in aa lava flows [Calvari e Pinkerton, 1998].

When a lava flow expands on the ground, cooling of the flow margins produces lateral rigid levées which enclose a middle, fluid lava channel. Levées can grow by accretion and they can eventually merge in the upper part of the lava channel forming a stable roof.

Little variations of the lava level inside the channel can add more lava to this bridge causing its growth both upslope and downslope. This mechanism is very efficient in narrow (less than 5 m) lava channels. Sudden changes in lava level may destroy these delicate structures, and the process will start again. Incomplete sealing of the tube's roof leaves openings called skylights. They often allow measurements, sampling and observations into the tube while still active. The second mechanism of tube formation was observed in wide (more than 5 m) lava channels. The merging of lateral levées in this case is more difficult because a wide roof is less stable. However, cooling of the flow surface causes an accumulation of aa blocks that jam together forming a continuous carpet on the flow surface. The hot fluid flowing below may intrude between the loose blocks forming a cement that increases the stability of the crust. The third mechanism was described on Etna for the first time [Calvari e Pinkerton, 1998] using data from the 1991-1993 eruption. This process occurs in the frontal zone of aa lava flows that expand on low gradient ground. When the flow reaches the maximum distance allowed by the limiting effect of the crust, and supply from the source continues, flow front grows and inflates.

When the pressure of lava stored in the front region overwhelms crust resistance, an ephemeral vent opens, draining the fluid part of the flow and producing another lava flow. If this process is slow enough to allow the development of a stable crust, a tube sector will form at the flow front of the aa flow. These three mechanisms can occur in the same lava flow and eventually produce a main lava tube.

2.5 Lava tubes and lava caves

Not all lava tubes form lava caves. In order for a lava tube to become a cave it is necessary that drainage takes place. Moreover, an opening on the tube roof or side is essential for the cave to be discovered. The size of a lava cave depends on both primary and secondary factors. Primary processes are those that produced the size of the lava tube, such as effusion rate, ground slope, thermal and mechanical erosion of the base, tube capture. Secondary processes can be drainage, roof collapse, or tube coalescence due to roof collapse. An important effect in defining the size of the tube is erosion. In Hawaii erosion of tube's base has been measured as high as 10 cm/day, suggesting that Hawaiian tubes become larger with time [Cooper and Kauahikaua, 1992; Kauahikaua et al., 1998]. This has not been demonstrated for Etna, where no clear evidences of tube erosion have yet been found. The size of lava tubes on Etna is apparently related to different processes, such as tube coalescence which has been found extremely common in many lava tubes [Calvari and Pinkerton, 1999]. Beautiful examples are the Intraleo cave and the more recent Cutrona cave that formed into the 1991-1993 lava flow field [Giudice and Leotta, 1995]. Lava caves cannot form without drainage of lava tubes. Drainage can be improved by higher downslope ground gradient [Wood, 1975]. However, it is also necessary that the viscosity of the lava inside the tube is low enough to allow drainage.

2.6 Caves inside eruptive fissures

Mt Etna is characterised along its flanks by many cones that testify flank eruptions. Not all flank eruptions on Etna show also caves into their fissures, and this has not a simple explanation. Possible explanations could be that inner collapses obstructed caves into eruptive fissures, or that drainage did not happen. However, drainage inside eruptive fissures is essentially vertical, and caves in this environment develop mainly in a vertical direction, producing very narrow rooms several tens of meters deep. The magma movement inside an eruptive fissure is variable and changes with time. Here there are vertical flows, directed both upwards and downward, and horizontal flows determined by topography and drainage. All these factors influence the morphologies inside caves developed into fissures, which are also dependent on the variations of effusion rate during the eruption.

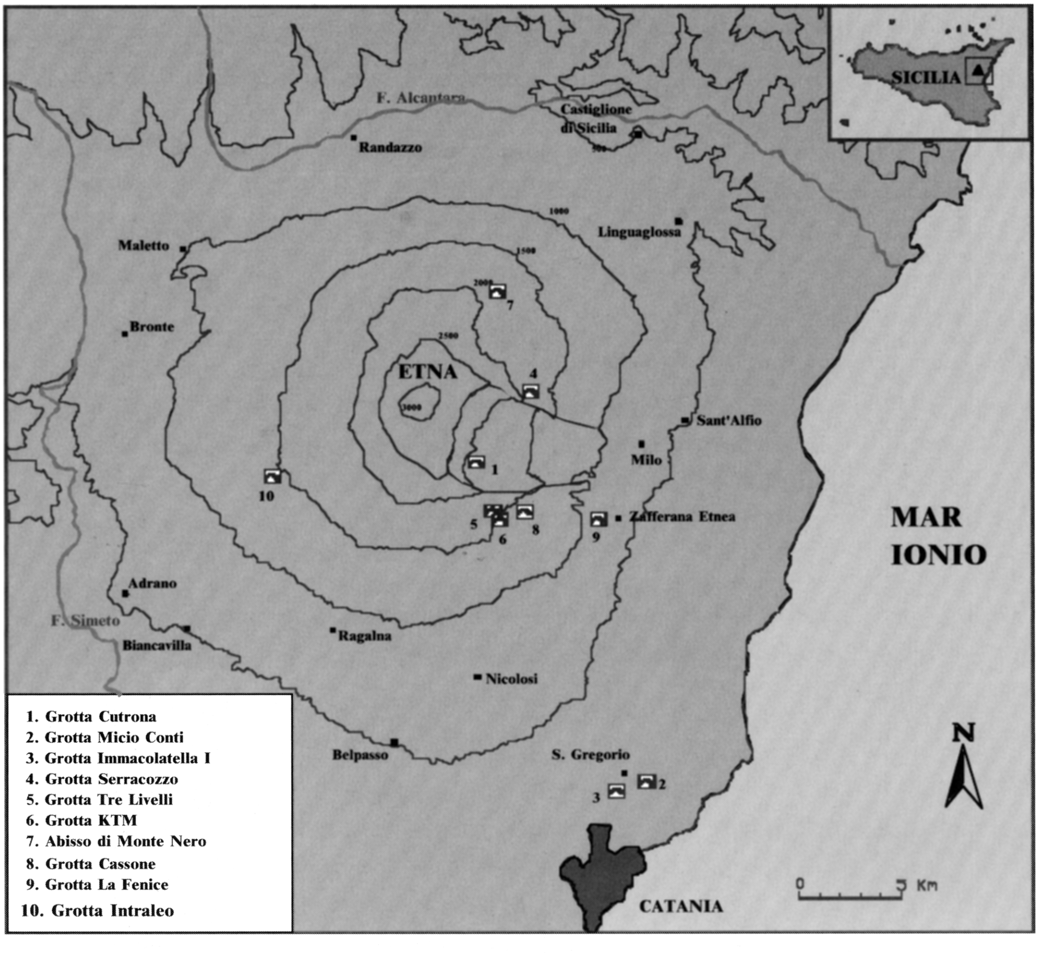
The lava flowing into an eruptive fissure is quickly cooled down by the contact with the surrounding rocks. This produces an insulating effect, which allows the flow into the innermost part of the fissure to move without additional heat loss. The cooling into a fissure propagates inward, causing multiple inner linings [Leotta and Liuzzo, 1998].

One of the main features inside caves developed into eruptive fissures is that they do not present a single vertical chamber, but a number of stacked cavities separated by narrow intermediate passages. This causes the formation of very complex caves, whose downward exploration is possible passing through constrictions around fallen blocks [Leotta and Liuzzo, 1998].

The decrease in effusion rate at the end of an eruption causes drainage of the upper part of the eruptive fissure, and it is this part that will be explored by speleologists.

Caves into eruptive fissures have orientations due to the regional tectonic structures, but not all of them have a linear pattern, and a good example is given by the caves developed into the eruptive fissure of the 1981 eruption [Leotta and Liuzzo, 1998].

PART III: EXCURSIONS AND CAVES DESCRIPTIONS



3.1 CUTRONA CAVE

1991-1993 eruption

Saturday, 11 September

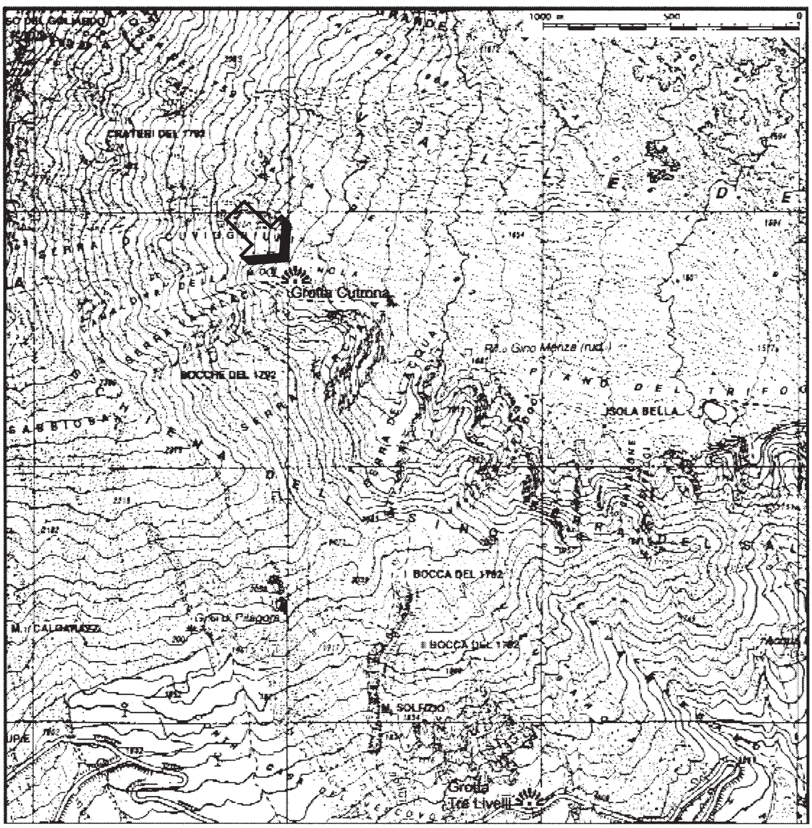
DEPARTURE FROM CATANIA 07:00
EXPECTED RETURN TIME 21:00

ITINERARY OF APPROACH

Elevation at departure	1835 m
Elevation at arrival	1875 m
Maximum elevation	2100 m
Maximum elevation range	265 m
Difficulty	Demanding
Walking distance	3.5 km
Walking time	2.5 hrs

INSIDE THE CAVE

Total length	870 m
Elevation range	97 m
Difficulty	Medium



IGM Serie 25 Foglio 625
SEZ. IV - Sant'Alfio

ITINERARY

The Grotta Cutrona opens at the lower end of the Canalone della Montagnola, in the south-western area of the Valle del Bove. The visitor should follow the S.P. 92 road linking Zafferana to Rifugio Sapienza, and park his car at a lay-by at 1850 m height, in front of the crossroad of Pedara. One hour is necessary from this point to the lower end of Schiena dell'Asino, at about 2100 m elevation (remarkable sightseeing over the Valle del Bove), through a well-marked path of the Forest Service. An off-track rove north-westward brings the visitor from here to the sandy slope below Serra Pirciata; the rove prosecutes downslope, eastwards and then northwards, between Serra Pirciata and Serra Vavalaci, up to the lava flow field of the 1991-1993 eruption. A final off-track rove northward, through the recent lava field, will bring the visitor to the cave entrance in 2.5 hours altogether.

Cutrona Cave

DESCRIPTION OF THE CAVE AND OF ITS FEATURES

The cave is formed by two sub-parallel branches of about 400 m length each, oriented E-W and joined at the western end, for a total development of 870 m.

A roof collapse, occurred in a passage connecting the two branches, leads into the cave by a 5 m shaft, to be descended by metallic speleological ladders. A ten meters on-all-fours crawl, 5 m wide, takes the visitor northward, up to the fork wherefrom the two branches start. This passage is very wide, and its floor displays several ropy flows having different directions [Giudice and Leotta, 1994]. The floor becomes rugged, or covered by collapse debris, in the remainder segment of the crawl.

The northern branch develops downslope eastward by segments with variable gradients. Low gradients correspond to wide sections, whereas gradient increases involve dramatic reductions of the passage width. The gallery closes with a wide room, featured by large collapses, which mark the end of the cave or hide a possible passage to an unknown prosecution.

A stack of collapse debris, some 20 m long, hampers the way from the entrance to the southern branch, which is also affected by gradient (and relevant width) variations.

Most of the walls are intensely grooved, and many remelting short stalactites (called in Italian "denti di cane", literally "dog's teeth") hang from the ceiling. Several lateral benches give evidence of prolonged maintenance in flow rates. The floor of the gallery, in its final segment, is featured by large lava slabs, which gradually trend and weld to the roof, thus closing any prosecution.

This cave is well known for the abundance of speleothems, generated by secondary mineralisations, including very rare minerals [Forti et al., 1994] discovered during the first survey, which was performed less than one year after the eruption end. Unfortunately this very specific feature of the cave cannot be observed any longer, due to the extreme solubility of these minerals.

3.2 SAN GREGORIO CAVES

Prehistoric and historic lava flows

Sunday, 12 September

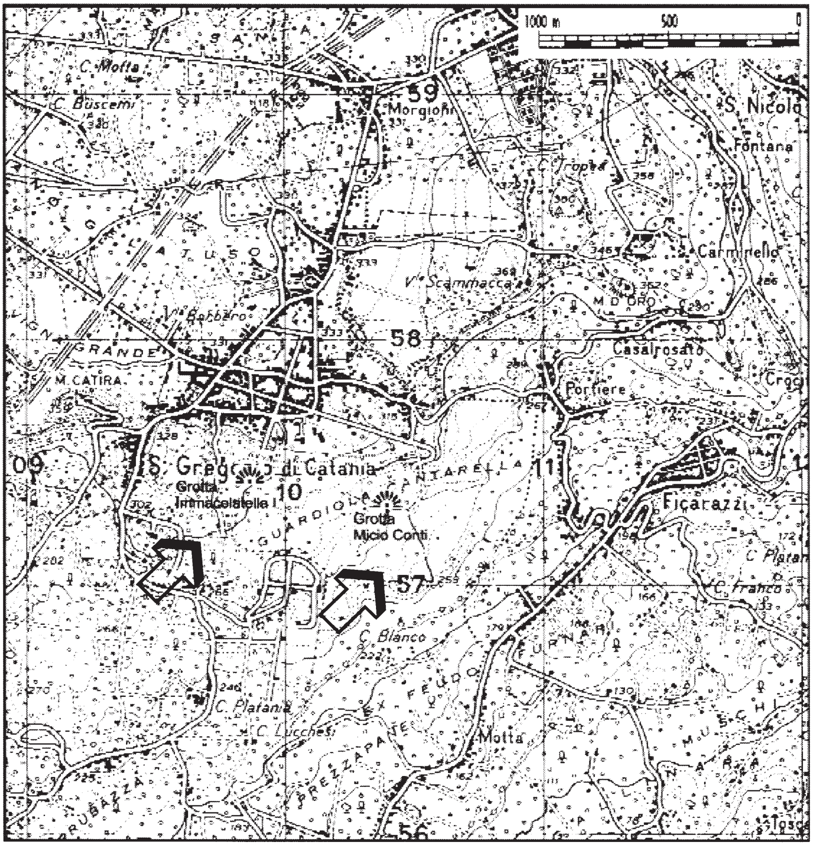
DEPARTURE FROM CATANIA 8.30
EXPECTED RETURN TIME 17.00

ITINERARY OF APPROACH

Elevation at departure	280 m
Elevation at arrival	300 m
Maximum elevation	20 m
Difficulty	Easy
Walking distance	200 m
Walking time	10 min.

INSIDE THE CAVE

Total length Micio Conti	350 m
Total length Immacolatella	305 m
Difficulty	Low



IGM Foglio 270
Quadrante IV Orientamento S-E (edizione 1971) Catania

The Guardiola Cantarella area, at the southeast margin of the built-up area of San Gregorio di Catania, contains 12 known caves in two different lava fields, respectively formed by prehistoric undated and historic lava flows [Cavallaro et al., 1985]. The excursion concerns the caves Micio Conti, formed inside prehistoric undated lava, and Immacolatella I, inside historic lava.

ITINERARY

The visitor shall follow northward the urban road up to Aci Castello crossing, in the middle of a bend, some 1000 m away from the starting point, the City Hall of San Gregorio di Catania. The itinerary turns to the right, according to the road plate indicating the city sports ground. The car(s) shall be parked on the right side of the road, just before its end, close to an olive tree. San Gregorio Caves lie beyond a low fencing wall, to be strode over right of a gate.

3.2.1 MICIO CONTI CAVE

A small roof collapse at mid length splits the cave into two branches, giving access to the upper segment, developing northwestward, and to the lower segment, southeastward oriented.

The upper segment displays the most interesting morphologies of this cave. Different flow directions at different levels join together, and give evidence of repeated capture phenomena. The cave is here very wide, and several columnar structures can be observed, which could be interpreted as a consequence of flow anastomosis. In fact the coalescent flows could have left small column shaped diaphragms, welded and plastered by the subsequent surrounding flow. Here and there small collapses display their inner composition, made by lava blocks and scoria, lined with a thin vitreous plaster with horizontal strips [Puglisi, 1981].

The inner floor of the cave, hosted by a pahoehoe parent flow, is largely made by ropy lava covered here and there by a thin sandy carpet. In the upper part of the cave the floor is characterized by large uplifted slabs and welded blocks, which hamper the progression. The upper end lies beyond this barrier. It is a semicircular room, where archaeological remains of the Bronze Age were found [Messina, 1970]. They are today exhibited at the "Paolo Orsi" Archaeological Museum, in Syracuse.

A tight and short crawl passage, below the collapse entrance, takes the visitor to the lower segment of the cave. This is in turn split into two parts by an anastomosis at half of its length. A sedimentary carpet of external origin, covering almost entirely the floor, features the first part. The typical pahoehoe ropy surface can be observed here too, where the sandy cover is missing. This segment of the gallery is some 10 m wide and about 1.5 m high.

The second part, almost orthogonal, is reached through a 3 m crawlway, which leads again the visitor to the main gallery body. This segment is sensibly tighter (only 4-4.5 m) and higher (about 2.5 m) than the previous one. Its floor is almost unaffected by sedimentary debris, and its ceiling section is largely deformed in the middle, and affected by frequent longitudinal and traverse cracks. The final part of the gallery is split into two swallow-tail shaped ends.

The walls and the ceiling of the whole cave are intensely striated, and lava stalactites hanging from the ceiling are very common.

Micio Conti Cave

3.2.2 IMMACOLATELLA I CAVE

This cave is a lava tunnel about 350 m long, mainly NW-SE oriented, characterized by rooms and passages with different size and shape.

A large roof collapse introduces to the first room, a wide hall gently sloping, whose floor is obstructed by blocks collapsed from the ceiling. A branch of the cave to the left takes the visitor upslope, through rooms and crawlways, partially formed by collapse debris stacks. A low, semi-hidden passage, takes back the visitor to the main cave body. The entrance environment, a large collapse chamber, proceeds downslope southeastward for some tens of meters. The floor is hampered by numerous collapse blocks and by several lava laminae and rolls. The subsequent segment rises again slightly upslope, with more regular section. The average height of the passage is 3-5 m, and the floor is covered by bat guano. At the end of this gallery the cave is segmented into two parts: a small room to the right, holding a pillar, and a short raised passage ending at a few meters distance.

3.3 GENERAL EXCURSION TO THE SUMMIT OF MT ETNA

Wednesday, 15 September

Personal equipment

- Clothing for changeable weather and temperature conditions
- Leather gloves
- Climbing booths
- Although sandwiches and drinks will be provided by the organisation, we suggest you to carry extra water supply.

PROGRAM

We will travel by bus to Piano Provenzana (north flank of Mt Etna). From here we will proceed towards the Summit Craters using STAR's 4WD buses. At 2900 m elevation we reach the base of the Summit Craters (Central Crater, North-East Crater and South-East Crater), where we will park the 4WD buses and start our walk.

Wiew from south of the Summit Craters of mt. Etna, videocamera of the Istituto Internazionale di Vulcanologia

Due to safety reasons, the Prefettura of Catania placed the limit of 2900 m elevation as the safety boundary. Who wishes to climb further will do it at its own risk and responsibility, as it is reminded by many indications there.

Walking downslope from 2900 m elevation we can observe the recent lava flow field which developed from an eruptive fissure opened at the base of the South-East Crater on 4th February 1999. The flow field shows many interesting structures and various morphologies, as for example hornitos, tumuli, lava bridges and lava tubes.

Leaving the spectacular landscape of the Summit Craters we will walk back stopping along the way to the Volcanologic Observatory of the Istituto Internazionale di Vulcanologia located at Piano delle Concazze. Here we will stop for a short lunch break offered by the organisers of the meeting, and will have the chance to admire the wonderful landscape offered by the Valle del Bove depression. On the way back we will stop at Linguaglossa, where the City Major will offer soft drinks. We will then continue towards Randazzo and stop at Caserma Pirao Refuge where the Park Rangers will offer us lunch.

3.4 SERRACOZZO CAVE

1971 eruption

Friday, 17 September

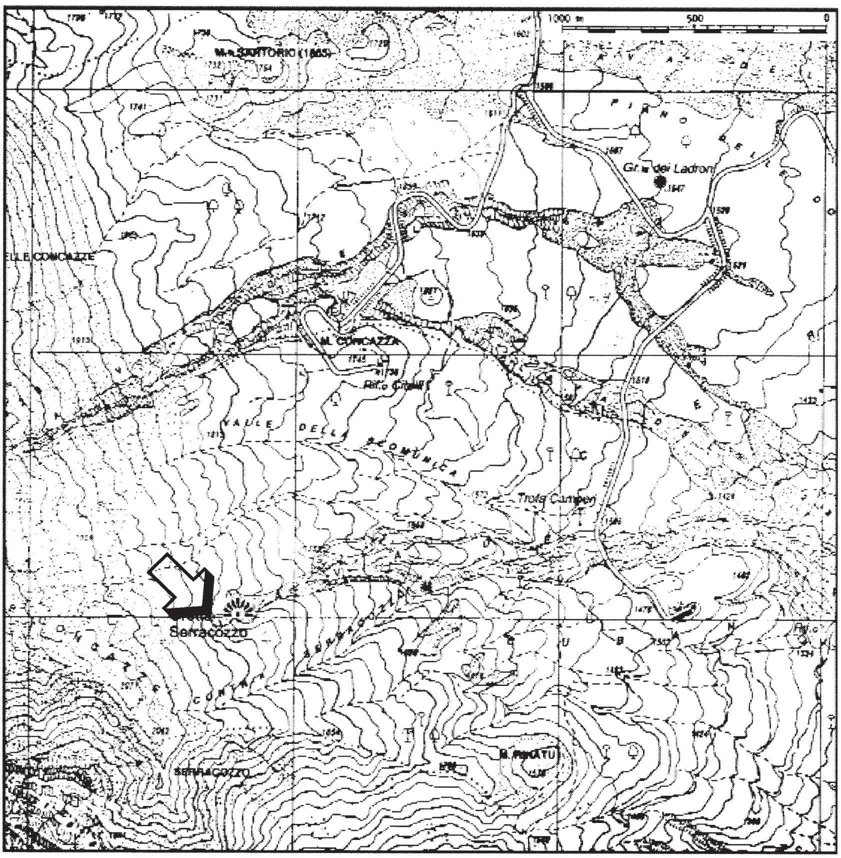
DEPARTURE FROM CATANIA 7.00
EXPECTED RETURN TIME 18.00

ITINERARY OF APPROACH

Elevation at departure	1745 m
Elevation at arrival	1840 m
Maximum elevation	1900 m
Maximum elevation range	155 m
Difficulty	Easy
Walking distance	≈1.5 km
Walking time	1.5 hrs

INSIDE THE CAVE

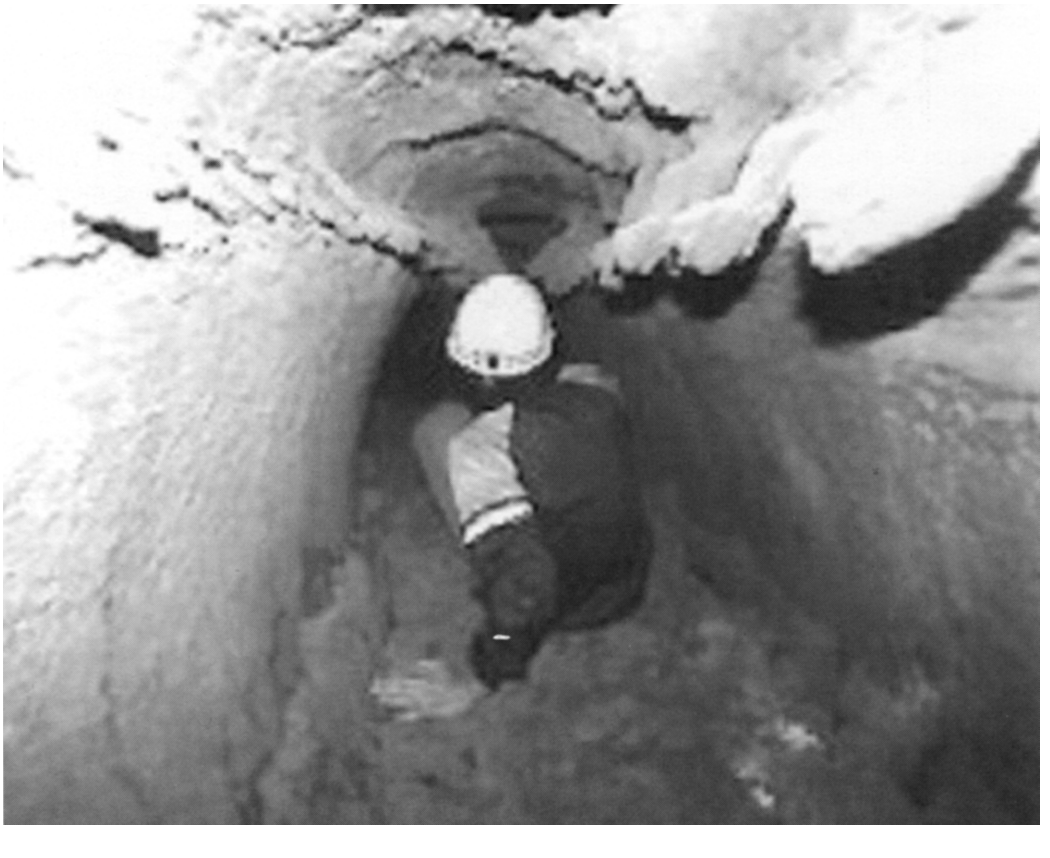
Total length	350 m
Elevation range	60 m
Difficulty	Medium



IGM Serie 25 Foglio 625
SEZ. IV - Sant'Alfio

ITINERARY

The approach starts westward from Rifugio Citelli, where the car(s) shall be parked, looking to the top of Monte Pizzi Deneri. The visitor leaves the paved road at the first bend, 200m from the refuge, and climbs westward, following a visitor track identified by colored enamel spots, through a birch wood, up to 1900 m, at a sheepfold wreck. From this point the track turns to left in SSE direction, maintaining the height for about 1 km, up to the upper end of a broad amphitheater wherefrom a superb panorama can be enjoyed. A downslope descent of about 50 m takes the visitor to the middle of the amphitheater bowl, wherefrom the lava flow, containing the cave and its entrance, cropped out in 1971.



Serracozzo Cave

DESCRIPTION OF THE CAVE AND OF ITS MAIN FEATURES

Serracozzo Cave is developed about 350 m, with a range of some 60 m in height. The entrance - a square shaped wall collapse at the end of the eruptive fissure, splits the cave into two branches: an upslope short segment, seated inside the fissure, and a downslope braided lava tube cave, with three flow trends partially superimposed.

The floor of the eruptive fissure, to the right of the entrance, largely buried by collapse debris, is almost six meters lower than the corresponding floor of the tube cave to the left. This segment ends with a small tilted lava slab.

The hollow to the right gradually shifts from the effusive vent to the flow gallery about 2 m wide, with an ogival section choked at mid of its 5 m height [Cavallaro and Licitra, 1975]. The lava tube cave sensu strictu starts 30 m away from the entrance, after a small skylight in the ceiling.

The lower (and longest) branch of the tube turns abruptly to the left, trending northward, with an almost right angle; the gallery resumes its ENE direction after a step descent some 40 m long, and maintains this trend until its downhill end. The average size of the passage ranges between 2 and 4 m width per 1 and 2 m height throughout the tunnel length, with a generally squeezed section. The gradient is constantly over 25°, and the tunnel is partially hampered by collapses at two thirds of its length.

Two overlying levels are located 4 m over the fissure floor, and can be entered through an external access generated by a small roof collapse. They are two sub-parallel northbound galleries with elliptic traverse section and 1m height, which most likely formed during the maximum discharge period of the effusion [Cavallaro and Licitra, 1975]. The first gallery is about 50 m long and a small chamber operating as an ephemeral vent during the eruption constitutes its end. The second one is about 20 m long and its lower end is open to the surrounding ground.

The cave walls are largely striped both in the main lava tube segment and in the eruptive fissure, and numerous re-melting stalactites and festoons hang from the ceiling; the walls are also affected by small vitreous blisters and exploded bubbles [Cavallaro and Licitra, 1975]. Some lava rolls can be observed along the walls of the main body, both in the terminal part of the eruptive fissure and at the lower end of the lava tube.

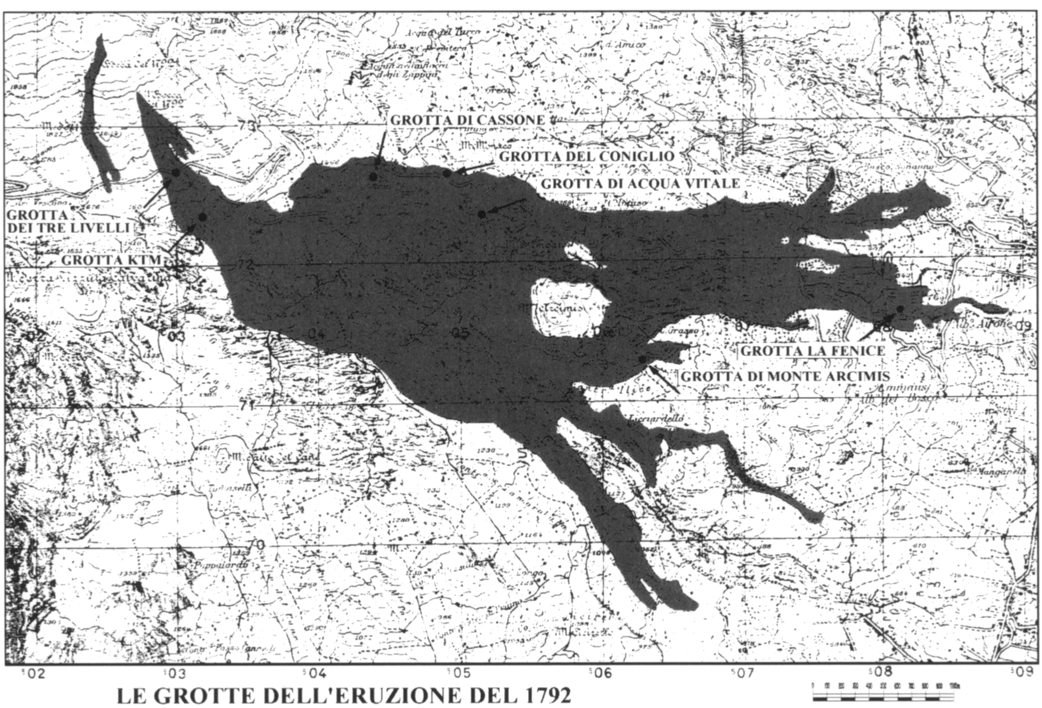
3.5 TRE LIVELLI AND KTM CAVES

1792-1793 eruption

Saturday, 18 September

DEPARTURE FROM CATANIA 7.00
EXPECTED RETURN TIME 21.30

The Tre Livelli cave is between the most important lava caves discovered into the lava flow field of the 1792-1793 eruption. It is located along the eruptive fissure and along the proximal master tube. The KTM cave represents the downslope extension of the Tre Livelli cave. Other caves to be visited into the same flow field are the more surficial Cassone and La Fenice caves, which developed at different distances from the source region. The visit to these caves will offer the chance to discover and compare the different features related to caves of the same eruptions, which have formed at different distances from the source.



IGM Serie 25 Foglio 625 SEZ. III Aci Catena e
IGM Serie 25 Foglio 625 SEZ. IV - Sant'Alfio

3.5.1 TRE LIVELLI CAVE

ITINERARY OF APPROACH

Elevation at departure	1625 m
Elevation at arrival	1625 m
Maximum elevation	0 m
Difficulty	None
Walking distance	-
Walking time	-

INSIDE THE CAVE

Total length	1150 m
Elevation range	304 m
Difficulty	Medium

ITINERARY

The Tre Livelli cave is located at Contrada Case del Vescovo, and is reached driving along the S.P. 92, which connects Zafferana Etnea to Rifugio Sapienza, on the southern flank of Mt Etna. The entrance is just next the road, at about 1 km east of Case del Vescovo.

Tre Livelli Cave

DESCRIPTION OF THE CAVE AND OF ITS MAIN FEATURES

The name of the cave is due to three overlapped flow levels, which comprise the cavity. However, the number of stacked tubes is probably more than five. The entrance is located on the roof of the upper tube, which can be followed for a few metres before it joins to the middle-level tube. The merging of the two tubes occurs as 6 m step indicating tubes capture. The middle tube is larger than the upper one and characterised by many blocks on the floor. A few metres further downslope another two-metre-high step brings to the lower tube. A narrow passage artificially opened brings to the lower tube, which can be visited for about 350 m downslope and 750 m upslope, where it extends below the middle tube. After the narrow passage, the lower part of the tube shows a wide section and a constant slope, and it presents the same inner morphologies up to the lower end. The floor is made of clinkers with sometimes very large blocks. The inner morphologies are very variable in the upslope part of the tube. The first 150 m are characterised by a narrow path, where lateral benches often produce a key-hole shape of the section. Sometimes the lateral benches are broken into unusual features, each about 30 cm, which have the aspect of petrified sea waves.

Continuing along the upslope portion of the tube there is a talus caused by block fall from the roof, and from there we can reach a wide chamber opened at the roof. After a very narrow passage, which is only 2 m long, the slope increases significantly, reaching 40° in the upper part. It is in this very steep portion of the tube that there is the passage between a lava tube and a cave developed into the eruptive fissure. The section becomes narrower, the lateral walls are more vertical, and there is a gradual increase in the height of the roof. In many places where the inner lining has collapsed is possible to see the nearly horizontal sequence of lava flows and pyroclastics which bounds the walls of the eruptive fissure. This is the most difficult part of the tube, but it is rich of many interesting features, such as many degassing points that correspond to the hornitos on the surface, skylights between stacked lava tubes, changes in colour from red to black on the walls of the tube due to differential oxidation and cooking of the boundary rock, lava bridges and lateral benches.

3.5.2 KTM CAVE

ITINERARY OF APPROACH

Elevation at departure	1500 m
Elevation at arrival	1549 m
Maximum elevation	49 m
Difficulty	None
Walking distance	150 m
Walking time	10 min

INSIDE THE CAVE

Total length	643 m
Elevation range	100 m
Difficulty	Low

ITINERARY

Starting from the lowest end of the S.P. 92, which connects Zafferana Etnea to Rifugio Sapienza, on the southern flank of Mt Etna, we need to drive for 12.2 km upslope. Leaving the car at 1500 m elevation, on the left side of the road we will follow a foot path for about 50 m. Then, leaving the foot path on the left, we will climb for about 100 m on the surface of the 1792-1793 flow field, up to a hole which represents the entrance to the cave. The whole path will take about 10 minutes walk.

DESCRIPTION OF THE CAVE AND OF ITS MAIN FEATURES

The KTM cave is a lava tube whose access is through a small collapse of the roof of the upper level tube. The upper tube is only 6 m long, but from there we can descend into a lower level after a step of 4 m depth which can be descended with a speleological metal ladder. The lower tube is parallel to the upper one but much wider. The features of this lava tube are very similar to the lower part of the Tre Livelli tube, which continues into the KTM, being only separated by a 20 m thick septum of lava [Corsaro et al., 1990].

The size of the tube increases downslope, but along its length there are a number of narrow passages. The half lower part of the tube is 8 m wide and 6-7 m high. At about half distance from the entrance the tube splits into two branches, which merge a few metres downslope. The left branch is larger than the right, and the merging of the two branches produced a section larger than usual.

Typical features of this part of the tube are wide lateral benches, sometimes asymmetric, many stacked tubes evidenced by middle skylights, lava stalactites and lateral grooves.

3.6 ABISSO DI MONTE NERO

1923 eruption

Saturday, 18 September

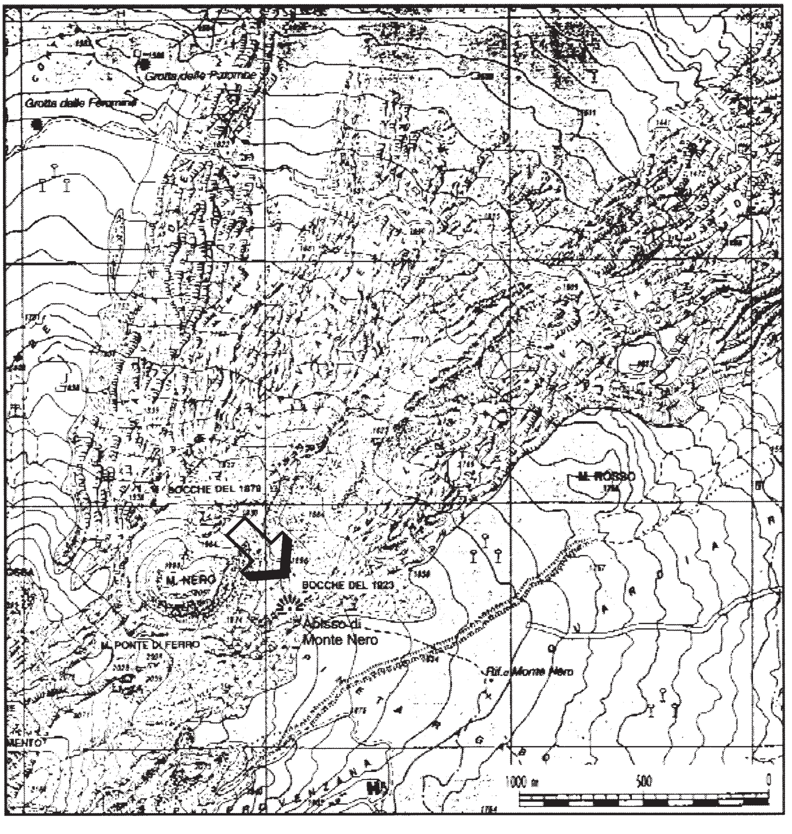
DEPARTURE FROM CATANIA 7.00
EXPECTED RETURN TIME 21.00

ITINERARY OF APPROACH

Elevation at departure	1770 m
Elevation at arrival	1905 m
Maximum elevation	135 m
Difficulty	Easy
Walking distance	≈2 km
Walking time	40 min

INSIDE THE CAVE

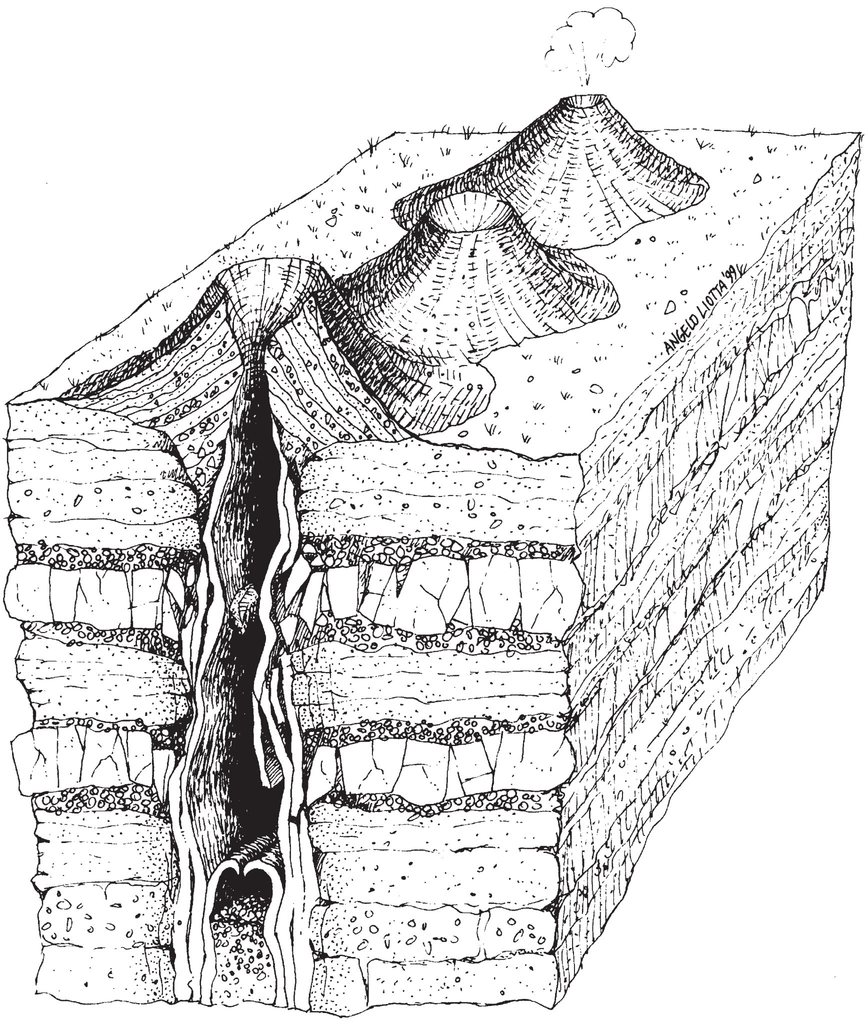
Total length	756 m
Elevation range	84 m
Difficulty	Demanding



IGM Serie 25 Foglio 613
SEZ. III - Linguaglossa

ITINERARY

The way to the cave starts from Piano Provenzana (North Etna), where the car(s) shall be parked at the Hotel "le Betulle". A private track, climbing uphill to the top of the volcano through the Ragabo wood, is to be followed for about 30 minutes, up to a false flatland wherefrom Monte Nero rises. An off-track rove toward the butte leads the visitor at its foot, where the eruptive crack comes into sight. The cave entrance is inside one of the lower hornitos.



Example of cave into eruptive fissure

DESCRIPTION OF THE CAVE AND OF ITS MAIN FEATURES

The eruptive fissure of Monte Nero was formed by the 1923 eruption, and was entirely explored in 1993, after the casual joining with the Profondo Lavico Abyss during some rope-walking ascents. This cave system, hosted inside a single eruptive fissure, is the longest cave on Etna, with a total linear length of 1169 m [Giudice and Scalia, 1994]. The excursion concerns only the downhill portion of the cave, named Monte Nero Abyss.

The cave can be entered through the hollow conduit of one among the lowest hornitos, built on the eruptive fissure, during the active eruption, by degassing phenomena. A 35 m narrow shaft, whose floor represents the fissure bottom, immediately follows an initial 30 m pit. The fissure closes downhill 250 m away from the arrival point, whereas it can be followed for 500 m uphill, wherefrom the Profondo Lavico Abyss starts.

The first 100 m of the downhill part is featured by small shafts and climbs through collapse areas, then a narrow 12 m pit reaches again the actual bottom of the fissure, where typical lava rolls feature the floor or represent same until the cave end.

A 4 m crumbly jump leads to the fissure bottom, featured by lava rolls, in the uphill part of the fissure, a few meters away from the arrival point. A large collapse area hampers the visit some 50 m farther, then a long stretch follows, featured by wonderful lava rolls - frequently jamming together - along the opposite fissure walls. Several subsequent climbs, harnessed by fixed ropes, mark the joining area with Profondo Lavico Abyss.

Secondary minerals were found in the area close to the fixed harnessing. Careful laboratory tests revealed they were formed by Portlandite, a very rare mineral ascertained for the first time inside a cave [Forti and Marino, 1990].

The main features affecting the whole fracture system concern its walls. They are almost vertical and rather parallel, with an average distance of 3 m from each other. The inner surface of the fissure walls is plastered with a vertical layer of re-melted lining intensely affected by vertical stripes, whereas the engulfing rock behind the lining is formed by preexisting material altered by the heath, wherever it can be observed through collapse gaps.

3.7 CASSONE AND LA FENICE CAVE

1792-1793 eruption

Sunday, 19 September

DEPARTURE FROM CATANIA 8.00
EXPECTED RETURN TIME 20.00

3.7.1 CASSONE CAVE

ITINERARY OF APPROACH

Elevation at departure	1400 m
Elevation at arrival	1400 m
Maximum elevation	-
Difficulty	-
Walking distance	-
Walking time	-

INSIDE THE CAVE

Total length	246 m
Elevation range	1 m
Difficulty	Low

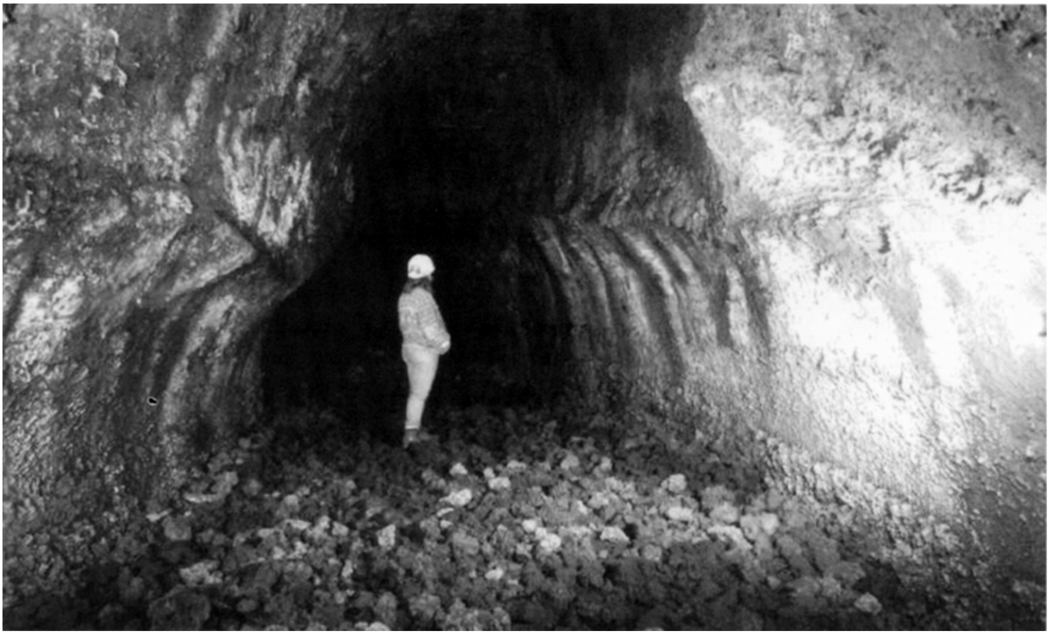
ITINERARY

The entrance of the lava tube is reached after 10.8 km upslope drive along the S.P. 92 road, which connects Zafferana Etnea to Rifugio Sapienza, on the southern flank of Etna. The entrance is a small hole on the right side of the road, close to Valle del Tripodo.

DESCRIPTION OF THE CAVE AND OF ITS MAIN FEATURES

The entrance is located on the lower end of the tube. Here a block fall from the roof shows the inner linings constituted by a number of millimetre-thick layers. The first 50 m of the tube show an oval section, where the roof is protruding downwards due to plastic deformation. Also on the roof there are many longitudinal and transversal fractures. Here it is also common to observe stalactites due to roof remelting, and on the walls and roof sometimes the inner lining shows rugged contours produced by bubbles or by the incomplete adherence of the lining to the walls.

The inside of the tube is also characterised, especially in the upper part, by striae at the walls showing flow direction. Upslope the size of the section increases and has a more circular shape of generally 5 m width and 5 m height. In one point the section is even larger



Cassone Cave *(by Alfio Amantia)*

due to tube capture, and a typical key-hole section shows the merging of two overlapped tubes. The floor of the cave is made of aa clinker, but the last 40 m show a smoother, more compact surface with rough ropes. At the upper end of the lava tube there are small lateral benches on the sides of the floor due to peeling off and rolling over of the inner linings.

3.7.2 LA FENICE CAVE

ITINERARY OF APPROACH

Elevation at departure	835 m
Elevation at arrival	850 m
Maximum elevation	15 m
Difficulty	None
Walking distance	80 m
Walking time	10 min

INSIDE THE CAVE

Total length	80 m
Elevation range	15 m
Difficulty	Low

ITINERARY

This cave is located along the S.P. 92, which connects Zafferana to Rifugio Sapienza. Following the road from Zafferana and driving upslope, about 500 m after the Emmaus Hotel, there is a short road that joins the S.P. 92 to the right and stops after a few tens of meters. The lava tube is located on the left side of this road, a few tens of metre upslope.

La Fenice Cave

DESCRIPTION OF THE CAVE AND OF ITS MAIN FEATURES

La Fenice lava tube formed at the distal margins of the 1792-1793 lava flow field, at a distance of 5 km from the main vent. It is an incompletely sealed lava tube, which develops along 4 budded flows having mainly aa morphology. These flows formed from first-order ephemeral vents [Calvari and Pinkerton, 1998] which have been fed from a large tumulus located just above the SP92 road. The ephemeral vents opened at progressively lower elevation points, producing interconnected flows. Each vent opening corresponded to a cycle of flow front inflation, crustal growth, partial sealing of the earlier developed lava channel, and new ephemeral vent opening from its frontal zone. Each cycle produced a lining into the upper flow/tube.

Although this lava tube is not exceptional for its inner features, and could not be considered interesting by many speleologists, it is extremely interesting from a volcanological point of view. In fact, this is the only example on Etna where the number of inner linings in the upper flow/tube corresponds to the number of budded flows, suggesting that the observation of the number and thickness of inner linings into inactive tubes may furnish important elements in the understanding of flow emplacement mechanisms [Calvari and Pinkerton, 1999].

3.8 INTRALEO CAVE AND ERUPTIVE CENTERS OF Mt GALLO, Mt FORNO AND Mt TESTA

Mt Gallo, Mt Testa and Mt Forno eruption; uncertain dating.

Sunday, 19 September

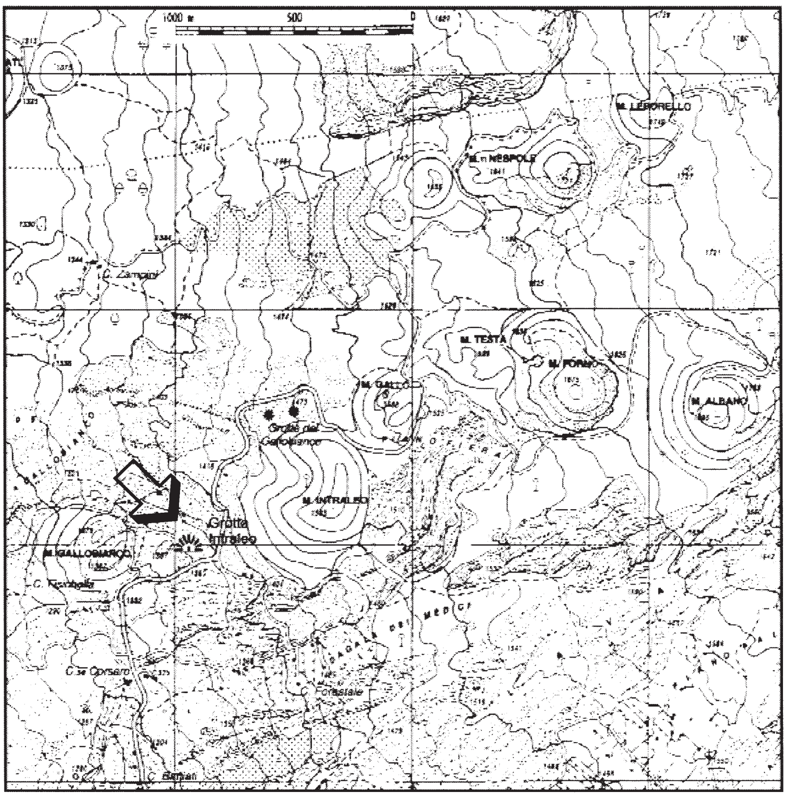
DEPARTURE FROM CATANIA 8.00
EXPECTED RETURN TIME 20.0

ITINERARY OF APPROACH

Elevation at departure	1370 m
Elevation at arrival	1370 m
Maximum elevation	-
Difficulty	-
Walking distance	-
Walking time	-

INSIDE THE CAVE

Total length	300 m
Elevation range	16 m
Difficulty	Low

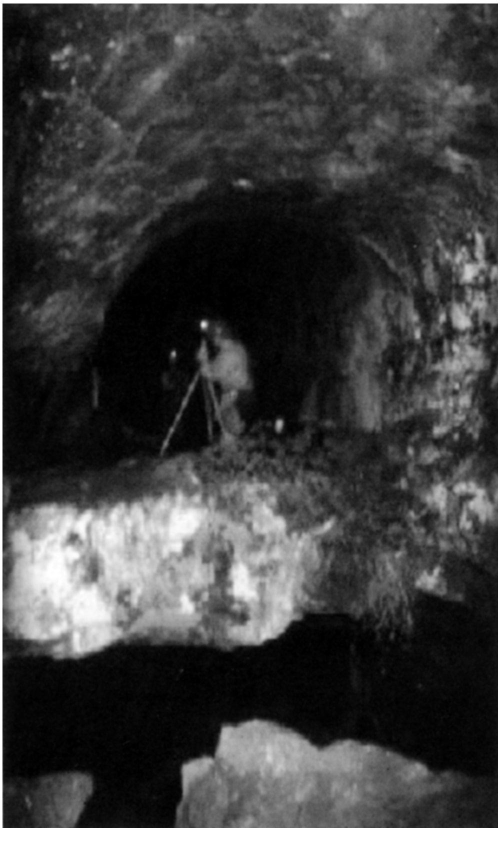


IGM Serie 25 Foglio 624
SEZ. I – Monte Etna

ITINERARY

The itinerary follows the road to Rifugio Sapienza for some 6 km from the main square in Nicolosi, until the crossroad to Belpasso and Adrano. After a hundred meters to the left, the itinerary turns again to the right, following the road arrow-plate to Adrano. After 12 km route an additional crossroad is met, indicating Monte Intraleo to the right. Two more km along this route will lead the party to a small parking place, left of the road and featured by a wooden fence, where the car(s) shall be parked. The broad cave entrance lies a few meters beyond the parking.

The eruptive centres of Mt Gallo, Mt Testa and Mt Forno are at two additional km distance, where the road - after turning behind Mt Intraleo - ends at a broad esplanade.



DESCRIPTION OF THE CAVE AND OF ITS MAIN FEATURES

Grotta Intraleo is a lava tube cave laid down on different flow trends, departing from both ends of the broad entrance trench. The higher gallery, some 40 m long, starts from the NE end of the trench. A broad room, segregated from the trench by an artificial wall, was used for human purposes (sheepfold, stable, and storage room) in former times. After a few meters the gallery narrows and becomes impracticable, due to lava slabs uplifted from the floor, hiding tube-in-tube phenomena.

The SW end of the trench hosts further galleries partially superimposed. The lowest level is formed by a short tunnel 15 m long, parallel with the overlaying level, and rich of interesting morphological features, such as lava rolls and large-sized laminae detached from the walls [Fanciulli et al., 1989].

The upper level starts by a single westward passage; after some 25 m it splits into three different branches. The right branch sinks down and ends after ten meters, whereas the central branch is 60 m and the left branch is 90 m long.

The main feature of this tube cave is represented by the crossing point of its three branches, situated at different heights, which give evidence of repeated flow captures.

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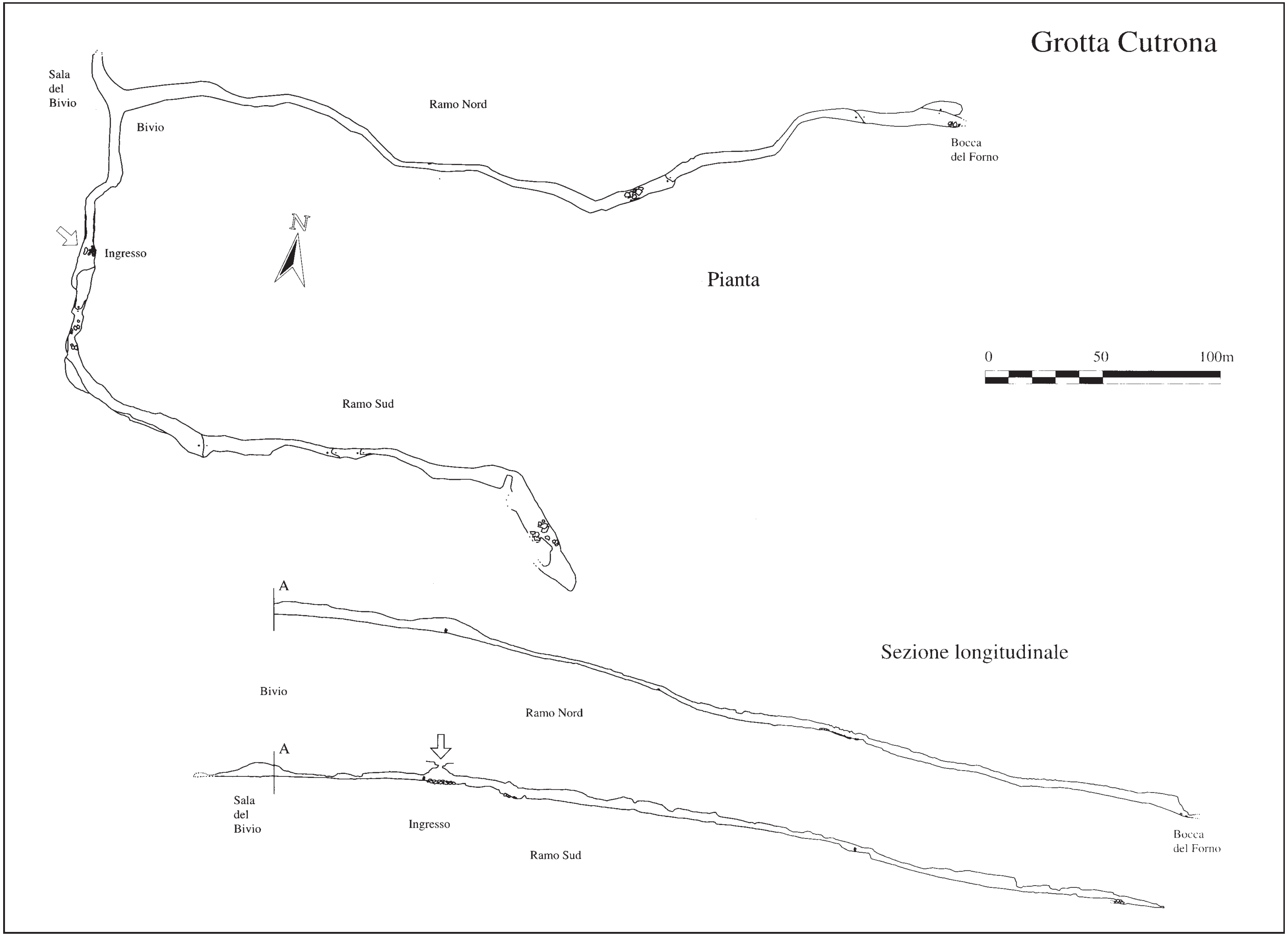
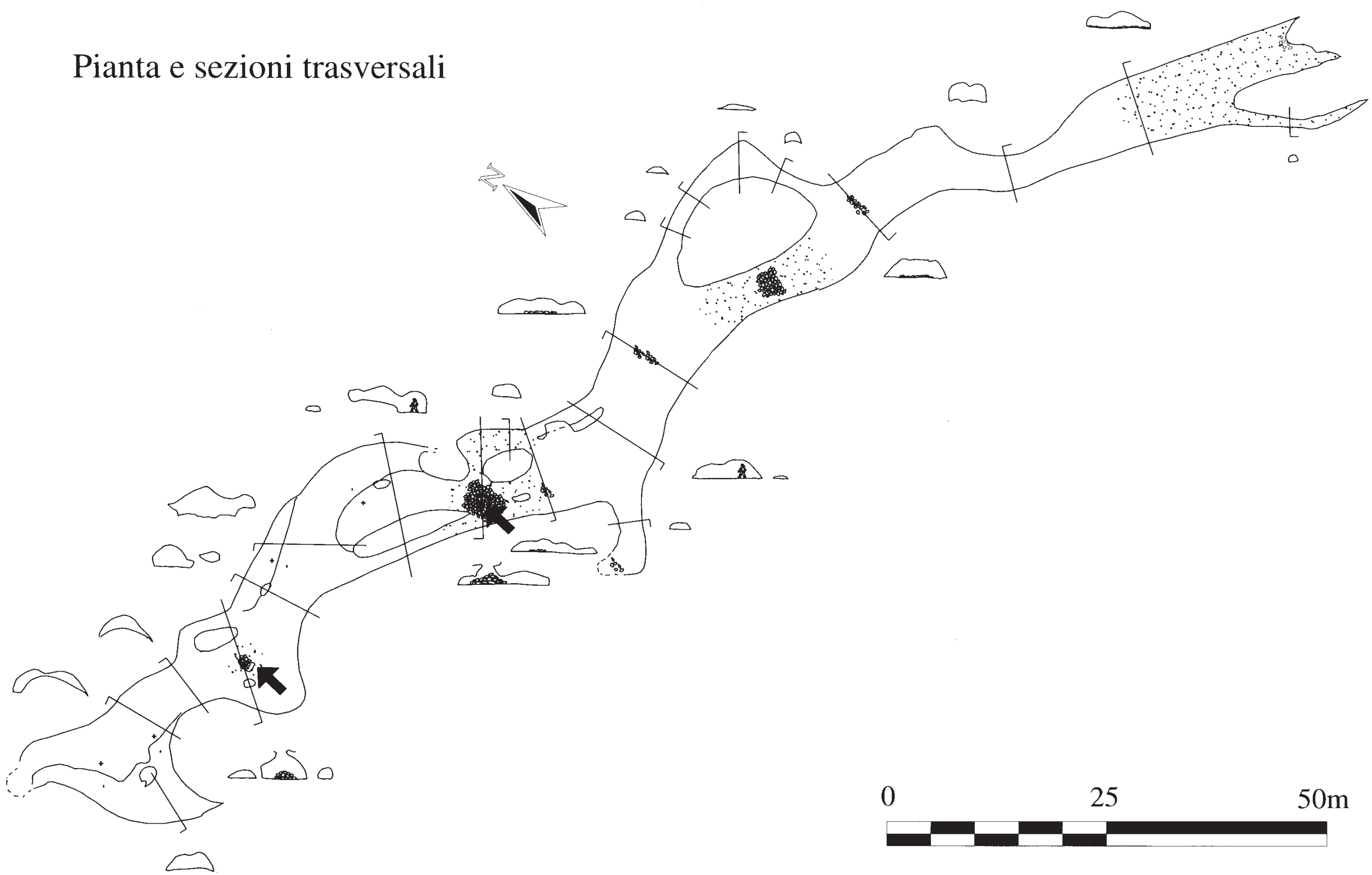
The ten maps that follow were loose folded maps in a pocket in the back of the original book. They are legible, however, at single-page size and have been reduced and placed here for convenient viewing and printing.


Grotta Cutrona
Sala del Bivio
Bivio
Ramo Nord
Bocca del Forno
N
Ingresso
Pianta
0
50
100m
Ramo Sud
A
Sezione longitudinale
Bivio
Ramo Nord
A
Sala del Bivio
Ingresso
Ramo Sud
Bocca del Forno

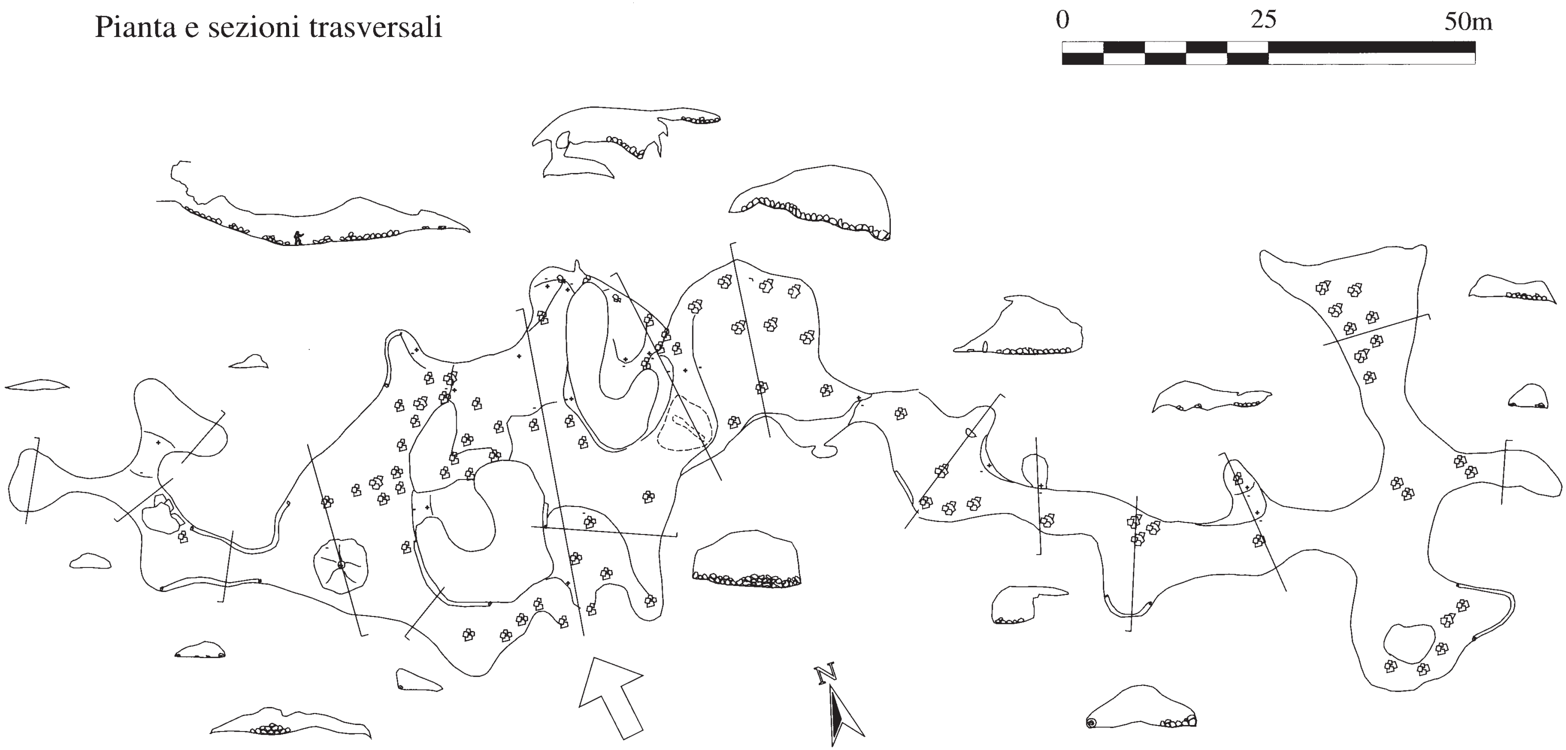
Grotta Micio Conti

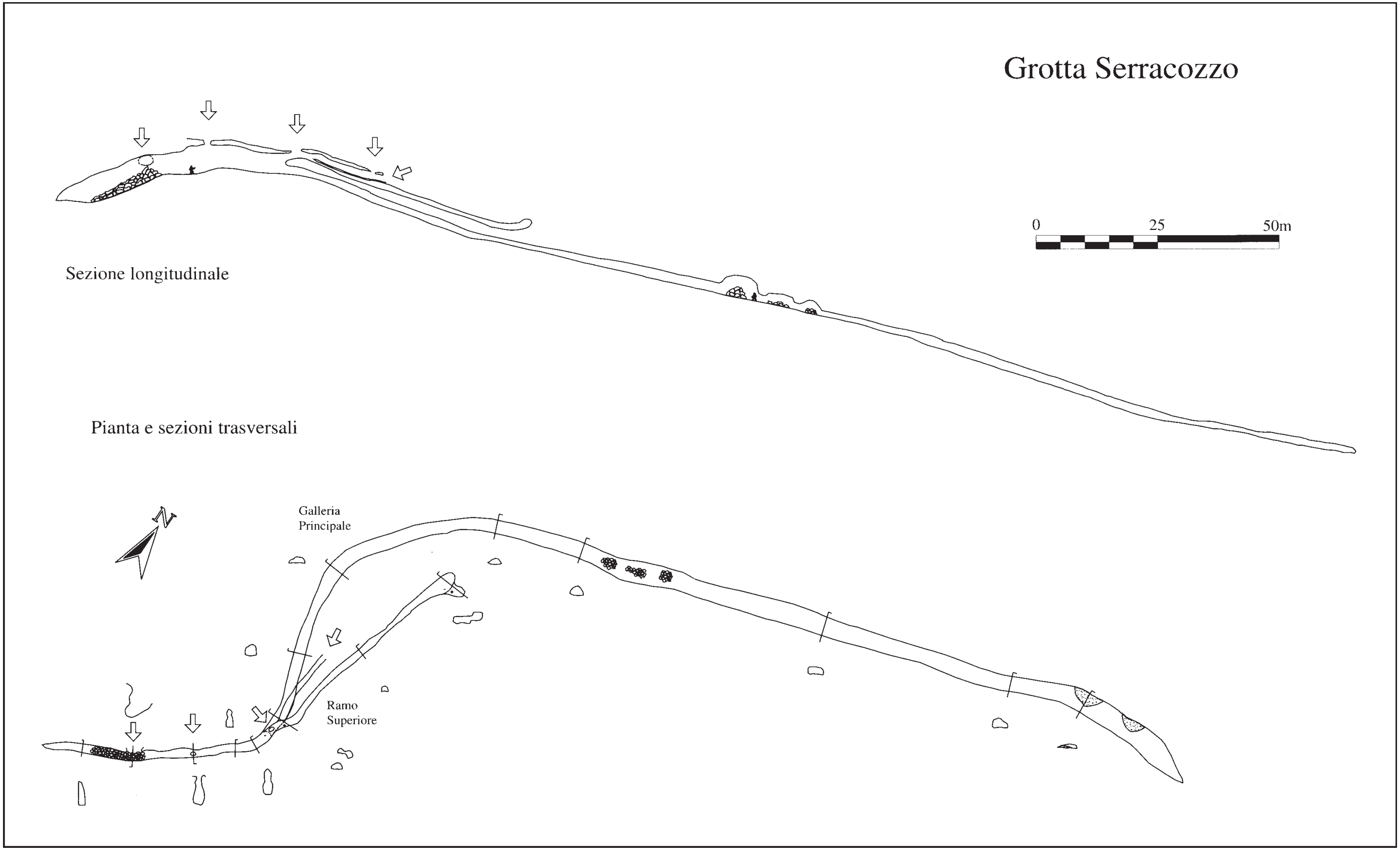
Pianta e sezioni trasversali

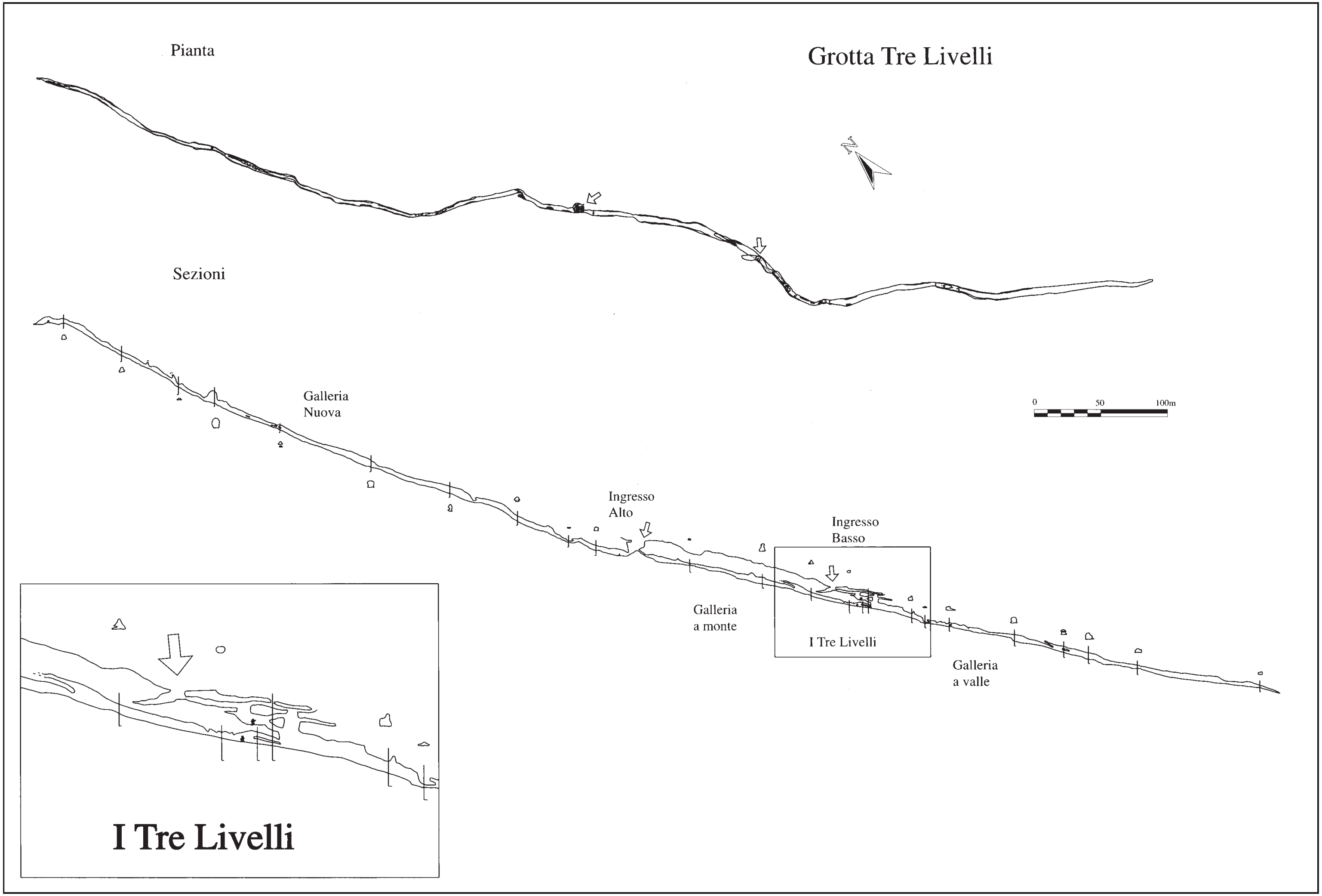


Grotta Immacolatella I

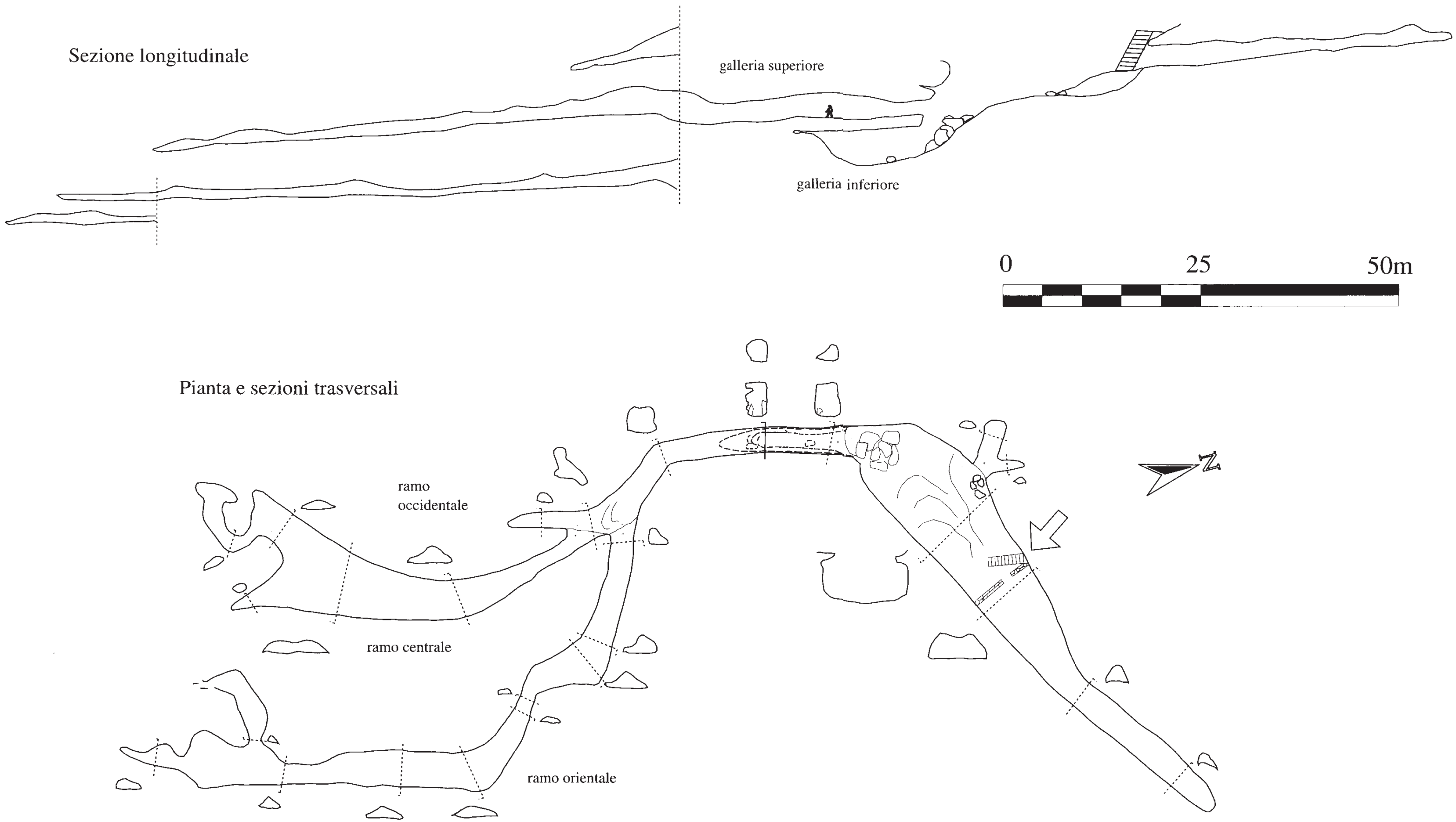
Pianta e sezioni trasversali

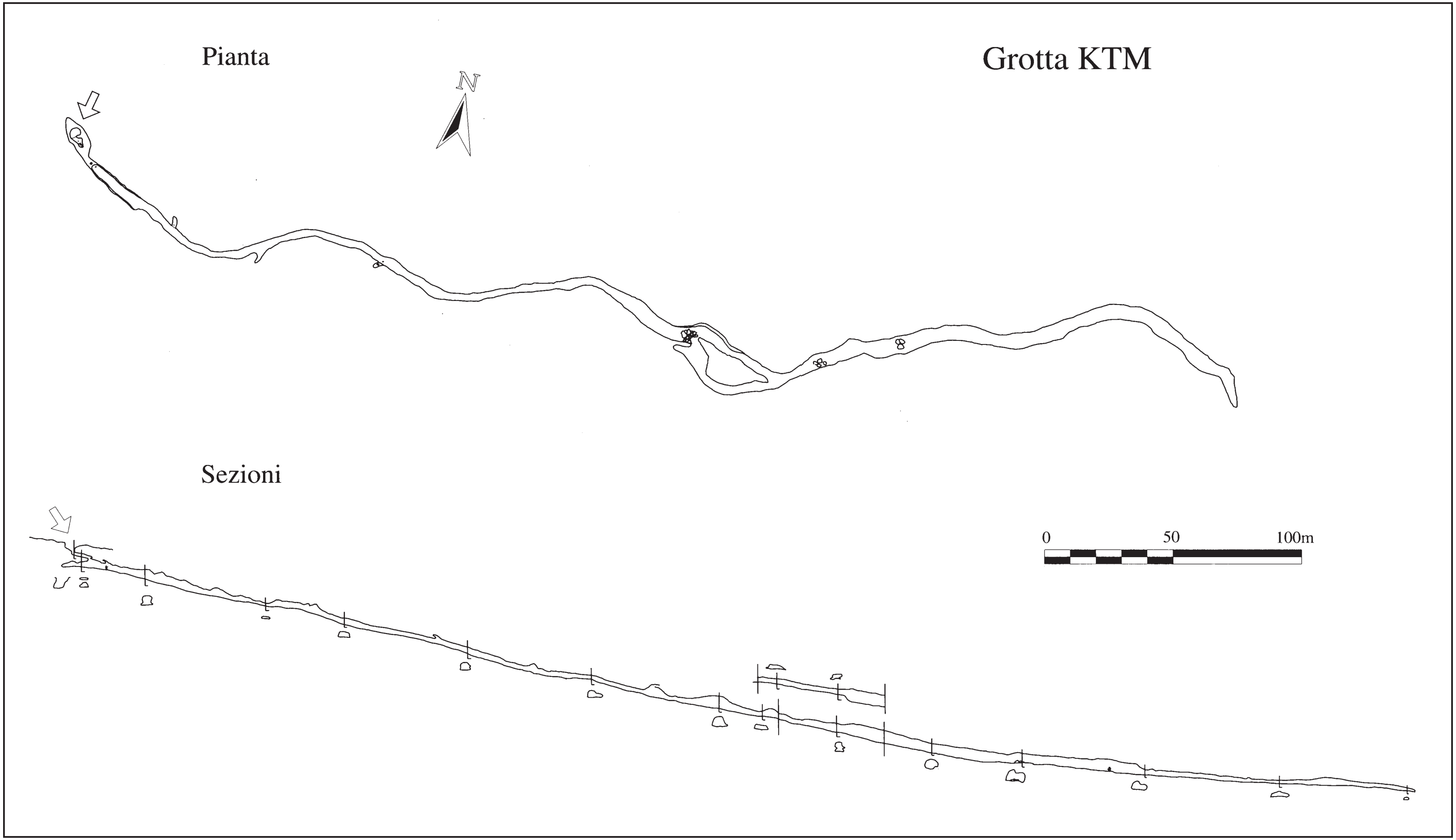



Grotta Serracozzo
0
25
50m
Sezione longitudinale
Pianta e sezioni trasversali
N
Galleria Principale
Ramo Superiore


Grotta Tre Livelli
Pianta
Sezioni
N
0
50
100m
Galleria
Nuova
Ingresso
Alto
Ingresso
Basso
Galleria
a monte
I Tre Livelli
Galleria
a valle
I Tre Livelli

Grotta Intraleo




Grotta KTM
Pianta
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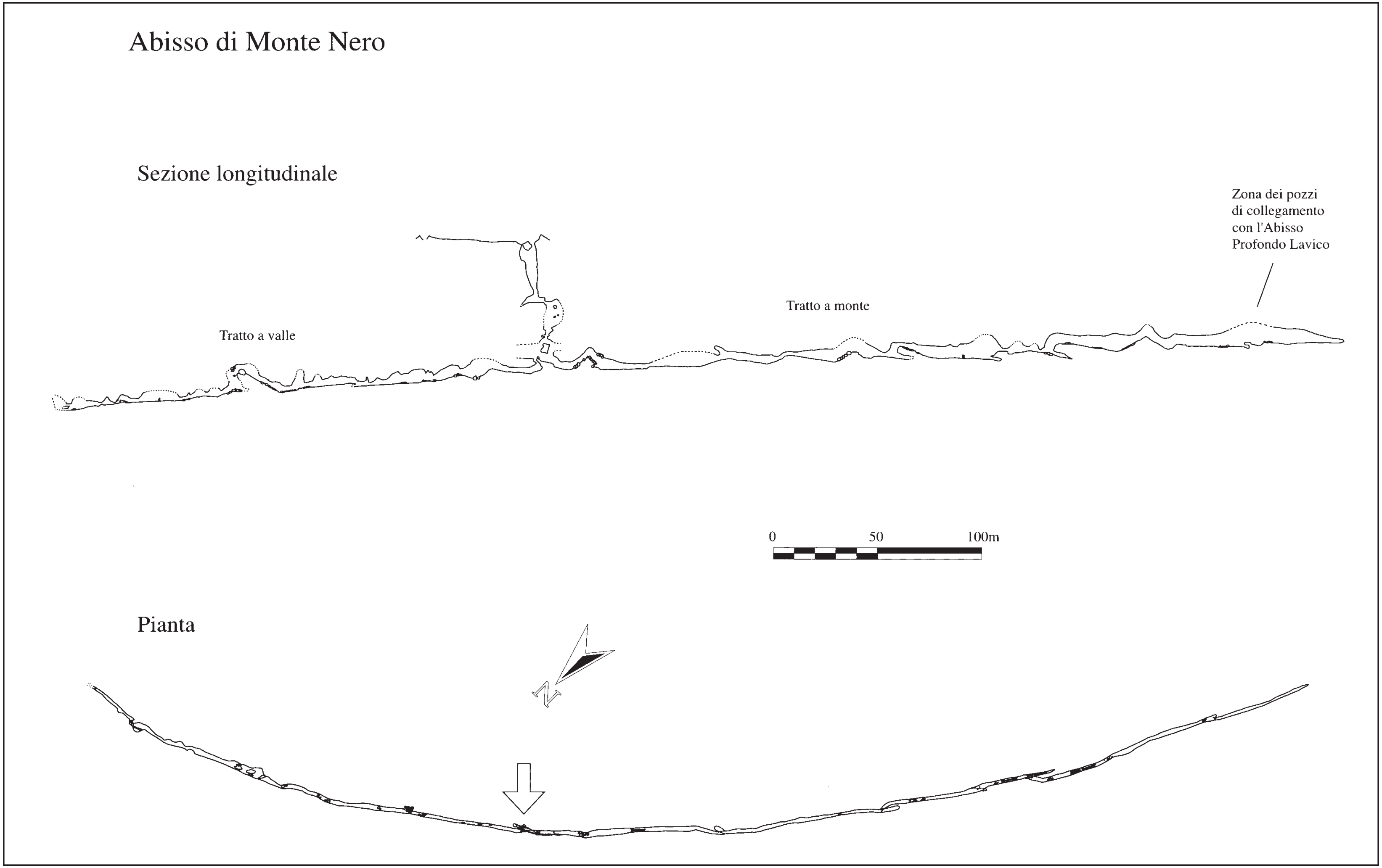
Abisso di Monte Nero
Sezione longitudinale
Zona dei pozzi
di collegamento
con l'Abisso
Profondo Lavico
Tratto a monte
Tratto a valle
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100m
Pianta
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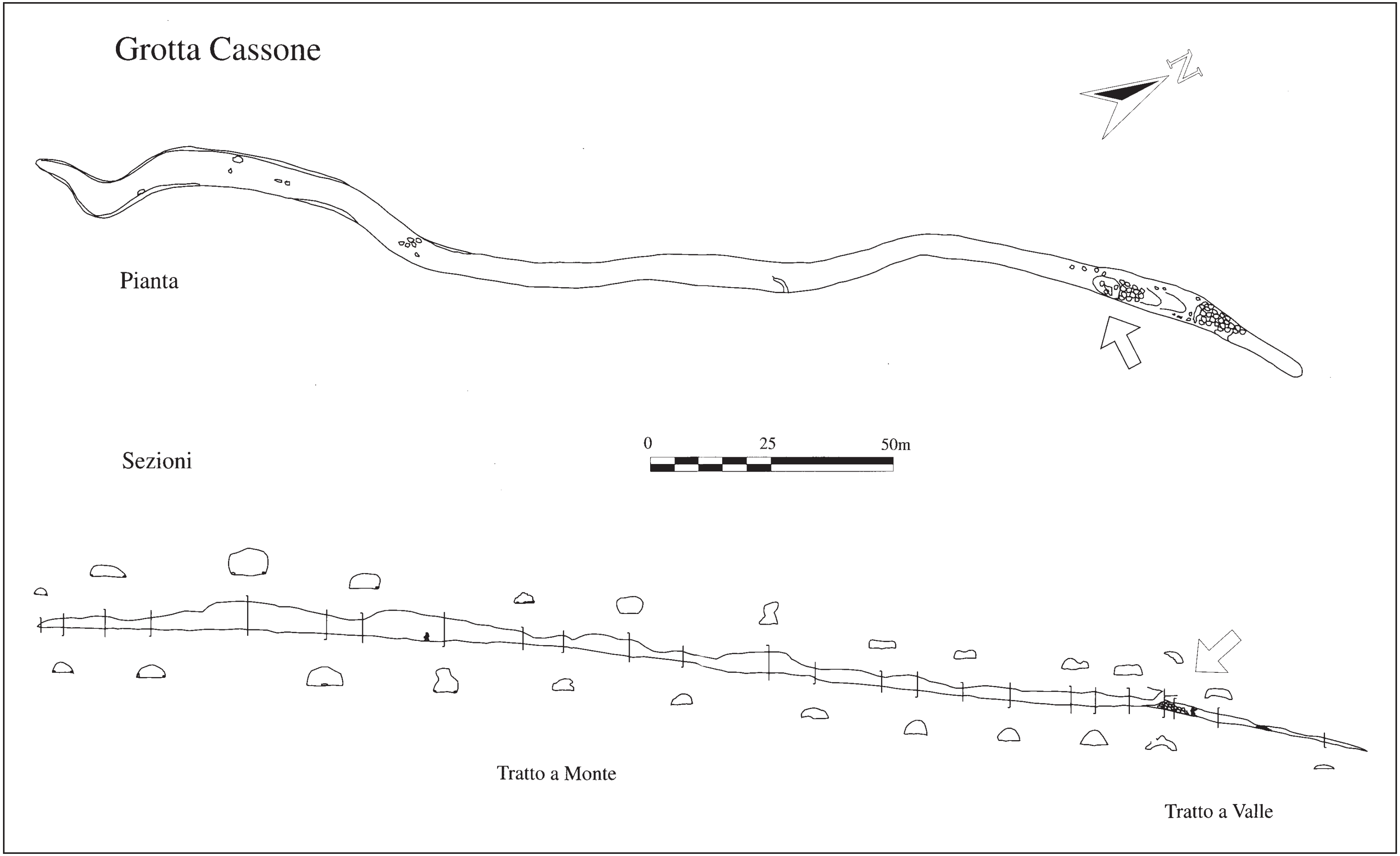
Grotta Cassone
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Pianta
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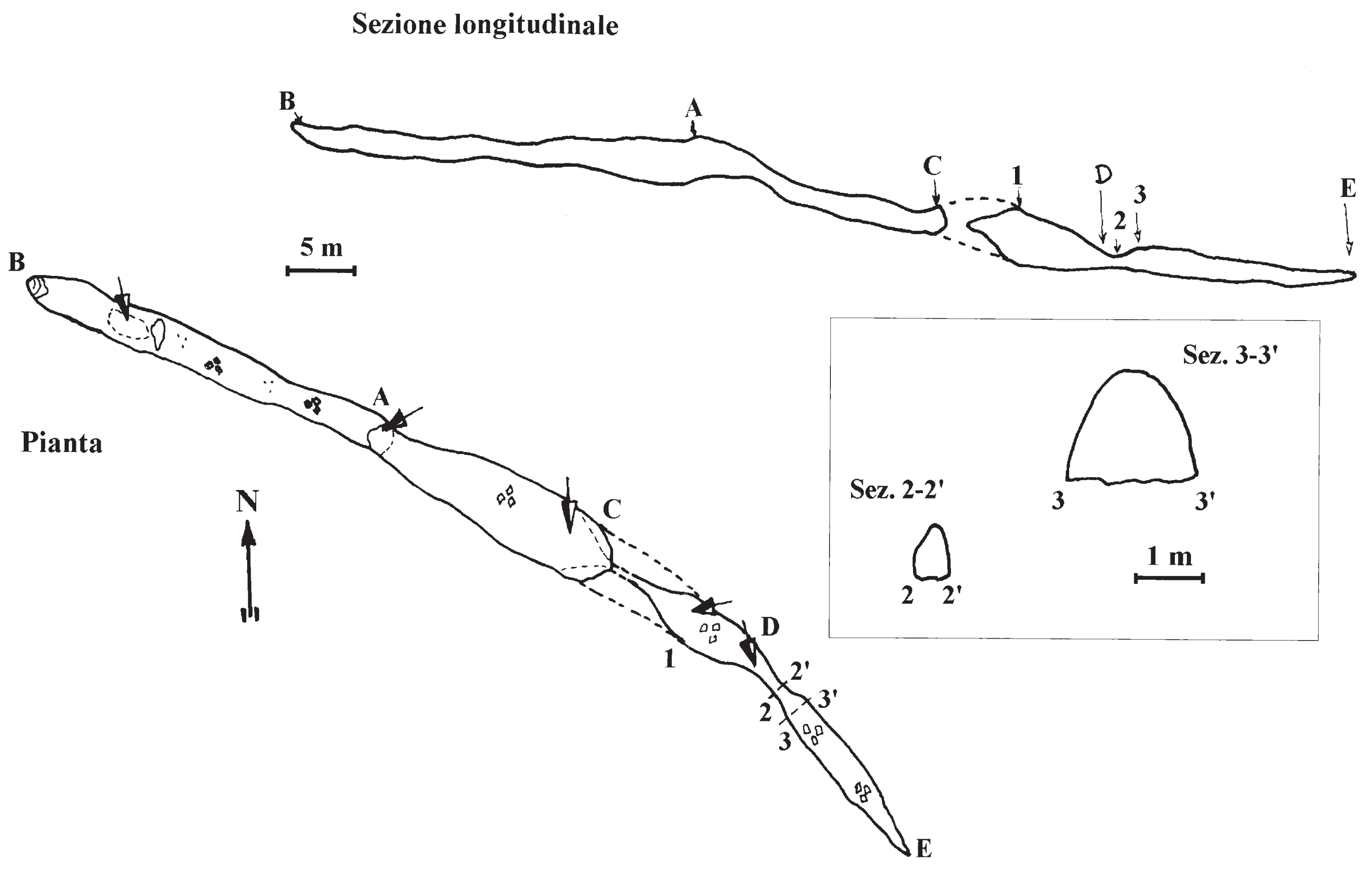
Tratto a Monte
Tratto a Valle



Grotta La Fenice Si CT 90. Rilievo: Priolo A., Priolo G., Sanfilippo G., Scammacca B., 1994. Svl. 80.15 m.