*Ipogea*
*n. 4 (2005): pp. 53 - 64*

Giulio CAPPA, Alberta FELICI, Emanuele CAPPA

# SOME PECULIAR FEATURES OF KARST DEVELOPMENT IN LATIUM DURING THE QUATERNARY

## Abstract

Cappa G., Felici A. & Cappa E. - Some peculiar features of karst development in latium during the quaternary - *Alcuni aspetti particolari dello sviluppo dei fenomeni carsici nel lazio durante il quaternario* – Ipogea, 4: 53-64.

The development of karstic phenomena in Latium is fairly recent: the traces of any appreciable evolution older than the beginning of Quaternary are scanty. Yet, there is evidence of peculiar features which mark this region, depending on other three factors that have influenced the karst evolution, they have been identified during these last years and are the subject of this note.

The most remarkable and widely spaced phenomenon is a consequence of the superimposition of volcanic ash deposits onto calcareous massifs, at a time when their karst was already well developed; the pyroclastites went up to a thickness of a few metres, concentrated in the hollows and stopped many hypogean water flows. After several ten thousands years the surface ablation and the percolation reactivate such karstic networks, some times by sudden and catastrophic collapses.

A second feature is related to karst hypogean very fast development in pleistocenic conglomerates, owing to the sudden uplift of one of such units.

The third one is a consequence of the formation during Pleistocene and even Holocene of large and thin units of travertines in several parts of the region, laying both upon calcareous and volcanic rocks; the authors have particularly investigated them along the river Aniene valley.

L'evoluzione dei fenomeni carsici nel Lazio è abbastanza recente: le tracce di sviluppi precedenti al Quaternario sono scarse. Invece si notano particolari forme evolutive che contraddistinguono questa regione; esse derivano dall'influenza di tre fattori che sono stati messi in luce in questi ultimi anni e che sono oggetto della presente nota.

Il fenomeno più rilevante deriva dalla estesa copertura di piroclastiti depostesi, con spessori di alcuni metri e concentrazioni nelle depressioni, sui massicci calcarei quando il carsismo era già abbastanza sviluppato. Esse hanno interrotto molte linee di assorbimento sotterraneo. Dopo decine di migliaia di anni l'ablazione superficiale e la percolazione riattivano la circolazione idrica nell'ipocarso e può dar luogo ad improvvisi e catastrofici collassi.

Un secondo fenomeno concerne la rapida evoluzione del carsismo nei conglomerati (puddinghe) pleistocenici, che è stata posta in relazione con la rapida surrezione di tali unità.

Il terzo è la conseguenza della deposizione nel Pleistocene e Olocene di estese e sottili formazioni di travertini in diverse parti della regione, sovrapposte sia a calcari che a rocce vulcaniche; gli autori hanno in particolare esaminato tali formazioni lungo la valle del fiume Aniene.

**Key words**: Latium (Italy) - karst development - pyroclastites and karst - collapse sinkholes - safety of human settlements - karst in conglomerates - karst in travertines.
**Parole chiave**: Lazio (Italia) - morfogenesi carsica - piroclastiti e carsismo - voragini da collasso - sicurezza degli insediamenti umani - carsismo nei conglomerati - carsismo nei travertini.

*Author's Address: Via Montiglioni 118 (15/S) - 00046 Grottaferrata (RM)*

## Index

## 1. INTRODUCTION

Two main geological formations fill the greatest part of the territory in the region Latium (Fig.1):

i - the calcareous chains of “anti-Apennines” and “pre-Apennines”, which are mainly of Mesozoic and Miocene ages (Symbol a in Fig. 1). These units are deeply karstified and feed almost the full network of aqueducts of the region.

ii - a line of important volcanic complexes rises between these chains and the seashore: the Vulsini, Cimini, Sabatini Mountains and Alban Hills (Colli Albani). Their formation started during Quaternary [from 1.35 Ma on, with the main development between 0.9 and 0.15 Ma - according to radiometric dating (Accordi & Carbone, 1988)]. Other minor volcanic units can be found in limited areas of Tolfa-Cerite Complex, Pontian Isles [both started during Pliocene, 4-1 Ma], and in localised eruptions intruded within the calcareous chains of Simbruini, Ernici, Lepini Mountains, which are likewise of Pleistocene ages [0.7-0.2 Ma] (Fig. 1 - b). These eruptions flowed up through prevailingly calcareous units and the pyroclastic products widely spread around and covered large areas of such limestones (Fig. 1 - c).

Other two kinds of geological formations are present in Latium, with a lot of small units:

iii - polygenic conglomerates mixed to clay and sand deposits, of Plio-Pleistocene age (Fig. 1 - d).

iv - compact (thermal and cold water travertines) or impure travertines (calcareous tufa) of Plio-Pleistocene age and even from Holocene to present days (Fig. 1 - e).

Both these two formations show karstic extensive developments, despite their very young age.

## 2. THE HYPOGEAN KARSTIC PHENOMENA IN LATIUM

### 2.1 Their general features and the development of studies

Famous geographers took the karst in Latium into consideration in the XIX century but Segre (1948) has published the first comprehensive study. A lot of work on limited areas followed between 1950 and 2000, (e.g.

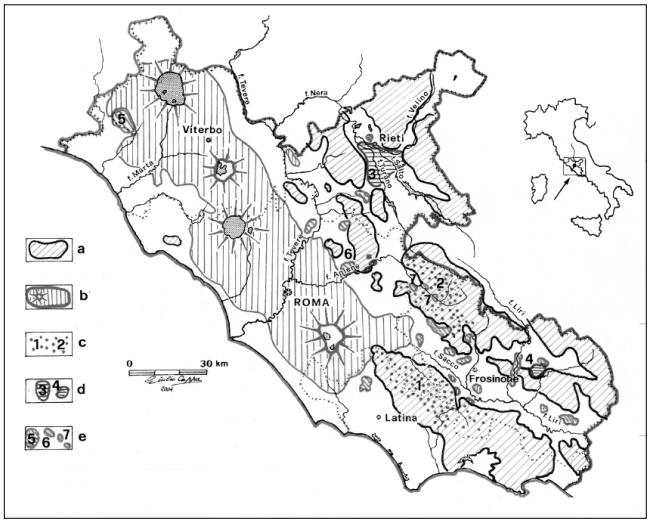



Fig. 1 – The main geological formations in Latium
Legenda: a = karstified limestones; b = volcanic complexes; c = volcanic air-fall deposits still remaining over the karstified limestones; d = main units of Plio-Pleistocene conglomerates; e = Plio-Pleistocene and Holocene travertines.
1 = location of former observations of air-fall deposits over the karstified limestones; 2 = location of later observations of air-fall deposits over the karstified limestones; 3 = conglomerate unit near Rieti; 4 = Mount Montecòccioli conglomerate unit; 5 = cave system >1km in travertine near Ischia di Castro; 6 = travertine quarries of Tivoli; 7 = travertine formations near Subiaco.
*Fig. 1 - Le principali formazioni geologiche del Lazio*
*Legenda: a = calcari carsificati; b = complessi vulcanici; c = depositi cineritici sopra i calcari; d = principali unità conglomeratiche Plio-Pleistoceniche; e = travertini Plio-Pleistocenici e Olocenici; 1 = localizzazione dei primi depositi cineritici esaminati; 2 = localizzazione dei successivi depositi cineritici esaminati; 3 = unità conglomeratica di Rieti; 4 = unità conglomeratica del Montecòccioli; 5 = sistema carsico nei travertini, di oltre 1 km, presso Ischia di Castro; 6 = cave di travertino sotto Tivoli; 7 = formazioni travertinose vicino a Subiaco.*

Felici, 1976, 1977, 1978). One of the authors presented two short synthesis (Cappa G., 1996, 2000).

In this region the development of karstic phenomena started more recently than in other Italian units of the Alps and Peninsula, because in Latium the uplift of calcareous massifs, that brought them above the sea-level, generally started in late Miocene only and was widely stopped by submersions during Pliocene. The inception horizons are related to a sequence of tectonic phases, from Miocene to Pliocene, but few are the traces of any appreciable evolution older than the end of Pliocene.

### 2.2 The present level of discoveries

So far about 1600 caves have been assessed in Latium, mainly due to karstic processes; many of them still show juvenile features, few are already in a fossil state. A few, that include large hollows, are claimed to be a consequence of hyper-karstic thermal processes. The maximum depth reached by the exploration of some cave scarcely exceeds -600m, though the difference in height between the inlets and the resurgences at the base of the massifs achieves up to 1000-1500m. Less than 20 caves only have a total development of more than 1km and none has been surveyed over 4km.

Yet, there is evidence of peculiar features which mark this region, depending on other factors that have influenced the karst evolution. Three of them are of greater importance; they have been identified during these last years and are the subject of this note.

## 3. THE INTERACTION BETWEEN PYROCLASTIC AIR-FALL DEPOSITS AND THE DEVELOPMENT OF KARST

### 3.1 The main geological features

In Latium the most remarkable and widely spaced phenomenon of this interaction is a consequence of the superimposition of the volcanic ash deposits, which covered some calcareous massifs, at a time when their karstic features were already developed.

The limestones in Lepini, Ausoni, Aurunci Mountains (anti-Apennines chain, parallel to the coast line) and Simbruini Mountains (a massif along the border between Latium and Abruzzi, belonging to the pre-Apennines chain) during the volcanic eruptions (occurred repeatedly from medium Pleistocene to the beginning of Holocene in Alban Hills and many smaller emission points, distributed both around and within the calcareous massifs) were covered with such air-fall deposits: their final thickness was of a few metres, substantially increased in the karstic hollows where the subsequent rains conveyed them.

The former observations were carried on in the core of Lepini Mountains (Fig. 1, 1), more than twenty-five years ago, by one of the authors (Felici, 1976 at pag. 70 and 71, 1977 at pag. 41, 1978 at pag. 298 and 301): several swallets were seen recovering their original function and, every year from then on, some new inlet was found in the basins where the covering of pyroclastites was widespread.

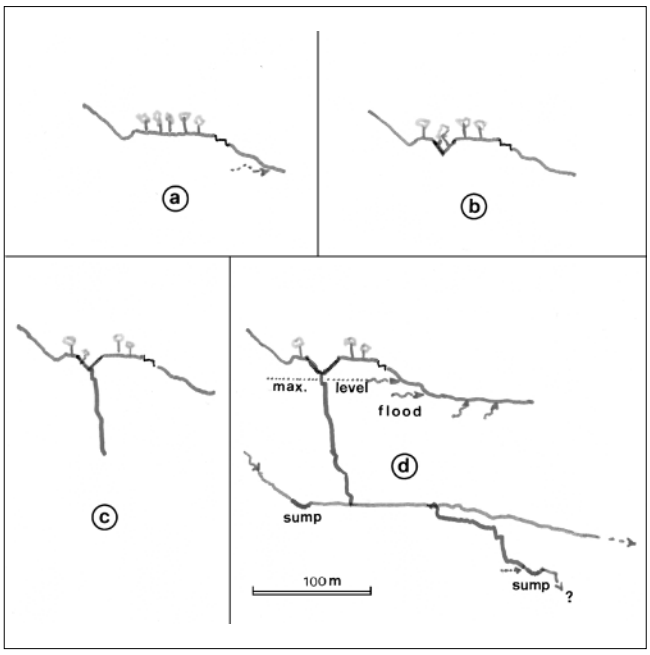



Fig. 2 – Evolution of Ciaschi karstic system (vertical simplified profiles)
Legenda: a = situation before 1972; b = the doline at the end of 1972; c = opening of the first shaft (1978); d = the situation after 1994.
*Fig. 2 - Fig. 2 Evoluzione del sistema carsico della Grotta Ciaschi (profili verticali semplificati)*
*Legenda: a = situazione ante 1972; b = la dolina alla fine del 1972; c = apertura del primo pozzo nel 1978; d = situazione dopo il 1994; max. level = massimo livello delle acque in piena; flood = fuoriuscite di piena; sump = sifone.*

### 3.2 Two events in Lepini Mountains

In 1972 A. Felici observed that in a plain surface of an orchard near Carpineto R. a collapse created a conical funnel-shaped doline (diameter 20m, depth 10m, volume approx. 1000m3) within a deposit of pyroclastites, discovering near the bottom some pinnacles of limestones: the event evolved in two stages during less than one year, swallowing a pair of tall cherry trees (Fig. 2, a/b).

After five years in standstill this doline, at the end of 1977, very quickly evolved with the opening of a shaft 80m deep (–90m below the surface, Fig. 2, c) but during winter 1978-79 the collapse of other two trees plugged the narrow access to this shaft; any way the doline was classified as a cave, with the name “Inghiottitoio sotto casa di Amedeo Ciaschi - 832 LaRM” later briefly called “la Ciaschi”. Finally in 1994 (Felici et alii, 1997) the access opened again (Fig. 2, d), a further shaft was descended down to –113m and a cave nearly 1,5km long was found, with many descending and ascending branches whose exploration is not yet completed. These branches are an important part of the network of the

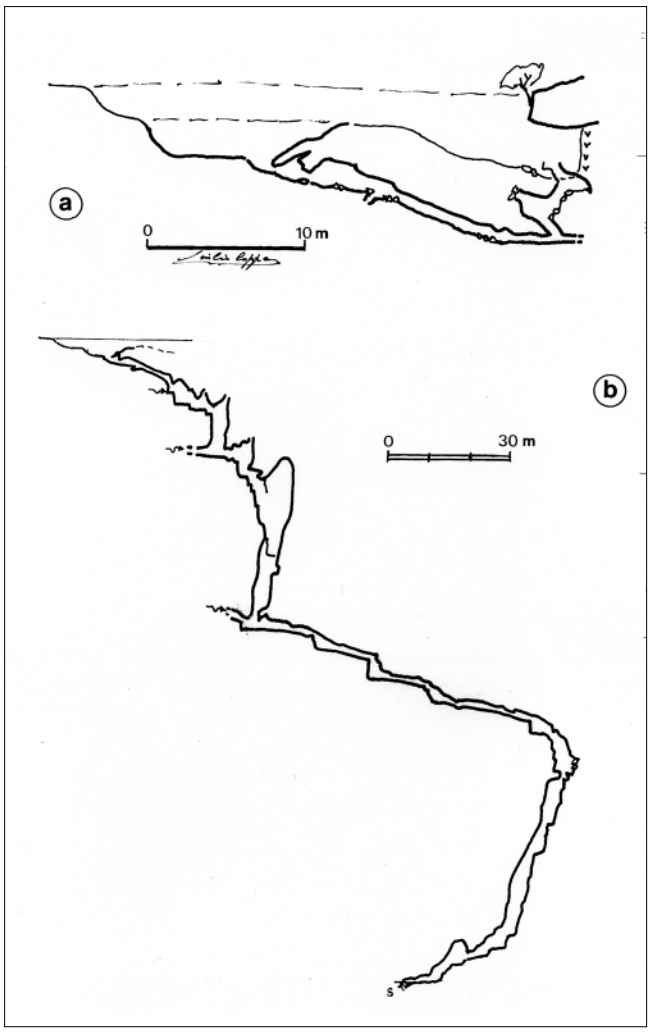



Fig. 3 – Vertical profile of Capodafrica karstic system.
Legenda: a = 1997 survey (A. Felici, G. Cappa, F. Cappucci, M. Rosatella); b = situation at the end of the explorations in 1995 (E. Cappa, M. Mecchia, M. Barbati).
*Fig. 3 - Profilo verticale del sistema carsico dell'abisso Capodafrica.*
*Legenda: a = rilievo 1997; b = rilievo al termine delle esplorazioni nel 1995.*

deep karstic drainage ascertained in the core of Lepini Mountains, certainly older than the volcanic air-fall deposits; it continued to run after such external events, in part it has been filled with huge mud deposits containing pyroclastic elements too, and was clearly responsible of the reopening of the Ciaschi access through an upward action of hydraulic ram from below, against the base of the plug during the worst floods.

The land owner suffered the loss of a fair part of his orchard but no real danger for the persons; the young cavers enjoyed with the discovery and exploration of a long and complex cave: the knowledge about the deep karst in Lepini Mountains got a substantial improvement.

Again in 1972 A. Felici discovered in the basin Le Faggeta (somewhat like a polje but of more complex structure (see Cappa G. & Felici, 2001)), in the mountains above Carpineto R., a cave composed by a doline and two short branches connected by too narrow passages (Felici, 1977). The cave took the name "Dolina con due Ousi in località Le Fosse - 799LaRM". In 1994 (Cappa E. et alii, 1997), the speleological group Associazione Speleologica Romana (ASR'86) opened again the access to one of the two holes, that had been plugged with many debris, and at its bottom they found a narrow fissure trough which all the percolating water was swallowed; after some work into a muddy deposit of pyroclastites they passed and discovered a cave nearly 250m long and 152m deep.

In this case the last operation that lead to the reopening of the cave was made by men, but it was just at the moment of a natural opening by means of percolating waters; what is interesting is to note that the scallops observed on the inside walls indicate an ascending water flow: consequently before the air-fall depositions, may be well before, this cave had functioned as a resurgence, not a sinkhole. In Fig. 3, a the survey of the cave in 1977, Fig. 3, b the present situation (1995).

### 3.3 A catastrophic event in Simbruini Mountains

New observations were carried by the authors during these last years in another important massif: the Simbruini Mountains (Fig. 1, 2). This massif is more distant than Lepini from the main volcanic complex of Alban Hills and the deposits of air-fall ashes less remarkable: they are usually by now mixed with terra rossa and not clearly mentioned in the geological maps. Nevertheless the extensive and repeated searches for new caves, that the authors perform together with other members of Shaka Zulu Club Subiaco, allowed to discover many places in which the soil subsides by swallowing of the covering composed by small detritus mixed to pyroclastites and terra rossa: new dolines develop and become wide and deep every year more.

At Campo dell'Osso (Subiaco) a flat urbanised area, which includes many buildings, is scattered with dolines and small sinkholes: near the road at the centre of this area in a flat meadow (Felici et alii, in print) an altar was built up to allow the Sunday tourists multitude to hear Holy Mass. But only few years later, now we see the grass pitted by several small collapses, at present only 0.5-1.5m deep, that obviously makes dangerous the attendance, especially for children. The reopening of ancient sink-holes and karstic fissures obliterated by the pyroclastites is an ubiquist and unpredictable phenomenon; it reveals more frequently in flat and regular areas, just those which appeared more suitable for the settlement of new inhabited places.

### 3.4 The risk of future collapses

Some spectacular event ought to strengthen the concern of authorities when they allow the establishment of such settlements. Just 250m beneath Campo dell'Osso

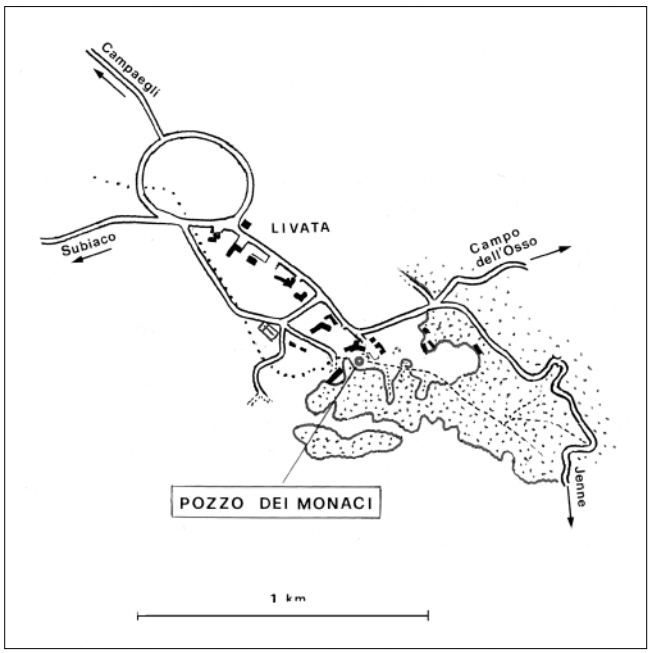



Fig. 4–Location of Pozzo dei Monaci sinkhole.
*Fig. 4 -Localizzazione della voragine Pozzo dei Monaci.*

there is another tourist village, Livata; on Sept. 2nd 2002, at 1 p.m., a sinkhole 25m deep, with a nearly cylindrical profile, 7-10m wide, suddenly collapsed with a terrific roar (Procaccianti et alii, 2002). It opened in the centre of a flat meadow, it was Monday and just the day before the children were playing there: a long building, a condominium, is situated 30m only near that place. Immediately informed of such event the authors and their colleagues of Shaka Zulu Club Subiaco (SZCS) the day after inspected the hole, and again every month for a long period: a second smaller shaft was found, which starts from a meander that a temporary brook has recently dug in the meadow short upstream; the meander penetrates underground for some metres, then falls down into the minor shaft which ends down in the main sinkhole near its present bottom (Fig. 4 and 5). The walls are unstable vertical surfaces of a deposit composed by a mix of clay, terra rossa and pyroclastites, and pinnacles of a former karstic structure crop out here and there; a volume well exceeding 1000m3 has been swallowed and now fills the bottom of the shaft like a fluid mud; the pebbles that frequently fall down from the sides, disappear into that mass. An inside more precise inspection is impossible for the time being, we need that the sinkhole walls shall stabilise; its inlet has been encircled with a fencing, the shaft cannot be filled up, on account of the continuous flow of water in the rainy periods and of the extremely high costs of such intervention. The near living inhabitants are very troubled, a continuous check is carried on, both for safety reasons and because this one is perhaps the most interesting phenomenon of that kind:

Fig. 5 – Survey of Pozzo dei Monaci sinkhole (September 2002).
*Fig. 5 - Rilievo della voragine Pozzo dei Monaci: situazione al settembre 2002.*

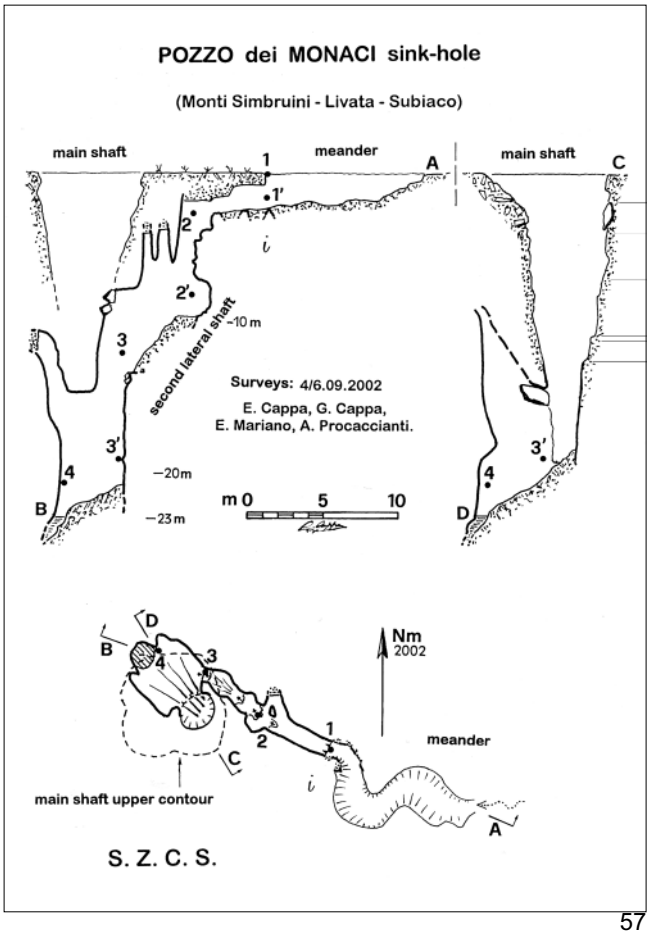
it could allow after some years to explore some unknown, extensive and deep karstic system.

### 3.5 The general development of these peculiar features

In conclusion, the ridges and steep slopes of the mountains were released of the pyroclastites and the karstification soon started again, while the obstructions of the shaft inlets, formerly opened in the dolines, got consolidated. After a long time the surface ablation started to reduce these plugs; the process was in recent years accelerated by the human activities (deforestation, farming, deep excavations for buildings and roads); at the same time, as the karst hypogean processes had resumed deep below and some percolation had found its way down through fissures in the plugging sides, their stability becomes critical, bearing to sudden collapses just in these years. They open the way to very interesting explorations of unexpected caves but, as the examples that are reported in this note show, they raise serious troubles for the safety of the human settlements close to them.

## 4. KARST IN CONGLOMERATES

Besides many Flysch sequences and Allochthonous complexes, in Latium exist several deposits of conglomerates subsequent to the formation of wide lakes during Pliocene; though usually of polygenic composition, often



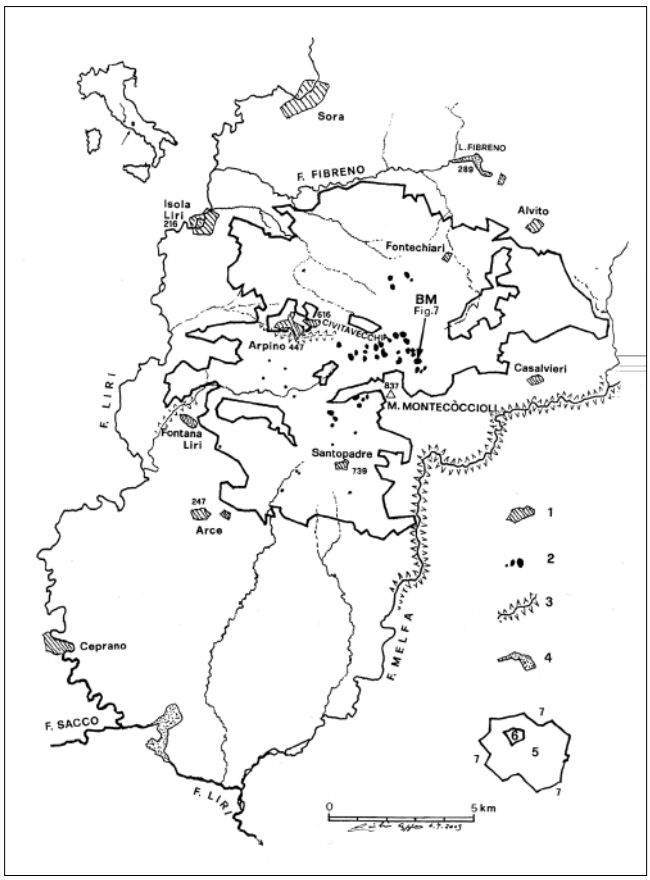



Fig. 6 – Geomorphological map of Mount Montecòccioli near Sora (FR). Legenda: 1 = towns; 2 = main dolines; 3 = river gorges; 4 = lakes; 5 = main conglomerate unit (pudding-stone and sands-stone); 6 = rising Cretaceous-Palaeocene limestones; 7 = surrounding units (Cretaceous to Miocene limestones and calcarenites; Pliocene travertines); BM = Buco Marcello location.
*Fig. 6 -Carta geomorfologia del monte Montecòccioli presso Sora . Legenda: 1 = città; 2 = principali doline; 3 = gole fluviali; 4 = laghi; 5 = principale unità conglomeratica (puddinghe e arenarie); 6 = calcari del Cretacico-Paleocene emergenti; 7 = altre unità circostanti (calcari e calcareniti dal Cretacico al Miocene; travertini del Pliocene); BM = posizione del Buco Marcello.*

both the pebbles and the matrix are mainly calcareous. Two main units have been taken into consideration: they were produced during middle-upper Pliocene and Pleistocene by large continental water flows coming from the surrounding Mesozoic calcareous mountains and include banks of well-cemented polygenic conglomerates. As the matrix is mainly calcitic, there is evidence of pretty fast karstic development.

### 4.1 The conglomerates in Northern Latium

One unit (Fig. 1, 3) is situated SE of the town Rieti and covers the western sectors of Sabini, Carseolani and Nuria Mountains. In spite of extensive investigations, still very few and small caves are known there

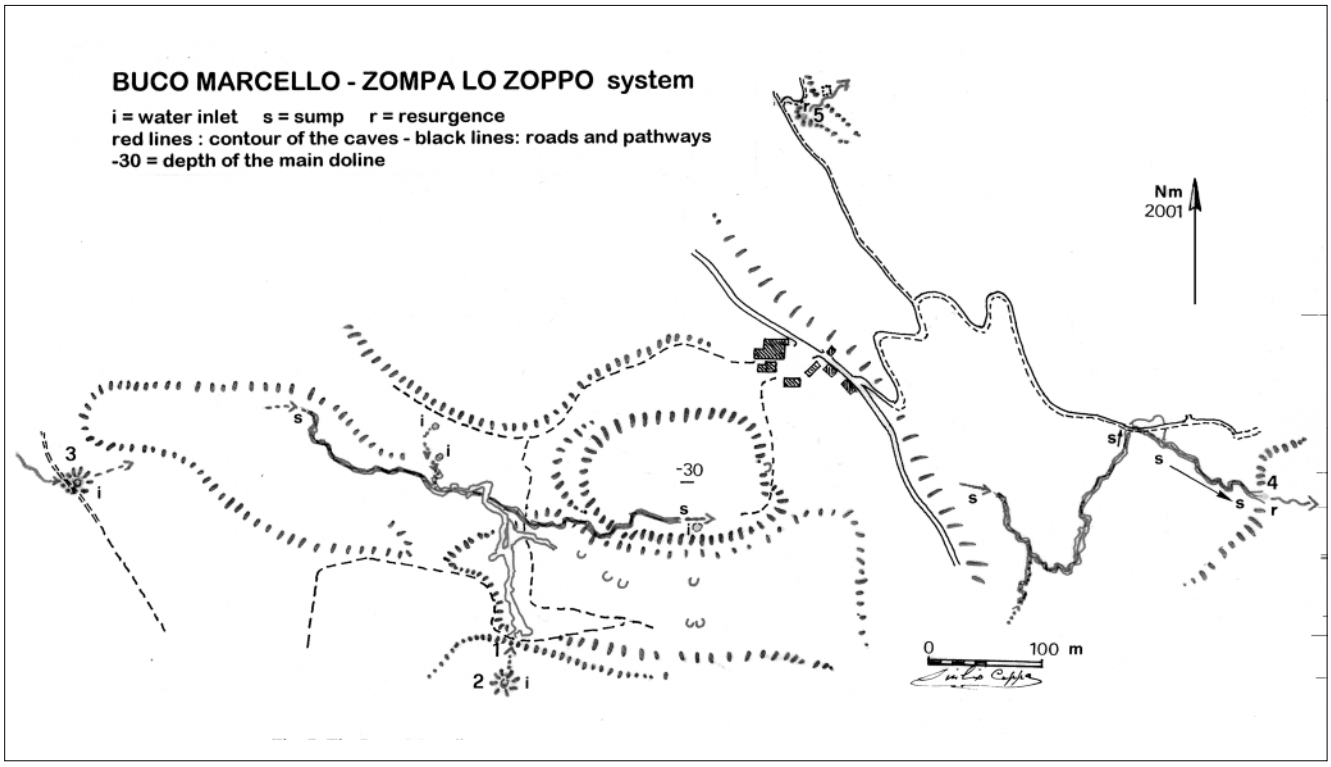



Fig. 7 The Buco Marcello - Zompa lo Zoppo caves hydrokarstic system (Arpino). Legenda: 1 = Buco Marcello; 2 = Sinkhole South of Buco Marcello; 3 = Probable inlet to Buco Marcello; 4 = Zompa lo Zoppo cave and resurgence; 5 = temporary resurgence La Barca
*Fig. 7 Sistema idrocarsico delle grotte Buco Marcello e Zompa lo Zoppo (Arpino). Legenda: 1 = Buco Marcello; 2 = inghiottitoi a Sud del Buco Marcello; 3 = probabile inghiottitoio principale del Buco Marcello; 4 = Zompa lo Zoppo e risorgenza; 5 = risorgenza temporanea La Barca; i = inghiottitoio, s = sifone, r = risorgenza; linee rosse = contorno delle grotte, linee nere = strade e sentieri, –30 = profondità della dolina*

and the surface karst features are really scanty; nevertheless this unit is an important part of the catchment basin of Peschiera spring, which gives nearly a 50% of the drinkable water to Rome; waters come from a large and deep sump, whose exploration by divers is of course banned: this remark would suggest a deeper investigation on the hypogean karst by means of geophysical investigation tools.

### 4.2 A particular case in Southern Latium

The second unit (Fig. 1, 4) is situated South of Sora (Frosinone), it dates mainly to Pleistocene and takes the larger part of Mount Montecòccioli (Fig. 6): its surface is studded with tens of large and deep dolines which give the appearance of a very mature karst. Their bottom is prevailingly flat and cultivated: the soil includes, besides terra rossa, a considerable amount of sand because the conglomerates are frequently alternated by arenaceous lenses. After severe rains the large dolines are flooded and their emptying takes several days owing to percolation through the arenaceous deposits; only few dolines still show evidence of a sinkhole, which in any case becomes impassable to humans at shallow depth.

Below the surface a few caves were recently found in the central part of this unit. In the present configuration the surface of this area is very limited (ca. 10km2) and no possibility exist of water feeding from surrounding areas, which are all considerably at lower levels; even so a perennial stream, fed by some inlets and a local watertable, flows through a cave, several sumps and gets out through a second cave and perhaps a pair of other impassable resurgences: the Fig. 7 shows a map of this complex. The system is more than 1km developed; its upper part (Buco Marcello) was discovered in 1988 by Belgian cavers who draw a first survey, recently visited by one of the authors (E. Cappa) who explored some new branch, completed and revised the survey in cooperation with the cavers of Gruppo Speleologico Guidonia-Montecelio (GSGM); the entrance to this cave gives access to a first system of fossil passages, then a steep descent leads to the active stream which is fed by some small sinkholes, shown in the western part of Fig. 7, and flows eastwards. The fossil level corresponds to a step in the side profile of the doline just at the South of the cave. Later was discovered, following information from local people, the resurgence (Zompa

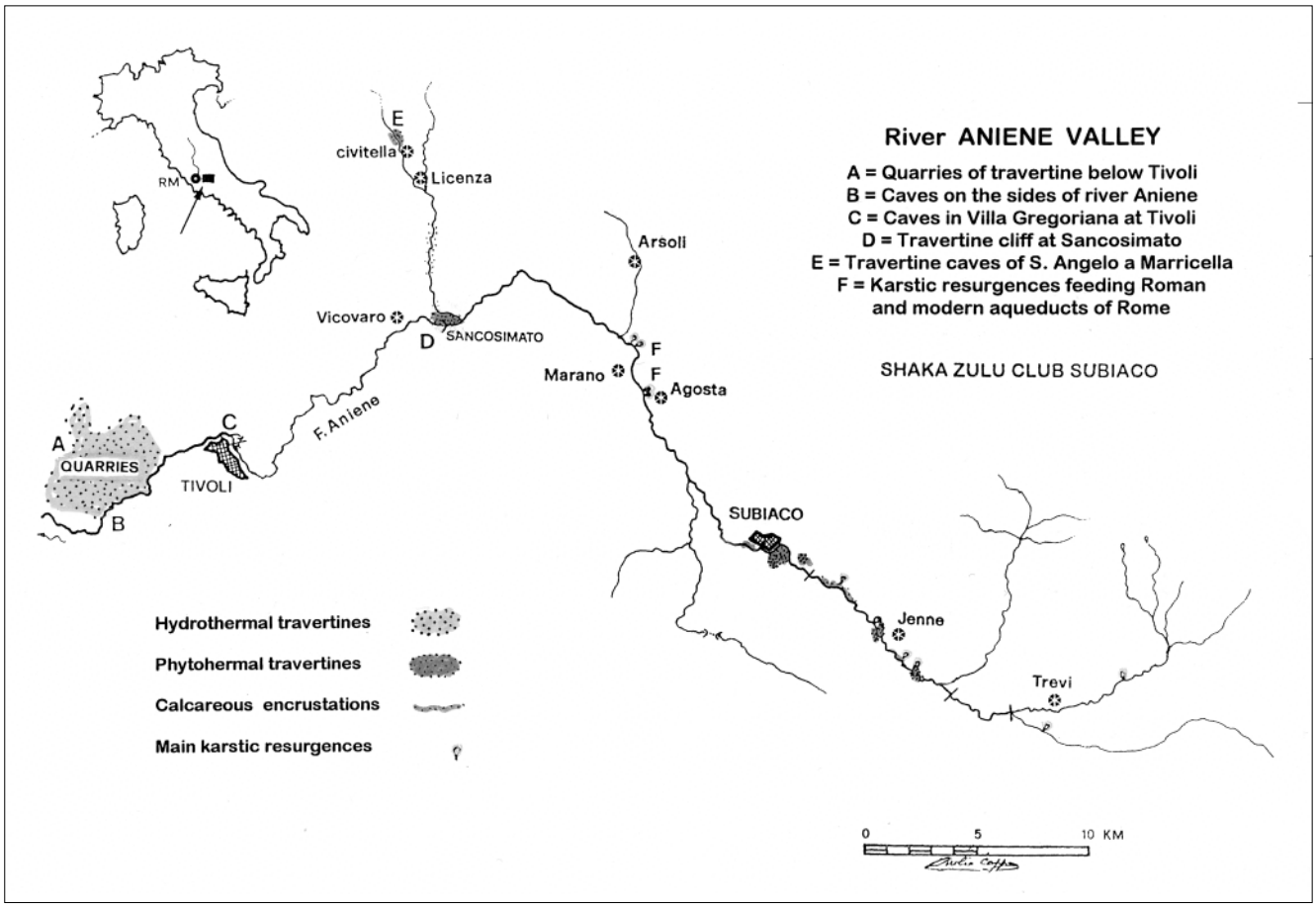



Fig. 8 – Travertine units and related karst phenomena along Aniene valley (Legenda inside the figure).
*Fig. 8 - Unità di travertino e relativi fenomeni carsici lungo la valle del fiume Aniene*
*A = cave di travertino sotto Tivoli; B = grotte in riva al Fiume Aniene; C = grotte nella Villa Gregoriana a Tivoli; D = rupe di travertino di Sancosimato; E = grotte nel travertino a S. Angelo a Marricella; F = risorgenze carsiche alimentanti gli antichi acquedotti romani e l'attuale Acqua Marcia;*
*1 = travertini idrotermali, 2 = travertini fito-ermali, 3 = incrostazioni calcaree, 4 = principali risorgenze carsiche.*

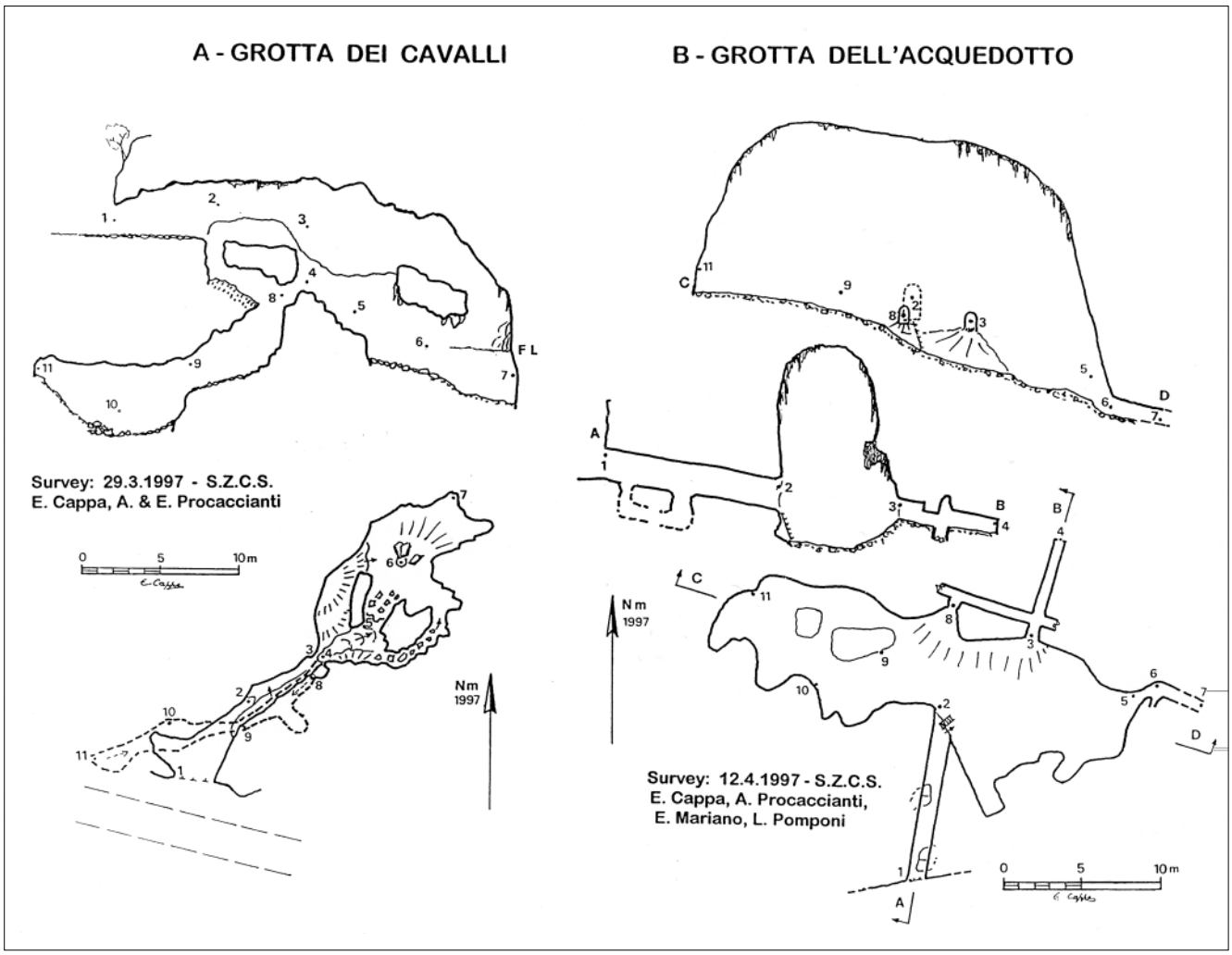



Fig. 9 – Caves in travertines at Sancosimato (Vicovaro). A - Grotta dei Cavalli - FL = standstill water fossil level near point 6; B - Grotta dell'Acquedotto - some cuniculi of ancient Roman origin.
*Fig. 9 - Grotte nei travertini a Sancosimato (Vicovaro). A = Grotta dei Cavalli (FL = livello fossile di invaso idrico presso il caposaldo 6); B = Grotta dell'Acquedotto (con alcuni cunicoli di antica origine romana).*

lo Zoppo), finding a sump 100m long, initially explored by the diver Giancarlo Spaziani, then emptied by means of several pumps; subsequent exploration by GSGM went over a second sump and a third one (Ciocci, 2001) after a long meander, approaching the lower end of Buco Marcello. The intermediate and still unknown part between the two caves starts in BM below the –30m doline, by a sump partially filled with sand; just above it is situated the leakage at the bottom of the doline, where the temporary floods percolate through impassable fissures and drive the sand down.

The role of the arenaceous lenses and deposits does not interfere with the natural evolution of the hypogean karst but with the cavers accessibility only. The explorations are still advancing but it is possible to anticipate the results of the investigations already achieved: the passages follow a set of joints of different orientations, the matrix is dissolved very quickly, leaving the pebbles (mainly calcareous) considerably protruding, but it shows the typical features of the caves in limestones, like scallops and potholes; where the cave meets a lens of poorly cemented sandstone it widens and the vault becomes unstable, the thick deposit of sand which grows just below creates some problem and can choke the passage to humans, even if water continues to flow.

This unit was subjected, during the same Pleistocene, to a very quick uplift of nearly 500m: now it is surrounded by valleys deeply incised and is separated, on the North side, from the area of Lake Fibreno, which includes limestones and conglomerates too, and is fed by important submerged resurgences.

In conclusion, an example of very fast evolution of the hypogean karst has been met there; what is still unresolved is the determination of the age and processes of the huge dolines above (diameters up to 200m, depth to 30-40m): did they start to form when the unit still was at the base level or later?

## 5. KARST IN TRAVERTINES: THE PECULIAR FEATURES ALONG THE RIVER ANIENE VALLEY

The third feature concerns the travertines, which in

Latium are arranged in a lot of units (Fig. 1 e), covering a surface that may be as little as one tenth of hectare or even larger, up to a few square kilometres. In the NW sector of the region one very wide unit (Fig. 1, 5), now raised above the watertable, includes and hypogean stream that can be followed along three caves for more than 1km.

In the river Aniene valley, downstream of Tivoli (Rome) are the famous quarries of thermal water travertine which have been exploited along more than two thousand years (Fig. 1, 6 and Fig. 8, A); upstream of Tivoli, a lot of limited strips of phyto-hermal cold water travertine were recently investigated (Felici & Cappa G., 2002) by the authors (Fig. 8, C, D, E); their origin is very recent (from middle Pleistocene to present days). They show a lot of small syngenetic cavities (Fig. 9), but also some karstic development with caves generated by underground streams, even more than 100m long.

Nearly all these cavities include interesting speleothemes: traces of ancient water levels and, usually related to them, mammillary stalactites. Some of this speleothemes aid to define the position of ancient lakes, like those connected to the famous Villa of Nerone upstream of Subiaco, and a few caves show modifications carried on during the Roman Empire, e.g. in Sancosimato (Fig. 8, D) and in Licenza, near Civitella (Fig. 8, E: and interesting Nymphaeum) (Felici, 2001).

All these formations, that should be better defined as Calcareous Tufa (Capezzuoli & Gandin, 2004), are considered of Holocene age, though no local dating has been made so far: in connection with these formations is the discovery of some cold springs that show an active incrustation immediately downstream, both near Civitella and in St. John valley near Subiaco.

## 6. CONCLUSIONS

We have investigated three quite different features that display an extremely fast evolution of karst, both epigean and hypogean, that took place in late Pleistocene or even Holocene, as a consequence of peculiar situations: consequently they can be considered interesting fields for an accelerated study of karst processes. Two of them show the influence of deposits which are unusual in karstic regions; in the third, the deposit itself is at the origin of the karstic phenomena. At the same time they involve serious concern when unaware people have created human settlements close to them.


## Acknowledgements

The authors are grateful to the colleagues of Shaka Zulu Club Subiaco, Gruppo Speleologico Guidonia-Montecelio and Associazione Speleologica Romana ’86 club, who were of great help in recces, explorations and fulfilment of surveys.



## Summary

The region Latium (Italy) is peculiar owing to the two main geological formations which cover a great part of its territory: the calcareous chains (mainly of Mesozoic and Miocene ages) and the pyroclastic rocks (emitted through the limestones and widely spread around, as air-fall deposits, during Quaternary). The development of karstic phenomena in Latium is recent: the inception horizons are related to a sequence of tectonic phases, from Miocene to Pliocene, but very few are the traces of any appreciable evolution older than the beginning of Quaternary.

So far about 1600 caves have been assessed in Latium, mainly due to karstic processes; a few, that include large hollows, are claimed to be a consequence of hyper-karstic thermal processes.

Yet, there is evidence of peculiar features, which mark this region, depending on other factors that have influenced the karst evolution. Three of them are of greater importance; they have been identified during these last years and are the subject of this note.

The most remarkable and widely spaced phenomenon is a consequence of the superimposition of the mentioned volcanic ash deposits, which covered some calcareous massifs, at a time when their karstic features were already well developed.

The limestones in Mounts Lepini, Ausoni, Aurunci (anti-Apennines chain, parallel to the coast line) and Mounts Simbruini (a massif along the border between Latium and Abruzzi, belonging to the pre-Apennines chain) during the volcanic eruptions (occurred repeatedly from medium Pleistocene to the beginning of Holocene) of Alban Hills and many smaller emission points (distributed both around and within the massifs) were covered with such air-fall deposits: their final thickness was of a few metres, substantially increased in the karstic hollows where the subsequent rains conveyed them.

In part these incoherent materials were washed down, deep into the caves of the karstic networks, where now crystals of mica, leucite, etc. can often be found; moreover some measurement of Radon concentration have shown radioactivity levels considerably higher than usual.

The ridges and steep slopes of the mountains were released of the pyroclastites and the karstification soon started again, while the obstructions of the shaft inlets, formerly opened in the dolines, got consolidated. After a long time the surface ablation started to reduce these pluggings; the process was in recent years accelerated by the human activities (deforestation, farming, deep excavations for buildings and roads); at the same time, as the karst hypogean processes had resumed beneath and some percolation had found its way down through fissures in the plugging sides, their stability became critical, bearing to sudden collapses just in these years. They opened the way to very interesting explorations of unexpected caves but, as the examples that will be reported in this note show, they raised serious troubles for the safety of the human settlements close to them.

The second feature can be found within the conglomerates: two main units of clay, sand and pebbles deposits exist in Latium. They were produced during middle-upper Pliocene and Pleistocene by large continental water flows and include banks of well-cemented polygenic conglomerates. As the matrix is mainly calcitic, there is evidence of pretty fast karstic development. One unit is situated SE of the town Rieti and covers the western sectors of Mounts Sabini, Carseolani and Nuria. Very few and small caves are known there and the surface karst features are really scanty; nevertheless this unit is the main catchment basin of Peschiera spring, which gives nearly a 50% of the drinkable water to Rome: this remark would suggest a deeper investigation on the hypogean karst, by means of geophysical investigation tools.

The second unit is situated South of Sora (Frosinone), it dates mainly to Pleistocene and takes the larger part of Mount Montecòccioli: its surface is studded with tens of large and deep dolines and a few caves were recently found underneath. Now a perennial stream, fed by some inlets and a local watertable, flows through a cave, several sumps and gets out through a second cave. The system, more than 1km developed, is under investigation and the results attained up to present days are summarised in this note.

The third feature concerns the travertines, which in Latium are arranged in a lot of units, covering a surface that may be as little as one tenth of hectare or even larger, up to a few square kilometres. In the NW sector of the region one very wide unit, now raised above the watertable, includes and hypogean stream that can be followed along two caves for more than 1km.

In the river Aniene valley, upstream of Tivoli (Rome), a lot of limited strips of fito-hermal travertine were recently investigated by the authors; their origin is very recent (from middle Pleistocene to present days). They show a lot of small syngenetic cavities (few of them can be included in the Italian Caves Register), but also some karstic development with caves generated by underground streams, even more than 100m long, and they include interesting speleothemes. In connection with these formations is the discovery of some springs that show an active incrustation immediately downstream. A map of these formations, some cave surveys and descriptions are included in this note.

In conclusion, all these three features show an extremely fast evolution of karst, both epigean and hypogean: consequently they are peculiar fields for an accelerated study of karst processes.

## Riassunto

*La regione Lazio (Italia) è caratterizzata dalla presenza di due formazioni geologiche estese a gran parte del suo territorio: le catene calcaree (di epoca prevalentemente Mesozoica o Miocenica) e le coperture piroclastiche (emesse dal vulcanesimo laziale durante il Quaternario, anche attraverso le formazioni calcaree, e diffuse sopra queste ultime sotto forma di cineriti). Nel Lazio la formazione del carsismo è recente: sono stati osservati condotti embrionali connessi ad una successione di fasi tettoniche, dal Miocene al Pliocene, ma pochi sono gli indizi di una loro effettiva evoluzione precedente al Quaternario.*

*Attualmente nel Lazio sono note circa 1600 grotte, in assoluta prevalenza di natura carsica; alcune, che comprendono grandi cavità, sono ritenute di origine termo-iper-carsica. Tuttavia ci sono anche altre morfologie particolari, tipiche di questa regione, che derivano da altri fattori che hanno influenzato l'evoluzione del carsismo. Tre sono le principali: esse sono state messe in luce dalle ricerche di questi ultimi anni e sono perciò l'oggetto della presente relazione.*

*Il fenomeno più diffuso e rilevante è una conseguenza della deposizione delle cineriti che hanno coperto interi massicci calcarei ad un'epoca in cui i fenomeni carsici si erano già abbastanza sviluppati. I calcari dei Monti Lepini, Ausoni, Aurunci (catena degli anti-appennini, parallela alla costa marina del Lazio) e Monti Simbruini (massiccio che si sviluppa al confine tra Lazio ed Abruzzo, facente parte della catena pre-appenninica) durante le eruzioni vulcaniche (ripetutesi più volte tra il medio Pleistocene e l'inizio dell'Olocene) dei Colli Albani e di altri centri d'emissione minori (distribuiti sia al contorno che all'interno dei massicci calcarei) furono ricoperti dalle cineriti fini trasmesse dal vento, il cui spessore finale fu di alcuni metri ma divenne assai più considerevole nelle depressioni carsiche in cui esse vennero concentrate dai dilavamenti meteorici. In parte questi materiali incoerenti furono trascinati anche dentro le cavità carsiche: al loro interno si osservano grandi sedimenti ricchi di cristalli di mica, leucite, ecc. e alcune misure di concentrazione di Radon hanno evidenziato livelli di radioattività molto superiori al normale.*

*Le creste ed i pendii delle montagne sono stati ripuliti dai depositi cineritici ed i processi carsici riattivati; alcune ostruzioni di imbocchi dei pozzi posti nelle depressioni hanno potuto invece consolidarsi. Dopo tempi assai più lunghi l'ablazione superficiale ha incominciato ad intaccare anche questi depositi, fenomeno recentemente accelerato dalle attività umane (deforestazione, arature, scassi per costruzione di strade e edifici); contemporaneamente la ripresa del carsismo profondo e le percolazioni al contorno attraverso fenditure riattivatesi hanno resa critica la stabilità di tali ostruzioni, portando ad improvvisi crolli e catastrofici collassi proprio nel corso di questi anni. Essi hanno aperto la strada all'esplorazione di grotte di cui finora nemmeno si supponeva l'esistenza ma, come gli esempi che vengono descritti chiariscono, hanno anche sollevato serie preoccupazioni per la sicurezza degli insediamenti umani situati in loro prossimità.*

*Il secondo fenomeno particolare concerne i conglomerati: due estese formazioni di sabbie, argille e ciottoli sono note nel Lazio. Esse si sono deposte dal Pliocene medio-superiore al Pleistocene, ad opera di grandi flussi idrici, e comprendono banchi di conglomerati poligenici (puddinghe) ben cementati. Dato che la loro matrice è prevalentemente calcitica, si nota uno sviluppo notevolmente veloce (che lascia sulle pareti in rilievo anche i ciottoli prettamente calcarei). Una unità si trova a SE della città di Rieti ed occupa il settore occidentale dei Monti Sabini, Carseolani e del Nuria. Poche e piccole le grotte che vi sono per ora note e le forme dell'epi-carso sono assai scarse; tuttavia questa unità costituisce l'impluvium principale delle sorgenti del Peschiera, che forniscono quasi il 50% dell'acqua potabile diretta a Roma. Queste considerazioni dovrebbero suggerire ricerche sistematiche sull'ipo-carso della zona, col ricorso a ricerche geofisiche strumentali. La seconda unità si trova a Sud di Sora (Frosinone), risale al Pleistocene ed occupa buona parte del gruppo montuoso di Montecòccioli; la sua superficie è costellata da decine di ampie e profonde doline e vi sono state recentemente scoperte alcune grotte. Un corso d'acqua perenne, alimentato da alcuni piccoli inghiottitoi e da una falda locale sospesa, defluisce attraverso una grotta, vari sifoni e sbocca da una seconda grotta. Il sistema ha uno sviluppo superiore a 1 km, è tuttora in esplorazione ed i risultati finora conseguiti sono sintetizzati nella presente nota.*

*Il terzo fenomeno riguarda il carsismo nei travertini, che nel Lazio comprendono numerose unità aventi singolarmente superfici*

*da molto limitate (meno di un decimo di ettaro) ad estese fino a diversi chilometri quadrati. Nel NW del Lazio un'unità molto grande, attualmente sopraelevata rispetto alla falda basale, racchiude un corso d'acqua sotterraneo che può essere seguito parzialmente in due grotte, per oltre 1 km di sviluppo. Nella valle del fiume Aniene, a monte di Tivoli (Roma), si incontrano numerosi lembi di travertini fito-ermali che sono stati recentemente esaminati dagli scriventi; la loro origine è molto recente (dal medio Pleistocene ai giorni nostri). Essi includono numerose piccole cavità singenetiche (non sempre inseribili nel Catasto delle Grotte d'Italia) ma evidenziano pure alcuni sviluppi carsici con grotte generate da corsi d'acqua ipogei, talora lunghe più di 100 m, e racchiudono interessanti speleotemi. Connesse a tali grotte sono state trovate alcune sorgenti che mostrano, subito a valle, un'attiva formazione di croste calcaree. Nella presente nota è mostrata una carta della distribuzione di tali formazioni nella media e alta valle del fiume Aniene, oltre a rilievi e descrizioni di alcune cavità.*

*In conclusione, tutte queste tre classi di fenomeni carsici mostrano una elevata velocità di evoluzione e potrebbero pertanto costituire interessanti campi di studi speleogenetici.*

## REFERENCES


Accordi G. & Carbone F. (a cura di) (1988) - Carta delle litofacies del Lazio-Abruzzo ed aree limitrofe con note illustrative, C.N.R. Prog. fin. Geodinamica - La Ricerca Scientifica n. 114, Roma

Capezzuoli E.& A. Gandin A. (2004) - I "travertini" in Italia: proposta di una nuova nomenclatura basata sui caratteri genetici - Conv. "La Geologia del Quaternario in Italia: temi emergenti e zone d'ombra", Roma, 16-18 feb. 2004

Cappa E.,. Halgass R. & Santini A. (1997) - Morfologie carsiche freatiche in una cavità verticale profonda al piano delle Faggeta (Carpineto Romano, Lazio, Italia) - Atti XVII Congr. Naz. Speleol., Castelnuovo G. 1994, Firenze, Vol. 1: 19-24

Cappa G. (1996) - I fenomeni carsici nella regione Lazio - Notiziario Speleo Club Roma, Roma, n. 12: 10-13

Cappa G. (2000) - I fenomeni carsici del Lazio - Speleologia del Lazio, (Notiz. Feder. Spel. Lazio), Roma, n. 1/2000: 3-5

Cappa G., Cigna A. A., Tommasino L. & Torri G. (1996) - Radiation protection and Radon concentration measurements in Italian caves - Proc. of the Internat. Symp. Show Caves and Environmental Monitoring, Frabosa Soprana (CN, Italy) 1995: 169-182

Cappa G. & Felici A. (2001) - Fenomeni carsici al Piano delle Faggeta (Lazio, Carpineto Romano) - Atti XVIII Congr. Naz. Speleol, "Chiusa '98", 29-31 ottobre 1998, Vol. unico: 277-280

Ciocci F. (2001) - Fra i sifoni di Zompa lo Zoppo - Speleologia del Lazio (Notiz. Feder. Spel. Lazio), n.2/2000: 12-13

Felici A. (1976) - L'idrologia carsica nel territorio di Carpineto Romano (Pre-Appennino laziale) - Atti VI Congr. Internaz. Speleol., Olomouc 1973, Olomouc, n. III-Ca: 63-72

Felici A. (1977) - Il Carsismo nei Monti Lepini (Lazio) - Il territorio di Carpineto Romano - Notiziario Circolo Speleol. Romano, Roma, anni XXI-XXII, n. 2-1/2: 3-230 + 6 Tav. f.t.

Felici A. (1978) - Considerazioni sull'evoluzione del carsismo dei Monti Lepini (Anti-Appennini laziali) - Atti XII Congr. Naz. Speleol., S. Pellegrino T. 1974, RSI Memoria XII, Como, Vol. unico: 293-302

Felici A. (2001) - Sant'Angelo a Marricella - Speleologia del Lazio (Notiz. Feder. Spel. Lazio), Roma, n. 2/2001: 35-38

Felici A. & Cappa G. (2002) - Indagine preliminare sulle grotte e sorgenti nei banchi di travertino lungo l'Aniene, da Subiaco a Comunacque - Atti del II Convegno della Federazione Speleologica del Lazio, Trevi nel Lazio, 11-13/10/2002: 104-112

Felici A., Cappa G. & Cappa E. (in print) - L'uomo e l'ambiente Carsico nel massiccio Simbruino-Affilano (Lazio) - Atti del Conv. Naz. "L'ambiente carsico e l'uomo", Frabosa Soprana (Cuneo), 5-8/9/2003:

Felici A., Cappa G. & Cappa E. (in print) - Le grotte nei travertini della valle dell'Aniene - Atti Convegno "Spelaion 2003", S. Giovanni Rotondo (FG), dic. 2003:

Felici A., Giura Longo A., Grassi L. & Triolo I. (1997) - L'esplorazione della Grotta Ciaschi apre la porta alla scoperta del drenaggio profondo dei Monti Lepini (Lazio, Italia) - Atti XVII Congr. Naz. Speleol., Castelnuovo G. 1994, Firenze, Vol. 1: 25-30

Procaccianti A., Mariano E. & Cappa E. (2002) - Nuova voragine carsica al Livata (Subiaco), ovvero, Pozzo dei Monaci - Atti del II Convegno della Federazione Speleologica del Lazio, Trevi nel Lazio, 11-13/10/2002: 92-96

Segre A. G. (1948) - I fenomeni carsici e la Speleologia del Lazio - Istit. Geografia Univ. Roma La Sapienza, s. A, n. 7, Roma