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ENDOKARSTIC EVOLUTION OF CARBONATIC MASSIFS IN CAMPANIA (SOUTHERN ITALY): GEOLOGICAL AND GEOMORPHOLOGICAL IMPLICATIONS.

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ABSTRACT

G.K.W: Mountain karst areas, endokarst, neotectonic
Geogr.K.W: Campanian Apennine, Southern Italy

In the Campanian Apennine many deep karst phenomena occur within the thick Cretaceous limestones formations. In this paper the morphology of the most important caves is described and interpreted in relation to the external geomorphological evolution.

Particulary prominence is given to differences in endokarst evolution between Picentini and Matese mountains and Alburno - Cervati mountains.

In the Picentini - Matese mountains we recognized at least two karstification phases: the oldest is characterized by horizontal phreatic networks, often in a senility stage of evolution, which are broken by neotectonics and unlevelled with present local base levels. It is important to stress that these caves can be generally correlated with relicts of mature erosional landscapes (Paleosurface Auct.) which were modelled during the Pliocene and the early lower Pleistocene (i.e. prior to the main uplift of the chain).

The second karstification phase is characterized above all by active vertical caves, generally representing the revival of the first phase's cave. Said revival was determined by a deepening of the local base level caused by the uplift of the massifs. Geomorphological considerations allow us to affirm that this second karstification phase started not earlier the beginning of Middle Pleistocene.

The Alburno - Cervati mountains instead lack caves related to the first karstification phase. They too have horizontal phreatic networks in a senility stage of evolution, but these are located near the present local base level and, with the other endokarst phenomena represented by vertical caves, devoleped after the main uplift of the massif.

This difference in endokarst phenomena distribution can be explained on the basis of regional geological and geomorphological considerations.

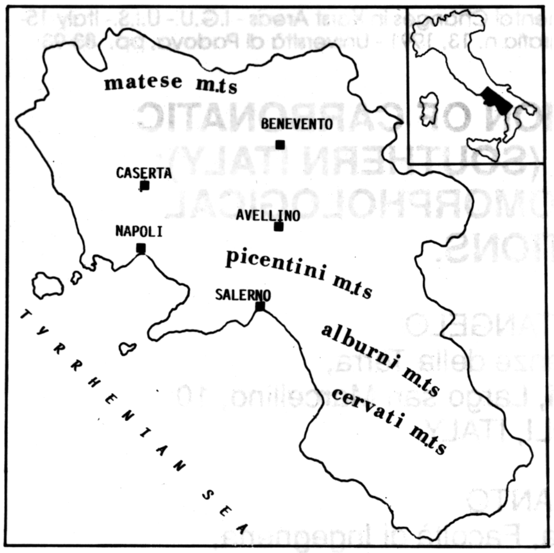


FIG. 1: Location map of examined area

INTRODUCTION

The study of deep karst phenomena can be very important in the anlysis of geomorphological evolution of a carbonatic massif. In fact knowing the behaviour and morphology of main karstic network inside a mountainous complex, we can make intersting considerations about local base level variations caused by neotectonic movements or, on a minor scale, by important climatic oscillations.

In the last years this kind of study became easier thanks to the advance of speleological explorations. In the Campania region, we have been able to make intersting observation about endokarst of the most important carbonatic massifs (Picentini Mts., Matese Mts., Alburno Mts., Cervati Mts.; fig. 1). In this paper we will describe first each of them individually, then we will compare their karstic evolution.

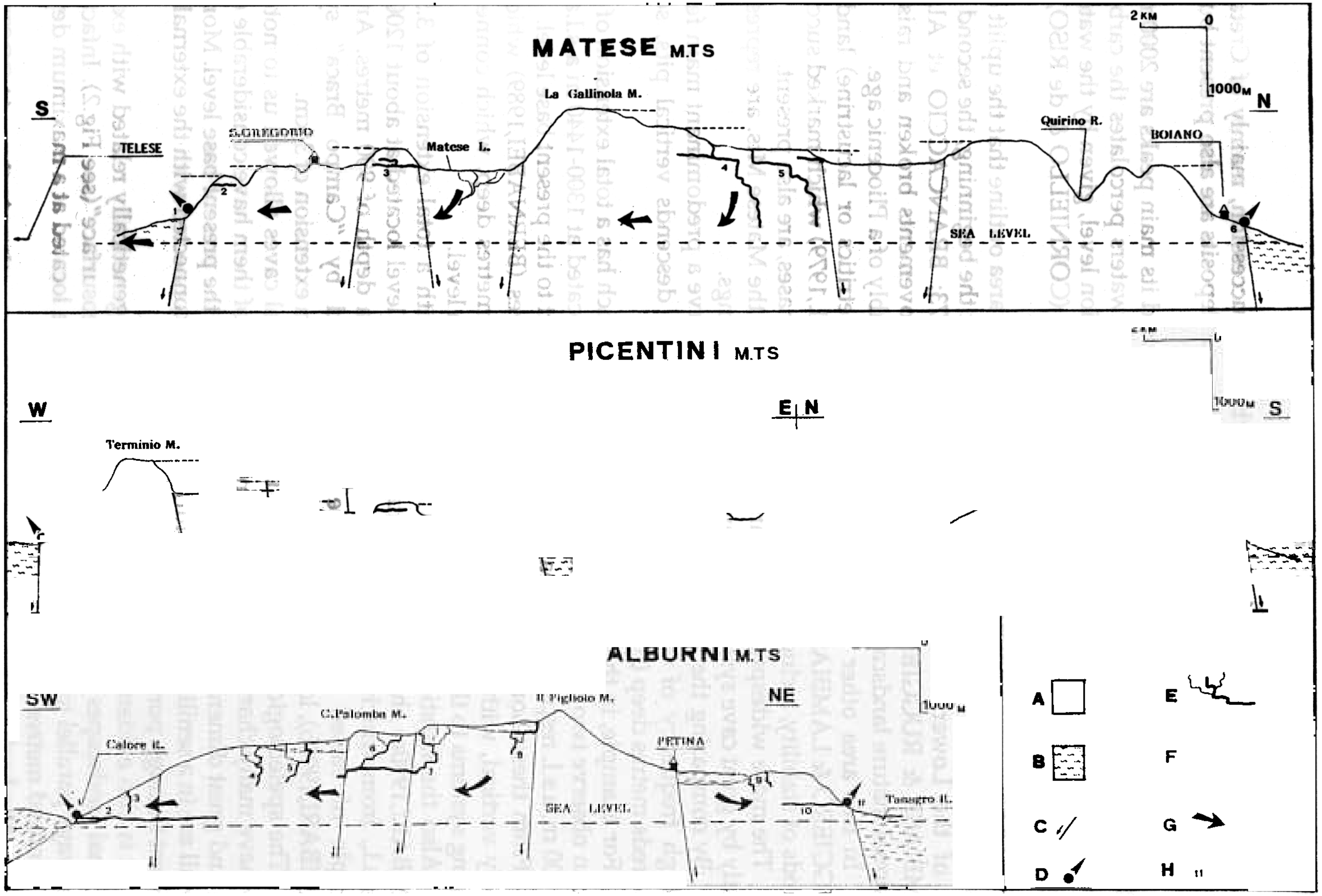
FIG.2: Vertical cross sections of Matese, Picentini and Alburni Mts..

a) Mesozoic limestones; b) flysch deposits; c) post-paleosurface faults; d) main springs; e) caves; f) paleosurface; g) groundwater flow directions; h) Reference number of caves or springs:

MATESE AREA - 1) Torano spring; 2) M.Cigno cave; 3) Campo Braca cave; 4) Pozzo della Neve cave system; 5) Cul di Bove or Sfonnaturo cave system; 6) Boiano springs.

PICENTINI AREA -1) Serino springs; 2) Piani d'Ischia cave; 3) Candraloni cave; 4) Troncone e Tronconcello springs; 5) Caliendo cave system; 6) Strazzatrippa cave; 7) S.Michele e Nardantuono cave; 8) Caposele springs.

ALBURNI AREA - 1) Castelcivita springs; 2) Castelcivita-Ausino cave system; 3) Melicupolo cave; 4) Gatti cave; 5) Gentili cave; 6) Fumo cave; 7) III Piani di S.Maria ponor; 8) Maria cave; 9) Milano cave and Capostrada ponor; 10) Pertosa cave system; 11) Pertosa springs.



MATESE M.TS
S
N
2 KM
0
1000M
TELESE
S.GREGORIO
Matese L.
La Gallinola M.
Quirino R.
BOIANO
SEA LEVEL
PICENTINI M.TS
W
E N
S
1000M
Terminio M.
ALBURNI M.TS
SW
NE
Il Figliolo M.
C.Palomba M.
Calore R.
PETINA
SEA LEVEL
Tanagro R.
1000 M
A
B
C
D
E
F
G
H

THE ENDOKARST OF MATESE MOUNTAINS.

The Matese massif is formed by a carbonatic succession, mainly of Cretaceous age, about 2000 metres thick. Terrigeneous Miocene deposits are also present but they are located mostly around the massif.

Its areal extension is of about 750 square km and its main peaks are 2000 metres a.s.l. (Miletto Mt., La Gallinola Mt.,etc.). The groundwaters percolates the carbonatic rocks for about 1500 metres since the basal karstification level, given by the water bed of Telese springs, is located at about 100 metres a.s.l. (CORNIELLO & de RISO, 1986; CIVITA, 1969; RUGGIERO, 1926).

The geomorphological studies carried out in this area outline that the uplift of this massif occured in two principal stages, the first one at the beginning, the second at the end of the Lower Pleistocene (BRANCACCIO, 1973; BRANCACCIO et Al.,1979; LAMBIASE & RUGGIERO, 1980). These tectonic movements broken and raised an erosional mature landscape (Paleosurface Auct.) probably of a Pliocenic age.

In this area other erosional or depositional (detritics or lacustrine) landscape (RUGGIERO & LAMBIASE,1980; BRANCACCIO et Al.,1979) which marked successive periods of stability, included between the two uplift phases, are also present.

The more widespread endokarst phenomena in the Matese Mts. are represented mostly by great cave systems and few ponors and springs.

By comparing the various systems we can observe a predominant main feature: an high frequency of horizontal caves from which descends vertical pits, several hundreds metres deep (Fig.2).

For example, in the "Pozzo della Neve" cave which has a total extension of 8 km, we can observe two horizontal karstification levels, located at 1300-1440 m a-s.l.and at 800-900 m. a.s.l. respectively, clearly raised with respect to the present base level.

From these horizontal systems begin other caves (BERNABEI,1989) which are mainly vertical, with pits and falls several hundred metres deep, which connect the hanging systems to the present day basal karstification level.

Also the karstic complex of "Cul di Bove" (with a total extension of 3.5 km; GAMBARI,1990a) shows an horizontal karstification level located at about 1200-1100 m. a.s.l., from which descend other caves down to a depth of 900 metres. Another example of raised horizontal cave is represented by "Campo Braca" system (GAMBARI,1990b), located at 1100 m. a.s.l. and with an extension of 3 km.

The speleological exploration of these horizontal caves allowed us to note that they have many characteristics in common. In fact all of them have considerable extension and great dimensions and are not connected with the present base level. Moreover they all are in a senility stage of evolution and are not connected with the external environment through ponors.

It is also evident that those horizontal caves are genetically related with external erosional landscapes belonging to the so called "Paleosurface"(see Fig.2). Infact they are always parallel to that topographic surface and are located at a maximum depth of one hundred metres from it.

On the basis of this observation and according to other Authors (AGOSTINI & BORTOLANI, 1983) we believe these horizontal caves formed near an old phreatic level when the top of the carbonatic massif was little uplifted relatively to the surrounding landscapes.

The vertical caves instead are rich of idromorphic features, are often active and generally show youthful morphology. We believe they formed in a second karstification phase after the last uplift of the massif.

THE ENDOKARST OF PICENTINI MOUNTAINS.

Orographycally the Picentini mountainous complex has an areal extension of about 580 square km and is characterized by several peaks (Accellica Mt., Terminio Mt., Cervialto Mt., Polveracchio Mt.) the highest of which is 1890 metres a.s.l.. This massif is formed by carbonatic rocks of Cretaceous age (mainly limestones) especially in its northern sector; the basal terms of the Mesozoic sucession (Triassic-Giurassic) instead prevail in the southern sector. Terrigeneous Tertiary deposits are almost absent all over the massif but they are widely present around its boundaries, plugging it laterally.

The most important present underground flow directions are towards Serino springs (Western sector) and Caposele springs (northern sector), located at about 350 and 420 metres a.s.l respectively.

Thus, also in this case, the groundwater before reaching the basal water table, has to cross carbonatic rocks for more than one thosusands metres.

Recent geomorphological studies (CINQUE, 1986; LIPPMAN-PROVANSAL, 1987; BRANCACCIO et Al,1988; CAPALDI et Al.,1988) have pointed out that neotectonic uplift of this massif took place in three diferent moments during Quaternary time. The early two were particulary important and happened at the beginning and at the end of Middle Pleistocene. Also in this area the Authors recognize the presence of an ancient erosional landscape, probably of Pliocenic age, broken and uplifted by neotectonic movements, which is a marker of an old base level.

The Picentini Mts. show important endokarst phenomena often represented by wide networks of caves (Fig.2).

In the karst area of "Laceno lake" there are good evidence of the karst evolution of the massif. The "Caliendo cave (with a total extension of 4 km; BELLUCCI et Al., 1983) and the "Strazzatrippa" cave (GIULIVO et Al.,1987) have both a horizontal style and are located at about 1100 a.s.l., that is to say many hundred metres above the present basal karstification level.

Particulary some geomorphological studies of Caliendo cave (BELLUCCI et Al.,1983; BRANCACCIO & CINQUE, 1988) show that it formed when the carbonatic massif was gently uplifted with respect to the surrounding terrigeneous hills forming the impervious rim around the limestones and controlling the elevation of the water table.

Another important horizontal endokarst system is represented by "S. Michele e Nardantuono" cave, located at about 900 metres a.s.l. inside Raione Mt. (Southern Picentini Mts.). This complex has spectacular dimension and a typical senil aspect with abundance of collapses and speleothems, often organised in various superimposed generations.

CINQUE et Al.(1982) consider that also this karstic system formed near a paleo water table and went then broken and uplifted by neotectonic movements. The AA. outline the correspondence between these horizontal caves and external subhorizontal erosional surface, belonging to the "Paleosurface" Auct.

Also in the Terminio Mt. (Northern Picentini Mts.) there are horizontal caves (Candraloni and Risorgenza Piani d'Ischia caves; BELLUCCI et Al.,1987) raised in respect to the present basal karstification level. Actually they are broken by neotectonics but, if we ideally restore their original continuity by eliminating the neotectonic throws, they clearly mark a single karstification level at a little depth from the Paleosurface.

Thus in the Picentini Mts. too we can recongnize a lot of large endokarst horizontal morphologies, not connected with the present base level and often filled up with speleothems, that have never been linked to ponors. As proposed by various Authors, the most probable hypothesis for their spelogenesis is to assume a cave level connected with an ancient piezometric surface.

Actually in the Picentini massif no vertical endokarst system is known but their existence is demonstrated indirectly. Infact many tracing tests carried out in the most important ponors of the area (Dragone ponor for example; CIVITA, 1969; CELICO & RUSSO, 1981) testified that groundwater moves towards the basal water table very fast, evidently because it follows karstic channels.

THE ENDOKARST OF ALBURNI AND CERVATI-MOTOLA MOUNTAINS

The Alburno massif has an areal extension of about 280 square km and orographically is characterized by a wide summit plateau between 1700 m. and 1000 m. a.s.l. . At a great scale it is a fault block dipping 20 degrees southward, just like the top surface does.

This structure is almost entirely made up of Cretaceous limestones on which terrigeneous deposits of Miocenic age (Tortonian) transgress. The latter are widely preserved only within some small grabens NW-SE striking.

From an hydrogeological point of view it is to be noted that the underground flows are directed towards three important springs: "Castelcivita and Auso" springs (70 metres a.s.l. and 250 metres a.s.l. respectively, at the base of the southern slope) and "Tanagro" and "Pertosa" springs (70 metres a.s.l. and 250 metres a.s.l. respectively, at the base of the northern slope); so the thickness of potentially karstificable limestones exceedes again one thousand metres.

In literature no specific geomorphological study on this massif exists, but some works on the analysis of its bordering fault scarps (BRANCACCIO et Al.,1978) and on regional geomorphological evolution (LIPPMANN-PROVANSAL,1987; BRANCACCIO & CINQUE,1988) let us to confirm that the present orographic order has been reached not later than beginning of Middle Pleistocene.

Also the Alburni Mts. are characterized by the presence of wide horizontal and vertical cave systems; however their spatial distribution within the carbonatic massif is very different from that of the Matese and Picentini Mts. .

In fact in a vertical cross-section of the Alburni Mts. (Fig.2) we find a diffused vertical network of caves which transfer groundwaters from the topographic top surface down to the basal water table. Phreatic horizontal caves are also here well developed, but they are not remarkably raised with respect to the present basal karstification level.

On the summit plateau the more diffused endokarst morphologies are ponors located at the bottom of blind valleys, waterproofed by Miocenic terrigeneous deposits (SANTO,1988). The ponors receive run off waters from this impermeable depositis and convey them in depth, forming large cave systems which are well hierarchysed, always active and prevailingly vertical. Moreover these caves lack spelothems and other filling deposits and are characterized by hydromorphic section profiles.

The best known system is certainly that of "Fumo-S.Maria"; it feeds the spectacular Auso springs, near S.Angelo a Fasanella village, which are 7 km far and 1 thousand metres less elevated than the infiltration points.

Besides these well developed vertical systems there are also some important horizontal caves of phreatic origin, generally located at about 100-200 a.s.l.. Among them we must remember the "Castelcivita-Ausino" complex which attains a total lenght of 4 km and marks the present basal water table (CELICO, 1983; BELLUCCI et Al., 1991). Here some fossil levels, characterized by many and wonderful speleothems and filling deposits, are also present. According to DI NOCERA et Al. (1973) and BRANCACCIO et Al.,(1978) they can be interpreted as ancient levels that were abandoned upon the last important quaternary climatic changes (or recent reactivation of the perimetral faults).

An other example is that of Pertosa caves system which has an extension of about 3 km (DE PAOLA, 1939).

Contrary to Matese and Picentini Mts., the Alburni Mts. lack raised phreatic cave systems. This essential difference has definitely been demonstred by exploration of more than one hundred caves, from which it resulted that in the Alburni Mts. caves the rare and short horizontal segments are due to lithological or structural conditions (presence of less karstificable levels) and they never have morphological features of phreatic origin. Some geomorphological and hydrogeological observations let us to affirm that both the vertical and horizontal segments belong to the same karstification phase and formed after the main uplift of the massif.

In fact the analysis of distribution of the main ponors on the plateau shows that they are always located at the base of north facing fault scarps. This situation can be explained observing that the homoclinal structure of Alburni Mts., as its topographic top surface, are south dipping and the drainage network follows this structural inclination, leading runoff water towards the short and steep north exposed slopes of each graben like structure (Fig. 2). Since the present orographic style is the effect of the main uplift of the massif, we can affirm that also the ponors catching the water of each drainage basin, formed after it.

The endokarst morphology of Cervati - Motola Mts. (areal extension: about 320 square km), located in the southern part of Campania region, is very similar with that of Alburni Mts. Although less developed, here the most important endokarst phenomena are represented by ponors and relative vertical caves (Vallivona, ponor, Raccio cave, A cave, Campolongo ponor, Vesalo cave; MECCHIA et Al.,1991), which are fed by important catchment basins located on impermeable deposits (flysch) and go down through the Cretaceous limestone formations for some hundred metres.

SUMMING UP AND CONCLUSION

Substantial differences about deep karstic evolution of Picentini - Matese Mts. and Alburno - Cervati Mts. have been noticed.

The former show a "polyfasic endokarst" with presence of ancient phreatic cave-systems in a senility stage of evolution. They appear fragmented and uplifted by neotectonic movements well above the present basal karstification level. Ponors and vertical caves are also present but they formed after the main uplift of the massif during a second karstification phase.

The Alburno - Cervati Mts. instead show a "monophasic endokarst"; in fact they

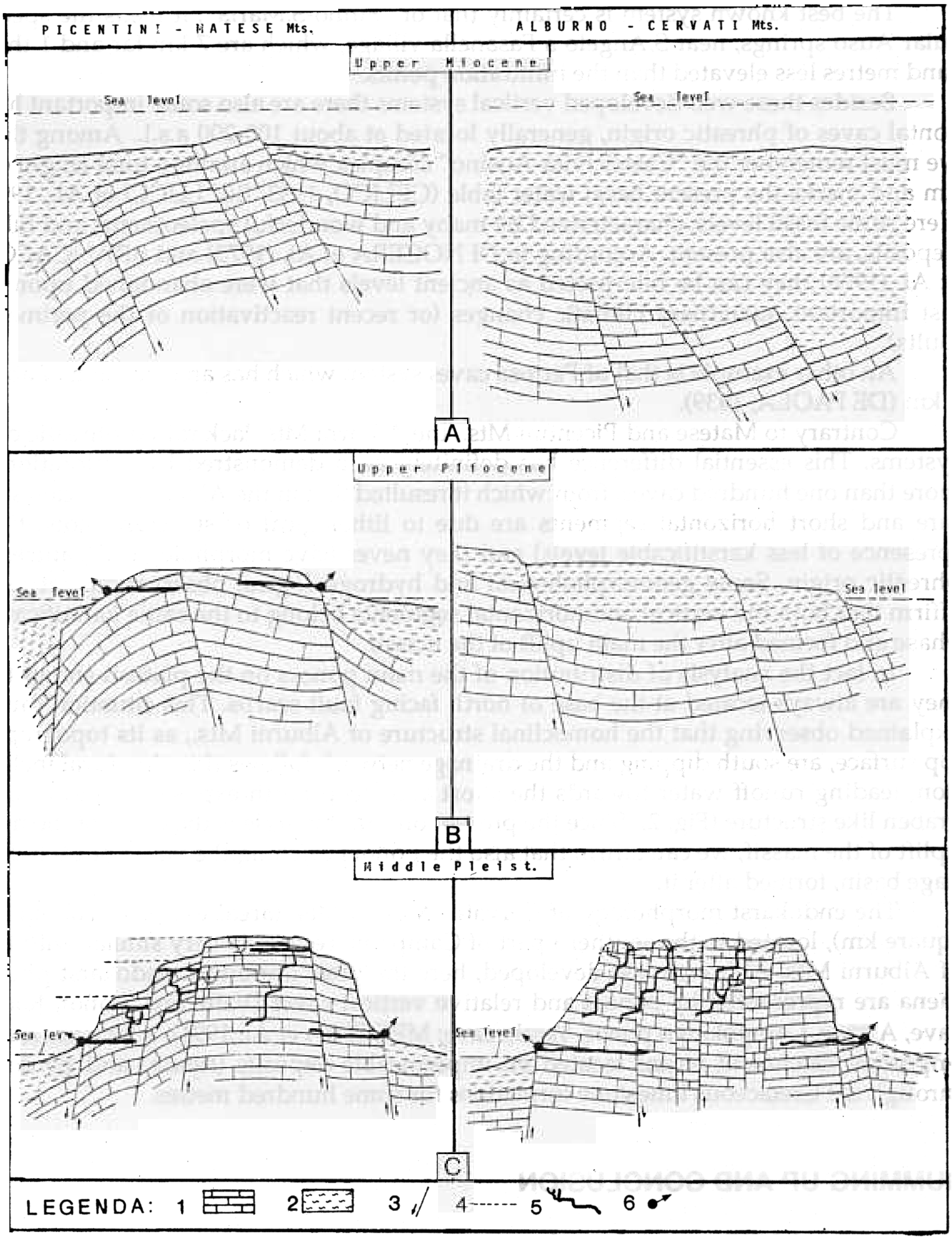


Fig.3: Schematic geological and geomorphological evolution of the two examined sectors from the Upper Miocene to the Middle Pleistocene. 1) Limestones; 2) flysch; 3) faults; 4) relicts of the "paleosurface; 5) caves systems; 6) main springs.

lack in raised phreatic systems and are characterized by vertical and horizontal caves, all formed after the main uplift of the massif.

The above stressed differences can be explained with geological and geomorphological considerations.

Firstly it must be underlined that both in Matese and Picentini Mts. very little terrigeneous deposits are preserved, whereas Alburno Cervati Mts. are still "drowned" in flysch deposits, located both on the plateau and at the base of boundaring fault slopes.

It seems to be unreliable to explain the lack or limited thickness of terrigeneous deposits in Picentini - Matese area only with a greater erosion maybe due to a different recent evolution (for example with precocious neotectonic uplift). This difference in areal distribution and thickness of Miocenic terrigeneous deposits is more likely to be linked to different paleogeographic situation during Miocene.

Particulary geological evidences suggest Matese and Picentini areas during Miocene time (Fig.3A) were relatively "high zone" inside a wide sedimentary basin, whereas the Alburni area was relatively low so that very thick flysch sequences accumulated on it.

This difference is to be considered as the main responsible for the differing karstic evolution of the two sectors, as some recents geomorphological studies suggest that during Plio-Quaternary time they had substantially the same evolutive history.

Infact regional data for the thyrrenic sector of Campanian Apennine agree enough and let us to confirm the main uplift phases of various carbonatic massifs came true at the beginning and at the end of Middle Pleistocene (BRANCACCIO & CINQUE,1988b; BRANCACCIO et Al.,1991). Therefore we believe it isn't possible to assume early uplift phase for Alburni area to explain the lack of raised horizontal systems.

When all the area surfaced the subaerial shaping, owing to different distribution of terrigeneous deposits, on the one hand (Picentini - Matese area) interested carbonatic deposits, on the other (Alburno - Cervati) terrigeneous lithologies (Fig.3B). So only in the Picentini - Matese area the first karstification phase took place and phreatic cave correlated to base level of Paleosurface formed.

The following neotectonic uplifts delineated present orographic order of Campanian Apennine and created relief energy for the beginning of second karstification phase (Fig. 3C). The faulting network was different in the two examined areas: in the Picentini-Matese created a lot of blocks and depressions and a typical esokarst morphology like "polje" started to form (BRANCACCIO,1974). Contemporarly the horizontal cave systems were raised of many hundreds metres above the new base level and therefore quickly deepened.

In the Alburni area instead the uplift was more omogeneous and a wide south-dipping plateau formed, causing the erosional removal of terrigeneous deposits and the beginning of the karstification of the massif.

This recent esumation of carbonatic lithologies is confirmed by the high frequency in the Cilento area of fault line scarps and inherited morphologies (BRANCACCIO et Al.,1978; BRANCACCIO et Al.,1986), which are lacking in the Picentini - Matese area.

On the Alburni plateau the run off of rainwater was favoured by the presence of relict patches of terrigeneous cover that contributed their discharge to few restricted areas of sinking. Here "contact ponors" developed and a well developed network of vertical caves connected them with the basal water table where,in the same while, wide horizontal phreatic systems formed.

The cronology of the two karstification phases can be obtained by some regional geomorphological data.

In fact the first karstification phase is to be assumed as contemporary of the "paleosurface" landscapes which in literature have an age included between Middle-Upper Pliocene and the begining of Pleistocene. The second karstification phase surely began after the main uplift of carbonatic massif, i.e. at the beginning of Middle Pleistocene.

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KARST PROCESSES AND POTENTIAL VULNERABILITY OF THE CAMPANIAN CARBONATIC AQUIFERS: THE STATE OF KNOWLEDGE.

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ABSTRACT

G.K.W.: Hydrology in Karst areas, water's protection human impact, speleology
Geogr. K.W.: Italy, Campanian carbonatic Apennine

The Campanian Apennine is for the great part made up of calcareus-dolomitic mountains which are very susceptable to Karst phenomena and are the seat of important aquifers. The main springs of these carbonatic massif are caught by important aqueducts and furnish the chief towns in the Campania and Puglia region.

Recent hydrogeological studies and speleological explorations show that these springs are often connected with superficial karst areas through endokarst drainage systems and therefore are potentially very vulnerable.

In this paper the main risk situations are reported because the understanding of karst phenomena and their development degree is essential for the water resources management and control.

INTRODUCTION

In the last decade technicians, politicians and managers, in consequence of clamorous cases of pollution caused by uncontrolled anthropic activities, are interested in problems related to water resources protection .

Generally the degradation risk is very high in the porous aquifers of the plain areas, where the settlements density (urban, industrial, agricultural, zootechnical) is elevated and the water feeding is furnished by fields of wells. This is the case of the Po Plain and, for the Campanian region, of the Low Volturno river area, the middle-lower Regi Lagni basin and the Nocera-Sarno plain. In fact in these areas the protective "geological barriers" of aquifers, represented by the biological, chemical, physical filter action of the unsatured porous body located above the water table level, are exceeded by direct letting in of polluting substances through excavations or wells.

The risk evaluation in fissured aquifers, like the calcareous - dolomitic mountainous ridge which in Campania has a wide extension (26% of the whole regional area), presents peculiar aspects. Infact to a relatively low percentage of impact occasions (due to the reduced anthropic presence in the mountainous regions), we must associate the high vulnerability of the medium (due to a high speed of groundwater flow through

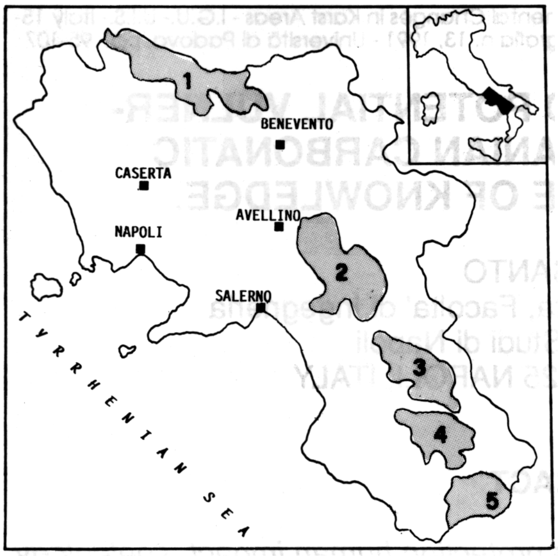

Fig.1: Location map - 1) Matese Mts.; 2) Picentini Mts.; 3) Alburni Mts.; 4) Motola-Cervati Mts.; 5) Bussento river area.

joints and karstic networks) and the seriousness of the consequences of possible polluting events. In fact the great aqueducts which furnish the campanian chief towns including Naples, are largely fed by springs linked to the carbonatic structures located between the Matese and the Cilento area (Fig.1).

In this context karstic phenomena have great importance and the knowledge of their development degree is essential for an exact risk evaluation and, consequently, for the adoption of landuse suitable principles to prevent impact actions.

The recent development of speleological explorations and the progress in hydrogeological research in the campanian Apennine are the basis for an organic setting up of the relationships between karstic processes and the subsurface drainage modality in various massifs, which are the seats of important aquifers.

In this paper the results of these studies, which are part of the long-time research activity of members of the Institute of Applied Geology (Engineering Faculty) of the University of Naples with the grant of M.P.I 40% and 60% and of the C.N.R. (VAZAR Project of G.N.D.C.I.) are reported.

THE MAIN RISK SITUATIONS

MATESE MOUNTAINS (Fig.2)

The areas of concentrated infiltration.

The areas of concentrated infiltration in the Matese massif are represented by a set of closed basins or polje which are graben-like structures generally NW-SE striking and filled by waterproof pyroclastic deposits (LAZZARI,1949; BRANCACCIO, 1974); the rain waters which are concentrated in these areas feed important localized ponors. The most extended basin is that of the Matese lake but of not minor importance are the Campo Braca plain, the Piano d'Acqua plain, the Campitello plain, Prato di Civita, Campo Rotondo, Campo delle Secine etc., which all feed isolated ponors.

The endokarst drainage systems.

The above mentioned ponors are directly linked up with cave systems, often explored for hundreds of metres, like Campo Braca cave (GAMBARI,1990), Camporotondo cave (LAZZARI,1949), Lete cave, Valle Cila cave (MANISCALCO & PASQUINI,1963), Sava cave (CIVITA,1969) and many others (FELICI, 1973; AGOSTINI & BERTOLANI,1983). Some ponors instead , like that of Matese lake, aren't explored but it's clear that they are in communication with endokarst systems.

Among the cave systems of Matese Mts., the "Pozzo della Neve" cave (BERNABEI,1989) and "Sfonnaturo" cave (GAMBARI,1990) are of primary hydrogeological importance. They have complessively a total extension of more than 8 km and are 1000 metres and 900 metres deep respectively . Their exploration is possible only in low water periods, when the flow is of a few tens of litres/second.

The topographic plotting of these caves has permitted to verify that their bottom is at a lower altitude (360 and 460 metres a.s.l. respectively) than that of the Boiano springs (500 metres a.s.l.; TERRAGNI,1990) and that they are situated some hundreds metres above the Telese springs (60 metres a.s.l.). Therefore many authors suppose that at least in this sector of the Mates Mts., the karstic channels directly link up the superficial infiltration points with the basal water table which is related to Telese springs. On the grounds of this hypothesis in the autumn of 1990 a tracing test has been made by the Speleo Groups of Piedimonte M., Roma and Naples (immission of about 30 kg of tracer in the Sfonnatore cave) but the response at the most important perimetrical springs of the massif has been negative (probably the tracer amount was insufficient).

A positive answer instead is given by tracing tests made in Matese lake ponors (RUGGIERO, 1926) that allowed the confirmation of the connection between the lake and the Torano -Maretto springs. This connection can be extended to Campo Braca plain because there is a continuity of the endokarstic system between that and Matese lake (GAMBARI, 1990).

Finally some great exokarst phenomena in the Matese Mts. represented by deep gorges (LAMBIASE & RUGGIERO,1980) are to be mentioned. Some of these in fact are affected by environmental impact problems like the low Titerno stream gorge (immission of substances which cause the pollution of the water table in Faicchio area; CORNIELLO & DE RISO,1986) and like the low Quirino stream gorge where the Guardiaregia town sewer discharges.

PICENTINI MOUNTAINS (Fig.3)

The areas of concentrated infiltration.

Like in the Matese Mts. the principal areas of concentated infiltration in the Picentini Mts. are related to blind valleys or polje waterproofed by pyroclastic deposits, the most important of which are represented by the Volturara and the Laceno Plain.

The Volturara plain, which is delimitated by the structures of Tuoro, Serrapullo and Terminio Mts., receives the waters from a wide catchment basin which has an extension of about 40 square km and drains them towards Dragone ponor, located on its eastern border.

The Laceno plain (catchment basin of 14 square km) receives the waters from the Cervialto, Cervarolo , Raiamagra and Nusco Mts. and drains them through a series of ponors located on its western side (Ponte Scaffa, S. Nesta etc.).

Besides these there are other smaller similar basins like Piano Cupone, Piano

Fig.2: 1) Boundary of carbonatic massif; 2) Areas of concentrated infiltration; 3) Gorges; 4) Ponors; 5) Main springs mentioned in the paper.

l'Acernese (Cervialto Mt), Piani di Verteglia, Piano delle Aacque Nere etc. (Terminio Mt.), which all drain towards temporary ponors.

The endokarst drainage systems.

The Dragone ponor in the Volturara plain (Terminio Mt.), according to CIVITA (1969) is directly linked up, through an unexplored karstic channel, with the Cassano springs which feed Pugliese Aqueduct and Alto Calore Aqueduct. Tracing tests confirm this hypothesis and demonstrate a very high underground flow velocity

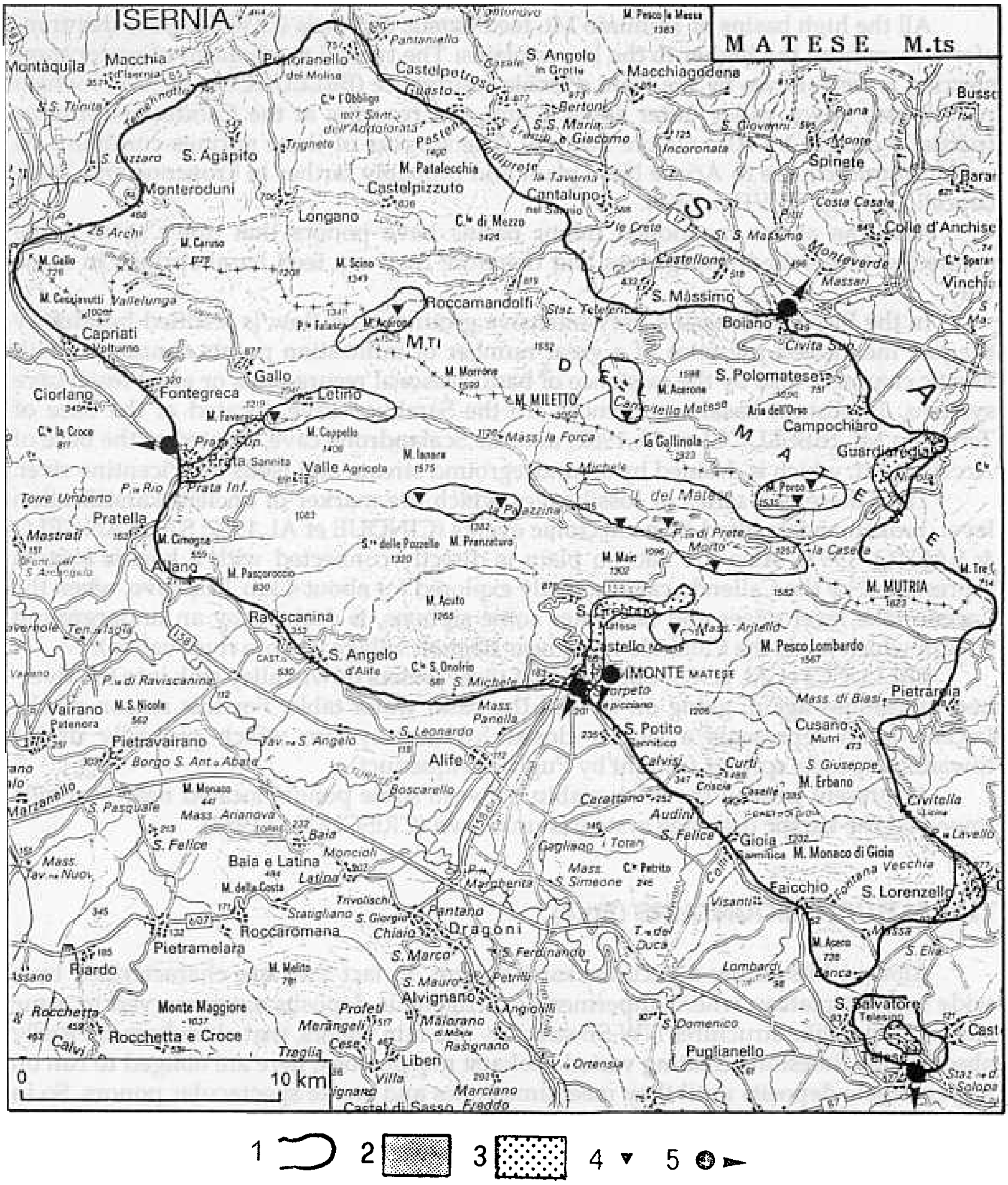

Fig.3: 1) Boundary of carbonatic massif; 2) Areas of concentrated infiltration; 3) Gorges; 4) Ponors; 5) Main springs mentioned in the paper.

(CELICO & RUSSO,1981).

All the high basins of Terminio Mt. feed karstic channels (CIVITA,1969) that transfer waters from the higher to the lower plains. The typical mechanism of water transferring is well shown by the Piani d'Ischia resurgence (BELLUCCI et Al.,1987) which reinfiltrates down valley (after about 1 km) and resurges at the Candraloni springs (partially caught by Alto Calore Society). The surplus of these springs continues its underground course to Acque Nere plain and probably farther to Troncone and Troncocello springs (CIVITA,1969).

Also the above mentioned minor basins have ponors that don't seem to be connected to perched resurgences and therefore they can feed basal springs in some way.

In the Picentini massif a very intensive groundwater flow is testified besides by the just mentioned presence of a great number of infiltration points connected with karstic channels, also by the existence of basal seasonal resurgences or great fossil cave systems. Important basal resurgences are the Sambuco cave, located at the base of Terminio Mt. (BELLUCCI et Al.,1982) and the Scalandrone cave, located at the base of Accellica Mt, which is drained by an undreground stream and feeds the Picentino river.

Then there is a series of fossil caves which are marker of ancient karstification level, broken and uplifted by neotectonic events (CINQUE et Al.,1982; SANTANGELO & SANTO, 1991). Also the Laceno plain is directly connected with a karstic system represented by the Caliendo cave, actually explored for about 4 km This cave, when the Laceno lake level raises and activates some siphons, is drained by an underground stream which feeds the Caliendo river, near Bagnoli village (Calore river valley).

BELLUCCI et Al. (1983) outlined that these waters downvalley sink into the riverbed limestones again, going on to feed the basal water table. For this reason all the Laceno plain represents a single, closed hydrical system which probably drains towards Caposele springs (caught by Pugliese Aqueduct).

At present instead the relationship between some ponors located near Montella town and the karstic drainage system is unknown (CRISCUOLO,1983).

THE ALBURNI MOUNTAINS (fig.4).

Alburni Mts. show a peculiar karst system. In fact they are characterized by a wide summit plateau where impermeable terrigenous deposits are preserved in some closed graben-like structures NW-SE striking. The rain waters, that elsewhere are easily absorbed by limestone creating varied exokarst morphology, here are obliged to run on impermeable deposits until they meet limestones and create spectacular ponors. So in this massif the exorheic runoff is absent (BRANCACCIO et Al.,1973; SANTO,1988).

The author in collaboration with other researchers, is studying the main basal springs to control their regime in relation with the endokarst system. Data gathered for 18 months are in course of elaboration.

The areas of concentrated infiltration.

The areas of concentrated infitration are represented by little graben located on the plateau, prevailingly in its central sector. There are more than 20 of them in an area of 50 square km.. The most important are the basins of Varroncelli, Sicchitiello , etc..

They all feed one or more ponors that, contemporarily to eleveted rainfall, show high discharges.

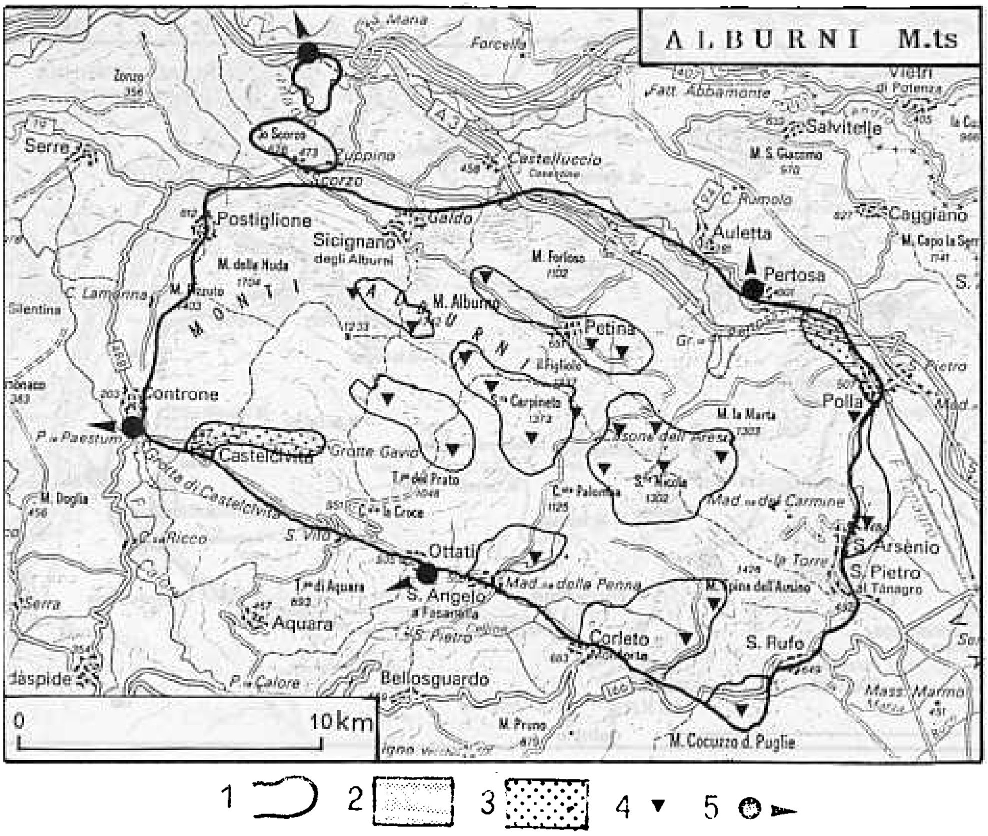

Fig.4: 1) Boundary of carbonatic massif; 2) Areas of concentrated infiltration; 3) Gorges; 4) Ponors; 5) Main springs mentioned i the paper.

Other areas of concentred infiltration are located in the eastern edge where Vallo di Diano quaternary impermeable (lacustrine) deposits outcrop (NICOTERA & DE RISO, 1969) and are represented for example by the Mulino Spinelli and Crive di Polla ponors.

Finally it has to be outlined that also in the Tanagro river gorges near the localities of "Campostrino" and "Sicignano station" infiltration and exchange phenomena with basal water table can be supposed.

The endokarst drainage systems.

The karstic channels that have been discovered and explored that directly communicate with the above mentioned infiltration areas are more than a hundred (DAVIDE,1973; SANTO,1988; BELLUCCI et Al.,1991).

The most important are Fumo, Gentili, Falco, Campitelli caves etc. etc.,which are all well hierarchised, one hundred metres deep and show a planimetrical extension of some tens of km. Some of them (central sector of Alburni Mts.) feed the important Auso resurgence (260 metres a.s.l.; BELLUCCI et Al.,1991) with a very short time of response (24/48 hours); others instead communicate directly with the basal water table related to the level of Castelcivita (70 m a.s.l.), Pertosa (250 m a.s.l.) and Tanagro (70 m a.s.l.) springs (CELICO,1983; BUDETTA et Al.,1989).

This hipothesis is confirmed by the presence of karstic channel mouths observed

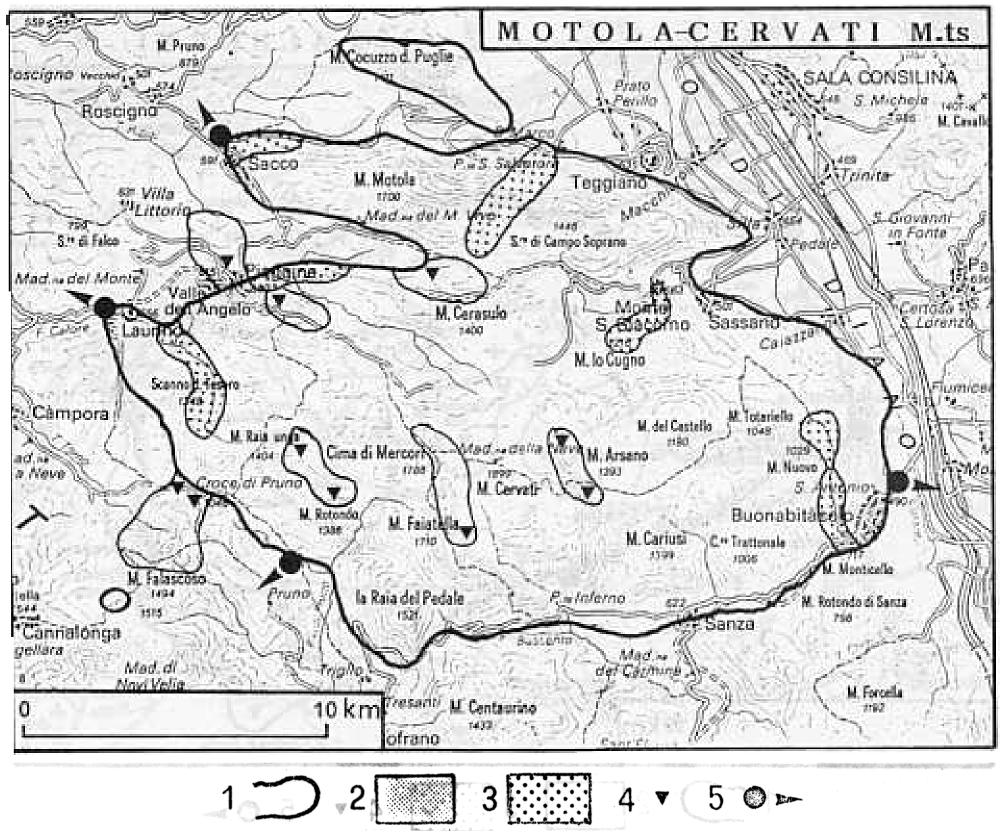

Fig.5: 1) Boundary of carbonatic massif; 2) Areas of concentrated infiltration; 3) Gorges; 4) Ponors; 5) Main springs mentioned in the paper.

in the terminal lake of Castelcivita cave during low water periods and, moreover, by the direct observation of notable increases of lake level and spring discharge two days later on elevated rainfall (April, 1991; personal observation).

Also the Pertosa springs, for which we don't have experimental data, are the outlet of a karstic channel which has an extension of about 3 km (DE PAOLA, 1939) Besides, all the ponors located in the Vallo di Diano area, among which the greatest is Polla cave (DAVIDE,1959), are planimetrically oriented toward Pertosa springs.

Therefore these ponors are more interesting as regards to environmental impact; in fact they are topographycally near to the basal Pertosa water table (CELICO,1983) and located in urbanized areas. Particulary the Mulino Spinelli ponor, that in the period of 1960-1970 drained more than 500 l/s (NICOTERA & DE RISO,1969), for several years has been functioning as the drain of S.Arsenio sewer and has been transferring directly a lot of polluting substances into the basal water table.

There aren't direct data of discharge of the basal Tanagro springs which represent an other emergence of the Alburno basal water table (CELICO,1983). However, considering the development and importance of Alburni karst drainage system, it can be hypothisized that they are fed in some way by karstic channels, which are linked up with the areas of concentrated infiltration located on the plateau.

THE MOTOLA CERVATI MOUNTAINS (Fig. 5)

The Motola-Cervati Mts. are geologically very similar to Alburni Mts. but show a smaller concentration of deep karst phenomena due to the limited presence of closed structural basins.

The areas of concentrated infiltration.

Also here the main areas of concentrated infiltration are represented by a series of little closed graben waterproofed by miocenic flysch deposits and collected directly with ponors.

The most important are the basins of Vesalo (about 6 square km in extension), Raccio's stream, Campolongo plain, Vallicelli and a series of smaller ones; they all are able to drain high discharges in concomitance with elevated rainfall.

Also in this massif there are deep gorges (Sacco gorge for example) that can increase the exchange between polluted superficial waters and basal water table.

The endokarst drainage systems.

Each of these above mentioned closed basins is linked up directly with one or more karstic channels (MECCHIA et Al.,1991).

Some channels are not linked up with basal water table but with raised temporary resurgences and therefore the result of their pollution can be less dangerous. An example is given by Vallicelli ponor which seems to feed the seasonal resurgences of Bocca La Tronata (MECCHIA et Al.,1991). Other ponors instead communicate with resurgences linked up with perched aquifers, often caught. This is the case of Vallivona ponors (CIVITA,1974) which feeds Varco La Peta springs.

Also in this massif some infiltration points, like Raccio cave, are directly connected with the basal water table. This cave is more than 350 metres deep (its bottom is 650 m. a.s.l.) and is situated in the Motola Mt. structure which feeds the Sammaro springs (CELICO,1983) located at about 340 m a.s.l.

Also other important ponors, like Vesalo and Campolongo (both with a notable vertical extension) seem to feed the basal water table (CIVITA,1974).

Like Alburni Mts., also in the Cervati massif there are ponors, located at the base of perimetral slopes, that can be medium for polluting agents due to the nearness of basal water table and of inhabited places. An example is given by the ponor located near Piaggine, into which drains the village sewer.

Finally the possible karstic exchanges in the Calore gorges near the villages of Laurino and Piaggine can be mentioned. Also the Sammaro stream gorge near Sacco village receives waters from a wide catchment basin on terrigeneous deposits. This gorge, in its terminal part, is linked up, through karstic channels explored for some metres, with the springs of the Motola Mt. basal water table.

In conclusion, even if the state of knowledge concerning karstic circolation in the Motola-Cervati massif is very modest, it has to be outlined that in these mountains the karst is well developed and testified not only by the above mentioned exo and endokarst morphology but also by important fossil caves like that of Festolaro cave (D'ARGENIO, 1963) and Rotondo Mt. caves (CIVITA,1974).

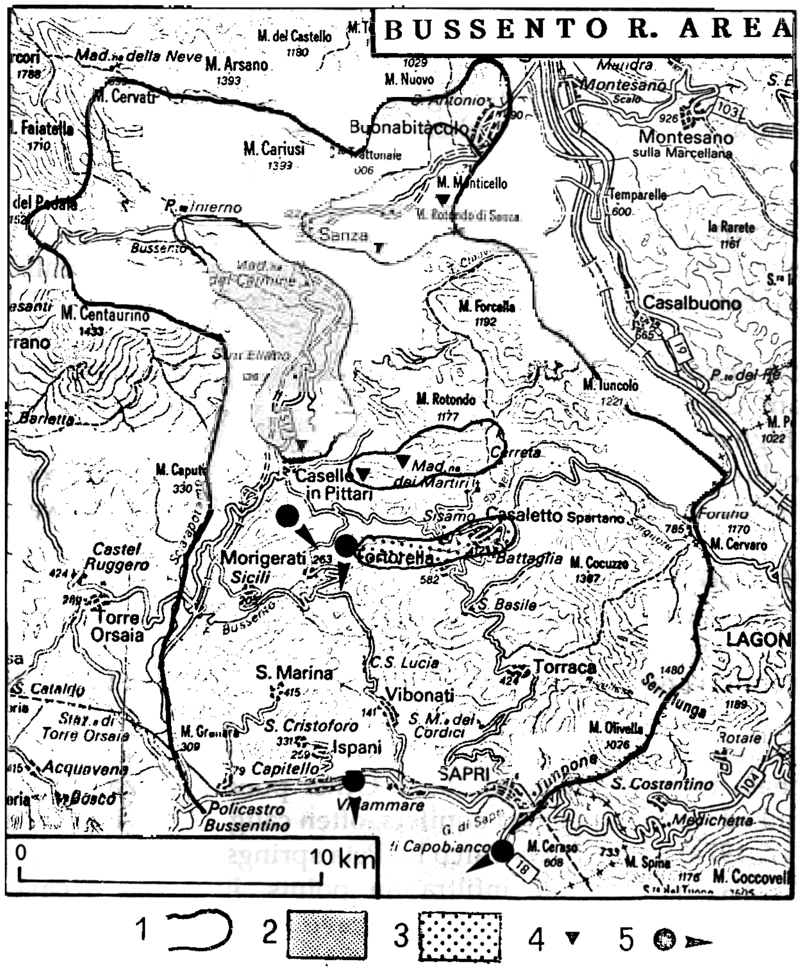

Fig.6: 1) Boundary of carbonatic massif; 2) Areas of concentrated infiltration; 3) Gorges; 4) Ponors; 5) Main springs mentioned in the paper.

THE BUSSENTO RIVER AREA (Fig.6)

In this area endokarst phenomena seem to be located in correspondence of complex tectonic compressive lines and sometimes are related, as suggested by GUIDA et Al. (1987), to deep-seated gravitational slope deformations. However in this sector, karst phenomena, even if little known, are above all represented by great ponors.

The areas of concentrated infiltration.

Certainly the most important concentrated infiltration area for its great dimension is the catchment basin of Bussento river; not less important, besides, are the Rio bacuta basin and the Caravo area.

The Bussento basin is made up of, in the greatest part, clay deposits belonging to Miocenic flysch or Ligurids units, which are located in a N-S oriented depression.

The area, with an extension of about 315 square km, drains rain waters in a ponor which has a spectacular entrance.

The Rio Bacuta basin, perpendicular to the Bussento one, has an extension of several square km and drains water towards the homonymous ponor. Other two important karstic infiltration areas are represented by two blind valleys near Sanza village which feed the Rio Torto cave and the Lago cave respectively.

The endokarst drainage systems.

The Bussento ponor (PARENZAN, 1956; LAURETI, 1960; D'ELIA et Al., 1987;) for its size as fascinated various speleologists generations; infact after Timavo river in Friuli region, it is the most important example of underground streamin Italy. The river sinks into near Caselle in Pittari (La Rupe) and resurges, after about 4 km, at Morigerati.

In successive stages 600 metres in the mount side and 400 metres in the valley side have been explored.

In the same area there are other ponors like those of Caravo, Rio Bacuta and Orsivacca; recently it has been demonstrated that they join forming a single underground system of more than 1300 metres in extension which drains waters from North towards South, like Bussento, in the direction of Morigerati resurgences. Here in fact, besides Bussento resurgence which has shown discharge increases in respect of its entrance points (PARENZAN, 1956), a series of important springs related to a single water table exists (CELICO, 1983). However these resurgences have never been studied and for this reason we are not able to confirm the existence of exchanges between above mentioned karstic channels and water table.

Likewise the endokarst drainage systems of Rio Torto ponor and Lago cave (which can permit an easy underground immission of polluting agents) are still unknown.

Nevertheless in this sense it is important to outline that in the last years the water quality which sinks into the ponors has become considerably worse because in the Bussento river waste of various origins (for example oil mills waste) are discharged.

CONCLUSION

In the Campania region many carbonatic massifs feeding very important springs (for their high discharges values and for their aqueductistic use) are the seat of well developed endokarst and exokarst phenomena.

In some cases the direct relationship between karstic system and water table has been demonstrated; in other cases this relation is only hypothetical (because of difficulty in speleological exploration and lack of experimental tracing tests).

Anyhow the signal of their existence must be considered as a dutiful alarm sign that scientific community addresses to the people responsible for the water management and control.

In fact it is essential that the conceipt of "protection perimeter" provided by the present rules (D.P.R. 24/5/88, n.236) for the "catching point" (even if with very disputable criteria) is extended to other sectors of the massif where the anthropic presence can increase in a determinant way the risk level of pollution.

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