The contribution of the 'Sibilla Appenninica' legend to karst knowledge in the Sibillini Mountains (Central Apennines, Italy)

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Abstract: Geological studies of the Sibillini Mountains carried out mainly during the last century, provided evidence of a hypogeal karst characterized by a small number of caves of limited extent. The only one mentioned by numerous ancient authors is the 'Grotta della Sibilla', on account of its legendary references. This cave is the keeper of one of the most fascinating secrets of the Apennines, having been both a place of mountain cult as far back as pre-historical times and the home of the fortune-telling prophetess 'Sibilla'. Historical sources tell of the presence of someone mysterious at the site from the time of the Romans but amongst the historical descriptions, the testimony of Antoine de la Sale is most notable: he visited the cave in 1420 and described it as a good-sized cavity within the bowels of the mountain. Nothing about this setting is mentioned in the geological literature or in topographic descriptions, made for the first time at the beginning of the 1940s, when a regular but small cave was revealed. Today rockfall deposits completely obstruct the entrance.

On the basis of the above-mentioned legendary references, geomorphological and geophysical studies started helping to define the real extent of the cave. The planimetric trend of the electromagnetic anomalies surveyed allow us to make hypotheses about the presence of a vast hypogeal system.

The myth of the 'Sibilla Appenninica'

Different values and meanings have been given to myth, the earliest being *c.* 11 000 years ago, in the area of the Fertile Crescent. Myth is understood as being a 'subordinate or deformed product of intellectual activity'; in the history of western thought, myth is opposed to *logos* in Aristotle's sense of the term, whereas Plato, considered it a defective and different way of approaching the world of ideas, and gave it a certain moral and religious validity.

Myth implicates co-operation with the historical investigation of a people, systematic and scientific studies of the mythical-narrative sources with the contribution of the earth sciences, of the human sciences and of the social sciences, that in 'transversal and integrative' synergy are able to promote a new scientific language. Due to their own narrative continuity, their mediation between man, nature and the cosmos, and to their content of tradition, knowledge, values and wisdom, they can be considered inter-cultural elements.

The territory of the Sibillini Mountains, which gave rise to this myth and where the cave of the Sibilla is located, constitutes a natural watershed between Umbria and the Marches (Fig. 1). The landscape characterizing this mountainous group is dotted with places of notable natural suggestiveness that have influenced popular imagination for a long time. Place names such as Peak of the Devil, Summit of the Redeemer, Cave of the Fairies, Gorge of Hell, Rock of the Miracle, to name only some, testify to the coexistence of a tenacious pagan history on these mountains.

In the morphology of this Apennine area, characterized by reliefs of particular shapes and profiles, the roots and persistence of the myths and legends of the Sibilla are to be found. If in the past this spellbound landscape was attractive for human settlement, recently it has been employed to trace of the boundaries of a national park, not only to protect the ecosystem of a still miraculously intact area, but also to save a cultural heritage made up of traditions and reports, handed down orally by way of myths and popular legends, or picked up in this place and set into the framework of medieval, Renaissance and contemporary literature. The Piceno area of the Sibillini Park is, in particular, a very rugged and wild area (Fig. 1). It is called the magic slope, and confers extra enchantment on the park, thereby increasing its attraction, differentiating it from other purely natural parks and rendering it worthy of the attribute 'legendary' (the Legendary Park of Europe).

The mountain and the cave of the Sibilla, located in the Umbro-Marchean Apennines, archaic symbols of never disclosed mysteries, both physical and metaphysical, local and universal, sacred and

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Fig. 1. The Sibillini Mountains and the valley of Pilato Lake.

profane, so beloved and so ignored, constitute the mythical omphalos of this central-Italian area, the meeting place for contact with and access to the celestial universe and the chthonian world. In the Myth, the Sibilla, who is a femme fatale archetype not only for the classical prophetic role of the woman of the time, that represents present, future and past, but also for that of the fairy (from the Latin *for-faris*, to speak, to narrate) and therefore as narrator of mystery, values, wisdom and knowledge, is in close interaction with the geophysical and geographical reality of the mountain and the foothills in which she exists.

The existence, now verified through geological investigation of an archaic hypogeal site about 600 m long, placed at a height of nearly 2000 m a.s.l. under the rugged 'crown' of the Sibilla Mountain and about 15 m underground, made up of labyrinthine tunnels and great unexplored chambers, testifies to the places and scenery so dear to the myth. The universal archetype of the labyrinth, that of the mountain, of the cave, of the lake (the nearby Lacum Sibillae, later called Lake of Pilate, due to the introduction of a post-Christian legend), here dominate the scene with their symbolic and mysterious references to the collective subconscience and their reminders of early pilgrimage.

In accordance with the authoritative opinion of the anthropologist Tullio Seppilli (Piscitelli 2001), this 'myth' is the result of the memory of a cave divination cult and therefore of the participation of people, not immediately close to any built-up area and in a context in which these zones were much more central with respect to the roads of communication (Ristori & Carobbi 1999). The memory of this well developed and articulated hypogeal system would otherwise not have been preserved for so long, nor would the popular legend which has come down to us have taken shape so strongly. Therefore, cave, femininity and divination, are the three key-points of the sibylline myth and it can be assumed that the persistence of such a vivid memory, in the Umbro-Marchean Apennines, is to be accredited to the presence of a Sibilla, a priestess, who made divinations and prophecies in a cave, the memory of which remains only thanks to oral tradition.

Among the essential elements of the sibylline myth emerges the mysterious wisdom of the archaic magic of the Neolithic cave cults (Lucentini 2001). The intrinsic mystery of the initiatory cults practised in caves, and in particular in the high-altitude hypogeal site of the Sibilla mountain (known throughout Europe in ancient times as the centre of the Apennine oracle), as well as having been transmitted from the Middle Ages onwards through 'cult' narration, has been kept alive by the large number of pilgrims that have passed by here in time, and has been narrated orally both by the local people, as a heritage of their own anthropological and cultural roots, and by visitors that have come to the land of the Sibilla for very different reasons.

In the sibylline territory, the mostly oral popular tradition of the myth of the 'Sibilla Appenninica', could never have been separated from the environmental context (mountain, cave, lake, nature, mountainous and agricultural-pastoral civilization) where it was born and from where it was handed down. Here the respect for nature, the cohabitation with its indomitable forces (earthquakes, avalanches, bad weather, rigid winters, and so on ...) and with that seasonal rhythm that regulates the tasks and the daily flow of time, are still a reality today.

The fame of the cave spread all over Europe in the Middle Ages, transmitted by the chivalrous literature concerning it, by the novel written by Andrea da Barberino, by the manuscript of the travel account of the knight of 'Provence' Antoine de la Sale (Fig. 2; Piscitelli 1999), by the transcriptions that followed, up to the novels interspersed with autobiographic 'licence' by more recent authors. The many faceted character of the Apennine Sibilla, the immortal lady of the myth, and the prophetic cave that, with its arcane mysteries constitutes the 'symbol', represent tangible proof of the persistence of the lay rendering of a very ancient myth, in a narrative style typical of different periods.

Chronology of main historical notes on the cave of the Sibilla

In 69 BC, Suetonius reported that Vitellius 'celebrated a sacred vigil on the Apennine ridges'; later, in 270 AD, Trebellius Pollio in '*Scriptores Historiae Augustae*' wrote that Clodius II the Goth consulted in that year the Apennine oracle; to 820 AD can be dated back to the examination of the cave by an anonymous knight, the same one described in the first years of the fifteenth century by Andrea da Barberino in his novel Guerin Meschino. During the period 1320–1340, a probable closing of the cave occurred due to natural

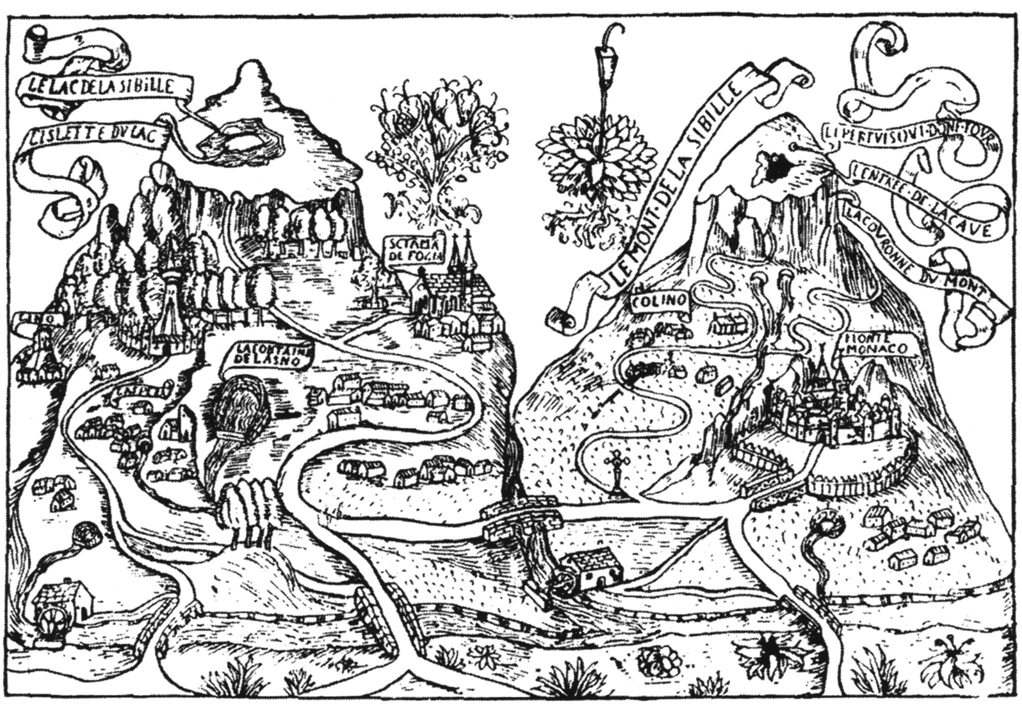

Fig. 2. Sketch of Sibilla Mountain by Antoine de la Sale in 1420 (after a gothic edition of 1521, National Library of Paris).

causes (the terrible earthquake of 1328; Blumetti *et al.* 1990), or to political-religious causes reported by the historical notes (struggles between Guelph and Ghibelline factions of Umbria and the Marches, and between heretics and Dominicans; an ordinance of the church to oppose the heresies of Templars, Alchemists, Spirituals, Cathars, Patareni etc. whose survivors had found shelter in the land of the Sibilla). The visit of the German knight Hans van Bamburg, subsequently named by Antoine de la Sale in his travel diary, dates back to 1338. Later on, in the years 1420–1450, Antoine de la Sale examined the sibylline cave twice leaving in his diary manuscript, dedicated to his agent, Agnese de Bourbon-Bourgogne, a description and detailed and realistic drawing of the natural morphology of the place and of the sibylline chamber (Piscitelli 1999; Fig. 2).

There are various significant reports: for example that of the historical archives of the town of Montemonaco, in parchment No. 40, in which knights coming from all over Europe visited the land, lake and cave of the Sibilla to practise alchemy and consecrate books on magic is documented in 1452; or that of 1578, a date carved on a rock overlooking the currently collapsed vestibule and still clearly visible today. This date, that is oddly connected to the legend of the birth of Christian Rosenkreuz, would be symptomatic as well of the presence of Rosicrucians in the land of the Sibilla. In more recent times (1610–1612), Martino Bonfini frescoed in the ancient sanctuary of Our Lady of Ambro, at the foot of the Sibilla mountain, a cycle of twelve Sibyls among which one that was a chemist or alchemist.

Important events followed during the nineteenth century: the attempted speleological exploration, without any particular result, by the Caponecchi brothers, called the Vezzanesi, in 1870; the climbing to the cave in the hope of finding the continuation of the tunnel after the vestibule by G. B. Miliani, the forerunner of modern speleologists, in 1885; after an excursion to the cave in 1897, the opening of the cultural debate on the Sibilla by the intellectuals Pio Rajna and Gaston Paris, that, in the midst of publications and conferences and increasingly rich scientific data, has been continued to the present day; and in 1889 the arrangement of the entry to the cave by a committee of alpinists.

Significant events happened in the last century. In 1920 an expedition led by Falzetti, went into the vestibule, and apparently identified a probable continuation of the cave by way of a descending tunnel; an attempt at excavation by unknown persons followed between the years 1921 and 1925, when Falzetti returned to the cave he discovered the modifications effected by the incompetent explorers and the disappearance, under rock-fall deposits, of the supposed descending tunnel (Falzetti 1954). In 1926, the superintendent of archaeological findings, Dr Moretti, obtained the first technical scientific data on the state of the chamber of the time: 'The chamber, that across an unusual open fissure along the oblique seam of rock is not more than eight metres long, four in width and three in height, does not have other access to tunnels or to rooms in the inside abysses. The only open space that is left is the vestibule from which a hole lets us suppose that there once existed or still exists, not only the rooms that the legend attributed to the heaven of the Sibyls, but at least some other chambers of which the present one is the vestibule'.

There then followed numerous expeditions and examinations of the site: in 1929–1930 by the Belgian philologist Fernand Desonay and by Falzetti again, without result; in 1946 by the Marchean poet Tullio Colsalvatico who made an excavation on his own which was interrupted by the superintendency on the basis of an unfounded suspicion of the use of explosives to enlarge the chamber. He was followed by the geologist Lippi Boncampi who, in a report dedicated to karstification in the Sibillini Mountains, furnished the first official document on the hypogeal development of the cave of the Sibilla, illustrated by topographical surveys, sections, planimetric models and other technical data. In 1952, General Emidio Santanché, water diviner and president of the tourist office of Ascoli Piceno, effected a reconnaissance, that did not yield results, together with members of the Forestry Corps probably aimed at a reopening of the chamber for purposes of tourism; in 1953, Annibali, the superintendent of archaeological findings, gave permission for an excavation that was more ambitious than any tried before. But the inadequacy of his techniques worsened the obstruction of the chamber adding deposits to the previous deposits.

Later during the period 1953–1965, the cave's vestibule collapsed completely and certain significant remains, including a stone carved with illegible characters, were stolen. Subsequently, in 1968, the geologist Odescalchi from Pesaro, with the aid of geoelectrical instrumentation, succeeded in surveying anomalies, probably evidence of the existence of a tunnel. Recently (1983–1984) the Speleological Group of the Marches from Ancona, led by the speleologist Giuseppe Antonini, made repeated attempts to identify the descending tunnel indicated by Odescalchi, through systematic prospecting particularly on the 'crown' of the Sibilla mountain and guided digging. But the precarious working conditions forced the speleologists to abandon the enterprise, when they were probably close to discovering the access to the tunnel.

A scientific debate on the Apennine Sibilla and her cave was reopened in the years 1997–2001, encouraged by the scientific committee of the cultural project 'Elissa' of Montemonaco, presided by Paolo Aldo Rossi of the University of Genoa. Three main conferences were organized, to which researchers of national and international fame came to the Piceno region. Besides establishing the historical, literary and anthropological data of the myth, they called for geological and geophysical investigations that aimed at denying or confirming the hypotheses formulated. As a result, in 2000 the committee for the 'Cave of the Apennine Sibilla', backed up by the presence in the field of Nora Lucentini, Gilberto Pambianchi and Angelo Beano, promoted the geological and geophysical investigation on the site of the 'Cave of the Sibilla' (Pambianchi 2001; Beano 2001; published in the Proceedings of the Conference 'Sibyl, Shaman of the mountain and the Apennine Cave').

The chronology of the visits to the cave reported above provides evidence of the close connection between man (curious believer, historian, or scientist) and the territory; there is a close relationship between myth on the one hand and geography and geology on the other, in a little-known territory, which all the same is a site with strong cultural ties. The reasons for this close relationship perhaps lie in the apparent majesty displayed by the mountains, even from some distance away, or else in the impressive feature offered to the visitor of mountain slopes spread almost menacingly on the crests of the chain, and bordered by precipices. In particular, it is the unknown potential of the cave development that brought the questions regarding the world of myth and the aims of the scientific community together. After the initial and historical setting in geography, a deeper geological knowledge about this place of religious cult is seen to be the only tool able to overcome the barrier of limitations imposed on the spatial setting and to throw light back in time. In fact, geological information is able to establish a solid scientific point of contact between a new spatial element (in this case a hypogeal one) and its history, thereby demonstrating (or not) the truth of what has been handed down orally through time.

Geological and geomorphological features

The Umbro-Marchean Apennines are made up of a sedimentary stratigraphic sequence (having a thickness of up to 2500 m) primarily calcareous at the bottom and with limestone alternations, marly-limestone and marl, in the remaining upper portion. In the first phases of the Jurassic age, in the great gulf of the Tethys Sea, that divided the African continent from the Eurasian one, the Calcare massiccio formation, with a thickness of up to 1000 m, the most ancient one known in the Umbro-Marchean area, was deposited, in a shallow sea and in a carbonate platform environment. Toward the end of the Lias, the carbonate platform began to sink slowly, associated with the extensional tectonics that separated Africa from Europe and produced in the gulf of Tethys numerous and deep sedimentary basins, including the Umbro-Marchean one. Afterwards, from middle Jurassic up to middle Eocene, during a relative tectonic calm, about 2000 m thickness of primarily calcareous rocks (flinty calcareous, marly calcareous and marly) were deposited. Between the middle Cretaceous and the middle Eocene, the marly calcareous formation of Scaglia rosata was deposited in the Umbro-Marchean sedimentary basins. This formation constitutes the upper skeleton of the Sibilla Mountain that has sub-horizontal bedding where the beds are locally affected by intense folds, connected to inter-formational slumpings, and to calcarenitic benches with thicknesses of tens of metres, the thickest in the area (Chiocchini *et al.* 1976). The big calcarenitic pack forms the characteristic and fascinating 'crown' of the Sibilla Mountain (Fig. 3). The inter-formational slumpings were formed on a sea bottom which was neither uniform nor stable; the calcarenitic benches were tied to turbiditic flows that pushed northwards from the Abruzzi carbonate platform towards the Umbro-Marchean sedimentary basin.

After the deposition of the Scaglia rosata in the upper Eocene, the collision between the African and European–Asian plates caused extension of the emerged areas. In the Umbro-Marchean sedimentary basin (narrowed by the surrounding continental areas) mainly clayey sedimentation began and continued throughout the Pliocene. During this period, the structure of the Umbro-Marchean Apennine chain, characterized by thrusts and folds, developed, producing two large ridges: the Marchean and the Umbro-Marchean (Fig. 4).

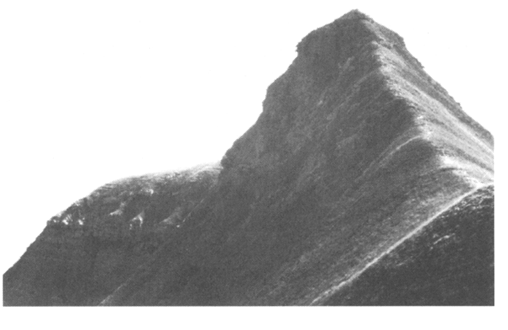

Fig. 3. The Sibilla Mountain and its characteristic 'crown'.

In central Italy between the upper Pliocene and lower Pleistocene, there was a low-lying continental landscape. The traces of this ancient landscape are represented by wide flat spaces (erosion surfaces) formed in an arid environment that can be found on the Apennines and pre-Apennine reliefs. In the late stages of the lower Pleistocene, there was intense and general tectonic uplift, connected with the collision of Africa and Europe, that broke up the earlier landscape and was subjected to rapid uplifted (Gentili & Pambianchi 1999).

The most intensely karstified rock formations are those at the base of the statigraphic sequence that are made of pure limestone from the carbonate platform (Calcare massiccio, Hettangian-Sinemurian). Minor karst phenomena affect the following calcareous and marly-calcareous formations of the Maiolica (upper Titonic–lower Aptian) and of the Scaglia rosata (Cenomanian p.p.–middle Eocene p.p.) cropping out on Mount Sibilla.

In the Umbro-Marchean Apennines the outcrops of the calcareous formations are extensive and the karst phenomena are commonly of a different type, affecting the two Apennine ridges: the Umbro-Marchean Ridge and the Marchean ridge, located slightly further to the east (Fig. 4).

The speleogenesis that may affect the calcareous formations in the central Apennines may be explained by the interaction of several factors: a) erosion from the infiltration of waters, the action of CO_2 of superficial derivation; b) hyperkarstic processes connected to the mixing of different waters and to the oxidation of H_2S both in the phreatic environment and in the atmosphere, caused by the action of sulphurous steam; c) the interaction of H_2SO_4, produced by the metabolism of certain bacteria on the calcareous surfaces of the hollows (Galdenzi & Sarbu 2000).

The northern portion of the Apennine ridges do not have relevant karst phenomena, with the

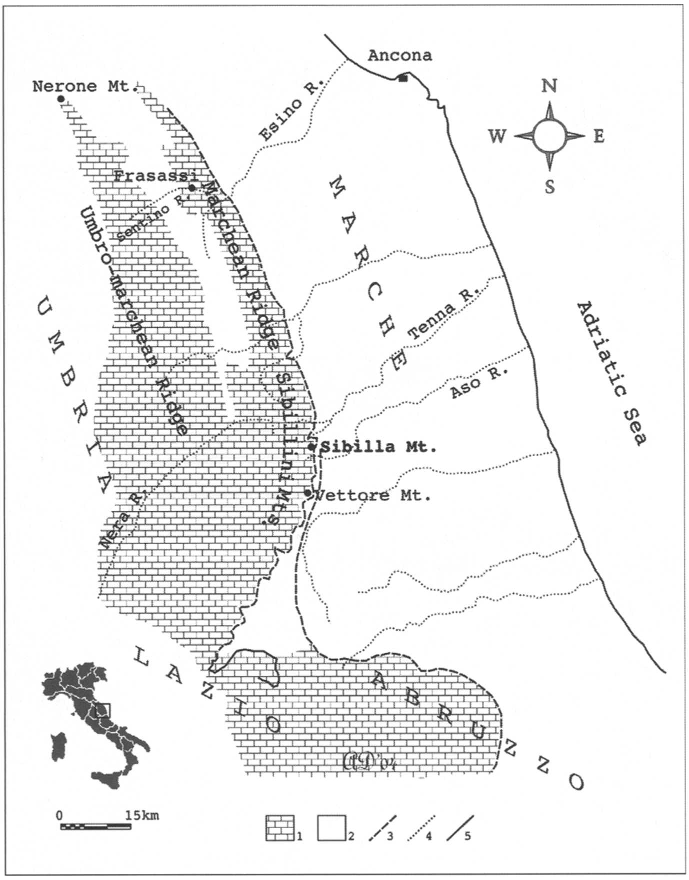

Fig. 4. Geological sketch of the central Apennines: 1, limestones; 2, marls and terrigenous sediments; 3, main thrusts; 4, rivers; 5, coastline.

exception of the mountain group of Mount Nerone (1525 m a.s.l.; Fig. 4), where cavities and natural arcs are carved in the Calcare massiccio along the steep walls. Here the Grotta delle Tassare is found, the deepest cave of the Marches; one of the deepest caves in Italy lies a short distance to the south, in the Cucco Mountain (1566 m a.s.l.), in Umbrian, part of the same formation (Bisci & Dramis 1991).

In the middle portion of the Marchean Ridge, is the best known and developed hypogeal karst system of the region: the Frasassi Caves (Figs 4 & 5). They are set in an anticlinal core constituted by the formation of the Calcare massiccio cropping out on the inside of a narrow and deep valley. This area is characterized by a sub-continental mountain climate, with an average temperature of about 13 °C and precipitation of about 1000 mm a^{-1}, and the surface karst forms are little diffused. Numerous caves with a general development of over 25 km open at heights of between 200 m (the level of the Sentino river) and 500 m a.s.l. In this karst system phreatic morphologies generally prevail; the vertical variations of the water table have played a determinate role. Large and deep pits connect chambers with hundreds or thousands of cubic metres in volume at different levels, showing a clear hypogenic origin (Bocchini & Coltorti 1990; Galdenzi & Menichetti 1995).

In the central area of the Umbro-Marchean Apennines, relatively important karst phenomena characterize the inter-mountain tectonic basins as well (Castelluccio, Norcia, Colfiorito, Montelago, etc.); there are numerous sinkholes that drain the water from the surface (Scarsella 1947; Bisci & Dramis 1991; Gentili 2002).

The Sibillini Mountains constitute the southern joining area of the two mountainous ridges and exhibit the highest reliefs (Mt Vettore, 2476 m a.s.l.). Here the superficial karstification, however

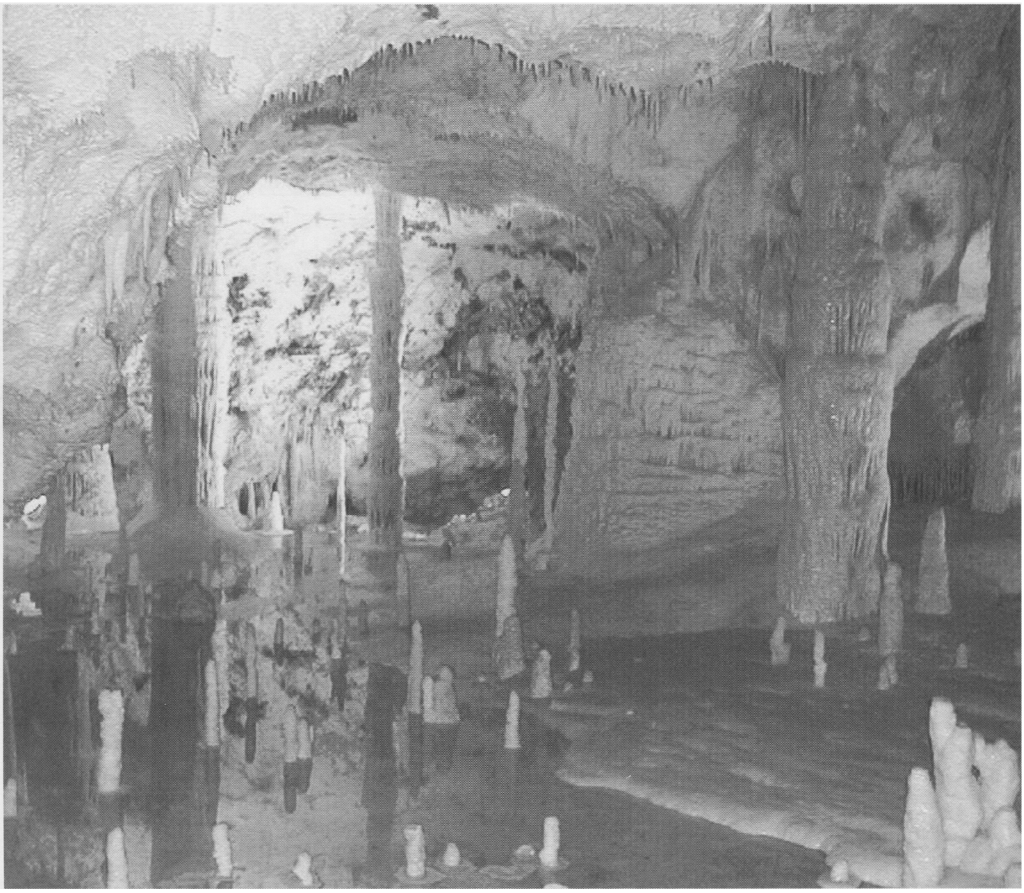

Fig. 5. The Frasassi Caves.

limited, reaches its maximum regional diffusion with karrenkampfs, streamsinks, and dolines (Bisci & Dramis 1991; Gentili 2002).

In the Sibillini Mountains area, the hypogeal, karst phenomena are much rarer and are mainly associated with the Calcare massiccio formation, in which the karst system is made up of small caves, channels and sinks, with horizontal, vertical and oblique development. The horizontal cavities are located in the lower portion of deep valley incisions, the vertical ones are less developed and located in the upper portion of the relief where calcareous formations (aquifers) occur with impermeable marly units at the base (Gentili 2002). More interesting caves, wells and natural tunnels are found along the Rio Garrafo (labyrinth system) on nearby Mount Bove (the 'Cave of Sin' or the 'Cave of the Devil') and Mount Patino (the'Cave of Patino'). The highest known cave of all in the Sibillini Mountains, famous for its legends which has given rise to the vast historical, romantic and poetic literature regarding it, is the Cave of the Sibilla located almost at the top of the mountain bearing this name.

The Sibilla Mountain with its height of 2173 m. a.s.l. is one of the most important mountains in the group of the Sibillini Mountains; the summit is characterized by a rocky crest, developed in a roughly east–west direction, that causes very steep slopes that erode northwards into the Tenna River Valley and southwards into that of the Aso River (Fig. 3).

The main lithotypes that crop out from the valley floor, are made up of the micritic limestone of the Maiolica formation (upper Titonic–lower Aptian) and by the marly calcareous formation of the Marne a Fucoidi (Aptian p.p.–Cenomanian p.p.) and, near the top, of the Scaglia rosata (Cenomanian p.p.–middle Eocene p.p.) that are essentially in a subhorizontal bedding or locally characterized by minor folds or slumping.

The minor folds, for example those observed at the entrance of the cave, also affect the less thick calcarenitic layer. Here, the fallings have pointed to a structure of recumbent folds, where the major fold probably constituted the roof of the cavity and corresponded to the vestibule described by Lippi-Boncambi (1948) (Fig. 6). The fallings of

Fig. 6. Slumping fold near the cave entrance where the location of the roof of vestibule (A–A), today collapsed (A′–A′), may be reconstructed.

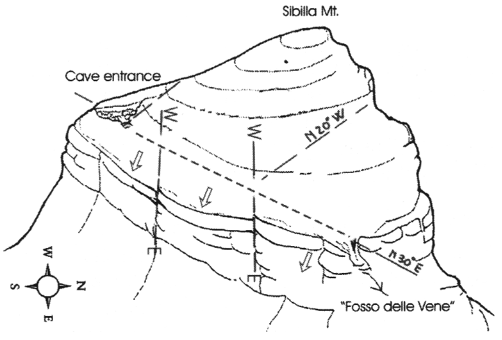

Fig. 7. Sketch of the summit portion of the Sibilla Mountain: main joint direction in dashed lines and relaxing direction of calcareous plates with arrows.

the vestibule are surely attributable to tampering by man, as well as to the strong earthquakes that characterize this area.

Detailed geological surveys, recently carried out at the cave's entrance and neighbourhood, enabled the authors to define different geological and geomorphological characters around the site (Fig. 7). They identified faults and fractures oriented in an approximately N 30° E direction where probable phenomena of left-strike slip have produced widening of the plicate structure. The system of faults and fractures continues towards the 'Fosso delle Vene' with a development of about 1 km. Tectonic action on the bedrock favoured the infiltration of meteoric waters, and karstification has developed preferentially in the calcarenitic layers. The widening of underground chambers has also been aided by gravitational phenomena with regard to the summit portion of the relief (Fig. 7). Translational slide phenomena, valleyward of the cave entrance were recognized; these affect the Scaglia rosata layers along the bedding. The decimetric marly-calcareous level acts as a shear plane. It has been strongly fractured by gravitational movement and in some places the bedding (crush breccia levels) can no longer be identified. On the Sibilla's relief and on surrounding slopes, gravitational phenomena developed. Deep-seated gravitational slope deformations (of which evident double crest is a basic diagnostic element) and vast landslides have been favoured by the lithostratigraphic setting. These can be identified by: 1) the overlaying of lithotypes with rigid deformation (limestones) on ductile deformation levels (marls); 2) the rapid Quaternary tectonic uplifting and consequent deepening of hydrographic system, that produced high relief; 3) glacial-decompression phenomena, related to the melting of Pleistocene glaciers; and 4) numerous and strong earthquakes (Aringoli *et al.* 1996; Dramis *et al.* 2002).

Geophysical investigation

The present research was backed up by a detailed geophysical investigation that started in 2000 (Beano 2001). The purpose of this field survey was to confirm the first geological hypothesis regarding the localization of hypogeal structures in the area surrounding the vestibule of the Sibilla cave and along the line (in N 30° E direction) that connects the entry of the cave to the 'Fosso delle Vene' spring (Fig. 8). The zone is not large; it is encircled by precipices, and lies on a very steep slope, which is difficult to reach; therefore, the use of seismic, and geoelectrical methods was excluded. The authors considered a georadar analysis to be the most appropriate method for this kind of survey, to maintain data quality, completeness of information, and easy transportation of equipment to the site. Although 'geoelectrics' allows a generic identification of a situation, georadar is able to reconstruct with greater precision, in this particular litho-stratigraphic setting, to a much greater depth. To estimate the reflected radar signal attenuation, and therefore the radar penetration depth, two geoelectrical tomography surveys were carried out to check the effective radar prospecting. The maximum depth that could be achieved was about 40 m below the surface level. The georadar data were also calibrated at a depth of 10 m, the depth found during excavations in the 1980s.

The present field programme consisted of a series of measurements along longitudinal and transverse lines to the slope and, where possible, in a grid of lines spaced 2.5 m one from another for a total length of 8975 m.

The electro-stratigraphic sequence, shown by the geological profiles, confirms the presence of a maximum in the superficial area, and at greater depth, reveals a fold of material of medium resistivity (marls or calcareous marls) overlying a medium–high resistivity core (marly limestone). Geoelectrical tomography was carried out to evaluate the attenuation of electromagnetic signals irradiated by the georadar techniques; in a preliminary phase it was possible to attest that an adequate surveying depth of about −25 m could be reached, and therefore it was decided to proceed with the survey using georadar. The authors were concerned about the penetration capability of the electromagnetic waves (with a good quality of recorded data) from the georadar and the possibility of identifying any hypogeal structures, of a limited 'horizontal' extension at a depth of 10–20 m. A set of profiles, allowing all the uncertainties to be settled, was therefore obtained in the vicinity of the (collapsed) chamber. It was then possible to proceed to the systematic acquisition of data.

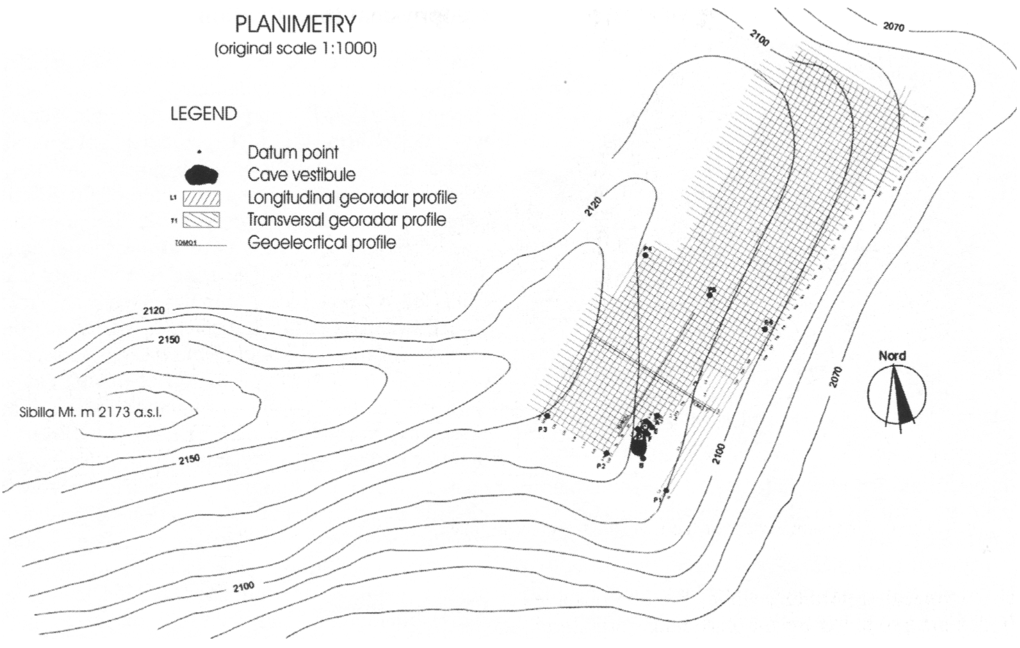

Fig. 8. Planimetry of the investigated area on the basis of geophysical prospecting.

During the subsequent phase of data elaboration, after a long process of normalization, filtration and amplification of recorded signals, three types of electromagnetic anomalies ('A', 'B', and 'C') were scanned and identified. The type 'A' anomalies (Fig. 9) are characterized by strong signal reflection due to the transit between two media having a very different dielectric constant (high reflection coefficient) as would happen in this case, in the event of contact between rock and

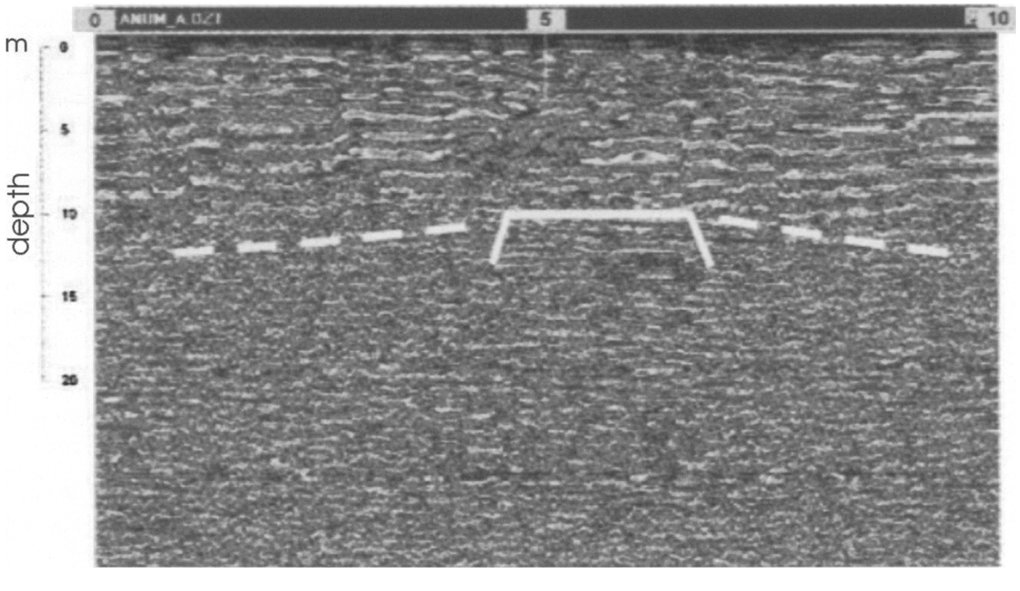

Fig. 9. 'A' anomaly radargram; the white dashed line shows the roof of the cave.

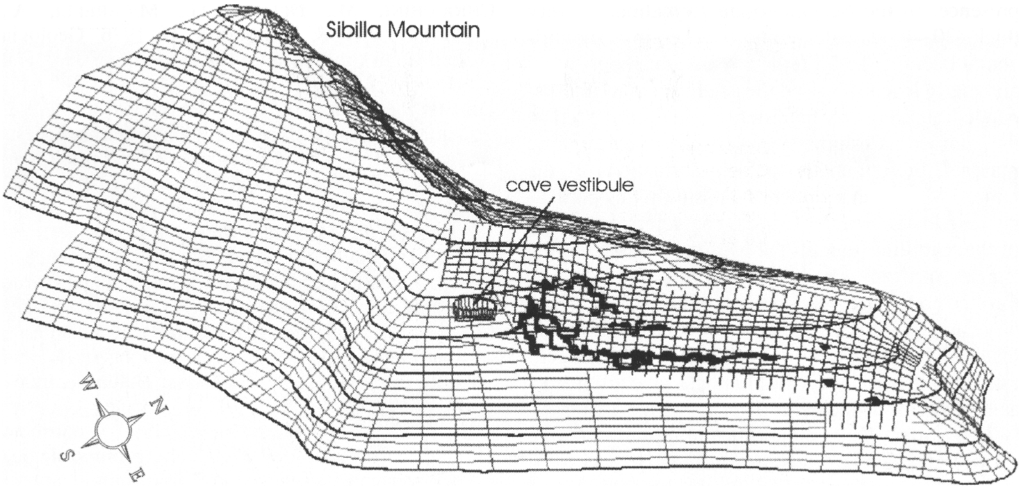

Fig. 10. Three-dimensional view of the investigated area: in black, the anomaly's contour.

air (hypogeal structures), while, the two observed 'tails' are produced by the particular form (arch) of the side walls and of the roof. The type 'B' anomalies are similar to those mentioned previously, but they are less evident due to different factors: a low reflection coefficient, reverberation of the signals on the side walls (sub-vertical) and/or the presence of chaotic and/or fractured material. The 'C' type anomalies are easily recognizable on the net radargrams because of two or more parallel and inclined bands: they have been correlated to fractures and/or open surface discontinuity (in accordance with geological–tectonic information for the area).

Many type 'A' and 'B' anomalies are located close to or on the projection of the type 'C' ones (fractures). All the sets of 'A' and 'B' anomalies, placed preferentially along tectonic alignments surveyed on the surface (N 30° E, the prevailing direction) have been contoured to identify the distribution of underground voids better.

The anomalies examined clearly show an underground fracture, stretching in an east–west direction and emerging to the south. The surface geological surveys confirm the presence of a similar preferential orientation (east–west and NE–SW) of the different tectonic structures. As far as the dimensions of the identified cavities are concerned, they are both horizontal and vertical, with an average width of about 2 m (increasing to a width of 8 m), located at varying depths of between of 10 and 14 m.

The compilation of an elaborate three dimensional graph viewed from the SE (Fig. 10) allows a spatial image of all the sets of anomalies that is related to the 'roof' or upper portion of the objects that produce it.

Conclusions

The myth of the Sibilla, already well established before the birth of Christ, has attracted people to this area from all over Europe for centuries. Even among researchers of different disciplines, it has aroused intense interest and in particular has furnished earth science researchers with interesting material for thought and a challenge: to verify the physical setting, that has been recorded by historical documents or legend, or else handed down orally throughout the ages.

The geological-geomorphological and geophysical studies in this paper seem to confirm this general setting. They point to a high-elevation karst system (up to about 2000 m) which has well developed horizontal levels at different altitudes, that are joined by vertical and inclined caves. In accordance with the geophysical data, that confirm the geological surface information, the system develops for about 600 m mostly following a preferential N 30° E direction, (starting) from the entrance of the cave to the 'Fosso delle Vene' spring. The karstified levels with horizontal development reach a maximum size of about 300 m, with tunnels a few metres in diameter, located at different depths, from 10–14 m underground. These karst forms, with prevailing horizontal development, represent a rare episode, if not the only one, in the more elevated areas for the Umbro-Marchean Apennines, generally characterized by karstification in vertical development.

This karst episode, pertaining to the classical typology of the calcareous rocks of the Umbro-Marchean sequence, can be explained by considering different geological features. In particular, the presence, in the Scaglia rosata formation, of very thick (30–40 m) calcarenitic benches in a subhorizontal bedding, that alternate with calcareous-marly and marly levels, allowed the establishment of a suspended aquifer, that persisted in time entrapped in the numerous slumped folds. The calcarenitic material, present in the pelagic formations of the Umbro-Marchean sedimentary basin (in this particular case in the Scaglia rosata), characterize the area of the 'Sibillini' that, in the Mesozoic, bordered the 'Lazio-Abruzzo' carbonate platform to the north. Further northwards, the Umbro-Marchean sedimentary basin was an open sea, without detritic turbiditic material. The calcarenites in this area are the thickest, since the palaeogeographic data reveal this area as a sediment depocentre.

The karst phenomenon is imposed on the calcarenitic levels, favoured by the presence of a stagnant aquifer and following a fault with N 30° E direction. This fault and the other sub-orthogonal ones, broken up the Scaglia rosata formation, creating blocks with different dimensions, that were subsequently deformed by translational mass movements. Such gravitational phenomena enlarged the fractures, and increased the rate of movement.

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