



## ON SOME VOLCANIC CAVES OF SARDINIA (ITALY)

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### Abstract

Volcanic Tertiary activity in Sardinia has started in the South about 60 Ma ago, but the most important volcanic period goes from 32 Ma to 13 Ma, and is related to the Oligo-Miocene rifting of the Sardinian-Corsican microplate. From 13 Ma to about 5,5 Ma no important volcanic events occur, but due to the opening of the Southern Tyrrhenian Sea, a new volcanic cycle starts (5,5-0,1 Ma), with the formation of the so-called "Giare", basaltic highflats, and of the Campidano Graben. On the island are known almost 100 volcanic caves, mostly of secondary origin, but some of these are of reogenetic and pneumatogenetic origin.

In this article the Authors present the most interesting lava caves of Sardinia. Some of these caves, because of their primary origin and of their rarity, represent one of the less known speleological particularities of the island, and therefore these should be appropriately protected.

### Introduction

In these last years the volcanic tertiary complex in Sardinia has been studied in detail, with the determination of the absolute ages, the palaeomagnetism, the petrographic stratigraphy, but nevertheless the strictly volcanogenic aspects of the different rocks have never been thoroughly taken in consideration; the aim of this work is to put in evidence the existence of primary volcanic caves in Sardinia, describing their morphology and explaining their formation.

In Sardinia non-carbonatic caves aren't easy to encounter; many caves develop in volcanic rocks, most of which have an exogenic and secondary origin (eolic, fluvial, tectonic, etc.). There are some rare examples of rheogenetic volcanic caves that present singular characteristics. The most interesting of all these caves in volcanic rocks of Sardinia will be described.

### Tertiary volcanism in Sardinia

The first tertiary volcanic activity in Sardinia occurs in the Sulcis area; in this region can be found alkaline volcanic rocks, appearing as *sills*, interposed by sediments of the Upper-Palaeocene to Under-Eocene (ASSORGIA et al., 1992). The age of these volcanic rocks is determined between 62.1 and 60.2 Ma (MACCIONI et al., 1990). Probably this volcanic activity is related to the Iaramic-pyrenean tectonic cycle, that manifested itself in Sardinia only during the early phases (BARCA et al., 1997).

Later on, beginning from 32 Ma, Sardinia has been interested by important geodynamic and tectonic events, responsible for the opening of the North-Western Mediterranean and connected to the drifting of the Sardinian-Corsican microplate; due to these phenomena starts a new volcanic cycle of prevalently calc-alkaline character that has been related to the subduction of oceanic lithosphere underneath the Sardinian-Corsican microplate (COULON, 1977; BECCALUVA et al., 1987).

In Sardinia the geodynamic trend of this movement is characterised both by distensive and compressive tectonic phases and therefore, the volcanic products related to these cycles are alternatively basic and acid.



Recently LECCA et al. (1997) have proposed a stratigraphy that isn't based on the distinction between different volcanic events, but on the chronology of all the volcanic products in general, without distinguishing sequences.

ASSORGIA et al. (1997) instead, classify these volcanic rocks in four series that outcrop in particular in Northern Sardinia, but nevertheless also in different localities in Southern Sardinia.

Today most Authors collect these volcanic terms in four different sequences that represent a cyclic character for what concerns chemistry; from the oldest to the most recent we have:

**LOWER BASIC LAVA SEQUENCE (LBLS):** outcrops in Central-West and South Sardinia, and is characterised by lava with an intermediate to basic chemistry, related to a Peléan volcanic activity. These rocks generally present a dome structure at which are associated often pyroclastic sediments. The K/Ar age of this sequence varies from 32 to 23 Ma.

**LOWER ACID EXPLOSIVE SEQUENCE (LAES):** in this sequence converge all lithologies with acid-intermediate chemistry that overlie in concordance the earlier described volcanic rocks. The sequence is characterised by lava flows, pyroclastites and high grade temperature ignimbrites. The K/Ar age is given between 23 and 20 Ma. This sequence outcrops in several parts of Central-Sardinia.

**UPPER BASIC LAVA SEQUENCE (UBLS):** outcrops prevalently in West-, Central- and South-Sardinia. These volcanic rocks are composed of andesites and basalts that have been deposited by means of lava flows and pyroclastic sediments, both subaqueous and subaerial, or as lava domes and associated explosive phreatic-magmatic products. Their K/Ar age goes from 19 to 16 Ma.

**UPPER ACID EXPLOSIVE SEQUENCE (UAES):** this sequence is characterised by ignimbritic, pyroclastic and lava-like rocks. These products are rhyolitic and dacitic (with rare episodes of pyroclastic sedimentation with Sanidine), sometimes commenditic (Sulcis), and represent the last eruptive activities related to the calc-alkaline Sardinian volcanic cycle. Their K/Ar age varies between 17 and 13 Ma.

With the end of the calc-alkaline cycle, about 13 Ma ago, a long volcano-tectonic quiescence reigns over Sardinia. Only about 5,5 Ma ago a new volcanic cycle of alkaline type starts, and goes on with various grades of intensity up until 0,2-0,1 Ma ago (BECCALUVA et al., 1985). This volcanic cycle has been ascribed to the opening of the Southern Tyrrhenian Sea, related to a large scale expansive geodynamic context (BECCALUVA et al., 1977), that has also caused the formation of the Campidano Graben in East Sardinia (PECORINI et al., 1969) and the great volcanic table-like mountains, locally known as "Giare", in Central Sardinia.

The most abundant products of this cycle are alkaline and sub-alkaline basalts that outcrop in a rather discontinuous way in several parts of the Island (mostly in Central and Northern Sardinia). Besides these basalts sometimes more evolved types of volcanic rocks can be found, such as phonolites (in the Montiferro volcanic complex, West-Sardinia), rhyolites, dacites and trachytes (at Monte Arci and Monte Fortuna in Central-West-Sardinia) and latites and trachytes (at Capo Ferrato, East-Sardinia) (BROTZU et al., 1975).

Most of these volcanic rocks although represent lava flows that often form great tabular mountains (ASSORGIA et al., 1983).

The most important volcanic rocks for what concerns this work are the basalts, because these represent the main characteristics for the formation of syngenetic volcanic caves at the end of the eruption.

### **Caves in the volcanic rocks of the calc-alkaline cycle (Oligocene-lower-middle-Miocene)**

As has been explained in the previous chapter this volcanic cycle is characterised by both basic and acid rocks. Only little caves have been found in the basic volcanic rocks, while in the acid-intermediate lava's are known several interesting caves, most of which of secondary origin and created by wind or water erosion.



These pyroclastic rocks, mostly characterised by scarcely consolidated ignimbrites, present various erosional cavities especially in Central-Sardinia, but also in the SW (Monte Su Crobu, Carbonia, Sulcis), or great fractures successively eroded by the wave motion (Capo Marargiu-Bosa, Island of San Pietro). Some of these caves, as for example the Cave of the Pelicans (Bosa), show a significant development and are well decorated by limestone concretions, due to a Miocene limestone cover upon the volcanic rocks (PIRAS et al., 1995).

The great wind-erosion caves of Central-Sardinia are normally used by the shepherds and can also represent great archaeological interest. At Montresta, Villaperuccio and Bonorva are documented vast underground settlements or necropolis formed by both natural and artificial caves in rhyolites, ignimbrites and other fragile volcanic rocks.

### **Caves in the volcanic rocks of the alkaline cycle (Pliocene-Pleistocene).**

Volcanic rocks of the alkaline cycle outcrop in many parts of Sardinia, even though little caves are known from these rocks, probably due to a lack of speleological exploration.

Although these lavas are very abundant, only some types of these rocks are suitable for the formation of volcanic caves, depending on temperature and viscosity. For what concerns the Island especially basalts are likely to have the right characteristics for the formation of lava tubes. Basalts in fact, have a high fluidity and are likely to flow for several miles, causing the formation of tunnels that can be explored once the eruption ends.

In general the primary lava caves that will be described in this work are of two types: lava tubes or rheogenetic caves and bubble or pneumatogenic caves (CONDARELLI D., 1972; RITTMANN A., 1975).

The first are formed when, during the flowing of the lava, the external parts solidify, forming first lava channels, then lava tunnels, that stay active until the alimentation stops.

The latter have a much more simple formation when the gases, that come out of the liquid lava, are trapped underneath a semi-solid peel of lava, creating a spherical chamber.

The volcanic caves of the Island are not very important from a speleological point of view, being characterised by small developments and lacking of concreting.

In what follows we have described the most important of these volcanic caves, separated on a geographical scale.

### **Short description of the caves in volcanic rocks**

In what follows are described some of the most interesting primary and secondary volcanic caves of Sardinia. Along with the name of the cave, between brackets is given the official register number followed by two letters that stay for the region (SA=Sardinia) and two for the province (SS=Sassari, CA=Cagliari, NU=Nuoro or OR=Oristano). These numbers refer to Fig.1 in which are represented the volcanic outcroppings in Sardinia and the location of the caves described in this work.

Close to Torralba, on the homonymous mountain, exists the "Grotta di Monte Oe" (57 SA/SS), formed by wind erosion in trachy-andesites of the calc-alkaline volcanic cycle. This subcircular room of about 15 meters in diameter, is used by the local shepherds (BARTOLO G. et al., 1994).

At Cossoine a little cave called "Ucca de su Vicariu" (1414 SA/SS) is formed on some fractures in calc-alkaline volcanic rocks (BARTOLO G. & FADDA A.F., 1998). In the same area are known other secondary volcanic caves, signed on the geographic maps.

Near Montresta (SS), in the trachy-andesites of the calc-alkaline volcanic cycle, has been reported the little cave named "S'istampu de Pippetto" (1412 SA/SS) (MELE E., 1997), composed of an 8 meter pitch that ends in a subcircular room. The genesis of this cave is due to water erosion along some small fractures close to the entrance.



In the territory of Villanova Monteleone is known the cave called "Pentuma de Pala Umbrosa" (574 SA/SS), that is formed on a fracture in Miocene trachy-andesites (MELONI A., 1985). Reaching a development of about 40 meters, the cave has a pure tectonic origin, and is inhabited by a colony of bats.

More to the South, in the region of Cuglieri, Scano Montiferro, Magomadas, Mogoro, Sennariolo, Bosa etc. are known the most interesting lava caves of Sardinia: these caves are "Suterru de Murada" (163 SA/OR), "Monte Santu" (206 SA/OR), "Cappas" (2 caves: 181 and 1933 SA/OR), "s'Istampu de Ziu Nanni" (224 SA/NU), "Ispelunca de Nonna" (226 SA/OR), "Coro Malzu" (2 caves: 255-256 SA/OR), "Terra di San Giovanni" (1939 SA/NU), "Motzo" (2 caves 1940-1941 SA/NU) and "Baraggiones" (1942 SA/OR) (FURREDDU P.A. & MAXIA C., 1964; MELONI A., 1986; SPELEO CLUB DI CAGLIARI, 1986).

Most of these caves are formed in the basalts and the phonolites of the Montiferro volcanic complex. "Suterru de Murada" (163 SA/OR) is a lava tunnel of 40 meters length revealing clear lava flow features, ropy lava and two entrances. More interesting is the "Cappas 1" cave (181 SA/OR), with its length of about 120 meters the longest primary lava tunnel cave of the Island. It has an entrance due to collapsing of the roof, and develops in two directions (FURREDDU P.A. & MAXIA C., 1964). The vertical cave "s'Istampu de Ziu Nanni" (224 SA/NU) is formed on some fractures near the vertical wall of a basaltic flow (MELONI A., 1985) while "Ispelunca de Nonna" (226 SA/OR) is the relic of a gas bubble, which roof has collapsed (SPELEO CLUB DI CAGLIARI, 1986). The caves "Baraggiones" (1942 SA/OR) and "Voragine di Coro Malzu" (256 SA/OR) instead are formed on great vertical faults and develop in horizontal for 50 meters. The first cave is interesting for the presence of a bat colony. Of secondary origin is the "Monte Santu cave" (206 SA/OR), formed by water erosion in ignimbrites and almost 100 meters in development (FURREDDU P.A. & MAXIA C., 1964).

Of marine erosion origin are the numerous caves along the Capo Marargiu coast (Bosa). The most interesting of these is the Cave of the Pelicans (1270 SA/NU), composed of two distinct branches both formed on faults. The total development reaches 160 meters, partly submerged, and in the dry branch are present several calcareous concretions and a bat colony (PIRAS V. & PANI D., 1995). Close to the Corona Niedda island, in the context of a submerged caldera, is known another submarine lava cave, probably the relic of an ancient lava tunnel (PIRAS V., 1995, personal communication).

Near the villages of Nurri and Orroli, above Palaeozoic sediments, Jurassic and Miocene limestones, outcrops a vast basaltic plain with several lava caves: "Su Fossu Corroga" (761 SA/NU) (BARTOLO G. et al., 1995), "Baraci" (3 caves: 1947-1949 SA/NU), "Rutta de Su Cannoni" (2002 SA/NU), and "Gurti Acqua" (2 caves: 2009 SA/NU and 2027 SA/NU) (SPELEO CLUB DI CAGLIARI, 1986). The first is characterised by a little pitch and a 20 meter wide chamber, developed on the contact between the basal lava conglomerate and the lava flow. The genesis of this cave is due to water erosion of the basal clayey volcanic breccia and the subsequent collapse of the roof. From a cave dwelling fauna point of view the presence of an important bat colony has enhanced the development of a rich animal population (Pseudoscorpiones, Diplura, Speleomantes, etc.). The "Baraci" and "Cannoni" caves are small shelters of secondary origin (wind and water erosion) while the "Gurti Acqua" caves are the relic of a single lava tunnel with clear lava flow features. In both caves, distant one from another about 10 meters, have been noticed ropy lava and gas bubble prints.

In the basaltic outcrops near Orroli have been reported several caves: "S'Inginnu" (4 caves: 561-563 and 565 SA/NU) (GRUPPO GROTTA CAI CAGLIARI, 1982; BARTOLO G. & FADDA A.F., 1998). Even though all of these are relatively small in size, they are interesting for the presence of ropy lava, columnar jointing on the outside wall above the caves, the basal lava conglomerate and several lava flow features. Furthermore in many of these shelters have been found remains of pottery of 4000 years ago.



Of great archaeological interest is the cave called "Caombus" (1654 SA/OR) near Morgongiori, formed on an open fracture in the basalts of Monte Arci (LECIS A. & MUZZETTO G., 1989). In this tectonic cave, with a development of almost 200 meters, has been discovered a so-called "sacrepit", for the devotion of water, together with the ancient stairs, dated about 4000 years ago. Not far away from "Caombus" is reported another tectonic lava cave, "Is Benas" (291 SA/OR), of no particular interest (FURREDDU P.A., MAXIA C., 1964).

In the Sulcis area, close to the city of Carbonia, many caves are known in the Monte Crobu rhyolitic mount. All of these are mainly formed by wind erosion and hydrolysis of the silicates along the fractures, and some reach developments of several tenths of meters. These caves have been used in ancient times as burial places or as shelters.

One of the most interesting volcanic areas in Sardinia for what concerns caving is the San Pietro Isle and the nearby Sant'Antioco Isle, composed of Miocene volcanic rocks (commendites and liparites) of the calc-alkaline cycle. CAPPÀ G. (1974) describes as much as 70 caves on San Pietro Island, mostly of marine and structural origin, some of which have a development of almost 70 meters. Among the marine caves can be remembered these called "del Bue Marino" (14 SA/CA), "Marine" (54 SA/CA), "delle Oche" (67 SA/CA), "Enea" (1844 SA/CA), "Sa Xitta" (1845 SA/CA), "Punta delle Colonne" (3 caves: 1846-1847-1848 SA/CA), "delle Colonne" (2 caves: 1849-1850 SA/CA), "Geniò" (2 caves: 2094-2095 SA/CA)). Formed by wind erosion in the commendites are the caves "Commende" (29 SA/CA) and of "Bricco Patella" (not classified) (CAPPÀ G., 1974; BARTOLO G. & FADDA A.F., 1998).

On the island of Sant'Antioco only two volcanic caves, both of wind erosion origin and with less than 10 meters of development, are known: "Luttoni Biancu" (2079 SA/CA) and "Gruttacqua" (2080 SA/CA) (SPELEO CLUB DI CAGLIARI, 1986).

In East Sardinia, nearby the village of Barisardo, has been explored one of the longest secondary lava caves of the Island, "Sa Ucca 'e Su Vulcanu" (1283 SA/NU), with its 132 meters of length. This cave, developed close to the border of the Pliocene-Pleistocene basaltic high plain locally known as "Teccu", is formed on several orthogonal faults that opened in recent times (BARTOLO G. & ZANDA G., 1995).

To end this long list of caves in volcanic rocks, it is interesting to mention some caves known by local people to be the "mouth of volcanoes": the great shafts of "Golgo" (63 SA/NU) and "Genna s'Armentu" (421 SA/NU) at Baunei, and the "Ucca de Mammuscione" at Cossoine (180 SA/SS). The speleological exploration of these caves, that have their entrances in basaltic rocks, has immediately shown their karstic origin, being formed by inverse erosion of the underlying limestones (respectively Jurassic and Miocene in age) and the subsequent collapse of the basaltic cover (FURREDDU P.A., MAXIA C., 1964; DE WAELE J. et al., 1995; MUCEDDA M., 1985).

## References

- ASSORGIA A., MACCIONI L., MACCIOTTA G., 1983, *Carta geopetrografica del vulcanismo pliocenico della Sardegna centro-meridionale*; S.E.L.C.A. editor, Firenze; 1:50.000.
- ASSORGIA A., FADDA A., GIMENO A., TORRENTE V., OTTELLI L., SECCHI F. A., 1992, *Le successioni ignimbritiche terziarie del Sulcis (Sardegna Sud-Occidentale)*; Mem. Soc. Geol. It., Roma; # 45, pp. 951-963.
- ASSORGIA A., BARCA S., SPANO C., 1997, *A synthesis on the Cenozoic stratigraphic, tectonic and volcanic evolution in Sardinia (Italy)*; Boll. Soc. Geol. It., Roma; # 116, pp. 416-420.
- BARCA S. & COSTAMAGNA G. L., 1997, *Compressive "Alpine" tectonics in western Sardinia: Geodynamic consequences*; C. R. Acad. Sci. Paris; # 325, pp. 791-797.
- BARTOLO G., FADDA A.F., 1998, *Sardegna il mondo sotterraneo*; Coedisar editor, Elmas; 300 p.





- BARTOLO G., RATTU M., ZANDA G., 1994, *Ulteriori grotte per il Catasto*; Speleologia, Milano; # 30, pp. 118-119.
- BARTOLO G., ZANDA G., 1995, *Sa Ucca de Su Vulcanu*; Speleotransfer, Milano; # 1, p.3.
- BARTOLO G., ZANDA M., RATTU M., 1995, *Su Fossu 'e Corroga*; Speleologia, Milano; # 33, p.91.
- CAPPA G., 1974, *Nota informativa sulle cavità nell'Isola di S.Pietro (Sardegna)*; Rassegna Speleologica Italiana, Milano; # 11(1), pp. 73-76.
- BECCALUVA L., DERIU M., MACCIOTTA G. SAVELLI C., VENTURELLI G., 1977, *Geochronology and magmatic character of the Pliocene-Pleistocene volcanism in Sardinia (Italy)*; Bull. Volcanol.; # 40, pp. 1-16.
- BECCALUVA L., CIVETTA L., MACCIOTTA G., RICCI C. A., 1985, *Geochronology in Sardinia: results and problems*; Rend. Soc. It. Min. Petr.; # 40, pp. 57-72.
- BROTZU P., FERRINI V., MORBIDELLI L., TRAVERSA G., 1975, *Il distretto vulcanico di Capo Ferrato (Sardegna sud-occidentale)*; Rend. Sem. Fac. Sc. Univ., Cagliari; # 45(3-4), pp. 119-144.
- CONDARELLI D., 1972, *Le grotte vulcaniche, loro genesi e morfologia*; Rassegna Speleologica Italiana, Como; # 11(2), pp. 29-31.
- COULON C., 1977, *Le volcanisme calco-alcalin cenozoique de Sardaigne (Italie). Petrographie; Geochimie et Génèse des laves andésitiques et des ignimbrites-signification geodynamique*; Thèse Doct. 3 Cycle Univ. Aix-Marseille III; 288 pp.
- DE WAELE J., GRAFITTI G., LOCCI C., PISANO M., SPIGA R., 1995, *Attuali conoscenze speleologiche nel Supramonte di Baunei*; Monografia di Anthéo, Cagliari; # 4, 88 p.
- FURREDDU P.A., MAXIA C., 1964, *Grotte della Sardegna*; Fossataro editor, Cagliari; 310p.
- GRUPPO GROTTA CAI CAGLIARI, 1982, *Su Cannoni de Pardu S'inginnu - Grotta Genniau*; Speleologia Sarda, Cagliari; # 42, pp. 11-15.
- LECCA L., LORIS R., LUXORO S., MELIS E., SECCHI F., BROTZU P., 1997, *Oligo-Miocene volcanic sequences and rifting stages in Sardinia: a review*; Per. Min.; # 66(7), pp. 7-61.
- LECIS A., MUZZETTO G., 1989, *Sa Grutta de Is Caombus*; Speleologia Sarda, Cagliari; # 69, pp.19-22.
- MACCIONI L., MARCHI M., SALVADORI A., 1990, *Eocene alkaline lamprophyre in south-western Sardinia (Italy)(new occurrence)*. Rend. Sem. Fac. Sc. Univ. Cagliari; # 60, pp. 217-231.
- MELE E., 1997, *S'Istampu 'e Pippetto*; Speleomantes, Sassari; # 0, pp. 45-46.
- MELONI A., 1985, *Sa Pentuma de Sa Pala Umbrosa*; Speleologia Sarda, Cagliari; # 53, pp. 6-7.
- MELONI A., 1986, *S'Istampu 'e ziu Nanni*; Speleologia Sarda, Cagliari; # 59, pp. 25-26.
- MUCEDDA M., 1985, *La grotta Sa Ucca 'e Mammuscane di Cossoine*; Bollettino del Gruppo Speleologico Sassarese, Sassari; # 9, pp. 38-44.
- PECORINI G., POMESANO CHERCHI A., 1969, *Ricerche geologiche e biostratigrafiche sul Campidano meridionale (Sardegna)*. Mem. Soc. Geol. It.; # 8, pp. 421-451.
- PIRAS V., PANI D., 1995, *Le grotte marine di Capo Marargiu*; Sardegna Speleologica; # 8, pp. 15-22.
- RITTMANN A., 1975, *La formazione delle grotte vulcaniche*; Atti del Seminario sulle Grotte Laviche, Catania, 1977; pp. 87-100.
- SPELEO CLUB DI CAGLIARI, 1986, *20 anni nelle grotte della Sardegna*; Guido Bartolo editor, Cagliari; 239 p.