THE SYSTEM GROTTA DEL FUMO - MACCHIA GIALLA – GROTTA DELL'ARCO

Gaetano Giudice and Angela Privitera

Centro Speleologico Etneo, via Cagliari 15 - 95127 Catania, Italy

Summary

This paper describes the explorations of the galleries located in the upper part of the 1991-93 eruptive fissure. During 1994 three caves were discovered in the main tunnel of the lava flow, named Grotta del Fumo (2375 m asl), Macchia Gialla (2275 m asl) and Grotta dell'Arco (2220 m asl), but only in the spring of 1995 it was possible to reach the lava tube from the shaft of Macchia Gialla, because of the high values of Rh and temperature recorded before. Later it was possible to partially explore the Grotta del Fumo, where salt depositions were found on the floor and a continuous flow of steam was observed on the roof. This steam had a temperature of about 57°C, which restrained further explorations. Finally, the Grotta dell'Arco was explored, but it was impossible to descend a shaft in the bottom part because temperature and Rh inside were still too high. Already in 1995 the three caves were connected after digging for a few days, but only in the spring of 1997 the bottom of the system was reached. We descended the shaft and discovered the final room, totally clogged and with ambient temperature above 30°C and Rh of 100%. More recently, in the summer of 1999, the upper limit of the system was surpassed in the Grotta del Fumo, probably reaching the zone connecting the lava tube with the 1991-93 eruptive fracture. On the same occasion we also descended for few meters inside the uppermost part of the same fracture. Furthermore, during this last recognition we observed both the persistence of the steam flow and the increase in salt deposition. On the basis of these observations, and considering the long time span since the end of the eruption (more than 6 years), a preliminary hypothesis on the dynamics of the phenomena is attempted.

Approach

Following the track that starts from the Strada Provinciale 92 about 1 km east of the Rifugio Sapienza, on the direction towards Zafferana Etnea, the Schiena dell'Asino, on the SW edge of the valle del Bove, is reached in about 1 hour walk. Here is a tombstone, named Lapide Malerba. From this point onward the track leads into the Valle del Bove, maintaining the same altitude. After crossing the Canalone della Montagnola the track goes up and down to finally reach the upper part of the 1991-93 lava flow, which is clearly visible on the right because it is darker than the other flows around.
Once approached the 1991-93 lava flow, climbing up to the altitude of 2375 m, the Vent of the Grotta del Fumo is visible.
The total time of the approach is about 3 hours.

History of the explorations and description of the cave

From the fissure that opened in December 1991 at 2400 m of altitude in the western side of the Valle del Bove a huge quantity of lava flowed along the steep slope below forming a deep lava channel. In a short time the external part was consolidated, thus forming a so called lava tube.
Many fissures remained open in the tube roof, and from these both vapours and fragments of lava were emitted.
At the end of the eruption, in March 1993, three windows were still present from which sprung a lot of vapour.

In January 1994 tree members of the Centro Speleologico Etneo explored the lava flow, searching for possible access points to the lava tube. Three caves were eventually discovered in the main tunnel of the lava flow, the Grotta del Fumo (2375 m asl), the Macchia Gialla (2275 m asl) and the Grotta dell'Arco (2220 m asl). It was only in the spring of 1995 that the lava tube from the shaft of Macchia Gialla could be approached, because of the high values of Rh and temperature recorded until then. Later it was possible to partially explore the Grotta del Fumo, in which salt depositions were found on the floor and a continuous flow of steam was observed on the roof. Steam had a temperature of about 57°C, which restrained further explorations. Finally, the Grotta dell'Arco was explored, but it was impossible to descend a shaft on the bottom part of the cave because temperature and Rh inside of it were still too high. Already in 1995 it was possible to connect the three caves after digging for a few days, but only in the spring of 1997 was the bottom of the system reached, descending the shaft and discovering the final room. It was totally clogged and had ambient temperature above 30°C and Rh of 100%. More recently, in the summer of 1999, the upper limit of the system was surpassed in the Grotta del Fumo, probably reaching the zone connecting the lava tube with the 1991-93 eruptive fracture. On the same occasion the uppermost part of the same fracture could be visited, although only for a few moments because of the prohibitive ambient conditions (temperature above 42°C and Rh of 100%). Furthermore, during this last recognition both the persistence of the steam flow and an increased salt deposition were observed.
The total length of the system is about 450 m, and its depth is about 200 m.
The average slope of the tube is remarkable, being about 40 degrees. From a morphological point of view this cave is a typical lava tube with high slope, similar to the upper part of the tube of the Tre Livelli (Corsaro et al., 1995), with cross section often shaped like that of a pagoda, that is large at the bottom and narrow at the top.
The peculiarity of this cave lies on the phenomena observed in its upper part, just upslope of the Grotta del Fumo entrance. There (see detail in Figure 2) the tube changes its slope abruptly, which then remains below 5 degrees. On moving further up along the tube, passed the entrance, a large tunnel about 30 m long is reached. There lava balconies on both walls testify flowing morphologies (reogenetic), and indicate a quite constant level of lava that partially invaded the cave for a sufficient period of time.
In 1995 the ceiling of this tube was found covered with hot vapour that flowed over it like a river. The stream of vapour was about 2 meters above the tube floor and was directed towards the entrance of the tunnel, forming a sort of smoky chimney in the entrance shaft. Underneath the bottom of the vapour stream temperature was 25°C and Rh was 73%.
The upper part of the tube is narrower, being a cylindrical cuniculus with radius of less than one meter. In the spring of 1995 temperature inside this cuniculus was 58 °C in the vapour stream, whereas it was about 40°C near the floor. Due to such unfavourable ambient conditions, only 10 meters of cuniculus were explored in that occasion. The gas stream seemed to be composed principally of water vapour and CO_2 (measured CO_2 concentration of about 1% vol.), with traces of CO.

- Cadastral number: SICT 1236	- Commune: Zafferana Etnea
- System of Grotta del Fumo, Macchia Gialla, dell'Arco	- Year of eruption: 1991-93
- Location: Sasso del Goliardo	- Development: 450 m
- Map: I.G.M.: Serie 25, Foglio 625, Sezione IV, Sant'Alfio, Ed. 1993	- Total deepness: 200 m - Altitude: 2375 m, 2275 m, 2220 m
- Fumo Longitude: 15° 00' 52" E	- Latitude: 37° 43' 40" N
- Macchia Gialla Longitude: 15° 00' 57" E	- Latitude: 37° 43' 39" N
- Arco Longitude: 15° 01' 01" E	- Latitude: 37° 43' 38" N
- Survay: (1999) G.Garozzo, G.Giudice, A.Marino, A.Privitera, G.Tomasello	- Park zone: A

Table 1: Cadastral data

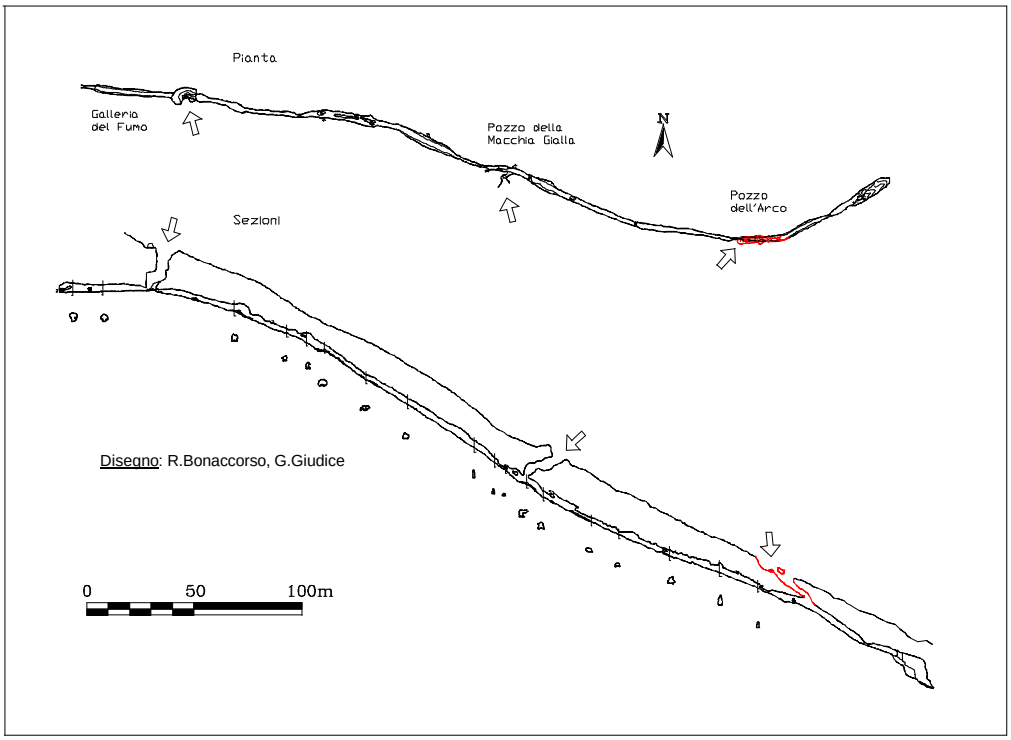

Fig. 1

Beneath the vapour level abundant deposition of salt speleothems was found, in all similar to that observed in 1994 in the Grotta Cutrona (Giudice & Leotta, 1994; Forti et al., 1994).
Only in the summer of 1999 was the cuniculus surpassed, leading to a room invaded with vapour at temperature above 42°C and Rh of 100%. From this room (about 3 meters of diameter) a little cave continued with a high slope, and a massive flow of hot vapour came out of it. The exploration was stopped there, because more adequate equipment was needed and it was impossible to resist in that atmosphere for more than a few minutes.
In that occasion it was observed that compared to 1995 temperature in the cuniculus had decreased to about 40°C in the vapour, and to 23°C underneath, whereas near the entrance of the large cave measured temperature was 13°C. Furthermore, minerals deposition was still active in the cuniculus, and new blue coloured stalagmites were observed.
The morphology of the upper part of the cave and the altitude reached, same as that of the 1991-93 vent (at least in the central and terminal phase of that eruption), gave the impression that the connection between the 1991-93 eruptive fissure and the emission point of the lava flow had been reached. A similar morphology is also observable in the upper part of the Grotta dei Tre Livelli (Corsaro et al., 1995).
The 1999 exploration could not be completed because of large collapses at the base of the entrance shaft, and a short period of digging was needed. Unfortunately it is probable that this problem will occur more and more frequently in the future, because of large rock and sand falls from the slope above the entrance, especially during the spring when snow melts. Further, it was impossible to reach the lower gallery from this entrance, because the passage was buried by rock collapse. Now to visit this part of the cave it is necessary to enter from the Macchia Gialla shaft. The cave above this shaft has some peculiarities: it is narrow, extremely deep, very high (above 6 meters in many places) and with its walls striated by lava flow erosion, that further deepened the floor constituted of small piroclastic materials.
Under the Macchia Gialla shaft a short narrow passage (excavated in 1995) leads to the Galleria dell'Arco, below the Grotta dell'Arco entrance, which is the lowest of the system. From here the tunnel becomes larger but again very steep. In 1995 the exploration was stopped over a shaft about 10 metres deep, from which a stream of hot vapour (above 50°C) flowed.

Only in the spring of 1997 was it possible to reach the actual bottom of the system in a room closed “a cul de sac”, surpassing the shaft (a rope is needed). During this exploration vapour’s temperature was still over 30°C.

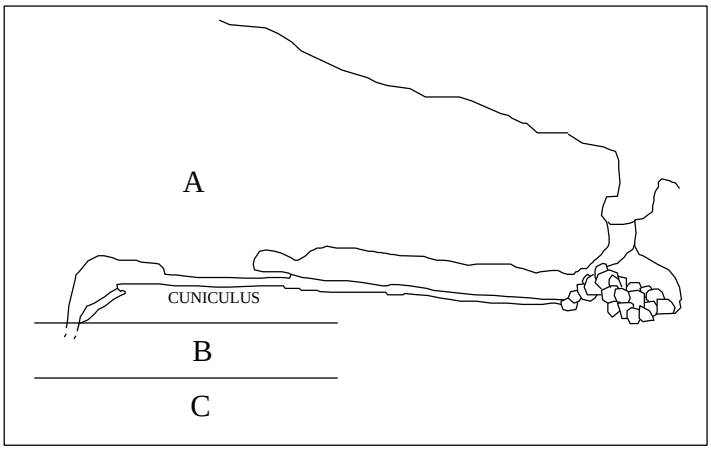

Fig. 2

Observations And first hypothesis on the dynamic evolution of speleothems

The comparison between the physico-chemical conditions found in 1995 and those in 1999 inside the Grotta del Fumo suggests us a possible way to explain the observed phenomena. We take into account especially the observations related to the cuniculus indicated in Figure 2. In this site steam was ever present, with the stream directed towards the entrance. Inside the vapour, near the cave ceiling, neither in 1995 nor in 1999 considerable incrustation was found, whereas near the floor, out of the vapour, a lot of speleothems were observed in both explorations.
Between 1995 and 1999 temperature in several points of the cave decreased by 15-20°C. In 1999 the temperature near the entrance of the cave was about 13°C, and this causes vanishing of almost all of the incrustations in this site. Conversely, only minimal changes in speleothems occurred in the cuniculus. Unfortunately, no observations are available for the inner part of the cave before 1999.
We assume that initially, that is immediately after the end of the 1991-93 eruption, the whole mass of new lava was very rich in salts, especially sodium chloride (P.Forti et al., 1994), and water could not infiltrate because rock temperature was above 100°C.
Cooling of the surface of the new lava after a certain period allowed water to penetrate down to a certain depth, for example the limit between A and B zones of Figure 2, and to dissolve salts. If along its descent a cave with opportune conditions of temperature and humidity is met, the solution may deposit dissolved salts originating incrustations. This situation is perfectly represented in what observed in zone A of Figure 2. It is easy to consider that rain water infiltration, after the rainy season, causes the decrease in salt concentration in the new lava, starting from the most superficial zone. In this zone the contribution to development of speleothems (in a cave incidentally encountered) is generally irrelevant. On the contrary, water will again dissolve salt of speleothems, so the concretions will vanish rapidly. This phenomenon was largely observed both in the Grotta Cutrona (Giudice & Leotta, 1994) and in the Grotta del Salto della Giumenta.
After the first phase in which the superficial zone is depleted in salt content, water can continue its downward infiltration encountering and dissolving salt in deeper zones of the lava flow, such as zone B of Figure 2, that are still rich in salt. Other deeper zones remain with initial salt concentration, as they are not yet cooled sufficiently. If a lava tube is situated in such a zone (B), salty water may produce concretions, but it may also vaporize and this vapour may transport a certain amount of salt (in the form of aerosol). This salt may be transported again towards the exit:

in fact the density of air inside the cave, warmed by the still hot deep rocks, will be lower than that of external air so as to produce an upward motion of air in the tube (which was effectively observed). Motion of this warm air will suck down fresh external air through cracks and fissures, ever abundant in new lava. On moving upward, aerosol may encounter relatively cold rocks and deposit part of the transported salt, hence contributing to the increase of incrustations. This particular kind of deposition was first envisaged by P.Forti (P.Forti et al., 1994), but this author suggested that aerosol was of primary origin (i.e., from fumarole vapours), while we believe that it is also due to water infiltration in new lava, dissolution of the salt present and then vaporisation in hypogean environment.

The strong air flow present in narrow passages, as in the case of the cuniculus considered in this study, facilitates and accelerates aerosol deposition. Water condensed on the ceiling of the cuniculus cannot produce deposition here because humidity is too high. However, dripping of water still meets appropriate conditions to create concretions: for this reason only the floor has been found covered with salt depositions.

It is possible that still in 1999 zone A conserved a sufficient concentration of salt, so a little contribution to deposition may come from a normal mechanism, similar to that described for the first phase (zone A, 1995) of the phenomena.

We believe that both mechanisms, gravity and aerosol deposition, contribute to generation of speleothems. At the beginning the first one has a preponderant role because the conditions are more favourable, while after rainy seasons the importance of the second mechanism increases and probably at a certain point becomes the only factor in salt deposition. Inevitably, at the end the speleothems will vanish totally.

In conclusion, we describe a simple experimental device that could give us some information on real contribution of aerosol mechanism. It consists of a little pipe placed on the floor with its longest axis parallel to the axis of the cuniculus and containing a small obstacle that simulates a stalactite. Deposition of salt inside the pipe in this case is only due to aerosol transport, whereas externally both are possible causes of deposition.

Unfortunately, it is quite certain that in the future it will become increasingly difficult to enter the lava tube, because of frequent rock collapses on the shaft entrance and accumulation of sand transported by water produced by melting of the snow. A long and hard work of excavation and consolidation would be necessary to assure the access to the lava tube without problems, but the great distance of the tube from the road track and the difficulties of approach could severely thwart this project.

Fig. 3 - Grotta del Fumo: Entrance shaft

Fig. 4 - Grotta del Fumo: Speleothems at the entrance of the cuniculus

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Fig. 5 - 1991-93 vent and lava flow: 1-Grotta del Fumo 2-Macchia Gialla 3-Grotta dell'Arco
Fig. 6 - Grotta del Fumo: Speleothems and vapour in the cuniculus in 1995
Fig. 7 - Grotta del Fumo: Gallery in 1999
Fig. 8 - Grotta del Fumo: Speleothems and vapour in the cuniculus in 1999
Fig. 9 - Grotta del Fumo: Vapour in the gallery in 1995
Fig. 10 - La Macchia Gialla: Entrance shaft in 1999

References

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