THE ICE CAVE AND ITS GLACIOLOGICAL PHENOMENON

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Abstract

The Ice Cave (La Grotta del Gelo) is well known among Mt Etna's volcanic caves for its main feature: the largest part of the hollow is occupied by a massive stack of ice, the formation of which is governed by the geographic position, the altitude (2,030 m) and the cave's morphology.

Geographic profile

The Ice Cave (Grotta del Gelo) is one of Mt. Etna's most well known volcanic caves due to the year round presence of a stack of ice which occupies 30% of the cave's volume. The cave is located on the north side of the volcanic structure at about 2,030 m in the area of "Sciara del Follone" (Randazzo's municipality) (fig. 1). It can be reached from the Linguaglossa side by a dirt road which starts at the Pitarrone Forestry station and continues, beyond the "Raspberry Cave" (La Grotta dei Lamponi), on a footpath. From the Randazzo side the footpath begins at the Pirao Forestry station. From the Maletto side there are the "Monte La Nave" and "Dagala dell'Orso" footpaths. From Piano Provenzana there are the "Monte Nero and Monte Timpa Rossa" footpaths. From 2,400 m there is a footpath which begins at Monte Pizzillo.
The large entrance faces uphill and in front of it there is a big gully which is sometimes full of snow into the summer months.

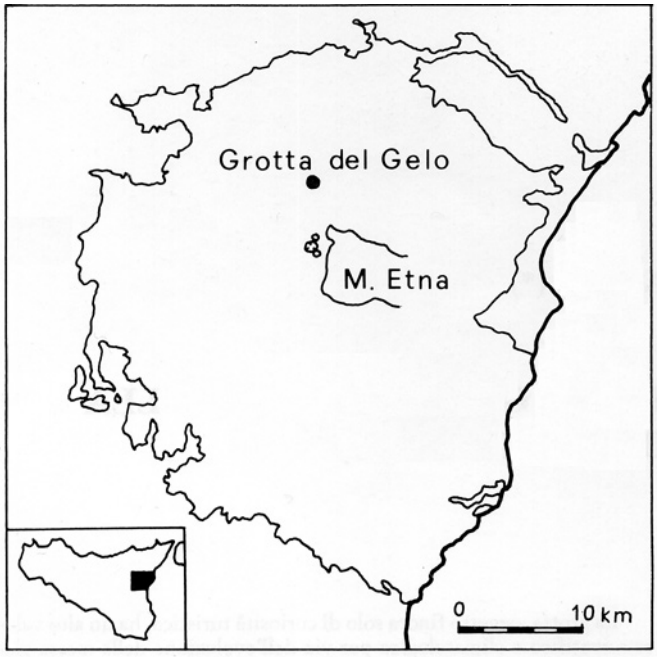

Fig. 1 - Location of the Ice Cave

Tourist profile

For more than 70 years, and in especially the last 20, The Ice Cave has been a favorite destination of hikers on Etna's tourist excursions. Even though it is not that easily reached (it is, on the average, a 3 hour hike with a 400 m difference in level) more and more people are visiting it. Only just recently the visitors have been accompanied by the Etna Park guides who lead and regulate the visitations. In the past, especially in the summer months, more than 30 people at a time, with consequential impact on the stack of ice, in spite of its remarkable size, continuously passed through and were disrespectful leaving behind, in the entrance, graffiti with names and dates. Presently the limit is set at 20 per visit, hoping to slow down man's impact on this peculiar cave.

Previous observations

Even though this cave has been mentioned since the late 1800s, bibliographical references are not that many. Sartorius (1880) called it "Bocche del Gelo". At last, after nearly a century, other reports have been published: Brunelli & Scammacca (1975) include it in their list of Etna's caves. Biffo & Cucuzza Silvestri (1977) call attention to the cave's possible deterioration due to the high number of visitors and hope that the cave will be visited only on scientific terms. Bella et al. (1982) give the land office's data, the access itinerary and morphology. He made note, for the first time, of the decreasing volume in the ice which was perhaps tied to the eruption and events in 1981 which occurred just a few meters west of the cave's entrance It has been mentioned in other magazines such as "Lo Scarpone (C.A.I.'s magazine), "Etna Territorio", (an ecological and environmental magazine printed in Catania) and in the daily newspaper "La Sicilia" where Licitra (1991) made note of the cave's deterioration caused by an excessive number of visitors. Marino (1992) describes the glacial phenomenon and urges scientific institutions to monitor and protect the cave. Starting in 1997, the cave's atmospheric humidity and temperature were, and still are, being measured. In 1998 Marino (1998) reports on the data collected in the first year.

Geological aspects

The Ice Cave's hollow was formed by the lava flows called the "Lave dei *Dammusi*" [1] which lasted about ten years, from 1614 to 1624. This was Etna's longest eruption ever in historical times. The lava flowed on the north side from 2,500 m to 1,200 m, (Monte Collabasso's altitude), branching off to 975 m; covering an area of 21 square km (Romano & Sturiale, 1982). The series of flows which followed overlapped during the different eruptive stages and formed many tubes which helped the lava reach lower altitudes. Often, large main heaps, upon surface solidification, formed thick lava crusts under which lava continued to flow as in a tube. At the end of the eruption the feed ran out, reducing the lava flow, and the tubes were left almost completely empty. That is how the numerous existent hollows were formed in the *"Dammusi";* roofs centimeters thin on the surface levels and meters thick at deeper levels.

The formation of the stack of ice

Fig. 2 - Entry of the Ice Cave.

The Ice Cave has only one aperture which is the large funnel shaped entrance facing uphill (fig. 2). As mentioned above, the gully in front of the entrance is full of snow for many months. A fair amount of snowfall enters the first part of the cave due to its conformation. The cave is about 120 m long and it is mainly flat with a slight downhill slope. Lava's non-conductivity doesn't favor external temperature exchange, even if the lava walls are quite thin. This type of morphology allows atmospheric circulation to keep the colder air masses inside and release the warmer ones (fig. 3). The cave's temperature is lower than the outside's. Since the cave is on the shady side of Mt. Etna and at a high altitude its

[1] The word "Dammusu" in Sicilian dialect means the floor or covering. This lava flow has this name because the surface is formed by a thin crust, which is the roof or covering of smaller caves underneath. Walking on this crust sounds like someone walking on an attic floor.

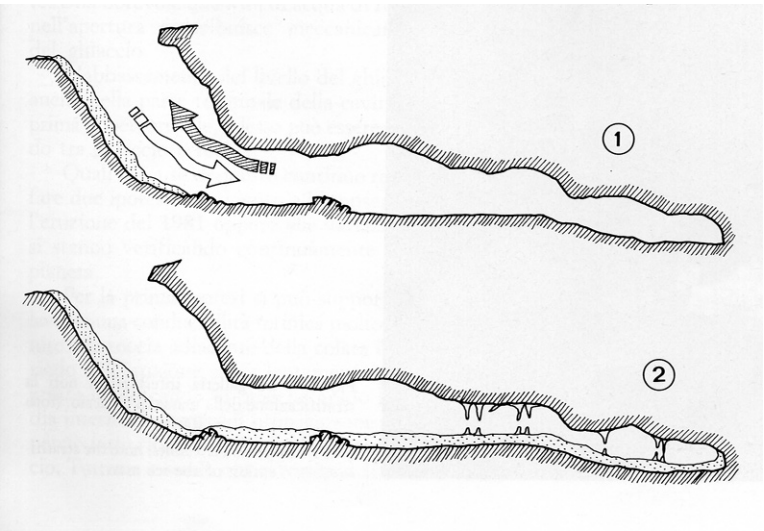

Fig. 3 - Probable evolution of the glacial mass inside the Ice Cave: the cold air tends to enter while the warm air goes out from the tunnel. So we have a lower temperature in the tunnel and the snow remains the same, some of it melting and becoming ice.

average annual temperature is never above 5° C. The snow doesn't disappear totally as in other near-by caves with numerous apertures and different morphologies. The snow stays inside of them only in the winter months. In The Ice Cave during the warmer months, at the very beginning, in a flat area of the entrance, you can watch the snow melt, forming a 10 m in diameter lake.
It is likely that the formation of the stack of ice began in the second half of the 17th century; ten years after the end of the eruption. It has been as ascertained (Bullard,1978) that a lava flow of such a vast size as this (50 m average thickness) would take more than ten years to cool down completely. Year after year snow and ice layered inside the hollow, reaching a thickness of over 2 m. The stack of ice covers the total length of the cave. It ends in a final shaft which is accessible, only on certain occasions, by sliding between the ice and the ceiling of the cave. The upper part (fig. 4) has always been empty except in the colder years when it is partially filled by abundant stalactites and ice columns which regularly disappear in the warm season. On the right side, in the lower part, there is a smaller hollow between the lava and the stack of ice (fig. 5).

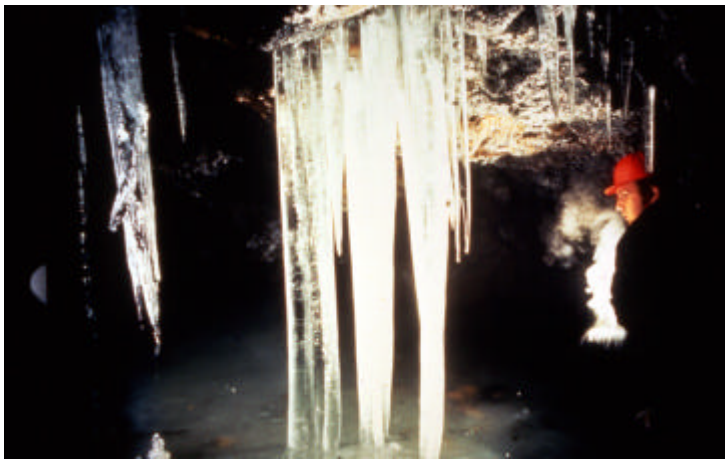

Fig. 4 - Ice stalactites in the main cave.

Fig. 5 - The hole in the ice between the main cave and the lower one in July 1993.

In the final part of the cave the roof slopes down towards to the floor and the ice almost reaches the ceiling; leaving only a few centimeters of space between them. On the left wall of the smaller hollow the continuous layering can be easily observed in the ice. There are different types of waste materials (lava scoriae, plant residuals) frozen in the ice layers (fig. 6).

Fig. 6 - The numerous vegetable and rocky debris included in the ice.

The evolution of the stack of ice

There is no precise information on the evolution of the stack of ice as only in the last few centuries there have been sporadic observations of the phenomenon and for the most part without details. However, in the last decades, up to 1981, the periodical visitors of the cave had noticed a progressive increase in the ice's thickness. It increased by several centimeters a year and due to insufficient space, the final shaft was not accessible (verbal communications and personal observations). In that year, at a few meters distance from the cave, an eruptive fracture opened on Etna's north flank. As the river of lava flowed from the lower part, destroying numerous cultivated fields and even threatening the inhabitants of Randazzo, in the upper part of the fracture, very close to The Ice Cave, a huge cavity came to light and massive quantities of lava scoriae, ashes and lapilli tumbled out; covering the fields and even entering the cave itself. The sudden rise in temperature, even though short, caused the stack of ice in the entrance to retreat. In the entire cave a small decrease in the ice's thickness was noticed; new fractures were formed inside the hollow (Bella et al., 1982). Luckily the eruption lasted only a few days and in a short while the situation appeared normal. In the following winters the ice's thickness increased slightly. However since the late 80s, probably due to an increase in the average internal temperature (fig. 7), a slow but constant decrease in the thickness has been noted. A hole has formed in the thinner part; exactly between the upper hollow and the smaller one underneath.

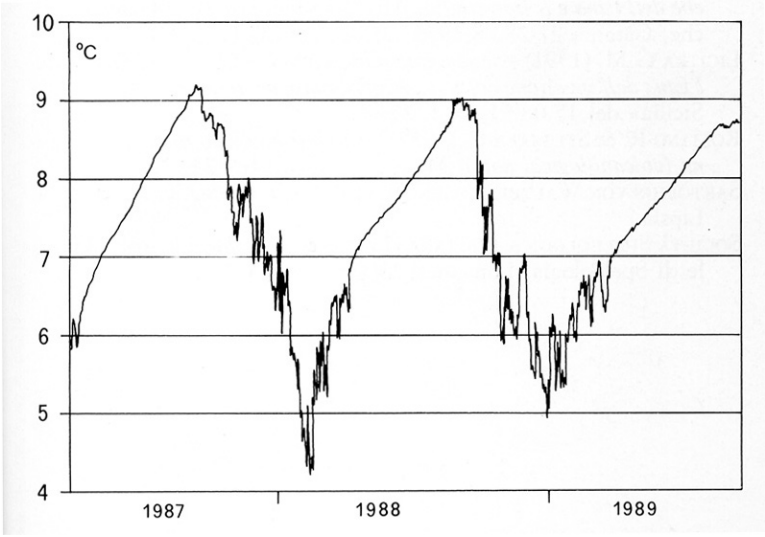

Fig. 7 - Temperature recorded from April 1987 to October 1989 in the clinometer station installed inside the Grotta del Cernaro by I.P.G.P. (France). Note that the minimum temperature since 1989 is about one degree higher than, that of the previous year.

The present situation

Between 1988 and 1996 the hole deepened by over five meters and a third small hollow was found. Large amounts of melt water, flowing into the entrance, have mechanically contributed to the ice's erosion.
The decrease in the ice's thickness was noticed in the final part of the cave too. The space between the floor and the ceiling increased, making it possible to slide between lava and ice so as to reach the final shaft.
In the last two years the ice has decreased in the upper part and increased in the final part and in the trench of the former smaller hollow because of a sort of transfer of the stack of ice due to a more favorable temperature in the lower part. The thickness has once again increased making it impossible to reach the final shaft.
What are the causes of all these changes? Two hypotheses can be formulated: the first is that these are late consequences of the 1981 eruption and the second is that the whole planet is experiencing climatic differences.
As regards the first hypothesis, we can suppose that since lava has such a low conductivity level; the heat gathered by the lava rocks near the flow, in the brief time of the eruption, slowly spread to the cave itself: changing the inside temperature by a few degrees. The beginning of the melting of the ice occurred later because of the slow diffusion of the heat. However it has been 18 years since the eruption and the lava rock should have its normal temperature by now; therefore the stack of ice should not still be melting. The second hypothesis, is supported by the slight decrease in rainfall in the last decade. Snowfall, on the other hand , has been heavier.
Up until 1997 the only control of the evolution of the phenomenon was through sporadic observations of the stack of ice. There weren't instruments available to conduct appropriate tests. The only data, on the differences in temperature in Etna's caves, was courtesy of The International Institute of CNR Volcanology. The data was provided by the *"Institute de Physique du Globe"* of Paris. In its study, on the slow deformation of Etna, temperatures of cave environments, over several years, were also measured. It gave temperatures of the "Grotta del Cernaro", which is near The Ice Cave at a lower altitude (1400 m). It can be seen from the temperature graphs that in 1989 the minimum inside temperature is one degree higher than the previous year's. The measurements ceased in 1990 and there was no more official data until July 1997 when The "Ente Parco dell'Etna" provided funds to buy instruments (two thermometers and two hygrometers). They were set up on the bottom and in the center of The Ice Cave to get direct readings on climatic differences inside the cave. A third thermometer was set up, outside, at "Timpa Rossa" in order to compare the internal and external differences. After one year of measurements it was found that the humidity is constantly elevated: therefore the hygrometer data is of little interest. On the other hand the temperature data showed that the temperatures in the central part of the cave varied a lot more than in the final part. This could explain the transfer of the stack of ice to the lower parts. Furthermore it was found that external temperature changes only slightly influence the cave's internal conditions (CAFFO S. & MARINO A., 1999).
Presently we are not sure whether we will be able to continue our climatic research due to bureaucratic will to remove our instruments from inside the cave. It would be a good idea to continue the research project in view of the new and quite evident changes that are occurring in the stack of ice. Once again, perhaps they are due to excessive visits and/or the lighting used when televising inside the cave. The fast rise in temperature may have cracked the surface of the ice. It would also be helpful to increase the number of instruments so as to further the research and obtain more details and truths as to the causes of the continuous changes in the stack of ice.

Conclusion

It would be good idea to continue the research and measurements of the phenomenon. It is well known that in the cave, due to the difficulty in exchanging temperature with the outside, the inside temperature is the average of the annual outside temperature at the entrance. Since the outside temperatures are changing there will certainly be repercussions on the cave's micro climate. The climatic research on caves could help us better understand environmental changes in the area. The Ice cave, because of its peculiarity, is of considerable scientific value and should not be underestimated especially since, still today, the stack of ice is undergoing persistent changes.

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