ESSAY ON GENETIC CLASSIFICATION OF VOLCANIC CAVES

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Vulcanospeleology, the study of caves formed in volcanic rocks, reached a great importance in the '70s as a result of interpretation of their analogies to extraterrestrial morphologies (Moon, Mars).

A thorough study of volcanism is required for rational planning of vulcanospeleological research; it allows the formulation of volcanic caves, based upon their main speleogenetic processes, and is an essential instrument for these studies.

An essay on genetic classification of a theoretical kind, which can be applied to whatever cave generated by volcanism is therefore suggested. This classification is based on the effects of flowing lava and expanding gases; both these factors are actually common to every volcanic manifestation and are independent of local features of volcanism.

Different types of caves are described in connection with their position in the classification, and their genetic processes are outlined.

RATIONALE

Speleological studies are supported by different interacting disciplines, which explain speleological phenomena, or extract from them their relevant investigational field. A remarkable position among these disciplines is held by vulcanospeleology, which studies volcanic caves.

These caves often show a striking morphological analogy with karstic caves generated by chemical and mechanical erosion in limestone rocks, though they greatly differ from the latter for obvious reasons. Their genetic processes are quite different from those generating karstic caves; they are formed in such a short time that their formation velocity can be considered near instantaneous. Furthermore, their formation is contemporary with that of the engulfing rock, and is controlled by the same factors, thus they were defined syngenetic by Montoriol-Pous and De Mier (1970), as contrasted to caves generated by erosive or tectonic or other phenomena in a pre-existing rock. The latter were defined epigenetic by the same authors.

Like karstic caves, volcanic caves have been well known too, and used by people since the most ancient times. They were explored and described and studied by excursionists, travelers and naturalists. But for a long while, they met a marked disinterest in the scientific world, and were always considered as simple morphological peculiarities of volcanic environments.

Vulcanospeleology gained importance for scholars only at the beginning of the '70s, when its role became evident as a key in the interpretation and analogical study of extraterrestrial morphologies, photographed by space satellites. Many specialists started exacting studies, both on solid lava fields and extant volcanic caves, and also on active lava flows during eruptions. They formulated new genetic theories and suggested complex classifications which do not entirely agree. Many doubts remain because of scanty availability of comparative terms and because of limits due to over-generalization based on local evidence.

In addition to a thorough knowledge of volcanism, in all its aspects, a simple and rational classification of volcanic caves, based upon valid and generally applicable genetic considerations, is needed for correct planning of studies in the vulcanospeleological field. It does simplify a general systemization of all such caves, regardless of location, whatever morphology they display, however they are formed.

The aim of this paper is to propound such a classification and to link the fundamental cave types herein considered with their genetic processes.

Caves hollowed out in volcanic rocks by speleogenetic factors other than volcanism have been intentionally excluded, as they are in the general category of epigenetic caves.

TYPICAL VOLCANIC FACTORS CONTROLLING CAVE FORMATIONS

Volcanic manifestations characterizing each eruption are numerous, of a varied nature, and are so much dissimilar, one from another, in time and space, as to form the investigation field of a proper discipline.

The grounds for these differences must be investigated in the polygenetic character of volcanism. One may be of distension type in crustal divergence areas, or of compression type in subduction areas. Many intermediate types occur.

In turn, the primary differences are reflected in chemical and mineralogical composition of the erupted materials, in their physical conditions at the moment of eruption, in their way of spread and emplacement in the external environment, and in the resulting morphological features.

In different parts of the earth, scholars have undertaken studies of genetic and systematic problems of volcanic caves — mainly of lava tube caves — but they have been involuntarily affected by the local set of interacting factors which characterize the volcanism of a given area (or type), and differentiate it from others.

As a consequence, systematic arrangements or genetic theories often do not succeed in meeting a vulcanospeleologist's requirements in Japan, or Victoria, or Sicily, when they were elaborated through studies carried out in Icelandic, or Hawaiian, or Northwest American caves. Therefore, it is necessary to loose the volcanic cave systematics from the particular morphogenetic bonds connected with local volcanism, especially as they often are further complicated by single topographical and/or environmental features.

A classification of volcanic caves should be linked only with the most general volcanic features common in every eruption, viz:

1. The shifting of coherent volcanic material, more or less fluid, moved by gravity and/or by hydrostatic pressure and/or by endogenetic pushes (originated by the steam pressure of the engulfed gas).
2. The action of gases, when their volume and steam pressure reach such a power that irreversible deformations are caused in the engulfing molten lava or volcanic deposit or rock.

These actions are limited to primary volcanism. When a speleologically appreciable gap is thus formed in the rock mass, it results in a syngenetic cave, namely a cave generated by the same phenomena which controlled, more or less contemporarily, genesis and emplacement of the engulfing rock.

GENETIC CLASSIFICATION OF VOLCANIC CAVES

In the light of the previous considerations, and of others reported in earlier papers (Licitra 1978(a), 1978(b)), the writer introduced a genetic classification upon typical volcanic factors controlling cave formation, in the third Gruppo Grotte Catania Speleology Lecture Course in 1975.

In this classification, caves are divided into two primary classes, concerned with the peripheral speleogenetic action. Each class in turn is divided into two groups, according to the place and/or way of operating of the speleogenetic action.

Caves generated by flow of lava are classed as rheogenetic (from ancient Greek "rheo" = flow), whether the flow occurs on the surface, in an active lava flow (rh. surface cave) or through pre-existing rocks, when lava flows to the surface through an eruptive fissure and next flows downwards (rh. fissure cave).

On the other hand, the class of pneumatogenetic caves (from ancient Green "pneuma" = blow, breath) action of gases, whether they are volcanic gases released by lava, or induced ones, generated by masses of water, snow or ice contacting hot volcanic gas or lava.

MAIN VOLCANIC CAVE TYPES CONSIDERED IN THE CLASSIFICATION

The main volcanic cave types are hereinafter reported, in connection with the classification mentioned before, and their relevant genetic processes are outlined.

1.1 Rheogenetic Surface Caves

This group includes the most widespread, best known and most studied volcanic caves on a world scale. They are reported as lava tube caves or lava tunnels or galleries; they were also termed emptying out tunnels by Cucuzza-Silvestri (1977) and vary in a wide range of forms and sizes. Lava channels also are classed in this group; in spite of their small importance in speleology, they play an important role as intermediate stage in the formation of lava tube caves, and are valuable terrestrial analogues in studying morphogenesis on the Moon and Mars.

Different hypotheses exist on the formation of rheogenetic surface caves (Licitra, 1977) and it is needless to repeat them all here. According to many ruling opinions, their formation should occur through drainage of still-molten lava from a lava tube (or roofed channel) when the feeding of the flow at the source vent ceases. But it is more likely that a lava tube hollows as a result of gradual lowering of the flowage surface (and bottom) of flowing lava during its active phase (viz. when the flow is being actively fed by lava pouring out from the vent) than at the end of the effusion. In fact, if one considers the high viscosity of lava when compared with other fluids, and the modest temperature interval (1,000/1,000 degrees) within which it maintains a significant flowage capacity, it is very unlikely that such a significant drainage can occur even in water-like fluid lavas, as to generate long caves such as the "Kazumura Cave" of Hawaii.

The lowering of the flowage level could operate either by evacuation through division of lava into new flow units in the flow front, or (more likely) by simple lowering of the flowage bed, through remelting and erosion of the tube bottom (Finch 1943).

Also, some geomorphic features of lesser speleological interest must be classed in this group, such as those surveyed and described by Montoriol-Pous and De Mier (1970) in Grindvik lavas, Iceland; large traverse fractures gaping across the flow direction, corresponding with an underlying slope incretion (cavidades fractogeneticas) or collapse holes of small dimensions (cavidades embudiformes) or blind sections of tube unroofed by collapse (cavidades serpentiforms);or even bowl shaped subsidence holes, as Alae Crater, Hawaii, described by Swanson and Peterson (1972).

If the downward reflux is not followed by conduit collapse, a vertically developed hollow is formed, with parallel walls. This is defined as a rheogenetic fissure cave (Licitra 1978(c); 1981). The more effusive the activity, the lesser the collapse is probable.

2.1 Pneumatogenetic Explosive Caves

Caves engendered by gas explosions are classed in this group, whether the exploding gases are volcanic or phreatic.

In addition to diatremas, which are of limited importance from a speleological angle (they somewhat resemble Mexican sotanos, originated by tectono-carstic phenomena), hornitos are included in this group. They are tall welded spatter cones, with a hollow core, built up by spatters of molten lava splashed by gurgling gas bubbles, around a rootless vent from which very fluid and partially degassed pahoehoe lava emerges.

Rheogenetic surface or fissure caves are frequently found beneath hornitos or at their base.

2.2 Pneumatogenetic Expansion Caves

This type of cave is not very widespread and is generally associated with rheogenetic surface caves Furthermore, this is the only type of volcanic cave which has been noticed in volcanic rocks other than basic lava flows. A pneumatogenetic expansion cave occurs when two different factors are interacting:

i — presence of abundant gases, the steam pressure of which is incapable of completely overcoming the resistance of the engulfing material;

ii — volcanic products (basic lava, or ignimbrites) too viscous to allow the engulfed gases to be released, yet plastic enough to be warped by the gas pressure before the stiffness of the solid state has been attained.

Caves of this type are called blister caves by English authors, and cavidades cutaneas by the Spanish Montoriol-Pous and De Mier (1970), and may be formed when a lava flow enters a large quantity of water (lakes, sea) or buries a marshy ground (such as Myvatn, Iceland). Such caves have been noticed in Iceland, in Australia and at the foot of Mt. Etna along the Ionian coastline.

Perhaps the most remarkable type of pneumatogenetic expansion cave has been surveyed and studied in a prehistoric ignimbritic deposit at Fantale Volcano, Ethiopia. Gibson (1974) ascribes the formation of such blister caves to expanding gases and steam held beneath wrappings of ashes and viscous rhyolitic lava scraps, at very high temperature, after red-hot ash flow has halted.

Although no information is available in this report, such caves might be found in the Valley of the Ten Thousand Smokes, Alaska, in the ignimbritic deposit laid down in 1912 by Katmai Volcano.

CONCLUSION

The theoretical classification presented in this paper, based upon general speleogenetic factors of volcanism, should simplify and assist collection and interpretation of observational data.

By this classification, it is actually possible to ascertain how very dissimilar local morphologies may be related to one another and traced back to a single genetic pattern. Thus, the risk is avoided, that an excessive subclassification of syngenetic caves (due to seemingly different morphological and/or dimensional standards) leads to misclassification of caves generated by the same processes into different classes or groups.

The researcher's task then, will be to ascertain the set of local factors (chemical, physical, topographical, environmental, etc.) and the degree of interacting relationships, which control the specific morphogenesis of each cave.

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