RUPESTRIAN WORKS AND ARTIFICIAL CAVITIES: CATEGORIES OF CONSTRUCTION TECHNIQUES

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Abstract: *Artificial cavities, i.e. man-made structures excavated within rock masses in the mountains, below the ground, or in the subsoil of urban areas, are typically distinguished based upon the epoch of realization and the function for which they were originally used. They can be ranked into the following types, in turn divided in sub-classes: hydraulic works, dwelling works, worship works, war works, mining works, transit way works and others. The above criteria are essential for establishing a general common line aimed at providing optimal elements for cataloguing and comparing subterranean features, which may favor the creation of databases functional to knowledge, protection and enhancement of the hypogean works. In addition, there is another useful aspect for studying the origin and evolution of underground structures that takes into account their implementation modalities. The National Commission on Artificial Cavities of the Italian Speleological Society has identified, according to its experience in the field and in function of the construction techniques, six general categories of underground works: cavities dug in the subsoil, cavities built in the subsoil, cavities obtained by re-cover, anomalous artificial cavities, mixed artificial cavities and natural caves modified by men (anthropized caves). In this contribution we will discuss the specific details of each category, thus extending the concept of rupestrian heritage, usually confined to temples or dwellings carved in the rock, to a culture of building in "negative" that finds larger and more diversified evidences.*

Keywords: *Rupestrian Works, Artificial Cavities, Categories, Typologies, Underground, Construction Techniques.*

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Introduction

And nowadays, man-made structures excavated within rock masses in the mountains, below the ground, or in the subsoil of urban areas (artificial grottos, cavities), do not cease to attract the researchers' attention, although they are sufficiently studied and classified based on the epoch of realization and the function for which they were originally used.

For those who study the origin and evolution of underground structures, accurate records of the ways of their implementation become very important in order to correctly understand the scientific problem, its significance and direct the study to certain results. As such, six general categories of underground work defined by the National Commission on Artificial Cavities of the Italian Speleological Society, according to its experience in the field and in function of the construction techniques are considered, which, in their important details, expand the hitherto existing conception of the rupestrian heritage.

Materials and Methods

During the preliminary research, data in the scientific literature was examined. Materials about the cavities located in Armenia were developed from publications in international conferences. The necessary sections of geological, stratigraphic, geomorphological, hydrogeological, and geophysical maps were collected and

developed. During the fieldwork of the scientific expeditions, a comparative analysis of these maps was carried out using data gathered from each site.Then the main works began, such as identifying the artificial caves, determining their location in the rock mass, comparing the conformation of the cavity elements with appropriate topographical surveys, and drawing the relevant conclusions.

From "rupestrian works" to "artificial cavities"

Usually, when the "rupestrian works" topic is dealt with, one thinks immediately to structures dug by men in the rock-faces in order to obtain underground spaces to inhabit, with related sites for productive activities (warehouses, stables, mills, dovecotes, etc.), or to spaces used for worship, both for liturgical purposes (temples, churches, etc.) and for the burial (tombs of various types), according to a functional types subdivision [1-4].

We find striking examples in various parts of the world, as the rupestrian settlements in southern Italy, the most famous of which are the Sassi of Matera, consisting of thousands of dwelling units. However, not less important are the many sites excavated in the gorges (locally named *gravine* [5]) of the Apulian-Lucan area, counting almost 600 churches, nearly the same number estimated for the hundreds of rupestrian settlements of Cappadocia, in central Turkey, and others in Armenia. Equally well known are the Dogon cliff villages of Mali, the Buddhist "caves" of China and India, the rupestrian city of Petra, in Jordan, the Pueblo villages in Colorado, and many others in different parts of the world.

The use of exploration techniques derived from the experiences of cave progression has allowed, since the 1960s, the finding of underground man-made works, less visible than those mentioned above, more dangerous to explore, and more difficult to be documented. This approach has produced a quantitative increase in knowledge of underground structures and, especially, has extended the investigations to issues not much considered before about the use by man of underground structures. This union, which began in prehistoric times with occupation of the caves by man, later evolved over the millennia with surprising and ingenious works. These are not limited to the already mentioned cavities intended for dwelling or worship, but include structures for transit, hydraulic engineering, mining, war, and related sub-classes (see Table at the end of the article).

Furthermore, the research field has expanded from the works excavated by man in the rocky outcrops or below the countryside level to those in the subsoil of urban areas.

It was therefore necessary to go beyond the idea of "rupestrian work", as defined above, replacing it with the most extensive "artificial cavity," or "anthropic cavity", in its turn complementary to that of a natural cavity, or cave. We can define artificial cavity as a space created by man in the subsoil, in broad sense, which implies an idea of a "negative" construction culture, as an alternative to the outer buildings at the surface, but also to the hypogean environment produced by meteoric agents and geological phenomena.

This approach completely defines the relationship between man and the underground world, taking into account not only the many variable purposes - identified in the types above described – but also the different construction ways according to morphological, lithological and urban characteristics of the environment in which the structures have been made over time, also including those structures which were not excavated, but share many similarities with hypogean places.

Categories of construction techniques

The *Commissione Nazionale Cavità Artificiali (CNCA), i.e.* National Commission on Artificial Cavities of the *Società Speleologica Italiana* (Italian Speleological Society), according to the exploration experience of its researchers, has developed a catalogue of artificial cavities based upon the construction techniques, identifying six categories, according to their intended purpose [6]. In the Register of Artificial Cavities, compiled by the Commission [2,7-9], not only the strictly rupestrian works are therefore included, but all those structures built or dug by man in the subsoil and, sometime, in the above ground, according to the following criteria.

Cavities dug in the subsoil

These are obtained exclusively by removal of stone materials (rocks), and can be divided into two groups [10].

a) Rupestrian (or rock-cut) structures, strictly speaking. They consist of spaces (rooms, tunnels, shafts) dug by man above the ground surface, in the outermost portion of rocky towers, pinnacles, cliffs, canyons, slopes. These are also defined "cliff cavities" [11].

Generally they can have very long horizontal development, even kilometres, on a single level (linear cavities/settlements), or on a series of stepped levels (terraced cavities/settlements), or on levels superimposed over the same vertical wall (wall cavities/settlements). When dug inside individual pinnacles they are called "cone cavities" (Fig. 1,2).

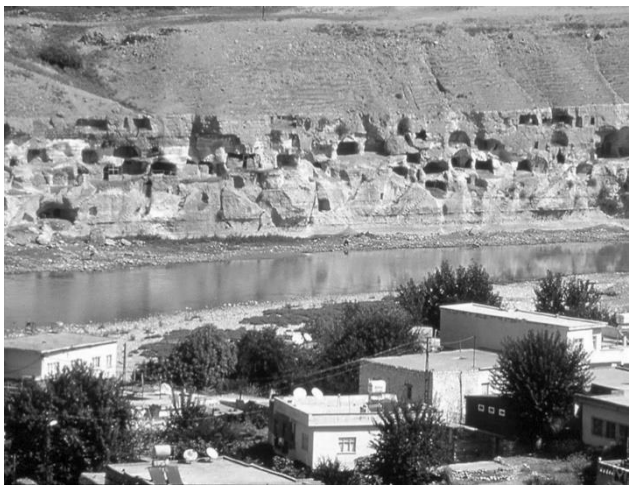


Fig. 1. *Cliff rock-cut village of Hasankeyf on the Tigris River, in southeasternTurkey (photo M. Traverso)*

b) Underground structures, dug in depth (deep layer), under the ground level (mesas or plateau areas) or in the inner part of rock mountains (butte and other ridges). In this case, too, we can have networks extending on a single horizontal level (Figs. 3,4), or networks descending in the subsoil for tens of meters on superimposed levels (Figs. 5,6).

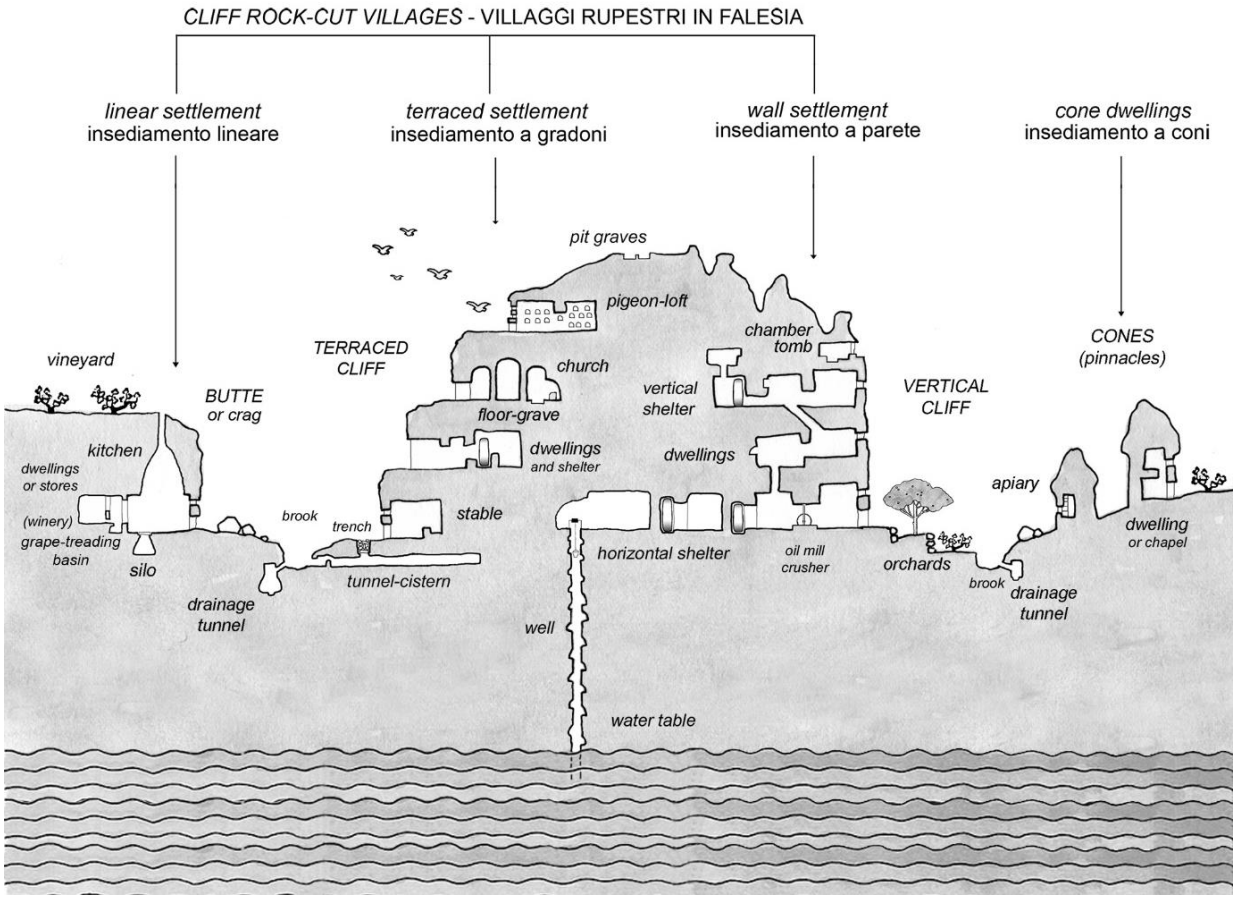


Fig. 2. *Exemplification of different cliff rock-cut village models in Cappadocia, central Turkey (drawing R. Bixio)*

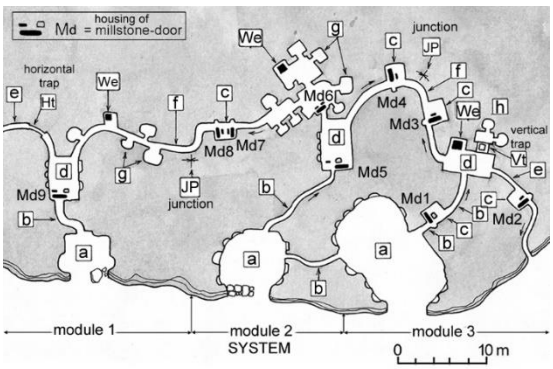


Fig. 3. *Scheme of the "horizontal" underground shelter of Filiktepe in Cappadocia, central Turkey (drawing R. Bixio)*

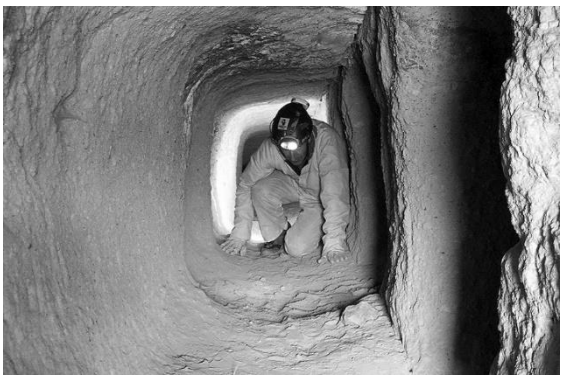


Fig. 4. *Artificial tunnel under the site of Ani, ancient capital of Armenian kingdom, now in - eastern Turkey (photo R. Bixio)*

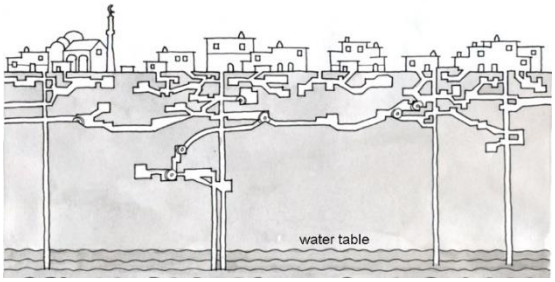


Fig. 5. *Scheme of the "vertical" underground settlement of Derinkuyu, in Cappadocia, central Turkey (drawing R. Bixio)*

Fig. 6. *Underground settlement of Derinkuyu in Cappadocia. Well at depth of about 40 m (photo G. Bologna)*

Note: the distinction between rock-cut cavities and underground cavities is not always clear, so that often the terms can be used interchangeably.

Cavities constructed in the subsoil

The underground spaces belonging to this category are those obtained with masonry works created to define volumes produced as a result of excavation of the subsoil, through two techniques.

c) Tunnel excavation technique (tunnelling). Removal of the rock is carried out entirely underground. The rooms are then coated with different masonry techniques. Coating can interest only part of the excavation.

d) Trench excavation technique. It is realized with a open air excavation, followed by total or partial coating of the walls, building of the vault, and finally re-covering (Fig. 7). It is a technique very useful at not great depths: generally, it is simpler, faster, and cheaper than the tunnel excavation technique. It can also be used in clayey soils.

In some cases, the walls are not coated, and the only built part is the cover, which can be with flat ceiling, obtained by laying stone slabs or concrete slabs, or barrel-like ceiling, obtained using various materials such as ashlars, bricks, or concrete.

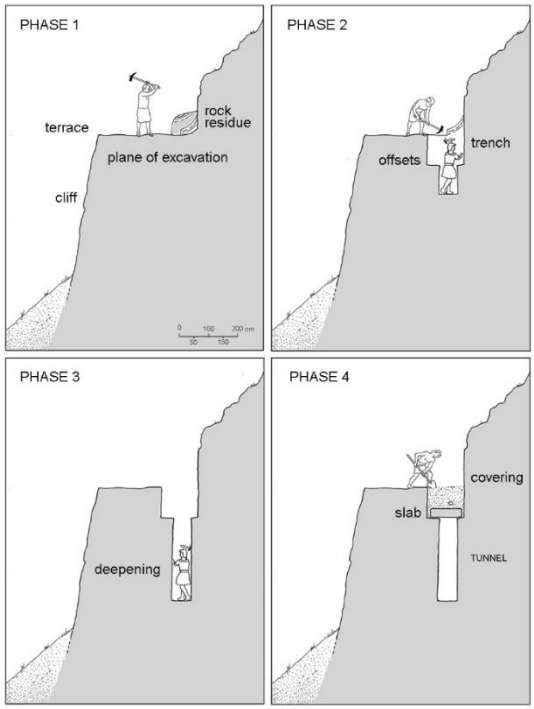


Fig .7. *Reconstruction of the excavation technique of the trench of Ahlat, lake Van, eastern Turkey (drawing R. Bixio)*

The underground aqueduct of Gravina in Puglia (Southern Italy), for example, has been realized with both the tunnelling technique, without any coating, and the trench excavation technique, with partial coating and barrel covering by tuff blocks (Fig. 8) [12,13].

Mixed artificial cavities

These are works dug to reach, extend or modify substantially a natural cave. The artificial part can be carried out with one of the methods described above.

We found a significant example of mixed cavity in the archaeological site of Troy (Turkey). This is a work for the low city's water supply, attributed to the 3rd millennium BC and used until the Byzantine period [14]. The initial part, accessible from the outside, is a natural tunnel. The artificial part consists of a long tunnel, almost straight, led from an internal point of the cave to the base of some ascending shafts/wells, dug into the body of the rock. The excavation of the tunnel was made using the opposite fronts technique, that is, by two teams digging one towards the other, most likely simultaneously: this is evidenced at the junction point, typically identified because of the change in direction and the related blind appendix due to a slight alignment error (Fig. 9).

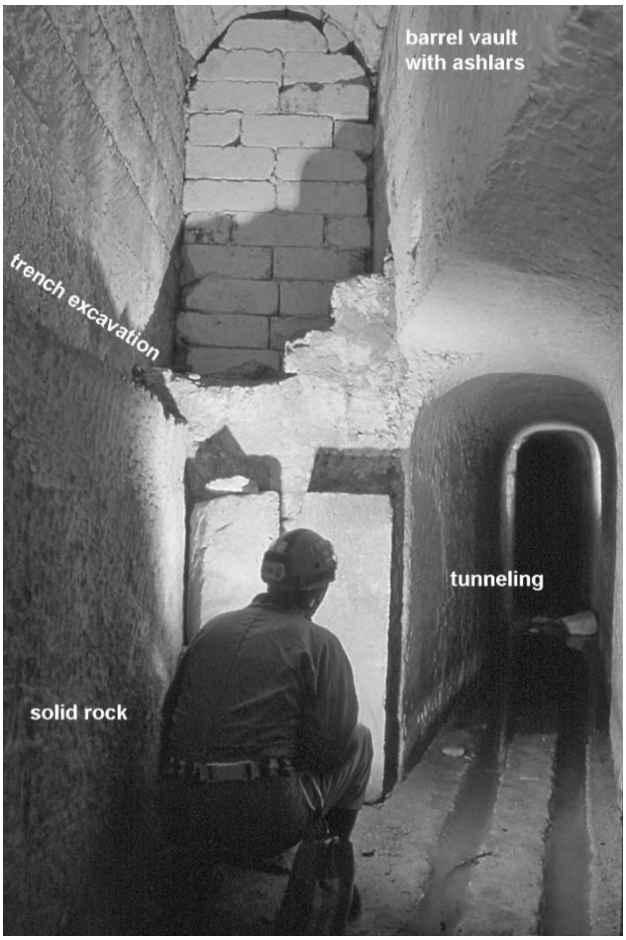


Fig. 8. *Underground aqueduct of Gravina in Puglia (southern Italy). Mixed excavation technique in solid rock: tunnel and trench, with partial coating and cover in stone ashlars (photo M. Traverso)*

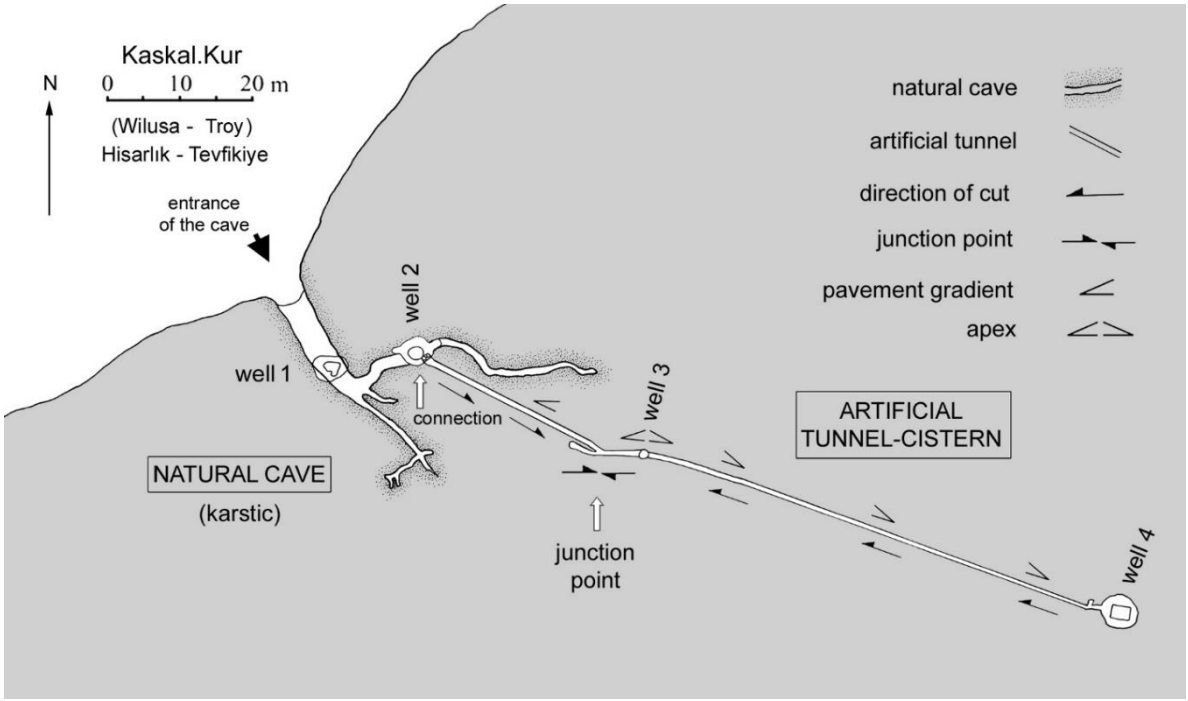


Fig. 9. *Plan of Troia water supplying tunnel, mixed cavity (R. Bixio, elaboration after M. Korfman 2003)*

Anthropized caves

We define "anthropized caves" the natural caves that have undergone limited human interventions. They represent the boundary line between the natural cavities, produced by weathering and geological phenomena, and the artificial or anthropic cavities, entirely man-made in the subsoil.

In general, these are wide but not very extensive caverns, in which man has built masonry structures, for dwelling and/or for worship, sometimes supplemented by small digging actions.

The best known examples are, for the first type, the "Pueblo" villages built by American Indians in Arizona, Colorado and New Mexico between the 12th and 14th centuries (Fig. 10).

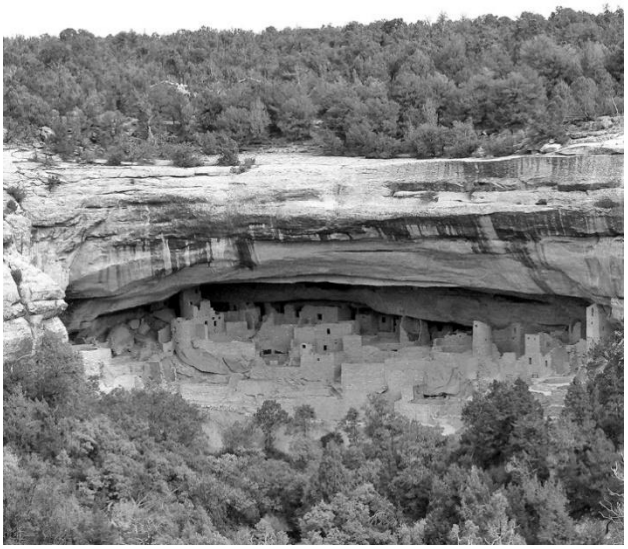


Fig. 10. *Antrophized cave: Pueblo at Mesa Verde in Colorado, USA (photo G. Stalteri)*

The second type is represented by the sanctuary-caves. We have examples in Italy (Santa Lucia, Toirano), France (La Saint Baume, near Var), Turkey (Sumela, near Trabzon), to cite a few, and in many other places in the Mediterranean basin, where there are churches and monasteries from the early centuries of Christianity, built inside karst caves.

Non-excavated artificial cavities

Finally, we describe the "re-covered cavities" and the "anomalous cavities" that are quite different from the rupestrian works, as previously defined, because they do not contemplate digging works to obtain spaces within the rock mass. However, they are included in the classification of the *Commissione Nazionale Cavità Artificiali* and inserted in the related register, as there is no doubt that, by their nature, they fall within the categories of anthropic cavities.

Cavities obtained by re-covering

Often the human activity on surface, particularly in urban areas, has produced the overlap, the burial and the embedding of natural or artificial spaces originally not located in underground spaces.

For example, the fifty-two streams crossing the city of Genoa (Italy), in medieval times flowed in sub-aerial beds [15,16]. The need, with urban growth, to obtain new spaces for the city, has caused over the centuries their progressive coverage (Fig. 11), almost always coincident with road axis, producing the incorporation of existing structures (bridges, dikes, masonry banks, remains of buildings, etc.).

Fig. 11. *Rio Groppo, Liguria, Italy. Tunnel obtained with the cover of the river bed (photo M. Traverso)*

For the sake of completeness, we would like to remind that there are also natural underground waterways (karst rivers) throughout the world. In this case, they are considered as natural caves, and therefore included in the Register of the Natural Cavities of the Italian Speleological Society.

Anomalous cavities, constructed above the surface

These are works built in elevation, or as part of buildings at the surface, but with characteristics similar to real underground spaces.

The best known example is documented inside the pyramid of Cheops at Giza (Cairo, Egypt), dating from the fourth dynasty, about 2500 BC [17]. The "Great Pyramid", a massive structure composed of gigantic blocks of stone, is crossed by a series of tunnels and rooms where it is possible to transit for a total extent of about 400 metres. The oldest tunnels were dug under the basement, directly into the solid rock. They fall into the category of "underground cavities". Other passages are placed in the body itself of the structure, above the natural level of the plateau. They were realized simultaneously to the laying of the blocks, and are therefore classified as "anomalous cavitie" (Fig. 12).

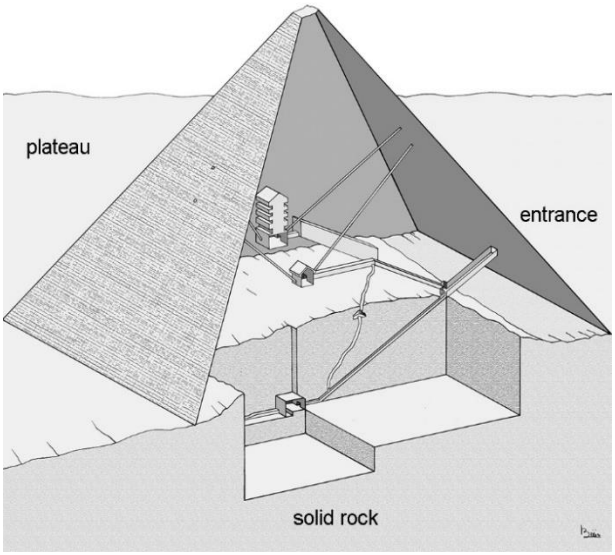


Fig. 12. *Section of Cheops' pyramid with tunnels and sepulchral chambers representation (drawing R. Bixio)*

Another striking example is the "Ponte Monumentale" (Monumental Bridge) at Genoa (Italy). It is a viaduct that crosses a road below, therefore suspended at 20 m from the ground (Fig. 14). The internal structure is hollow, supported by transversal wings (wall sections) in exposed stone with sub-circular arches that appear concentric due to the curvature of the extrados (Fig. 13). Access and investigation inside the bridge are faced as real speleological explorations [18].

Fig. 13. *Genoa (Italy). Interior of Ponte Monumentale (photo C. Leoni)*

Results and Discussion

The results of the study and the indicated classification (Table) will enable builders, engineers, and urban planners to take appropriate measures to ensure the safety and stability of their designs already at the planning stage, to reduce possible risks while designing roads and hydro-engineering structures in places where underground structures are numerous. These investigations particularly refer to the central and southeastern part of Turkey, including Cappadocia, Akhlat, Ani, and Armenia's Syunik, Shirak, and Aragatsotn regions.

Fig. 14. *Genoa (Italy). Exterior of Ponte Monumentale (photo A. Bixio)*

Conclusion

Definition of the different categories of artificial cavities according to the construction techniques, here illustrated, started up - as mentioned - in CNCA after decades of explorations conducted with a multidisciplinary approach, in various underground works all over the world, and from the need to establish clear and shared criteria useful to their study and classification.

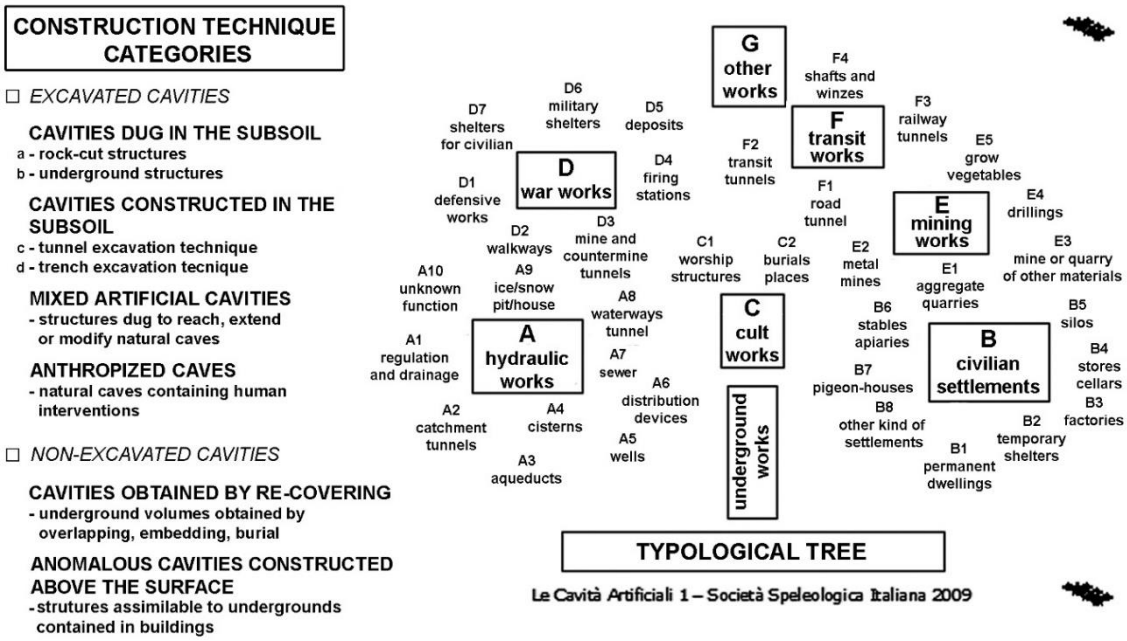
The formalized categories allow, together with the functional investigation of artificial cavities and the relating typological cataloguing, to have a reading-key for a basic scientific analysis, from which to develop – case by case - the specific research on each underground structure, aimed at better understanding the fundamental elements such as age, original purpose, modification, and reuse over time.

For each artificial cavity the survey and the study of the construction techniques are fundamental, inextricably linked to that of the work signs left during the construction of the work itself, such as marks produced by pickaxes, hammers and chisels on the rock walls, from which one can also infer the digging direction. These observations and surveys can provide crucial elements of interpretation and understanding about the underground setting, borrowing and adapting to artificial cavities those systems and approaches improved in the last thirty years by the Archaeology of the Architecture [19-22]. They allow to read properly, according to stratigraphic principles, the peculiar characteristics of the "masonry evidences" shaped by subtraction of the raw material, following the excavation of rock masses whose modelling of empty spaces create the hypogean structure: from the general structures (floors, wall covering, pillars and roofs), to the specific elements (frames, capitals, scaffolding holes and plasters) forming the artificial cavity.

In many cases it is possible to distinguish different "stratigraphic masonry unit" useful for relative dating of the structure, and often in connection with various construction techniques. The measurement of recurring elements in artificial cavities, such as niches and footholds, in addition to the possible presence of structural components also characteristic of the elevated architecture, such as brick and stone ashlars, can be used to recognize these elements as possible chronological indicators, as developed again by the Mensiochronology [23].

In summary, the study about the origin and the evolution of underground structures through the analysis of their way of execution and the use of the six general categories developed by the CNCA, based on the construction techniques above described (summarized in the Table together with the "type tree"), is a basic survey instrument designed to achieve a thorough historical understanding of the hypogean architectural heritage.

Table. Categories and Types of artificial cavities classified by Commissione Nazionale Cavità Artificiali of Società Speleologica Italiana (R. Bixio, elaboration after Bixio and Galeazzi 2009: //document.speleo.it/)



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