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VOLUME 2




Edited by
Michal Filippi
Pavel Bosák

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WHERE HISTORY MEETS FUTURE

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Cover photos (some photos were adjusted/cropped)
Top left – A gallery along the "Rio de los Venezuelanos" in the Imawarì Yeuta Cave system in quartz sandstones, Auyan Tepui, Venezuela. Photo V. Crobu. For details see the paper by Sauro et al.
Top right – The 15th siphon of Ramo Nord in the Grotta del Bue Marino, Sardinia. Photo by R. Husák. For details see the paper by D. Hutňan.
Bottom left – Using an Xbox Kinect equipment to survey a cave. Photo by J. Gulley. For details see the paper by Covington et al.
Bottom right – Inclined workings of the Voskresenskyi Mine, Ural Mountains, Russia. Photo by A. Gunko. For details see the paper by A. Gunko.

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CLASSIFICATION OF ARTIFICIAL CAVITIES: A FIRST CONTRIBUTION BY THE UIS COMMISSION

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The article representes a contribution by the Commission on Artificial Cavities of the Union Internationale de Speleologie (UIS) aimed at defining a general classification of artificial cavities. The amount and variety of cavities realized underground by man is extremely high, and cover with variable peculiarities many areas of the world. Nevertheless, it is important to perform an attempt in classifying such great variety, through a classification comprising at least the main categories of observed situations. Starting from the work carried out in past years by the Italian Speleological Society, it is here presented a classification of artificial cavities based upon time and modality of realization, and organized through a typological tree where seven main categories are defined, each one of them in turn subdivided into sub-types. We hope that, referring in the next future to this classification, it will be possible to better organize and describe the works and researches on artificial cavities, and compare the situations present in different areas of the world.

1. Introduction

In several occasions, attempts have been made to develop a classification of artificial cavities, as a common base to describe the underground cavities produced by man's activities over time, and to share the related knowledge and great amount of researches done, that embrace many different fields of science (from geology and geomorphology, to archaeology, anthropology, history, and so on). In the past, more than one classification has been proposed. In most of the cases, the main drawback of these attempts relied in their strong dependence on the country of provenance of the authors (with, in turn, a stronger attention paid upon the most typical cavities of that country).

In very few occasions the proposed classifications derived from the work of an international group where different countries were effectively represented. Nevertheless, some attempts have been done to put together international teams, with outcomes such as the lexicon of terms dealing with underground works presented at the International Symposium on Underground Quarries in Naples (Capuano et al. 1991).

In Italy, a strong effort was produced during the last decades to put together the cavers and researchers interested in the topic of artificial cavities, by creating a dedicated Commission within the framework of the Italian Speleological Society (SSI). The Commission started its works in 1981, focusing on the issues of producing a preliminary classification of artificial cavities and, at the same time, preparing a form to be filled for inclusion of each artificial cave in the Italian register, managed by the SSI Commission itself (for further details, see www.ssi.speleo.it). In the years, many meetings and discussions were the object of the matter, until in the late 1990s a preliminary classification was proposed.

Following the last International Congress of Speleology, held in Kerrville (Texas, USA) in 2009, and the re-start of the activity of the new UIS Commission on Artificial Cavities, the issue of producing a general classification of artificial cavities became again matter of discussion. At this aim, a specific workshop was organized in May 2011, and held in Turin (Italy), with the outcomes presented in a special issue of the journal Opera Ipogea, published by SSI (Parise 2013). On that occasion, starting from the Italian classification, some adjustments were produced, both in the organization of the structure, and as linguistic improvements; further, inclusion of new typologies was also considered, which brought to the present classification, that will be described in detail in the following sections, and is illustrated in the flow chart of Figure 1.

2. Definition of artificial cave

Artificial cavities are defined as underground works of historical and anthropological interest, realized by man or positively readjusted for his needs. Thus, artificial cavities include both man-made works (excavated, built underground or turned into underground structures by stratigraphic overlap) and natural caves, when these latter are readjusted to human needs in significant parts. To provide some examples to this regard, the natural caves used as shelters in the Alps during the First World War, and the hermitages in natural shelters can be mentioned.

Size, development and frequency of artificial cavities at a given place are directly dependent upon the hardness of the rock, and, as a consequence, easiness of excavation. The characteristics of the cavities present in a given urban area are also closely related to the peculiarities of the site itself, and to its evolution and transformation as well. In many cases artificial cavities go back to a historical period of which there is no longer evidence at the surface. Therefore, cavities are often the only evidence left of pre-existing territorial organisations and of a lifestyle wiped out by the present urban development, owing to new and different needs developed in the course of time.

The main reasons at the origin of the realization of artificial cavities in different epochs were the need to:
- obtain water and/or minerals;
- exploit the natural thermal properties of underground sites to survive in adverse weather conditions (Givoni and Katz 1985);
- overcome the shortage of timber for building and/or heating;
- bury the dead;
- find conditions of ascetic isolation;
- defend against raids, persecution, war;
- hide from justice;
- exploit the economy and/or ease of excavation of some types of rock compared to other construction techniques;
- take advantage of the shape of some rocky hills;
- obtain free areas for productive activities.

2. Classification of artificial cavities

The main criteria at the origin of the present classification of artificial cavities have to be found in the need to characterize each man-made cave in terms of age of realization, technique of construction, and use of the cavity itself.

As concerns the first issue above (that is, age of realization), it has to be noted that artificial cavities have been constructed for over thousands of years without interruptions since the remote past to the present days. Even our modern civilisation is still "colonising" the subsoil with a variety of works, that include but are not limited to: subways, car parks, road tunnels, shopping centres, scientific laboratories, military works, mines, etc.

To provide an indication about age, following the standards in use in Italy the underground facilities can be distinguished as follows (lettering is the reference used in the Italian Register of Artificial Cavities):
a = prehistoric
b = protohistoric
c = pre-Roman
d = Roman kingdom / Republican
e = Roman Imperial
f = Late Antiquity (Sunset of the Roman Empire)
g = high-Medieval (until about 1000)
h = middle-late Middle Ages
i = Renaissance (approximately, 1400–1600)
l = Modern Ages (until the French Revolution)
m = XIX century
n = XX century and later

Apart from age, other elements have to be identified. These include:
- the technique of construction;
- the function (or purpose);
- the shape and development of the underground structure;
- the spatial correlation with the surrounding environment;
- the temporal correlation with the general historical events on a general, regional and local scale.

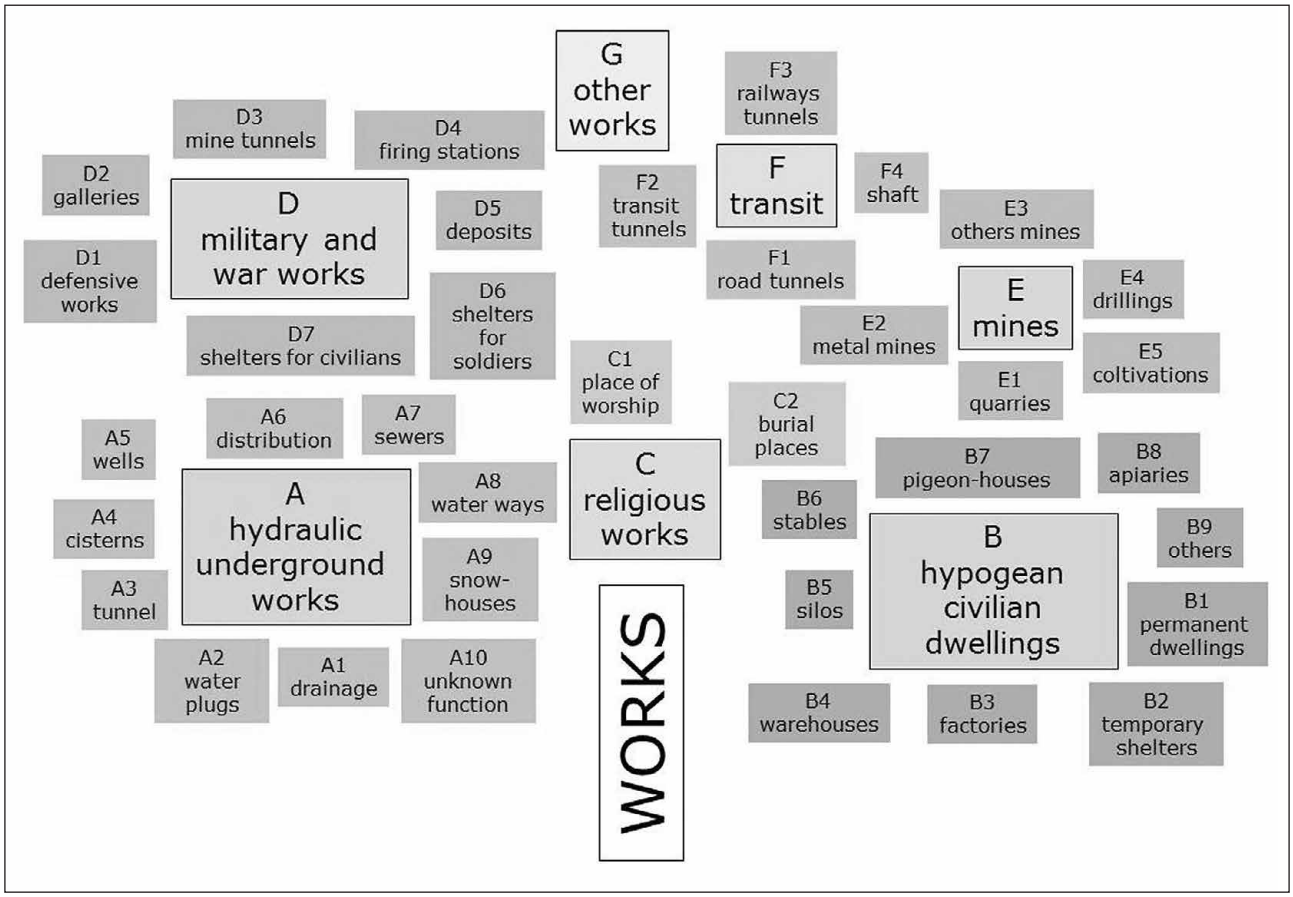

Figure 1. Typological tree for the classification of artificial cavities.

3. Categories

Taking into consideration the construction technique, several situations can be considered:
• cavities dug in the subsoil;
• cavities constructed in the subsoil;
• cavities obtained by re-covering;
• anomalous artificial cavities;
• mixed artificial cavities;
• natural caves modified by men.

Cavities dug in the subsoil. These are underground structures in the strict sense: rooms obtained by removing stone materials (rocks) under the surface level, or inside rocky hills, or carved close to the surface of the cliff faces, canyons, ravines (for example, troglodytic structures).

Cavities constructed in the subsoil. Excavation in trenches is realised with an open air excavation, followed by coating of the walls and construction of the vault. Excavation in gallery is realised by removing the rock entirely underground. The walls are then coated with different masonry techniques.

Re-covered cavities. Human activity in urban areas often produces the covering, natural or artificial, of structures originally located on the surface.

Anomalous artificial cavities. These structures are built on the surface, but with characteristics similar to those underground (for example, some military bunkers).

*Mixed artificial cavities***.** They are the result of the digging to reach, extend or alter natural caves.

Caves with anthropogenic interventions. Natural caves that have undergone limited human interventions. They represent the boundary between the natural caves and those of artificial origin (anthropogenic). In general, they are of limited extent.

4. Types

According to the function for which an artificial cavity was, or is still, used, it can be classified in a specific type.

The variety of underground artificial structures is very large. Consequently, the classification is organised like a tree, based on seven main types, in turn divided into sub-types (Fig. 1). The use is made easy by alphanumeric codes. Often different uses overlap in time; thus, a single site may have multiple classifications representing different periods in its life.

4.1. Type A – Hydraulic underground works

A.1 – Water level control, drainage-ways
Tunnels dug for the reclamation of marshlands and to stabilise the level of lakes (emissaries) and reservoirs (Judson and Kahani 1963; Castellani and Dragoni 1991, 1997; Caloi and Castellani 1991; Galeazzi et al. 2012).

A.2 – Underground stream interception structures
Tunnels and galleries designed to capture underground water veins or dripping waters (Sadaf Yazdi and Labbaf Khaneiki 2010). The work of interception can consist either of a simple duct cut into the rock, or of a complex system integrated with building works.

A.3 – Underground water ducts: aqueducts
Galleries and tunnels to carry water from the stream interceptions or other body of water to the users (Ashby 1935; Hodge 1992; Bodon et al. 1994; Parise et al. 2009). Deviations into galleries of water courses can allow the construction of bridges: the so-called *Ponti Terra* or *Ponti Sodi* (Etruscan technique).

A.4 – Cisterns, water reservoirs
Underground spaces to store water, usually completed with waterproofing of the walls (Fig. 2).

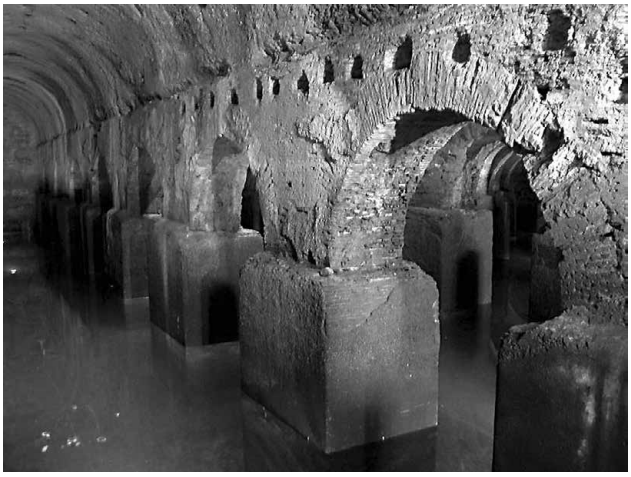

Figure 2. Cistern at Albano (Italy). Photo: G. Marchesi.

A.5 – Wells
Vertical shaft to reach the water table and carry water to the surface. Those located within other underground structures are considered an integral part thereof.

A.6 – Hydraulic distribution works
Tanks or other underground rooms in which one or more ducts converge and from which other ducts go out to distribute water to the users (*castellum aquae*).

A.7 – Sewer
Tunnels or galleries for the discharge of grey or black waters produced by human settlements and industrial facilities.

A.8 – Ship, boat canals
Canals built for passage of ships or boats (Fig. 3). They are found mainly in central Europe and the United Kingdom.

A.9 –Ice wells, snow-houses
Deposits and/or manufacture of ice in the subsoil. Both natural cavities and artificial cavities were used for ice conservation, and use during the dry seasons.

A.10 – Tunnels or ducts with unknown function
This sub-type include those traces of ducts that are identified as water works, but which specific function is not known with certainty.

4.2. Type B – Hypogean civilian dwellings

B.1 – Permanent dwellings
The sub-type comprises long term settlements, cave dwellings, and underground houses (i.e. Bixio 2012). Most cavities of this type have nowadays been abandoned. However, the historic Sassi of Matera (Southern Italy) are recovering thanks to recent, extensive renovation works. In

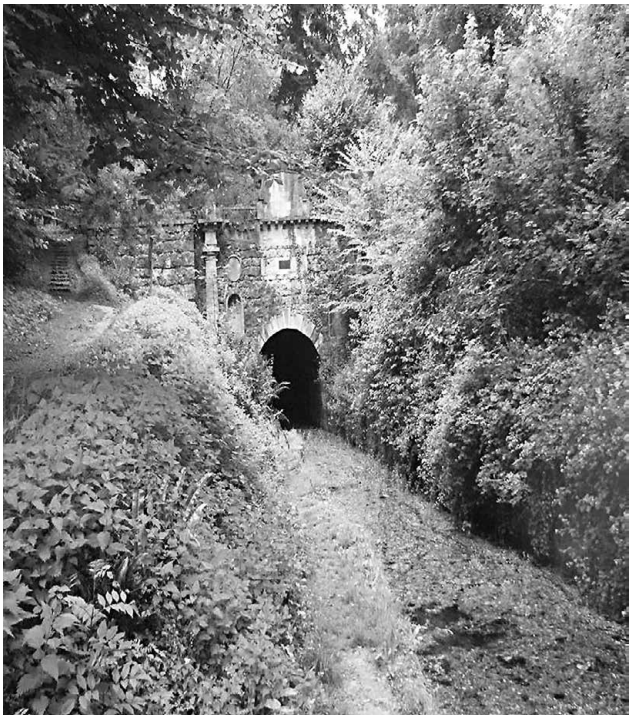

Figure 3. Canal at Cotswold (England). Photo: J. Orbons.

China public buildings and private houses are still being digged into the rocks, and are inhabited by about thirty million people. In antiquity some sites have achieved the size and organisation of real urban hypogean areas, often complemented by brickworks (Golany 1988).

B.2 – Temporary shelters
Seasonal settlements, shelters for shepherds during the transhumance, hiding-places of bandits, places of temporary detention.

B.3 – Underground plants, factories
Rope-makers caves, oil mills, factories, working places no longer in use (Fig. 4). Military factories are classified D.1.

B.4 – Warehouses, stores, cellars
Storage for farming equipment, wine cellars, storage for fruits and vegetables. If military, they are classified in D.5.

B.5 – Underground silos
Cavities general accessed from above, carved into the rock and carefully closed by a stone to guarantee the preservation of food from animals or humidity. Sometimes they are bell-shaped.

B.6 – Stables for any kind of animals
Shelters for animals of any size: horses, chickens, other birds (except pigeons, see B7, and bees, see B8).

B.7 – Pigeon-houses
Dovecote or pigeon-house are synonyms to indicate rocky structure used for the housing of pigeons, doves or similar birds (Fig. 5).

B.8 – Apiaries
This sub-type has been recently included, following the proposal by Bixio and De Pascale (2013). Rock apiaries are widespread in many countries of the Mediterranean Basin.

B.8 – Any other kind of civilian settlements
It is difficult to establish a complete list of all the types of settlements. Unusual or not understood works can be included here.

4.3. Type C – Religioust structures, veneration works

C.1 Nymphaeum, Mithraea, temples, sacred wells, shrines, monasteries, churches and chapels, etc.
This category includes the main structures built for religious purposes (Rodley 2010; Fig. 6). In case they contain many burials, they are also classified in C.2. Conversely, if in a catacomb there are clear traces of the altar the site is also classified as type C.1.

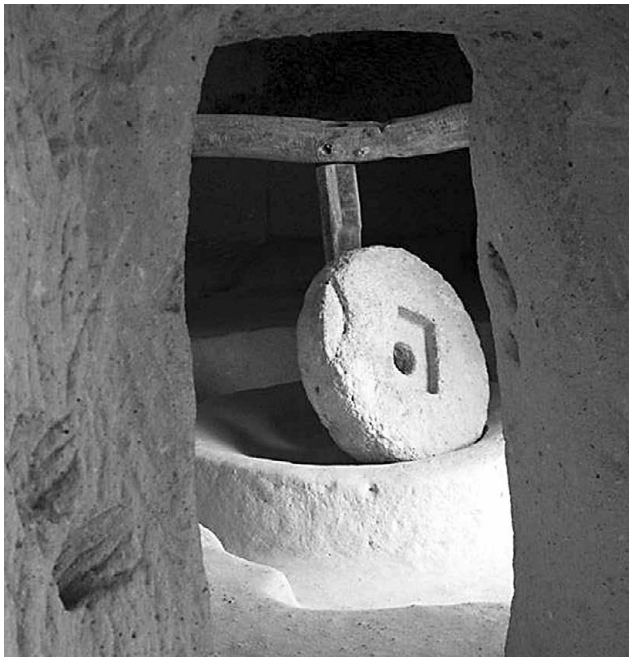

Figure 4. Oil mill factory at Zelve (Turkey). Photo: R. Bixio.

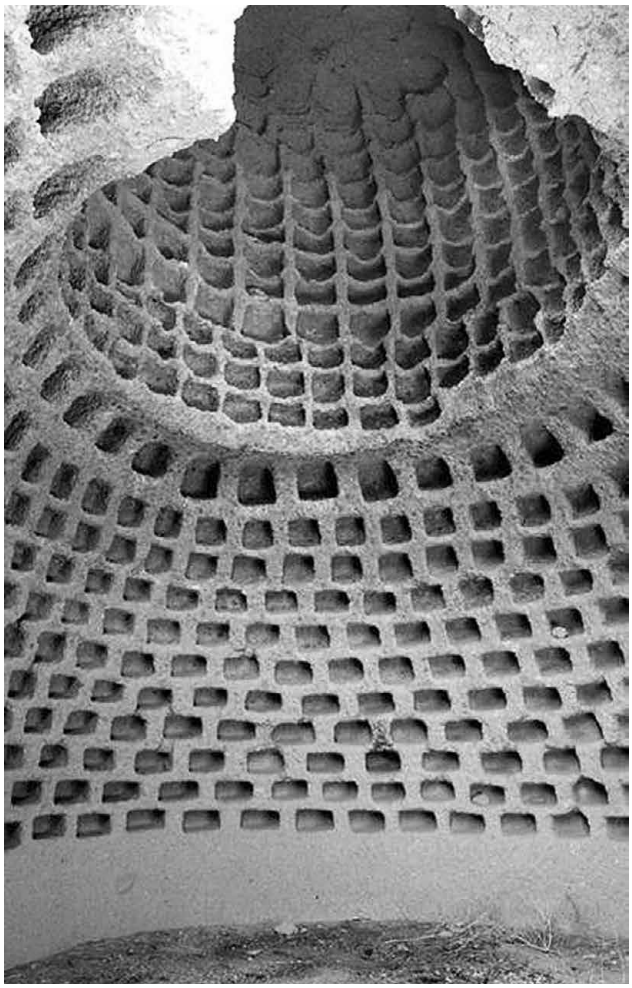

Figure 5. Pigeon-house at Anì (Turkey). Photo: R. Bixio.

C.2 – Burial Places
Crypts, chamber tombs, complex systems such as funerary columbaria, catacombs, and necropolis.

Figure 6. Church at Kizil Cukur (Turkey). Photo: M. Traverso.

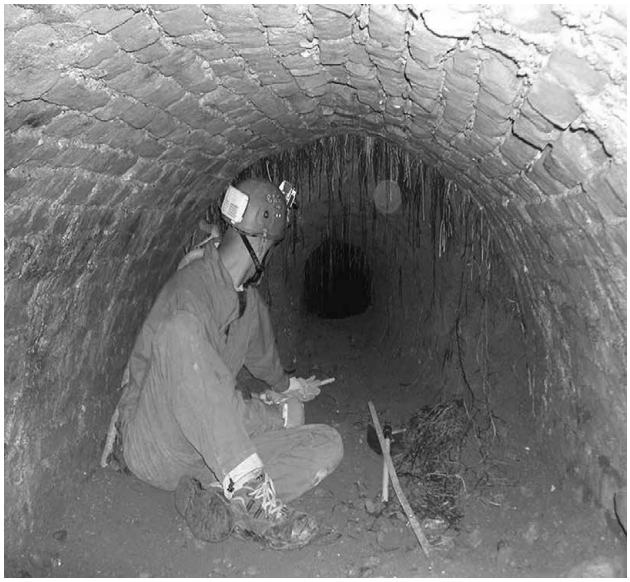

Figure 7. Bastione Verde tunnel at Torino (Italy). Photo: F. Milla.

4.4. Type D – Military and war works

D.1 – Defensive works
Underground fortifications and linked works.

D.2 – Galleries and connecting passages
Military structures for the transit of soldiers and arms; tunnels with military purposes, dating back to a number of different age and in many countries worldwide (Triolet and Triolet 2011).

D.3 – Mine and countermine tunnels
Military tunnels and trenches with a specific role.

Mine galleries: tunnels dug by the attackers to reach and undermine the foundations of the walls or defences of the defenders, or dug by the defenders to reach and undermine the artillery of the enemy (Fig. 7).

Countermine galleries: tunnels dug by the defenders to intercept the mined tunnels and prevent the attack.

D.4 – Firing stations
Rifles, machine guns, cannons and weapons of earlier periods, such as crossbows. In the First and Second World Wars many defensive structures were built underground: some of them were very large (like the Maginot Line, the Siegfried, the Metaxas etc.), whilst many others were isolated sites where the guns and other weapons were located.

D.5 – Deposits
Underground military stores of ammunition, food or other commodities. It is not always easy to determine the intended use of some of these facilities.

D.6 – Sheltered accommodation for soldiers
Shelters from the bombing, dormitories, military command posts.

D.7 – War shelters for civilians
Underground places where the civilian population sought refuge during raids, invasion, shelling, and (particularly) air bombing. They can consist of a single room or develop for many hundred metres.

4.5. Type E – Mining works

These structures can reach huge depths and development (Craddock 1980).

E.1 – Aggregate quarries
Quarries of sandstone, pozzolana, limestone blocks, building stone or ornamental. The structures of this type which are no longer active, frequently have been or are still employed for other uses: cultivation, refugee, sport, tourism, scientific purposes, etc.

E.2 – Metal mines
Mines of copper, iron, tin, lead, gold, etc.

E.3 – Mines and quarries of other materials (non-metallic)
Underground quarries of flint, alum, sulphur, coal, sand for glass, ochre, salt, etc.

E.4 – Non-specific mining surveys
Traces of excavation activities aimed at the identification of mineral deposits. They are typically exploratory tunnels of limited size.

E.5 – Underground spaces to grow vegetables
In these spaces plant products are grown, typically mushrooms and vegetables.

4.6. Type F – Transit underground works

F.1 – Tunnels for vehicles, pedestrian or horses
Galleries at least a couple of metres wide, used in the past for the transit of carriages, wagons, horses.

F.2 – Transit works, not military
The function is the same as F.1, but the dimensions are such as to not allow the transit of wagons and large animals. Only for pedestrian use: tunnels related to villas, castles, monasteries, tunnels to escape, and so on. They certainly do not include military works.

F.3 – Railway tunnels, tramways or funicular (out of use)
Although fairly recent, many are already out of use. They include mine tunnels intended solely for haulage purposes and not for mining.

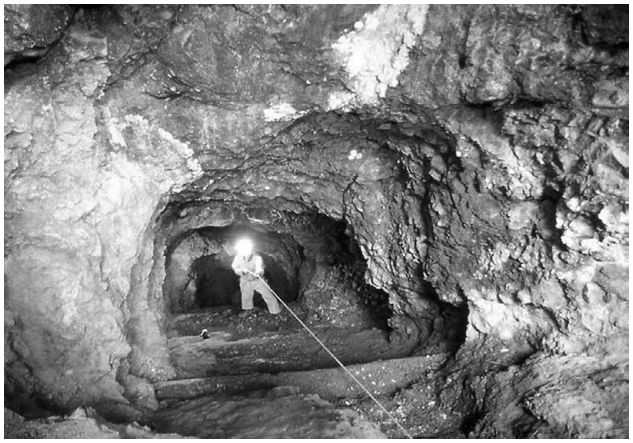

Figure 8. Well at M. Loreto (Italy). Photo: R. Bixio.

F.4 – Non-hydraulic wells, shafts etc.
The wells created for the access, the inspection, or the maintenance of artificial cavities (Fig. 8), today no longer in use because of occlusions or other reasons.

4.7. Type G – Other works

This final and generic category is intended to include all those underground works that do not directly belong to one of the before mentioned types. For instance, the wells that are not part of other undergrounds structures with unknown function (ventilation wells, light wells, cavities for technical spaces, passages, wells for alignment) find space in this typology.

5. Conclusions

The classification here presented, derived from that defined by the Italian Commission, and with further work by the UIS Commission, is not exhaustive, but can represent a starting point for further work and discussion by other scholars interested in artificial cavities.

We hope it may be widely used, as it is mostly aimed at facilitating the discussion among researchers, and at stimulating other cavers and scientists interested in artificial cavities.

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