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The typological tree of artificial cavities: a contribution by the Commission of the Italian Speleological Society

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Abstract

The variety of underground man-made structures is very large. Consequently, the classification chosen by the Commission of Artificial Cavities of the Italian Speleological Society to identify synthetically the nature of a cavity is organised like a tree, based on seven main types, in turn divided into sub-types. The use is made easy by alphanumeric codes. The typological classification of artificial cavities we use today, is due to the work of many colleagues during the last twenty-five years. In particular, in Italy Giulio Cappa and Paolo Guglia and in the international context Joep Orbons, Jérôme and Laurent Triolet, and Roberto Bixio deserve to be mentioned.

In order to write this contribution, some basic texts on speleology in artificial cavities have been consulted: namely, lectures number 41, 42 and 43 of the didactic project of the SSI - UIS, the Speleology Notebook (Quaderno di Speleologia) on artificial cavities published by the SSI in 2006, and the handbook (in press) of the National Course on Speleology in artificial cavities, organised by the SSI Commission in 2011 at Urbino.

KEY WORDS: *speleology in artificial cavities, typologies of artificial cavities, man-made underground structures, typological tree, classification.*

Riassunto

L'ALBERO TIPOLOGICO DELLE CAVITÀ ARTIFICIALI: IL CONTRIBUTO DELLA COMMISSIONE NAZIONALE SSI

In Italia, sin dalla costituzione del gruppo di studio della Società Speleologica Italiana denominato Commissione Nazionale Cavità Artificiali, si è avvertita l'esigenza di procedere ad una suddivisione tipologica delle opere sotterranee di origine antropica. In altri paesi, dove probabilmente le tipologie di sotterranei oggetto di studio da parte di speleologi sono minori, viene utilizzata la sola distinzione fra grotte e cavità artificiali. Da noi la varietà delle strutture ipogee artificiali, con usi che spesso si sovrappongono nel corso dei secoli, ha richiesto la creazione di un albero tipologico che identificasse sinteticamente la natura delle cavità, basato su sette tipologie principali a loro volta suddivise in sotto-tipologie, indicate con codici alfanumerici.

La classificazione correntemente in uso è frutto del lavoro di molti colleghi nel corso degli ultimi venticinque anni: in particolare, in Italia Giulio Cappa e Paolo Guglia ed in ambito internazionale Joep Orbons, Jérôme e Laurent Triolet, Roberto Bixio.

Il contributo qui pubblicato è frutto di una elaborazione di testi ritenuti fondamentali nello studio della speleologia in cavità artificiali: le lezioni numero 41, 42 e 43 del progetto didattico SSI, il Quaderno di Speleologia in cavità artificiali pubblicato dalla SSI nel 2006 ed il manuale del Corso Nazionale di Speleologia in cavità artificiali (in stampa) organizzato dalla Commissione SSI nel 2011 a Urbino.

PAROLE CHIAVE: *speleologia in cavità artificiali, tipologie cavità artificiali, albero tipologico, classificazione.*

INTRODUCTION: MAN AND THE SUBSOIL

The use of underground natural spaces (caves) is as old as mankind. From prehistoric times man has developed a culture of building that, from a simple adapta-

tion of hypogean spaces (Fig. 1), has led to the creation of modern skyscrapers. However, technology has produced not only architectures on the surface (epigean), but also in the subsoil.

The very fact that when thinking of prehistory one

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thinks of the caveman, shows how humanity, since its very beginning, has been familiar with the subsurface and the underground sites. It appears broadly plausible that prehistoric man was led into the ground in search of water and minerals, reasons that still after many millennia variously lead us to dig the earth.

The beginnings of such activities date back to very remote times. Australian aborigines, at a level of development similar to the European Palaeolithic, had already dug deep galleries to find water and mines for the extraction of flint, known since the early Neolithic.

So initially they dug to extract pigments (red ochre) and flint cores to be transformed into tools. Then, during the Copper age (3,500 to 2,500 B.C.), man used the techniques of excavation to capture underground water veins (especially in the arid North African or Asian regions) and for mining purposes (for example, copper and iron mines in Etruria, Latium, Italy).

In Italy between the eighth and sixth centuries B.C., the work of excavation became frenetic: in Latium alone, the number of cavities made in that period is estimated at several thousand. Digging the soil to extract what is necessary for survival, man discovers that he can find shelter from the natural elements in the cavities so obtained, exactly as in a cave. Therefore, the

Neolithic mining technique can be considered the origin of the architecture in the negative.

In Roman times the hydraulic technique, using the knowledge previously acquired by the Etruscans and Greeks, reached its highest peak. Long stretches of aqueducts were built underground. The Greek and Roman tunnels were aimed at the transport of water derived from springs or streams.

Underground tunnels, in a trench or in the subsoil, alternate with channels on arches in order to maintain the slope required to reach the predetermined point of arrival.

Similarly, to drain excess water from valuable agricultural areas, long underground tunnels were dug with techniques similar to those used for aqueducts (Fig. 2).

The ease of processing and utilisation of volcanic materials has allowed, since Roman times, the use of pozzolana for the construction of hydraulic mortar and of lithoid tuff as material used in construction. Therefore, stuff in the subsoil has been intensively exploited, removing the material from underground quarries and digging in the course of ages many galleries and tunnels, distributed in areas of great extent, often on multiple levels. The quarries were developed mainly in central-southern Italy, in the soft soils of tufa and pozzolana, in lithoid tuff or, more rarely, in sands and gravels.



Fig. 1 - Permanent dwelling: Petruscio settlement, Apulia (photo C. Germani).

Fig. 1 - Insediamento permanente: Gravina di Petruscio, Puglia (foto C. Germani).



Fig. 2 - Emissary of Nemi Lake, Latium (photo C. Germani).

Fig. 2 - Emissario del Lago di Nemi, Lazio (foto C. Germani).

In the Middle Ages, the cave environment was identified as the devil's kingdom and for about a millennium the natural caves were no longer populated, except by witches, alchemists, and bandits. In the same period, where the geological structure was favourable (easy to cut rocks such as tuff and sandstone), people continued to dig the earth, thus creating complex settlement structures, which were easy to defend and self-sufficient. These were much safer than the towns left in disrepair.

To this period belong the many monastic complexes (eremical, cenobitic and of mixed type) that characterised, in particular, the areas close to the Via Francigena, and, more generally, the areas marked by the stay, or the passage, of Basilian and Benedictine monks.

Also to be mentioned are the military works, which since the Middle Ages and until the Second World War have marked the historical events of the territory: strongholds, ramparts, tunnels and trenches, mine and countermines, firing positions, fortifications and even the underground shelters in towns to escape air raids.

In conclusion, where climatic conditions or historical events required it, and the morphology and lithology were favourable, techniques of excavation or construction in negative (by subtraction) were developed, and they produced in the course of ages a large part of what we now call artificial cavities (Fig. 3). They are underground structures, spread all over the world, diversified by age, excavation technique and purpose, and of which man is the speleo-genetic factor.

CONCEPT OF ARTIFICIAL CAVITIES

In Italy, conventionally, artificial cavities are the underground works of historical and anthropological interest, man-made or readjusted by man for his needs. Therefore artificial cavities are considered to include both man-made works (excavated, built underground or turned into underground structures by stratigraphic overlap) and natural caves if readjusted to human needs, at least in part. For example, the natural caves used as shelters in the Alps during the First World War, the hermitages in natural shelters, etc. Both of these sorts of underground space are included in the classification system and site-register ('cadastre').



Fig. 3 - Jordan (photo C. Germani).

Fig. 3 - Giordania (foto C. Germani).

cation system and site-register ('cadastre').

It is obvious that the size of the "phenomenon of artificial cavities" in a given place, both by number and by extension, is in direct and inverse correlation with the hardness of the rock and, as a consequence, with the 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 on 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.

MOTIVATION

The reasons why very different people, in different epochs, dug the depths of the rock are to be found in the need to:

- obtain water and/or minerals;
- exploit the natural thermal properties of underground sites to survive in adverse weather conditions;
- 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.

EPOCHS

Even our modern civilisation is "colonising" the subsoil: subways, car parks, road tunnels, shopping centres, scientific laboratories, military works, mines, and so on. The artificial cavities have been constructed for over thousands of years without interruptions since the remote past to the present days.

To provide a first statistical indication, in the Italian Register of Artificial Cavities there is a field that shows the time of construction (indicated by a lowercase letter) of the underground facilities, conventionally grouped as follows:

- a = prehistoric
- b = protohistoric
- c = pre-Roman (Etruscan for example)
- 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

STUDY AND CLASSIFICATION OF ARTIFICIAL CAVITIES

To ensure the proper investigation and cataloguing of anthropogenic cavities it is crucial to identify:

- the technique of construction;
- the function (or purpose);
- the time of excavation;
- 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.

PART ONE: CATEGORIES

A first broad general subdivision is based on the construction technique. In turn, each category is classified (see: part two, Types) with respect to the use for which each structure was, or is, used.

Techniques of construction

- 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 the dressing of the walls and the 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. Often in urban areas human activity 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 cav-

ities and those of artificial origin (anthropogenic). In general, they are structures with limited extent, within which man has built housing and/or has dedicated the cave to the cult: a cave-shrine.

PART TWO: TYPES

According to the function (intended use) for which an artificial cavity was, or is still, used it has been established a classification into types, regardless of the construction techniques ("categories" described above).

TYPOLOGICAL TREE

The variety of underground artificial structures is very large. Consequently, the classification chosen by the Commission of Artificial Cavities of the Italian Speleological Society to identify synthetically the nature of a cavity is organised like a tree, based on seven main types, in turn divided into sub-types (Fig. 4). 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.

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; Fig. 5) and reservoirs.

A.2 – Underground stream interception structures

Tunnels and galleries designed to capture underground water veins or dripping waters (Fig. 6). 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. 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.

A.5 – Wells

Vertical drilling to reach the drinking water 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*).

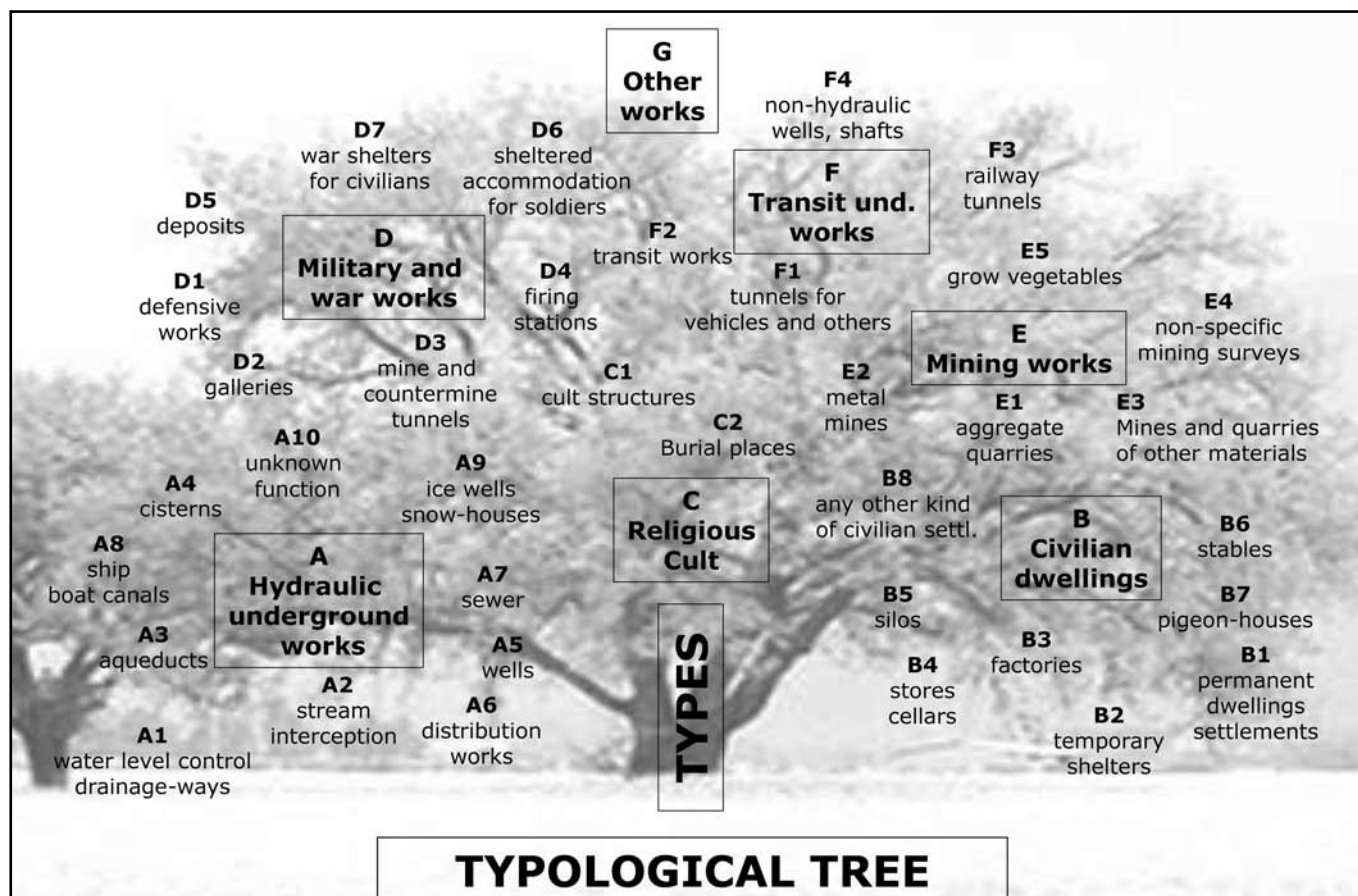


Fig. 4 - The typological tree of Artificial Cavities by the Commission of the Italian Speleological Society.

Fig. 4 - L'albero tipologico delle cavità artificiali elaborato dalla Commissione Cavità Artificiali della Società Speleologica Italiana.



Fig. 5 - Emissary of Nemi Lake, Latium: the marble filter of Roman epoch (photo C. Germani).

Fig. 5 - Emissario del Lago di Nemi, Lazio: il filtro in marmo di epoca romana (foto C. Germani).

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

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.

A.10 - Tunnels or ducts with unknown function

Sometimes there are traces of ducts that are identified as water works, but their specific function is not known with certainty.

Type B - Hypogean civilian dwellings

B.1 - Permanent dwellings

Long term settlements, cave dwellings, underground houses. Most cave dwellings have now been abandoned. However, the historic Sassi of Matera (Southern Italy) are recovering thanks to a recent, extensive renovation. In China, Cappadocia (Turkey) and Granada (Spain) they are still digging into the rocks public buildings and private houses, 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.



Fig. 6 - Underground stream interception of Egeria Nymphaeus, Roma (photo C. Germani).

Fig. 6 - Captazione sotterranea del Ninfeo di Egeria, Roma (foto C. Germani).

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. Military factories are classified in 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 closed by a stone carefully worked 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 and bees (except pigeons, see B7).

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. 7).

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. For example, the rocky apiaries (see Bixio & De Pascali, this volume) represent a typology identified just recently (currently included in B.6).

Type C – Religious/cult structures, veneration works

C.1 Nymphaeum, Mithraea (Fig. 8), temples, sacred



Fig. 7 - Pigeon-houses. Cappadocia, Turkey (photo C. Germani).

Fig. 7 - Piccionaie. Cappadocia, Turchia (foto C. Germani).



Fig. 8 - Mithraeum of St. Nicholas, Guidonia, Latium (photo C. Germani).

Fig. 8 - Mitreo di San Nicola, Guidonia, Lazio (foto C. Germani).

wells, shrines, monasteries, churches and chapels, etc. (Fig. 10).

If the structures 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.

C.2 – Burial Places

Crypts, chamber tombs, complex systems such as funerary columbaria, catacombs, necropolis, *Domus de Janas* (Sardinia).

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 that can be found in every age and every country.

D.3 – Mine and countermine tunnels

Military 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.
- 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 (Fig. 9). They can consist of a single room or develop for many hundred metres.

Type E – Mining works

They are structures that can reach huge depths and development.

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, refuge, 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, in general, exploratory tunnels of modest size.

E.5 – Underground spaces to grow vegetables

In these spaces plant products are grown, typically mushrooms and vegetables.

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.



Fig. 9 - Caetani Caves: shelter (for civilian) of the War World II. Cisterna di Latina, Latium (photo C. Germani).

Fig. 9 - Grotte Caetani: rifugio (per civili) della II Guerra Mondiale. Cisterna di Latina, Lazio (foto C. Germani).

F2 – 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. Certainly not military works.

F3 – 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.

F4 – Non-hydraulic wells, shafts etc.

The wells created for the access, the inspection or the maintenance of artificial cavities, today no longer in use because of occlusions or other reasons.

Type G – Other works not included in former categories

Certainly you cannot expect to classify all structures: a generic category is therefore needed. For example, 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.

DEFINITION OF THE REQUIREMENTS OF ARTIFICIAL CAVITIES TO BE INSERTED INTO THE REGISTER

In Italy it is possible to insert into the register of artifi-



Fig. 11 - Cappadocia, Turkey (photo C. Germani).

Fig. 11 - Cappadocia, Turchia (foto C. Germani).

cial cavities all man-made underground cavities which have particular historical importance, or particular importance in relation to the construction techniques adopted and the mode of use. They have to be not in use.

The size of the cavities has to be not too small: a minimum size of 5 metres (horizontal, vertical, oblique) has been used as a guideline.

Natural caves with artificial parts over fifty percent of the overall development can be inserted in both registers of natural and artificial cavities.

The procedures to be followed to insert an artificial cavity into the register, the basic information and documentation to be delivered with the card register, are set by the National Cadastre of Artificial Cavities of



Fig. 10 - Religious/cult structure: a rupestrian church in Apulia (photo C. Germani).

Fig. 10 - Struttura religiosa/di culto: chiesa rupestre in Puglia (foto C. Germani).

SSI. Any additional data relating to the artificial cavities can be reported and must always be taken into account by the Coordinator of the Register at the time of archiving and data management.

PROPOSAL FOR ADOPTION OF STANDARD SYMBOLS IN SURVEYING AND MAPPING OF ARTIFICIAL CAVITIES.

For many years UIS has been adopting schemes of ref-

erence both for the mapping of caves and for the indications relating to the karstic surface phenomena.

Similarly, it would be very important to encode the most suitable graphic symbols to represent the artificial cavities, comparing and sharing those already in use in different countries.

In particular, it would be interesting to include the indication of the artificial wells (water, light, ventilation wells), the magnetic north, the direction of excavation, the direction of water flow, etc.

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