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CAVE SCIENCE

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*Cave Science**

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THE study of caves in all their varied aspects is given the general name of spelæology.

Caves offer many different subjects of research to the student, and in the following pages we will glance briefly at their principal aspects, dwelling chiefly on the biological researches which have been the writer's particular concern.

No less worthy of consideration, however, is the explorative side of spelæology, which generally absorbs much energy and makes especial demands on the spelæologist. Indeed it requires a form of "Alpinism" whose chief characteristics are quite peculiar: it must be remembered that if the locality is new, a genuine *exploration* has to be made with all the unknown quantities and surprises inherent in unexplored territory, and with the disadvantage of being nearly always cut off from any kind of communication with the outside world. But if this were all it involved it would still be a relatively simple affair.

The exploration proper is only started after a long series of preliminaries ranging from locating the exact site of the cave to transporting the necessary equipment and making all the preparations. Lined up together on the ground for hunting and collecting are strange-looking bandoliers made like cartridge belts but provided with thick glass test-tubes, and in some cases, pairs of peculiar steel pincers or leather harness with hooks and strong rings; small cases containing compasses, goniometers, altimeters, thermometers, barometers, and hygrometers; helmets with odd-looking lamps and flexible tubing fixed on top, coils of rope, ladders of flexible steel cable, miners' lamps, accumulators for under-water lighting, overalls,

*Translated by Teresa Magnani.

floats, diving suits, field telephones, and other objects which are of less bulk but just as necessary and precious as the others. Then, if we are dealing with chasms, begins the longest, most fatiguing and most delicate of all the preparations, the one on which the outcome of the exploration largely depends—the putting together of the equipment used in descending the abysses. The actual exploration often presents extreme difficulties; climbing down overhanging walls, wading through rivers or basins of ice-cold water, negotiating cascades or under-water 'siphons' or large semi-liquid deposits of bat guano, in which there is a risk of sinking and being swallowed up as in quick-sands.

All this often necessitates spending long periods underground, which may stretch into days on end, often in danger of an unexpected storm bringing down enormous torrents of water from which escape is difficult. On August 25th, 1925, this misfortune actually befell the unlucky expedition which was exploring the Bertarelli Abyss, when two men were swept away and dashed to pieces by the force of an unexpected flood, while the rest of the party escaped only with great difficulty after indescribable adventures.

Even greater complications and perils are encountered when exploring caves with vertical shafts, especially when these are the site of water phenomena.

Since lively interest has always been aroused by the great depth of some of the caves, a table is given below of the principal caves of the world arranged in order of depth. (Multiply by $3\frac{1}{4}$ times to convert metres to feet).

Cave	Depth	Locality
Spluga della Preta (Chasm of the Preta)	637 m.	Venetia, Italy.
Antro di Corchia	559 m.	Tuscany, Italy.
*Fledermaushöle (The Bat Cave)	557 m.	Styria, Austria.
Anou Boussouil	520 m.	Djurjura, Algeria.
Abisso di Verco	518 m.	Venezia Giulia, Italy.
Abisso di Montenero	500 m.	Venezia Giulia, Italy.

*not completely explored

Cave	Depth	Locality
Abisso Bertarelli	450 m.	Venezia Giulia, Italy.
*Henne Morte	446 m.	Haute Garonne, France.
Abisso Frederic Prez	420 m.	Venezia Giulia, Italy.
Grotta Gugliemo	350 m.	Lombardy, Italy.
Pozzo di Trebiciano	329 m.	Venezia Giulia, Italy.
Tana dell' Uomo selvatico (The Wild Man's Den)	318 m.	Tuscany, Italy.
Il primo abisso del Colle Schirlenico	316 m.	Venezia Giulia, Italy.
Abisso Revel	316 m.	Tuscany, Italy.
Sarkotich	310 m.	Montenegro, Yugoslavia.
Grotta dei serpenti (The Serpents' Cave)	304 m.	Venezia Giulia, Italy.
Abime Martel	303 m.	Ariège, France.
Inghiottoio di Slivia (Gulf of Slivia)	303 m.	Venezia Giulia, Italy.

In France they have recently explored the Chevalier Cave (Dent de Crolles, between Grenoble and Chambéry) which has its own peculiar morphology, formed systematically so to speak by a tunnel with two mouths on opposite slopes of a mountain and with a series of wells rising vertically from the middle of the cave to the summit of the mountain. The distance from the outer mouth of the well to the lowest mouth of the tunnel is 658 metres.

Primitive human and animal life in the caves

Spelæology is indeed young; it has approached full status and taken its place as a serious science only in the final decades of the last century, mainly owing to the work of the Frenchman E. A. Martel. From its first beginnings it has owed a great deal to many other branches of science, and throughout its development has always maintained far-reaching and intimate connections with the other sciences.

A generalised interest in caves had already been aroused in the rare observer as far back as the Middle Ages, but we have few accounts of their explorations which are worthy of record, apart from awe-struck reports of the inevitable "stone-forest" or the immensity of the subterranean regions.

*not completely explored

A particular interest was awakened in their minds by the mysterious origin of underground caverns, and among a variety of extraordinary hypotheses put forward on the subject were some reasoned views ascribing that origin to the erosive action of water. The underground circulation of water continued to be a favourite topic right up to the nineteenth century: during this period the hydrology of the caves was considered to be the largest and most important problem raised by spelæology: and it is not out of the question that from a practical point of view this may indeed be one of the fields in which the study of the world underground will yield the greatest results.

In the course of these early investigations, layers of fossilised bones were discovered, which were considered tangible evidence of the much discussed destruction wrought by the hypothetical Flood.

The discovery some time later of the remains of human occupation revealed the customs and habits of a people who had taken refuge in these regions tens of thousands of years ago. All the articles of those distant times, fashioned in the hardest types of stone (flint, crystalline rock, etc.), came to light a few at a time, and along with them were found not only the bones of animals now vanished from these regions, or even completely extinct, but also the remains, though of course also fossilised, of our remote ancestors.

Such finds aroused at first—and it was not many years ago—an unusual degree of interest, since they were held to belong to the famous, though according to present opinion fictitious, man-ape, the connecting link between us and the animals which became the subject of lively polemics between the supporters of this theory and those students who rightly opposed it. The palæanthropologists went on with their researches in this field in the hope of one day discovering the hypothetical "Tertiary man"; although this result has not yet been achieved, the discoveries which follow from year to year are both important and encouraging.

The spelæologists can certainly be given credit for discovering most important traces of the art of primitive man—marvellously preserved after tens of thousands of years—in caves in various parts of the world and, especially in Europe in the Pyrenees. For example, there is the statuette of a bison found by M. Begouen in the Tuc d'Audobert cave, and the headless statue of a cave bear, whose origin is attributed to an era twenty thousand years ago, which was discovered in 1923 in the Montespan cave, thanks to the efforts of N. Casteret.

These surprising and sensational discoveries aroused enormous interest all over the world, for they were destined to shed new light on the much-debated problems of primitive mankind.

Parallel with these celebrated studies there has in the last few decades been a remarkable expansion in all the other scientific or practical fields of research, especially in palæontology. Systematic excavation has brought to light vast layers of fossilised bones of animals now vanished from the face of the earth, making possible a better knowledge of the fauna and flora of geological periods remote from humanity, and showing up clearly the different climatic phases which followed one another on each continent and which determined the successive different types of fauna and flora, of which clear traces remain in the caves.

It seems to-day almost impossible that the European continent should once have been overrun by elephants, or mammoths, by gigantic cave-bears, or by lions and tigers, but the fossils found in the caves bear certain witness to it. In some caves in the Pyrenees they have found traces of claws and fur left in the clay by *Ursus spelæus*, while in other caves it has even been proved that the rock walls in very narrow passages have been rubbed smooth by the friction of the bears' fur as, perhaps for thousands of years in succession, they pushed their way into the caverns where they had their lairs.

The palæontological deposits found in caves are of remarkable thickness—sometimes many feet—and often very rich in precious fossil substances. In the cave called Bucco dell' Orso (The Bear's Mouth) on Lake Como in Italy, for example, it has been calculated that there are at least three hundred skeletons of cave-bears !

The practical importance of subterranean hydrology

The importance of geological researches carried out in the caves is immediately obvious if we consider that one of the endeavours of the geologist is to compile maps of the earth's depths, proceeding by examination of the surface evidence.

The help which can be derived from direct investigation into the heart of the rock is, however, limited by the fact that the existence of caves is not a universal phenomenon but appears only in certain territories containing soluble rock (calcium carbonate). Caves in other regions are due to different causes possibly having nothing to do with the dissolution of calcareous rock under the action of water. They are rare and of negligible importance.

The geologist can, in any case, study all the problems inherent in the origin, development, and destiny of subterranean caverns; valuable discoveries can often be made of the circulation of underground water, with particular regard to its practical utilisation for hydroelectric power, irrigation, and the supply of water for the needs of man.

In connection with the supply of drinking water to the city of Trieste a lengthy investigation was made into the subterranean hydrology of the Carso, which was summarised in masterly fashion by E. Boegan in "The Timavo", a work published in the collection of "Memoranda of the Italian Institute of Spelæology (Postumia)". As a result the aqueduct serving Trieste uses water from the Randaccio spring, which is fed from the subterranean course of the Timavo—the largest and most typical underground river in Europe.

It is a widespread belief that underground water is free from impurities detrimental to the health of man, but although we may drink such water quite freely when it is distributed by modern aqueducts furnished with perfect sterilisation plants, there can be no such guarantee of safety when the water reaches us without undergoing the special purifying process. In actual fact water circulates through the strata of calcareous rock by means of cracks which are large enough to allow the passage of dangerous organic impurities along with the liquid. It is very rare for water flowing underground through the fissures in calcareous rock to be free from dangerous infection. Moreover people living on the mountains frequently get rid of the carcasses of animals which have died of sickness, and of offal and domestic refuse by tipping it all into the caves. The water infiltrating into the ground then soaks up these deposits of decaying matter and carries their poisons and disease-laden bacteria to the distant spring, which is not suspected of being anything but pure and wholesome. The annals of hygiene record numerous cases of epidemics and of wholesale and persistent poisoning whose origin has been traced to the deplorable practices described above. Sanitary legislation has therefore intervened in many countries and forbidden the throwing of any kind of rubbish whatever into the caves.

The Trou du Toro (Hole of the Bull) is a great gully 2,000 metres above sea-level in Spanish territory in the Maledetta massif of the Pyrenees, not far from the French frontier. The waters of the Rio Barranco are swallowed up and engulfed within it. The Spaniards had intended to divert the waters of this torrent before they disappear into the Trou du Toro, but there were some who suspected that the water spread underground and went to feed the Garonne in French territory, so that its diversion within Spanish territory might irremediably weaken the flow of the French river, with grave consequences for the farming population.

In 1938, after courageous and patient investigation, the French spelæologist N. Casteret succeeded in demonstrating scientifically the correctness of this thesis, and the international issue it raised was settled in favour of France, which, thanks to this expert student of caves, was able to safeguard the interests of the vast area irrigated by the Garonne.

In recent years the caves have been the site of important work in geodesy carried out with delicate and expensive scientific instruments, and a parallel study has been made of the singular meteorology of subterranean caverns, often with strange and unexpected results.

As cosmic radiation is studied in all the layers of the atmosphere, in the depths of the sea, and of fresh water, so too this study has very properly gone underground in order to find out the penetrative powers of these mysterious rays through different types of rock and under varying conditions. This kind of research will not of course remain isolated, but interesting possibilities are bound to develop of transferring its results from a purely theoretical field and applying them to the study of subterranean biology and to mining conditions.

Nor should we forget the important place taken by caves in the history of warfare, and above all the military and civil function they might assume in atomic warfare.

The United States are therefore carefully investigating the complex possibilities of the vast collection of galleries in the Mammoth Cave in Kentucky, an enormous natural cavern covering several miles.

Biospelæology: the study of cave vegetation

After this brief summary of some of the principal fields of study and possibilities of practical application in spelæology, we will pay somewhat closer attention to its biological aspect.

The flora of the caves has aroused scant interest in botanists, but they would in fact repay the most thorough study, since there are many particular aspects worthy of investigation.

The higher plants are only found in the areas near the cave-mouth and those parts of the cave lighted either directly or by reflection from outside, which do not offer conditions of life differing excessively from the normal, and therefore give rise to no outstanding phenomena.

In the interior of the caves, where there is no light at all, the synthesis of the leaf-green pigment chlorophyll cannot occur, and in consequence the flora consists entirely of saprophytes which live on decaying organic matter, instead of relying on photosynthesis.

The fungi frequently found in caves, upon the usually plentiful organic vegetable or animal remains, often exhibit obvious cryptomorphic phenomena, *i.e.*, alterations in their usual structure which make it impossible to recognise the species to which they belong, for in the majority the reproductive organs rarely reach maturity, and so there can be no examination of the seeds, the usual determining factor in the identification of the different species. In some caves which have been adapted for tourists, and have electric light installed (which is turned on at intervals), species of the higher plants have succeeded—though with difficulty—in developing near these sources of intermittent light, making use of the little that they provide for photosynthesis. As an instance we may mention the existence of a new variety of moss (*Brachytegium velutinum* var. *spelæorum* Latzel) which developed near the "Grande Monte Calvario" in the Postumia Cave 1,700 metres from the entrance. This new moss formed a group with other vegetation in proximity to a 500 watt lamp which was turned on for about 500 hours a year (see plate 26).

In recent years attention has been drawn to the common phenomenon of the blackening of concretions in the Postumia Cave, and examination of the blackened patina has revealed the presence of micro-organisms in various stages of development.

I. Politi, who performed the preliminary work, suggests that the bacterial flora present on the concretions may be at least partly responsible for the blackening of the surface, since one suspects the presence of micro-organisms which take up iron oxide and manganese oxide, salts with the characteristic brown or black colour of the discoloration. The blackening of the walls of caves is often, however, due to different, non-biological causes, such as deposits from the dust-laden atmosphere, or particles of carbon from the combustion of the lights used by visitors, or from the fires of cave-dwellers in remote times. Apparently identical phenomena do not always spring from the same cause.

After this note on the study of vegetable biology we will look at some details of animal biology.

The fauna of the caves

If little work has been done on the flora of the caves the same cannot be said of the fauna, which has aroused and continues to arouse a most lively interest.

The first documentary evidence of cave fauna proper comes straight out of the prehistoric Magdalenian epoch, for it is an incising on a fragment of a bison's bone found in the "Trois Frères" cave at Ariège in the French Pyrenees.

The incision represents a cavernicolous insect (*Troglophilus*) which has now disappeared from the Pyrenees and from the whole of Western Europe, but which still exists in regions further East (Italy, the Balkans, Asia Minor). The unknown artist has transmitted in this fragment the most ancient evidence we possess of real cave fauna, which is attributed to an age many thousands of years past (Plate 28).

Prehistoric sculpture and drawings representing other animals (bears, lions, mammoths etc.) which go back to an epoch even more remote than that of the *Troglophilus* incising, do not possess the significance attributed to the latter, since though these animals were presumably the guests, even regular ones, of the caves, they were not properly at home in the subterranean regions.

Next we make a jump to G. B. Trissino who, in the first half of the sixteenth century, saw in the Covolo di Costozza in the Veneto, some little fresh-water crustaceans (*Niphargus*), referred to briefly by F. Leandro Alberti in his "Description of the whole of Italy" (see Fig. 1).

No really significant event occurred, however, until 1768 when the first description appeared of the "Proteus", that extraordinary amphibious newt belonging to the Cave of Istria, which became the most celebrated cavernicolous animal (see Plate 29).

In the last century the general flowering of science gave a notable impulse also to research on animal life in caves, which, it came to be realised, raised biological problems which were both new and highly interesting even from a general point of view. But while the few spelæologists concerned themselves with the new problems presented by the animal population of the caves, the biological aspect was somewhat neglected in favour of the systematic study of zoology. This played the most important part for a long time, which is understandable when it is considered that the caves, even in our own regions, were—and in part still are—virgin territory full of the most alluring new things. To cite only one example from one of the regions most studied by spelæologists—the province of Brescia in Northern Italy—in the past twenty years of biological research we have found at least fifty genera and species hitherto unknown to science!

At the beginning of this century, Racovitza made a survey of biospelæology and drew up a research programme based on the subjects which seemed to him the most important ones to investigate. His work aroused the attention of cave explorers and was a spur to the widening of our knowledge of the life of cavernicolous fauna.

When considering animals in relation to their cave environment, it should immediately be made clear that not all those found in caves are inseparable from them. For many years animals were in fact grouped in three categories

—those which lost their power of reproduction in a cave environment (troglosseni), those which retained this power and could still live in daylight (troglophili), and those which were compelled to spend their whole existence underground, from birth to death, and could not survive in daylight (troglobi). In 1944, the writer extended the scope of this division by pointing out that the troglosseni only arrive in caves by accident, whereas the troglophili actively seek out and prefer the underground dark.

Opinion is divided on the origin of the third group, the compulsory cave-dwellers. Some hold that in very remote times there was no proper cave fauna; that following the setting in of external climatic conditions unsuitable to many forms of animal life, these took refuge in the caves; and after a long period spent in their new surroundings they became completely dependent on the conditions of life underground and incapable of returning to the outside world.

Others suppose that through an actual organic tendency in certain animals these were to some extent forced to seek living conditions which only exist underground, and that the origin of the ties which they have contracted with the caves existed prior to their migration into that world.

One of the various other hypotheses finds the origin of the true troglobi in animals which came into the caves by chance and slowly settled in these surroundings, giving rise to all the troglobian fauna that we now know.

It is obvious that none of these hypotheses can be accepted or rejected in its entirety. Each one of them may correspond to some actual case, but none of them can be accepted outright as having a general validity.

When the distribution of cave animals is studied in further detail, it is found that underground water, like the land, shelters well-defined groups of animals. Even round the mouths of caves, there is a characteristic animal population made up of organisms which love damp, and seem to seek out this environment because the humidity varies less than does that of the normal open world. Occasional caves which are excessively dry, or subject to passing seasons of dryness, often possess a fauna few in numbers and variety.

Light is not a decisive factor in determining the population of a cave. Many other considerations are of much greater importance: temperature, presence and degree of decomposition of vegetable and animal remains, constancy or renewal of the atmosphere, and the physical structure and chemical composition of the ground itself.

Some of the troglobi which love a high humidity can pass indifferently from land to water and back again. The writer has repeatedly seen this in different species of arthropods in caves in Northern Italy; for example Machilia, Trichoniscus, and an unidentified millipede. Sometimes, too, aquatic animals are found out of the water, for example a flat-worm (planarian), and an amphipod crustacean called Niphargus. This latter animal is often

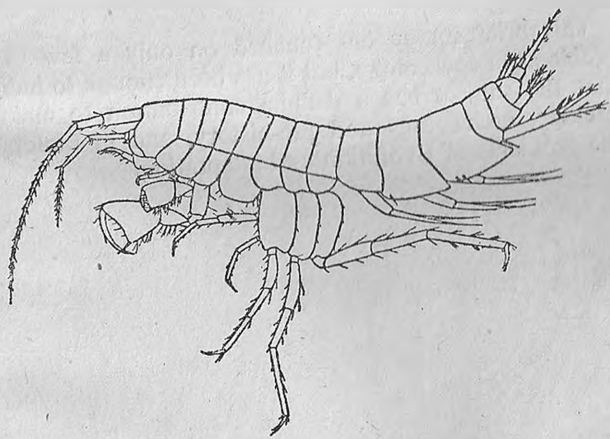
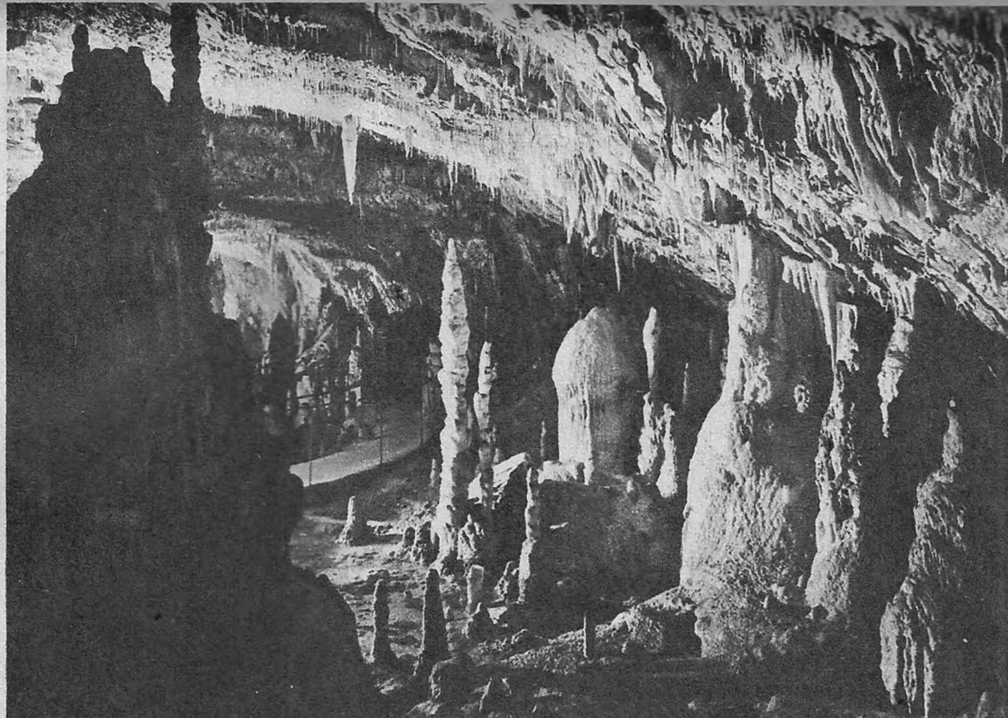


Figure 1

found in the waters of European caves, but where the cave is dry it digs out a little hole in clay with a tiny tunnel running vertically to the surface. This shaft collects the minutest droplets of infiltrating water, and so keeps the Niphargus moist, however dry the cave as a whole may be. If its cell is opened inside the dry clay, a drop of water is often found. Facts of this sort suggest that given a saturated atmosphere, some cave animals do not distinguish clearly between air and water, and their respiratory processes must function equally well in both environments.

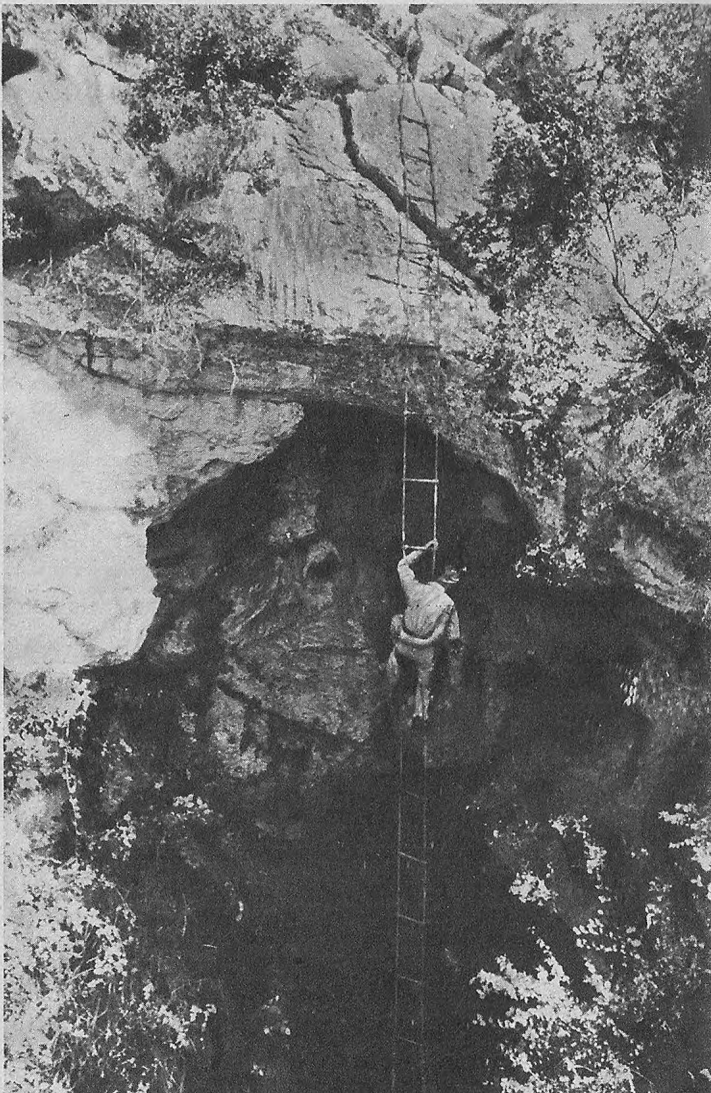
A problem of this kind is perhaps best studied in the laboratory in large experimental chambers in which the conditions of temperature, moisture, etc., can be controlled at will; or at the special underground laboratory fitted out fifteen years ago in the wonderful cave of Postumia in the province of Trieste. Unfortunately this laboratory was damaged by the German Army during the 1939-45 war, and it has recently come under Yugoslav administration; political unrest in the Trieste region makes its future uncertain.

This brief survey has touched on only a few of the problems of spelæology, but it has been enough to indicate that the subject has a definite contribution to make to geology, archæology and pre-history, and in biology to the problems of Evolution and adaptation.

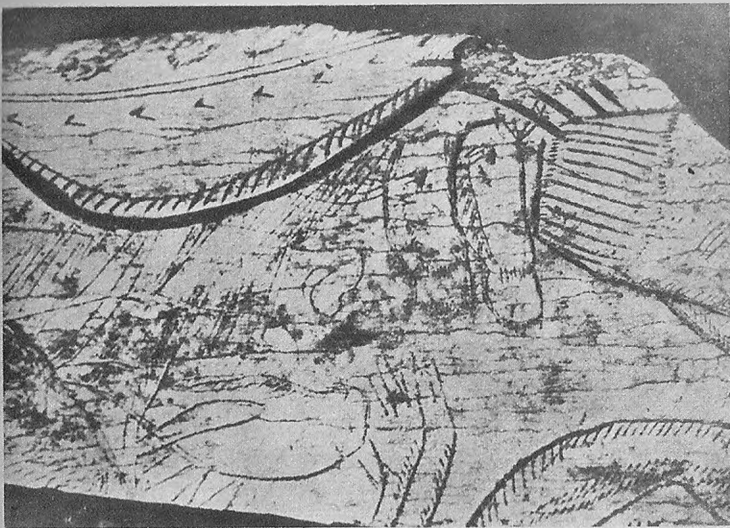


Plates 26-30 illustrate Cave Science *p.* 41.

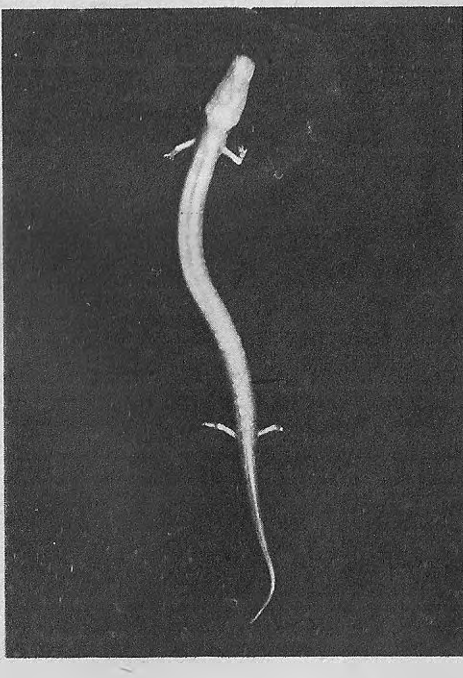
26. View of the Cave of Postumia.



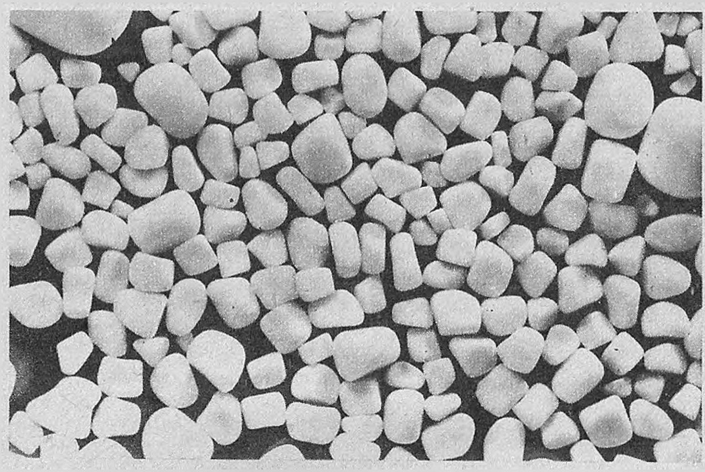
27. Descent into cave on a rope ladder.



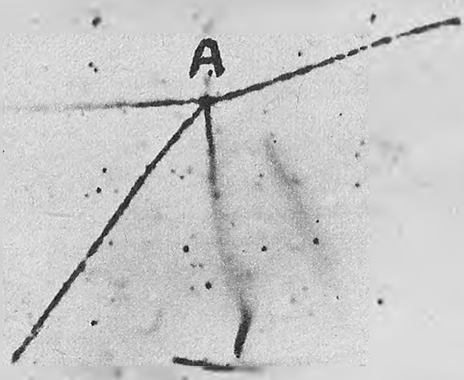
28. Prehistoric drawing of the Grasshopper Troglophilus on a piece of bone from the Grotte des Trois Frères in the Pyrenees.



29. A cavernicolous amphibian, Proteus anguineus *Laur.*



30. Concretions formed in underground water.



31. Atoms of the radioactive element thorium have been incorporated in the emulsion of a photographic plate. At A one of them has burst, giving off four alpha particles (helium nuclei) which have marked the emulsion in their passage. Two of the tracks look fuzzy because they are out of focus in this microphoto of the plate. *See page* 57.