CLASSIFICATION CONFIDENTIAL

CENTRAL INTELLIGENCE AGENCY
INFORMATION REPORT
FOREIGN DOCUMENTS OR RADIO BROADCASTS
CONFIDENTIAL

REPORT CD NO.

50X1-HUM

COUNTRY	USSR	DATE OF INFORMATION	1948
SUBJECT	Speleology		
HOW PUBLISHED	Monthly periodical	DATE DIST.	3 Dec 1948
WHERE PUBLISHED	USSR	NO. OF PAGES	13
DATE PUBLISHED	March 1948	SUPPLEMENT TO	
LANGUAGE	Russian		

THIS IS UNEVALUATED INFORMATION FOR THE RESEARCH USE OF TRAINED INTELLIGENCE ANALYSTS

SOURCE IDENTIFICATION Priroda, No 3, 1948. (FDB Per Abs 77T27 -- Translation specifically requested.)

UNDERGROUND TOPOGRAPHY

N. A. Gvozdetskiy

[Figures referred to herein are appended.]

In this article we shall deal chiefly with the topography, and to a lesser extent with the hydrography, of the underground world.

The largest, most complicated, and varied caverns are found in the so-called cavernous regions, that is, in regions where certain types of rock, soluble in water, are found below the surface or near the surface of the earth.

Rock salt is easily and quickly dissolved in water. But the deposits of rock salt, in which the dissolving process and the formation of cavities and other cave formations takes place very rapidly, occupy only small portions on the surface of the earth and in the inner regions of the earth's crust. Much more widely distributed are gypsum and anhydrite; these are also soluble in water, although not as easily as rock salt.

In the gypsum regions there are many caverns of considerable size and of various topographic formations, developed as a result of the dissolution of rocks.

Even more difficult and slower is the dissolving process of limestone. However, limestone deposits are found in some regions over a vast area in the upper strata of the earth's crust; and due to the continuous action of water the dissolving effect can be seen clearly in the form of huge labyrinths and the most varied surface forms of the caves. In chemically pure water, limestone is practically insoluble, but in water containing carbon dioxide, the solubility of limestone is increased considerably. Natural water always contains carbon dioxide to some extent and, therefore, is capable of dissolving limestone. Due to the action of carbon dioxide the calcium carbonate, which is the substance of limestone, turns into bicarbonate which is more easily soluble in water than in carbonate:

CLASSIFICATION CONFIDENTIAL

STATE	X	NAVY	X	NSRB	DISTRIBUTION
ARMY	X	AIR	X		

CONFIDENTIAL

/

$$CaCO_3 + \underbrace{H_2O + CO_2}_{H_2CO_3} \rightleftarrows Ca^{\cdot\cdot} + 2\ HCO'_3$$

This reaction of limestone dissolution is reversible. Increase in the amount of carbon dioxide in water causes the transformation of solid calcium carbonate into a liquid solution. Conversely, decrease in the amount of carbon dioxide causes the opposite reaction and results in the precipitation of limestone deposits from the liquid calcium bicarbonate solution. This process is connected with the formation of stalactites, stalagmites, and other limestone incrustations and deposits in caverns.

In the same manner the solution of other calcareous rocks such as chalk, marl, and dolomite takes place; but the solution of gypsum and rock salt can take place without any accompanying chemical reactions. The presence in the water of various organic and mineral acids and salts increases the solubility of rocks.

Sometimes the water-soluble minerals only act as a cement, reinforcing the insoluble mineral grains in a certain kind of rock. For instance, in sandstone, particles of quartz and others can be combined by lime. The solution of lime in such a case can also lead to the formation of a cavity, but for this purpose the insoluble sand particles must be carried out by the mechanical action of running water or else by the wind if a shallow grotto is to be formed with a large entrance.

In order that the solution may occur within the rock strata and cause the formation of caves, the soluble rocks must be penetrable by water. Sometimes this penetrability depends on the porosity of rocks, but more often the penetrability of solid rocks, in which large cavities arise, is caused by the presence of many cracks in the rocks. It is, therefore, not surprising that the systems of cracks, forming water passages from the surface and means of circulation of the water in the deeper regions, are usually very clearly reflected in the form of the caverns.

In absolutely horizontal or nearly horizontal layers of rock deposits, which have not been exposed after their sedimentation to fold-formations or other intensive tectonic movements (with the exception of raising and lowering almost without disturbing the character of stratification), one can distinguish two basic types of fissure systems: stratum fissures, passing through the contacts of rock layers corresponding to the top and bottom levels of adjacent layers; and cleavage fissures or diaclases, running in a direction perpendicular to the first, or at an angle to it.

NOTES: (i) Reference is made here to so-called fissures of tectonic cleavage. There are also fissures of primary cleavage, which the French geologist Daubree calls "sinclases" (39).

(ii) The terms "diaclases" and "paraclases" were suggested by Daubree (38, 39) during the past century. These terms are often used by our investigators, but many of them prefer various other technical terms. For the time being, unfortunately, there is no uniform, generally accepted terminology for the designation of various types of fissures.

50X1-HUM

Vast regions consisting of very thick limestone layers with an almost undisturbed stratification are found in the United States. In these regions the influence of stratum fissures on the formation of caverns is usually stronger than the influence of vertical and nearly vertical fissure systems, that is, cavern tunnels and chambers often have greater dimensions in width than in height. It is not surprising that American geomorphologists (37, 45, 42), in their scientific writings on caverns and in textbooks, strictly differentiate the influences of the two above-described types of fissure systems on the development of cavities.

However, if the layers of limestone (or other soluble rocks) are taken out of their horizontal position by dislocation processes, for instance, if they form folds or are strongly inclined in one direction, the stratum fissures (Figure 1) [photograph, not reproduced] can be almost as important as diaclases. In greatly dislocated regions, for instance, the limestone ridges of the northern foothills of the Alayskiy mountain range (southern Fergana), the systems of stratum fissures can be almost undistinguishable from the diaclase systems (fissures of tectonic cleavage). In regions where the layers of rock are dislocated, an important part in the formation of separate caverns is played by paraclases, i.e., fissures formed by the dislocation of adjacent parts of the earth's crust (fault fissures).

The shapes of caves, therefore, depend to a great extent on the character of fissures and the tectonic conditions in each locality.

Figure 2 shows one of the caverns in the valley of the Khosta River in the Caucasus. The shape of the cavern in the diagram is determined by a complicated system of vertical and nearly vertical fissures (diaclases) in the slightly inclined layers of limestone in the saddle of an anticlinal fold. In the formation of the cave's tunnels and narrow passages, the diaclases have played a more important part than the stratum fissures. The tunnels and passages, as shown in the cross section diagram, more often represent cavities extending vertically upwards, or narrow, slightly inclined cavities.

Figure 3 shows a cavern (in the vicinity of Sukhumi), of a different type, consisting of a number of fairly large chambers connected by very narrow passages and openings. The chambers are formed along the steep planes of diagonal fissures; however, the contour of the cavern is influenced not only by the development of cavities through solution and erosion by water of the fissure walls but also by deposits of lime in the form of stalactites along the walls of the cavity. The narrow openings connecting the chambers pass through deposits of lime and are formed as a result of wider openings being filled in by these deposits. Apparently, a cavern of the same type, but on a larger scale, is the Yün Shui T'ung grotto (36) in North China (60 kilometers southwest of Pei-p'ing).

Another cavern (Figure 4), also in the vicinity of Sukhumi (the description of this cavern and of the above-mentioned one is given by the author in Geografiya V Shkole [6]), stresses even more definitely the importance of deposit formations in the profile of the cavern. Here the deposits of lime (shaded areas) have divided one large cavity into four chambers by means of partitions. The ceiling of the cavern is similar to a gable roof of a village hut. The south side corresponds to the inclination of the layer bottom, at an angle of approximately 40 degrees. The other side is covered by stalactite deposits.

The tunnels of underground rivers often form caverns. Sometimes they contain no water, but the formation of the long and narrow tunnels branching out but never interlacing, clearly shows that they were caused by an underground river and its tributaries. In other instances, caverns represent systems of complicated, interlacing, labyrinth passages and large chambers. Such labyrinths, apparently, were formed by great masses of water moving slowly under considerable pressure. The following conditions are necessary for the formation of a cave: rocks soluble in water, water capable of dissolving the rock (water containing carbon dioxide for calcareous rocks), and the movement of such water, even though it might be very slow, within the rock, along the crevices or pores.

Dienert (41) has published the results of observations, made during the building of tunnels, which show that at a depth of more than 300 meters below the present underground rivers there are expanded zones of fine crevices, filled with slowly circulating water. These results showed that cavern processes can develop considerably below the level of subsurface water. At a later date, Davis (37) and Lehmann (44), prominent researchers, stressed the importance of the circulation (under pressure) of water below the level of subsurface water in the development of caverns. In our country, the importance of this question has been considered by geologist D. S. Sokolov and other researchers. Soviet geologists, who have carried out cavern research in connection with hydrotechnical construction, have accumulated a great quantity of material which might aid in solving many questions pertaining to the hydrogeology of cavernous regions.

The nearly horizontal position of the majority of large caverns is a matter of interest. If this had been observed only in regions with horizontal layers, it could be explained by the influence of the layer crevices and the lesser degree of solubility of a certain layer above which a cavern is being formed. However, the nearly horizontal position of large cavities can also be found in dislocated rock layers, and therefore the formation of a cavity should be explained by the circulation of ground water in a horizontal direction (especially underground rivers).

One can often observe several levels of caverns, one above the other. This serves as a proof of the progressive, relative lowering of levels of ground water (levels of underground riverbeds), which is usually connected with the rising of the terrain. The upper caves are found to be more ancient, usually filled to a greater extent with deposit formations, partly destroyed, whereas the lower cavities are more recent. On the very lowest level one can often find underground rivers. The separate cavern levels thus appear as original underground rivers "terraces" which determine the ancient location of underground water currents in the same way as the terrace ledges on the edges of regular erosion valleys determine the level of ancient riverbeds.

NOTE: Regions with horizontal layers form the exception to this rule. Davis (37) proves that in horizontally stratified limestone, where the crevices in layers of different levels form circulatory passages of ground water, one ground elevation may lead to a simultaneous development of several new cavern levels.

The underground water circulation in cavernous mountain ranges may be connected with the development of the surface river network and with the change in position of its erosion basis. However, one should be very careful in drawing parallels between cavern levels and river terraces, as well as other traces in the development of an erosion contour in the vicinity of cavernous mountain ranges, since the lowering of the level of subterranean water currents in cavernous ranges usually occurs later than the incision of surface river valleys. One can often observe rivers flowing out of horizontal cavern passages (vigorous springs, the so-called "voklyuzy") on the slopes of river valleys at a considerable height above the river level. The author has observed in the Caucasus, in the vicinity of Sukhumi, a cavern river flowing out of a horizontal tunnel on the slope of the valley of the Zap. Gumista river at a height of not less than 100 meters above the river level. In Central Asia, in the front ranges of the Alayskiy mountain range (southern Fergana), in the valley of the small Apshir-say River, there is a spring of the "voklyuza" type, which flows out of a horizontal cavern passage at a height of 20 meters above the riverbed. In both cases, the cavern tunnels pass through dislocated layers of limestone. Consequently, the caverns, deprived of water currents, cannot always be compared, according to their location, with river terraces of corresponding height. One must always bear in mind the retarded development of the subterranean hydrographical network compared to the surface river network.

Cavern rivers and lakes are characteristic features of the underground landscape. Long stretches of cavern rivers are sometimes accessible to exploration, but an insurmountable obstacle is often found in the form of "siphons."

The underground Poyk River, flowing through one of the largest caverns of Western Europe, Postoyna Yama (Adelsberg Grotto), has been explored for a distance of several kilometers from its entrance and from the direction of the river outlet in the Planina region, situated 9 kilometers northwest of the entrance to the grotto. This river has been explored by several scientists, among them the French speleologist, Martel who, with the help of a folding canvas boat, has also explored many subterranean rivers in the cavernous regions of France (46).

The largest cavern of Ablaskir in the limestone regions of the Caucasus contains the subterranean Achkhahstyz-gua River. The author has observed several subterranean rivers in the limestone mountains of the southwest Caucasus, and has explored one, together with its subterranean tributaries, for a distance of several hundred meters, in the quaternary limestone conglomerates in the vicinity of the town of Gudauta. In the northern Caucasus, subterranean rivers and brooks can also be found in gypsum regions. Subterranean rivers are found in the Urals, in Crimea, in Siberia, for example, on the south slope of the Aldanskiy mountain range (22), in the Minusinsk region (35), and in other districts.

One can often find accumulations of water in caverns in the form of small lakes. In the foothills of the Kopet Dagh range, there is a hydrogen sulfide subterranean lake, Kou, located in a cavern not far from the town of Bakharden. In the famous Kungursk Cavern in the Ural Mountains, there is a subterranean lake in the Friendship of Nations Grotto (the Titanic Grotto) at a considerable distance from the entrance (Figure 5) [photograph, not reproduced]. Subterranean lakes are found in many caverns of the Caucasus and in other places.

Caves can reach deep below the surface of the earth. Deep cavernous wells, precipices, abysses, or so-called natural shafts, are fairly common in many cavernous regions, although they were formerly considered as exceptional phenomena. In 1924 Martel (49) counted all the abysses known at that time in an area bounded by the Peloponnesus peninsula in Greece, Austria, northern England, and the Pyrenees. The number amounted to around 3,000. More than a third of them are found in the cavernous regions of the Balkan peninsula and about a third in the cavernous regions of France (Causse, Jura, the calcareous Alps, Pyrenees). Martel considers, not without foundation, that similar phenomena will sooner or later be found on the surface of the earth by the thousands. In the USSR natural shafts are found in Crimea (13), the Caucasus, Central Asia, and other regions.

The depth of natural shafts extends down to 100 meters, and sometimes 100-200 meters. Many such abysses were explored by Martel (46), especially in the cavernous regions of France. He and his assistants descended into the deep abysses with the aid of a windlass and a special "swing" and a long rope ladder with wooden rungs. The explorations were made with the aid of a telephone. Some of the cavern shafts reached a depth of more than 300 meters.

Linder's explorations of the 322-meter deep natural shaft located east of Trieste in the region of Trebich (Figure 6), which were conducted in 1840-1844, represented real engineering work which took 11 months (47). This shaft ends in a large cavern with water at the bottom.

However, the depth of 322 meters does not appear to be the maximum depth reached in subterranean explorations. Southeast of Trieste near Raspo, is the Bertarelli Abyss (Grotto della Marna), which presents a system of grottos with funnel-shaped entrances and deep wells descending vertically one after the other and separated by low terraces, with a long tunnel below, proceeding from the wells at a slight incline (Figure 7). In 1924, a subterranean alpine expedition of 22 persons reached a depth of 381 meters (50) in this cavern system. Further advance was obstructed by a stone blockade. Later, this blockade was cleared away by a subterranean flood, and the next expedition, sent out in the summer of 1925, found the passage to be free and reached a depth of 450 meters, at which point the passage of the tunnel went below the water level. A sudden downpour took place above, and violent torrents rushed into the abyss. Two persons were carried into the chasm by the flood, and eight alpinists barely managed to save their lives after being trapped 30 hours at the bottom of the abyss. (51)

Among the caverns of Western Europe, the largest one apparently is the Eis-Riesenwelt Cavern, 36 kilometers south-southwest of Salzburg. In 1923, 30 kilometers of underground labyrinth passages were measured by means of a theodolite (scale 1:400) in this cavern. The cavern owes its name to the ice formations which extend 2 kilometers from the entrance. (48).

The Agtelek Cavern in Hungary, which has been thoroughly explored, is 22 kilometers long. The best-known cavern in Western Europe is Postoyna Yama (Adelsberg Grotto) east of Trieste with the subterranean Poyk River. The cavern is equipped for inspection by tourists for more than 4 kilometers, and the length of its known galleries totals 21 kilometers (11 kilometers extend without interruption).

Huge caverns with magnificent ornaments of stalactites and stalagmites are found in Czechoslovakia (caverns of the Moravian "kras", i.e., caves).

In the USSR, caverns are found in various regions. The largest of the explored caverns is the famous Kungursk Cavern in the Urals. (1, 12, 25), which has a labyrinth with a total length of 4.6 kilometers. The cavern is formed in a gypsum stratum, deposited between limestone and dolomites. There are also a great number of other interesting caverns in the Urals.

In the Caucasus, in Central Megreliya (Mingreliya), there are caverns 3 to 4 kilometers long which have been formed in Neogenic lime conglomerates, representing tunnels of subterranean rivers (18, 19). These caverns contain few limestone deposits. However, in the limestone conglomerates (of the lower Quaternary period) on the terrace plateau, which is on the left bank of the Belaya River (Khipsta) in Gudouty rayon, there are caverns with beautiful pure stalactites. The largest one of the explored stalactite caverns in the massive limestones of the Caucasus reaches a length of 2 kilometers. It is the Ablaskir Cavern, southeast of Sukhumi (17, 19). There are also fairly large stalactite caverns in Crimea (13). There are glacier-caverns in the Caucasus similar to those in the Urals, (14 and others), and in Crimea.

Caverns may be found in many places on the plains of European USSR: in the central district along the Volga River in Gor'kiy Oblast (16, 23) and in the Tatarsk ASSR (30); in the Lower Volga district in the vicinity of Lake Baskunchak (7), and in other places.

Not much exploring has been done in the caverns of Siberia (29, 21, 35, 33) and the Far East. Some of them, apparently, are quite imposing in size.

The caverns of Central Asia are interesting. The famous Chil'-Ustunskaya stalactite cavern in the Oshskiye mountains (southeast Fergana) is known for its inaccessibility -- the entrance to the cavern is located on a high rocky precipice (34). The intricate labyrinth of the Kan-i-gut Cavern (24) in the foothills of the north range of the Turkestan mountains, bordering the Fergana valley on the south is notable (Figure 8). The individual chambers in this labyrinth reach a height of 40 to 50 meters. The formation of these huge caves was strongly influenced by the reaction on the limestone of the sulfuric acid contained in the circulating water, which was generated through oxidation of iron sulfides, lead sulfides, and others, contained in the rock. The Karlyuk Cavern on the west slope of the Kukitang-tau range in the easternmost part of the Turkmen SSR apparently competes with the Kungursk Cavern in the length of its passage. (9).

50X1-HUM

The study of cave formations is necessary for hydrogeological investigations of areas containing soluble rocks. In this case it is related to the water supply of inhabited places and business enterprises. It is very important to take into account the presence of cave formations in carrying out forest exploitation measures. The influence of cave formations on agriculture (40), is varied in nature and can be very important.

Cave phenomena often create considerable difficulties in carrying out various kinds of technical construction work, especially in hydrotechnical construction. There have been cases of the leakage of water from a reservoir into the fissured limestone which is subject to cave formation. The reservoir of the dam at Monte-Khako in Spain, at an elevation of 72 meters, which was built over fissured limestone, has never been filled with water. According to the testimony of the geologist M. Lyuzhon, "it is nearly always possible to approach the base of the dam from the upper side" (15). The small dam at Saint-Guillelme-le-Desert in France "does not hold one drop of water, all of which leaks out under the construction." Such reservoirs, along whose bottom it is possible to walk without getting the feet wet, are the result of not taking the specific geological conditions into consideration at the time the project was constructed.

There have been instances of the destruction of dams because of cave formations (8). The dam at Austin, Texas (USA) caved in on a cavern. The cave process (solution of gypsum layers in the conglomerates of the dam foundation) was one of the reasons for the gigantic catastrophe -- the destruction of the St Francis Dam in California.

However, even in cases where development of cave processes in a certain area is known, it is not always necessary to refrain from erecting hydrotechnical structures. In such a case, a detailed study of the cave area can indicate the choice of a site for the construction, the necessary precautionary measures, etc.

In the USSR, the planning and building of dams and reservoirs in limestone areas in places where gypseous rocks are abundant is carried out after a careful study of the forms and conditions of the cave phenomena.

The choosing of sites for buildings and other heavy structures in cavernous areas also requires serious investigation of the cave phenomena. The study of cave phenomena is also important in railroad construction. There have been instances of railways being built without consideration of the cave phenomena, which led to very undesirable results (10, 31, etc.). Sometimes cave phenomena give rise to unexpected results in the construction of tunnels (26).

The importance of cave phenomena in the mining industry is great and varied. They greatly complicate the exploitation of mineral resources found below rocks which are subject to cave processes, or found within the layer of such rocks (20, etc.). Many of the deposits of mineral resources are genetically connected with cave phenomena (2, 32, 43, 47, etc.). In cases where the mineral fills in ancient caverns, the cave theory is a great aid in prospecting, as the knowledge of present cave processes offers the key to an understanding of the expansion and forms of ancient cavities. From a practical standpoint, a study of the surfaces of the buried mineral caverns is very important. The present surface forms of cavernous regions make it easier to expose the location of such mineral resources as limestone and gypsum.

The great and manifold practical importance of the study of cave phenomena and their widespread occurrence in the USSR, was the reason for the scientific conference held in the city of Molotov in January 1947, under the sponsorship of the Natural Science Institute and the Molotov State University imeni A. M. Gor'kiy. This conference was dedicated to problems of cave investigation and was attended by specialists from Moscow, Leningrad, Voronezh, Sverdlovsk, Kazan', Simferopol', and other cities of the USSR. After 47 reports were made on various questions connected with the study of cave phenomena, a resolution was passed.

One of its chief points was that a new branch of science, speleology, the study of caves, had arisen in the USSR. Actually the conference in Molotov marked a great improvement in the accumulation of facts, in the elaboration of methods for studying cave phenomena, and in the consideration of theoretical problems connected with caves in the USSR. The establishment of speleology is connected with numerous scientific investigations in the process of fulfilling the program of magnificent construction work of the Stalin Five-Year Plans.

BIBLIOGRAPHY

1. V. Ya. Al'tberg, "The Kungursk Ice Cavern," Priroda, No 10, 1930, pp 1,036-1,041
2. G. Berg, "Geochemistry of Sites of Mineral Resources," 2d edition, ONTI, Moscow, Leningrad, 1937, pp 94, 96, 168-171, 191, 273, 275
3. Ya. A. Birshteyn, "Life in the Caverns," Uspekhi Sovremennoy Biologii, Vol XIII, No 3, 1940, pp 385-402; "Adaptation and Evolution of Cave Animals," Uspekhi Sovremennoy Biologii, Vol XIV, No 3, 1941, pp 436-553
4. Ya. A. Birshteyn and G. V. Lopashov, "Exploration of the Fauna of Caverns in USSR in the Years 1935-1939," Byulleten' Mosk Obshch Isp Prir, Otd Biol, Vol XLIX (3-4) 1940, pp 29-38
5. V. Vitkovskiy, "Beyond the Ocean," 2d edition, St Petersburg, 1901, pp 252-277
6. N. Gvozdetskiy, "In the Caverns of Abkhaziya," Geografiya V Shkole, No 4, 1940, pp 9-15
7. A. A. Gedeonov, "Caverns in the Vicinity of Lake Baskunchok," Izv Vses Geogr Obshch, Vol 72, No 3, 1940, pp 400-403
8. A. A. Gel'fer, "Causes and Forms of Destruction of Hydrotechnical Installations," ONTI, Leningrad, Moscow, 1936, pp 39, 82, 135, 145, 146, 189, 191, 199
9. A. V. Danov, "Geological Outline of the Karlyukskiy Rayon of Kerkinskiy Okrug TSSR, Western Bukhara," III Vses Geol S"yezd v Tashkente v 1928 g, Putevoditel Ekskurs, Leningrad No 1, 1928, pp 26-28
10. D. L. Ivanov, "Ufimskiye Craters, Collapses on the Samara-Zlatoust Railroad," Izd Sobr Inzh Put Soobshch, St Petersburg, 1899
11. Ya. D. Kirshenblat, "Peculiarities of Cave Animals," Priroda, No 8, 1939, pp 38-48
12. M. Kittary, "The Ice Cavern in the Vicinity of Kungur," Zhurn Min Vnutr Del, Vol XXIII, St Petersburg, 1848, pp 357-381
13. A. A. Kruber, "Cave Region in the Mountains of Crimea," Moscow, 1915
14. K. M. Kurdov, "Notes on Caverns-Glaciers of Southern Dagestan," Zemlevedeniye, Book III-IV, 1905, pp 131-135
15. M. Lyuzhon, "Dams and Geology," ONTI, Moscow, Leningrad, 1936, pp 14-17, 103-110
16. A. N. Mazarovich, "Collapses and Caverns in the Southwest Portion of Nizhegorodskaya Gub," Zemlevedeniye, Book III- IV, Vol XIX, 1912, pp 30-46
17. L. I. Maruashvili, "The Cavern of Ablaskir: A Remarkable Cave Formation in Abkhaziya," Priroda, No 10, 1938, pp 117-120

50X1-HUM

18. L. I. Maruashvili, "Cave Phenomena in the Neogenic Conglomerate of Central Megreliya (Western Gruziya). Geomorphological Characteristics of Kriptokarst," Tez Dokl Karst-Speleo Konf, Molotov, 1947

19. L. I. Maruashvili, "Karst of Clastic Rocks, Its Geomorphological Characteristics, in the Light of General Speleology, With the Example of Central Megreliya (Western Gruziya)," 1947, Dissertation

20. Materials of the Karst Conference, Kizel, December 1933, ONTI, Moscow-Leningrad, 1935

21. V. N. Makhayev, "The Ice Cavern Abogydzhe," Izv Gos Geogr Obshch, Vol 71, No 6, 1939, pp 874--878

22. A. Middendorf, Travel to the North and East of Siberia, St Petersburg, 1861, pp 308-309

23. V. Monakhova and A. Bulochkina, "Journey in the Summer of 1925 to the Southern Part of Nizhegorodskaya Gub," Zemlevedeniye, Vol XXVIII, No III-IV, 1926, pp 67-86

24. M. G. Popov, "The Kan-i-gut Cavern in the Ferganskiye Mountains," Izv Turkest Otd Russk Geogr Obshch, Vol XVII, Tashkent, 1924, pp 179-184

25. Z. F. Rakusheva, "The Kungurek Cavern," Uch Zap Molotovsk Gos Ped Inst, Vol VII, Molotov, 1940, pp 169-180

26. F. P. Savarenskiy, Engineering Geology, 2d edition, GONTI, Moscow-Leningrad, 1939, pp 146-148

27. V. P. Semenov-Tyan-Shanskiy, Region and Country, Moscow-Leningrad, 1928, p 51.

28. D. S. Sokolov, "Karst and the Interstitial Water of the Central Portion of the Ufimskiy Amphitheatre,"Tez Dokl Karst-Speleol Konf, Molotov, 1947

29. Ya. V. Stefanovich, "From Yakutsk to Ayan," Zap V-Sib Otd Russk Geogr Obshch po Obshch Geogr, Vol II, No 3, Illustr 2-3, Irkutsk, 1896, pp 66-69

30. A. V. Stupishin, "Karst Phenomena and Caverns of Central Povolzhye With Examples From the Tatarskaya ASSR and Gor'kovskaya Oblast," Tez Dokl na Karst-Speleol Konf, Molotov, 1947

31. P. Tutkovskiy, "Karst Phenomena and Original Artesian Springs in Volynskaya Gub. Chapter I. Instances of the Breakdown of Soil on the Polleskaya Railroad," Tr Obshch Issl Volyni, Vol IV, Zhitomir, 1911

32. A. Fersman, "On the Mineralogy of Caverns," Priroda, No 1-2, 1925, pp 97-99

33. P. Khoroshikh, "Caverns of Altay," Priroda, No 4, 1938, pp 158-159

34. D. I. Shcherbakov, "On Geochemistry of the Alayskiy Range," Tr Pamirsk Eksp 1928 g, No 7, Geol i Geokhim, Izd Akad Nauk SSSR, Leningrad, 1931, pp 48-50

35. Ya. S. Edel'shteyn, "Geomorphological Outline of the Minusinskiy Region," Tr Inst Fiz Geogr Akad Nauk SSSR, No 22, Moscow-Leningrad, 1936

36. G. Bouillard, "Les grottes de Yün Shui T'ung du Shang Tang Shan," Bull of the Geolog Soc of China, Vol III, No 2, Peking, 1924, pp 147-152

37. W. Davis, "Origin of Limestone Caverns," Bull of the Geol Soc of Amer, Vol XLI, 1930

38. A. Daubree, Etudes synthetiques de geologie experimentale, Paris, 1879, pp 351-352

39. A. Daubree, Les eaux souterraines a l'epoque actuelle, Vol I, Paris, 1887, pp 130-144

40. S. N. Dicken and H. B. Brown, Soil Erosion in the Karst Lands of Kentucky, United States Department of Agriculture, Soil Conservation Service, Circular No 490, Washington, 1938

41. F. Dienert, "Sur l'hydrologie souterraine," Comptes rendus de l'Acad d Sci Vol 178, Paris, 1924, pp 2265-2266

42. N. E. A. Hinds, Geomorphology: The Evolution of Landscape, New York, 1943, pp 737-750

43. M. Kispatic, "Bauxite des Kroatischen Karstes und ihre Entstehung," Neues Jahrb für Miner, Geol und Paläontologie, Supplement, Vol XXXIV, 1912

44. O. Lehmann, "Hydrographie des Karstes," Enzyklopädie der Erdkunde, O. Kende, Leipzig and Vienna, 1932

45. A. K. Lobeck, Geomorphology: An Introduction to the Study of Landscapes, New York and London, 1939, pp 135-147

46. E. A. Martel, Les Abimes: Les eaux souterraines, les cavernes, les sources, la speleologie, Paris, 1894

47. E. A. Martel, "Applications geologiques de la speleologie: Origine et role des cavernes, leurs variations climateriques, leurs rapports avec les filons," Annales des Mines, 9th Series, Vol X, Book 7, Paris, 1896

48. E. A. Martel," Sur la plus grande caverne d'Europe (Eis Riesenwelt) et les paleo-circulations d'eaux souterraines en hautes montagnes," Comptes rendus de l'Acad d Sci, Vol CLXXVIII, Paris, 1924, pp 1429-1431

49. E. A. Martel, "Sur l'universalite et l'importance de phenomena des abimes ou puits naturelles des calcaires," Comptes rendus de l'Acad d Sci, Vol CLXXVIII, Paris, 1924, pp 1738-1740

50. E. A. Martel, "Le record des gouffres: L'Abime Bertarelli (Istrie) et la Jhourun Martin (Devoluy)," La Nature, No 2656, 1925, pp 141-144

51. E. A. Martel, "Le drame du gouffre Bertarelli," La Nature, No 2704, 1926, pp 68-69

52. W. E. E., "Mammoth Cave," Encyclopedia Britannica, 14th edition, Vol XIV, London, New York, 1932, pp 757-758

[Appended figures follow.]

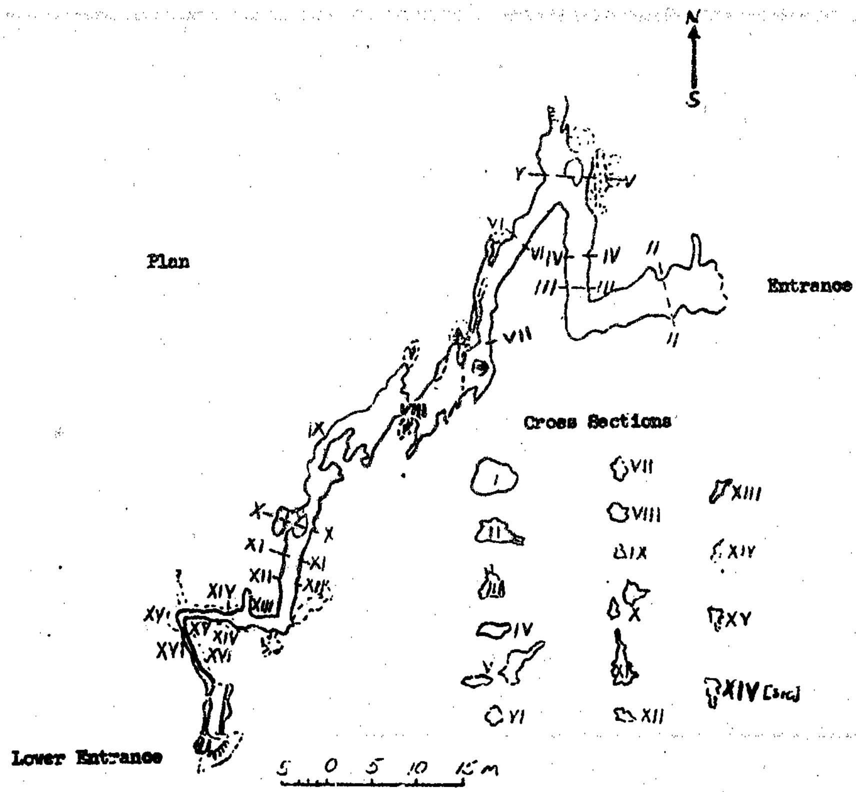

Figure 2. One of the Caverns in the Khosta River Valley in the Caucasus

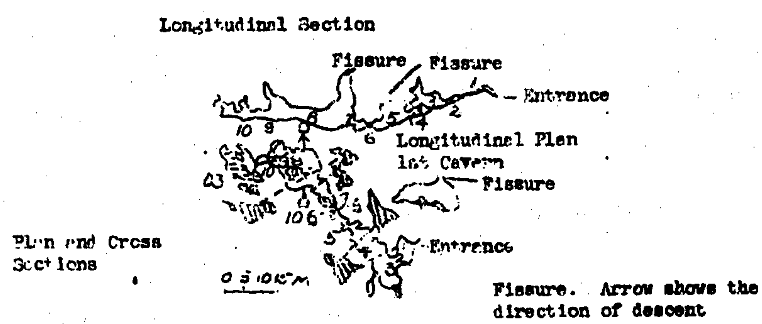

Figure 3. Cavern in the Vicinity of Sukhumi

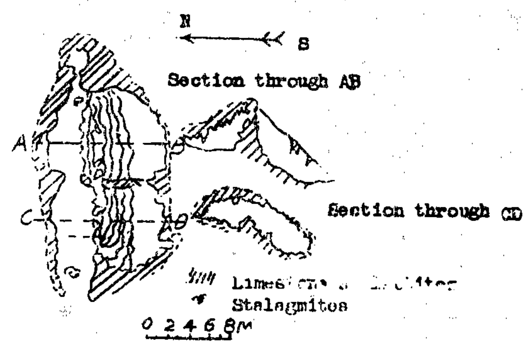

Figure 4. One of the Caverns in the Vicinity of Sukhumi. In the plan above the winding lines show the slope of lime deposits which do not join with the ceiling of the cavern.

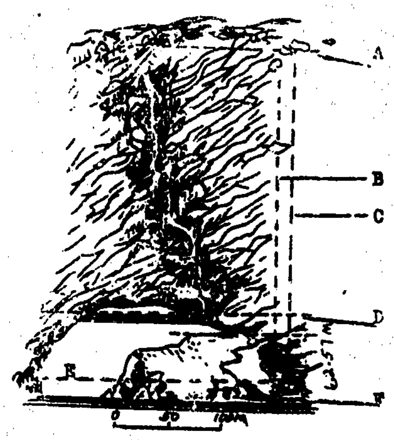

Figure 6. The Trebich Grotto. Vertical cross section of natural shaft and cavern. A - Level of earth's surface at entrance to cavern. B - Distance to normal water level in cavern, 321.37 meters. C - Distance to sand, 298.8 meters. D - Height reached by water, 22-26 Sep 1868. E - Approximate water level, 1 Oct 1868. F - Normal water level, 18.96 meters above sea level.

CONFIDENTIAL

50X1-HUM

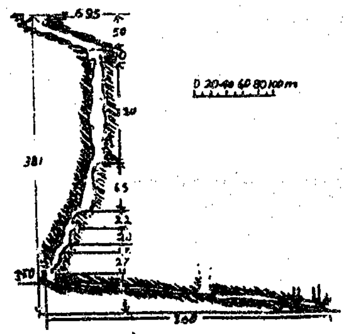

Figure 7. Vertical Cross Section of Bertarelli Abyss

Figure 8. Entrance to the Kan-i-gut Cavern. Bare calcareous rocks, with traces of the dissolving effect of water, form the characteristic feature of the landscape in the foothills of the Turkestan range.

- E N D -

CONFIDENTIAL

CONFIDENTIAL