Proc. Univ. Bristol Spelaeol. Soc., 1992 **19** (2) 117-149

CUPP-COUTUNN CAVE SYSTEM, TURKMENIA, CENTRAL ASIA

by

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ABSTRACT

Cupp-Coutunn/Promeszutochnaya is the longest limestone cave in the (former) Soviet Union. The cave is part of an extensive area of palaeokarst, perhaps of Middle Cretaceous age, rejuvenated by tectonic movement in Neogene times. During the Middle Quaternary the cave was invaded by thermal waters which deposited calcite, fluorite and metallic sulphides. Post-thermal and modern re-working of these deposits has produced a stunningly decorated cave, with a unique mineral assemblage. The quality and unusual nature of these speleothems matches that of any cave in the world. In 1991, the caves were placed on the Global Indicative List of Geological Sites (GILGES) by a working group of the UNESCO World Heritage Convention.

INTRODUCTION

The Kugitangtau is a mountain ridge some 50 km long in Soviet central Asia (Figures 1, 2 and 3). The ridge is aligned north/south and forms the boundary between the republics of Turkmenia (Turkmenistan) and Uzbekistan. Immediately south of the ridge, the Amu Darya river marks the border with Afghanistan. In broad geographical terms, the Kugitangtau may be regarded as an outlier near the south-western end of the higher Baysun ridge, which connects directly with the Gissar range of mountains at the western end of the Tien Shan mountain chain. The well-known mineral cave Fata-Morgana (also known as Gaurduckskaya) lies on the independant Gaurduck ridge to the west of Kugitangtau (Figure 3). The name Kugitangtau is a combination of both Tadjik and Uzbek words and means literally "mountain-canyon-mountain". The local people normally use only the Tadjik part of the name — Kugitang — but since this abbreviated version is also used for a village, a river and a lake the full version specifies the mountains themselves. This is the form normally used on maps.

The Kugitangtau is geologically an anticlinal dome whose core comprises Pre-Cambrian gneisses into which a Hercynian granite batholith has been intruded (Figure 4). Unconformably overlying the gneisses are a 300 m sequence of Triassic and Lower Jurassic flysch, with locally some material of volcanic origin. The flysch leads up into the main limestone sequence, the 400 m thick Kugitang Series of Upper Jurassic age. The Kugitang Series passes conformably up into the 200 m thick gypsums and limestones of the Gaurduck Series, also of Upper Jurassic age. Cretaceous rocks, of both shallow sea and continental type, disconformably overlie the Gaurduck beds but do not outcrop on the Kugitangtau ridge itself. Similar deposits of Palaeogene and Neogene age may be found some 40 km from the ridge.

Tectonic structures dominate the topography of the region. A major fault, the

Figure 1. *Turkmenia and the Soviet Union.*

Eastern Kugitang Upthrust runs within the granite along the long axis of the anticline, and it is the uplifted western side which forms the Kugitangtau cuesta. The cuesta presents a scarp face over 1 km high, the upper limestone wall of which is near vertical and dominates the Uzbek plain to the east. The anticlinal dome is not symmetrical across the fault line, the dip to the west varying between about 7° and 15°, being much steeper to the east at about 60°. As a result, the western (Turkmenian) flank of Kugitangtau is an extensive limestone dip slope, while on the Uzbek plain the steeply dipping limestones form only low hills (though in the north-east there are two larger hills with caves of archaeological importance).

The Turkmenian dip slope of the cuesta is cut by a second major fault, sub-parallel to the Eastern Kugitang Upthrust but smaller and with opposite throw. The central spine of Kugitangtau may thus be regarded as a horst block, mostly gently sloping, but with a central mountain group culminating in a peak of over 3000 metres. The dip slope of the horst block is known as the "upper plateau" and, though made of limestone, it has few karst features. Surface weathering forms dominate, with spectacular canyons which give the region its name. At the northern end of Kugitangtau, another small fault within the horst block raises an area of limestone as the "top plateau". Active modern karst seems to be restricted to this small area, where there are vertical cave systems.

To the west of the sub-parallel fault, flanking the horst block, the lower ground is a narrow ribbon of sloping land comprising the uppermost beds of the Kugitang Series. In the south and south-west this ribbon becomes a more extensive dip slope known as the "lower plateau" (see Figure 4, section). Like the upper plateau, surface weathering forms dominate but here the cliff-walled canyons have intersected caves from an earlier cycle of erosion. Most speleological study has been concentrated on the south-western flank of the lower plateau, where access has been made easier by the building of mining roads. Here Cupp-Coutunn and

Figure 2. *Regional map.*

its associated caves are found, comprising Cupp-Coutunn (main), Promeszutochnaya, Tush-Yurruck, Hushm-Oyeek, Geophyzicheskaya, Verticalnaya and some minor caves. To the east lie the separate drainage systems of Bezuimyannaya, Chindjeer and Kainar. The cave entrances are all found in the walls of canyons, with the single exception of Hushm-Oyeek which has a collapse entrance from the plateau. Cupp-Coutunn is a locally common cave name, so the term Cupp-Coutunn (main) is sometimes used to designate the main cave of the region. In some references, particularly in mining journals, the name Karlyukskiye Caves is used (see Figure 3 for location of Karlyuk village).

To the south-west of Cupp-Coutunn, the sloping limestone plateau passes beneath the (Gaurduck Series) gypsum beds of the surrounding alluvial plain. Along the lower margin of the limestone there are often small flanking hills capped by gypsum beds, with some small gypsum caves unrelated to the drainage in the

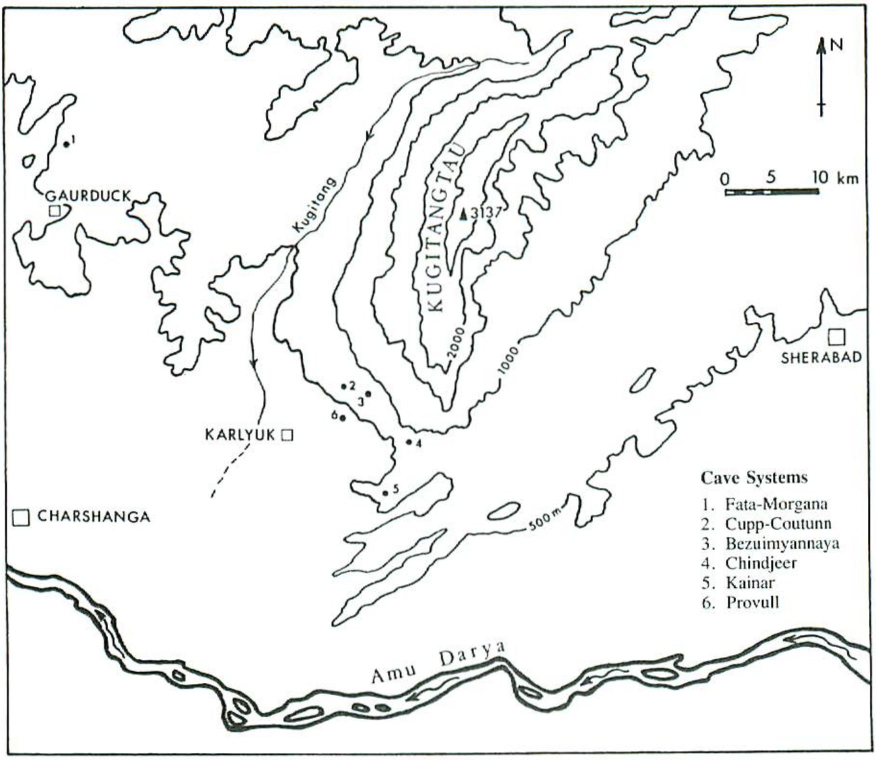


Figure 3. *Kugitangtau.*

limestone. There are also subaqueous caves in the gypsum karst of the plains (eg. Provull), but there is no proven hydrological connection with the underlying limestone.

The climate of the region is semi-desert, with rain for only a short period during the spring and autumn. Flowing water in either caves or canyons is unusual, though major floods do periodically occur. The temperature in the caves varies with altitude, from 17°C in Geophyszicheskaya to 22°C in the southern part of Promeszutochnaya. In some parts of the cave there are high concentrations of hydrogen sulphide and carbon dioxide gases. Radon is present in low concentrations, mostly in the vicinity of middle Quaternary clay infills. Apart from a few isolated pools of water the caves are very dry, though the cave air remains humid. In areas of weak air circulation the humidity is usually 100%. Along the windier galleries it varies with the season. When air is being drawn into the cave, the humidity at 300 metres from the entrance, can fall to as low as 70%. When the wind is flowing from the cave, the humidity is normally 100% at 100 metres from the entrance. New (mined) entrances have seriously affected the humidity and airflow patterns in the caves and are already having a deleterious effect on speleothem growth. Late in the year 1991, the mined entrances to Cupp-

Coutunn and to Promeszutochnaya were gated by the Gaurduck Geological Service, greatly reducing the problems of both airflow and casual visitors. Access for responsible cavers is still available by arrangement.

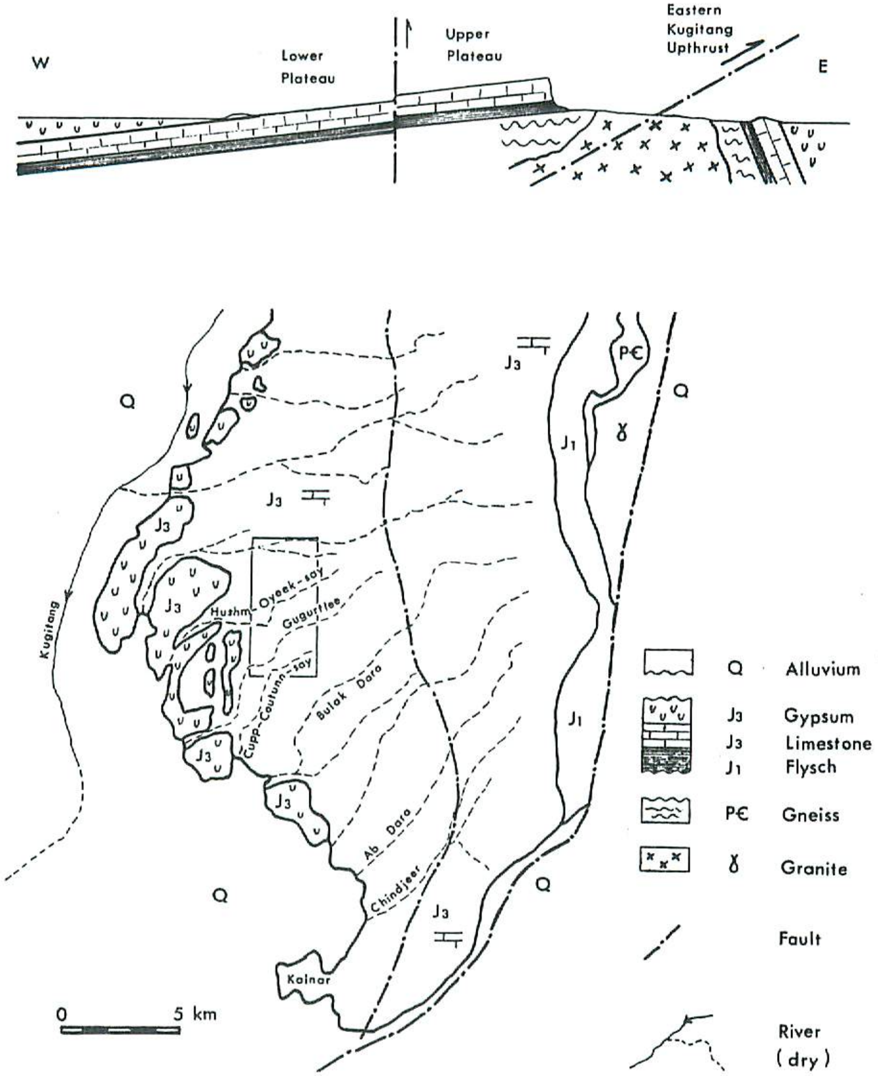


Figure 4. *Geology of southern Kugitangtau.*

HISTORY OF EXPLORATION

Hushm-Oyeek cave has been known from ancient times and may, according to Gvozdetsky (1981), correspond to a cave recorded in the "Bibliotheka Historica" of Diodorus Siculus (c. 40 BC). Other caves of the area have probably been known to local shepherds, but the earliest proof of exploration is a bottle left in Cupp-Coutunn (main) cave, some 700 m from the entrance. The bottle, found some forty five years later, contained a piece of paper dated 1932 left by a party of tourists from Moscow. Unfortunately the names of this party were at the bottom of the page and this part of the paper had already begun to disintegrate.

The first proper study of the caves was by Sultan Yalkapov of Ashkhabad during the period 1956-64. Cupp-Coutunn (main) cave (originally named by Yalkapov Cupp-Coutunn II, to distinguish it from the gypsum karst cave Cupp-Coutunn I, also in this region) was explored for a length of 2 km. Hushm-Oyeek was explored to 3 km and early explorations made in Tush-Yurruck, Bezuimyannaya and Dalnaya (part of the Bezuimyannaya system of caves). Yalkapov first described the karst drainage of the area and suggested that the caves are older than the canyons (Baikalov et al, 1970). The canyons are generally agreed to be of mid-Quaternary age (Geology of USSR, vol XXII, 1972).

During the 1970s some geological studies and explorations were made by Samarkand cavers led by V. Kucheryavuih. Cupp-Coutunn (main) was extended to 5.6 km, Hushm-Oyeek to 7 km, and some small caves also found. Kucheryavuih generally agreed with Yalkapov's karst drainage model (Kucheryavuih and Abdujabarov, 1982) but thought the caves and the canyons to be of the same age.

From 1970 to 1982, several of the caves were mined for calcite speleothems which were then made into wall tiles and ashtrays. Gypsum formations were sawn off and taken as souvenirs. Cupp-Coutunn (main), Hushm-Oyeek and Tush-Yurruck were affected and during this phase the cave Promeszutochnaya was discovered and also mined. At this time the known length of Promeszutochnaya was 1.5 km. The mining was eventually stopped by adverse public opinion, following a campaign led by Moscow and Ashkhabad cavers.

In 1981, the systematic study of the Cupp-Coutunn system was started by our group, then called the speleological section of the Institute of Mineral Resources. (This team has an amateur and informal membership and currently works under the aegis of the USSR Geological Society.) During the first expedition in 1981, the blind fish *Noemacheilis starostini parini* was collected by V. Maltsev in the gypsum cave Provull. This new species, of the stone loach family (Figure 5), lacks even the relics of eyes and two fish were sent alive to Moscow for further study by S. Smirnov and V. Parin (referred to in Zalesskaya and Golovatch, 1989). During the second expedition, V. Stepanov identified hydromagnesite in Cupp-Coutunn (main) and since then mineralogical studies have become an important part of our expedition programmes.

In 1982, the Gaurduck Geological Service (GGS) took over responsibility for the caves, ostensibly for their preservation. By 1986, however, the GGS were preparing to mine Geophyzicheskaya and only the action of one of their engineers prevented them. Y. Kutuzov blocked himself inside the cave with two friends and stayed there for six weeks. He lost his job as a result of this action, but the cave was saved. The stunning speleothems of Geophyzicheskaya (Frontispiece) give some impression of the former beauty of the main galleries of other caves before mining.

Between 1983 and 1984 the length of Cupp-Coutunn (main) was increased to

19 km, mostly as a result of detailed surveying, though some new areas were also found. In 1985, a breakthrough was made into the most interesting part of the cave, increasing the length to 23 km. The new areas contained very unusual speleothems with concentrations of many different minerals in one region — calcite, aragonite, cerussite, hydromagnesite, celestite and manganese oxides (Maltsev and Bartenev, 1989). During this period the gypsum karst cenote Provull was dived by E. Voidakov to a depth of 58m. Promeszutochnaya was resurveyed by A. Vyatchin of Gorky and new areas discovered, increasing the length of the cave to 17.5 km. Two new caves were found in 1985: Y. Chernuish of Moscow found Geophyzicheskaya with a team of schoolboys, and a cave of 2.5 km, as yet still unnamed, was found by Shakhmatova of Krasnoyarsk in Ab-Dara canyon (Figures 3 and 4). This cave is part of the Chindjeer system and lies to the east of both the Cupp-Coutunn and the Bezuimyannaya cave systems.

Figure 5. *Blind fish* Neomacheilis starostini parini.

In the years 1986 and 1987, Cupp-Coutunn was extended to 27.5 km and a connection made with Promeszutochnaya. Unfortunately, the connection gave easy access from Promeszutochnaya to one of the most beautiful areas of Cupp-Coutunn, so the passage was immediately resealed. In 1991, a new link was made via the strenuous B-podval series. After several years of work by one of our teams in Cupp-Coutunn, and by a Krasnojarsk team in Promeszutochnaya, the first traverse of the two caves was made by a combined group of Moscow, Bristol and Siberian cavers. In 1988 the Kugitangtau National Park was established and control of the caves is now contested between the Kugitangtau National Park and the Gaurduck Geological Service. Since 1988, the focus of attention for most of our group and that of S. Volkov (Balashikha) has been Promeszutochnaya, which has been extended to 25.5 km.

Since our first brief report in 1982 (Maltsev, 1982), a number of papers have been published in Russian on specialist topics concerning this cave system (Maltsev, 1987a; Bartenev and Veselova, 1987; Bartenev, 1987; Maltsev, 1987b; Bartenev and Maltsev, 1989; Maltsev and Bartenev, 1989; Maltsev, 1989; Maltsev and Malishevsky, 1989). The present paper is the first broad over-view and general description of the caves.

With local official bodies now competing for the right to manage the caves for tourism, it is to be hoped that the mining of the caves has ended for ever. There are, however, still many other problems for conservation. Traditionally, local people have used gypsum stalagmites (which are hollow) as lampshades, and even among cavers there is a problem of souvenir-collecting. Worst of all are visiting geologists who are able to recognise rare and unusual mineral deposits. Having picked clean Fata-Morgana (an inevitable loss since it underlies at shallow depth the encroaching Gaurduck sulphur mine) they are now visiting the Cupp-Coutunn caves. In April 1990 our team found a unique occurrence of fluorite crytals growing on helictites. Returning two days later for photography, we found the formation vandalised. It is for conservation reasons that a description and survey of the caves has never before been published. Even in this report, published outside the Soviet Union, we feel that a general rather than a detailed description serves better to preserve the beautiful and often unique formations in this cave.

CAVE SYSTEMS OF SOUTHERN KUGITANGTAU

In this section only the limestone caves of the southern part of the lower plateau are considered. Beneath the sloping limestone surface, which here follows the gentle 7° dip of the strata, there appears to be an extensive network of ancient sediment-filled caves. The caves are planar phreatic mazes, each one developed on several levels aligned with the dip of the limestone. Passage dimensions can be quite large, but the accessible cave is often much smaller due to ancient infil material and modern alluvium. At the present state of knowledge, it is impossible to prove that these caves were once all part of a single phreatic network, but this is certainly a possibility.

The accessible caves have all been reinvaded by meteoric waters and have lost, at least in part, their ancient argillaceous filling. The major caves with extensive open passages are all to be found to the west of small sub-meridional (sub-north/south) faults, as shown in Figure 6. At their northern end these faults split off from the major fault that marks the boundary with the upper plateau, but they have the opposite throw (10-20 metres upthrow to the west is typical). They vary a little in orientation but generally follow the direction of the dip at first, then curve to the south. They were formed during the same uplift period as the major faults of the Kugitangtau central spine. The canyons mostly have a north-northeast/south-southwest trend and are crossed by these minor faults, usually with springs at the lowest point of intersection. The faults appear to be the main groundwater route, both now and in the past, and to have been responsible for the rejuvenation of the caves (see Karst History section). A group of much smaller faults of the Chilgas tectonic zone, oriented about 330°, are also present but do not carry water. These Chilgas faults are tear faults with a small displacement (usually less than 10 metres) but where there is vertical movement, the upthrown block is to the east, the opposite throw to the more significant sub-meridional faults. The Chilgas faults sometimes have lead/zinc mineralisation.

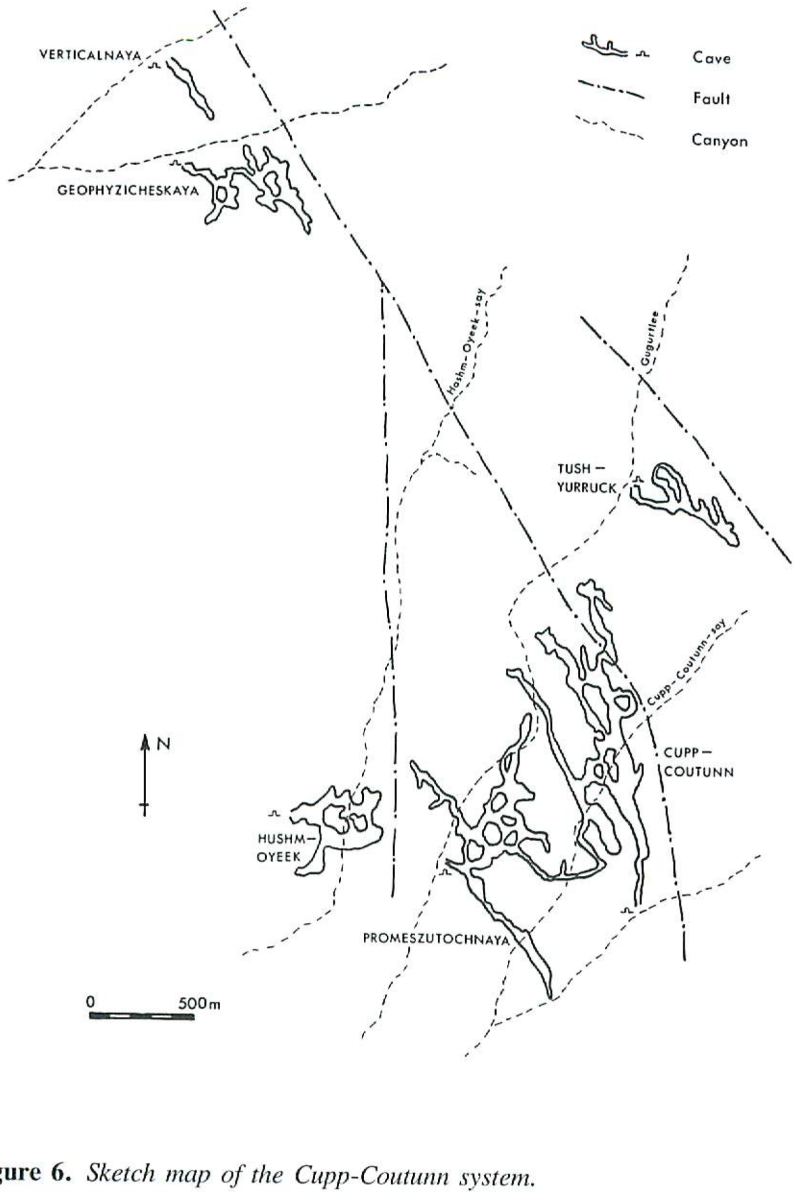


Figure 6. *Sketch map of the Cupp-Coutunn system.*

The caves of southern Kugitangtau appear to be grouped into systems (as shown in Figure 3) each associated with (and rejuvenated by) a sub-meridional fault, but since the caves are older than the faults (see Karst History) we cannot say that the systems do not interconnect. The cave systems are here treated separately and described below in order from north to south.

The Cupp-Coutunn system has a total explored length of 72 km, of which the longest cave is Cupp-Coutunn (main)/Promeszutochnaya at 52 km. The system is based on one major sub-meridional fault (Figures 6 and 7) with a spring of 15 l/s in Bulak-Dara canyon. This fault was responsible for most of the rejuvenation of the cave, but a smaller fault to the west has influenced Hushm-Oyeek. The cave Promeszutochnaya traverses between both these faults. A second small fault has affected Tush-Yurruck and Yalkapova Chamber in the north-eastern part of Cupp-Coutunn (main) (see Figure 6).

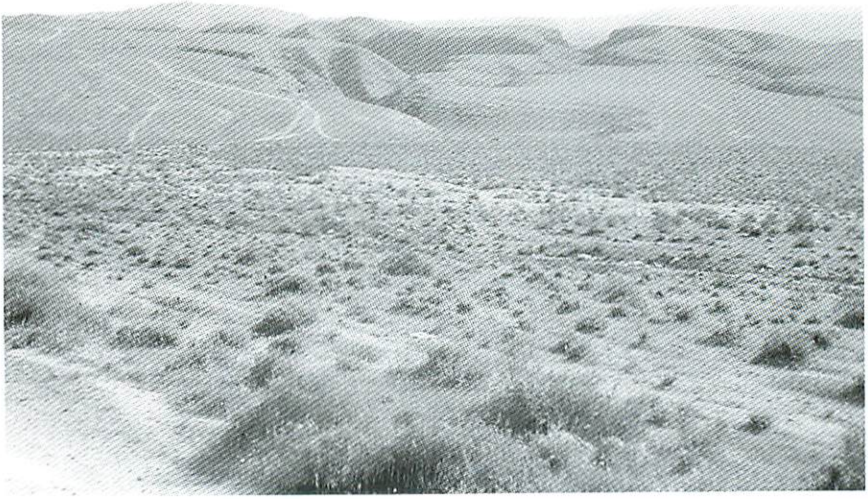


Figure 7. *Cupp-Coutunn-say canyon viewed from the plain. The near skyline is the surface expression of Cupp-Coutunn's sub-meridional fault. The far skyline is the upper plateau.*

The Bezuimyannaya system length is only 5 km, divided between Bezuimyannaya and some smaller caves. The system is controlled by a fault whose spring of 10 l/s is in Ab-Dara canyon. The explored length of the Chindjeer system (by Shakhmatova in 1985) is 2 km in one cave as yet un-named in the upstream part of Ab-Dara canyon. The fault controlling the system drains to Chindjeer spring, which has a flow of 20 l/s. The spring is accessible for 10 m but is blocked underwater by collapse.

The Kainar system probably covers the largest area, and has a more complicated tectonic structure. Two small anticlines, with axial direction east-southeast and bedding angles up to 40° are separated by a graben. These structures control the surface relief, producing a pair of small ridges 1 km apart and extending for 3 km. Only a few small caves of up to 200 m are as yet explored, some of which have strong air flows. Kainar spring has a flow of 1000-1500 l/s emanating from a large collapse, but digging is impossible without undermining a nearby road. 50 metres beyond the main resurgence there is a second resurgence, gushing up from small holes in the plain at 30 l/s and with a high hydrogen sulphide content. Similarly foul water is seen at a cenote in the gypsum karst 1.5 km south-east of Provull, with hydrogen sulphide probably derived from bacterial activity in the gypsum phreas. The two Kainar springs feed into Kainar lake, where troglobitic fauna (*Stenasellus asiaticus*) sometimes appears.

The discharge from the Kainar springs does not significantly alter during the year, suggesting that the aquifer is sufficiently large to balance seasonal input variations. The small springs associated with the faults to the north are, by contrast, very variable and respond quickly to rainfall. In the caves, dripping water in passages close to sub-meridional faults also responds rapidly to rainfall, being appreciably colder than cave temperature when snow has fallen on the upper plateau.

It should be stressed that flowing water is seldom observed in the caves, which are very dry except during major floods recurring at intervals of about ten years. The springs are thus drainage from diffuse flow groundwater systems draining to the faults, and rising to the surface in the floors of the canyons near the boundary of the limestone plateau and the gypsum plains. The small springs are overflow outlets, while Kainar is a major resurgence at the hydrological base level.

Beneath the plains at a depth of 10-40 metres there are large diameter conduits entirely water-filled and phreatic in form, such as can be seen at the cenote Provull. At greater depths (200-300 m) boreholes have yielded artesian water in the limestone beneath the plains. Chemically, the waters in pools inside the caves and the artesian waters are similar, but the phreatic water of the caves beneath the plains is dissimilar. This is however to be expected as the caves beneath the plains are in gypsum and there is no noticeable water flow. Chemically there is no way of determining whether the limestone cave water feeds the sub-plains phreas or goes deeper to the artesian zone.

The plains phreas may be quite old because of the fauna it contains. The blind cave fish seen in Provull is more cave-adapted than normal, lacking even the relics of eyes, and must have had a stable environment for a considerable time to so evolve. Though it is possible that the fish evolved elsewhere and only subsequently colonised the gypsum phreas, we favour the theory that the plains phreas is a single common collector for the water of the region, both from the faults and from the caves. At present we have no idea whether the water eventually drains to the Amu-Darya, the major river to the south, or evaporates through the porous surface rocks. The evaporation model is attractive because there are no springs near the Amu Darya noticeably contaminated by hydrogen sulphide. Boreholes in the gypsum rocks of the plains phreas often reach such contaminated water. The range of the troglobitic fauna would in this case be limited to those parts of the collector near to the drainage points of the caves and/or faults, where the water is still fresh. Further limits to this range are suggested by the presence of normal river fish in cenotes close to the Kugitang River to the west.

THE CAVES OF THE CUPP-COUTUNN SYSTEM

CUPP-COUTUNN (Main)

Also known as Cupp-Coutunn II

Length 27 km Vertical range 203 m

The natural entrance is a hole at the top of a large collapse, 40 m high, in the north wall of a small canyon, tributary to Cupp-Coutunn-say (Figure 6). There is evidence of a continuation of the cave in the south wall of the canyon, but access has not been made.

The entrance leads to a great gallery (Figures 8 and 16), up to 20 m high and 50 m wide, which heads north for 1500 metres until it is blocked by alluvial sediments as it approaches Gugurtlee Canyon (Figure 6). This main gallery of Cupp-Coutunn rises steadily to the north, but has a number of flood channels in its floor that enter from the east and leave to the west, sometimes flowing south along the gallery floor for a short time. The

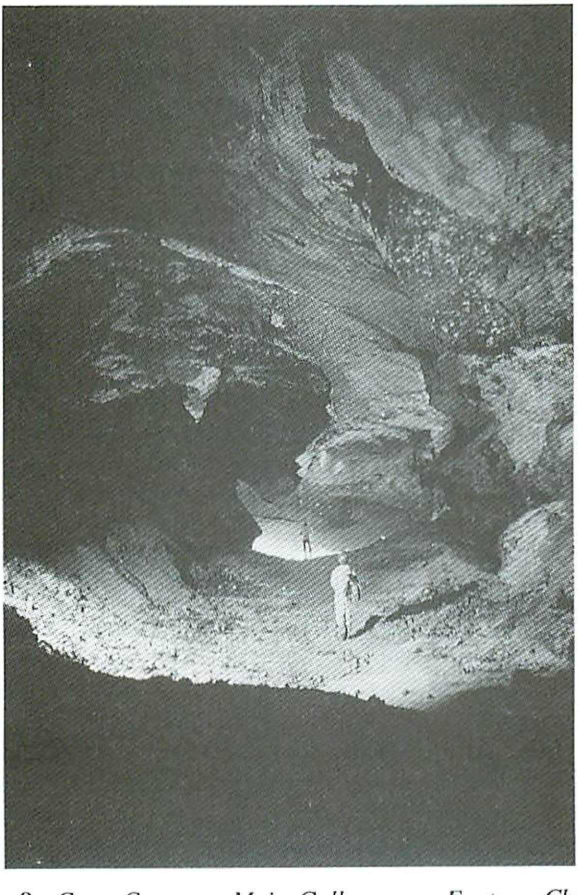


Figure 8. *Cupp-Coutunn. Main Gallery near Fontyan Chamber.* (Photo: J.T. Griffiths)

flood channels are contemporary, the water entering the cave from a sub-meridional fault that parallels the main passage at a distance of 150 metres to the east.

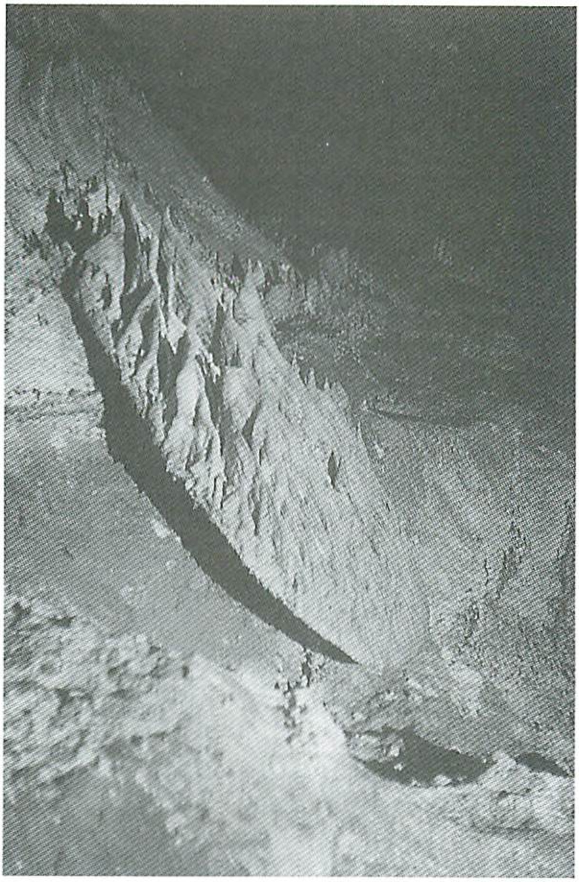


Figure 9. *Calcite shield in Cupp-Coutunn.*

Between the main gallery and the fault there are some minor mazes, generally of quite large passages and chambers, with an unusual spherical morphology (discussed in Karst History). Closer to the fault these passages divide into much smaller tubes. These eastern mazes have a connection, via Dvukh Kolodtsev (''Two Shafts'') chamber, to the eastern part of the system located beyond the fault in the same structural block as Tush-Yurruck cave. (Note: though this series appears from the survey to be the northern end of the cave, it is described as ''eastern'' because it lies to the east of the main gallery). These passages lead to the very large Yalkapova chamber, but are then blocked by alluvial sediments in the region of the surface Gugurtlee canyon. Dvukh Kolodtsev chamber lies at the crossing of a Chilgas fault and the sub-meridional fault, the cave showing 10 metres displacement across the Chilgas fault. The main fault is not seen in this chamber and the tentative evidence we have for this crossing is mineralogical — a plot of the location of calcite shields (Figure 9), which can only grow where the percolating water has a hydrostatic head and in this cave occur only in the close vicinity of this fault.

Cupp-Coutunn (main) also has an extensive lower series, below and to the west of the main gallery. This lower series also contains roomy galleries oriented north/south, usually with evidence of southerly water flow along them. In many places they have a distinctly vadose appearance, unlike the collapse chambers that are typical of this system. On closer inspection these ''vadose'' walls are seen to be ancient sediments in a larger phreatic passage.

The connection between the upper and lower levels is via a low labyrinth whose walls are part rock and part ancient infill material. The roof has been strongly affected by condensation corrosion and the floor is covered with recent alluvium and gypsum sand. The main gallery of this labyrinth is crossed by a zone of east/west fissures. These fissures are 10 metres high but only one is passably wide. This chimney climb, Soochy Dety (''Children of a Bitch''), provides the only access from the upper to the lower cave.

The lower cave consists of a central maze with some large chambers (eg. MGRY, Baobab) and four main galleries. The northern gallery has four levels and is very extensive, leading from Zazavallny (''After Boulder Choke'') chamber to Plasznaya (''Beach'') gallery where it ends in a mud blockage. The passage has been blocked, for conservation reasons, near Bolshoi Geophyzicheskaya (''Big Geophysical'') chamber. For two thirds of its length, the northern gallery takes flood water from the main gallery of the upper cave. In Bolshoi Geophyzicheskaya chamber, stoping has exposed some small palaeokarst cavities in the roof containing a distinctive yellow clay. Similar clays in palaeokarst pockets of Fata-Morgana cave (Gaurduck) are a mixture of illite and haematite. In all the caves, palaeokarst pockets are only seen in areas of breakdown, which suggests that they have the same age as the main cave passages.

The second gallery, Strana Durakov (''Country of Fools'') and Kuzkina Mutt (''Bad Beetle's Mother''), is in beds 15 metres deeper. This passage heads north-west in a very direct line, suggesting that a structural control along its left wall (perhaps a small fault) has limited the rejuvenation of this part of the cave. The gallery has at least two levels, the lower of which is a flood channel. The upper level is not continuous and consists of large chambers, much collapsed, with some side mazes. In the middle of the lower level, just beneath Gugurtlee Canyon, there is a short syphon with stalactites underwater. In this region there is an air and voice connection with Promeszutochnaya and an air connection with Vorony Sir (''Crow Cheese'') in the northern gallery. The far part of this gallery appears to be a maze of at least three parallel passages, much collapsed and partly filled with mud.

The third gallery contains Nadeszda (''Hope'') chamber, one of the largest chambers in the cave. The chamber ends with a structural drop caused by a Chilgas fault, and considerable collapse.

The final gallery is Makaronnaya Rechka (''Macaroni River''), which heads south at the level of the end of Nadeszda Chamber. The gallery turns to the west into a maze, somewhat similar to the one between Cupp-Coutunn main gallery and the lower levels, and enters the B-podval (''Very Bad Basement'') area. The B-podval maze takes the flood drainage of 20% of Cupp-Coutunn and 15% of Promeszutochnaya, with its outflow to the south blocked by mud. It is also the deepest part of the cave, 170 metres below the natural entrance. In the north-west part of the maze a connection has been found to Promeszutochnaya.

Cupp-Coutunn also has an artificial entrance to the main gallery. This mined entrance, and the mined entrances to Promeszutochnaya, have greatly altered the circulation of air, both within and between the caves. The most obvious effect has been to draw in cooler and drier air, which reduces floor sediments to dust and gives an ''abandoned'' appearance to nearby parts of the cave.

PROMESZUTOCHNAYA

Length 25.5 km Vertical range 95 m

The cave has a natural entrance in the bottom of Gugurtlee Canyon and two artificial (mined) entrances, the most northerly of which is the normal point of access. The natural entrances of Promeszutochnaya and Cupp-Coutunn (main) are 1 km apart in adjacent canyon systems.

Promeszutochnaya generally consists of a net of northwest/southeast and northeast/southwest passages with some mazes and with extensive clay fills. No lower level series is known, probably because the passages are blocked by clay. Large collapse chambers and collapse mazes along the eastern side could be an indication of lower level passages that are not completely infilled. The cave passes under both Gugurtlee Canyon (in the Skazka (''Fairy Tale'') region, and in the north) and also the Cupp-Coutunn canyon (Oksanochka chamber).

The large size of passages in the central part of the cave are due to invasion by surface water from the canyons, with removal of sediment and subsequent collapse. The water drains to the southern part of the cave, access to which is sometimes blocked by alluvium after floods. The shifting alluvium causes ephemeral lakes in some passages. The Kanalizatsia (''Sewage'') region is the lowest part of the southern series and there is probably a (temporarily choked) hidden passage here which takes the flood water and its sediment to the west, since alluvium does not reach the most southern part of the cave. A narrow fissure on the south-western side of Oksanochka chamber allows access to the far south, via a low passage containing calcite formations. The southern end of the cave is a great ancient collapse with condensation corrosion on all faces of the constituent boulders. The bottom part of this collapse, 7-10 metres below the main level, is accessible and also shows evidence of periodic flooding. The low corrosional activity of such flood water can be demonstrated by the similar morphology of the boulders at the top and bottom of this collapse. Only gypsum formations are corroded.

The northern part of the cave, beyond Kaskidniy (''Cascade'') chamber, is generally low and wide with recent alluvium choking the western margins. Where the cave passes beneath Gugurtlee canyon a coarser infill, up to cobble size, is seen with deeply incised flood channels. This is well displayed in the upper part of the Gallery Fanatikov. The northern termination is an area of collapse where tectonic fractures cross the line of the cave. The eastern margin of this part of the cave is passable at several different levels within the collapsed beds but no route can be followed far. There is a wind connection from here to both levels of Strana Durakov in Cupp-Coutunn. Fortunately, the extensive nature of the collapse should deter attempts to dig an easy route to the vulnerable lower series of Cupp-Coutunn.

The western branch, comprising Zyelonykh Zmiev (''Green Snakes'') and OSKHY passages, is not well understood. The passages are generally of small dimension with strong evidence of condensation corrosion. The circulation of air is variable but usually from the west, where the cave Hushm-Oyeek lies at a few hundred metres distance.

One unusual feature of this cave is an apparent structure oriented northwest/southeast, governing not the cave passages themselves but the general accessibility to some of the mazes. This is best seen in the western branch, where there is no main gallery linking the mazes. The nature of this feature is unknown, but it appears to be tectonic and may indicate the line of a major drainage route in Mid-Quaternary times. To the northwest this structure points directly towards Geophyzicheskaya and Verticalnaya; to the southeast it points to the spring in Bulak Dara canyon and beyond it to Provull, the gypsum cenote.

HUSHM-OYEEK

Length 7 km Depth 170 m

Hushm-Oyeek is a very complicated cave consisting (in plan) of an isometric maze of gigantic chambers (up to 270 m long, 95 m wide, 25 m high) and large collapses (up to 120 m deep). One of these collapses reaches all the way to the surface and is the entrance to the cave. The extensive nature of the collapses has foiled attempts to find continuations at the main level of the cave. 10-15 metres above the main level there is an upper level of small tubes which have partially collapsed into the chambers. Beyond the perimeter of the chamber maze these tubes all become impassably small.

A lower level in the western part of the cave, Shakhterov passage, provides the modern drainage of the cave, but is blocked by mud. One kilometre further west there are a large group of gypsum karst caves, the largest of which is Cupp-Coutunn I (length 250 m, depth 46 m). These gypsum caves are at about 100 m lower altitude than the bottom level of Hushm-Oyeek.

Hushm-Oyeek is probably the modern drainage route for half of Promeszutochnaya (250 m distant) and for Geophyzicheskaya (3 km away). Seven hundred metres north of the cave there is a large drainage area in the floor of Hushm-Oyeek-say canyon, but this almost certainly enters Promeszutochnaya.

The hollow gypsum stalagmites of Hushm-Oyeek have traditionally been used by the local people as lampshades. Most of the smaller ones have now gone, but there are larger gypsum stalagmites (up to 20 m tall) and gypsum stalactites (up to 5 m long) remaining. There is a currently a plan to develop Hushm-Oyeek as a show cave. (Gypsum stalagmites are polycrystalline structures that normally grow from a gypsum floor crust. The humidity is higher within the hollow structure, causing gypsum to dissolve in the surface water film and then be re-deposited on the top and outside.)

GEOPHYZICHESKAYA

Length 4.5 km Depth (not measured, c. 100 m)

The cave has a collapse entrance in the wall of a canyon and has two main galleries, oriented SE directly towards Zyelonykh Zmiev in the western branch of Promeszutochnaya, 3 km distant. The cave also has mazes between the two galleries and a maze to the north. The chambers and passages of this cave have some interesting features, in part due to the location of the cave very close to the main water-bearing fault, in part because of drainage from the canyon into the cave. As a result, the galleries are much taller than in other parts of the system (up to 30 metres high). Some of the chambers are of the same spherical morphology as are seen to the east of Cupp-Coutunn main gallery.

Flood water from the canyon has considerably modified the cave, moving boulders from areas of collapse and introducing large quantities of alluvium. As a result, the main galleries end in clay blockages, and the presumed lower levels of the cave are not accessible. The potential exists for side passages to the main galleries, and for upper level passages. The relatively recent discovery of this cave, plus access restrictions, means that Geophyzicheskaya is one of the best preserved caves of the region. The cave lies beneath a plateau remnant of the Guarduck gypsum beds, and so contains the best gypsum chandeliers in the area. (Gypsum chandeliers are branching stalactites formed of large crystals (see Frontispiece). Gypsum swords are stalactites formed by a single crystal.)

VERTICALNAYA

Length 1.6 km Depth 95 m

The cave entrance lies near the top of a canyon to the north-west of Geophyzicheskaya. A short horizontal passage opens abruptly at the limit of daylight onto a vertical drop of 80 m, a danger to the unwary, to gain a gallery 600 m long oriented southeast. At the end of this gallery a large collapse separates the cave from Geophyzicheskaya. There are minor mazes to the side of the main gallery. The upper level of this cave has not been explored, but part of it can be seen in Nosorog cave whose entrance is in the wall of the canyon opposite Geophyzicheskaya. Nosorog cave is 120 m long and ends in a clay blockage.

TUSH-YURRUCK

Length 3.2 km Depth (not measured, c. 40 m)

The cave entrance is in Gugurtlee Canyon 600 m beyond the northern end of Cupp-Coutunn (main). The cave in plan is an isometric maze (like Hushm-Oyeek) but also has main passages oriented west-northwest/east-southeast. Because there is active drainage from the canyon, the passages are blocked by sediment and there is little hope of connection to Cupp-Coutunn (main). The cave is normally very dry and has no air circulation. No lower levels are known.

MINOR CAVES

There are at least twenty minor caves of length 100-500 metres associated with the Cupp-Coutunn system.

KARST HISTORY

The first estimate of the age of the Kugitangtau karst was made by Yalkapov (Baikalov *et al.*, 1970), who recognised that the caves were older than the canyons and so declared the karst to be pre- Middle Quaternary. Kucheryavuih (1982), however, thought that the caves and canyons were of a similar age. His ideas were based on the Middle Quaternary date of the last activation of the Chilgas faults which control the largest chambers of Cupp-Coutunn (main) and Hushm-Oyeek. Kucheryavuih thought that these faults were responsible for initiating cave development. It is now recognised that the caves are relict from an ancient palaeokarst and that the Middle Quaternary was merely a period of rejuvenation and excavation. There were several major phases of development:

Ancient Karstification.

In central Asia a very old period of karstification has been recognised, which predates the mountain-building that gives the area its present topography. Bosak (1989) in his study of the Karjantau karst proposes a Middle Cretaceous age for the main karst phase. Because of the similarities of palaeoclimate and post-Cretaceous geology, a similar age can be postulated for the Kugitangtau karst, though later dates are equally possible.

Within the caves there is clear evidence that they were formed before the raising of the Kugitangtau ridge. The caves seem to have developed as an extensive maze under planar phreatic conditions, the different levels reflecting different positions of the water table in what were, at the time, horizontally bedded limestones. In Cupp-Coutunn three main levels can be recognised, with the lower level often further sub-divided. For example, the Yo maze in the north gallery of Cupp-Coutunn's lower series has four levels that seldom interconnect, yet the thickness of rock separating them is less than one metre. If the (modern) 7° bedding angle had been present during the formation of the cave, one would expect to see phreatic loops and a more organised drainage pattern. With three distinct levels one would expect to find vadose passages, but this is not so. The plan survey of Cupp-Coutunn/Promeszutochnaya (Figure 16) is typical for a cave formed near the water table. At the end of this phreatic period all levels of the caves were completely filled with sediments. This ancient filling became consolidated and now forms the walls and roof in several parts of the modern cave. In the Svynyachy Siar ("Pig Cheese") maze, at the beginning of the northern branch of Cupp-Coutunn's lower series, an area of ancient argillites 150 x 100 metres can be seen with a marked yellow zone 2 cm thick, having the same bedding angle as the limestone. This proves that the cave infill is also older than the phase of mountain-building. Other examples of bedding-oriented ancient clays are known both in this cave and in Promeszutochnaya. In the surface canyons, Bulak Dara for example, horizons of palaeokarst pockets are also parallel to the bedding.

The Cretaceous palaeogeography of this area has not yet been determined in detail, but there are many similarities between the Kugitangtau cave mazes and the (small diameter) cave mazes currently forming in the salt water/fresh water mixing zone on the Ust-Urt shore of the Caspian Sea. These mazes have four levels, reflecting changing levels of the Caspian Sea. Perhaps the Kugitangtau caves also developed close to a large body of salt water. If the Middle Cretaceous age of the karstification is correct, a marine transgression during the Upper Cretaceous may have been responsible for ending the karst episode.

Regeneration

During uplift of the Kugitangtau ridge, which began in Neogene times and is still continuing, the planar cave passage mazes were tilted and then disrupted by faulting. Uplift had largely been completed by Middle Quaternary times, when the karst process restarted, accompanied by the formation of a dendritic pattern of canyons on the inclined plateau surface. Four phases of canyon incision are recognised, perhaps related to regressions of the Caspian Sea. A high water table in the caves during the early regeneration phase prevented underground drainage of the developing canyon systems.

Fluvial erosion has destroyed all traces of ancient surface karst forms and also parts of the upper levels of the caves. A cave remnant modified by such erosion is Tunnel Cave, part of the Bezuimyannaya system, where a canyon 100 metres deep enters the cave and re-emerges after 50 metres; the cave has some side mazes blocked by alluvial sediments. During the regeneration phase, the direction of underground drainage changed from the original south-southeast, as shown by clay and silt deposits in the main galleries, to the modern southwest. Three sequential sub-phases have been recognised for the underground karst process.

Rejuvenation. During this first phase the caves were in part freed from their ancient argillaceous filling. This was almost certainly as a result of water from the "upper plateau" being transmitted by the sub-meridional faults. With an altitude difference between cave and upper plateau of approximately 1 km, it is possible that the water was under pressure. All the major caves now made accessible by sediment removal lie on the western (downhill) side of such faults. In Cupp-Coutunn's eastern mazes, the passages leading to the fault divide into smaller phreatic tubes on several levels. These invasive tubes are younger than the rest of the cave. This rejuvenation phase appears to have been brief, with a quick transfer from phreatic to vadose to dry conditions. Erosion was mainly confined to the infill materials, with little dissolution of the limestone itself except near the faults. It is unfortunate that at no point can a sub-meridional fault be seen underground, though they form distinct surface features (Figure 7).

Chambers near the fault in the eastern mazes of Cupp-Coutunn are characteristically spherical and without collapse. Tintilosov (1983) has found that similar chambers in a Caucasus cave are the result of rapid seasonal flooding, where conditions change from dry to phreatic without a vadose river phase. In Cupp-Coutunn, such flooding may have been caused by a seasonally high water table during cold stages of the Quaternary. Alternatively, the chambers may have been formed during the subsequent hydrothermal phase of the cave's history, with slightly aggressive water entering via the fault. No thermal minerals have been found in this part of the cave.

Thermal Sub-phase. The air-filled passages of the caves were now invaded by thermal waters, entering from faults, which caused a chemical alteration of both the limestone of the cave walls and the ancient cave sediments. No ancient speleothems appear to have survived the thermal process. The water seems not to have been very aggressive and no evidence of cave enlargement by corrosion has been found, except (perhaps) in the immediate vicinity of the fault. The thermal waters deposited minerals in the cave, particularly calcite, fluorite and metallic sulphides. The mineralogy is described in detail in the next section.

The thermal process in the Kugitangtau caves appears markedly different from that of other, better known, hydrothermal systems. Carlsbad and Lechuguilla caves in New Mexico (Hill, 1987), Jewel and Wind caves in South Dakota (Bakalowicz *et al.*, 1987), the caves of Budapest in Hungary (Bolner, 1989) were all formed by the corrosive action of the thermal water. Mineral deposition occurred later, as the thermal waters lost their power to dissolve calcite. The Kugitangtau thermal water had already lost its aggressive potential before it entered the caves. The exotic Cupp-Coutunn mineralogy may represent the final evolution of the thermal water, with greater concentration of rare elements than in the American or Hungarian caves. A thermal karst cave may even be present, at depth beneath Cupp-Coutunn.

Activisation of Chilgas Faults. During the Middle Quaternary (according to non-published reports of the Gaurduck Geological Service) there was some movement of the small northwest to north-northwest oriented Chilgas faults. These Chilgas faults can be seen underground where there is a displacement of cave passages (structural drops). Most of this displacement took place during the Neogene uplift period when the faults were formed. Movement during the middle Quaternary had an even more profound effect, causing collapse in what were by then air-filled passages, and the formation of large collapse chambers in the vicinity of these faults. Subsequent enlargement of the main galleries by collapse through the upper levels postdates this movement.

Modern Phase

In the caves, the Modern Phase is marked by condensation corrosion of the cave walls and roof. The cave air contains a mixture of acidic gases (CO_2, H_2S and SO_2) which are taken up in thin films of water which condense from the vapour phase onto the cave walls. Dissolution occurs and the thin water film carries away the soluble material, leaving insoluble material as a crust that may eventually fall to the ground. This surface crust of residual clays is particularly evident in zones of thermal alteration of the parent limestone. Condensation preferentially occurs in depressions of the wall relief and the ensuing corrosion exaggerates such irregularities to give the cave a characteristically ''rugged'' appearence (e.g. Figure 10).

Figure 10. *Condensation corrosion enhances the jaggedness of the Vorony Sir maze in Cupp-Coutunn.*

Another feature of the Modern Phase is the irregular floods of surface water which enter the caves from the points where they cross under the canyons. These floods have had a considerable influence, bringing fresh alluvium into the cave, reworking the original argillaceous deposits, and both blocking and unblocking passages. Where large quantities of the original fill have been removed, roof collapse may occur, as seen in the central parts of Promeszutochnaya. Otherwise, these floods do not seem to have caused any significant enlargement of the cave, either by abrasion or by corrosion of the limestone. The Modern Phase has seen considerable deposition of both calcite and gypsum. V. Stepanov has studied the gypsum speleothems in the main level of Hushm-Oyeek and found six cycles of wet to dry conditions during growth. In other caves, decorated passages have been partially filled by coarse stream debris, with younger formations overlying both. The Modern Phase would appear to extend some way back into the glacial phases of the Quaternary.

In the surface canyons and on the lower plateau, there is little evidence of new karstification. Modern karst processes are represented by the development of caves in the gypsum beds (Gaurduck Series) that form small hills at the foot of the limestone plateau. The longest known is Kaptyarkhana, 1.5 km long and located on the middle-west flank of the ridge. These caves are not beautiful and are dangerously prone to collapse. Most are unexplored. The origin of these caves is interesting. Their lower levels are usually connected to the sub-plain phreas and may be quite old. Above the water table condensation corrosion is vigorous and the cave grows very quickly, soon collapsing through to the surface. The process is helped by a thin and porous roof, very warm water temperature and cold surface temperature in winter.

MINERALOGY

Mineralisation of Cupp-Coutunn and its associated caves may be divided into three phases, though there is some overlap particularly between the second and third phases. The first phase is thermal in origin, when the cave was filled with hot mineralised water. The second, post-thermal phase featured the destruction of the thermally altered limestone, mostly by the process of condensation corrosion. The mineral products of this second phase were concentrated in the residual clays or reworked into speleothems. The third phase of mineralisation is of normal speleothem growth. Nothing is known of pre-thermal phase mineralisation dating from the early history of the cave, and if there are any surviving samples of minerals from this period they will be buried in the remnants of the original argillaceous infill.

Thermal Phase

The first part of the thermal phase featured the deposition of giganto-crystalline white calcite (Plate 1). The calcite is of sub-aquatic crystal form and was deposited at a temperature of 100-150°C (determined from the homogenisation temperature of gas/liquid inclusions in the crystals). Mineral inclusions within the calcite, identified by X-ray diffraction, include galena (PbS), metacinnabar (HgS) and manganese oxides, the exact composition of which has not been determined. These inclusions normally comprise less than 0.25%. Subaquatic fluorite (CaF_2) crusts were then deposited under slightly cooler conditions, usually not more than 80°C. The fluorite is normally purple in colour with crystals up to 10 cm in diameter. The crystals (unusually) have no luminescence and lose their colour within a year when exposed to sunlight. In Dvuketajniy "Two Levels" chamber in Promeszutochnaya, a "hot" fluorite has been identified with a homogenisation temperature up to 170°C. Crystals of galena (up to 1.5 mm size) and quartz (SiO_2, up to 1 mm size) have been identified by binocular microscope on the surface of this "hot" fluorite. In other cases calcite is seen to be growing paragenetically with the fluorite. The fluorite has a high strontium content (up to 4%), but no rare elements. The strong colour of the fluorites in the western branch of Promeszutochnaya (Plate 2) seems to be concentrated on the outer part of the crystals, and may be a dissolution effect. Thermal minerals also entered the palaeokarst pockets, with calcite deposition seen in pockets exposed in Bulak Dara canyon and fluorite in Geophyzicheskaya.

During a late part of the thermal phase substantial dissolution of fluorite took place, with an etched relief on some crystals of as much as 3 cm. During this period (and also the post-thermal period) the giganto-crystalline calcite was also corroded. The ore mineral inclusions were not dissolved and so became concentrated on the surface of the crystals, giving them a metallic lustre (Plate 1). This surface coating is normally 0.02 to 0.1 mm in thickness. Metacinnabar surface coatings in Fata-Morgana cave (Gaurduck) are thought to have a quite different origin due to erosion caused by pressurised steam, lost into the cave during sulphur extraction from the nearby Gaurduck sulphur mine (D. Belyakovsky, pers. comm.).

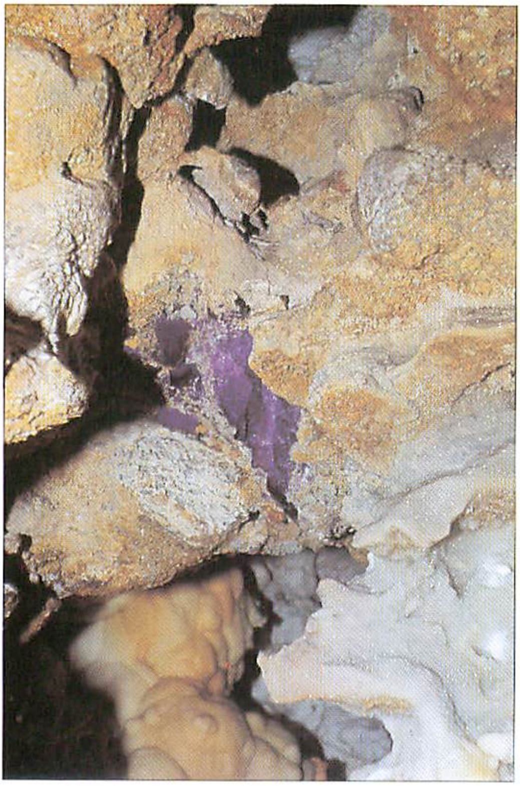
During the thermal period, the limestone of the cave walls was substantially altered, to a depth of 0.5 to 1.0 m. In fresh limestone, the non-soluble component is 2-5%, but in altered limestone this can be as much as 30%. Alterations include recrystallisation of calcite and partial replacement by other minerals, mostly sulphides and silicates. Small amounts of quartz and plagioclase feldspar also grew in the limestone during this period. The presence of plagioclase is unusual, since it is normally formed at much higher temperatures. This suggests there may have been a very hot phase at the beginning of the thermal process, most products of which did not survive later phases. Temperature variations during a thermal episode are difficult to prove, but may be quite common. Bakalowicz et al (1987) propose cyclic warm episodes for the hydrothermal process in Jewel Cave (South Dakota), to cause degassing and so bring the mineralising solutions to supersaturation.

Post-thermal Phase

During this period residual clays were formed by dissolution of the thermally altered limestone (seen in Plate 1). The clays contain clearly visible sulphides and what appears to be mica but detailed studies have yet to be undertaken. The similarity of the Cupp-Coutunn residual clays to those of Fata-Morgana suggests the mica may be illite; for the same reason, the iron oxide haematite is probably present (Lazarev and Philenko, 1976). The main component of the residual clays still attached to the cave roof is goethite (X-ray identification by M. Tranteev of Bulgaria, pers. comm.). Normal clay minerals are usually less common, perhaps because of leaching of Al and Si during the thermal process. In the Dvuketajniy region of Promeszutochnaya, the orange-red clays have been found to contain zinc-based analogues of the alumino-silicates muscovite and chlorite. In southern Promeszutochnaya, the main component of the clays is kaolinite, but up to 5% lead oxide is present near the point where a galena vein is exposed in the cave wall.

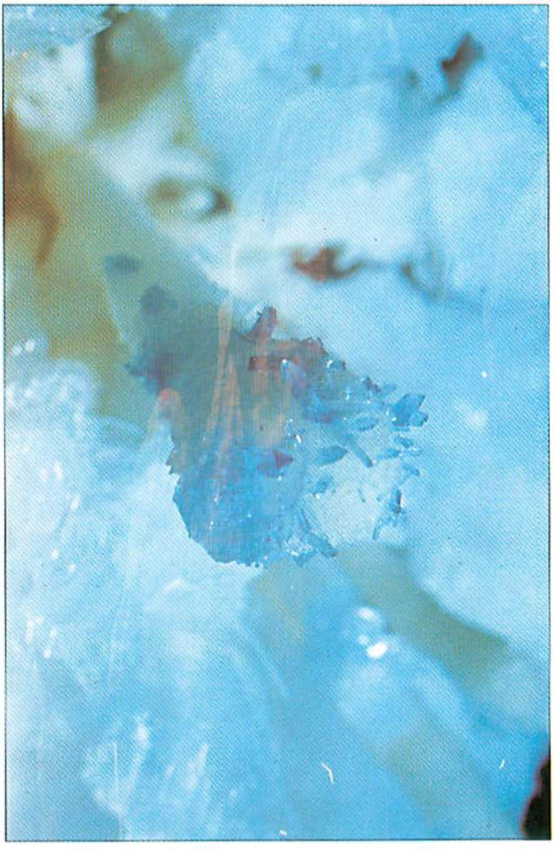
In some of the cave mazes which were deeply corroded during the post-thermal period "mostly-gypsum sands" have been found. Analysis by Tranteev shows that these sands contain, in decreasing concentrations, gypsum ($CaSO_4.2H_2O$) crystals up to O.5 mm size, iron oxides and hydroxides, clay minerals, calcite, dolomite, sulphur, silicates and sulphides. The gypsum sand develops in regions of high atmospheric H_2S concentrations, where more gypsum forms than can be removed by condensing water. A bacterial process is probably involved, for free

Calcite deposited during the thermal phase in Cupp-Coutunn. The grey lustre is caused by metal sulphides. The limestone has an orange crust coating of residual clay.



''Hot'' fluorite from western Promeszutochnaya.

Green sauconite within calcite flowstone in Promeszutochnaya.



Celestite crystals on a calcite helictite in Promeszutochnaya.

sulphur is found both within and as a dust layer upon the sand (these sulphur patches can be as much as 1 metre across). Some of the clay minerals are reworked within the sand, with reduction of Fe^{3+} to Fe^{2+}.

Some of the products of the thermal phase were also reworked into speleothems. This reworking of material has continued into the third (modern) phase, but for convenience the unusual minerals are all described in this section. Cerussite ($PbCO_3$) paragenetically grows as crystals of up to 2 mm size with aragonite ($CaCO_3$). The aragonite forms under normal cave conditions but its growth is governed by trace concentrations of lead, which in the northern branch of Cupp-Coutunn lower series can be as high as 1%.

Isolated spherulites of sauconite, a zinc montmorillonite clay, are found both upon and underneath normally deposited calcite (X-ray diffraction, Belyakovsky, pers. comm.). The sauconite is usually coloured green by the presence of nickel (Plate 3). The mineral appears here not as a clay (typical for all montmorillonites) but as structured aggregates of clear mineral. An interesting feature of the sauconite is that it is often found near occurrences of an unusual orange aragonite. The aragonite has either a branching, coral-like morphology or grows as a spherulite sector within the surface of a calcite flowstone. In both cases the aragonite has small holes where a second, more soluble mineral once resided. A sample of this aragonite cannot be taken without very visible damage. A reported visual identification of copper sulphate (in Maltsev and Bartenev, 1989) is now questionable. A sample taken from the cave was washed in the laboratory and immediately dissolved. Recent discoveries in other parts of the system suggest the mineral was more likely to have been a nickel salt. The specimen was found in a region that was then sealed for conservation, but another team re-opened the passage and ignorantly trampled the remainder of the mineral.

In Promeszutochnaya, a very green mineral has been found which on analysis proved to be a mixture of sauconite, fraipontite (a zinc analogue of serpentine) and a third mineral of the fluorite group (as yet not identified). Fraipontite is a very rare mineral, with only a handful of occurrences worldwide; this is the first time it has been found in a cave. The green colour is almost certainly due to partial substitution of zinc by nickel. A colour photograph has been recently published in a mineralogical magazine (Maltsev and Belyakovsky, 1992).

Some minerals grow as isolated crystals upon calcite helictites or are found inside gypsum crystals. Celestite ($SrSO_4$) grows as blue to colourless crystals up to 1.5 cm size (Plate 4), individually or as rosettes, and always on calcite or paragenetically with gypsum. It is never found in association with aragonite, except at one location where it is in asociation with orange aragonite and sauconite. Stepanov (pers. comm.) reports some very old celestite in Hushm-Oyeek, predating all other minerals, but no other such occurrence is known. In one part of Cupp-Coutunn (main) celestite is a cementing material for the floor deposits. Yellow-coloured isolated crystals with a more elongated crystal form, growing on helictites, proved also to be celestite. The celestite may be thermal in origin, but could alternatively derive by normal groundwater flow from the strontium-rich Gaurduck beds which overlie parts of the cave system (Belyakovsky, pers. comm.). Clear crystals of a typically celestite crystal form in one location were, on analysis, found to be barite ($BaSO_4$).

Tyuyamunite, a vanadium-uranium mineral, has been visually identified in Geophyzicheskaya (Belyakovsky, pers. comm.). Radioactivity in the nearby cave air is 300-500 micro-Roentgens per hour, about ten times higher than in other caves of the area. Ordinary montmorillonite has also been found on (modern phase) calcite helictites, where it occurs as milky-coloured crusts 1-2 mm thick together with celestite crystals (X-ray diffraction, Belyakovsky, pers. comm.).

Modern Phase

After the post-thermal phase the cave returned to a more normal regime of speleothem growth, though the abundance and variety of the minerals must owe something to the previous thermal history. The calcite group of minerals are particularly interesting. Staining techniques showed that what appeared to be calcite speleothems contained zones of calcite, high-magnesium calcite, mangano-calcite, dolomite ($CaMg(CO_3)_2$), ankerite ($((Ca,Mg,Fe)CO_3)$) and ferro-calcite. Thin crusts of orange to red ankerite crystals, 1-4 mm in size, were also identified by staining. Siderite ($FeCO_3$) flowstone crusts up to 1 mm thick also occur. Other unusual speleothems include polycrystalline crusts of calcite (occasionally aragonite) containing manganese oxide dendrites.

Two major types of aragonite speleothems are also present, one paragenetic with sauconite, the second with hydromagnesite ($Mg_5(CO_3)_4(OH)_2.4H_2O$). The hydromagnesite mostly occurs as spherulites on the ends of aragonite frostwork (Figure 11).

The cave also has very large quantities of gypsum, mostly occurring as wall crusts and as floor debris derived from these crusts. In places gypsum speleothems occur, often of very large size. These take the form of mono-crystalline stalactites, chandeliers, both mono-crystalline (Figure 12) and the normal hollow stalagmites, shelfstone and efflorescences (hair and beards, needles and flowers). The gypsum is probably derived from two sources: the overlying Gaurduck beds (remnants of which still exist on the Kugitangtau plateau) and as the product of the reaction of atmospheric hydrogen sulphide with the limestone during the post-thermal and modern phases. Growth of gypsum with dolomite and celestite is common.

In the driest areas of the cave, soluble minerals such as epsomite ($MgSO_4.7H_2O$), halite (NaCl) and mirabilite ($Na_2SO_4.10H_2O$) form speleothems. These crusts, flowers, needles and small chandeliers were for several years mistakenly thought to be gypsum. In one such case a halite-epsomite flower has grown to a size of 40 cm. Epsomite is also found as a thin grey efflorescence. Other efflorescent deposits prove to be saltpetre (KCl) growing as thin crusts with halite and gypsum.

During the 1990 expedition a cold phase (21°C), second generation purple fluorite was discovered in Promeszutochnaya (colour photograph in Maltsev and Belyakovsky, 1992). Crystals of up to 0.3 mm length were seen growing on both calcite helictites (Figure 13) and gypsum crystals. Gypsum tends to recrystallise because of humidity changes, so fluorite growing on gypsum is probably less than 100 years old. This modern fluorite may be the product of chemical attack on both calcite and gypsum by atmospheric HF gas, but as yet no gas tests have been made on the present cave air. Fluorine is thought to have been a component of the deep thermal fluids. A possible second modern fluoride mineral may be forming. In one part of Cupp-Coutunn, aluminium survey station markers have been corroded in only four years to form a glassy spherulitic mineral deposit.

Figure 11. *Hydromagnesite spherulites growing upon aragonite frostwork, on rounded calcite crystals on the side of a calcite stalactite (Cupp-Coutunn lower series).*

Unidentified Minerals

One of the most interesting unidentified minerals comprises two silicates growing together in a highly porous arrangement inside gypsum clouds. The minerals may possibly be a result of a reaction of sulphuric acid on montmorillonite, but the individual fibrous crystals are too thin for X-ray analysis. In one of the conserved parts of the cave there is a single highly-reflective and colourless crystal of 2 cm size, growing on a calcite helictite. There is no other occurrence of this mineral, which was left in place. In Cupp-Coutunn (main), there are five crystals of up to 1 cm size that have the crystal form of aragonite, but on colour staining gave the reaction of dolomite.

Figure 12. *Monocrystalline gypsum stalagmites in Promeszutochnaya.*

MAIN SPELEOTHEM FORMS

The speleothems of the Cupp-Coutunn system are mostly eccentric in form; helictites (Figure 13) and corallites are far more common than normal stalactites and stalagmites. A full list of speleothems is beyond the scope of this paper (the cave has "almost everything", according to those who know it well) but some form of classification of the main types may be useful. Speleothems are here grouped by the process defining their morphology, in order of decreasing amounts of free water needed for their formation.

Subaquatic. Most of these forms are thermal in origin, notably the fluorite and the massive calcite spar. There are also cold-origin shelfstone deposits in rimstone pools formed by calcite. In rare cases aragonite and even gypsum shelfstones have been found.

Sub-aerial gravitation controlled. These are mostly calcite stalactites, stalagmites and flowstones. In rare cases they may be made of aragonite or gypsum.

Sub-aerial near-gravitation controlled. To this group are assigned the hollow gypsum stalagmites, which can reach 20 m in height, and the gypsum chandeliers, which can be 5 m long. The morphology of these gypsum forms is controlled both by gravitation and by seasonal changes in humidity. To the same group are assigned some stalactite-like aragonite aggregates of very strange morphology: sectors of spherulites hang one from another in the manner of a daisy-chain (Figure 14).

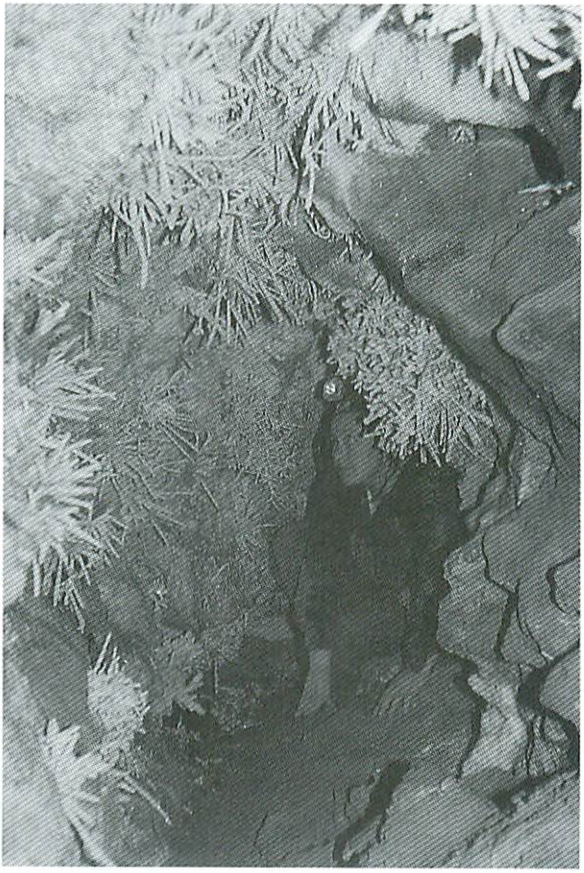


Figure 13. *Difficult caving conditions in Promeszutochnaya.*

Subaerial gravitational-capillary controlled. To this group we assign vertically directed helictite bushes, which can be 2 m long and 0.5 m thick.

Capillary controlled. Various forms of helictites, corallites and crystallites have a capillary channel origin or are formed from capillary films.

Capillary-airflow controlled. Calcite and aragonite anemolites are assigned here, as they are airflow directed.

Humidity controlled. This group comprises the speleothems whose morphology is controlled by humidity changes, such as gypsum hair and flowers, gypsum crusts, and efflorescences of soluble salts.

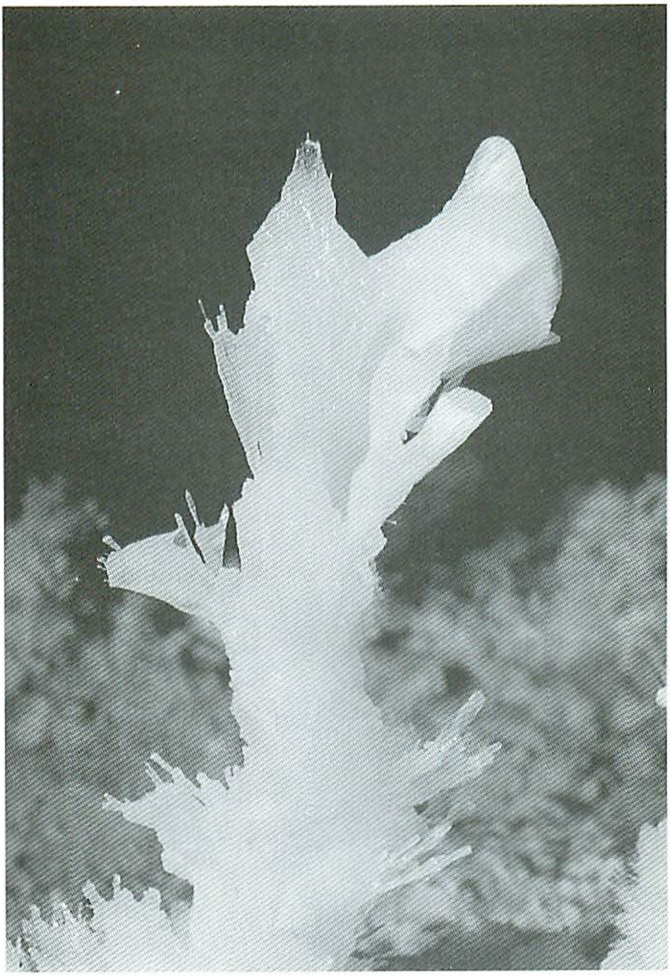


Figure 14. *Aragonite pseudostalactites of needle aggregates in Cupp-Coutunn.*

Special speleothem forms

Pseudohelictites. These look similar to acicular anthodites. Controlled by crystallisation pressure, they are formed when calcite and aragonite grow together (Figure 15).

Isolated crystals, rosettes and spherulites. These speleothems are formed of various minerals, as described earlier in this section, but we can offer no explanation why an otherwise uncommon cave mineral should be concentrated in one place. Examples include a lone spherulite of sauconite sitting on a calcite flowstone, many metres from any other, and a calcite helictite with many celestite crystals on its sides, when other helictites in the same bush are bare.

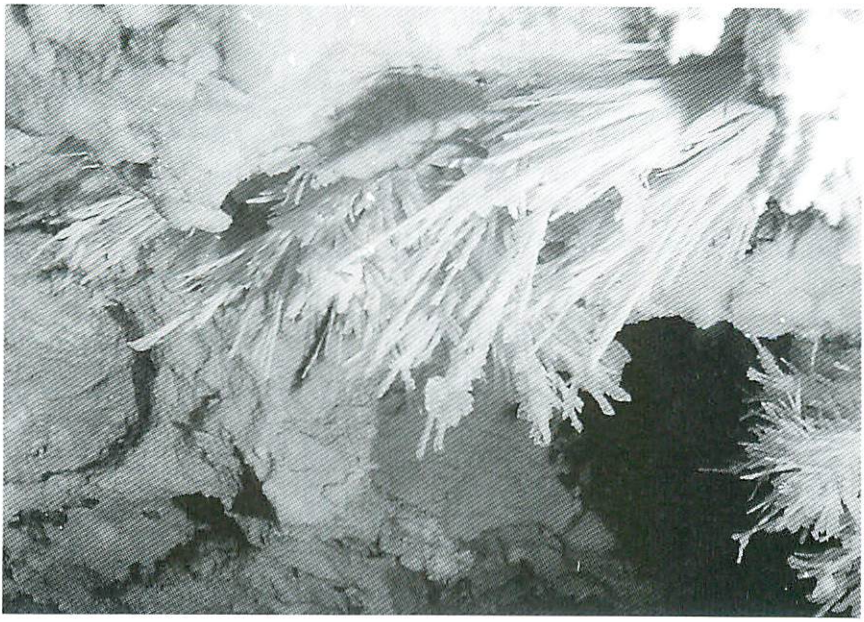


Figure 15. *Calcite/Aragonite needle pseudochelictites with gypsum crystals in Promeszutochnaya.*

CONCLUSIONS

The Cupp-Coutunn system is one of the most scientifically interesting caves in the world. Its mineralogy, fauna and microclimate features make it unique, yet until very recently it was considered only as a natural resource to be mined. The threat of mining has now receded (hopefully for ever) but individual geologists are still a serious menace to the cave. Such deliberate vandalism is fortunately decreasing, as more people become aware of the value of conservation, but this greater awareness of the beauty of the Cupp-Coutunn system brings a corresponding increase in the number of visitors. As visits by geologists have now dropped below 200 per year, caver visits have increased to 500 and tourist (casual caver) numbers have reached 3000 per year. Such tourist parties commonly number more than 40 people, usually with less than this number of working lights. This is far too many people for the safety of the cave environment, particularly when so many of them are not experienced cavers. Heat, dust and accidental damage are all on the increase. By contrast, the number of serious cavers, those involved in exploration or scientific work, has remained steady at 50 visitors per year.

At present, no viable scheme exists for regulating visitors to the caves. We hope this will change in the future, but in the meantime we ask that NO CARBIDE be used in the caves. The residual clays attached to the walls are a very effective temperature insulator and temperatures as high as 60°C have been recorded at roof level above carbide lamps. Underground camps using liquid fuel can also cause thermal damage to speleothems: at one microclimate study station, in a chamber 600 metres from the campsite, an air temperature of 37°C was recorded.

There is very little standing water in the caves and visitors are recommended to carry water with them; the cave water is needed by explorers operating from underground camps. Cave divers visiting the gypsum cenotes are asked to limit their attention to the sites that do not have troglobytic life, until more is known about the nature of the aquifer.

APPENDIX

FAUNA, ARCHAEOLOGY AND SURVEY

Fauna

The Cupp-Coutunn caves have only one true troglobite, a microscopic insect that lives in the clays. As yet unstudied, the insect was discovered by S. Smirnov. The clays in which the insects live are high in organic material (up to 20%).

A number of troglophiles, both insects and mammals, make use of the caves. The mammals include bats, mice, porcupines, foxes and a member of the ferret family (*Martes foina*) — the farthest travelling of all the visiting species. The presence of water in some parts of the cave appears to be the main reason for the visits of these animals, even the mice routinely travelling 150 metres down (vertically) into the cave to drink. The mice can be a problem if an underground camp is placed too near a water supply, the smell of food attracting them in 2-3 days. The routine precautions of hanging up the food sacks and daily re-packing one's sleeping bag are necessary. The foxes and ferrets probably use the caves as a hunting ground for mice.

The porcupines also travel long distances underground and often have their nests within the cave. Unfortunately they carry a very unpleasant skin parasite, *Argazida*, which can cause a serious relapsing fever in man. Prompt and intensive treatment with a spirocheticidal antibiotic is needed to prevent a prolonged illness. The danger is in the dry parts of the cave where fallen parasites can survive for up to three years.

Aquatic troglobites can be found in the phreatic cave systems beneath the plains. A cave-adapted shrimp, *Stenasellus asiaticus*, is locally common. The blind cave fish, *Noemacheilis starostini parini*, is unique to the cave Provull.

Archaeology

No archaeological material has been found in the main parts of the Cupp-Coutunn system, but some remains have been recovered from Verticalnaya. The horizontal entrance soon opens onto a pitch, at the foot of which the bodies of two travellers with money and baggage were found. Also found were the remains of several animals, including wild goats and a leopard. This material is in the collection of the Ethnographic Museum in Leningrad, but further details are not available.

Survey

The caves were surveyed in two phases, to determine the plan and elevation. The plan was made with hand held compass (±1° accuracy) with internal plumb-bob clinometer (±5° accuracy, used only for correction of length) and fibron tape (measurements to the nearest 10 cm). The first survey was drawn manually from these notes while in the cave. A second survey was then made in Moscow, line drawn by computer with error distribution using the electric resistance nets algorhythm (Orevkov,1987).

The vertical survey was made independantly by hydrolevelling (accuracy 10 cm, length of tube 15-30 m). A theodolite (accuracy of angles 0.5°, distance 50 cm) survey was made on the surface and in the main gallery of Cupp-Coutunn (main). When Cupp-Coutunn and Promeszutochnaya were connected via the B-podval series, the closure error was only 20 metres horizontally, but 60 metres vertically. The vertical error almost certainly indicates problems with the surface survey between the two caves.

Permanent metal survey stations have now been installed in all the main caves of the Cupp-Coutunn system except Verticalnaya and Hushm-Oyeek. The original survey at 1:1000 has been greatly reduced for publication. Some detail has necessarily been omitted.

Spelling of Place Names

The names of towns, villages and caves in this part of Central Asia are normally found written in the Cyrillic alphabet. In converting to Roman letters we have tried to indicate local pronunciation of the names, rather than a strict transliteration. Occasionally, English language texts may be found using a different spelling, particularly of the main cave Cupp-Coutunn (eg Kap-Kutan). These differences are not important since the only "correct" spelling is in Cyrillic script.

ACKNOWLEDGEMENTS

The information summarised in this paper is the result of many years of expeditions, and credit is due to the many members of our team who have worked in these caves. In particular we would like to thank O. Bartenev, D. Belyakovsky, D. Kitaev, D. Malishevsky, N. Skorobogatova, S. Smirnov, M. Tranteev and A. Vyatchin for permission to print the results of their research, results that would otherwise not have been published.

The USSR Geological Society (Moscow Dept) has given financial support to our research and we would like to thank the Society, and in particular the President E. Grachov and the Scientific Secretary G. Karpushina, for help in the organisation of our expeditions. As one of the authors of this report, C. Self would like to thank the Society for their invitation to join the April 1990 expedition. For advice on planning the scientific research we would like to thank A. Klimchouck, M. Korotaev and Y. Shopov.

REFERENCES

BAIKALOV, A.A., YALKAPOV, S.D. and SEDLETSKY, V.I. 1970. A deposit of marble onyx. *Razvedka i ohrana nedr (Estimating and conserving underground resources)*, Soviet Ministry of Geology, **2**, 14-16. (in Russian)

BAKALOWICZ, M.J., FORD, D.C., MILLER, T.E., PALMER, A.N. and PALMER, M.V. 1987. Thermal genesis of dissolution caves in the Black Hills, South Dakota. *Bulletin of the Geolological Society of America*, **99**(6), 729-738.

BARTENEV, O.S. 1987. Secondary karst deposits of the Cupp-Coutunn system and the method of studying its development. *Proceedings of the 6th U.S.S.R. Conference on Karst Studies*, Kiev, 58. (in Russian)

BARTENEV, O.S. and MALTSEV, V.A. 1989. A concept of three stages of speleogenesis as a basis for creating models of evolution of karst systems. *Problems of Complex Karst Study of Mountainous Countries*, Metsniereba, Tbilisi, 88-90. (in Russian, English abstract)

BARTENEV, O.S. and VESELOVA, N.V. 1987. Dust caused by people in the cave system Cupp-Coutunn. *Proceedings of the 6th U.S.S.R. Conference on Karst Studies*, Kiev, 159. (in Russian)

BOLNER, K.T. 1989. Regional and special genetic marks of the Pal-Volgy cave, the largest cave of thermal water origin in Hungary. *Proceedings of the 10th International Congress of Speleology*, Budapest, **3**, 819-822.

BOSAK, P. 1989 Mountainous karst of the Karjantau ridge (Southern Kazakhstan, USSR) :Phenomena and Development. *Problems of Complex Karst Study of Mountainous Countries*, Metsniereba, Tbilisi, 99-102.

DIODORUS SICULUS. c40 B.C. *Bibliotheka Historica*. 12 vols. (Loeb Classical Library, Harvard University Press, 1933-1967. (Classical Greek with English translation)

FRIEDMAN, J.M. 1959. Identification of carbonate minerals by staining methods. *Journal of Sedimentary Petrology*, **29**(1), 87-97.

GAURDUCK GEOLOGICAL SERVICE. 1960-75. Unpublished reports kept in Geological Fund. (in Russian)

GEOLOGY OF U.S.S.R., **XXII**, TURKMENSKAYA S.S.R., 1972. Moscow. (in Russian)

GVOZDETSKY, N.A. 1981. *Karst*, Moscow, 65. (in Russian)

HILL, C.A. 1987. Geology of Carlsbad Cavern and other caves in the Guadalupe Mountains, New Mexico and Texas. *New Mexico Institute of Mining and Technical Bulletin*, **117**, 79-80.

KUCHERYAVUIH, V.I. and ABDUJABAROV, M.A. 1982. Kapkotan-2 the biggest cave in Central Asia. *Nekotoriye aspectiy fizicheskoy geografy yugo- zapadnogo Uzbekistana (Some physical aspects of the geography of south-western Uzbekistan)*, Samarkand University, 29-30. (in Russian)

LAZAREV, K.S. and PHILENKO, G.D. 1976. Geological-mineralogical peculiarities of the Gaurduck cave. *Peshcheriy (Caves)*, University Press, Perm, **16**, 45-63. (in Russian)

MALTSEV, V.A. 1982. Carbonate karst of the south-western slope of the Kugitangtau ridge. *Proceedings of the 3rd U.S.S.R. Conference on Karst Studies*, Moscow, 153. (in Russian)

MALTSEV, V.A. 1987a. Heat pollution of caves during underground expeditions. *Proceedings of the 6th U.S.S.R. Conference on Karst Studies*, Kiev, 158. (in Russian)

MALTSEV, V.A. 1987b. State of study of the underground karst hydrosystem Cupp-Coutunn. *Proceedings of the 6th U.S.S.R. Conference on Karst Studies*, Kiev, 104. (in Russian)

MALTSEV, V.A. 1989 The influence of season changes of the cave microclimate to the gypsum genesis. *Proceedings of the 10th International Congress of Speleology*, Budapest, 3, 813-814.
(Extensively revised and reprinted in 1991 as: The influence of seasonal changes of cave microclimate upon the genesis of gypsum formations in caves. *National Speleological Society Bulletin*, **52**, 99-103.)

MALTSEV, V.A. and BARTENEV, O.S. 1989. Results of minerallogical studies in the Cupp-Coutunn cave system in Turkmenia. *Problems of Complex Karst Study of Mountainous Countries*, Metsniereba, Tbilisi, 209-211. (in Russian, English abstract)

MALTSEV, V.A. and BELYAKOVSKY, D. 1992. The Kap-Kutan cave system in the Kugitang mountains in East-Turkmenia. *Mineralien Magazin Lapis* **17**(2), 13-18. (in German)

MALTSEV, V.A. and MALISHEVSKY, D.I. 1989. About the hydrothermal stage on the later part of evolution of the Cupp-Coutunn cave system. *Proceedings of the 10th International Congress of Speleology*, Budapest, 3, 815-816.
(Extensively revised and reprinted in 1991 as: On hydrothermal phases during later stages of the evolution of Cup Coutunn cave system, Turkmenia, USSR. *National Speleological Society Bulletin*, **52**, 95-98.)

MOROSHKIN, V.V. 1984. Minerals of the Kugitang caves, *Priroda (Nature)*, **3**, 45-50. (in Russian)

OREVKOV, S.Y. 1987. Using the solution for the task of electric network design for the task of processing survey data in caves. *Proceedings of the 6th U.S.S.R. Conference on Karst Studies*, Kiev, 190. (in Russian)

TINTILOSOV, Z.K. 1983. *Novaphonskaya cave system*, Metsniereba, Tbilisi. (in Russian)

ZALESSKAYA, N.T. and GOLOVATCH, S.I. 1989. The condition of biospeleology in the USSR. *Problems of Complex Karst Study of Mountainous Countries*, Metsniereba, Tbilisi, 240-242. (in Russian)

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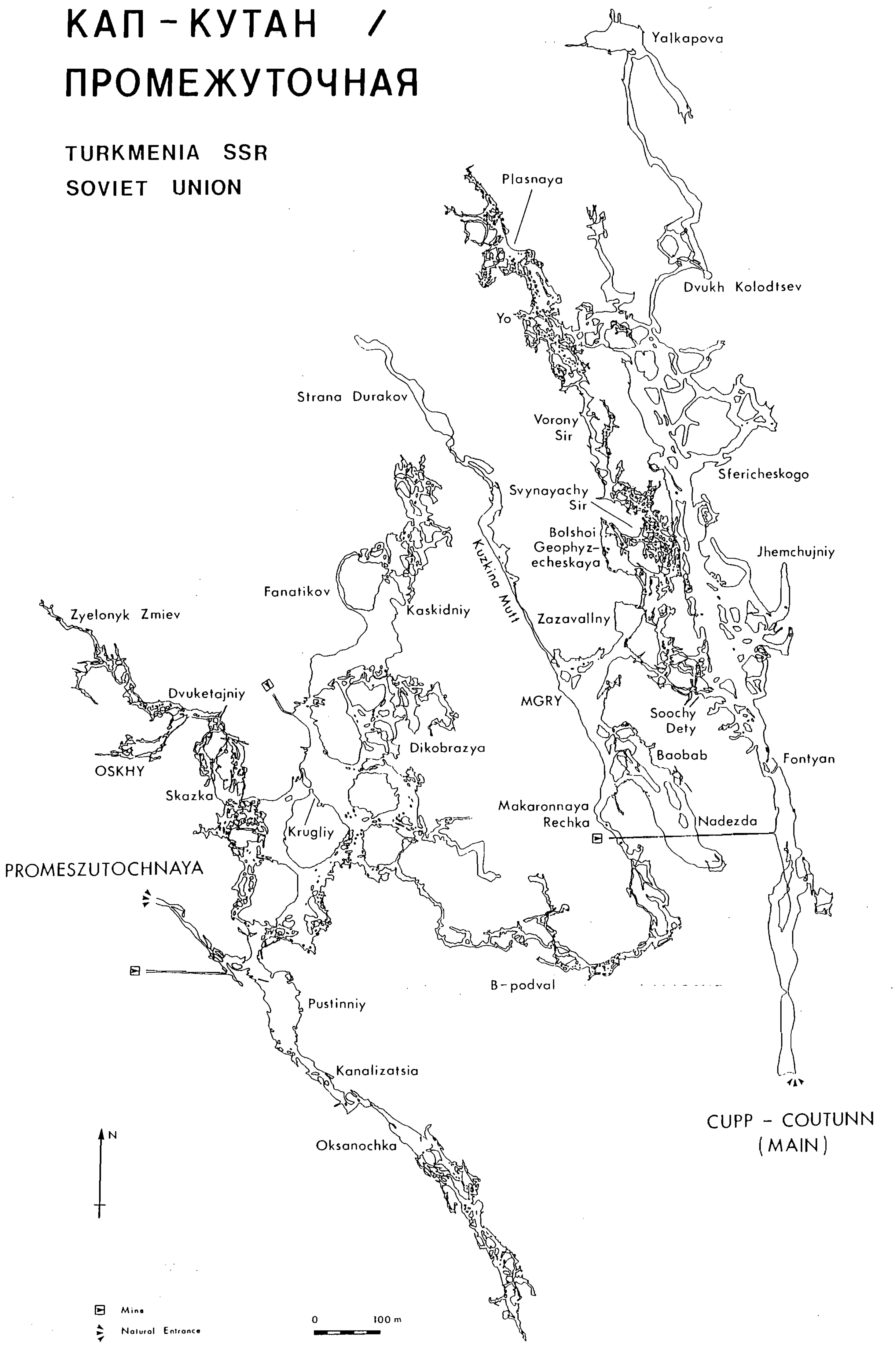

Figure 16. *Plan survey of Cupp-Coutunn-Promeszutochnaya cave system.*