In Russia's Frozen North

GYPSUM CAVES OF PINEGA

Written by Tony Waltham

tony@geophotos.co.uk

Geologists and cavers from Arkhangelsk have explored over 100 km of caves in a region of low gypsum plateaux traversed by the Pinega River. Many of the passages are large elliptical phreatic tubes, and some carry substantial streams. In winter, the entrance zones are beautifully decorated with large ice formations and extensive covers of snow crystals.

Russia

The Pinega karst extends beneath more than 2000 km^2 of forested terrain near the northern coast of Russia, 100 km east of Arkhangelsk. Caves were first mapped in 1972 by cavers from St.Petersburg, but most of the exploration and surveying has been carried out by geologists and cavers from

Zusammenfassung

IN RUßLANDS GEFRORENEM NORDEN: DIE GIPSHÖHLEN VON PINEGA, von Tony Waltham

Geologen und Höhlenforscher aus Arkhangelsk haben über hundert Höhlen in einer von dem Fluß Pinega durchquerten Region erforscht. Die in diesem Gipsplateau gelegenen Höhlen sind durch ihre vielen elliptischen Druckstollen gekennzeichnet, in denen manchmal noch gewaltige Höhlenflüsse vorzufinden sind. Im Winter ist der Eingangsbereich dieser Höhlen mit wunderschönen Eiszapfen und großen Schneekristallen verziert.

Riassunto

NEL FREDDO NORD DELLA RUSSIA: LE GROTTE DI GESSO DI PINEGA, di Tony Waltham

Geologi e speleologi del Arkhangelsk hanno esplorato più di 100 km di grotte in una bassa regione di "plateaux" di gesso attraversati dal fiume Pinega. Molti passaggi sono grandi gallerie freatiche a forma di ellisse e alcuni di essi sono attraversati da potenti corsi d'acqua. In inverno, le zone di ingresso sono decorate in maniera stupenda da grandi formazioni di ghiaccio e ricoperte in larga misura da cristalli di neve.

Résumé

DANS LES TERRES GELEES DU NORD DE LA RUSSIE: LES GROTTES DE GYPSE DE PINEGA, par Tony Waltham

Des géologues et des spéléologues de Arkhangelsk ont exploré plus de 100 km de cavités dans une région de bas plateaux de gypse que traverse la rivière Pinega. Nombre de ces galeries sont de larges conduites forcées elliptiques, où s'écoulent toujours, pour certaines, de conséquents cours d'eau. En hiver, les entrées sont superbement décorées de sculptures de glace et couvertes de cristaux de neige.

Sumario

EN EL NORTE HELADO DE RUSIA: CUEVAS DE YESO DE PINEGA, por Tony Waltham

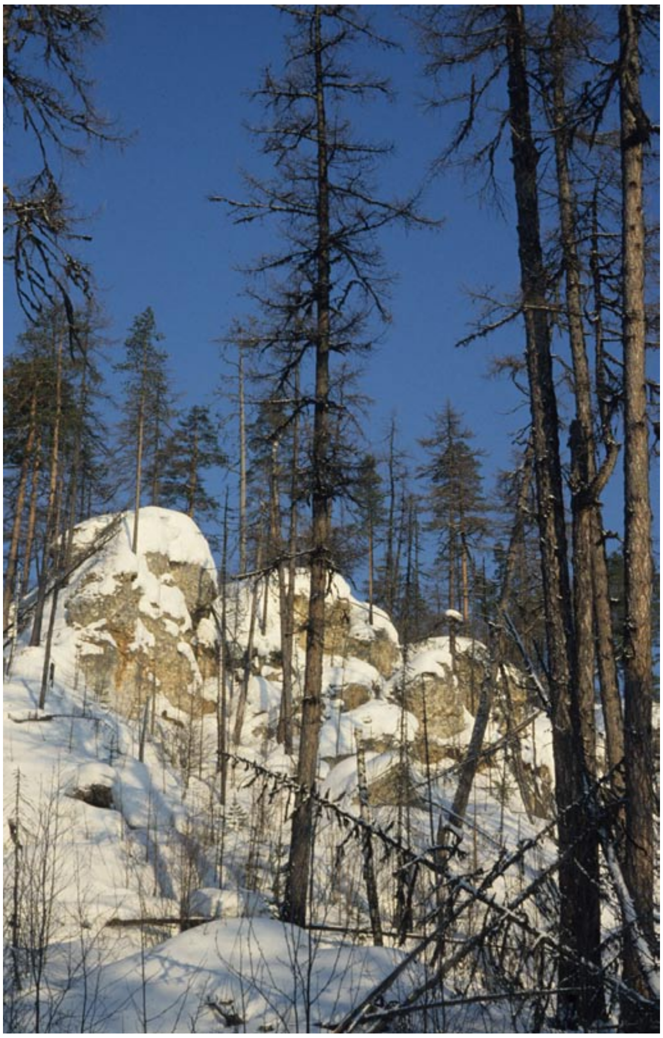
Geólogos y espeleólogos de Arkhangelsk han explorado alrededor de 100 km de galerías subterráneas en una región de muelas de yeso poco elevadas, atravesada por el río Pinega. Muchas de esas galerías son amplios tubos freáticos y algunas de ellas están recorridas por torrentes caudalosos. Durante el invierno las entradas de las cuevas están decoradas con grandes carámbanos y extensiones de cristales de nieve.

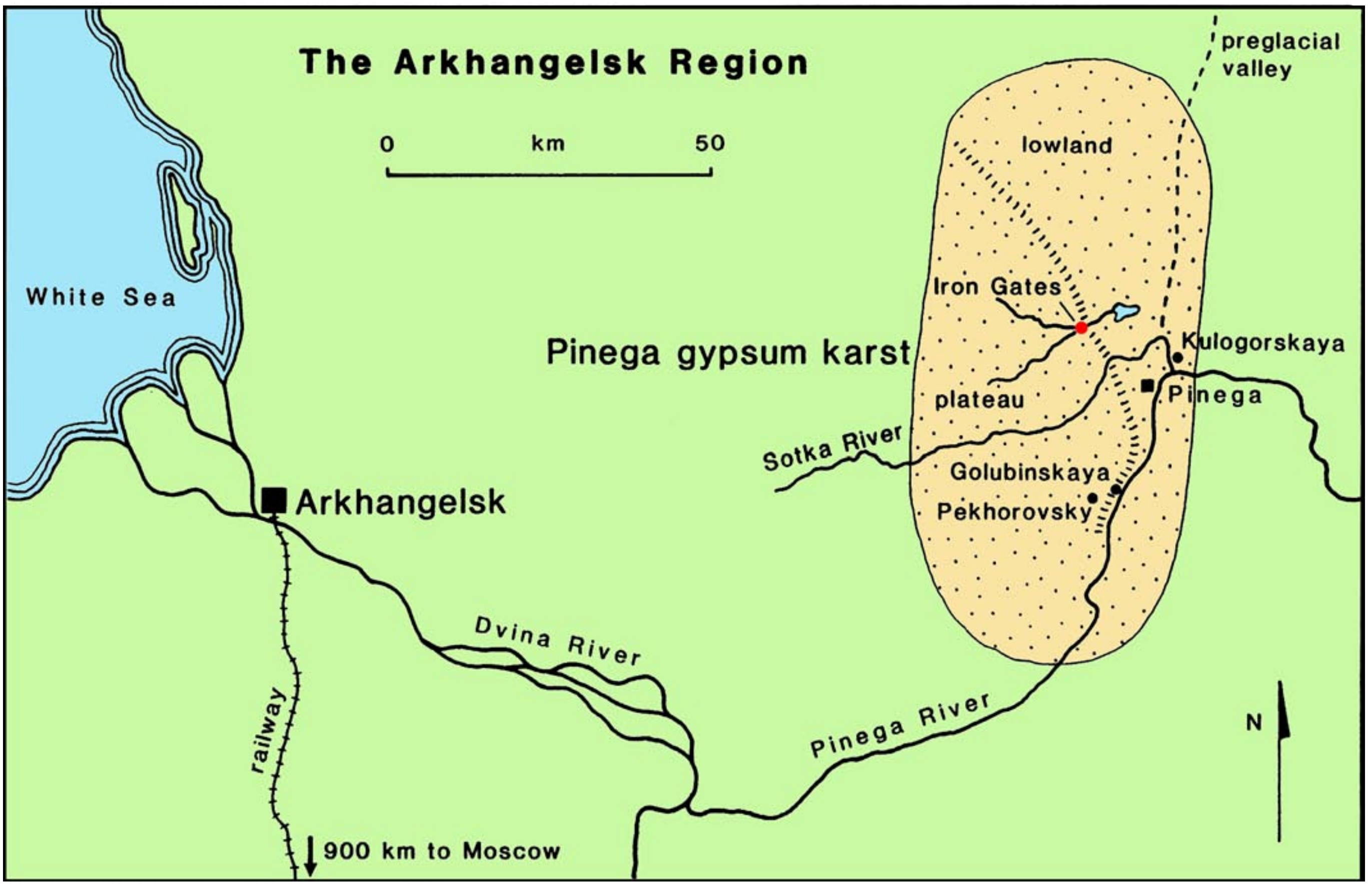
Arkhangelskgeologia. More than 100 km of passages are now mapped, and the geological studies have revealed a splendid story of karstic development.

Geology of Pinega

The karst is all developed in a sequence of Permian evaporites just 50 m thick. These consist of bands of blue anhydrite and white gypsum containing thin beds of brown dolomite and red clay. Within the zones of weathering and groundwater flow, much of the anhydrite is converting to gypsum by hydration. Star gypsum has small clusters of pink selenite crystals in massive white gypsum, and also originates from hydration transformations. Beds of nodular gypsum are laced with red clay, and contain eroded paleokarstic features. The whole sequence is characteristic of a sabkha origin, and is spectacularly exposed in colourful profiles in the cave walls.

The gypsum sequence forms a very shallow syncline which dictates its outcrop shape. It is underlain and overlain by limestones and dolomites





which are little karstified. A low plateau rises west of Pinega , and the gypsum is exposed in numerous valleys which have cut down through the dolomite caprock. To the east, a monoclinal flexure separates the plateau from a lowland pocked by karst lakes, where the gypsum is largely buried beneath 10 m of glaciofluvial sands.

The Pinega terrain

Endless forest of birch and pine provides the lasting impression of Pinega. The lowlands have minimal relief and are crossed by a shallow preglacial valley which is now essentially abandoned north of Pinega. The broad and sluggish Pinega River crosses from the lowland and follows a shallow trench through the higher ground west of the monocline. The gypsum plateaus rise only about 50 m, but broken gypsum crags line the flanks of the many valleys which dissect them. Many of the cave entrances lie in the crags, and the difficulties of access ensure that plenty more caves await discovery. There are few roads away from the main valley. Walking over the broken karst is hard work in summer, and the only access in winter is by cross-country skiing.

Logging is the main occupation for the relatively sparse local population - and is also an environmental threat. The Pinega National Park was established in 1974, covering a large chunk of forested karst west of the Pinega River and south of the small town of Pinega. It protects substantial numbers of deer, moose, and black bears in a beautiful forest setting. Some of the caves lie within the Park, but a group of the finest lie just outside to the north. These are under and beside the valley of Zheleznye Vorota - the Iron Gates - named after the rocky crags at the valley exit where it breaks out of the plateau. In 1992, the Iron Gates Nature Reserve was established, primarily to protect the karst and caves from the threat of logging.

The caves of Iron Gates

The heart of the Iron Gates nature reserve consists of two dry valleys cut into the gypsum just west of the monoclinal plateau margin. A stream sinks in each valley, and they join in a fine system of caves which lies largely under the intervening

LEFT The gypsum crags at Zheleznye Vorota (Iron Gates). Photo : Tony Waltham ridge. The combined waters flow to a resurgence at the head of a stream; this flows east into a karst lake, from where drainage is underground again to springs in the banks of the Pinega River.

Both dry valleys have their floor profiles broken into a chain of shallow depressions. Overall gradients are low - from sink to resurgence the fall is only about 25 m. The valleys are lined by gypsum scars, with crags 20 m high providing the only conspicuous terrain features in a continuous forest cover. Most of the cave entrances are in the gypsum scars. The instability of the rock means that collapses are not uncommon, and have blocked some recorded entrances. However, new entrances are yielded where doline floors collapse or snow and ice plugs melt away; these are found by summer prospecting, as they remain hidden beneath the winter snow blankets.

The active cave passages have now been explored for most of the way between the main sinks and the rising. The combined system of Olympiyskaya and Lomonosovskaya has just over 9000 m of passage; the other caves are not connected.

The main passage of Olympiyskaya carries the southern stream. Its upper reaches are low and wide, and are complicated by breakdown. They enlarge into chambers up to 30 m wide, where the stream drops over a 6 m waterfall into a canyon. This contains some deep water, and runs into a lower series of splendid wide elliptical tubes. A maze of these tubes bring in the stream from the northern sink, and also provides the main route into the cave from the newer, eastern entrance. Down from the stream junction, a canal leads to the sump which was dived through to Lomonosovskaya by Vladimir Kisseljov early in 1994.

In Lomonosovskaya, the main phreatic tube is still about 10 m wide and elliptical in profile; both the modern entrances have formed where scar retreat has breached the old tube. Much of it has now been abandoned by the main stream which takes an immature route to the south. Old passages leading out under the dry valleys are blocked by sediment.

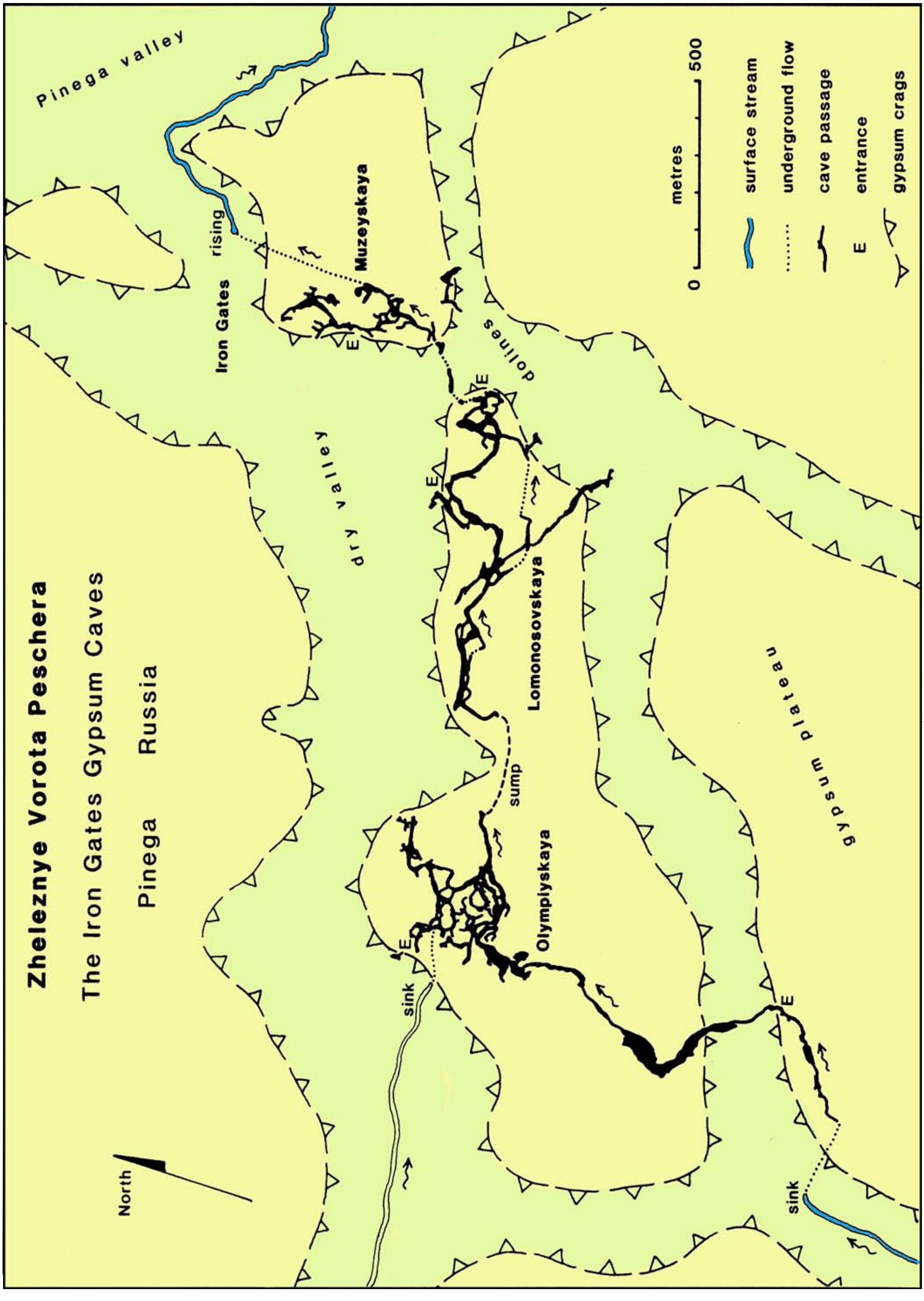
East of Lomonosovskaya, the ridge narrows and lowers to a broad saddle. This has breached the caves, and the stream is now seen in a few karst windows. Fragments of passage do survive, but most are blocked by breakdown and collapse of the thin remnant roofs. Muzeyskaya (generally known as Cave 253) has more fossil passages, which are flooded towards the east. The hydrology is much more complex than the cave map reveals, and there appears to be a series of parallel flooded caves heading north. These feed the main rising and some flood outlets a little higher up the valley.

Cave development at Pinega

The very high solubility of calcium sulphate (which forms both the gypsum and the anhydrite) permits cave inception to take place along the slightest of structural weaknesses. The cave passages appear to have developed at various levels within the evaporite sequence. At some sites, the less permeable dolomite bands and the paleokarst

A large elliptical phreatic tube in Lomonosovskaya containing a long frozen lake.

Photo : Tony Waltham


Zheleznye Vorota Peschera
The Iron Gates Gypsum Caves
Pinega Russia
North
Pinega valley
rising
Iron Gates
Muzeyskaya
dolines
dry valley
Lomonosovskaya
sump
Olympiyskaya
sink
gypsum plateau
metres
0
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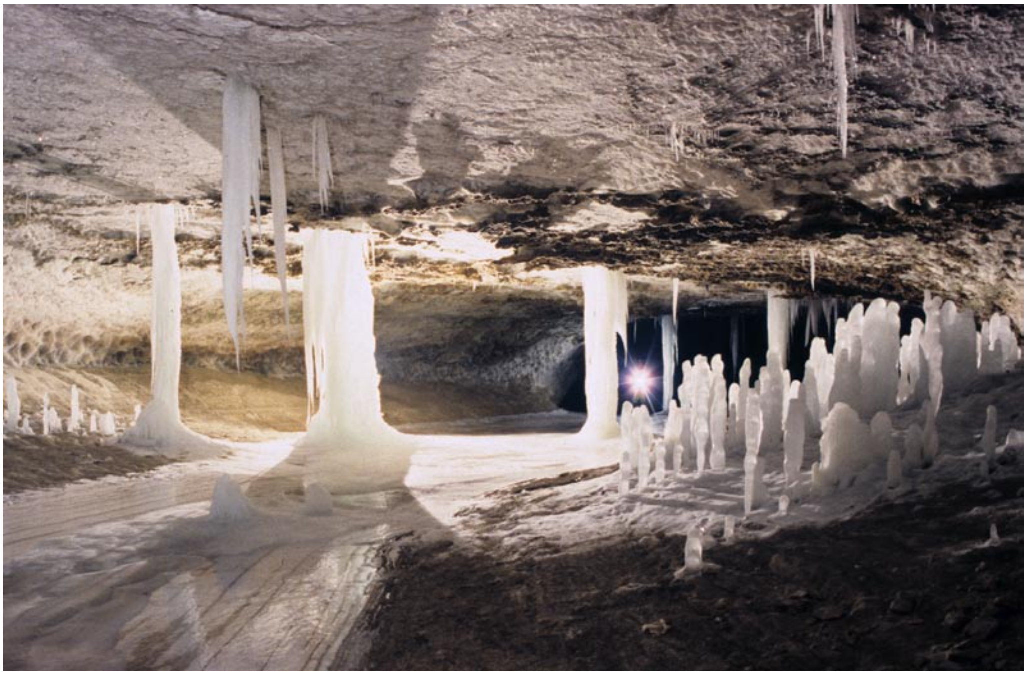
surface stream
underground flow
cave passage
E entrance
gypsum crags



Beautiful ice decorations in Lomonosovskaya just east of the western entrance.

Photo : Tony Waltham

horizons with clay have clearly guided the initial caves. The largest phreatic tubes have then developed in, and with their roofs formed of, the most massive anhydrite beds; fortuitously, these occur just above the dolomite and clay horizons.

Gypsum caves are notorious for their unstable roofs; the wide, old high level chambers upstream in Olympiyskaya contain a spectacular and sobering amount of fresh collapse debris. Roof degradation is made worse by the transformation of anhydrite to gypsum. The primary anhydrite (calcium sulphate) converts to gypsum (hydrated calcium sulphate), with an increase in volume, wherever it meets water. So an anhydrite cave roof develops a crust of gypsum which curls, peels and ultimately falls away from the main rock span. Locally this enforced breakdown has continued until the cave roof has collapsed up to a dolomite horizon.

In the active stream passages the rate of roof and wall decay due to the hydration and peeling process is exceeded by the rate of whole-rock solution. Rates of surface retreat in the stream channels have been measured at up to 20 mm per year. Fine scallops form on the passage walls, and the tubes are perfectly shaped. Roof joints are neatly etched out of phreatic caves but a steady level maintained in flowing water cuts a perfectly flat roof in the blue anhydrite or the white gypsum.

Gypsum caves are generally renowned for their joint-controlled maze patterns - exemplified by the very long Ukraine caves. A passage maze usually originates by solution in slow-moving water - as occurs under the low hydraulic gradients developed in areas of low relief; these characterise gypsum karsts which generally form lowlands because of the low mechanical strength of both the evaporites and their host mudstones. The large, efficient phreatic tubes of the Iron Gates caves are distinctly different and appear to indicate their development under much higher hydraulic gradients. However, the Pinega karst has only low relief.

The Pinega caves are young and were formed rapidly. Many passages are occupied by high summer flows, but others are now permanently dry and fossilized. The early development of the caves was under conditions rather different to those of today. Pleistocene ice sheets covered Pinega, and the glacier margins were very close to the Iron Gates during the last Ice Age. Meltwater would have flowed in abundance, and cut the braided valleys through the low plateau. Furthermore, meltwater's ability to dissolve gypsum is not hindered by any dependence on biogenic carbon dioxide. Steep hydraulic gradients could have been created temporarily within the contiguous aquifers of both the glacier crevasses and the gypsum fissures. The main phreatic tubes in the gypsum could have been formed by powerful flows of subglacial or proglacial meltwater - stamping a special individuality on the morphology of the Iron Gates caves.

Ice in the caves

Pinega is just outside the permafrost zone, but it does get very cold in winter. Snow cover is normal from November through to May, and

Ice formations below the 18m entrance shaftt in Pekhorovsky Provol.

Photo : Vladimir Kisseljov

temperatures vary from 0 to -40°C. Summer temperatures may reach 20°C. The caves flood every summer, with high flows and ponding behind collapses on the low gradients. Winter has minimal flow from the frozen terrain, and water levels in the Iron Gates caves typically drop by 2-5 m from the summer levels. The main streams maintain a winter flow, and do not freeze as the ground remains unfrozen at depth.

Very cold air flows down into all the caves in winter - and creates a wonderland of snow and ice formations. Unfrozen percolation water seeps down fissures, and freezes as it enters the cold cave air. Icicles and frozen cascades grow through the winter to decorate all the cave passages close below an entrance or chilled by air sinking through any open fissures.

Pools of standing water left from the summer floods freeze solid to form underground skating rinks. Sheets of ice also form on any cave lakes which are windows into the phreas but which lack the throughflow to keep them unfrozen. As water levels drop, the ice can be left suspended; new ice growing below on the falling lakes may thicken and support these sheets, or they may drop and break into huge slabs as they are left unsupported. Some ice columns which grew on the falling sheets are left hanging from the cave roof.

Many of the cave roofs and walls are coated with snow crystals - precipitated like giant hoar-frost as water vapour condenses on the cooled rock. Fragile hexagonal crystals of ice grow in thick rimes

BELOW A sunken ice floor in a cave opening from a karst window near Muzeyskaya.

Photo : Tony Waltham

which can extend into crystal masses hanging a metre down from the cave ceiling. Individual crystals are small, as they only represent intermittent growth through the weather fluctuations of a single winter, but the overall effect is stunning.

All the Iron Gates caves contain beautiful winter ice displays. Probably the finest are in Lomonosovskaya, in the passages just each side of the western entrance. Almost all the ice melts away in summer to leave room for a new sparkling clean display each winter. The only ice to survive through the summer is in a few underground glaciers supplied by thick snow banks which form in the deeper dolines. Some of this cave glacier ice is 3000 years old. The northern entrance to Olympiyskaya is down the terraces of an eroded underground glacier.

Outlying caves at Pinega

There are plenty of caves in the Pinega karst outside the selected group in the Iron Gates valley. Many are similarly linear, with large phreatic trunk passages. These include Kulogorskaya, the longest single system with 14.5 km of passages; it lies in the main valley east of Pinega. Leningradskaya, situated in the upper reaches of the Sotka River valley, is 2900 m long. Many more have single linear passages 2 or 3 km long.

Symphoniskaya is a more conventional gypsum cave with 3200 m of passages forming a rectilinear joint maze; it lies in the side of the valley upstream from Iron Gates. Golubinskaya is one of many caves in the gypsum scar left down the west bank of the Pinega River. It has 1600 m of passages, much controlled by jointing and with some very long straight tubes. In the plateau west of the river, Pekhorovsky Provol has an 18 m daylight shaft giving access to 2260 m of cave, with a trunk passage which is an elliptical tube 20 m wide and 2-3 m high. The frozen waterfall in the entrance shaft is just the highlight of some magnificent ice and snow crystal decorations.

Many more caves have been explored and mapped at Pinega. There are certainly yet more awaiting discovery along the remoter valleys where access is an increasing challenge. And there is another similar outcrop of gypsum north of Pinega, half way to the Arctic Ocean. The location and climate mean that future discoveries will probably come slowly, but the Arkhangelsk region is already a significant item in the world of caves.

Acknowledgements

All the main explorations and all the geological studies at Pinega have been carried out by members of the Scientific and Technical Centre of Arkhangelskgeologia; a major report on the karst is in preparation by the senior geologist, Viktor Malkov. These brief notes derive from a short and very enjoyable visit to Pinega in March 1994, when the author was accompanied by Tim and Pam Fogg. Our incomparable hosts were Yuri Nikolaev and Viktor Malkov, both from Arkhangelskgeologia. We were joined by Vladimir Kisseljov, who was a splendid interpreter and cave companion, and by Larisa Zakharchenkova who was an inspired cook. To all these we owe our thanks.

Ice nearly fills the main gallery in Muzeyskaya.

Photo : Tony Waltham

International Caver

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